INVITATION FOR BIDS
22 MW JAGRAN-IV HYDROPOWER PROJECT

(Bid Reference: JRN-IV/Lot-II/2026)

ENGINEERING, PROCUREMENT AND CONSTRUCTION CONTRACT FOR ELECTRICAL AND MECHANICAL WORKS UNDER LOT - II OF 22 MW JAGRAN-IV HYDROPOWER PROJECT

1. The Power Development Organization (PDO), Azad Jammu & Kashmir (the "Employer") has received financing from the Saudi Fund for Development (SFD) towards the Construction cost of "22 MW Jagran-IV Hydro Power Project" and it is intended that part of the proceeds of the loan will be applied to eligible payments under the Contract for Lot-II (Electrical & Mechanical Works). Bidding is open to all eligible bidders in accordance with the applicable provisions of the bidding documents.

2. The procurement process shall be conducted in accordance with the Guidelines for the Procurement of Goods and Contracting for the Execution of Works (First Edition, 2001) of the Development Institutions of the Coordination Group, as required under the SFD Loan Agreement. Accordingly, all bidding procedures, evaluation reports and the contract award will be subject to prior review and no objection from SFD.

3. The Employer invites sealed bids in accordance with Single Stage-Two Envelope (Technical + Financial) procedure. The procurement is limited to Joint Ventures comprising at least one Saudi National Company and one Pakistani Firm/Company (having valid C-A Category registration with Pakistan Engineering Council). Firms from other eligible nationalities (registered with Pakistan Engineering Council) can also participate in Joint venture with Saudi-Pakistani firms. No single bidder is allowed to participate in individual capacity. The successful joint venture shall be registered with Pakistan Engineering Council as per PEC by-Laws.

4. A complete set of bidding documents may be obtained by interested bidders upon submission of a written application to the undersigned and payment of non-refundable fee of PKR 50,000/- (Rupees Fifty Thousand Only). The Payment shall be made in the form of Call Deposit Receipt (CDR) in favor of Project Director, 22 MW Jagran-IV Hydropower Project. The application must be accompanied by a copy of valid PEC license, where applicable.

5. Bidders are responsible for acquainting themselves with the local conditions, including site conditions, access, climate, and other relevant factors and shall take these into account while preparing their bids.

6. Deadline for purchase of bidding documents is **23rd October, 2026 (during office hours)**. The bids shall be submitted on **4th November, 2026 at 12:30 PM**. The bids shall be submitted in the office of undersigned. Technical bids will be opened on the same day at **01:00 PM** in the presence of bidders' representatives who choose to attend.

7. All Bids (Technical) must be accompanied by a Bid Security of PKR 80,000,000/- (Rupees Eighty Million only) or an equivalent amount in a freely convertible currency. The bid security shall be furnished in the form of a Call Deposit Receipt or a bank guarantee (in the prescribed format in the bidding document) issued by any scheduled bank of Pakistan or issued by a foreign bank duly counter guaranteed by a schedule bank in Pakistan, in favor of the Project Director 22 MW Jagran-IV HPP.

8. The Employer reserves the right to reject bids before award of contract without assigning any reason.

Project Director
22 MW Jagran-IV Hydropower Project AJK,
Searbean Residency, Western Bypass Road
Near Saif Plaza, Muzaffarabad Azad Kashmir, Pakistan
pdjrniv@gmail.com
☎:05822-940064

POWER DEVELOPMENT ORGANIZATION
GOVERNMENT OF AZAD JAMMU & KASHMIR

EPC/ TURNKEY BIDDING DOCUMENT
FOR
ENGINEERING, PROCUREMENT AND CONSTRUCTION
OF
22 MW JAGRAN-IV HYDROPOWER PROJECT

LOT-2: ELECTRICAL & MECHANICAL WORKS

Volume-I Bidding Documents

Contract No.: JRN-IV/Lot-2/2026 **July 2026**

Associated Consulting Engineers ACE Limited
36-Civic Centre, M Bloc, Model Town Extension, Lahore – Pakistan. Tel: +92 42 35759417 – 19

Rehman Habib Consultants
160 Khayaban-e-Jinnah, Airline Society, Lahore

Saudconsult Saudi Consulting Services
11451 Sheikh Mubarak Al-Sabah, Sulaymaniyah Riyadh, Saudi Arabia

Volume-I Bidding Documents

Part-1 - Instructions to Bidders and Appendices

Part-2 - Letters of Technical & Price Bid and Schedules to Technical & Price Bid

Part-3 - Schedule of Prices

Part-4 – General Conditions of Contract

Part-5 – Particular Conditions of Contract

Part-6 – Standard Forms

Volume-II Employer Requirements & Specifications

Part-A – Employer Requirements

Part-B – Mechanical Works Specifications

Part-C – Electrical Works Specifications

Volume-III Bidding Drawings

Supplementary Information

1 Tender Design Report, Feb 2026
2 Feasibility Study and Design Review Report, Nov 2025
3 Third Party Validation Report, July 2021
4 Feasibility Study Report, 2010

Volume-I

Part-1

Instruction to Bidders and Appendices

TABLE OF CONTENTS

INVITATION FOR BIDS **1**
INSTRUCTIONS TO BIDDERS & APPENDICES **3**
INSTRUCTIONS TO BIDDERS AND APPENDICES 4
(A) GENERAL 4
IB.1 Scope of Bid and Source of Funds 4
IB.2 Eligible Bidders 5
IB.3 Eligible Goods and Services 6
IB.4 Cost of Bidding 6
(B) BIDDING DOCUMENTS 6
IB.5 Contents of Bidding Documents 6
IB.6 Clarification of Bidding Documents 7
IB.7 Amendment of Bidding Documents 7
(C) PREPARATION OF BIDS 8
IB.8 Language of Bid 8
IB.9 Documents Comprising the Bid 8
IB.10 Letters of Bids and Schedules 9
IB.11 Bid Prices 9
IB.12 Currencies of Bid 9
IB.13 Documents Establishing Bidder's Eligibility and Qualifications 9
IB.14 Documents Establishing Plant's Eligibility and Conformity to Bidding Documents 11
IB.15 Bid Security 12
IB.16 Validity of Bids 12
IB.17 Format and Signing of Bid 13
(D) SUBMISSION OF BIDS 13
IB.18 Sealing and Marking of Bids 13
IB.19 Deadline for Submission of Bids 14
IB.20 Late Bids 14
IB.21 Modification, Substitution and Withdrawal of Bids 14
(E) BID OPENING AND EVALUATION 14
IB.22 Bid Opening 14
IB.23 Clarification of Bids 15
IB.24 Preliminary Examination & Determination of Responsiveness of Bids 15
IB.25 Conversion to Single Currency 17
IB.26 Detailed Evaluation of Bids 17
IB.27 Not Used 23
IB.28 Process to be Confidential 23
(F) AWARD OF CONTRACT 23
IB.29. Post-Qualification 23
IB.30 Award Criteria 24
IB.31 Employer's Right to Vary Quantities 24
IB.32 Employer's Right to Accept any Bid and to Reject any or all Bids 24
IB.33 Notification of Award 24
IB.34 Performance Security 25
IB.35 Signing of Contract Agreement 25
(G) ADDITIONAL INSTRUCTIONS 25
IB.36 Instructions not Part of Contract 25
IB.37 Contract Documents 25
IB.38 Sufficiency of Bid 25

IB.39 One Bid per Bidder 25
IB.40 Bidder to inform himself 25
IB.41 Not Used 26
IB.42 Site Visit and Local Conditions 26
IB.43 Pre-Bid Meeting 26
IB.44 Integrity Pact 27
IB.45 General Performance of the Bidders 27
IB. 46 Grievance Redressal Mechanism 27
(H) APPENDICES 29
Appendix A to Instructions to Bidders 30
NAME OF ELIGIBLE COUNTRIES 30
Appendix B to Instructions to Bidders 31
EVIDENCE OF BIDDER'S CAPABILITY 31
Form B1: Bidder's Information Sheet 33
Form B2: JV Information Sheet 34
Form B3: Financial Situation 35
Form B4: Average Annual Turnover 36
Form B5 (a): General Experience (Contractor) 37
Form B5 (b): Specific Experience of Contractor 38
Form B5 (c): Specific Experience of the Designer & Manufacturer 39
Form B6: Manufacturing Facility Information 40
Form B7: Quality Control Facilities 41
Form B8 (a): Personnel 42
Form B8 (b): Resume of Proposed Personnel 44
Form B9: List of Similar Works Done 45
Form B10: Projects Contractual Commitments 46
Form B11: Financial Resources 47
Form B12: Health, Safety & Emergency Plan 48
Form B13: Training & Employment Plan 49
Form B14 – Litigation or Arbitration 50

INVITATION FOR BIDS

INVITATION FOR BIDS
22 MW JAGRAN-IV HYDROPOWER PROJECT

(Bid Reference: JRN-IV/Lot-II/2026)

ENGINEERING, PROCUREMENT AND CONSTRUCTION CONTRACT FOR ELECTRICAL AND MECHANICAL WORKS UNDER LOT - II OF 22 MW JAGRAN-IV HYDROPOWER PROJECT

1. The Power Development Organization (PDO), Azad Jammu & Kashmir (the "Employer") has received financing from the Saudi Fund for Development (SFD) towards the Construction cost of "22 MW Jagran-IV Hydro Power Project" and it is intended that part of the proceeds of the loan will be applied to eligible payments under the Contract for Lot-II (Electrical & Mechanical Works). Bidding is open to all eligible bidders in accordance with the applicable provisions of the bidding documents.

2. The procurement process shall be conducted in accordance with the Guidelines for the Procurement of Goods and Contracting for the Execution of Works (First Edition, 2001) of the Development Institutions of the Coordination Group, as required under the SFD Loan Agreement. Accordingly, all bidding procedures, evaluation reports and the contract award will be subject to prior review and no objection from SFD.

3. The Employer invites sealed bids in accordance with Single Stage-Two Envelope (Technical + Financial) procedure. The procurement is limited to Joint Ventures comprising at least one Saudi National Company and one Pakistani Firm/Company (having valid C-A Category registration with Pakistan Engineering Council). Firms from other eligible nationalities (registered with Pakistan Engineering Council) can also participate in Joint venture with Saudi-Pakistani firms. No single bidder is allowed to participate in individual capacity. The successful joint venture shall be registered with Pakistan Engineering Council as per PEC by-Laws.

4. A complete set of bidding documents may be obtained by interested bidders upon submission of a written application to the undersigned and payment of non-refundable fee of PKR 50,000/-(Rupees Fifty Thousand Only). The Payment shall be made in the form of Call Deposit Receipt (CDR) in favor of Project Director, 22 MW Jagran-IV Hydropower Project. The application must be accompanied by a copy of valid PEC license, where applicable.

5. Bidders are responsible for acquainting themselves with the local conditions, including site conditions, access, climate, and other relevant factors and shall take these into account while preparing their bids.

6. Deadline for purchase of bidding documents is **23rd October, 2026 (during office hours)**. The bids shall be submitted on **4th November, 2026 at 12:30 PM**. The bids shall be submitted in the office of undersigned. Technical bids will be opened on the same day at **01:00 PM** in the presence of bidders' representatives who choose to attend.

7. All Bids (Technical) must be accompanied by a Bid Security of PKR 80,000,000/- (Rupees Eighty Million only) or an equivalent amount in a freely convertible currency. The bid security shall be furnished in the form of a Call Deposit Receipt or a bank guarantee (in the prescribed format in the bidding document) issued by any scheduled bank of Pakistan or issued by a foreign bank duly counter guaranteed by a schedule bank in Pakistan, in favor of the Project Director 22 MW Jagran-IV HPP.

8. The Employer reserves the right to reject bids before award of contract without assigning any reason.

Project Director
22 MW Jagran-IV Hydropower Project AJK, Searbean Residency, Western Bypass Road
Near Saif Plaza, Muzaffarabad Azad Kashmir, Pakistan
Email: pdjrniv@gmail.com
Phone: 05822-940064

INSTRUCTIONS TO BIDDERS & APPENDICES

INSTRUCTIONS TO BIDDERS AND APPENDICES

(A) GENERAL

IB.1 Scope of Bid and Source of Funds

1.1 Scope of Bid

The Power Development Organization (PDO) AJK (hereinafter called the "Employer") through Project Director wishes to receive Bids on EPC basis for the scope of work which includes, but shall not be limited to:

(a) Mechanical Works

Three 7.14 MW and one 2.24 MW Vertical Shaft Francis Turbines sets complete with Governors & Auxiliaries, Main Inlet Valves, Pressure Relief Values, Powerhouse Cranes, Workshop Equipment, Powerhouse Auxiliary Systems including Cooling Water System, Drainage and Dewatering System, Compressed Air System, Fire Fighting System, Oil Purification System, Heating, Ventilation And Air-Conditioning (HVAC), Fire Detection & Alarm System & Mandatory spare parts.

(b) Electrical Works

Three 6.80 MW (8.50 MVA) and one 2.13 MW (2.66 MVA) Vertical shaft, Salient pole, three-phase A.C. Synchronous Generator sets complete with all auxiliaries, Excitation System, Power & Auxiliary Transformers, Switchgears, Dc Supply System, Plant Control and Automation System, Protection Systems, Main Earthing System and Lightning Protection, Cables and Cable Trays, Emergency Diesel Generator Set, Telecommunication System, Electrification Work, 132 kV transmission line with interconnection works, 11 kV distribution line & Mandatory spare parts.

(c) Commissioning and joint operation for one year after completion

The scope of work under this Contract is Design, Supply, Installation, Test and Commission of Electrical and Mechanical Works etc. according to the scope of work as defined in forthcoming sections.

This Scope of Work, to be performed by the Contractor under EPC Contract for delivering the Employer with fully Commissioned and Operative 22 MW Jagran-IV Hydropower Project including Joint Operation with Civil Works Contractor during Defects Liability Period of one (01) year.

The Contractor shall plan and co-ordinate his activities with those being undertaken by the Civil contractor under Lot 1 – Civil, Auxiliary and Hydraulic Steel Works.

The Civil Works Contractor will provide such openings, holes, plinths and subsidiary foundations as may be necessary for the work under E&M Contract.

The Civil Contractor shall make application to the Employer for the date by which embedment's to be installed by E&M Contractor. If sufficient information and the necessary materials, templates and embedment's etc. are not installed within such time, any alterations or additions to such foundations, walls, floor ducts, pipes and trenches etc. resulted will be made by Civil Works Contractor at the expense of the E&M Contractor.

No Contractor shall be deemed to have fulfilled his obligation insofar as the commissioning of the Plant is concerned until complete end-to-end tests have been carried out to the satisfaction of the Employer.

The E&M Contractor shall provide in accordance with an agreed schedule by the Engineer and Employer early in the Contract period all loads that his equipment will impose upon the civil structure and other equipment already existing or to be provided as part of the Project.

A detailed scope of work has been exclusively described under "Employer Requirements and Specifications". The successful Bidder shall complete the Works within the stipulated period of 36 months / 1095 days as specified in these Bidding Documents.

Bidders must quote prices for the complete scope of work. Any Bid covering partial scope of work will be non-responsive, pursuant to Clause IB.24.

1.2 Source of Funds

The Government of the Islamic Republic of Pakistan, through the Ministry of Economic Affairs, has received financing from the Saudi Fund for Development (SFD) under Loan No. 18/830 for the Establishment of 22 MW Jagran-IV Hydropower Project. It is intended that a portion of the proceeds of this Loan shall be applied to eligible payments under the Contract for Lot-2 (Electrical and Mechanical Works) for which these Bidding Documents are issued.
Procurement, tendering, evaluation, and contract award for Lot-2 shall be carried out in accordance with the "Guidelines for the Procurement of Goods and Contracting for the Execution of Works (First Edition, 2001)" of the Development Institutions of the Coordination Group, as required under the Loan Agreement. All bidding procedures, tender documents, evaluation reports, and the proposed award shall be subject to SFD's prior review and no objection/approval. Any material modification to the Contract shall also require SFD's prior approval.

IB.2 Eligible Bidders

2.1 Bidding is open to all eligible Joint Ventures comprising:

a. Pakistani Firm/Companies (having valid C-A Category registration with Pakistan Engineering Council) and Saudi National Firms / Companies.

b. Firms from other eligible nationalities (registered with Pakistan Engineering Council) can also participate in Joint venture with Saudi-Pakistani firms.

c. No single bidder is allowed to participate in individual capacity.

d. The successful joint venture shall be registered with Pakistan Engineering Council as per PEC by-Laws.

e. Bidders that are Government-owned enterprises or institutions in the Employer's Country may participate only if they can establish that they (i) are legally and financially autonomous (ii) operate under commercial law, and (iii) are not dependent agencies of the Employer.

IB.3 Eligible Goods and Services

3.1 All Goods & ancillary Services to be supplied under this Contract shall have their origin in eligible countries as per Appendix 'A' to Instructions to Bidders and all expenditures made under the Contract will be limited to such Goods and Services.

3.2 For purpose of this Clause, "origin" means the place where the goods are mined, grown or produced or from where the ancillary services are supplied. Goods are produced when, through manufacturing, processing or substantial and major assembling of components, a commercially recognized product results that is substantially different in basic characteristics or in purpose or utility from its components.

3.3 The origin of Goods and Services is distinct from the nationality of the Bidder.

IB.4 Cost of Bidding

4.1 The Bidder shall bear all costs associated with the preparation and submission of its Bid and the Employer will in no case be responsible or liable for those costs, regardless of the conduct or outcome of the Bidding process.

(B) BIDDING DOCUMENTS

IB.5 Contents of Bidding Documents

5.1 In addition to Invitation for Bids, the Bidding Documents are those stated below, and should be read in conjunction with any Addenda issued in accordance with Clause IB.7.

1. Instructions to Bidders (ITB) with Appendices to ITB
2. Letter of Technical Bid & Schedules to Technical Bid

   Schedules to Technical Bid are the following:

   (i) Schedule A: Specific Works data
   (ii) Schedule B: Proposed Organization for the Project
   (iii) Schedule C: Method of Performing Works
   (iv) Schedule D: Proposed Programme of Works
   (v) Schedule E: Work to be Performed by Subcontractors
   (vi) Schedule F: Deviations from Technical & Contractual Provisions
   (vii) Schedule G: Specific Operation/Plant and Equipment Details
   (viii) Schedule H: Specimen JV Agreement
   (ix) Schedule I: Past Performance and Present Commitments
3. Letter of Price Bid & Schedules to Price Bid

   Schedules to Price Bid are the following:

   (i) Schedule J: Integrity Pact
   (ii) Schedule K: Estimated Progress Payments
   (iii) Schedule L: Lump Sum Cost Breakup for Major Cost Items
4. Schedule of Prices

5. Preamble to Conditions of Contract
6. General Conditions of Contract (GCC)
7. Particular Conditions of Contract (PCC)
8. Standard Forms

   Forms include the following:

   (i) Form of Bid Security
   (ii) Form of Contract Agreement
   (iii) Form of Performance Security
   (iv) Form of Bank Guarantee for Advance Payment
   (v) Indemnity Bond for Secured Advance (Not Applicable)
9. Employer Requirements and Specifications
10. Bidding Drawings

5.2 The Bidders are expected to examine carefully the contents of all the above documents. Failure to comply with the requirements of Bid submission will be at the Bidders own risk. Pursuant to Clause IB.24, Bids which are not substantially responsive to the requirements of the Bidding Documents will be rejected.

IB.6 Clarification of Bidding Documents

6.1 A prospective Bidder requiring any clarification(s) in respect of the Bidding Documents may notify the Employer with a copy to the Project Manager/Engineer in writing or by fax at the address as provided under Sub-Clause 49.2 of GCC. Employer will examine the request for clarification of the Bidding Documents which it receives not later than twenty eight (28) days prior to the deadline for the submission of bids and if needed will issue the clarification/amendment of the Bidding Documents at least fourteen (14) days before the date of submission of Bids (without identifying the source of enquiry) to all prospective Bidders who have purchased the Bidding Documents.

IB.7 Amendment of Bidding Documents

7.1 At any time prior to the deadline for submission of bids, the Employer may, for any reason, whether at his own initiative or in response to a clarification requested by a prospective Bidder, modify the Bidding Documents by issuing addendum.

7.2 Any addendum thus issued shall be part of the Bidding Documents pursuant to Sub-Clause 7.1 hereof, and shall be communicated in writing to all purchasers of the Bidding Documents. Prospective Bidders shall acknowledge receipt of each addendum in writing to the Employer. The Bidder shall also confirm in the Form of Bid that the information contained in such addenda have been considered in preparing his Bid.

7.3 To afford prospective Bidders reasonable time in which to take an addendum into account in preparing their Bids, the Employer may at its discretion extend the deadline for submission of Bids in accordance with Clause IB.19.

(C) PREPARATION OF BIDS

IB.8 Language of Bid

8.1 For all purposes related to procurement, evaluation, and communication under the Saudi Fund for Development (SFD) Loan No. 18/830, the English version of all documents shall prevail. The Bid prepared by the Bidder and all correspondence and documents relating to the Bid, exchanged by the Bidder and the Project Manager/Engineer shall be written in the English language, provided that any printed literature furnished by the Bidder may be written in another language so long as accompanied by an English translation (by the authorized translator certified by the Notary Public) of its pertinent passages in which case, for purposes of interpretation of the Bid, the English translation shall govern.

IB.9 Documents Comprising the Bid

9.1 The Bid prepared by the Bidder shall comprise the following components:

(a) Covering Letter

(b) Letters of Bids duly filled, signed and sealed, in accordance with Clause IB.17.

(c) Schedules (A to L) to Bid duly filled and signed, in accordance with the instructions contained therein.

(d) Schedule of Prices completed in accordance with Clauses IB.11 and IB.12 in separate sealed envelope.

(e) Bid Security furnished in accordance with Clause IB.15.

(f) Power of Attorney in accordance with Clause IB 17.5.

(g) Joint Venture Agreement: Must meet requirement. Please refer to Schedule-H for format. Each Joint Venture shall comprise at least one Pakistani firm, one Saudi firm and an additional JV partner, if any in accordance with Clause IB. 2.

(h) Documentary evidence established in accordance with Clause IB.13 that the Bidder is eligible to Bid and is qualified to perform the Contract if its Bid is accepted (past performance and present commitments to be filled in as per schedule I to Bid).

(i) Documentary evidence established in accordance with Clause IB.14 that the Plant and ancillary Services to be supplied by the Bidder are eligible Plant and Services and conform to the Bidding Documents.

(j) Any other documents prescribed in Particular Conditions of Contract or Technical Provisions to be submitted with the Bid.

(k) Signed Environmental & Social Commitment Letter requiring compliance with applicable environmental and labour laws, ILO core conventions, and implementation of mitigation measures in the Employer's ESMP/ESIA requirements.

(l) Non-Blacklisting (Non-Debarment) Affidavit.

IB.10 Letters of Bids and Schedules

10.1 The Bidder shall complete, sign and seal the Letters of Bids, Schedules (A to L, or as modified) to Bid and Schedule of Prices furnished in the Bidding Documents and shall also enclose other information as detailed in Clause IB.9.

IB.11 Bid Prices

11.1 The Bidder shall fill up the Schedule of Prices attached to these documents indicating the unit rates and prices of the Works to be performed under the Contract. Prices on the Schedule of Prices shall be entered keeping in view the instructions contained in the Preamble to the Schedule of Prices.

11.2 The Bidder shall fill in rates and prices for all items of the Works described in the Schedule of Prices. Items against which no rate or price is entered by a Bidder will not be paid for by the Employer when executed and shall be deemed covered by rates and prices for other items in the Schedule of Prices.

11.3 The Bidder's breakup of price components in accordance with Sub-Clause 11.1 above will be solely for the purpose of facilitating the comparison of Bids by the Employer and will not in any way limit its right to contract on any of the terms offered.

11.4 Unless otherwise stipulated in the Conditions of Contract, prices quoted by the Bidder shall remain fixed during the Bidder's performance of the Contract and not subject to variation on any account. When the Bidders are required to quote only fixed price(s), a Bid submitted with an adjustable price quotation will be treated as non-responsive, pursuant to Clause IB.24.

11.5 Any discount offered shall be valid for at least the period of validity of the Bid. A discount valid for lesser period shall be considered null and void.

IB.12 Currencies of Bid

12.1 Prices shall be quoted in the following currencies:

(a) For Plant/Goods and Services which the Bidder will supply from within Pakistan, the prices shall be quoted in the Pak. Rupees.

(b) For Plant/Goods and Services which the Bidder will supply from outside Pakistan, the prices shall be quoted in the US Dollars.

12.2 Further, a Bidder expecting to incur a portion of its expenditure in the performance of the Contract in more than one currency (but use no more than 3 foreign currencies), shall so indicate in its bid (Not Applicable).

12.3 The currency of payment shall be as stated in the Preamble.

IB.13 Documents Establishing Bidder's Eligibility and Qualifications

13.1 Pursuant to Clause IB.9, the Bidder shall furnish, as part of its Bid, documents establishing the Bidder's eligibility to Bid and its qualifications to perform the Contract if its Bid is accepted.

13.2 The documentary evidence of the Bidder's eligibility to Bid shall establish to the Employer's satisfaction that the Bidder, at the time of submission of its Bid is from an eligible source country as defined under Clause IB.2 and submitted documents to be translated in English.

13.3 The documentary evidence of the Bidder's qualifications to perform the Contract if its Bid is accepted, shall establish to the Employer's satisfaction:

a) that the Bidder has the financial, technical and construction capability necessary to perform the Contract; and

b) that all information required for post qualification, as specified in (Evaluation and Qualification Criteria) have been submitted.

13.4 (a) The experience of the Bidder/manufacturer shall be determined in accordance with the criteria provided under IB.26.

b) Documentation regarding the Bidder's experience on previous similar contracts must accompany with each Bid.

c) Bidder shall also submit proof of their financial capability to undertake the Contract.

d) In the event that the successful Bidder is a joint venture formed of two or more companies, the Employer requires that the parties to the joint venture accept joint and several liabilities for all obligations under the Contract.

e) Bidders shall furnish documentary evidence of qualification on the Form "Evidence of Bidder's Capability" (Appendix B to these Instructions).

13.5 **Joint Venture**

In order for a Joint Venture to qualify:

(a) The partners of joint venture shall jointly satisfy the relevant experience criteria specified in Sub-Clause 13.4(a) hereinabove.

(b) All firms comprising the joint venture shall be legally constituted and shall meet the eligibility requirement of Sub-Clause 2.1 hereof.

(c) All partners of the joint venture shall at all times and under all circumstances be liable jointly and severally to Employer for the execution of the entire Contract in accordance with the Contract terms and conditions and a statement to this effect shall be included in the authorization mentioned under para (f) below as well as in the Form of Bid and Form of Contract Agreement (in case of a successful Bidder).

(d) The Form of Bid, and in the case of successful Bidder, the Form of Contract Agreement, shall be signed so as to be legally binding on all partners.

(e) One of the joint venture partners shall be nominated as being in charge (Lead Partner) and this authorization shall be evidenced by submitting a power of attorney signed by legally authorized signatories of all the joint venture partners.

(f) The Lead Partner should have a share ≥40% of the overall bid price.

(g) The partner-in-charge shall be authorized to incur liabilities, receive payments and receive instructions for and on behalf of any or all partners of the joint venture.

(h) A copy of the agreement entered into by the joint venture partners shall be submitted with the Bid stating the conditions under which it will function, its period of duration, the persons authorized to represent and obligate it and which persons will be directly responsible for due performance of the Contract and can give valid receipts on behalf of the joint venture, the proportionate participation of the several firms forming the joint venture, and any other information necessary to permit a full appraisal of its functioning. No amendments / modifications whatsoever in the joint

venture agreement shall be agreed to between the joint venture partners without prior written consent of the Employer (Refer Schedule -H).

(i) The Joint Venture Agreement shall clearly identify which partner(s) assume responsibility for design and which partner(s) assume responsibility for construction, without limiting the joint and several liability of the partners

IB.14 Documents Establishing Plant's Eligibility and Conformity to Bidding Documents

14.1 Pursuant to Clause IB.9, the Bidder shall furnish, as part of its Bid, documents establishing the eligibility and conformity to the Bidding Documents of all Plant and Services which Bidder proposes to perform under the Contract.

14.2 The documentary evidence of the Plant and Services eligibility shall establish to the Employer's satisfaction that they will have their origin in an eligible source country as defined under Clause IB.3. A certificate of origin issued at the time of shipment will satisfy the requirements of the said Clause.

14.3 The documentary evidence of the Plant and Services' conformity to the Bidding Documents may be in the form of literature, drawings and data and shall furnish:

(a) A detailed description of the Plant, essential technical and performance characteristics.

(b) Complete set of technical information, description data, literature and drawings as required in accordance with Schedule A to Bid, Specific Works Data. Drawings and data submitted must be in sufficient detail and clarity to permit the Employer to verify compliance with the provisions of the Bidding Documents. This will include but not be limited to the following:

(i) A sufficient number of drawings, diagrams, photographs, catalogues, illustrations and such other information as are necessary to illustrate clearly the significant characteristics such as general construction dimensions and other relevant information about the Plant to be furnished.

(ii) The approximate weight and dimension of the main components, a brief description of the principal materials and fabrication processes to be used and recommended methods of assembly.

(iii) Any other information which is required for evaluation purposes.

(c) A clause-by-clause commentary on Technical Provisions, provided with the Bidding Documents, demonstrating the Plant's and Service's substantial responsiveness to those Specifications or a statement of deviations and exceptions to the provisions of the Technical Provisions as required in Schedule F to Bid.

14.4 For purpose of the commentary to be furnished pursuant to Sub-Clause 14.3(c) above, the Bidder shall note that standards for workmanship, material and equipment, and references to brand names or catalogue numbers, designated by the Project Manager/Engineer in the Technical Provisions are intended to be descriptive only and not restrictive. The Bidder may substitute alternative standards, brand names and/or catalogue numbers in its Bid, provided that it demonstrates to the Project Manager/Engineer's satisfaction that the substitutions are substantially equivalent or superior to those designated in the Technical Provisions. Copies of the standards proposed by the Bidder other than those specified in the Bidding Documents shall be furnished.

IB.15 Bid Security

15.1 Each Bidder shall furnish, as part of his Technical Bid, a Bid Security of an amount not less than Pak Rupees 80,000,000/- (Eighty million) or an equivalent amount in any freely convertible currency.

15.2 The Bid Security shall be, at the option of the Bidder, in the form of a Deposit at Call or a Bank Guarantee issued by a Scheduled Bank in Pakistan or from a foreign bank duly counter-guaranteed by a Scheduled Bank in Pakistan in favor of the Employer valid for a period twenty eight (28) days beyond the bid validity date. The option of submitting bid security through an insurance company shall not be permitted.

15.3 The Bid Security is required to protect the Employer against the risk of Bidder's conduct which would warrant the security's forfeiture, pursuant to Sub-Clause 15.7 hereof.

15.4 Any Bid not accompanied by an acceptable Bid Security shall be considered by the Employer as non-responsive, pursuant to Clause IB.24. The original bid security shall be submitted along with technical bid at the time of submission of bids.

15.5 The Bid securities of unsuccessful Bidders will be returned upon award of contract to the successful Bidder or on the expiry of validity of Bid Security whichever is earlier.

15.6 The Bid Security of the successful Bidder will be returned when the Bidder has furnished the required Performance Security, pursuant to Clause IB.34, and signed the Contract Agreement, pursuant to Clause IB.35.

15.7 The Bid Security may be forfeited:

(a) if a Bidder withdraws his Bid during the period of Bid validity;

(b) if a Bidder does not accept the correction of his Bid Price, pursuant to Sub-Clause 24.2 hereof; or

(c) in the case of a successful Bidder, if he fails to:

(i) furnish the required Performance Security in accordance with Clause IB.34, or

(ii) sign the Contract Agreement, in accordance with Clause IB.35.

(iii) provide a valid PEC license before signing of Contract.

IB.16 Validity of Bids

16.1 Bids shall remain valid for 120 days (One hundred & twenty days) after the date of Bid opening as prescribed in Clause IB.19.

In exceptional circumstances prior to expiry of original Bid validity period, the Employer may request the Bidders to extend the period of validity for a specified additional period which shall in no case be more than the original Bid validity period. The request and the responses thereto shall be made in writing. A Bidder may refuse the request without forfeiture of his Bid Security. A Bidder agreeing to the request will be required to extend the validity of his Bid Security for the period of the extension, and in compliance with Clause IB.15

IB.17 Format and Signing of Bid

17.1 Bidders are particularly directed that the amount entered on the Form of Bid shall be for performing the Contract strictly in accordance with the Bidding Documents.

17.2 All Schedules to Bid (A to L) are to be properly completed and signed.

17.3 No alteration is to be made in the Form of Bid nor in the Schedules thereto except in filling up the blanks as directed. If any alteration be made or if these instructions be not fully complied with, the Bid may be rejected.

17.4 Each Bidder shall prepare one (1) Original and two (02) Copies of the documents comprising the bid as described in Clause IB.9 and clearly mark them "ORIGINAL" and 'COPY" as appropriate. In the event of discrepancy between them, the original shall prevail.

17.5 The original and all copies of the Bid shall be typed or written in indelible ink and shall be signed by a person or persons duly authorized to sign (in the case of copies, Photostats are also acceptable). This shall be indicated by submitting a written Power of Attorney authorizing the signatory of the Bidder to act for and on behalf of the Bidder. All pages of the Bid and Schedules to Bid shall be initialed and stamped by the person or persons signing the Bid.

17.6 The Bid shall contain no alterations, omissions or additions, except to comply with instructions issued by the Employer, or as are necessary to correct errors made by the Bidder, in which case such corrections shall be initialed by the person or persons signing the Bid.

17.7 Bidders shall indicate in the space provided in the Form of Bid their full and proper addresses at which notices may be legally served on them and to which all correspondence in connection with their Bids and the Contract is to be sent.

17.8 Bidders should retain a copy of the Bidding Documents as their file copy.

(D) SUBMISSION OF BIDS

IB.18 Sealing and Marking of Bids

18.1 Each Bidder shall submit his Bid as under:

(a) ORIGINAL and two COPIES of the original Technical Bid and Price Bid shall be separately sealed and put in separate envelopes and marked as such.

(b) The envelopes containing the ORIGINAL and COPIES of both Technical Bids and Price Bids will be put in one sealed envelope and addressed/identified as given in Sub-Clause 18.2 hereof.

18.2 The inner and outer envelopes shall;

(a) be addressed to the Employer at the address given in Sub-Clause 6.1 heretofore.

(b) bear the Project name, Contract No. and Date of opening of Bid.

(c) provide a warning not to open before the time and date for Bid opening.

18.3 The Bid shall be delivered in person at the address to Employer as mentioned in the Invitation to Bids or as conveyed by the Employer in writing.

18.4 In addition to the identification required in Sub-Clause 18.2 hereof, the inner envelope shall indicate the name and address of the Bidder to enable the Bid to be returned unopened in case it is declared "late" pursuant to Clause IB.20.

18.5 If the outer envelope is not sealed and marked as above, the Employer will assume no responsibility for the misplacement or premature opening of the Bid.

IB.19 Deadline for Submission of Bids

19.1 (a) Bids must be received by the Employer at the address specified in Invitation for Bids not later than the time and date stipulated in the Invitation for Bids.

(b) Bids with charges payable will not be accepted, nor will arrangements be undertaken to collect the Bids from any delivery point other than that specified above. Bidders shall bear all expenses incurred in the preparation and delivery of Bids.

(c) Upon request, acknowledgment of receipt of Bids will be provided to those making delivery in person or by messenger.

19.2 Bids submitted through telegraph, telex, fax or e-mail shall not be considered. The Bids submitted to the specified office and address on the due date and time shall only be considered for evaluation and further process.

19.3 The Employer may, at his discretion, extend the deadline for submission of Bids by issuing an addendum in accordance with Clause IB.7, in which case all rights and obligations of the Employer and the Bidders previously subject to the original deadline will thereafter be subject to the deadline as extended.

IB.20 Late Bids

20.1 (a) Any Bid received by the Employer after the dead line for submission of Bids prescribed in Clause IB.19 will be returned unopened to such Bidder.

(b) Delays in the mail, delays of person in transit, or delivery of a Bid to the wrong office shall not be accepted as an excuse for failure to deliver a Bid at the proper place and time. It shall be the Bidder's responsibility to determine the manner in which timely delivery of his Bid will be accomplished either in person, by messenger.

IB.21 Modification, Substitution and Withdrawal of Bids

21.1 Any Bidder may modify, substitute or withdraw his Bid after Bid submission provided that modification, substitution or written notice of the withdrawal is received by the Employer prior to the deadline for submission of Bids.

21.2 The modification, substitution or withdrawal of any Bid shall be prepared, sealed, marked and delivered in accordance with the provisions of Clause IB.18 with the outer and inner envelopes additionally marked "MODIFICATION", "SUBSTITUTION" or "WITHDRAWAL", as appropriate.

21.3 Withdrawal of a Bid during the interval between the deadline for submission of Bids and the expiration of the period of Bid validity specified in the Form of Bid may result in forfeiture of the Bid Security pursuant to Clause IB.15.

(E) BID OPENING AND EVALUATION

IB.22 Bid Opening

22.1 A committee consisting of nominated members by the Employer and by the Project Manager/Engineer will open the Bids, including withdrawals, substitution and

modifications made pursuant to Clause IB.21, in the presence of Bidders' representatives who choose to attend, at the time, date and location stipulated in the Invitation for Bids. Technical Bids will be opened first. Only the Technical Bids shall be opened at this stage; the sealed Price Bids shall remain unopened. At Technical Bid opening, announce only: Bidder name, withdrawals/substitutions/modifications, presence/absence of Bid Security. Financial Bid envelope remains sealed and is opened later for technically qualified bidders only; prices/unit rates/discounts are read out at Financial Bid Opening. At the end of the evaluation of the Technical Bids, the Employer will invite Bidders who have submitted substantially responsive Technical Bids and who have been determined as being qualified for award to attend opening of the Price Bids.

The Bidders' representatives who are present shall sign a register evidencing their attendance.

22.2 Envelopes marked "MODIFICATION", "SUBSTITUTION" or "WITHDRAWAL" shall be opened and read out first and the name of the Bidder shall be read out. Bids for which an acceptable notice of withdrawal has been submitted pursuant to Clause IB.21 shall not be opened.

22.3 The Bidder's name, Bid Prices, unit rates, any discount offered, Bid modifications, substitutions and withdrawals, and such other details as the Employer at its discretion may consider appropriate, will be announced by the Employer at the Bid opening. The Employer will record minutes of Bid opening.

Any Bid Price or discount which is not read out and recorded at Bid opening will not be taken into account in the evaluation of Bid. Any discount offered by the Bidder on its quoted prices, shall only be considered if such discount is either shown on the duly filled-in, signed and stamped Form of Bid/Letter of price bid or on the Summary Page of the quoted amount for Lump sum contract/bill of quantities as applicable. In case of any discrepancy or difference in the rate or amount of discount mentioned in the Form of Bid/Letter of price bid (as duly filled-in and signed), and on the Summary Page of the Priced BOQ, the discount shown on the Priced BOQ shall prevail. Discount, if offered, through a separate letter of discount submitted with the Bid, will not be entertained and shall be considered null & void."

22.4 Discounts offered for lesser period than the Bid validity shall not be considered in evaluation.

IB.23 Clarification of Bids

23.1 To assist in the examination, evaluation and comparison of Bids, the Project Manager/Engineer may, at its discretion, ask the Bidder for a clarification of its Bid. The request for clarification and the response shall be in writing and no change in the price or substance of the Bid shall be sought, offered or permitted.

IB.24 Preliminary Examination & Determination of Responsiveness of Bids

24.1 Prior to detailed evaluation pursuant to Clause IB.26, the Project Manager/Engineer will determine the responsiveness of the Bids as follows:

(a) the Project Manager/Engineer will examine the Bids to determine whether;

(i) the Bid is complete and does not deviate from the scope,

(ii) any computational errors have been made,

(iii) required sureties have been furnished,

(iv) the documents have been properly signed,

(v) the Bid is valid till required period,

(vi) the *Bid prices are firm during currency of contract if it is a fixed price bid,

(vii) completion period offered is within specified limits,

(viii) the Bidder/Manufacturer is eligible to Bid and possesses the requisite experience,

(ix) the Bid does not deviate from basic technical requirements; and

(x) the Bids are generally in order.

(b) A bid is likely not to be considered, if;

(i) it is unsigned,

(ii) its validity is less than specified,

(iii) it is submitted for incomplete scope of work,

(iv) it indicates completion period later than specified,

(v) it indicates that Works and materials to be supplied do not meet eligibility requirements,

(vi) it indicates that *Bid prices do not include the amount of income tax, and

(vii) Alteration in Form of Bid as per IB.17.3.

(c) A bid will not be considered, if;

(i) it is not accompanied with bid security,

(ii) it is submitted by a Bidder who has participated in more than one Bid,

(iii) it is received after the deadline for submission of Bids,

(iv) it is submitted through fax, telex, telegram or email,

(v) it indicates that prices quoted are not firm during currency of the contract whereas the Bidders are required to quote fixed price(s),

(vi) the Bidder refuses to accept arithmetic correction,

(vii) it is materially and substantially different from the Conditions/ Specifications of the Bidding Documents.

[*Bid Prices can only be opened of the Eligible, Qualified and Technically Responsive Bidders, at the next stage after Technical Evaluation]

It is after review and determination of the responsiveness as per above that further action on technical evaluation will be taken.

24.2 Arithmetical errors will be rectified on the following basis:

If there is a discrepancy between the unit price and total price that is obtained by multiplying the unit price and quantity, the unit price shall prevail and the total price shall be corrected. If there is a discrepancy between the words and figures the amount in words shall prevail. If there is a discrepancy between the total Bid price entered in Form of Price Bid and the total shown in Schedule of Prices Summary, the amount stated in the Form of Price Bid will be corrected by the Employer/Project Manager/Engineer in accordance with the Corrected Schedule of Prices.

If the Bidder does not accept the corrected amount of Bid, his Bid will be rejected and his Bid Security forfeited.

24.3 Prior to the detailed evaluation, pursuant to Clause IB.26 the Employer/Project Manager/Engineer will determine the substantial responsiveness of each Bid to the Bidding Documents. For purpose of these Clauses, a substantially responsive Bid is one which conforms to all the terms and conditions of the Bidding Documents without material deviations.

A material deviation or reservation is one:

(i) which affect in any substantial way the scope, quality or performance of the Works;

(ii) which limits in any substantial way, inconsistent with the Bidding Documents, the Employer's rights or the Bidder's obligations under the Contract; or

(iii) whose rectification/adoption would affect unfairly the competitive position of other Bidders presenting substantially responsive Bids.

The Employer's/Project Manager/Engineer's determination of a Bid responsiveness will be based on the contents of the Bid itself without recourse to irrelevant evidence.

24.4 A Bid determined as substantially non-responsive will be rejected and will not subsequently be made responsive by the Bidder by correction of the non-conformity.

24.5 Any minor informality or non-conformity or irregularity in a Bid which does not constitute a material deviation may be waived by Employer, as long as the waiver does not prejudice or affect the relative ranking of any Bidder.

IB.25 Conversion to Single Currency

25.1 To facilitate evaluation and comparison, the Project Manager/Engineer will convert all Bid Prices, expressed in the amounts in various currencies in which the bid Price is quoted, to Pak Rupees at the Ready exchange rate for Mark to Market published/authorized by the State Bank of Pakistan and applicable to similar transaction, 28 days prior to Bid submission date.

IB.26 Detailed Evaluation of Bids

26.1 Only the Bids previously determined to be substantially responsive pursuant to Clause IB.24 will be evaluated and compared in detail by the Employer/Project Manager/Engineer as per the requirements given hereunder:

26.2 Evaluation and Comparison of Bids

(a) Bids will be evaluated for each item and/or complete scope of work.

(b) Basis of Price Comparison

The prices will be compared on the basis of the Evaluated Bid Price pursuant to Para (e) herein below.

(c) Technical Evaluation

(i) It will be examined in detail whether the Plant/facility offered by the Bidder comply with the Technical Provisions of the Bidding Documents. For this purpose, design offered by the Bidder will be reviewed for which the Bidder's data submitted with the Bid under Schedule A to Bid (Specific

Works Data) will be compared with the technical features/criteria of the Plant/facility detailed and prescribed by the Employer in these documents. Other technical information submitted with the Bid regarding the Scope of Work will also be reviewed including importations, if any, required.

(ii) The criteria for evaluation of technical bid shall be as per following details:

Evaluation and Qualification Criteria

Sr No	Requirement (Must Submit)	Documentation Requirement	JV – All partners combined	JV – Each partner	JV – At least one partner
1	Legal registration	Certified copy of incorporation/registration certificate; ownership/partners list	N/A	Must meet requirement	N/A
2	Power of Attorney for signatory	Original/attested Power of Attorney authorizing signatory (stamp paper as required)	N/A	Must meet requirement	N/A
3	PEC Registration	• PEC registration certificate (**C-A**) for Pakistan Firms • PEC registration certificate in appropriate category for JV partner	N/A	Must meet requirement	N/A
4	JV Agreement	Signed JV agreement stating roles/shares; lead partner nomination; joint & several liability;	Mandatory	N/A	N/A
5	Non blacklisting affidavit	Notarized affidavit of non blacklisting/ debarment for each entity	N/A	Must meet requirement	N/A
6	Bid security	Original with Technical Bid	Mandatory Collectively	N/A	On behalf of JV by Lead Partner
7	Acceptance of EPC scope + completion period	Signed acceptance of EPC design responsibility + 36 months completion; no conditionality	Must meet requirement	Must meet requirement	N/A
8	Addenda acknowledgement	Signed acknowledgement of each addendum issued	Must meet requirement	Must meet requirement	N/A

Construction Experience

- To substantiate the Experience, bidder shall submit authenticated Taking Over/ Performance certificate/ Defects Liability certificates, JV agreement and other relevant documents.
- For Works completed as JV Partner, the Bidder's share by value shall be considered to meet the requirement.

Criteria	Compliance Requirements			Documents
Requirement	Joint Venture			Submission Requirements
	All Partners Combined	Each Partner	One Partner	
General Experience of the firm as per schedule I				
Experience under construction contracts in the role of Lead Contractor, JV member, or management Contractor for at least 10 years prior to the deadline for submission of bids.	Not applicable	Not applicable	The Lead Partner of the JV must fulfill the experience requirement.	Form B5(a)
Particular/Specific Experience of the firm as per schedule I				
The Bidder shall have successfully completed at least One Electro Mechanical contract during the last Ten (10) years for hydropower projects having installed capacity of not less than 10 MW in capacity of Lead contractor, JV member or management contractor. The contract shall include design, manufacture, supply, installation, testing and commissioning of Hydro Mechanical (turbines, and auxiliary systems), associated electrical works (generators and other electrical equipment), I&C & Communication works i.e. complete electro-mechanical work of hydropower plant.	Must meet Requirement	Not applicable	The Lead Partner of the JV must fulfill the experience requirement.	Form B5(b) & Form B9

Manufacturing experience/ Design capacity

To substantiate the experience, the bidder shall submit authenticated Taking-Over, Completion/ Performance/ Defects Liability certificates, and other relevant documents.

Employer may ask Bidder for physical verification of the claimed projects at the cost of bidder.

Criteria	Compliance Requirements	Documents
Requirement	**Joint Venture or Its Specialist Subcontractors**	**Submission Requirements**
Manufacturing Experience		
The Bidder/ Manufacturers or its Sub-Contractors must have at least 10 years of general design, manufacturing, installation, testing, and commissioning experience of Electrical & Mechanical Plant & Equipment, similar to the Employer's Requirement including the following key activities: (i) The Manufacturers possess valid ISO Certification for Quality Management System or Equivalent. (ii) If Bidder is not the manufacturer, the Bidder shall obtain from the experienced manufacturers as above, its authorization & commitment to supply Electrical & Mechanical Plant & Equipment for the project.	Must meet requirement	Form B5 (C) & Form B6
Design Capacity		
The Bidder shall demonstrate in house or OEM backed design capability covering hydro turbines, generators, governors, electrical systems and instrumentation & control systems.	Must meet requirement	Form B5 (C)

Competence/ Performance

Criteria	Compliance Requirements			Documents
Requirement	**Joint Venture**			**Submission Requirements**
	All Partners Combined	**Each Partner**	**One Partner**	
Construction Schedule/ Work methodology/Resource scheduling plan	Must meet requirement	Not applicable	Not applicable	Schedules B, C and D
Available Resources of the firm i.e. Equipment and Manpower as per schedule G	Must meet requirement	Not applicable	Not applicable	Schedule G & Form B8(a) & Form B8(b)etc.
Past performance as per schedule I Certificate of satisfactory performance from the Client.	Not applicable	Must meet requirement	Not applicable	Schedule I
Current work commitments as per schedule I - Certificate of satisfactory performance from the Client.	Not applicable	Must meet requirement	Not applicable	Schedule I

Financial Situation

Criteria	Compliance Requirements			Documents
Requirement	Joint Venture			Submission Requirements
	All Partners Combined	Each Partner	One Partner	
Historical Financial Performance				
Submission of audited balance sheets and income statements for the last three (03) years to demonstrate the current soundness of Bidder's financial position and its prospective long term profitability. As a minimum, a Bidder's net worth, calculated as the difference between total assets and total liabilities, should be positive.	Not applicable	Must meet requirement	Not applicable	Form B3
Average Annual Construction Turnover				
Minimum average annual turnover of PKR 03 billion calculated as total certified payments received for contracts in progress or completed, within the last Three (03) years.	Must meet requirement	Must meet 25%. of the requirement	Lead Partner Must meet 40% of the requirement	Form B4
Financial Resources				
The Bidder must demonstrate access to or availability of financial resources such as liquid assets, unnumbered real assets, lines of credit, and other financial means, other than any contractual advance payment to meet the cash flow requirement of 500 million PKR net of other current contractual commitments.	Must t meet requirement	Must meet 25% of the requirement	Lead Partner Must meet 40% of the requirement	Form B3, Form B10 & Form B11

Note: The bidder must Pass all criteria mentioned above to be declared technically qualified. Financial bids of non-qualified bidders shall remain unopened. The similar Project Means a hydropower Project of 10 MW or above capacity involving similar major plant & equipment.

(d) Commercial Evaluation

It will be examined in detail whether the Bids comply with the commercial/contractual conditions of the Bidding Documents. It is expected that no major deviation/stipulation shall be taken by the Bidders.

(e) Evaluated Bid Price

In evaluating the Bids, the Employer will determine for each Bid in addition to the Bid Price, the following factors (adjustments) in the manner and to the extent indicated below to determine the Evaluated Bid Price:

(i) making any correction for errors pursuant to Sub-Clause 24.2 hereof.
(ii) excluding Provisional Sums, if any, but including priced Daywork.
(iii) making an appropriate adjustment for any other acceptable variation or deviation.

26.3 Evaluation Methods

Pursuant to Sub-Clause 26.2, Para (e)(iii) following evaluation methods for price adjustments will be followed in the financial evaluation:

(a) Price Adjustment for Completeness in Scope of Work

(b) Price Adjustment for Technical Compliance

(c) Price Adjustment for Commercial Compliance

(d) Price Adjustment for Deviations in Terms of Payment

(e) Price Adjustment for Completion Schedule

(i) Price Adjustment for Completeness in Scope of Work

No Deviation Allowed.

(ii) Price Adjustment for Technical Compliance

The cost of making good any deficiency resulting from technical non compliance will be added to the Corrected Total Bid Price for comparison purposes only. The adjustments will be applied taking the average price quoted by other Bidders being evaluated in detail in their original Bids for corresponding item. In case of non availability of price from other Bidders, the price will be estimated by the Project Manager/Engineer.

The price adjustment for variation in plant will be made as follows:

- The rated efficiencies of the turbine and generator will be 91% and 95% respectively.
- The reference weighted average efficiencies of the turbine and generator will be 89.5% and 93.5% respectively.
- The bidders shall state the offered weighted average efficiencies of the turbine and generator in the Technical Bids.
- The bid price will be increased by USD 10,000 for each 0.01% or part thereof if the offered weighted average efficiencies of the turbine and generator are less than the reference weighted efficiencies of the turbine and generator respectively for evaluation purposes only.

- If the offered weighted average efficiencies of the turbine and generator shall be less than by 1.5% or more from the reference weighted average efficiencies of the turbine and generator respectively, the Bid (s) shall be deemed non responsive and rejected.

(iii) Price Adjustment for Commercial Compliance

No Deviation Allowed.

(iv) Price Adjustment for Deviation in Terms of Payment
No Deviation Allowed.

(v) Price Adjustment for Completion Schedule

No Deviation Allowed.

26.4 If the Bid of the successful Bidder is seriously unbalanced in relation to the Employer's estimate of the cost of work to be performed under the Contract, the Employer may require the Bidder to produce detailed price analyses for any or all items of the Schedule of Prices to demonstrate the internal consistency of those prices with the construction methods and schedule proposed. After evaluation of the price analyses, the Employer may require that the amount of the Performance Security set forth in Clause IB.34 be increased at the expense of the successful Bidder to a level sufficient to protect the Employer against financial loss in the event of default of the successful Bidder under the Contract.

IB.27 Not Used

IB.28 Process to be Confidential

28.1 Subject to Clause 23 heretofore, no Bidder shall contact Employer and/or Project Manager/Engineer on any matter relating to its Bid from the time of the Bid opening to the time the Bid evaluation result is announced by the Employer. The evaluation result shall be announced at least ten (10) days prior to award of Contract. The announcement to all Bidders will include table(s) comprising read out prices, discounted prices, price adjustments made, final evaluated prices and recommendations against all the Bids evaluated.

28.2 Any effort by a Bidder to influence Employer and/or Project Manager/Engineer in the Bid evaluation, bid comparison or Contract Award decisions may result in the rejection of his Bid, in accordance with the Integrity Pact and applicable anti-corruption laws. Any bidder feeling aggrieved by any act of the procuring agency after the submission of his bid may lodge a written complaint concerning his grievances within seven days of announcement of the technical evaluation report and five days after issuance of final evaluation report.

(F) AWARD OF CONTRACT

IB.29. Post-Qualification

29.1 The Employer, at any stage of the bid evaluation, having credible reasons for or *prima facie* evidence of any defect in supplier's or contractor's capacities, may require the suppliers or contractors to provide information concerning their professional, technical, financial, legal or managerial competence whether already pre-qualified or not:

Provided that such qualification shall only be laid down after recording reasons therefore in writing. They shall form part of the records of that bid evaluation report.

29.2 The determination will take into account the Bidder's financial, technical and production capabilities. It will be based upon an examination of the documentary evidence of the Bidder's qualification submitted under Appendix B to Instructions to Bidders "Evidence of Bidder's Capability" by the Bidder pursuant to Clause IB.13, as well as such other information as required under the Bidding Documents.

29.3 An affirmative determination will be a pre-requisite for award of the Contract to the lowest evaluated Bidder. A negative determination will result in rejection of that Bidder's Bid in which event, Employer will proceed to undertake a similar determination of the next lowest evaluated Bidder's capabilities to perform the Contract satisfactorily.

IB.30 Award Criteria

30.1 Subject to Clause IB.32, the Employer will award the Contract to the Bidder whose Bid has been determined to be substantially responsive to the Bidding Documents and who has offered the lowest evaluated Bid Price, provided that such Bidder has been determined to be qualified to satisfactorily perform the Contract in accordance with the provisions of Clause IB.29.

IB.31 Employer's Right to Vary Quantities

31.1 Employer reserves the right at the time of award of Contract to increase or decrease by up to Fifteen (15%) the quantity of Plant and Services contained in the Schedule of Prices without any change in the unit price or other terms and conditions.

IB.32 Employer's Right to Accept any Bid and to Reject any or all Bids

32.1 Notwithstanding Clause IB.30, the Employer reserves the right to accept or reject any Bid and to annul the bidding process and reject all Bids, at any time prior to award of Contract, without thereby incurring any liability to the affected Bidders or any obligation to inform the affected Bidders of the grounds for the Employer's action except that the grounds for its rejection shall upon request be communicated, to any Bidder who submitted a Bid, without justification of grounds. Rejection of all Bids shall be notified to all Bidders promptly.

32.2 No negotiation with the Bidder having been evaluated as lowest responsive or any other Bidder shall be permitted. However, the Employer may have clarification meeting(s) to get clarified any item(s) in the Bid evaluation report.

IB.33 Notification of Award

33.1 Prior to expiration of the period of Bid validity prescribed by the Employer, the Employer will notify the successful Bidder in writing ("Letter of Acceptance") that his Bid has been accepted. This letter shall name the sum which the Employer will pay the Contractor in consideration of the design, execution and completion of the Works/facility by the Contractor as prescribed by the Contract (hereinafter and in the Conditions of Contract called the "Contract Price").

33.2 The Letter of Acceptance and its acceptance by the Bidder will constitute the formation of the Contract, binding the Employer and the Bidder till signing of the formal Contract Agreement.

33.3 Upon furnishing by the successful Bidder of a Performance Security, the Employer will promptly notify the other Bidders that their Bids have been unsuccessful and return their Bid securities.

IB.34 Performance Security

34.1 The successful Bidder shall furnish to the Employer a Performance Security in the form and the amount stipulated in the Conditions of Contract within a period of twenty eight (28) days after the receipt of Letter of Acceptance.

34.2 Failure of the successful Bidder to comply with the requirements of Sub-Clauses IB.34.1, IB.35 or Clause IB.44 shall constitute sufficient grounds for the annulment of the award and forfeiture of the Bid Security.

IB.35 Signing of Contract Agreement

35.1 Within fourteen (14) days from the date of furnishing of acceptable Performance Security under the Conditions of Contract, the Employer will send to the successful Bidder the Form of Contract Agreement provided in the Bidding Documents, duly filled in and incorporating all agreements between the parties for signing and return it to the Employer.

35.2 The formal Agreement between the Employer and the successful Bidder shall be executed within fourteen (14) days of the receipt of such Form of Contract Agreement by the successful Bidder from the Employer.

(G) ADDITIONAL INSTRUCTIONS

IB.36 Instructions not Part of Contract

36.1 Bids shall be prepared and submitted in accordance with the above Instructions to Bidders including Additional Instructions which are provided to assist Bidders in preparing their Bids, and do not constitute part of the Bid or the Contract Documents.

IB.37 Contract Documents

37.1 The Documents which will be included in the Contract are listed in the Form of Contract Agreement set out in these Bidding Documents.

IB.38 Sufficiency of Bid

38.1 Each Bidder shall satisfy himself before bidding as to the correctness and sufficiency of his Bid and of the rates and prices entered in the Schedule of Prices. Except insofar as it is otherwise expressly provided in the Contract, the rates and prices entered in the Schedule of Price shall cover all his obligations under the Contract and all matters and things necessary for the proper completion of the Works/facility.

IB.39 One Bid per Bidder

39.1 Each Bidder shall submit only one Bid either by himself, or as a partner in a joint venture. A Bidder who submits or participates in more than one Bid will be disqualified and Bids submitted by him shall not be considered for evaluation and award.

IB.40 Bidder to inform himself

40.1 The Bidder is advised to obtain for himself at his own cost and responsibility all information that may be necessary for preparing the Bid and entering into a Contract for execution of the Works/facility. This shall include but not be limited to the following:

(a) inquiries on Pakistani Income Tax to the Commissioner of the Income Tax and Sales Tax.

(b) inquiries on customs duties and other import taxes, to the concerned authorities of Customs and Excise Department.

(c) information regarding port clearance facilities, loading and unloading facilities, storage facilities, transportation facilities and congestion at Pakistan seaports.

(d) investigations regarding transport conditions and the probable conditions which will exist at the time the Plant will be actually transported.

(e) The Bidder shall further satisfy himself regarding the site conditions, climatic conditions, hydrological conditions, geological and geotechnical conditions, access to the site, health, safety and security conditions, availability of labour, materials and all other circumstances which may affect the cost, execution, completion and performance of the Works.

(f) For this EPC Contract, the Bidder shall be deemed to have fully acquainted himself with all information necessary for the design, fabrication, supply, construction, erection, testing and commissioning of the Works, and no claim whatsoever shall be entertained on account of failure to obtain such information prior to the submission of the Bid.

IB.41 Not Used

IB.42 Site Visit and Local Conditions

42.1 Bidder must verify and supplement by his own investigations the information about site and local conditions. However, Employer will assist the Bidder wherever practicable and possible.

42.2 All Bidders are required to visit the site at their own expense to review the areas allocated for the Plant and the interfacing facilities, if any. Bidders may also wish to study local conditions, available facilities, communications, craft wages, roads and other transport facilities. Bidders shall also acquaint themselves with the relevant laws, rules, and regulations of Pakistan.

42.3 The Bidders and any of their personnel or agents will be granted permission by the Employer to enter upon his premises and lands for the purpose of such inspection, but only upon the express condition that the Bidders, their personnel and agents, will release and indemnify the Employer, his personnel and agents from and against all liability in respect thereof and will be responsible for death or personal injury, loss of or damage to property and any other loss, damage, costs and expenses incurred as a result of such inspection.

IB.43 Pre-Bid Meeting

43.1 The Employer may, at his own or at the request of any prospective Bidder(s), hold a Pre-Bid meeting to clarify issues and to answer any questions on matters related to the Bidding Documents. The date, time and venue of Pre-Bid meeting, if convened, shall be intimated through letter for invitation.

All prospective Bidders or their authorized representatives shall be invited to attend such a Pre-Bid meeting.

IB.44 Integrity Pact

44.1 The Bidder shall sign and stamp the Integrity Pact provided in Schedule-J to Bid in the Bidding Documents for all Federal Government procurement contracts exceeding Rupees ten million. Failure to provide such Integrity Pact shall make the Bid non-responsive.

IB.45 General Performance of the Bidders

45.1 The Employer reserves the right to obtain information regarding performance of the Bidders on their previously awarded contracts/works (Schedule-I to bid). The Employer may in case of consistent poor performance of any Bidder as reported by the employers of the previously awarded contracts, interalia, reject his bid and/or refer the case to the Pakistan Engineering Council. Upon such reference, PEC in accordance with its rules, procedures and relevant laws of the land take such action as may be deemed appropriate under the circumstances of the case including blacklisting of such Bidder and debarring him from participation in future bidding for similar works.

45.2 The Employer may verify past performance, delays, contractual defaults, abandonment of work, poor quality, or disputes from any previous employer, consultant, engineer, or public record, whether or not such information has been provided by the Bidder.

45.3 Any adverse performance history discovered during Technical Evaluation or Post-Qualification, including material non-performance or failure to meet contractual obligations in past projects, shall render the Bidder's Bid non-responsive and shall constitute sufficient grounds for rejection of the Bid.

45.4 Any Bidder who has demonstrably failed to successfully complete any ongoing or past project, whether acting individually or as a constituent member of a Joint Venture, shall be disqualified from further consideration in this procurement process. The determination of such failure, including its relevance and materiality, shall rest solely with the Employer, whose decision shall be final, conclusive, and binding, and shall not be subject to challenge, appeal or claim by the Bidder.

45.5 The Bidder shall have no claim whatsoever against the Employer regarding the use of such verified information for the purpose of determining the Bidder's qualification or lack thereof

IB. 46 Grievance Redressal Mechanism

46.1 The procuring agency shall constitute a Grievance Redressal Committee (GRC) to address the complaints of Bidders.

46.2 Any Bidder who feels aggrieved by any act of the Employer after the submission of their Bid may lodge a written complaint regarding their grievance(s) as follows:

a) Within seven (7) calendar days of the announcement of the Technical Evaluation Report; and

b) Within five (5) calendar days of the issuance of the Final Evaluation Report.

46.3 In the event a complaint is filed against the Technical Evaluation Report, the Financial (Price) Bids shall not be opened until the GRC has reviewed and decided upon the complaint.

46.4 If a complaint is filed after the issuance of the Final Evaluation Report, the complainant shall not be entitled to raise any objections pertaining to the Technical Evaluation.

46.5 The GRC shall investigate and decide upon the complaint within ten (10) calendar days of its receipt. The decision of the GRC shall be communicated in writing to the complainant. The decision of GRC committee shall be final subject to its approval/consent by Donor Agency.

46.6 Litigation from any bidder after decision of GRC may lead toward debarment of fims/ companies/ JV's for future contracts.

(H) APPENDICES

The Appendices to ITB are as given below:

- Appendix-A: Name of Eligible Countries
- Appendix-B: Evidence of Bidder's Capabilities & its Form B1 to B14

Appendix A to
Instructions to Bidders

NAME OF ELIGIBLE COUNTRIES

All countries of the World with whom Islamic Republic of Pakistan have commercial relations.

Appendix B to
Instructions to Bidders

EVIDENCE OF BIDDER'S CAPABILITY

Note: Bidders to provide the following information with the Bid separately and indicate herein its references where this information is available.

Sr. No.	Information to be Supplied	Bid References
1	Name of Bidder, business address , and country of incorporation.	Form B1: Bidders Information Sheet.
2	Type of firm whether individually owned, partnership, corporation, or joint venture, and the names of its owners or partners.	Form B1 & B2: JV Information Sheet
3	The annual reports giving a general description of the firm, the sort of business carried out, balance sheets, profit and loss statements, turnover, and business done by the firm, duly authenticated, for the last three (3) years. Audited Balance Sheets for the preceding three (3) years and projected assets and liabilities for the next two (2) years shall be provided. i. Total value of works in hand on bid opening/preparation date. ii. Total value of works completed in the last three years	Form B3: Financial Situation, Form B10 & Form B 11. Form B4: Average Annual Turnover
4	(a) Has completed at least One Electro Mechanical contract during the last Ten (10) years for hydropower projects having installed capacity of not less than 10 MW (Schedule –I to bid); (b) Demonstrate experience in manufacturing, design and installation as per requirement of the Evaluation Criteria.	Form B5(b) & (c): Specific Experience & Form B9.
5	Location and address of manufacturing facilities as applicable.	Form B6: Manufacturing Facility Information
6	Full description of factories owned, and the annual manufacturing capacities of various items made therein.	Form B6: Manufacturing Facility Information
7	Details of the facilities where the offered equipment is proposed to be manufactured. This description should include the facilities and capacities of the particular factories including testing facilities and the processes used in manufacturing and testing. Where parts or components are purchased from outside, the details of equipment purchased, and the names and experience records of the suppliers.	Form B6: Manufacturing Facility Information
8	Detailed description of the quality control testing and research facilities. If the equipment is manufactured under license, the name of the licensee and details of the licensing arrangements, such as the duration of the license, the facilities provided to the Bidder by the licensee, and whether future improvements are available or not, etc. A copy of the license agreement may be attached. Quality Control/ Quality assurance plan must also be submitted.	Form B7: Quality Control Facilities
9	(a) Names, qualifications, and experience of the key technical personnel along with Resumes. (b) (i) Nos. of total permanent Staff on roll of the company. (ii)Nos. of total qualified engineers on roll of the company.	Form B8 (a): Personnel Form B8 (b): Resume of Proposed Personnel

Sr. No.	Information to be Supplied	Bid References
10	The time since the manufacturer has been in this business and the time since he has been doing work of a similar nature.	Form B6: Manufacturing Facility Information
11	The time since the particular equipment offered has been manufactured and the time for which it has been in service. The manufacturer shall have the experience stated in Sub-Clause IB 13.4(a).	Form B6: Manufacturing Facility Information
12	Reference lists of similar works done by the Bidder in its country and abroad indicating the name of customer, description, and quantity of product, year of supply, and the approximate value. This is an important consideration and should be filled in with full details stated in Sub-Clause IB 13.4(a). (attach separate sheet if needed)	Form B9: List of Similar Works Done
13	Details of projects under execution and future contractual commitments (for each partner, in case of a joint venture).	Form B10: Projects Contractual Commitments
14	(a) Banking reference, names of banks, and addresses may be given to whom reference regarding the financial capability of the Bidder may be made, with authority to make inquiries from the Bidder's bankers and clients regarding any financial and technical aspects (for each partner, in case of a joint venture). (b) Detail of OD limit allowed to the firm by the bank for the business including the amount and its validity period.	Form B11: Financial Resources
15	Health, Safety, and emergency plan as well as Risk Management plan for the project.	Form B12: Health, Safety & Emergency Plan
16	Detailed/ Integrated work plan along with methodology to complete the assignment.	Refer: Schedule C
17	Training and Employment plan of local workforce for which bidder is to at least have a budget of Rs 5.0 million for incurring expenditures on arranging such training (for a period of one (01) months minimum) for Employer staff who are to maintain and operate the facility after construction. This is not reimbursable and the bidder has to consider this the amount included in his rate and prices of Bid.	Form B13: Training & Employment Plan
18	Information on any litigation or arbitration resulting from contracts completed or under execution by the Bidder over the last ten (10) years. The information shall indicate the parties concerned, the matter of dispute, the disputed amounts, and the result thereof (for each partner, in case of a joint venture).	Form B14 Litigation or Arbitration

Form B1: Bidder's Information Sheet

Bidder's legal name	
Type of Firm, Name of owners and Partners / **In case of JV, legal name of each partner**	
Bidder's country of Incorporation	
Bidder'syear of incorporation	
Bidder's legal address in country of incorporation	
Bidder's authorized representative (name, address, telephone numbers, fax numbers, e-mail address)	
Attached are copies of the following original documents. ❑ 1. In case of single entity, articles of in-corporation of the legal entity named above, in accordance with IB 2. ❑ 2. Authorization to represent the firm or JV named in above, in accordance with IB 17.5. ❑ 3. Registration with Pakistan Engineering Council in Category C-A, in accordance with IB2.	

Form B2: JV Information Sheet

Each member of a JV must fill in this form

JV Information	
Bidder's legal name	
JV Partner's legal name	
JV Partner's country of constitution	
JV Partner's year of constitution	
JV Partner's legal address in country of constitution	
JV Partner's authorized representative information (name, address, telephone numbers, fax numbers, e-mail address)	
Attached are copies of the following original documents. ❑ 1. Articles of incorporation of the legal entity named above, in accordance with IB 2. ❑ 2. Authorization to represent the firm named above, in accordance with IB 17.5. ❑ 3. Registration with Pakistan Engineering Council in Category C-A or FC-1 or above, in accordance with IB2.	

Form B3: Financial Situation

Each Bidder or member of a JV must fill in this form

Financial Data for Previous 3 Years [US$ Equivalent]		
Year 1:	**Year 2:**	**Year 3:**

Information from Balance Sheet

Total Assets			
Total Liabilities			
Net Worth			
Current Assets			
Current Liabilities			

Information from Income Statement

Total Revenues			
Profits Before Taxes			
Profits After Taxes			

❑ Attached are copies of financial statements (balance sheets including all related notes, and income statements) for the last three years, as indicated above, complying with the following conditions.

- All such documents reflect the financial situation of the Bidder or partner to a JV, and not sister or parent companies.
- Historic financial statements must be audited by a certified accountant.
- Historic financial statements must be complete, including all notes to the financial statements.
- Historic financial statements must correspond to accounting periods already completed and audited (no statements for partial periods shall be requested or accepted).

Form B4: Average Annual Turnover

Each Bidder or member of a JV must fill in this form

Annual Turnover Data for the Last 3 Years			
Year	**Amount in Pak Rs.**	**Exchange Rate (Average Annual)**	**US$ Equivalent**
		Average Annual Turnover	

The information supplied should be the Annual Turnover of the Bidder or each member of a JV in terms of the amounts billed to clients for each year for contracts in progress or completed, converted to US Dollars at the rate of exchange at the end of the period reported.

Total Value of Works (i) in hand, (ii) completed in last three years			
Description	**Amount in Pak Rs.**	**Exchange Rate (Average)**	**US$ Equivalent**
(i) Total Value of Works in hand on bid opening/ preparation date			
(ii) Total Value of Works completed in last three years			

Form B5 (a): General Experience (Contractor)

Starting Month / Year	**Ending Month / Year**	**Contract Identification**	**Role of Applicant**
[indicate month/ year]	*[indicate month/ year]*	Contract name: *[insert full name]* Brief Description of the Works performed by the Bidder: *[describe works performed briefly]* Amount of contract: *[insert amount in Pak Rs]* Name of Employer: *[indicate full name]* Address: *[indicate street/number/town or city/country]*	*(insert "Contractor" or "Subcontractor" or "Contract Manager"]*
		Contract name: *[insert full name]* Brief Description of the Works performed by the Bidder: *[describe works performed briefly]* Amount of contract: *[insert amount in Pak Rs]* Name of Employer: *[indicate full name]* Address: *[indicate street/number/town or city/country]*	*(insert "Contractor" or "Subcontractor" or "Contract Manager"]*
		Contract name: *[insert full name]* Brief Description of the Works performed by the Bidder: *[describe works performed briefly]* Amount of contract: *[insert amount in Pak Rs]* Name of Employer: *[indicate full name]* Address: *[indicate street/number/town or city/country]*	*(insert "Contractor" or "Subcontractor" or "Contract Manager"]*

Form B5 (b): Specific Experience of Contractor

Fill up one (1) form per contract.

Contract of Similar Size and Nature		
Contract No. . . . . .of.	**Contract Identification**	
Award Date		**Completion Date**
Role in Contract	❑ **Contractor** ❑ **Management Contractor** ❑ **Subcontractor**	
Total Contract Amount	**US$**	
If partner in a JV or subcontractor, specify participation of total contract amount	**Percent of Total**	**Amount**
Employer's Name **Address** **Telephone/Fax Number** **E-mail**		
Description of the similarity in accordance with Criteria 13.4 (a) of IB		

Form B5 (c): Specific Experience of the Designer & Manufacturer

Fill up one (1) form per contract.

Contract of Similar Size and Nature		
Contract No. . . . . . **of**. . . .	**Contract Identification**	
Award Date		**Completion Date**
Role in Contract	❑ **Contractor** ❑ **Management Contractor** ❑ **Subcontractor**	
Total Contract Amount	**US$**	
If partner in a JV or subcontractor, specify participation of total contract amount	**Percent of Total**	**Amount**
Employer's Name **Address** **Telephone/Fax Number** **E-mail**		
Description of the similarity in accordance with Criteria 13.4 (a) of IB		

Form B6: Manufacturing Facility Information

Bidders and each partner to a JV should provide the description of the facilities owned and their respective capacities.

Manufacturing Facility Information				
Sr. No	**Description of Facility**	**Facility Location**	**Address**	**Annual Manufacturing Capacity**
1				
2				
3				
4				
5				

Major Items of Plant and Services	**If already manufactured, mention date of manufacturing**	**Proposed Subcontractors/ Manufacturers/ Supplier**	**Nationality & Year of Incorporation**	**Experience Record**

Form B7: Quality Control Facilities

The Bidders shall provide adequate details for the quality control testing and research facilities available along with the manufacturing license (if applicable) and the details of the Licensee. (Attach copy of License Agreement)

Form B8 (a): Personnel

Bidders should provide the names of suitably qualified personnel to meet the requirements. The data on their experience should be supplied using the Form below for each candidate.

Total No. of Staff	
Permanent Staff	**Qualified Engineers**

1.	**Title of position*:**
	Name
	Qualification/ Experience:
2.	**Title of position*:**
	Name
	Qualification/ Experience
3.	**Title of position*:**
	Name
	Qualification/ Experience
4.	**Title of position*:**
	Name
	Qualification/ Experience
5.	**Title of position*:**
	Name
	Qualification/ Experience
6.	**Title of position*:**
	Name
	Qualification/ Experience
7.	**Title of position*:**
	Name
	Qualification/ Experience
8.	**Title of position*:**
	Name

	Qualification/ Experience
9.	**Title of position*:**
	Name
	Qualification/ Experience
10.	**Title of position*:**
	Name
	Qualification/ Experience
11.	**Title of position*:**
	Name
	Qualification/ Experience
12.	**Title of position*:**
	Name
	Qualification/ Experience

*Criteria listed in Table B1 of Schedule-B to Bid.

Form B8 (b): Resume of Proposed Personnel

Resumes of the proposed persons should be duly signed by the concerned individuals, otherwise the Resumes will not be considered for the evaluation purposes.

Resume of Proposed Personnel		
Position		
Personnel Information	**Name**	**Date of birth**
	Professional Qualifications (Engineering Degree with Year)	
Present Employment	**Name of Employer**	
	Address of Employer	
	Telephone	**Contact (manager / personnel officer)**
	Fax	**E-mail**
	Job title	**Years with present employer**
	Overall Experience (Years)	**Relevant Experience (Years)**

Summarize professional experience in reverse chronological order. Indicate particular technical and managerial experience relevant to the project.

1. From	2. To	3. Company / Project / Position / Relevant technical and management experience

Form B9: List of Similar Works Done

Reference lists of similar works done by the Bidder in its country and abroad indicating the name of customer, description and quantity of product, year of supply and the approximate value. This is an important consideration and should be filled in with full details (attach separate sheet if needed)

List of Similar Works Done					
Sr. No.	**Name of Contract**	**Employer's Contact Address, Tel, Fax**	**Description and quantity of Product**	**Year of Supply**	**Approximate Value [US$]**
1					
2					
3					
4					
5					

Form B10: Projects Contractual Commitments

Sr. No.	Name of ongoing project(s)	Name of employer	Total cost	Start date	Planned completion date	%age of works completed	Award letter / Remarks regarding delays if applicable
1.							
2.							
3.							
4.							
5.							
6.							
7.							

In case a Bidder showing projects outside Pakistan, the information provided on the project needs to be substantiated by certification of the concerned country's embassy in Pakistan.

Form B11: Financial Resources

Specify proposed sources of financing, such as liquid assets, unencumbered real assets, lines of credit, and other financial means, net of current commitments, available to meet the total construction cash flow demands of the subject contract.

Financial Resources		
No.	**Source of financing (Name of Bank and Address)**	**Amount (US$ equivalent) and validity period**
1		
2		
3		

Form B12: Health, Safety & Emergency Plan

The Bidders shall give his proposed plans for Health, Safety & Emergency as well as risk management for the project to meet the requirements specified in the bidding documents.

Form B13: Training & Employment Plan

The Bidders shall mention the proposed training and Employment plans to train the Employer staff to maintain and operate the facility after construction.

Form B14 – Litigation or Arbitration

Information on any litigation or arbitration resulting from contracts completed or under execution by the Bidder over the last ten (10) years. Each Bidder or member of a JV must fill in this form.

Information on Litigation or Arbitration				
Year	**Parties Concerned**	**Matter in Dispute**	**Value of Pending Claim in US$ Equivalent**	**Value of Pending Claim as a Percentage of Net Worth**

Part-2

Letters of Technical & Price Bid
and
Schedules to Technical & Price Bid

TABLE OF CONTENTS

LETTER OF TECHNICAL BID AND SCHEDULES TO TECHNICAL BID 53
LETTER OF TECHNICAL BID 54
SCHEDULE – A TO BID 57
SPECIFIC WORKS DATA 57
SCHEDULE – B TO BID 58
PROPOSED ORGANIZATION FOR THE PROJECT 58
SCHEDULE – C TO BID 60
METHOD OF PERFORMING THE WORKS 60
SCHEDULE – D TO BID 61
PROPOSED PROGRAMME OF WORKS 61
SCHEDULE – E TO BID 62
WORK TO BE PERFORMED BY SUBCONTRACTORS 62
SCHEDULE – F-1 TO BID 63
DEVIATIONS FROM TECHNICAL PROVISIONS 63
SCHEDULE – F-2 TO BID 64
DEVIATIONS FROM CONTRACTUAL CONDITIONS 64
SCHEDULE – G TO BID 65
SPECIFIC OPERATION/PLANT AND EQUIPMENT DETAIL 65
SCHEDULE –H TO BID 68
JOINT VENTURE AGREEMENT 68
SCHEDULE –I TO BID 82
PAST PERFORMANCE AND PRESENT COMMITMENTS 82
LETTER OF PRICE BID AND SCHEDULES TO PRICE BID 83
LETTER OF PRICE BID 84
SCHEDULES TO PRICE BID 86
SCHEDULE – J TO BID 87
INTEGRITY PACT 87
SCHEDULE – K TO BID 88
ESTIMATED PROGRESS PAYMENTS 88
SCHEDULE –L TO BID 89
LUMP SUM COST BREAKUP FOR MAJOR COST ITEMS 89

LETTER OF TECHNICAL BID AND SCHEDULES TO TECHNICAL BID

LETTER OF TECHNICAL BID

Bid Reference No.: …….

To:

Project Director
22 MW Jagran-IV HPP, AJK
Searbean Residency, Western Bypass Road
Near Saif Plaza, Muzaffarabad AJK

Ph No: 05822-940064
Email: pdjrniv@gmail.com

Gentlemen,

1. Having examined the Bidding Documents including Instructions to Bidders, Conditions of Contract, Specifications, Drawings, Schedules to Bid, Schedule of Prices and Addenda Nos. …….. for the execution of the above-named Works, we, the undersigned, being a company doing business under the name of and address…… …… …… and being duly incorporated under the laws of …… hereby offer to execute and complete such Works and remedy any defects therein in conformity with the said documents including Addenda thereto.
2. We understand that all the Schedules attached hereto form part of this Bid.
3. As security for due performance of the undertakings and obligations of this Bid, we submit herewith a Bid Security in the amount of …… drawn in the favor of, or made payable to the Employer, **Project Director**, **22 MW Jagran-IV HPP** and valid for a period 28 days beyond the period of validity of Bid.
4. We undertake, if our Bid is accepted, to commence the Works and to deliver and complete the whole of the Works comprised in the Contract within the time(s) stated in Preamble to the Conditions of Contract.
5. We agree to abide by this Bid for the period of …….days from the date fixed for receiving the same and it shall remain binding upon us and may be accepted at any time before the expiration of that period.
6. Unless and until a formal Agreement is prepared and executed, this Bid, together with your written acceptance thereof, shall constitute a binding contract between us.
7. We undertake, if our Bid is accepted to execute the Performance Security referred to in Clause 10 of Conditions of Contract for the due performance of the Contract.
8. We do hereby declare that the Bid is made without any collusion, comparison of figures or arrangement with any other person or persons making a Bid for the Works.
9. We do hereby declare that our firm, including any subcontractors or suppliers for any part

of the Contract, have nationalities from eligible countries *[insert the nationality of the Bidder, including that of all parties that comprise the Bidder if the Bidder is a consortium or association, and the nationality of each Subcontractor and Supplier]*.

10. We, including any subcontractors or suppliers for any part of the Contract, do not have any conflict of interest.

11. We are not participating, as a Bidder or as a subcontractor, in more than one bid in this bidding process.

12. We confirm, if our Bid is accepted, that all partners of the joint venture shall be liable jointly and severally for the execution of the Contract and the composition or the constitution of the joint venture shall not be altered

Dated this …… day of ……. 2026

Signature ……... in the capacity of ……. duly authorized to sign the Bid for and on behalf of …….
(Name of Bidder in Block Capitals)
(Seal of Bidder)

Bidder's Address
……
……
……..……

Witness:

Signature: …….
Name: ……

Address:
……
……
……..……

Occupation …….

Schedules to Technical Bid

– Schedule A to Bid: Specific Works Data

– Schedule B to Bid: Proposed Organization for the Project

– Schedule C to Bid: Method of Performing Works

– Schedule D to Bid: Proposed Programme of Works

– Schedule E to Bid: Works to be Performed by Subcontractors

– Schedule F-1 to Bid: Deviations from Technical Provisions

– Schedule F-2 to Bid: Deviations from Contractual Conditions

– Schedule G to Bid: Specific Operation/Plant and Equipment Detail

– Schedule H To Bid: Specimen JV Agreement

– Schedule I To Bid: Past Performance and Present Commitments

SCHEDULE – A TO BID

SPECIFIC WORKS DATA

The main technical data is prescribed in the relevant sections of the Technical Provisions. However, the Bidder may supplement the main technical data by providing hereunder other salient parameters including main plant make, capacity and suitability for the works under consideration to enable the Employer/Project Manager/Engineer to assess technical conformance of the proposed process and the means available with the contractor to do it.

Initials of Signatory to Bid:……

SCHEDULE – B TO BID

PROPOSED ORGANIZATION FOR THE PROJECT

The Bidder shall provide in this Schedule Organization chart indicating the key personnel he will employ for Head office and for Site office involved in management, supervision and Project Management/Engineering of the Works to be done under the Contract to direct and execute the Works, together with their names, qualifications, experience, positions held and their nationalities.

(Minimum requirement of the key staff are shown in Table B1. Bidder shall add further necessary staff for his organization)

Designation	**Name of Person**	**Summary of Qualifications, Experience, Present Position and Nationality**

- Head Office:

- Site Office:

Initials of Signatory to Bid:……

Table B1 – Personnel

The Bidder must demonstrate that it has the personnel for the key positions that meet the following requirements:

Sr No.	Position	Minimum Number Required	Total Work Experience (Years)	In Similar Work Experience (Years)
A.	Key Personnel at Site			
1.	Project Manager	1	20	15
2.	Works Manager (Mechanical)	1	10	5
3.	Works Manager (Electrical)	1	10	5
4.	Planning & Scheduling Engineer	1	7	4
5.	Contracts Engineer	1	7	4
6.	Material Testing Engineer	1	10	4
7.	Quality Control Engineer	1	10	4
B.	Design Engineers			
1.	Chief Design Engineer	1	20	15
2.	Structural Design Engineer	1	15	10
3.	Mechanical Design Engineer	1	15	10
4.	Electrical Design Engineer	1	15	10
5.	SCADA Design Engineer	1	10	5
6.	Transmission Line Design Engineer	1	10	5
7.	Assembly and Testing Engineer(s)	1	10	5
8.	HSE/Environmentalist	1	10	5

The Bidder shall provide details of the proposed personnel and their experience records Cv(s) duly signed by the concerned person(s) in the relevant Information Forms included in Appendix B (Form B8).

SCHEDULE – C TO BID

METHOD OF PERFORMING THE WORKS

The Bidder is required to submit a narrative outlining the method of performing the Works. The narrative should indicate in detail and include but not be limited to:

- The sequence and methods in which he proposes to carry out the Works, including the number of shifts per day and hours per shift, he expects to work.
- A list of all major items of constructional and erection plant, tools and vehicles proposed to be used in carrying out the Works at Site, including number of each kind, make, type, capacity of all equipment, working condition, which shall be deployed by him for Erection, Testing and Commissioning of E&M Works, in sufficient detail to demonstrate fully that the equipment will meet all the requirements of the Specifications.
- The procedure for installation/erection of equipment and transportation of equipment and materials to the site.
- Details regarding mobilization in Pakistan, the type of facilities including personnel accommodation, office accommodation, provision for maintenance and for storage, communications, security and other services to be used.

- The Contractor shall provide description of his construction camp's facilities and staff housing requirements.

- The Contractor shall be responsible for pumps, electrical power, water and electrical distribution systems, and sewerage system including all fittings, pipes and other items necessary for servicing the Contractor's construction camp and staff housing facilities. The Bidder shall list or explain his plans for providing these facilities for the service of the Contract as follows:

    1. Site Preparation (clearing, land preparation, etc.).
    2. Provision of Services.
        a) Power (expected power load, etc.).
        b) Water (required amount and system proposed).
        c) Sanitation (sewage disposal system, etc.).
    3. Construction of Facilities
        a) Contractor's Office, Workshop and Work Areas (areas required and proposed layout, type of construction of buildings, etc.).
        b) Warehouses and Storage Areas (area required, type of construction and layout).
        c) Housing and Staff Facilities (Plans for housing for proposed staff, layout, type of construction, etc.)
    4. Construction Equipment Assembly and Preparation (detailed plans for carrying out this activity).
    5. Other Items Proposed (Security services, etc.).

Initials of Signatory to Bid:……

SCHEDULE – D TO BID

PROPOSED PROGRAMME OF WORKS

Bidder shall provide a programme on Primavera or MS Project or equivalent showing the sequence of work items by which he proposes to complete the Work of the entire Contract. The programme should indicate the sequences of work items and the period of time during which he proposes to complete the Works including the activities like designing, schedule of submittal of drawings, ordering/procurement of materials, manufacturing, delivering, allowance for Site specific weather conditions/constraints, interfacing activities with the Civil Contractor etc. testing and commissioning of Works to be executed under the Contract.

Initials of Signatory to Bid:……

SCHEDULE – E TO BID

WORK TO BE PERFORMED BY SUBCONTRACTORS

The Bidder will do the work with his own forces except the part (s) of the Works listed below which he intends to sub-contract.

Items of Works to be Sub-Contracted	**Name and address of Sub-Contractor**	**Statement of similar works previously Executed (attach evidence)**

Note:

1. No change of Sub-Contractor shall be made by the Bidder without prior approval of the Employer.
2. The truthfulness and accuracy of the statement as to the experience of Subcontractors is guaranteed by the Bidder. The Employer's judgment shall be final as to the evaluation of the experience of Subcontractors submitted by the Bidder.
3. Statement of similar works shall include description, location & value of work, year completed and name & address of the clients.
4. This may include manufacturer(s) who are proposed here and their relevant details to be provided accordingly including make, capacity and salient features to make it particularly suitable for the works. The technology used should also be detailed adequately.

Initials of Signatory to Bid:……

SCHEDULE – F-1 TO BID

DEVIATIONS FROM TECHNICAL PROVISIONS

It is presumed that the Bidder shall not take any deviation. However, if he intends to take deviations to the specified technical provisions, those must be listed in the space provided below:

Sr. No.	Clause No. / Section No.	Deviations/Clarifications

Note: Attach additional sheets, if necessary

Initials of Signatory to Bid:……

SCHEDULE – F-2 TO BID

DEVIATIONS FROM CONTRACTUAL CONDITIONS

It is presumed that the Bidder shall not take any deviation. However, if he intends to take deviations to the specified Contractual/Commercial Conditions, those must be listed in the space provided below:

Sr. No.	Clause No. / Section No.	Deviations/Clarifications

Note: Attach additional sheets, if necessary

Initials of Signatory to Bid:……

SCHEDULE – G TO BID

SPECIFIC OPERATION/PLANT AND EQUIPMENT DETAIL

(Minimum requirement of the equipment are shown in Annex 1 to Form G1. Contractor may however add further equipment if required in accordance with his methodology / method statement.)

Note: Attach additional sheets, if necessary

Initials of Signatory to Bid:……

Form G1: Equipment and Tools

The Bidder shall provide a list of Key Equipment it proposes to mobilize for the proposed contract. The Bidder must demonstrate that it has the key equipment needed for execution of the project. The list is given here below:

List of Main Equipment

Sr. No.	Description	Type / Model	Unit	Qty.	Manufacturer's Name	Year of Manufacture	powered	power	size	production rates	Extent	Worked Time since	sources (Owned, Purchased or Hired)	Arrival Time
								kW	Length x Height x Width					

***** *Minimum equipment and tools required are listed in Annex-1 to Form G1 .*

Annex – 1 to Form G1

Equipment and Tools

The minimum required main equipment and tools are listed below. The bidder must provide proof of access to the listed equipment or demonstrates its availability in the event of award:

Equipment	**Minimum Quantity**	**Documents Required from Bidder**
Mobile/Crawler Crane (50–80 ton	1	Proof of ownership (e.g., copy of equipment registration) or Letter of Intent/Agreement from a crane leasing company.
Chain Blocks (capacity 5–10 ton)	6	Inventory records (if owned) or purchase/lease commitment documents.
Lever Hoists (capacity 3–6 ton, for precise equipment positioning)	6	Inventory records or purchase/lease documents.
Rigging Gear Set	2 sets (min.)	Inventory records (if owned) or Letters of Intent from supplier/rental firm.
Hydraulic Jacks (20–50 ton capacity, for assembly of heavy components like turbine parts)	4	Proof of ownership or rental agreement/LOI.
Hydraulic Power Pack (for operating	1	Proof of ownership or rental agreement/LOI.
Diesel Generator 50 kva (backup power)	1	Proof of ownership or rental agreement.
Electrical Testing Kit (for high-voltage testing and protection relay testing)	1 set	Proof of ownership or vendor confirmation for provision.
Oil Processing Unit (for transformer oil filtration and filling)	1	Proof of ownership or rental/ subcontract arrangement.

SCHEDULE –H TO BID

JOINT VENTURE AGREEMENT

FOR

ENGINEERING, PROCUREMENT AND CONSTRUCTION OF

22 MW JAGRAN HYDROPOWER PROJECT

(CONTRACT No: JIVHHP/ICB-02)

TABLE OF CONTENTS

1. DEFINITIONS AND GENERAL PROVISIONS
2. OBJECTIVE & SCOPE OF THE JV AGREEMENT
3. SIGNING OF THE CONTRACT
4. DIVISION OF RESPONSIBILITIES
5. RESPONSIBILITIES, GENERAL OBLIGATION AND LIABILITIES OF PARTIES
6. LIABILITIES OF THE PARTIES TO THE EMPLOYER & THIRD PARTY
7. RELATIONSHIP AND LIABILITIES OF PARTIES BETWEEN THEMSELVES
8. LIABILITY OF INDIRECT AND CONSEQUENTIAL LOSSES
9. PRICES, PAYMENTS, DISCOUNTS AND TAXES
10. INSURANCE
11. TERM
12. TERMINATION
13. EXCLUSIVITY
14. BINDING AGREEMENT
15. NOTICES
16. ASSIGNMENT
17. CONFIDENTIALITY AND PUBLICITY
18. APPLICABLE / GOVERNING LAW
19. BREACH, DEFAULT AND INSOLVENCY
20. DISPUTE RESOLUTION AND ARBITRATION
21. OTHERS / MISCELLANEOUS

JOINT VENTURE AGREEMENT
FOR
ENGINEERING, PROCUREMENT AND CONSTRUCTION OF
22 MW JAGRAN-IV HYDROPOWER PROJECT
(CONTRACT No: JIVHHP/ICB-02)

This Joint Venture Agreement (hereinafter referred to as "JV Agreement") is made and entered into on this ---------- day of ----------2026:

BETWEEN

----------, a company incorporated and existing under the laws of the Islamic Republic of Pakistan and having its registered office at ----------, (hereinafter referred to as "----------") which expression shall where the context so permits include its successors in interest and assigns of the first part;

And

----------, a company incorporated and existing under the laws of the ---------- and having its registered office at ----------, ---------- (hereinafter referred to as "----------") which expression shall where the context so permits include its successors in interest, and assigns of the second part. (---------- and ---------- are hereinafter collectively referred to as **"Parties"** and individually as the **"Party"**)

And

----------, a company incorporated and existing under the laws of the ---------- and having its registered office at ----------, ---------- (hereinafter referred to as "----------") which expression shall where the context so permits include its successors in interest, and assigns of the second part. (---------- and ---------- are hereinafter collectively referred to as **"Parties"** and individually as the **"Party"**)

(According to no. of JV partners.)

WHEREAS

A. The Project Director (PD) to Power Development Organization

Government of AJK, hereinafter referred to as the "Employer" issued an Invitation to Tender for ENGINEERING, PROCUREMENT AND CONSTRUCTION OF 22 MW JAGRAN-IV HYDROPOWER PROJECT (hereinafter referred to as the "**Project**") under ICB No: JIVHPP/ICB-02 LOT-2: ELECTRICAL & MECHANICAL WORKS (hereinafter referred to as "**Contract**");

B. The Parties entered into a Pre-Bid agreement on -------- , 2026 formulated ----------Joint Venture (-------- JV) for the preparation and submission of the proposal/Bid in response to the Invitation to Tender and the same was submitted to the Employer for the aforesaid Project on ----------, 2026.

C. It was agreed between the Parties that if the Project is awarded to the parties, the Joint Venture shall enter into a Contract with the Employer for the execution of the Project in the name of ----------JV (hereinafter referred to as "**the Contractor**")

This Agreement WITNESSETH as follows;

1. DEFINITIONS AND GENERAL PROVISIONS

In this Agreement the following words and expressions shall have the meaning herein attached to them except where the context otherwise requires:-

- "Agreement" shall mean this Joint Venture Agreement.
- "Contract" shall mean the Contract entered into between the Employer and the ----------JV for the execution and completion of the Works.
- "Engineer" is Project Management Consultants (MC) duly appointed by the Employer and will act as the "Engineer" for the purpose of the Contract.

D. "Employer" shall mean Project Director, 22 MW Jagran-IV Hydropower Project, Power Development Organization Government of AJK, Pakistan.

- "Joint Venture" shall mean ----------JV for the purposes of this Agreement to execute the Project and actual collaboration shall be governed by this Agreement.
- "JV Bank Account" shall mean the Bank Account or Accounts opened by ----------JV.
- "JV Leader" shall mean ---------- as appointed to undertake the general coordination and administration of the JV.
- "Contractual Communications" shall mean any letter, certificate, instruction, order, direction, consent, approval, notice, claim, application or other such communication with, for which provision may be made, in the Contract.
- "Project" shall mean Engineering, Procurement and Construction of 22 MW Jagran-IV Hydropower Project Lot-2: Electrical & Mechanical Works.
- "Project Manager" shall mean the person appointed by JV Leader for the Project.
- "Tender" shall mean the tender prepared and submitted to the Employer by ---------JV.
- "Works" shall have the same meaning ascribed to the expression in the Contract and for the purpose of this Agreement, shall in each such case include all the obligations assumed or to be assumed, by the Joint. Venture as the Contractor under the Contract.
- "Work Package" shall mean that portion of the Works for which the Party is responsible in accordance with Article 4 of this Agreement.
- "Works Programme" shall mean the Programme submitted to the Engineer in accordance with the Contract, which may be amended from time to time.

1.1 In this Agreement, unless the context otherwise requires:

a) Words denoting the singular number shall include the plural and vice versa;

b) Where a word or phrase is defined, other parts of speech and grammatical form of that word or phrase shall have the corresponding meanings;

c) Words denoting natural persons shall include corporations, firms and unincorporated entities and vice versa;

d) References to Articles and Appendices are to articles and appendices of this Agreement and all appendices and annexes to this Agreement shall form part of it;

e) Headings are for convenience only and shall not affect interpretation;

f) References to any Party to this Agreement or any other agreement or instrument shall include the Party's successors and permitted assignees.

2. OBJECTIVE AND SCOPE OF THE JV AGREEMENT

2.1 The sole and exclusive purpose of the JV Agreement is that the Parties shall jointly perform the Contract after it is awarded to --------JV and complete the Works of the Project contemplated therein in accordance with the terms and conditions of this Agreement;

2.2 It is agreed between the Parties that this JV Agreement is a contractual relationship that exists only with respect to the engineering, procurement and construction works for the Project including all works and services required under the Contract ("Works").

2.3 This JV Agreement constitutes the entire understanding between the Parties hereto with respect to the Project and all obligations, responsibilities and liabilities of the Parties are limited as set forth herein and that the Parties make no other representation, promise or undertaking either expressed or implied, except as set forth in this Joint Venture Agreement. No representation, promise or undertaking made or given by any Party prior to the signing of this Joint Venture Agreement shall be of any force or effect except to the extent that the same is contained in the Joint Venture Agreement.

2.4 The participating shares shall be as --------- = and -------- ***(to be suitably amended as per the actual JV agreement)***. The correspondence address of the joint venture for the convenience of Employer shall be ……, ……, Pakistan.

3. SIGNING OF THE CONTRACT

3.1 ---------- shall be the lead Party for this JV Agreement. The Parties shall nominate the "JV Representative" who shall have the authority to enter into the Contract with the Employer and to sign any or all documents which have been agreed by both Parties in this behalf.

3.2 All partners of The JV shall at all times and under all circumstances be liable jointly and severally to Employer for execution of entire contract in accordance with the contract term and conditions regardless of their equity portion in The Joint Venture.

3.3 Each Party agrees that throughout the period of negotiations for the Contract, it will be prepared to act quickly on any matter requiring immediate attention and shall at all time co-operate with each other to ensure that the negotiations proceed in a satisfactory manner.

3.4 The Parties, prior to acceptance of the Contract and amendments or variations thereto, mutually agree between themselves and with the Employer on the acceptability of the Contract and amendments in terms and conditions. This JV Agreement shall apply and extend only to the performance of the Contract together with any changes or additions agreed by both Parties in writing thereto or supplementary work there under.

3.5 No amendments/ modification whatsoever in The Joint Venture agreement shall be agreed to between the JV partners without prior written consent of the Employer.

4. DIVISION OF RESPONSIBILITY

The intention of this JV Agreement is to proceed jointly and in good faith with the intention of executing the Project. It is mutually recognized that the joint proposal was based on a clearly defined divisible responsibilities of each Part and such divisible responsibilities shall form the basis of this JV Agreement. It is further agreed that this JV Agreement shall recognize the respective responsibilities of the Parties in accordance with the requirements of the Project and the Parties shall be liable for their respective responsibilities, as provided herein below The responsibilities of each Party including any necessary work and related warranties or guaranties constitutes its own part, for which said Party shall be individually and solely responsible and bear the corresponding over-runs and under-runs. The division of responsibilities (DOR) during execution phase between the Parties is set forth in detail as below:

(Party-A) ----------'S PART

---------- will be generally in charge of:

a. Overall Project and site Management,

b. Design, Planning, and execution of Works and related Field Activities, Local Logistics and Support.

(Party-B) ----------'S PART

---------- will be generally in charge of:

a. Designing for Electrical & Mechanical Works,

b. Manufacturing, Planning, Erection and testing & commissioning of all the Electrical & Mechanical Works and its related Logistics.

Note: (To be amended as per the work distribution among the parties to the JV)

5. RESPONSIBILITIES, GENERAL OBLIGATIONS AND LIABILITIES PARTIES

5.1 Pursuant to the provisions of Article 3.2 herein above and Article 6.1 herein below whereby the Parties to this joint Venture shall be jointly and severally liable towards the Employer for the performance of all obligations under the Contract; each Party is also solely and fully responsible for the good and timely performance of its own part under this JV Agreement and shall individually bear all commercial, technical, financial and other contractual risks in full compliance with the Contract, subject to the provisions set forth below. There shall be no cross charging, indemnification or reimbursement between the parties, except as may be specifically described in this JV Agreement.

5.2 Each party will assume the obligation of fulfilling any guarantees and warranties that will be given to the

Employer under the Contract, insofar as such guarantees or warranties relates to that Party's Own Part. Any defects in the Works performed by either Party which infringe any guarantee/warranty under the Contract shall be corrected promptly by the Parties, whereby each Party corrects what relates to its own part under article 4 so as to comply with the requirements of the Contract, without any recourse by either party against the other.

5.3 The Parties hereby agree to associate themselves in the JV, the sole object of which is to (i) conclude the Contract with the Employer for the Works and (ii) fulfill the obligations of the Contract.

5.4 The Parties in the JV shall, in accordance with the terms of this Agreement, enter in-to the Contract with the Employer and shall faithfully perform and observe all the terms and conditions thereof as to each other and as to the Employer.

5.5 This Agreement extends only to the execution and completion of the Works as defined above together with any variations thereto or extra works undertaken in accordance with the Contract.

5.6 As contained in Article 3.2 herein above and Article 6.1 herein below stating that the Parties to this joint Venture shall be jointly and severally liable towards the Employer for the performance of all obligations under the Contract; however, each Party shall also be responsible for its Work Package and the compatibility of its design, engineering, supply, construction and services forming part of its Work Package with the Work Package of the other Party. Each Party shall be responsible for ascertaining from the other Party the information needed to ensure such compatibility and the other Party has the obligation to provide such information.

5.7 As laid down in the provisions of Article 3.2 herein above and Article 6.1 herein below the Parties to this joint Venture shall be jointly and severally liable towards the Employer for the performance of all obligations under the Contract; however, each Party shall also be responsible for the proper and timely performance of its Work Package as in accordance with the provisions of the Contract. In performing its Work Package, each Party shall owe a duty to the other Party to ensure that all services, material and equipment used or provided by it and that all the Works undertaken is carried out in accordance with the Contract.

5.8 If any or the whole of the work implemented by a Party within its Work Package is or becomes defective and/or is required to be dismantled, replaced modified or repaired in any way in order to comply with the terms and conditions of the Contract, then such Party shall be responsible for and bear the cost of dismantling replacement, modification or repair as may be required (hereinafter referred to as "Remedial Work".

Each party shall be liable to the other Party to indemnify and hold harmless the other against third party for injury, damage, loss or expenses to the extent that such injury damage, loss or expense is attributable to:

a) Any breach for non-performance by the indemnifying Party of the Contract or this Agreement, and / or

b) If the delay or lack of performance is attributable to all the Parties, the liquidated damages (or other form of damages) shall be borne by them in proportion to their liability for the delay.

5.9 Neither Party shall be liable to the other Party under this Agreement for any claim for loss of profit (other than incidental to a breach of its obligation of exclusivity pursuant to Article 5 hereof) or for any other consequential damage suffered by the other Party.

5.10 Each Party shall make known to the other Party in due time any difficulty of any nature whatsoever, which it meets in the course of performance of its obligations under the Contract and, generally, shall communicate to the other Party all information which may affect the due and faithful performance of the Contract, in order to allow the other Party to take whatever steps it deems appropriate.

5.11 All technical or contractual communication between the JV and the Engineer / Employer shall be made through the Project Manager.

5.12 Whenever any contractual communication is received from the Employer or the Engineer, the Project manager shall forthwith pass such Contractual Communication to the Party concerned.

6. LIABILITY OF THE PARTIES TO THE EMPLOYER AND THIRD PARTY

6.1 The Parties shall be jointly and severally bound by the terms of the Contract and shall be jointly and severally liable to the Employer for the performance of all obligations under the Contract.

6.2 Notwithstanding Sub-Article 5.1 each Party is solely liable for injury to persons (including the employees, servants or agents of the Employer or of any other Third Party) and for loss of or damage to property (including the property of the Employer or of any other Third Party) caused by it or its representatives, employees or agents or its subcontractors or their representatives, employees or agents and arising in connection with the performance of the Contract. Each Party shall indemnify and hold harmless the other Party from all costs, claims, actions, expenses or liabilities incurred by or imposed upon such other Party as a result of or in connection with any such injury, loss or damage.

7. RELATIONSHIP AND LIABILITY OF PARTIES BETWEEN THEMSELVES

7.1 Each Party will be solely and entirely responsible for the performance of the Contract in respect of that Party's DOR and shall indemnify the other Party against any and all liabilities arising in connection therewith except and to the extent expressly otherwise provided in the JV Agreement. Except as aforesaid, each Party shall indemnify and hold harmless the other Party from all costs, claims, actions, expenses or liabilities incurred by or imposed upon such other Party as a result of or in connection with the first Party's failure, breach or default in the performance of its obligations under the Contract or the JV Agreement.

7.2 Each Party shall use its commercially reasonable efforts to mitigate its loss in the event of the other Party's default under the JV Agreement or the Contract.

7.3 Without prejudice to the provisions of Sub-Article 7.4 in respect of liquidated damages for delay or performance guarantees, the liability for default of a Party or Parties in the performance of the Contract shall be apportioned as follows:

a. In case of a default clearly and entirely attributable to a Party, the consequences shall be borne by the Party committing or contributing to such default;

b. In case of default which cannot be clearly attributed to any particular Party, the Parties shall negotiate in good faith a temporary allocation of costs and responsibilities in order that the financial consequences of such default may be apportioned equitably among the Parties pro rata to their PROPORTIONATE SHARES until a final apportionment is made in accordance with Article 19 of this Agreement.

7.4 With respect to any default in the performance of the Parties contractual obligations that may give rise to

the application of liquidated damages (or penalties or similar remedies under the Contract, referred to for the purpose of this Article 7 as "liquidated damages").

(a) For Delays

i. The Parties agree to inform each other promptly of any foreseeable delays in the performance of their respective DOR so that any action capable of avoiding or mitigating the anticipated delay, or the application of liquidated damages, may be implemented forthwith.

ii. If liquidated damages for delay are applied, the delay attributable to each Party shall be established by reference to the internal time schedule and the project master schedule, as may be amended from time to time by mutual agreement between the Parties and the Employer and made part of the Contract, and subject to any extension of time granted or awarded to the Parties pursuant to the Contract.

iii. Any liquidated damages payable to the Employer under the Contract shall be borne by the Party in default.

iv. For timely completing the Project, it is agreed between the Parties to perform the Works in accordance with the Schedule agreed by the Parties and duly consented by the Engineer. If any liquidated damages for delay shall become applicable due to delay in accordance with the Contract, the activity schedule in the project Construction Schedule shall be used for analyzing of the portion of

(b) Bank Guarantee Bonds and Sureties

i. Subject to the requirements of the Contract, each Party shall issue and maintain at its own expense any bank guarantees bond or other sureties required by the Contract, to the extent of its proportionate share.

ii. In case that the return of any bonds or bank guarantee in the Contract is delayed due to delay in Project by one Party or parties the defaulting Party(ies) shall bear additional charges for the extension of any bonds or bank guarantees.

7.5 To the extent that either:

a) It cannot be determined which Party or Parties caused or contributed to such delay or failure; or

b) The degree in which the Parties caused or contributed to such delay or failure cannot reasonably and economically be determined; or

c) Such delay or failure is attributable to a third party, not a Party to the JV Agreement, and who is not acting for any Party ; and

d) By agreement between the Parties, liability for liquidated damages cannot be avoided in negotiation with the Employer.

Then such liquidated damages shall be borne by both Parties pro rata to their respective Sharing until a final apportionment is made in accordance with Article 19.

7.6 Each Party shall be responsible for quantities in the bills of materials for its portion from the bidding stage until completion of the Project. Neither Party shall make any claim against the other Party due to the variation in the bills of quantities between the proposal design and final design unless there is inter-dependence of task.

7.7 The Parties enter into this JV Agreement for the purposes specified herein and without prejudice to the

existing status of the Parties. This Agreement shall not be interpreted or construed to create an association, agency, or partnership between the Parties or to impose any partnership obligation or liability upon either Party. Neither Party shall have any right, power, or authority to enter into any agreement or undertaking for, to act on behalf of, to act or be an agent or representative of, or to otherwise bind, the other Party.

8. LIABILITY OF INDIRECT AND CONSEQUENTIAL LOSSES

No Party shall be liable to the other Party whether by way of indemnity or in contract or in tort for any indirect or consequential loss or damages or loss of profit, loss of use, loss of production or loss of contract which may be suffered by the other Party in connection with the Contract except for gross negligence willful misconduct, or fraud.

9. PRICES, PAYMENTS, DISCOUNTS AND TAXES

9.1 Each Party shall prepare invoices for its own in accordance with the Article 4. Division of Responsibility (DOR) and requirement of the Contract. And submit to the Project Manager / or the lead party for processing and subsequent submittal to the Engineer / Employer by the due date stipulated in the Contract.

9.2 The Project Manager / or the Lead Party shall take due care and diligence in submitting the monthly invoices to the Engineer / Employer and shall make all possible efforts to timely release of payments of the invoices.

9.3 It is agreed between the parties than upon receipt of payment against the monthly invoices in the ----------JV Account from the Employer, the amounts due to the Parties shall be disbursed to them without delay.

9.4 Each Party shall be fully and solely responsible for the payment of any taxes, duties, fees, charges, social security contributions or assessments of any nature whatsoever including penalties and interests, if any, in connection with its DOR and any contracts or other arrangements entered into by it in connection therewith, including without limitation and personal income taxes levied or imposed upon any of its or its subcontractor's personnel. It is agreed between the Parties that each Party shall indemnify and hold the other party harmless from any and all liability arising due to non-payment of all taxes payable by each party under the Contract.

9.5 Claims: Each party shall be fully and solely responsible to submit the Claims for any contractual benefits to the Project Manager for onward submission to the Engineer / employer, however, both the partiers shall use their best endeavours together with the relevant Party to secure payment for the Claim.

10. INSURANCE

10.1 The Contractor i.e. ----------JV shall be responsible for effecting all the insurances required under the contract; however, each Party shall effect and maintain at its own risk and expense those insurances in respect of its DOR;

10.2 Each Party shall notify, administer and bear any and all costs of claims against its own or any common insurers in connection with its DOR, including but not limited to any excess or deductible or uninsured amounts under the relevant policy(-ies);

10.3 Where practicable and where available at reasonable conditions and economic cost, each Party shall ensure that the interest of the other Party is noted on any policy affected by it pursuant to the Contract.

11. TERM

Subject to Article 12, of this Agreement shall come into effect from the date of beginning hereof and shall remain in force until the completion of the Project.

12. TERMINATION

Parties reserve the right to terminate this JV Agreement, at any time, at no cost or compensation to the other Party, in the event if:

i. The Employer officially cancels the Project; or

ii. The Employer suspends the Project by more than Twelve (12) months; or

iii. The Employer does not award the Project to ----------JV; or

iv. The Employer does not approve this Joint Venture arrangement and asks for another party; or

v. Upon completion of the project according to the conditions of the Contract.

If this JV Agreement is terminated as per above events, the Parties shall have no claim against the other Party in relation to this JV Agreement.

13. EXCLUSIVITY

For the duration of the life of the JV, each Party commits itself to pursue the objectives of the JV within framework of this Agreement.

14. BINDING AGREEMENT

This Agreement shall bind the Parties hereto and their respective successors and assignees. Nothing contained in this Agreement expressed or implied shall be construed as conferring upon or giving to any person, firm or corporation, other than the Parties hereto their successors and assignees, any right, remedy or claim under this Agreement by reason thereof and all covenants, stipulations, promises and agreements herein contained shall be for the sole and exclusive benefit of the Parties hereto and their respective successors and assignees.

15. NOTICES

All notices or other communication to any Party under or in accordance with this Agreement shall be in writing in the English language and be delivered by hand or sent by certified or registered mail or confirmed receipt, cable or facsimile to the address of such Party shown herein below:

---------- **Limited**	---------- **Limited**
----------, ----------	----------, ----------
Phone: +92 ----------	Phone. +92 ----------
Fax: +92 ----------	Fax: +92 ----------

Email: ---------- Email: ----------

(Parties to be added as per actual Joint Venture Agreement).

16. ASSIGNMENT

No Party shall sell, transfer, assign, mortgage, charge, encumber or otherwise deal any manner whatsoever with all or any part of its interest in. the JV Agreement without the prior written consent of the other Party.

17. CONFIDENTIALITY AND PUBLICITY

17.1 Throughout the term of this JV Agreement and for a period of ten years after its termination or expiry:

a) The Parties undertake to keep confidential their discussions concerning matters related to the Project;

b) Ear party shall maintain confidential all information howsoever obtained, transmitted or recorded and all documents made available by the other Party pursuant to the JV Agreement or the Contract and

c) The Parties undertake;

i. To use such information and documents only for the purpose of the performance of the Contract, and

ii. Not to disclose or allow the said information or documents to be disclosed to any third party; Except where such information or documents are disclosed with the mutual agreement to a third party having entered into a like undertaking of confidentiality and non-disclosure, and such disclosure is made for the purposes of the performance of this JV Agreement or the Contract.

17.2 Sub-Article 17.1 shall not apply to information or documents which are in the public domain (other than by reason of a breach of Sub-Article 17.1 or which were already in the lawful possession of the Party concerned at the time or receipt from another party or which after their receipt from another party are independently received in good faith from a third party entitled to disclose the same:.

17.3 All matters relating to this Agreement, negotiations with the Employer and the Contract for the construction of the Works resulting there-from shall be regarded by the Parties hereto as being highly confidential and shall not be disclosed without consent of both Parties to any person, Party or entity who or which is not a signatory to this Agreement except such disclosure is necessary for the fulfilment of this Agreement or required by the Governing Law. No Party shall at any time hereinafter use any technical information, save that which is in the public domain, acquired from any Party hereto except for the purposes of fulfillment of the Contract.

17.4 No Party shall have the right to advertise, or otherwise permit the dissemination of publicity concerning its participation in the JV unless it is permitted under the Contract and in such a case:

17.4.1 The relevant material shall make due reference to and acknowledge the work of the other Parties;

17.4.2 The relevant material shall, if its dissemination is within the control of the Party in question, have been approved by the other Party and such approval shall not be withheld in-reasonably.

18. APPLICABLE / GOVERNING LAW

This JV Agreement shall be governed and construed in accordance with the laws of the Islamic Republic of Pakistan as specified in the Contract.

19. BREACH, DEFAULT AND INSOLVENCY

19.1 In the event of occurrence of any of the following:

(a) If the Employer serves a written notice of its intention to suspend or terminate the Contract for breach or default under the Contract and no reasonable action to remedy such breach or default is initiated by the Party or Parties responsible for such breach or default within twenty eight (28) working days of the service of such notice, sufficient to persuade the Employer to reverse its notice of intended suspension or termination; or

(b) If any Party is in material breach or default under the Contract, and such material breach or default is not cured within twenty eight (28) days after written notice thereof from the Employer or, if cure is not practically possible within twenty eight(28) days, reasonable action to cure such material breach or default has not been diligently initiated and pursued following the service of such notice; or

(c) If any Party becomes bankrupt or insolvent, or compound with its creditors, or commence to be wound up, not being a shareholders' voluntary winding up for the purpose of amalgamation or reconstruction, or make or have made against it a petition or application for the appointment of a trustee liquidator, administrator or administrative receiver, or if an order is entered appointing such trustee, liquidator, administrator or administrative receiver, or if any proceeding relating to such Party under any bankruptcy, insolvency, readjustment of debt, dissolution or liquidation or similar law of any jurisdiction now or hereafter in effect is commenced against such Party;

19.2 Employer's Default: In the event that the Employer is in material breach of the Contract or is otherwise in default of any of the Employer's obligations under or pursuant to the Contract (including in particular but without limitation the delayed payment or non-payment of sums due under and in accordance with the terms of the Contract), the Leader shall (and if the Leader is in default, other Party may) refer the matter without delay to the committee which shall decide upon the course of action to be taken.

20. DISPUTE RESOLUTION AND ARBITRATION

In the event of any question or difference or dispute whatsoever arising between the Parties under or in connection with this JV Agreement or any provision herein contained or the construction thereof, or as to any matter in any way connected herewith or arising there from which cannot be amicably settled, the same shall be referred to arbitration, under the Arbitration Act, 1940, for adjudication by a sole arbitrator. The language of arbitration shall be English and the venue of the arbitration shall be ---------- – Pakistan. The arbitral award shall be final and binding on the Parties who shall give full effect thereto.

21. OTHERS / MISCELLANEOUS

21.1 This Agreement shall supersede any prior agreements, arrangements or representations whether written or oral between the Parties concerning the Project, this Agreement, the Tender and the performance of the Contract

21.2 Any changes and supplementary provisions concerning this Agreement shall require the written approval of the Parties hereto.

21.3 Variation not effective unless in writing: No variation, modification or waiver of any provision of this Agreement, or consent to any departure there-from, shall in any event be of any force or effect unless confirmed in writing and signed by the Parties, then such variation, modification, waiver or consent shall be effective only in their specific instance and for the purpose and to the extent for which it has been

made or given.

21.4 Addition to JV: No additional parties shall be admitted to the JV unless approved by both Parties and consented by the Employer as well.

21.5 Each Party shall bear its own costs incurred in the preparation, negotiations and execution of this Agreement.

21. 6 General Cooperation: Parties shall endeavor to coordinate to find suitable sources and means of supply of materials to the Site. To reach such target, Parties shall from time to time exchange their procurement information related hereto. The Party who procures a larger quantity of any material will have better chances to get favorable quotations and offers and has the obligation to share his advantageous position in this regard to the other Party who also needs such material but with a less quantity. This cooperation will also apply for any other subject, such as labour supply, use of equipment and financing etc.

21. 7 Severability: Every part, term or provision of this Agreement is severable from all others, and if any part or provision is held to be invalid, unlawful or unenforceable, then the rest of any provision shall remain in effect to the extent permitted and all remaining provisions shall continue in full force and effect.

21.8 Waivers: The failure of any Party to insist in any one or more instances upon the strict performance of any of the provisions of this Agreement or to exercise any of its rights hereunder shall not be construed as a waiver of any such provisions or relinquishment of any such right but the same shall continue in full force and effect.

21.9 The provision of the Contract relating to Force Majeure shall apply to the JV Agreement. No Party may invoke the benefits of Force Majeure circumstances has been formally recognized by the Employer or in case of disagreement with the Employer, by final judgment of the jurisdiction or organization to which the Parties shall have agreed under the Contract to have recourse for settlement of disputes.

21.10 Neither Party shall withdraw from this JV Agreement without the mutual Agreement except anyone Party is in material Breach of terms and conditions Of the JV Agreement and /or he contact.

IN WITNESS WHEREOF duly authorized representatives of the Parties have executed and signed this JV Agreement in two original copies one for each Party on the date first hereinabove written.

FOR AND ON BEHALF OF

---------- Limited **---------- Limited**

Signature: _____ Signature: _____

Name	_____	Name	_____
Title :	_____	Title :	_____
Witness		**Witness**	
Signature:	_____	Signature:	_____
Name:	_____	Name:	_____
Address:	_____	Address:	_____
	_____		_____
	_____		_____

SCHEDULE –I TO BID

PAST PERFORMANCE AND PRESENT COMMITMENTS

Past Performance

Sr. No.	Name of project(s)	Name of employer	completed cost	Start date	Planned completion date	Actual completion date	Satisfactory performance certificate from employer / Remarks regarding delays if applicable
1.							
2.							
3.							
4.							
5.							
6.							
7.							

Present Commitments

Sr. No.	Name of ongoing project(s)	Name of employer	Total cost	Start date	Planned completion date	%age of works completed	Award letter / Remarks regarding delays if applicable
1.							
2.							
3.							
4.							
5.							
6.							
7.							

Any Bidder showing projects outside Pakistan, the information provided on the project needs to be substantiated by certification of concerned country's embassy in Pakistan.

LETTER OF PRICE BID AND SCHEDULES TO PRICE BID

LETTER OF PRICE BID

Bid Reference No.: …….

To:

Project Director
22 MW Jagran-IV Hydropower Project AJK,
Searbean Residency, Western Bypass Road
Near Saif Plaza, Muzaffarabad Azad Kashmir
Ph No: 05822-940064
E-mail: pdjrniv@gmail.com

Gentlemen,

1. Having examined the Bidding Documents including Instructions to Bidders, Conditions of Contract, Specifications, Drawings, Schedules to Bid, Schedule of Prices and Addenda Nos. ……. for the execution of the above-named Works, we, the undersigned, being a company doing business under the name of and address …… …… and being duly incorporated under the laws of …….. hereby offer to execute and complete such Works and remedy any defects therein in conformity with the said Documents including Addenda thereto for the Total Bid Price comprising of Local Currency Component of Pak Rupees …….. (Rs. ……) or such other sum as may be ascertained in accordance with the said Documents.

2. We understand that all the Schedules attached hereto form part of this Bid.

4. We undertake, if our Bid is accepted, to commence the Works and to deliver and complete the whole of the Works comprised in the Contract within the time(s) stated in Preamble to the Conditions of Contract.

5. We agree to abide by this Bid for the period of ……. days from the date fixed for receiving the same and it shall remain binding upon us and may be accepted at any time before the expiration of that period.

6. Unless and until a formal Agreement is prepared and executed, this Bid, together with your written acceptance thereof, shall constitute a binding contract between us.

7. We undertake, if our Bid is accepted to execute the Performance Security referred to in Clause 10 of Conditions of Contract for the due performance of the Contract.

8. We understand that you are not bound to accept the lowest or any Bid you may receive.

9. We do hereby declare that the Bid is made without any collusion, comparison of figures

or arrangement with any other person or persons making a Bid for the Works.

10. We confirm, if our Bid is accepted, that all partners of the joint venture shall be liable jointly and severally for the execution of the Contract and the composition or the constitution of the joint venture shall not be altered without the prior consent of the Employer.

Dated this ……. day of …….. 2026

Signature …….. in the capacity of ……duly authorized to sign the Bid for and on behalf of ……
(Name of Bidder in Block Capitals)

(Seal of Bidder)

Bidder's Address
……
…
……

…… Witness:

Signature:
……. Name:
……
Address:
……
…
……
Occupation ……

SCHEDULES TO PRICE BID

Schedules to Bid

- Schedule J to Bid: Integrity Pact
- Schedule K to Bid: Estimated Progress Payments
- Schedule L to Bid: Lump Sum Cost Breakdown for Major Cost Items

SCHEDULE – J TO BID

INTEGRITY PACT

[To be filled and signed by the Bidder]

DECLARATION OF FEES, COMMISSION AND BROKERAGE ETC. PAYABLE BY THE SUPPLIERS OF GOODS, SERVICES & WORKS IN CONTRACTS WORTH RS. 10.00 MILLION OR MORE

Contract No._____ Dated __
Contract Value: _____
Contract Title: _____

…… [Name of Supplier] hereby declares that it has not obtained or induced the procurement of any contract, right, interest, privilege or other obligation or benefit from Government of Pakistan (GoP) or any administrative subdivision or agency thereof or any other entity owned or controlled by GoP through any corrupt business practice.

Without limiting the generality of the foregoing, [name of Supplier] represents and warrants that it has fully declared the brokerage, commission, fees etc. paid or payable to anyone and not given or agreed to give and shall not give or agree to give to anyone within or outside Pakistan either directly or indirectly through any natural or juridical person, including its affiliate, agent, associate, broker, consultant, director, promoter, shareholder, sponsor or subsidiary, any commission, gratification, bribe, finder's fee or kickback, whether described as consultation fee or otherwise, with the object of obtaining or inducing the procurement of a contract, right, interest, privilege or other obligation or benefit in whatsoever form from GoP, except that which has been expressly declared pursuant hereto.

[name of Supplier] certifies that it has made and will make full disclosure of all agreements and arrangements with all persons in respect of or related to the transaction with GoP and has not taken any action or will not take any action to circumvent the above declaration, representation or warranty.

[name of Supplier] accepts full responsibility and strict liability for making any false declaration, not making full disclosure, misrepresenting facts or taking any action likely to defeat the purpose of this declaration, representation and warranty. It agrees that any contract, right, interest, privilege or other obligation or benefit obtained or procured as aforesaid shall, without prejudice to any other rights and remedies available to GoP under any law, contract or other instrument, be voidable at the option of GoP.

Notwithstanding any rights and remedies exercised by GoP in this regard, [name of Supplier] agrees to indemnify GoP for any loss or damage incurred by it on account of its corrupt business practices and further pay compensation to GoP in an amount equivalent to ten time the sum of any commission, gratification, bribe, finder's fee or kickback given by [name of Supplier] as aforesaid for the purpose of obtaining or inducing the procurement of any contract, right, interest, privilege or other obligation or benefit in whatsoever form from GoP.

Name of Buyer: …… Name of Seller/Supplier: ……

Signature: …… Signature: ……
[Seal] [Seal]

SCHEDULE – K TO BID

ESTIMATED PROGRESS PAYMENTS

Bidder's estimate of the value of work which would be executed by him during each of the periods stated below, based on his Programme of Works and the Rates in the Schedule of Prices, expressed in foreign and local currency of payments:

Period	Amounts	
	LCC (Rs.)	FCC
1st Month		
2nd Month		
3rd Month		
4th Month		
5th Month		
6th Month		

Up to 36th Month		
Total Bid Price		

Initials of Signatory to Bid: ……

SCHEDULE –L TO BID

LUMP SUM COST BREAKUP FOR MAJOR COST ITEMS

The Bidder is to provide a detailed breakup of his Lump sum costs in a manner that the overall picture for the quoted price can be understood. It should include major heading wise cost breakup including rate analyses for at least 10 major cost items as required to analyze it.

Part-3

Schedule of Prices

TABLE OF CONTENTS

SCHEDULE OF PRICES 90
PREAMBLE TO SCHEDULE OF PRICES 91
1. General 91
2. Description & Quantities 91
3. Units & Abbreviations 91
4. Rates and Prices 92
5. Bid Prices 93
5.1 Break-up of Bid Prices 93
a) Shipping & Insurance 93
i) Shipping 93
ii) Insurance 93
b) Unit Price for Supply of Goods 93
c) Local Transport 94
d) Erection & Other Work 94
e) Other Services 95
5.2 Total Bid Price 95
6. Erection & Testing Equipment and Maintenance Tools 95
7. Provisional Sums 95
SCHEDULE OF PRICES 96
Schedule 1 - Plant and Mandatory Spares Supplied from Abroad 96
Schedule 2 - Plant and Mandatory Spares Supplied from Pakistan 107
Schedule 3 - Design Services 108
Schedule 4 – General Items 109
Schedule 5 – Transportation from Karachi port/ EXW to project site including taxes, port charges, local taxes, insurance, etc. together with Erection, Testing and Commissioning 110
Schedule 6 – Grand Summary 118
DAYWORK SCHEDULE 119
Daywork Schedule 120

SCHEDULE OF PRICES

PREAMBLE TO SCHEDULE OF PRICES

1. General

1.1 The Schedule of Prices shall be read in conjunction with the Conditions of Contract together with the Employer's Requirement, Specifications and Bid Drawings.

1.2 The Bidder shall quote for all items of the Works executed on EPC/Turnkey basis and the prices shall be quoted for the complete scope of Work as described or implied from these Bidding Documents in schedule-L to bid.

2. Description & Quantities

2.1 The price given in the Schedule of Prices against each item shall be for the scope covered by that item as detailed in the Employer's Requirement, Specifications, Bid Drawings or elsewhere in the Bidding Documents. The general directions and descriptions of work and materials are not necessarily repeated nor summarized in the Schedule of Prices and do not generally give a full description of the Plant and equipment to be supplied and the Works/services to be performed under each item. References to the relevant sections of the Bidding Documents shall be made to ascertain the full scope of the requirements included in each item prior to filling in the rates and prices against each item in Schedule of Prices.

2.2 The Schedule of Prices only identifies major components of the structure, and it does not restrict the responsibility of the Contractor to furnish all equipment's, materials and services as deemed necessary by the Employer/Project Manager/Engineer for making the structure operationally complete and satisfactory as specified and/or implied in the Bidding Documents and subsequent revisions thereto.

2.3 The quantities as shown in the Schedule of Prices are estimated quantities and provisional only being given as an indication of the Scope of Work to enable the Bidder to bid for different items of the Works in accordance with his estimate of costs. The estimated quantities shall be used for comparing the Bids. It is, however, be noted that the basis of payment will be the actual quantities of work executed and measured by the Contractor and verified by the Project Manager/Engineer.

2.4 The sizes & dimensions mentioned and/or specified in the various technical descriptions and specifications including Bid Drawings are tentative and not final as the responsibility for detailed design rests with the Contractor under the Contract. If, in the opinion of the Project Manager/Engineer, at the time of review of Contractor's drawings/designs for approval, certain sizes & dimensions of some items have to be increased for proper completion and/or operation of the Works, then revised sizes & dimensions shall be supplied by the Contractor at no extra cost to the Employer.

3. Units & Abbreviations

3.1 Units of measurement, symbols and abbreviations expressed in the Bidding Documents shall comply both with FPS & MKS System.

The following abbreviations shall be used in the Schedule of Prices:

	Abbreviation
Local Currency Component	LCC
Pakistani Rupees	PKR/Pak Rs.
Ex Works	EXW
Quantity	Qty

4. Rates and Prices

4.1 Except as otherwise expressly provided under the Conditions of Contract, the unit rates and lump sum amounts entered in the Schedule of Prices will be the rates at which the Contractor will be paid, and shall be deemed to include for the full scope and all costs incurred by the Contractor in the performance of the Works, the provision of services including his overheads, income tax, super tax, other indirect costs, customs & other duties, profits and costs of accepting the general risks, liabilities and obligations set forth or implied in the Contract, except for such costs which are specified as reimbursable under the Contract.

4.2 The unit rates shall be extended to show the total amount for each item. The total of the Schedule of Prices is the Total Bid Price and shall be entered in Paragraph 1 of the Form of Price Bid. Where a discrepancy exists between the unit rate and the extended total amount, the unit rate shall be taken as correct and the total amount adjusted accordingly.

4.3 The whole cost of complying with the provisions of the Contract shall be included in the items provided in the priced Schedule of Prices, and where no items are provided in the Schedule of Prices for any work required to be executed by the Contractor on EPC/Turnkey basis under single responsibility for the completion of the Works and to make the structure operationally complete, the cost of such item(s) shall be deemed to be distributed among the rates and prices entered for the related items of the Works and no separate payment will be made by the Employer for those items executed by the Contractor.

The rates, prices and amounts shall be entered against each item in the Schedule of Prices. Where a Bidder fails to quote a price of any item of the Schedule of Prices, the Employer will consider that the price of that item is included among other items and the Contractor will be obligated to furnish that item at no extra cost to the Employer, if awarded the Contract.

4.4 The Bidder shall be deemed to have obtained all information as to port clearance facilities and charges, loading and unloading facilities and charges, storage facilities and charges, transportation facilities and charges, congestion and/or other conditions to be expected at Karachi Port and or any other seaport of Pakistan and all requirements related thereto.

The Contractor shall be responsible to make complete arrangements for the transportation of the Plant to the Site. The Bidder shall be deemed to have included all clearing, forwarding and other incidental costs in this regard in his Bid. The Contractor will have the option to use either Karachi Port or any other seaport of Pakistan.

4.5 The Contractor shall provide all parts of the Works to be completed in every respect for commercial operation. Notwithstanding that any details, accessories, etc. required for the complete installation and satisfactory operation of the Plant, are not specifically mentioned

in the Schedule of Prices, Employer's Requirements, Specifications including Bid Drawings, such details shall be considered as included in the Contract Price. All charges for the supply of goods, materials, accessories or work not specifically mentioned herein but necessary for the completion and operation of the Works shall be deemed to have been included in the quoted prices.

4.6 All costs in connection with inspection and witnessing of Factory Acceptance Tests within and outside Pakistan as per provisions of Sub-Clause 20.6 of Particular Conditions of Contract shall be borne by the Contractor and shall be deemed to have been included in the quoted prices.

All costs in connection with the holding of meetings shall be borne by the Contractor.

The rates in the Schedule of Prices shall also include Contractor's cost for providing Insurances, Performance Security and other Bank Guarantees required for performance of the Contract.

5. Bid Prices

5.1 Break-up of Bid Prices

The break-up of various elements of Bid Prices shall be provided as detailed below:

a) Shipping & Insurance

i) Shipping

The Bidder shall provide prices for shipping from port of shipment to the port of entry in Pakistan (Pakistan seaport) for the Plant, Erection Equipment, Spare Parts, Workshop Equipment and other materials to be imported in Pakistan for the Contract. Such prices shall include all marine transportation costs including ocean freight, heavy lift charges, fees and other charges, etc.

Cost of shipment(s) affected by the Contractor at his option by aircraft shall be deemed to be included in the Total Bid Price.

ii) Insurance

The Bidder shall provide prices for insurance cover from ex-factory/ex-works to the Site (warehouse to warehouse) for the sub-totals of the Plant, Erection Equipment, Spare Parts, Workshop Equipment and other materials to be imported in Pakistan for the Contract. Such prices shall include all insurance costs covering the responsibility for all loss or damages while loading, unloading, storing and trimming on board the vessel at the port of shipment or on inland carrier and transportation to Site.

The prices for transportation/marine insurance cover shall be on the basis of insurance through insurers from any country(ies) of the world acceptable to the Employer.

b) Unit Price for Supply of Goods

The Bidder shall provide prices for Local Goods, materials and equipment. Such prices shall include:

i) Design documentation, drawings, drafting, planning services, manufacturing, testing and packing of finished goods ready for delivery to Site including loading, unloading, transportation, storing and insurance costs,

ii) All custom duties, sales tax and other taxes already paid or payable on the components and raw materials used in the manufacture or assembly of Local Goods, materials and equipments.

c) Local Transport

Inland transportation for the Plant, Erection Equipment, Spare Parts and Workshop Equipment shall be the Contractor's responsibility in respect of:

i) the Plant, Erection Equipment, Spare Parts, Workshop Equipment and other materials offered from outside Pakistan; from the port of entry in Pakistan to the storage area at the Site, and

ii) indigenous Plant, Erection Equipment, Spare Parts, Workshop Equipment and other materials if any, offered from within Pakistan; from the factory in Pakistan to the storage area at the Site. The cost shall also include all insurance costs of Local Goods and other materials from factory to Site covering the responsibility of all losses or damages, while loading, unloading, storing, trimming on the carrier and transporting to Site. The cost of insurance of Local Goods shall be on the basis of insurance through any insurance company listed in Clause 5.1 a) ii) here above, acceptable to the Employer.

All charges occurring therefrom including octroi, zila tax, fees etc. and charges for loading, forwarding and unloading expenses shall be borne by the Contractor. Unloading at the Site, handling of the Plant, Erection Equipment, Spare Parts, Workshop Equipment and other materials to the designated point of Site storage, checking and verifying all shipments received against shipping documents, issue of all receiving reports and issues of damage reports (when applicable) shall be the Contractor's responsibility.

The Bidder shall recognize such elements of the costs which he expects to incur in the performance of the Works and shall include all such costs in the rates and amounts entered in the Schedule of Prices.

d) Erection & Other Work

The Bidder shall provide prices for Erection & Other Work for the sub-totals of the Plant at the Site. Such prices shall include the costs of handling of the Plant and other materials from Site storage to point of final installation, erection, installation, testing, commissioning including all inspection, performance tests, reliability tests and responsibility for operation & maintenance of the Plant until issuance of the Taking-Over Certificate, the cost of foreign and local erection staff and labour, tools and equipment etc. It shall also cover the services of qualified representative(s) of the supplier(s) of Plant or adviser(s) to assure proper erection and commissioning of the Plant.

The price shall also include cost of arranging insurances in respect of Contractor's operations in Pakistan which insurances shall be effected by the Contractor with any insurance company, acceptable to the Employer.

e) Other Services

In the Schedule of Prices, for the relevant items, the Bidders shall provide prices for all costs to be incurred in connection with inspections and witnessing of tests at manufacturers' works within or outside Pakistan by the Employer/Project Manager/Engineer's staff.

5.2 Total Bid Price

The total of Bid prices in the Schedule of Prices shall be entered in the Summary of Bid Prices.

6. Erection & Testing Equipment and Maintenance Tools

6.1 The Bidder shall be responsible to provide all Erection and Testing Equipment & Maintenance Tools at the Site, at his own expenses.

7. Provisional Sums

7.1 Provisional Sums included and so designated in the Schedule of Prices if any, shall be expended in whole or in part at the direction and discretion of the Employer/Project Manager/Engineer. The Contractor will only receive payment in respect of Provisional Sums if he has been instructed by the Employer/Project Manager/Engineer to utilize such sums.

Provisional Sums shall be expended for reimbursement of Contractor's invoices for any additional site protection works, relocation of services or any other work / payments as instructed by the Employer/Project Manager/Engineer through Variation Order.

SCHEDULE OF PRICES

Schedule 1 - Plant and Mandatory Spares Supplied from Abroad

The Components in description of this Schedule are indicative, Bidders may List down/shift the Components of Plant & Equipment in Schedule-2; which the Bidder decides to supply from within Pakistan.

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.1		**Mechanical Equipment**					
		Main Equipment					
1.1.1		**Turbines**					
1.1.1.1	Section-2, Part-B	7.16 MW Francis vertical type Turbines complete in all aspects including but not limited to Runner, Shafts, Spiral Casing, Shaft Seal, Wicket Gates, Guide vanes, Instruments and all other accessories required to generate and deliver 7.16 MW each and fulfill functional guarantees.		Set	3		
1.1.1.2	Section-2, Part-B	2.24 MW Francis, vertical type Turbine complete in all aspects including but not limited to Runner, Shafts, Spiral Casing, Shaft Seal, Wicket Gates, Guide vanes, Instruments and all accessories required to generate and deliver 2.24 MW and fulfill functional guarantees.		Set	1		
1.1.2		**Pressure Relief Valves**					
1.1.2.1	Section-3, Part-B	Howell Bunger type Pressure relief valves (DN 500, PN 40) complete with connecting pipes, fixed cones, operating systems and all accessories.		Set	3		
1.1.2.2	Section-3, Part-B	Howell Bunger type Pressure relief valves (DN 300, PN 40) complete with connecting pipes, fixed cones, operating systems and all accessories.		Set	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.1.3		**Governor Systems**					
1.1.3.1	Section-4, Part-B, Volume-II	Governor Systems for 7.16 MW turbines, including Governor Hydraulic System, Digital Governor, Nitrogen Accumulator and all accessories.		Set	3		
1.1.3.2	Section-4, Part-B	Governor System for 2.24 MW turbine including Governor Hydraulic System, Digital Governor, Nitrogen Accumulator and all accessories.		Set	1		
1.1.4		**Main Inlet Valves**					
1.1.4.1	Section-5, Part-B	Spherical type Main Inlet Valves (DN 1100, PN 25) including Valve Assembly, Operating Mechanism and other equipment including all accessories.		Set	3		
1.1.4.2	Section-5, Part-B	Spherical type Main Inlet Valves (DN 610, PN 25) including Valve Assembly, Operating Mechanism and other equipment including all accessories.		Set	1		
1.1.5		**Common Mechanical Auxiliaries**					
1.1.5.1	Section-7, Part-B	Cooling Water System complete with Cooling Water Pump, Self-Cleaning Back Flushing Filters, Raw and Clean Water Headers including all accessories etc.		Lot	1		
1.1.5.2	Section-8, Part-B	Drainage & Dewatering System complete with Drainage and Dewatering Pumps, Oil Water Separator, Valve and necessary piping including all accessories etc.		Lot	1		
1.1.5.3	Section-9, Part-B	Compressed Air System complete with Air Compressors, Air Receiver, piping, valves complete with accessories etc.		Lot	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.1.5.4	Section-10, Part-B	Fire Fighting System complete with Fire Water Pump, piping, Fire detection and alarm system, hydrant and hose reel system and automatic sprinkler system complete with all accessories.		Lot	1		
1.1.5.5	Section-11, Part-B	Oil Handling Purification system complete with all accessories.		Lot	1		
1.1.5.6	Section-12, Part-B	HVAC Equipment as specified complete with all accessories.		Lot	1		
1.1.5.7	Section-13, Part-B	Workshop Equipment complete with all accessories.		Lot	1		
1.1.5.8	Section-14, Part-B	Fire Detection & Alarm System complete with all accessories.		Lot	1		
1.1.6		**Lifting Equipment (Overhead Crane and Associated System)**					
1.1.6.1	Section-6, Part-B	45/10 ton Powerhouse Overhead Travelling Crane including all accessories etc.		No.	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.2		**Electrical Equipment**					
		Main Equipment					
1.2.1		**Generator and Excitation System**					
1.2.1.1	Section-1&2, Part-C	Three Main Generators (6.8 MW each), 0.80 pf, 50 Hz, 11KV as per the specifications, with accessories and auxiliaries (excitation system, cooling system, braking system, AVR, firefighting, detection and alarm systems, protection signaling devices, CT's, PT's, LAz, Isolators, SCADA, Protection& Control System, GCB's, etc.) for a complete functional unit.		Set	3		
1.2.1.2	Section-1&2, Part-C	One Auxiliary Generator (2.13 MW), 0.80 pf, 50 Hz, 11KV as per the specifications, with accessories and auxiliaries (excitation system, cooling system, braking system, AVR, firefighting, detection and alarm systems, protection signaling devices, CT's, PT's, LAz, Isolators, SCADA, Protection& Control System, GCB's, etc.) for a complete functional unit.		Set	1		
1.2.2		**Transformers**					
1.2.2.1		**Step-Up Transformers (3-Phase)**					
1.2.2.1.1	Section-3, Part-C	10/13 MVA Generator Step-up Transformers 11/132 KV, ONAN/ONAF, OLTC MK, HV & LV bushing, protection and control devices, Fire Fighting, Fire walls etc., as per the specification for a complete functional unit.		Set	3		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.2.2.1.2	Section-3, Part-C	3.5 MVA Generator Step-up Transformer 11/132 KV, ONAN/ONAF, OLTC MK, HV & LV bushing, protection and control devices, Fire Fighting, Fire walls etc., as per the specification for a complete functional unit.		Set	1		
1.2.2.2		**Auxiliary Transformers (3-Phase)**					
1.2.2.2.1	Section-3, Part-C	250 kVA, 11/0.4kV Oil-filled, Cu Winding Station Auxiliary Transformer complete with associated components.		No.	2		
1.2.2.2.2	Section-3, Part-C	200 kVA, 11/0.4kV Oil-filled Cu Winding Transformer complete with associated components.		No.	2		
1.2.3		**Switchgear**					
1.2.3.1		**MV Switchgear**					
1.2.3.1.1	Section-4, Part-C	M.V. Switchgear (incl. Circuit Breakers, load break switches, Earth switches, Current Transformers, Voltage Transformers, Protection Relays , meters, transducers, pushbuttons and switches, cabling etc). complete.		Set	1		
1.2.3.2		**LV Switchgear**					
1.2.3.2.1	Section-4, Part-C	400 V Switchgear (incl. Circuit Breakers, contactors, load break switches, Earth switches, Current Transformers, Voltage Transformers, Protection Relays , meters, transducers, pushbuttons and switches etc.) complete.		Set	4		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.2.4		**132 kV Switchyard**					
1.2.4.1	Section-4, Part-C	132kV Equipment for complete substation as detailed in single line diagram & as specified including monitoring and control system, protection system, AC/DC auxiliary supply and Lightning system etc. complete		Set	1		
1.2.5		**DC and UPS System**					
1.2.5.1	Section-5, Part-C	DC and UPS System (including batteries, chargers, switchboards, switches, meters, inverters, etc.) complete.		Set	1		
1.2.6		**Control, Protection and SCADA**					
1.2.6.1	Section-6, Part-C	Control and Instrumentation System including (RTU, SIC, GPS master clock system, Gateway, UPS and ancillary equipment, metering system & secure metering system) complete.		Lot	1		
1.2.6.2	Section-7, Part-C	Protection and Relay Equipment complete.		Lot	1		
1.2.7		**Earthing and Lightning Protection**					
1.2.7.1	Section-8, Part-C	Earthing and Lightning Protection System with Cu Materials (Powerhouse, weir/ intake and switchyard) complete.		Lot	1		
1.2.8		**Cabling**					
1.2.8.1	Section-9, Part-C	MV & LV Power & Control Cables and Fiber Optic cables complete with associated components.		Lot	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.2.9		**Auxiliary Equipment**					
1.2.9.1	Section-10, Part-C	Power House Diesel Generator (250 kVA) complete with cabling and associated components.		Set	1		
1.2.9.2	Section-12, Part-C	Lighting and Small Power System complete.		Lot	1		
1.2.10		**Communication System**					
1.2.10.1	Section-11, Part-C	EPABX, PAS and CCTV system complete with associated components.		Lot	1		
1.2.11		**Transmission Lines**					
1.2.11.1	Section-13, Part-C	132 kV overhead transmission network with redundant OPGW complete with associated components including interconnection from the project switchyard with existing 132 kV Transmission Line near Jagran-I substation.		Km	4		
1.2.11.2	Section-13, Part-C	11 kV overhead transmission network with redundant OPGW complete with associated components from the project powerhouse to weir site including Employer's colony.		LS	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.3		**Spare Parts - Mechanical Works**					
1.3.1	Section-2, Part-B	Francis turbine guide vane bushings, pins and sealing set for 4 units		Set	1		
1.3.2		Turbine shaft sealing rings / packing sets		Set	8		
1.3.3		Turbine guide bearing pads and thrust bearing pads (1 set for each type of turbine)		Set	1		
1.3.4		Turbine bearing RTDs, vibration probes and proximity sensors		Set	1		
1.3.5		Turbine coupling bolts, nuts and locking plates		Set	1		
1.3.6		Runner chamber wear ring and labyrinth seal spare set (1 set of each type)		Set	1		
1.3.7	Section-4, Part-B	Complete governor hydraulic seal kits, O-rings and gasket sets (1 set per governor)		Set	1		
1.3.8		Governor electronic controller / PID module		No.	1		
1.3.9		Governor feedback transducers / position sensors		Nos.	2		
1.3.10		Hydraulic oil filters and breather elements for governors		Lot	1		
1.3.11	Section-5, Part-B	Main inlet valve seat seal rings and gland packing (1100 mm and 610 mm valves)		Set	1		
1.3.12		Main inlet valve hydraulic cylinder seal kits		Set	2		
1.3.13		Main inlet valve limit switches, pressure switches and solenoid valves		Set	1		
1.3.14	Section-3, Part-B	Howell Bunger valve seal ring, nozzle liner and guide bush set		Set	1		
1.3.15		Howell Bunger valve hydraulic actuator seal kits		Set	2		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.3.16	Section-6, Part-B	Overhead crane wire ropes for both hoists		Set	1		
1.3.17		Overhead crane brake linings, brake coils and limit switches		Set	1		
1.3.18		Overhead crane wheel bearings and travel motor spare parts		Set	1		
1.3.19	Section-7, Part-B	Mechanical auxiliaries: cooling water pumps spare impellers, bearings and seals		Lot	1		
1.3.20	Section-8, Part-B	Drainage / dewatering pumps spare impellers, bearings and seals		Lot	1		
1.3.21	Section-9, Part-B	Air compressor maintenance kit, piston rings, valves and filters		Lot	1		
1.3.22	Section-12, Part-B	HVAC and ventilation fan bearings, belts and filters		Lot	1		
1.3.23	Section-13, Part-B	Workshop consumables and maintenance tools (gaskets, lubricants, bolts, welding rods, lifting slings, grease guns, oil seals etc.) for 5-years		Lot	1		
1.4		**Spare Parts - Electrical**					
1.4.1		**Generators**					
(a)	Section-1, Part-C	Thrust Bearing Pads		Set	6		
(b)		Guide Bearing Pads		Set	6		
(c)		Brake Linings		Set	3		
(d)		Gasket of all Types		Set	1		
(e)		Stator and Bearing RTDs		Set	2		
(f)		Special Tools for Generator Erection and Maintenance		Set	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.4.2		**Excitation System**					
(a)	Section-2, Part-C	AVR Control Cards/ modules		Set	2		
(b)		Thyristor		Set	4		
(c)		Excitation circuit breaker closing and tripping coils		Set	1		
(d)		Auxiliary contactor		Set	2		
(e)		Transducer		Set	2		
1.4.3		**11 kV Switchgear**					
(a)	Section-4, Part-C	Closing and tripping coil		Set	2		
(b)		Auxiliary contacts		Set	2		
(c)		Spring charging motor		Set	2		
(d)		Control fuses / MCBs		Set	2		
(e)		Indication lamps		Set	2		
1.4.4		**132 kV Switchgear**					
(a)	Section-4, Part-C	CB closing & tripping coil		Set	1		
(b)		CB, Isolator and earthing switch auxiliary contacts		Set	1		
(c)		Control circuit fuses, MCBs and auxiliary relays		Set	1		
(d)		CB/isolator operating mechanism motor		Set	2		
(e)		SF6 sealing kit / O-rings					
1.4.5		**DC System**					
(a)	Section-5, Part-C	Charger control cards		Set	1		
(b)		Charger rectifier/ power module		Set	1		
(c)		Control fuses/ MCBs		Set	1		
(d)		Auxiliary relays		Set	1		
(e)		Indication lamps		Set	1		

Item	Reference Technical Specification (Volume-II) of Bidding Documents	Description	Country of Origin	Unit	Qty	Unit CIP Price	Total CIP Price
						USD	USD
				1	2	3	4 = 2 x 3
1.4.6		**Control System**					
(a)	Section-6, Part-C	PLC/ controller CPU module		Set	1		
(b)		PLC Power supply module		Set	1		
(c)		Digital input/output module		Set	1		
(d)		Control fuses/MCBs		Set	1		
(e)		Auxiliary relays		Set	1		
(f)		Selector switches/ Push buttons		Set	1		
(g)		Indication lamps					
(h)		Multifunction digital meter		Set	2		
1.4.7		**Protection System**					
(a)	Section-7, Part-C	Spare numerical protection relay		Set	3		
(b)		Relay power supply module		Set	3		
(c)		Auxiliary relays		Set	3		
(d)		Control circuit fuses/ MCBs		Set	3		
1.4.8		**Diesel Generator**					
(a)	Section-10, Part-C	Oil filter		Set	2		
(b)		Fuel filter		Set	2		
(c)		Gasket set		Set	2		
(d)		Thermostat		Set	3		
(e)		Engine sensors		Set	3		
(f)		Controller module		Set	3		
TOTAL Column 4 to be carried forward to Schedule No. 6 Grand Summary							

Name of Bidder _____

Signature & Seal of Bidder _____

Country of Origin Declaration Form

Item	Description	Country

Schedule 2 - Plant and Mandatory Spares Supplied from Pakistan

Item	Description	Unit	Qty	Unit Price EXW	Total Price EXW
				PKR	PKR
		1	2	3	4 = 2 x 3
	The Bidders shall list down all the Components of Plant and equipment, which they consider appropriate to supply from within Pakistan.				
TOTAL Column 4 to be carried forward to Schedule No. 6 Grand Summary					

Name of Bidder _____

Signature & Seal of Bidder _____

Schedule 3 - Design Services

Item	Description	Qty/ Unit	Total Price	
			PKR	USD
		1	2	3
3.1	Design of E&M Works complete in all respect including but not limited to the design of all temporary Works, Mechanical Works, Electrical Works, Instrumentation & Control, Protection, SCADA, Switchgears, Switchyard, Transmission lines, Interconnection Works, etc. as per Employer's Requirement and Technical Specification with following submittals:	Job		
a	Level-1 Design			
b	Level-2 Design			
c	Construction / Erection / Manufacturer Drawings			
d	As-built Drawings and O&M Manuals			
e	Completion Report			
TOTAL Columns 2 & 3 to be carried forward to Schedule No. 6 Grand Summary				

Name of Bidder _____

Signature & Seal of Bidder _____

Schedule 4 – General Items

Item	Description	Unit	Qty	Unit Price	Total Price
				PKR	PKR
		1	2	3	4 = 2 x 3
4.1	Provision of vehicles and operating facilities for Consultant Supervision staff.	Per Month	30		
4.2	Cost of Training (Local & Abroad) of Employer's O&M Staff	LS	1		
4.3	Compliance with HSE Provisions as per Employer's Requirements (Water Quality Testing, Waste Disposal, First Aid equipment, PPEs)	PS	1	4,000,000	4,000,000
4.4	Provision of Construction Movie and Pictures Facility as per Employer's Requirements	Job	1		
TOTAL Columns 4 to be carried forward to Schedule No. 6 Grand Summary					

Name of Bidder _____

Signature & Seal of Bidder _____

Schedule 5 – Transportation from Karachi port/ EXW to project site including taxes, port charges, local taxes, insurance, etc. together with Erection, Testing and Commissioning

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.1	**Mechanical Equipment**							
	Main Equipment							
5.1.1	**Turbines**							
5.1.1.1	7.16 MW Francis vertical type Turbines complete in all aspects including but not limited to Runner, Shafts, Spiral Casing, Shaft Seal, Wicket Gates, Guide vanes, Instruments and all other accessories required to generate and deliver 7.16 MW each and fulfill functional guarantees.	Set	3					
5.1.1.2	2.24 MW Francis, vertical type Turbine complete in all aspects including but not limited to Runner, Shafts, Spiral Casing, Shaft Seal, Wicket Gates, Guide vanes, Instruments and all accessories required to generate and deliver 2.24 MW and fulfill functional guarantees.	Set	1					
5.1.2	**Pressure Relief Valves**							
5.1.2.1	Howell Bunger type Pressure relief valves (DN 500, PN 40) complete with connecting pipes, fixed cones, operating systems and all accessories.	Set	3					
5.1.2.2	Howell Bunger type Pressure relief valves (DN 300, PN 40) complete with connecting pipes, fixed cones, operating systems and all accessories.	Set	1					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.1.3	**Governor Systems**							
5.1.3.1	Governor Systems for 7.16 MW turbines, including Governor Hydraulic System, Digital Governor, Nitrogen Accumulator and all accessories.	Set	3					
5.1.3.2	Governor System for 2.24 MW turbine including Governor Hydraulic System, Digital Governor, Nitrogen Accumulator and all accessories.	Set	1					
5.1.4	**Main Inlet Valves**							
5.1.4.1	Spherical type Main Inlet Valves (DN 1100, PN 25) including Valve Assembly, Operating Mechanism and other equipment including all accessories.	Set	3					
5.1.4.2	Spherical type Main Inlet Valves (DN 610, PN 25) including Valve Assembly, Operating Mechanism and other equipment including all accessories.	Set	1					
5.1.5	**Common Mechanical Auxiliaries**							
5.1.5.1	Cooling Water System complete with Cooling Water Pump, Self-Cleaning Back Flushing Filters, Raw and Clean Water Headers including all accessories etc.	Lot	1					
5.1.5.2	Drainage & Dewatering System complete with Drainage and Dewatering Pumps, Oil Water Separator, Valve and necessary piping including all accessories etc.	Lot	1					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.1.5.3	Compressed Air System complete with Air Compressors, Air Receiver, piping, valves complete with accessories etc.	Lot	1					
5.1.5.4	Fire Fighting System complete with Fire Water Pump, piping, Fire detection and alarm system, hydrant and hose reel system and automatic sprinkler system complete with all accessories.	Lot	1					
5.1.5.5	Oil Handling Purification system complete with all accessories.	Lot	1					
5.1.5.6	HVAC Equipment as specified complete with all accessories.	Lot	1					
5.1.5.7	Workshop Equipment complete with all accessories.	Lot	1					
5.1.5.8	Fire Detection & Alarm System complete with all accessories.	Lot	1					
5.1.6	**Lifting Equipment (Overhead Crane and Associated System)**							
5.1.6.1	45/10 ton Powerhouse Overhead Travelling Crane including all accessories etc.	No.	1					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.2	**Electrical Equipment**							
	Main Equipment							
5.2.1	**Generator and Excitation System**							
5.2.1.1	Three Main Generators (6.8 MW each), 0.80 pf, 50 Hz, 11KV as per the specifications, with accessories and auxiliaries (excitation system, cooling system, braking system, AVR, firefighting, detection and alarm systems, protection signaling devices, CT's, PT's, LAz, Isolators, SCADA, Protection& Control System, GCB's, etc.) for a complete functional unit.	Set	3					
5.2.1.2	One Auxiliary Generator (2.13 MW), 0.80 pf, 50 Hz, 11KV as per the specifications, with accessories and auxiliaries (excitation system, cooling system, braking system, AVR, firefighting, detection and alarm systems, protection signaling devices, CT's, PT's, LAz, Isolators, SCADA, Protection& Control System, GCB's, etc.) for a complete functional unit.	Set	1					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.2.2	**Transformers**							
5.2.2.1	**Step-Up Transformers (3-Phase)**							
5.2.2.1.1	10/13 MVA Generator Step-up Transformers 11/132 KV, ONAN/ONAF, OLTC MK, HV & LV bushing, protection and control devices, Fire Fighting, Fire walls etc., as per the specification for a complete functional unit.	Set	3					
5.2.2.1.2	3.5 MVA Generator Step-up Transformer 11/132 KV, ONAN/ONAF, OLTC MK, HV & LV bushing, protection and control devices, Fire Fighting, Fire walls etc., as per the specification for a complete functional unit.	Set	1					
5.2.2.2	**Auxiliary Transformers (3-Phase)**							
5.2.2.2.1	250 kVA, 11/0.4kV Oil-filled, Cu Winding Station Auxiliary Transformer complete with associated components.	No.	2					
5.2.2.2.2	200 kVA, 11/0.4kV Oil-filled Cu Winding Transformer complete with associated components.	No.	2					
5.2.3	**Switchgear**							
5.2.3.1	**MV Switchgear**							
5.2.3.1.1	M.V. Switchgear (incl. Circuit Breakers, load break switches, Earth switches, Current Transformers, Voltage Transformers, Protection Relays , meters, transducers, pushbuttons and switches, cabling etc) complete.	Set	1					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.2.3.2	**LV Switchgear**							
5.2.3.2.1	400 V Switchgear (incl. Circuit Breakers, contactors, load break switches, Earth switches, Current Transformers, Voltage Transformers, Protection Relays , meters, transducers, pushbuttons and switches etc.) complete.	Set	4					
5.2.4	**132 kV Switchyard**							
5.2.4.1	132kV Equipment for complete substation as detailed in single line diagram & as specified including monitoring and control system, protection system, AC/DC auxiliary supply and Lightning system etc. complete	Set	1					
5.2.5	**DC and UPS System**							
5.2.5.1	DC and UPS System (including batteries, chargers, switchboards, switches, meters, inverters, etc.) complete.	Set	1					
5.2.6	**Control, Protection and SCADA**							
5.2.6.1	Control and Instrumentation System including (RTU, SIC, GPS master clock system, Gateway, UPS and ancillary equipment, metering system & secure metering system) complete.	Lot	1					
5.2.6.2	Protection and Relay Equipment complete.	Lot	1					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.2.7	**Earthing and Lightning Protection**							
5.2.7.1	Earthing and Lightning Protection System with Cu Materials (Powerhouse, weir/ intake and switchyard) complete.	Lot	1					
5.2.8	**Cabling**							
5.2.8.1	MV & LV Power & Control Cables and Fiber Optic cables complete with associated components.	Lot	1					
5.2.9	**Auxiliary Equipment**							
5.2.9.1	Power House Diesel Generator (250 kVA) complete with cabling and associated components.	Set	1					
5.2.9.2	Lighting and Small Power System complete.	Lot	1					
5.2.10	**Communication System**							
5.2.10.1	EPABX, PAS and CCTV system complete with associated components.	Lot	1					
5.2.11	**Transmission Lines**							
5.2.11.1	132 kV overhead transmission network with redundant OPGW complete with associated components including interconnection from the project switchyard with existing 132 kV Transmission Line near Jagran-I substation.	Km	4					

Item	Description	Unit	Qty	Transportation to Site including duties, taxes, insurance, etc.	Unit Price Erection, Testing & Commissioning		Total Price	
				PKR	PKR	USD	PKR	USD
		1	2	3	4	5	6 = 2 x (3+4)	7 = 2 x 5
5.2.11.2	11 kV overhead transmission network with redundant OPGW complete with associated components from the project powerhouse to weir site including Employer's colony.	LS	1					
	Spare Parts							
5.3	Spare Parts Mechanical supplied under Schedule 1&2	Lot	1		N.A	N.A		N.A
5.4	Spare Parts Electrical supplied under Schedule 1&2	Lot	1		N.A	N.A		N.A
TOTAL Column 6 & 7 to be carried forward to Schedule No. 6 Grand Summary								

Name of Bidder _____

Signature & Seal of Bidder _____

Schedule 6 – Grand Summary

Schedule No.	Title	Total	
		Foreign Currency (USD)	Local Currency (PKR)
1	Plant and Mandatory Parts Supplied from Abroad		N.A
2	Plant and Mandatory Parts Supplied from Within Pakistan	N.A	
3	Design Services		
4	General Items	N.A	
5	Transportation from Karachi port/ EXW to project site including taxes, port charges, local taxes, insurance, etc. together with Erection, Testing and Commissioning		
	Daywork Schedule	N.A	
	Sub Total		
Exchange rate for conversion of foreign currency into Local currency (28 days prior to Bid Submission)			
Grand Total Bid Price in PKR (C/F to Letter of Price Bid)			
Provisional Sums			
Total Provisional Sum (Fixed for Every Bidder)			100,000,000

Name of Bidder _____

Signature & Seal of Bidder _____

DAYWORK SCHEDULE

PREAMBLE

Dayworks

In the event of any part of the Works or any other works as may reasonably be instructed by the Employer's Representative is required to be executed on Dayworks basis, the value of work done thereof shall be ascertained based on the rates stated herein.

Rates

1. The Bidder shall completely price the Schedule of Daywork Rates here below and shall add and price other items that the Bidders reasonably foresee may be executed on daywork basis. The other items would however not be added in the summary and shall be subject to adjustment by the Employer and agreed to by the Bidder before the award of the Contract.

2. The rates shall be inclusive of all costs of whatsoever nature necessary to execute the works in full compliance with all the provisions of the Contract for the proper Execution of the Works, which shall include but not limited to wages, contributions, bonuses, gratuities, expenses, travelling and subsistence, use of ordinary plant and tools and their maintenance, scaffolding, fencing, water, power, fuel, lubricants, watching, lighting, supervision, overall establishment charges, all insurances and allowances, contractor's profit, etc.

3. Payment for labour shall be made only for actual time worked. Idling and travelling time will not be paid.

4. The time of gangers working with their gangs will be paid for by the appropriate items, but the time of foremen (or leading hands and charge hands) and walking gangers will not be included.

5. Claims for payment must be accompanied by labour and plant time sheets and evidence of costs as may reasonably be required in support of the claim for the Dayworks and shall be endorsed by the Employer's Representative. Such endorsement however shall not bind the Employer to accept or reject the Day work.

6. Where special machinery (not listed) are required for use on Daywork, the payment to be paid to the Contractor shall be subject to prior approval and agreement by the Employer.

7. Rates for power driven tools are not included in the labour rates, but charges for hand tools shall be deemed to be included.

Daywork Schedule

Item	Description	Unit	Qty	Unit Price	Total Price
				PKR	PKR
		1	2	3	4 = 2 x 3
1.1	Foreman (all trades)	Hours	100		
1.2	**Skilled, comprising the following trades**				
1.2.1	Mechanic (all trades)	Hours	100		
1.2.2	Electricians	Hours	100		
1.2.3	Carpenter	Hours	100		
1.2.4	Mason	Hours	100		
1.2.5	Crane operator	Hours	100		
1.2.6	Dozer operator	Hours	100		
1.2.7	Plumber	Hours	100		
1.2.8	Welder	Hours	100		
1.2.9	Pump operator	Hours	100		
1.2.10	Steel fixers	Hours	100		
1.2.11	Painters	Hours	100		
1.2.12	Greaser	Hours	100		
1.2.13	Concrete workers	Hours	100		
1.2.14	Grader operator	Hours	100		
1.3	**Semi-skilled comprising the followings Trades**				
1.3.1	Helper	Hours	100		
1.3.2	Wireman	Hours	100		
1.3.3	Driver	Hours	100		
1.4	**Unskilled (all trades)**				
1.4.1	Coolie	Hours	100		
1.4.2	Sweeper	Hours	100		
1.4.3	Chowkidar	Hours	100		
1.4.4	Labourer	Hours	100		
2	**Construction Equipment**				

Item	Description	Unit	Qty	Unit Price	Total Price
				PKR	PKR
		1	2	3	4 = 2 x 3
2.1	Excavator (PC400/1.8m^3)	Hours	100		
2.2	Excavator (PC220/1.0m^3)	Hours	100		
2.3	Loader (ZL50C/3.0m^3)	Hours	100		
2.4	Bulldozer (D8/220HP)	Hours	100		
2.5	Vibrating roller (13t/BW201AD)	Hours	100		
2.6	Hand-held vibrating roller **(0.9T/BW75S)**	Hours	100		
2.7	Hand drill (YT28)	Hours	100		
2.8	Crawler crane (WD400)	Hours	100		
2.9	Concrete mixer truck (6.0m3)	Hours	100		
2.10	Truck crane (8T)	Hours	100		
2.11	Dump truck 5t	Km	200		
2.12	Truck 10t	Km	200		
2.13	Bituminous distributor	Hours	100		
2.14	Diesel generator (100KW)	Hours	100		
2.15	Water pump (XA80/26B)	Hours	100		
2.16	Air compressor (4L-20/8, 20m3/min)	Hours	100		

Name of authorised representative of Bidder _____

Signature of authorised representative of Bidder _____
and official stamp of Bidder

Date: _____

The bidder shall also state the rates and nominal quantities for use on dayworks of other items in a separate table he expects to use on site: -

Part-4

General Conditions of Contract

TABLE OF CONTENTS

PREAMBLE TO CONDITIONS OF CONTRACT 122
PREAMBLE TO CONDITIONS OF CONTRACT 123
GENERAL CONDITIONS OF CONTRACT 126
[Notes on the Conditions of Contract] 127
PART-I: GENERAL CONDITIONS OF CONTRACT 128
Definitions and Interpretations 128
1.1 Definitions 128
1.2 Headings and Titles 130
1.3 Interpretation 130
1.4 Written Communications 131
1.5 Notices, Consents and Approvals 131
1.6 Costs, Overhead Charges and Profit 131
1.7 Periods 131
Engineer and Engineer's Representative 131
2.1 Engineer's Duties 131
2.2 Engineer's Representative 131
2.3 Engineer's Power to Delegate 131
2.4 Engineer to Act Impartially 132
2.5 Engineer's Decisions and Instructions 132
2.6 Confirmation in Writing 132
2.7 Disputing Engineer's Decisions and Instructions 132
2.8 Replacement of Engineer 132
Assignment and Subcontracting 133
3.1 Assignment 133
4.1 Subcontracting 133
Contract Documents 133
5.1 Ruling Language 133
5.2 Day to Day Communications 133
5.3 Priority of Contract Documents 133
5.4 Documents Mutually Explanatory 133
6.1 Contractor's Drawings 134
6.2 Consequences of Disapproval of Contractor's Drawings 134
6.3 Approved Contractor's Drawings 134
6.4 Inspection of Contractor's Drawings 134
6.5 Erection Information 134
6.6 Operation and Maintenance Manuals 135
6.7 Employer's Use of Contractor's Drawings 135
6.8 Contractor's Use of Employer's Drawings 135
6.9 Manufacturing Drawings 135
7.1 Errors in Contractor's Drawings 135
7.2 Errors by Employer or Engineer 136
Obligations of the Contractor 136
8.1 General Obligations 136
8.2 Setting Out 136
9.1 Contract Agreement 136
10.1 Performance Security 136
10.2 Period of Validity 137

10.3 Claims under Performance Security 137
11.1 Site Data 137
11.2 Sufficiency of Contract Price 137
11.3 Physical Obstructions and Conditions 138
12.1 Programme to be Furnished 138
12.2 Alteration to Programme 138
12.3 Revision of Programme 139
13.1 Contractor's Representative 139
13.2 Objection to Contractor's Employees 139
14.1 Contractor's Equipment 139
14.2 Safety Precautions 139
14.3 Electricity Water and Gas 139
14.4 Employer's Equipment 140
14.5 Clearance of Site 140
14.6 Opportunities for Other Contractors 140
14.7 Authority for Access 140
14.8 Information for Import Permits and Licenses 140
15.1 Compliance with Statutes, Regulations 140
15.2 Compliance with Laws 141
16.1 Patent Rights 141
16.2 Claims in respect of Patent Right 141
16.3 Employer's Warranty for Patent Rights 142
Obligations of the Employer 142
17.1 Access to and Possession of the Site 142
17.2 Assistance with Local Regulations 142
17.3 Civil Works on Site 142
17.4 Consents and Wayleaves 142
17.5 Import Permits and Licences 142
Labour 142
18.1 Engagement of Labour 142
18.2 Returns of Labour 142
18.3 Working Hours 143
18.4 Restriction on Working Hours 143
Workmanship and Materials 143
19.1 Manner of Execution 143
19.2 Covering up Work 143
19.3 Uncovering Work 143
20.1 Independent Inspection 144
20.2 Inspection and Testing During Manufacture 144
20.3 Dates for Inspection and Testing 144
20.4 Facilities for Testing 144
20.5 Certificate of Testing 144
21.1 Rejection 145
22.1 Permission to Deliver 145
Suspension of Works, Delivery or Erection 145
23.1 Order to Suspend 145
24.1 Cost of Suspension 145
24.2 Payment in Event of Suspension 146
24.3 Prolonged Suspension 146
24.4 Resumption of Work 146
Completion 147
25.1 Time for Completion 147

26.1 Extension of Time for Completion 147
26.2 Delays by Subcontractors 147
26.3 Earlier Completion 148
27.1 Delay in Completion 148
27.2 Prolonged Delay 148
Tests on Completion 149
28.1 Notice of Tests 149
28.2 Time for Tests 149
28.3 Delayed Tests 149
28.4 Facilities for Tests on Completion 149
28.5 Retesting 149
28.6 Disagreement as to Result of Tests 149
28.7 Consequences of Failure to Pass Tests on Completion 150
28.8 Use by the Employer 150
28.9 Test Certificate 150
Taking Over 150
29.1 Taking Over 150
29.2 Taking-Over Certificate 150
29.3 Use before Taking Over 151
29.4 Interference with Tests on Completion 151
Defects after Taking Over 151
30.1 Defects Liability Period 151
30.2 Making Good Defects 151
30.3 Notice of Defects 152
30.4 Extension of Defects Liability Period 152
30.5 Failure to Remedy Defects 152
30.6 Removal of Defective Work 152
30.7 Further Tests on Completion 153
30.8 Right of Access 153
30.9 Defects in Employer's and Engineer's Designs 153
30.10 Contractor to Search 153
30.11 Defects Liability Certificate 153
30.12 Exclusive Remedies 153
Variations 153
31.1 Engineer's Right to Vary 153
31.2 Variation Order Procedure 154
31.3 Disagreement on Adjustment of the Contract Price 154
31.4 Contractor to Proceed 155
31.5 Records of Costs 155
Ownership of Plant 155
32.1 Ownership of Plant 155
Certificates and Payment 155
33.1 Terms of Payment 155
33.2 Method of Application 155
33.3 Issue of Certificate of Payment 156
33.4 Corrections to Certificates of Payment 156
33.5 Payment 156
33.6 Delayed Payment 156
33.7 Remedies on Failure to Certify or Make Payment 156
33.8 Payment by Measurement 157
33.9 Application for Final Certificate of Payment 157
33.10 Issue of Final Certificate of Payment 157

33.11 Final Certificate of Payment Conclusive 157
Claims 158
34.1 Procedure 158
34.2 Assessment 158
Foreign Currency and Rates of Exchange 158
35.1 Payment in Foreign Currencies 158
35.2 Currency Restrictions 158
35.3 Rates of Exchange 159
Provisional Sums 159
36.1 Use of Provisional Sums 159
36.2 Ordering Work against Provisional Sums 159
36.3 Invoices and Receipts 159
36.4 Payment against Provisional Sums 159
Risk and Responsibility 159
37.1 Allocation of Risk and Responsibility 159
37.2 Employer's Risks 160
37.3 Contractor's Risks 161
Care of the Works and Passing of Risk 161
38.1 Contractor's Responsibility for the Care of the Works 161
38.2 Risk Transfer Date 161
39.1 Passing of Risk of Loss of or Damage to the Works 161
39.2 Loss or Damage Before Risk Transfer Date 161
39.3 Loss or Damage After Risk Transfer Date 161
Damage to Property and Injury to Persons 162
40.1 Contractor's Liability 162
40.2 Employer's Liability 162
41.1 Accidents 162
Limitations of Liability 162
42.1 Liability for Indirect or Consequential Damage 162
42.2 Maximum Liability 162
42.3 Liability after Expiration of Defects Liability Period 163
42.4 Exclusive Remedies 163
42.5 Mitigation of Loss of Damage 163
42.6 Foreseen Damage 163
Insurance 163
43.1 The Works 163
43.2 Contractor's Equipment 164
43.3 Third Party Liability 164
43.4 Employees 164
43.5 General Requirements of Insurance Policies 164
43.6 Permitted Exclusions from Insurance Policies 164
43.7 Remedies on the Contractor's Failure to Insure 165
43.8 Amounts not Recovered 165
Force Majeure 165
44.1 Definition of Force Majeure 165
44.2 Effect of Force Majeure 165
44.3 Notice of Occurrence 165
44.4 Performance to Continue 165
44.5 Additional Costs caused by Force Majeure 166
44.6 Damage Caused by Force Majeure 166
44.7 Termination in Consequence of Force Majeure 166
44.8 Payment on Termination for Force Majeure 166

44.9 Release from Performance 166
44.10 Force Majeure Affecting Engineer's Duties 167
Default 167
45.1 Notice of Default 167
45.2 Contractor's Default 167
45.3 Valuation at Date of Termination 167
45.4 Payment after Termination 167
45.5 Effect on Liability for Delay 168
46.1 Employer's Default 168
46.2 Removal of Contractor's Equipment 168
46.3 Payment on Termination for Employer's Default 168
Change in Cost and Legislation 168
47.1 Labour, Materials and Transport 168
47.2 Statutory and Other Regulations 169
Customs 169
48.1 Customs and Import Duties 169
48.2 Clearance through Customs 169
Notices 169
49.1 Notices to Contractor 169
49.2 Notice to Employer and Engineer 169
49.3 Minutes of Meetings 169
Disputes and Arbitration 170
50.1 Disputes concerning Engineer's Decisions 170
50.2 Arbitration 170
50.3 Works to Continue 170
50.4 Time Limit for Arbitration 170
Law and Procedure 171
51.1 Applicable Law 171
51.2 Procedural Law 171
51.3 Language 171

PREAMBLE TO CONDITIONS OF CONTRACT

PREAMBLE TO CONDITIONS OF CONTRACT

Commencement Date	Sub-Clause 1.1.1.(i) The date for commencement of the Works is the date of issuance of the Project Manager/Engineer's written Order to Commence which shall be issued within 14 days of signing of Contract Agreement and also site possession has been delivered to the extent required to enable the Contractor to proceed in accordance with the programme submitted under Sub-Clause 12.
Defect Liability Period	Sub-Clause 1.1.11 The Defect Liability Period is 12 months after the date certified in the Taking-Over Certificate but subject to extension as provided under Sub-Clause 30.4.
The Employer	Sub-Clause 1.1.12. The Employer is AJK Power Development Organization represented by the Project Director 22 MW Jagran-IV HPP The Address of Employer is: **Project Director** 22 MW Jagran-IV Hydropower Project AJK, Searbean Residency, Western Bypass Road Near Saif Plaza, Muzaffarabad Azad Kashmir Ph No: 05822-940064 E-mail: pdjrniv@gmail.com
The Project Manager/Engineer	Sub-Clause 1.1.15. The Project Manager/Engineer is Joint Venture of **Associated Consulting Engineers ACE Limited**, **Saudconsult Saudi Consulting Services** and **Rehman Habib Consultants (Pvt) Limited** or any competent person/firm appointed by the Employer, and notified to the Contractor. The Address of Project Manager/Engineer is: 36- Civic Center, M Block Model Town Extension, Lahore Pakistan
Time for Completion	Sub-Clause 1.1.35 The Time for Completion for whole of the Works is 1095 calendar days reckoned from the Commencement Date for the project.
Warranty Period	Sub-Clause 1.1.40 The Warranty Period is Five (05) years for (plant/equipment).
Project Manager/Engineer 's Duties & Authorities	Sub-Clause 2.1 The duties & authorities of the Project Manager/Engineer are specified in Particular Conditions of Contract.
Confirmation in Writing	Sub-Clause 2.6 i. The Contractor shall notify to the Project Manager/Engineer within ten (10) days, if he requires any confirmation. ii. Project Manager/Engineer shall confirm the decision/instruction within ten (10) days of the requirement.
Ruling Language	Sub-Clause 5.1. The version in English language (ruling language) shall prevail.

Day to Day Communications	Sub-Clause 5.2 The language for day to day communication is English.
As Built-Drawings	Sub-Clause 6.10 As-Built drawings and O&M Manual shall be provided to the Project Manager/ Engineer within thirty (30) days from the date of issue of Taking-Over Certificate.
Programme to be Furnished	Sub-Clause 12.1. The comprehensive Programme must be submitted in the form of Primavera or MS Project or equivalent with critical path/activities for individual activities and overall Project.
Employer's Equipment	Sub-Clause 14.4. There will be no Employer's Equipment available for use by the Contractor.
Working Hours	Sub-Clause 18.3. The normal working hours on the Site are to conform to the applicable labour laws and the existing customs of Pakistan.
Time for Completion	Sub-Clause 25.1 Period of Completion is as stated under Sub-Clause 1.1.35 hereof.
Earlier Completion	Sub-Clause 26.3 i. Not Applicable
Delay in Completion	Sub-Clause 27.1. Failure of the Contractor to meet the Time for Completion entitles the Employer to deduct from the Contract Price, the liquidated damages @ 0.05 % percent of the Contract Price as stated in Letter of Acceptance, excluding Provisional Sums for each and every day, including holidays, of delay or part thereof; but to a maximum limit of 10 % of the Contract Price as stated in Letter of Acceptance, excluding Provisional Sums.
Prolonged Delay	Sub-Clause 27.2. Maximum amount recoverable from the Contractor by the Employer shall be 10% of Contract Price as stated in the Letter of Acceptance, excluding Provisional Sum.
Terms of Payment	Sub-Clause 33.1. In addition to the provisions under Clause 33, the terms of payment shall be as stated in Sub-Clause 33.1 of Particular Conditions of Contract.
Payment in Foreign Currencies	Sub-Clause 35.1 Payment will only be made in PKR & USD.
Insurance of Works	Sub-Clause 43.1. The amount of insurance shall be for full replacement value of the Works. For the deductibles, if any, the Contractor shall submit an undertaking that he shall indemnify and keep indemnified the Employer for the amount of deductibles provided in the insurance policy.

	Sub-Clause 43.1.(a) The additional risks to be insured are as stated in Sub-Clause 43.1(a) of the Particular Conditions of Contract.
Third Party Liability	Sub-Clause 43.3 i) The amount of insurance against third party liability taken out by the Contractor shall not be less than Bodily Injury to Third Parties: PKR 500,000 per person, per occurrence, with the number of occurrences unlimited. ii) Death or Permanent Total Disability: PKR 2,000,000 per person, per occurrence, with the number of occurrences unlimited. iii) Loss or Damage to Third-Party Property: Full Replacement Cost of the property damaged or lost, plus any associated costs of restoration, per occurrence, with the number of occurrences unlimited..
Labour, Materials and Transport	Sub-Clause 47.1. The price adjustment shall not be permissible.
Notices to Project Manager/Engineer	Sub-Clause 49.2. The address of the Employer for notices is the same as given in Sub-Clause 1.1.12 here above. The address of the Project Manager/Engineer for notices is the same as given in Sub-Clause 1.1.15 here above.
Applicable Law	Sub-Clause 51.1. The Contract in all respects be read and construed and shall operate as a Pakistani Contract in conformity with the Laws of Islamic Republic of Pakistan.
Procedural Law for Arbitration	Sub-Clause 51.2. The procedural law for arbitration shall be the Rules of Pakistan Arbitration Act 1940 as amended.
Language and Place of Arbitration	Sub-Clause 51.3. The language of arbitration is English. The place of arbitration is Muzaffarabad, Azad Jammu & Kashmir.

GENERAL CONDITIONS OF CONTRACT

[Notes on the Conditions of Contract]

The Conditions of Contract comprise two parts:

(a) General Conditions of Contract
(b) Particular Conditions of Contract

Over the years, a number of "model" General Conditions of Contract have evolved. The one used in these Standard Bidding Documents was prepared by the International Federation of Consulting Engineers (Federation Internationale des Ingenieurs-Conseils, or FIDIC), and is commonly known as the FIDIC Conditions of Contract. (The used version is the 1987 edition, reprinted in 1988 with editorial amendments.)

The FIDIC Conditions of Contract have been prepared for an ad measurement (unit price or unit rate) type of contract, and cannot be used without major modifications for other types of contract, such as lump sum, turnkey, or target cost contracts.

The standard text of the General Conditions of Contract chosen must be retained intact to facilitate its reading and interpretation by Bidders and its review by the Employer. Any amendments and additions to the General Conditions, specific to the contract in hand, should be introduced in the Particular Conditions of Contract.

The use of standard conditions of contract for all electrical/mechanical Works will ensure comprehensiveness of coverage, better balance of rights or obligations between Employer and Contractor, general acceptability of its provisions, and savings in time and cost for bid preparation and review, leading to more economic prices.

The FIDIC Conditions of Contract are copyrighted and may not be copied, faxed, or reproduced. Without taking any responsibility of its being accurate, Pakistan Engineering Council with prior consent of FIDIC Secretariat, has reproduced herein the FIDIC General Conditions of Contract for reference purpose only which cannot be used by the users for preparing their bidding documents. The bidding document may include a purchased copy, the cost of which can be retrieved as part of the selling price of the bidding document. Alternatively, the FIDIC Conditions of Contract can be referred to in the bidding documents, and the Bidders are advised to obtain copies directly from FIDIC.*

* Add the following text if the bidding documents, as issued, do not include a copy:
"Copies of the FIDIC Conditions of Contract can be obtained from:
FIDIC Secretariat
P.O. Box 86
1000 Lausanne 12
Switzerland
fidic.pub@fidic.org – FIDIC.org/bookshop]

PART-I: GENERAL CONDITIONS OF CONTRACT

Definitions and Interpretations

1.1 Definitions

In the Contract (as hereinafter defined) the following words and expressions shall have the meanings hereby assigned to them:

1.1.1 "Commencement Date" means whichever the latest is of:

i) the date specified in the Preamble as the date for commencement of the Works or the date when the Contractor receives,

ii) such payment in advance of the commencement of the Works as may be specified in the terms of payment, or

iii) notice of the issue of any import license necessary for commencing performance of the Contract, or

iv) notice that any legal requirements necessary for the Contract to enter into force have been fulfilled, or

v) notice that any necessary financial or administrative requirements specified in Part II as conditions precedent to commencement have been fulfilled.

1.1.2 "Conditions" means the Preamble to and these Conditions of Contract, Parts I and II.

1.1.3 "Contract" means the agreement between the Employer and the Contractor for the execution of the Works incorporating the Conditions, Specification, Employer's Drawings and Contractor's Drawings, priced and completed Schedules, Tender, Letter of Acceptance and such further documents as may be expressly incorporated by the Letter of Acceptance.

1.1.4 "Contract Agreement" means the documents recording the terms of the Contract between the Employer and the Contractor.

1.1.5 "Contract Price" means the sum stated in the Letter of Acceptance as payable to the Contractor for the execution of the Works.

1.1.6 "Contractor" means the person whose tender has been accepted by the Employer and the legal successors in title to the Contractor but not (except with the consent of the Employer) any assignee of the Contractor.

1.1.7 "Contractor's Drawings" means all drawings, samples, patterns, models and operation and maintenance manuals to be submitted by the Contractor in accordance with Clause 6.

1.1.8 "Contractor's Equipment" means all appliances or things of whatsoever nature required for the purposes of the Works but does not include Plant.

1.1.9 "Contractor's Risks" means the risks defined in Sub-Clause 37.3.

1.1.10 "Defects Liability Certificate" means the certificate to be issued by the Engineer to the

Contractor in accordance with Sub-Clause 30.11.

1.1.11 "Defects Liability Period" means one year or the period stated in Part II following taking over, during which the Contractor is responsible for making good defects and damage in accordance with Clause 30.

1.1.12 "Employer" means the person named as such in the Preamble and the legal successors in title to the Employer but not (except with the consent of the Contractor) any assignee of the Employer.

1.1.13 "Employer's Drawings" means all the drawings and information provided by the Employer or the Engineer to the Contractor under the Contract.

1.1.14 "Employer's Risks" means those risks defined in Sub-Clause 37.2.

1.1.15 "Engineer" means the person appointed by the Employer to act as Engineer for the purposes of the Contract and designated as such in the Preamble.

1.1.16 "Engineer's Representative" means any representative of the Engineer appointed from time to time by the Engineer under Sub-Clause 2.2.

1.1.17 "Final Certificate of Payment", means the certificate to be issued by the Engineer to the Employer in accordance with Sub-Clause 33.10.

1.1.18 "Force Majeure" has the meaning assigned to it under Sub-Clause 44.1.

1.1.19 "Foreign Currency" means a currency of a country other than that in which Plant is to be installed.

1.1.20 "Gross Misconduct" means any act or omission of the Contractor in violation of the most elementary rules of diligence which a conscientious contractor in the same position and under the same circumstances would have followed.

1.1.21 "Letter of Acceptance" means the formal acceptance by the Employer of the Tender incorporating any adjustments or variations to the Tender agreed between the Employer and the Contractor.

1.1.22 "Performance Security" means the security to be provided by the Contractor in accordance with Sub-clause 10.1. for the due performance of the Contract.

1.1.23 "Plant" means machinery, apparatus, materials and all things to be provided under the Contract for incorporation in the Works.

1.1.24 "Programme" means the Programme to be submitted by the Contractor in accordance with Sub-Clause 12.1 and any approved revision thereto.

1.1.25 "Provisional Sum" means a sum, described as such for the execution of work or for the supply of goods or services, to be used in accordance with Sub-Clause 36.1.

1.1.26 "Risks Transfer Date" means the date when the risk of loss of or damage to the Works passes from the Contractor to the Employer in accordance with Sub-Clause 39.1.

1.1.27 "Schedule of Prices" means the completed and priced Schedule of Prices, or any part or

individual schedule thereof, submitted by the Contractor with his Tender and forming a part of the Contract documents.

1.1.28 "Section" means a part of the Works specifically identified as such as in the Contract.

1.1.29 "Site" means the place or places, provided or made available by the Employer where work is to be done by the Contractor or to which Plant is to be delivered, together with so much of the area surrounding the same as the Contractor shall with the consent of the Employer use in connection with the Works otherwise than merely for the purposes of access.

1.1.30 "Specification" means the specification of the Works included in the Contract and any modification thereof made in accordance with Clause 31.

1.1.31 "Subcontractor" means any person (other than the Contractor) named in the Contract for any part of the Works, or any person to whom any part of the Contract has been subcontracted with the consent of the Engineer, and the Subcontractor's legal successors in title but not any assignee of the Subcontractor.

1.1.32 "Taking-Over Certificate" means the certificate to be given by the Engineer to the Contractor in accordance with Clause 29.

1.1.33 "Tender" means the Contractor's priced offer to the Employer for the Execution of the Works.

1.1.34 "Tests on Completion" means the tests specified in the Contract or otherwise agreed by the Engineer and the Contractor to be performed before the Works are taken over by the Employer.

1.1.35 "Time for Completion" means the time stated in the Preamble for completing the Works or any Section thereof and passing the Tests on Completion calculated from the Commencement Date unless extended in accordance with Clause 26.

1.1.36 "Variation Order" means any written order, identified as such, issued to the Contractor by the Engineer under Sub-Clause 31.1.

1.1.37 "Works" means all Plant to be provided and work to be done by the Contractor under the Contract.

1.2 Headings and Titles

The headings and titles in these Conditions shall not be deemed part thereof or be taken into consideration in the interpretation or construction of the Contract.

1.3 Interpretation

Words importing persons or parties shall include firms and corporations and any organisation having legal capacity.

Words importing the singular only also include the plural and vice versa where the context requires.

1.4 Written Communications

Wherever in the contract provision is made for a communication to be "written" or "in writing" this means any hand-written, type-written or printed communication, including telex, cable and facsimile transmission.

1.5 Notices, Consents and Approvals

Wherever in the Contract provision is made for the giving of notice, consent or approval by any person, such consent or approval shall not be unreasonably withheld. Unless otherwise specified, such notice, consent or approval shall be in writing and the word "notify" shall be construed accordingly.

1.6 Costs, Overhead Charges and Profit

Whenever by these Conditions the Contractor is entitled to be paid cost, such cost shall be properly incurred and shall include any overhead charges properly allocable thereto but not profit unless so stated. Any profit entitlement shall be added to cost at the percentage stated in the Preamble.

1.7 Periods

In these Conditions "days" means calendar day and "year" means 365 days.

Engineer and Engineer's Representative

2.1 Engineer's Duties

The Engineer shall carry out the duties specified in the Contract.

If the Engineer is required, under the terms of his appointment by the Employer, to obtain the specific approval of the Employer before carrying out any of these duties, full particulars of such requirements shall be set out in Part II.

Except as expressly stated in the Contract the Engineer shall have no authority to relieve the Contractor of any of his obligations under the Contract.

2.2 Engineer's Representative

The Engineer's Representative shall be appointed by and be responsible to the Engineer and shall only carry out such duties and exercise such authority as may be delegated to him by the Engineer under Sub-Clause 2.3.

2.3 Engineer's Power to Delegate

The Engineer may from time to time delegate to the Engineer's Representative any of the duties vested in the Engineer and may at any time revoke such delegation.

Any such delegation or revocation shall be in writing and shall not take effect until a copy thereof has been delivered to the Contractor and the Employer.

Any decision, instruction or approval given by the Engineer's Representative to the Contractor in accordance with such delegation shall have the same effect as though it had been given by the Engineer. However:

(a) any failure of the Engineer's Representative to disapprove any Plant or workmanship shall not prejudice the right of the Engineer to disapprove such Plant or workmanship and to give instructions for the rectification thereof.

(b) if the Contractor questions any decision or instruction of the Engineer's Representative he may refer the matter to the Engineer who shall confirm, reverse or vary such decision or instruction.

2.4 Engineer to Act Impartially

Wherever under the Contract the Engineer is required to exercise his discretion by:

(a) giving his decision, opinion or consent, or

(b) expressing his satisfaction or approval, or

(c) determining value, or

(d) otherwise taking action which may affect the rights and obligations of the Employer or the Contractor,

he shall exercise such discretion impartially within the terms of the Contract and having regard to all the circumstances.

2.5 Engineer's Decisions and Instructions

The Contractor shall proceed with the decisions and instructions given by the Engineer in accordance with these Conditions.

2.6 Confirmation in Writing

The Contractor may require the Engineer to confirm in writing any decision or instruction of the Engineer which is not in writing. The Contractor shall notify the Engineer of such requirement without undue delay. Such a decision or instruction shall not be effective until written confirmation thereof has been received by the Contractor.

2.7 Disputing Engineer's Decisions and Instructions

If the Contractor disputes or questions any decision or instruction under Sub-Clause 2.5 or a written confirmation under Sub-Clause 2.6, he shall give notice to the Engineer within twenty eight (28) days after receipt thereof, giving his reasons.

The Engineer shall within a further period of twenty eight (28) days by notice to the Contractor and the Employer with reasons, confirm, reverse or vary such decision or instruction.

If either party disagrees with the action taken by the Engineer, or if the Engineer fails to reply to the Contractor's notice within the stipulated twenty eight (28) days, and the matter cannot be settled amicably that party shall be at liberty, subject to Sub-Clause 50.1, to refer the matter to arbitration in accordance with the Contract.

2.8 Replacement of Engineer

The Employer shall not appoint any person to act in replacement of the Engineer without the consent of the Contractor.

Assignment and Subcontracting

3.1 Assignment

The Contractor shall not assign the Contract or any part of his obligations under the Contract. A charge in favour of the Contractor's bankers of any monies due under the Contract shall not be considered an assignment.

4.1 Subcontracting

The Contractor shall not subcontract the whole of the Works.

Except where otherwise provided by the Contract, the Contractor shall not subcontract any part of the Works without the prior consent of the Engineer.

The Contractor shall however, not require such consent for purchases of materials or to place contracts for minor details or for any part of the Works of which the manufacturer or supplier is named in the Contract.

The Contractor shall be responsible for the acts, defaults and neglects of any Subcontractor, his agents or employees as fully as if they were the acts, defaults or neglects of the Contractor, his agents or employees.

Contract Documents

5.1 Ruling Language

Where versions of the Contract are prepared in different languages, the version which is to prevail shall be specified in the Preamble. The language of such version is referred to as the ruling language.

5.2 Day to Day Communications

The language for day to day communications is stated in the Preamble.

5.3 Priority of Contract Documents

Unless otherwise provided in the Contract, the priority of the Contract documents shall be as follows:

1. The Letter of Acceptance
2. The Preamble
3. The Conditions of Contract, Part II
4. The Conditions of Contract, Part I
5. Any other documents forming part of the Contract.

5.4 Documents Mutually Explanatory

Subject to Sub-Clause 5.3. the Contract documents shall be taken as mutually

explanatory. Any ambiguities or discrepancies shall be resolved by the Engineer, who shall then instruct the Contractor thereon.

If the Contractor considers that compliance with such instructions will result in any cost which the Contractor could not reasonably have anticipated, he shall forthwith inform the Engineer with full supporting details. The Engineer shall then, if he approves, certify such costs as may be reasonable, together with profit where appropriate, which shall be added to the Contract Price.

If on the other hand compliance with such instructions results in lower costs for the Contractor then he had reason to anticipate, the Engineer shall certify a deduction from the Contract Price allowing for profit where appropriate.

6.1 Contractor's Drawings

The Contractor shall submit to the Engineer for approval:

(a) within the time given in the Contract or in the Programme such drawings, samples, models or information as may be called for therein, and in the numbers therein required, and

(b) during the progress of the Works, such drawings of the general arrangement and details of the Works as specified in the Contract or as the Engineer may require.

The Engineer shall signify his approval or disapproval thereof. If he fails to do so within the time given in the Contract or the Programme or if no time limit is specified, within twenty eight (28) days of receipt, they shall be deemed to be approved.

Approved drawings, samples and models shall be signed or otherwise identified by the Engineer.

The Contractor shall supply additional copies of approved drawings in the form and numbers stated in the Contract.

6.2 Consequences of Disapproval of Contractor's Drawings

Any Contractor's Drawings which the Engineer disapprove shall be forthwith modified to meet the requirements of the Engineer and shall be re-submitted.

6.3 Approved Contractor's Drawings

Approved Contractor's Drawings shall not be departed from except as provided in Clause 31.

6.4 Inspection of Contractor's Drawings

The Engineer shall have the right at all reasonable times to inspect, at Contractor's premises, all Contractor's Drawings of any part of the Works.

6.5 Erection Information

The Contractor shall provide, within the times stated in the Contract or in the Programme, drawings showing how the Plant is to be affixed and any other information required for:

(a) preparing suitable foundations or other means of support;

(b) providing suitable access on the Site for the Plant and any necessary equipment to the place where the Plant is to be erected; and

(c) making necessary connections to the Plant.

6.6 Operation and Maintenance Manuals

Before the Works are taken over in accordance with Clause 29 the Contractor shall supply operation and maintenance manuals together with drawings of the Works as built. These shall be in such detail as will enable the Employer to operate, maintain, adjust and repair all parts of the Works.

Unless otherwise stated in Part II the manuals and drawings shall be in the ruling language, and in such form and numbers as stated in the Contract.

Unless otherwise agreed, the Works shall not be considered to be completed for the purposes of taking over until such manuals and drawings have been supplied to the Employer.

6.7 Employer's Use of Contractor's Drawings

Contractor's Drawings may be used by the Employer for no other purpose than completing, operating, maintaining, adjusting and repairing the Works.

6.8 Contractor's Use of Employer's Drawings

The Employer's Drawings, Specification and other information submitted by the Employer or the Engineer to the Contractor shall remain the property of the Employer. These shall not, without the consent of the Employer, be used, copied or communicated to a third party by the Contractor unless necessary for the purposes of the Contract.

6.9 Manufacturing Drawings

Unless otherwise specified in Part II, the Contractor shall not be required to disclose to the Employer or the Engineer the Contractor's confidential manufacturing drawings, designs, know-how or manufacturing practices, processes or operations.

7.1 Errors in Contractor's Drawings

The Contractor shall be responsible for any errors or omissions in the Contractor's Drawings unless they are due to incorrect Employer's Drawings or other written information supplied by the Employer or the Engineer. Approval by the Engineer of the Contractor's Drawings shall not relieve the Contractor from any responsibility under this Sub-Clause.

The Contractor shall bear any costs he may incur as a result of delay in providing Contractor's Drawings and other information or as a result of errors or omissions therein, for which the Contractor is responsible.

The Contractor shall at his own cost carry out any alterations or remedial work

necessitated by such errors or omissions for which he is responsible and modify the Contractor's Drawings and such other information accordingly.

The performance of his obligations under this Clause shall be in full satisfaction of the Contractor's liability under this Clause but shall not relieve him of his liability under Sub-Clause 27.1.

7.2 Errors by Employer or Engineer

The Employer shall be responsible for the Employer's Drawings and for other written information supplied by the Employer or the Engineer and for the details of special work specified by either of them. If such Employer's Drawings, information or details are incorrect and necessitate alterations of the work, the Employer shall pay the Contractor the cost of the alterations together with profit as certified by the Engineer.

Obligations of the Contractor

8.1 General Obligations

The Contractor shall, in accordance with the Contract, with due care and diligence, design, manufacture, deliver to Site, erect, test and commission the Plant and carry out the Works within the Time for Completion. The Contractor shall also provide all necessary Contractor's Equipment, superintendence, labour and, except as stated in Part II, all necessary facilities therefor.

8.2 Setting Out

The Contractor shall set out the Works in relation to original points, lines and levels of reference given by the Engineer in writing and provide all necessary instruments, appliances and labour for such purposes.

If, at any time during the execution of the Works, any error appears in the positions, levels, dimensions or alignment of the Works, the Contractor shall rectify the error.

The Contractor shall bear the cost of rectifying the error, unless the error results from incorrect information supplied in writing by the Employer, the Engineer or from default by another contractor, in which case the cost together with profit shall be borne by the Employer.

The checking of any setting-out by the Engineer shall not relieve the Contractor of his responsibility for the accuracy thereof.

9.1 Contract Agreement

The Contractor shall, if called upon so to do, execute a Contract Agreement recording all the terms of the Contract, to be prepared by and completed at the cost of the Employer in the form annexed hereto.

10.1 Performance Security

If Part II requires the Contractor to obtain a Performance Security, he shall obtain the same in the sum required, within twenty eight (28) days after the receipt of the Letter of Acceptance. The Performance Security shall be provided by a person and in a form

approved by the Employer. The cost of complying with the requirements of this Clause shall be borne by the Contractor.

10.2 Period of Validity

The Performance Security shall be valid until the Contractor has executed, completed and remedied defects in the Works in accordance with the Contract. No claim shall be made against the Performance Security after the issue of the Defects Liability Certificate and the Performance Security shall be returned to the Contractor within fourteen (14) days of the issue of the Defects Liability Certificate.

10.3 Claims under Performance Security

Whether or not the Performance Security is stated by its terms to be payable on the demand of the Employer the Employer shall not make a claim under the Performance Security unless one of the following conditions is satisfied:

(a) the Contractor is in breach of the Contract and fails to remedy the breach within fourty two (42) days after receiving written notice from the Employer requiring him so to do. The notice shall state the intention to claim under the Performance Security, the amount claimed and the breach relied upon, or

(b) the Employer and the Contractor have agreed in writing that the amount demanded is payable to the Employer, and the amount has not been paid within fourty two (42) days thereafter, or

(c) the Employer has obtained an award in arbitration under Clause 50 and the amount awarded has not been paid within fourty two (42) days after the award, or

(d) the Contractor has gone into liquidation or is bankrupt.

In every case the Employer shall, when making the claim, send a copy to the Contractor.

11.1 Site Data

The Tender shall be deemed to have been based on such data on climatic, hydrological and general conditions on the Site and for the operation of the Works as the Employer or the Engineer has made available to the Contractor for the purposes of the Tender. The Contractor shall be responsible for his own interpretation of such data.

11.2 Sufficiency of Contract Price

The Contractor shall be deemed to have satisfied himself on and taken account of in his Tender:

(a) all the conditions and circumstances affecting the Contract Price,

(b) the possibility of carrying out the Works as described in the Contract,

(c) the general circumstances at the Site (if access has been made available to him) and

(d) the general labour position at the Site.

The Contractor shall not be responsible for the accuracy of information given in writing by the Employer or the Engineer but shall be responsible for his interpretation of information received from whatever source.

11.3 Physical Obstructions and Conditions

If during the execution of the Works on Site the Contractor encounters physical obstructions or conditions of the kind stipulated in Sub-Clause 26.1.c) the Contractor shall be entitled to recover the additional cost incurred in consequence.

The Engineer shall certify and there shall be added to the Contract Price the additional cost of:

(a) complying with any instruction which the Engineer, after due consultation with the Employer and the Contractor, issues to the Contractor in connection therewith, and

(b) any necessary measures which the Contractor may take in the absence of specific instructions from the Engineer.

12.1 Programme to be Furnished

The Contractor shall submit to the Engineer for his approval the Programme which shall contain the following:

(a) the order in which the Contractor proposes to carry out the Works (including design, manufacture, delivery to Site, erection, testing and commissioning),

(b) the times when submission and approval of the Contractor's Drawing are required,

(c) the times by which the Contractor requires the Employer:

(i) to furnish any Employer's Drawings,

(ii) to provide access to the Site,

(iii) to have completed the necessary civil engineering work (including foundations for the Plant) and

(iv) to have obtained any import licences, consents, wayleaves and approvals necessary for the purpose of the Works.

The Contractor shall submit the Programme in the form stated in the Preamble within twenty eight (28) days after the Commencement Date.

The approval by the Engineer of the Programme shall not relieve the Contractor or the Employer from any obligation under the Contract.

12.2 Alteration to Programme

No material alteration to the Programme shall be made without the approval of the Engineer.

12.3 Revision of Programme

If the progress of the Works does not conform to the Programme, the Engineer may instruct the Contractor to revise the Programme.

If such modifications are required for reasons for which the Contractor is not responsible, the cost of preparing the revised Programme shall be certified by the Engineer and added to the Contract Price.

13.1 Contractor's Representative

The Contractor shall employ one or more competent representatives to superintend the carrying out of the Works on Site. They shall be fluent in the language for day to day communications. Their names shall be communicated in writing to the Engineer before work on Site begins.

Any instruction or notice which the Engineer gives to the Contractor's representative shall be deemed to have been given to the Contractor.

13.2 Objection to Contractor's Employees

The Contractor shall, upon the Engineer's written instruction, remove from the Works any person employed by him in the execution of the Works, who misconducts himself or is incompetent or negligent.

14.1 Contractor's Equipment

Except to the extent specified in Part II, the Contractor shall provide all Contractor's Equipment necessary to complete the Works.

All Contractor's Equipment shall, when brought on to the Site, be deemed to be exclusively intended for the execution of the Works. The Contractor shall not remove from the Site any such equipment, except:

(a) when it is no longer required for the completion of the Works, or

(b) when the Engineer has given his consent.

14.2 Safety Precautions

The Contractor shall observe all applicable regulations regarding safety on the Site.

Unless otherwise agreed, the Contractor shall, from the commencement of work on Site until taking over provide:

(a) fencing, lighting, guarding and watching of the Works, and

(b) temporary roadways, footways, guards and fences which may be necessary for the accommodation and protection of owners and occupiers of adjacent property, the public and others.

14.3 Electricity Water and Gas

The Contractor shall be entitled to use for the purposes of the Works such supplies of electricity, water, gas and other services as may be available on the Site and of which

details are given in the Preamble. The Contractor shall pay the Employer a fair price for such use. The Contractor shall at his own cost provide any apparatus necessary for such use.

14.4 Employer's Equipment

The Employer shall, if the Contractor so requests for the execution of the Works, operate any available equipment of which details are given in the Preamble. The Contractor shall pay the Employer a fair price for such use.

The Employer shall during such operation retain control of and be responsible for the safe working of the equipment.

14.5 Clearance of Site

The Contractor shall from time to time during the progress of the Works clear away and remove all surplus materials and rubbish. On completion of the Works the Contractor shall remove all Contractor's Equipment and leave the whole of the Site and the Works clean and in a workmanlike condition, to the satisfaction of the Engineer.

14.6 Opportunities for Other Contractors

The Contractor shall, in accordance with the Engineer's instructions, afford to other contractors engaged by the Employer to work on the Site and persons lawfully upon the Site all reasonable opportunities for carrying out their work provided that the same shall not obstruct or disturb the progress of the Works. The Contractor shall also afford such opportunities to the employees of the Employer.

If the Contractor, on the written request of the Engineer, makes available any Contractor's Equipment or provides any other service, the Employer shall pay the Contractor accordingly. The amount to be paid shall be certified by the Engineer and added to the Contract Price.

14.7 Authority for Access

No persons other than the employees of the Contractor and his Subcontractors shall be allowed on the Site except with the consent of the Engineer.

Facilities to inspect the Works shall at all times be afforded by the Contractor to the Engineer and his representative, the Employer's representatives, authorities and officials.

14.8 Information for Import Permits and Licenses

The Contractor shall submit to the Employer in good time such details of all Plant and Contractor's Equipment as will enable the Employer to obtain all necessary import permits or licenses.

15.1 Compliance with Statutes, Regulations

The Contractor shall, in all matters arising in the performance of the Contract, comply in all respects with, give all notices and pay all fees required by the provisions of any national or state statute, ordinance or other law or any regulation or bye-law of any duly

constituted authority.

15.2 Compliance with Laws

The Contractor shall comply with the laws of the country of manufacture concerning the manufacture of the Plant, and the laws of the country where the Plant is to be erected so far as such laws concern the manufacture, erection and operation of the Works.

16.1 Patent Rights

The Contractor shall indemnify the Employer against all claims of infringement of any patent, registered design, copyright, trade mark or trade name or other intellectual property right provided that all of following conditions are satisfied:

(a) The claim or proceedings arise out of the design, construction, manufacture or use of Works or any Plant supplied by the Contractor.

(b) The right was protected at the date of the Contract in the Contractor's country or the country in which the Plant is to be manufactured or erected.

(c) The infringement or allegation of infringement was not caused by any use of the Works otherwise than for purpose indicated by or reasonably to be inferred from date Specification.

(d) The infringement or allegation of infringement was not caused by the use of any Plant in association or combination with any plant not supplied by the Contractor, unless such association or combination was disclosed to the Contractor prior to the due of the Tender.

(e) The infringement of or allegation of infringement was not caused by the Contractor following the design or instructions of the Employer or the Engineer.

16.2 Claims in respect of Patent Right

The Contractor shall be promptly notified of any claim under this Clause made against the Employer. The Contractor may at his own cost conduct negotiations for the settlement of such claim, and any litigation that may arise there from.

The Employer shall not make any admission which might be prejudicial to the Contractor unless the Contractor has failed to take over the conduct of the negotiations or litigation within a reasonable time after having been so requested.

The Contractor may not, however, conduct such negotiations or litigation before he has given the Employer such reasonable security as the Employer may require. The security shall be for an amount which is an assessment of the compensation, damages, expenses and costs for which the Employer may become liable and which are the subject of the indemnity under Sub-Clause 16.1.

The Employer shall, at the request of the Contractor, provide all available assistance for the purpose of contesting any such claim or action, and shall be repaid all reasonable costs incurred in so doing.

16.3 Employer's Warranty for Patent Rights

If any matter for which the Contractor is not liable to indemnify the Employer under Sub-Clause 16.1 causes the infringement or allegation of infringement by the Contractor of any patent, registered design, trade mark, copyright or other intellectual property right, the Employer shall indemnify the Contractor against all claims damages, expenses and costs which the Contractor may incur in relation thereto. The provisions of Sub-Clause 16.2 shall apply mutatis mutandis.

Obligations of the Employer

17.1 Access to and Possession of the Site

The Employer shall in reasonable time grant the Contractor access to and possession of the Site, which may, however, not be exclusive to the Contractor.

The Employer shall to the extent stated in the Specification provide means of access for the delivery of all Plant and Contractor's Equipment to the Site.

17.2 Assistance with Local Regulations

The Employer shall assist the Contractor in ascertaining the nature and extent of any laws, regulations, orders or bye-laws, and customs in the country where the Plant is to be erected, which may affect the Contractor in the performance of his obligations under the Contract. The Employer shall if so requested procure for the Contractor copies thereof and information relating thereto at the Contractor's cost.

17.3 Civil Works on Site

Any building, structure, foundation or means of access on the Site to be provided by the Employer shall be in a condition suitable for the reception, movement, installation and maintenance of the Works within the time or times indicated in the Programme.

17.4 Consents and Wayleaves

The Employer shall in due time obtain or grant all consents including permits-to-work, wayleaves and approvals required for the Works.

17.5 Import Permits and Licences

The Employer shall obtain all import permits or licences required for any part of the Plant or Works in reasonable time having regard to the time for delivery of the Plant and completion of the Works.

Labour

18.1 Engagement of Labour

The Contractor shall, unless otherwise provided in the Contract, make his own arrangements for the engagement of all labour and for their payment, housing feeding and transport.

18.2 Returns of Labour

The Contractor shall submit detailed returns showing the supervisory staff and the numbers of the several classes of labour from time to time employed by the Contractor and Subcontractors on the Site. The returns shall be submitted in such form and at such intervals as the Engineer may prescribe.

18.3 Working Hours

On the Site, the Contractor shall observe the normal working hours stated in the Preamble. The Employer shall allow the Contractor to carry out work on the Site continuously during such working hours.

The Engineer may after consulting the Employer and the Contractor, direct that work shall be done at other times. The extra cost, together with profit, shall be added to the Contract Price unless it has become necessary for the completion of the Works within the Time for Completion, and this is due to the default of the Contractor.

18.4 Restriction on Working Hours

No work shall be carried out on the Site outside normal working hours or on the locally recognised days of rest, unless:

(a) the Contract so provides, or

(b) the work is unavoidable or necessary for the saving of life or property or for the safety of the Works, in which case the Contractor shall immediately advise the Engineer, or

(c) the Engineer gives his consent.

Workmanship and Materials

19.1 Manner of Execution

All Plant to be supplied shall be manufactured and all work to be done shall be executed in the manner set out in the Contract.

Where the manner of manufacture and execution is not set out in the Contract, the work shall be executed in a proper and workmanlike manner in accordance with recognised good practice.

19.2 Covering up Work

The Contractor shall give the Engineer full opportunity to examine, measure and test any work on Site which is about to be covered up or put out of view.

The Contractor shall give due notice to the Engineer whenever such work is ready for examination, measurement or testing.

The Engineer shall then, unless he notifies the Contractor that he considers it unnecessary, without unreasonable delay carry out the examination, measurement or testing.

19.3 Uncovering Work

If so instructed by the Engineer, the Contractor shall expose any parts of the Works. The Contractor shall reinstate and make good such parts to the Engineer's satisfaction.

If any parts of the Works have been covered up or put out of view by the Contractor after complying with Sub-Clause 19.2 and are found to be in accordance with the Contract the cost incurred by the Contractor in complying with the Engineer's instructions including profit shall be certified by the Engineer and added to the Contract Price.

20.1 Independent Inspection

The Engineer may, if so provided in the Contract or with the Contractor's consent, delegate inspection and testing of Plant to an independent inspector. Any such delegation shall be effected in the manner required by Sub-Clause 2.3 and for this purpose such independent inspector shall be considered as an Engineer's Representative. Notice of such appointment (being not less than 14 days) shall be given by the Engineer to the Contractor.

20.2 Inspection and Testing During Manufacture

The Engineer shall be entitled during manufacture to inspect, examine and test the materials and workmanship and check the progress of manufacture of all Plant to be supplied under the Contract. This shall take place on the Contractor's premises during working hours. If Plant is being manufactured on other premises, the Contractor shall obtain permission for the Engineer to carry out such inspection, examination and testing on those premises.

No such inspection, examination or testing shall release the Contractor from any obligation under the Contract.

20.3 Dates for Inspection and Testing

The Contractor shall agree with the Engineer the time and place for the testing of any Plant as provided in the Contract. The Engineer shall give the Contractor 24 hours notice of his intention to attend the tests.

If the Engineer does not attend on the date agreed, the Contractor may, unless the Engineer instructs the Contractor not to do so, proceed with the tests, which shall be deemed to have been made in the Engineer's presence.

The Contractor shall forthwith forward to the Engineer duly certified copies of the test results. If the Engineer has not attended the test, he shall accept the validity of the test readings.

20.4 Facilities for Testing

Where the Contract provides for tests on the premises of the Contractor or of any Sub-Contractor, the Contractor shall provide such assistance, labour materials, electricity, fuel, stores, apparatus and instruments as may be necessary to carry out the test efficiently.

20.5 Certificate of Testing

When Plant has passed the tests referred to in this Clause, the Engineer shall furnish to the Contractor a certificate or endorse the Contractor's test certificate to that effect.

21.1 Rejection

If, as a result of the inspection, examination or testing referred to in Clause 20, the Engineer decides that any Plant is defective or otherwise not in accordance with the Contract, he may reject such Plant and shall notify the Contractor thereof immediately. The notice shall state the Engineer's objections with reasons. The Engineer shall not reject any Plant for minor defects which do not affect the commercial operation of such Plant.

The Contractor shall then with all speed make good the defect or ensure that any rejected Plant complies with the Contract.

If the Engineer requires such Plant to be retested, the tests shall be repeated under the same terms and conditions. All costs incurred by the Employer by the repetition of the tests shall be deducted form the Contract Price.

22.1 Permission to Deliver

The Contractor shall apply in writing to the Engineer for permission to deliver any Plant or Contractor's equipment to the Site. No Plant or Contractor's Equipment may be delivered to the Site without the Engineer's written permission.

The Contractor shall be responsible for the reception on Site of the Plant and Contractor's Equipment.

Suspension of Works, Delivery or Erection

23.1 Order to Suspend

The Engineer may at any time instruct the Contractor to:

(a) suspend progress of the Works, or

(b) suspend delivery of Plant or Contractor's Equipment which is ready for delivery to the Site at the time for delivery specified in the Programme, or if no time is specified, at the time appropriate for it to be delivered, or

(c) suspend the erection of Plant which has been delivered to the Site.

When the Contractor is prevented from delivering or erecting Plant in accordance with the Programme the Engineer shall be deemed to have instructed a suspension except when such prevention is caused by the Contractor's default.

The Contractor shall during suspension protect and secure the Works or Plant affected at the Contractor's works or elsewhere or at the Site, as the case may be, against any deterioration, loss or damage.

24.1 Cost of Suspension

The additional cost incurred by the Contractor in protection, securing and insuring the Works or Plant and in following the Engineer's instructions under Sub-Clause 23.1 and in resumption of the work, shall be added to the Contract Price.

The Contractor shall not be entitled to be paid any additional costs if such suspension is necessary by reason of a default on the part of the Contractor.

The Contractor shall not be entitled to additional costs unless he notifies the Engineer of his intention to make such claim, within twenty eight (28) days after receipt of the order to suspend progress or delivery or of the date of deemed suspension under Sub-Clause 23.1.

24.2 Payment in Event of Suspension

The Contractor shall be entitled to payment for Plant which has not been delivered to Site if the work on Plant or delivery of Plant has been suspended for more than twenty eight (28) days. After twenty eight (28) days of suspension, the Contractor shall be entitled to payment of the value of such Plant as at the date of suspension.

A certificate of payment shall be issued on condition that:

(a) the Contractor has marked the Plant as the Employer's property in accordance with the Engineer's instructions, and

(b) the suspension is not due to the Contractor's default.

24.3 Prolonged Suspension

If suspension under Sub-Clause 23.1. has continued for more than eighty four (84) days, and the suspension is not due to the Contractor's default, the Contractor may by notice to the Engineer require permission to proceed within twenty eight (28) days.

If permission is not granted within that time, the Contractor may treat the suspension as an omission under Clause 31 of the Section it affects, or if the suspension affects the whole of the Works, terminate the Contract and the provisions of Clause 46 shall apply.

24.4 Resumption of Work

If the Contractor chooses not to treat prolonged suspension as an omission or termination under Sub-Clause 24.3, the Employer shall upon the request of the Contractor, take over the responsibility for protection, storage, security and insurance of the suspended Works and the risk of loss or damage thereto shall thereupon pass to the Employer.

After receipt of permission or an order to proceed, the Contractor, shall after due notice to the Engineer, examine the Works and the Plant affected by the suspension. The Contractor shall make good any deterioration or defect in or loss of the Works or Plant that may have occurred during the suspension. Cost properly incurred by the Contractor which would not have been incurred but for the suspension shall be added to the Contract Price together with profit.

The Contractor shall not be entitled to payment for costs incurred in making good any deterioration, defect or loss caused by faulty workmanship or materials or by the Contractor's failure to take the measures specified in Sub-Clause 23.1.

If the Employer has taken over risk and responsibility for the suspended Works under this Sub-Clause, risk and responsibility shall revert to the Contractor fourteen (14) days

after receipt of the permission or order to proceed.

Completion

25.1 Time for Completion

The Works shall be completed and shall have passed the Tests on Completion within the Time for Completion

26.1 Extension of Time for Completion

The Contractor may claim an extension of the Time for Completion if he is or will be delayed in completing the Works by any of the following causes:

(a) extra or additional work ordered in writing under Clause 31,

(b) exceptional adverse weather conditions,

(c) physical obstructions or conditions which could not reasonably have been foreseen by the Contractor,

(d) Employer's or Engineer's instructions, otherwise than by reason of the Contractor's default,

(e) the failure of the Employer to fulfil any of his obligations under the Contract,

(f) delay by any other contractor engaged by the Employer,

(g) any suspension of the Works under Clause 23, except when due to the Contractor's default,

(h) any industrial dispute,

(i) the Employer's Risks, or

(j) Force Majeure.

The Contractor shall give to the Engineer notice of his intention to make a claim for an extension of time within fourteen (14) days of the circumstances for such a claim becoming known to the Contractor. The notice shall be followed as soon as possible by the claim with full supporting details.

The Engineer shall, after due consultation with the Employer and the Contractor, grant the Contractor from time to time, either prospectively or retrospectively, such extension of Time for Completions as may be justified. The Engineer shall notify the Employer and the Contractor accordingly.

The Contractor shall be entitled to such extension whether the delay occurs before or after the Time for Completion.

26.2 Delays by Subcontractors

The Contractor shall be entitled to claim an extension of time if delay on the part of a Subcontractor is due to a cause mentioned in Clause 26.1 and such delay prevents the Contractor from meeting the Time for Completion.

26.3 Earlier Completion

The Employer may require completion of the Works or part thereof earlier than the Time for Completion, on the following conditions:

(a) The Employer and the Contractor shall first agree the extra sum to be paid for each day by which the Contractor completes the Works or part thereof earlier than the Time for Completion.

(b) The Contractor shall not become liable under Sub-Clause 27.1 for any failure to complete the Works or the part thereof by the earlier time.

27.1 Delay in Completion

If the Contractor fails to complete the Works within the Time for Completion, the Employer shall be entitled to a reduction in the Contract Price unless it can be reasonably concluded from circumstance that the Employer will suffer no loss.

The Employer shall within a reasonable time give the Contractor notice of his intention to claim a reduction.

The reduction shall be the percentage per day stated in the Preamble of that part of the Contract Price which is attributable to such part of the Works as cannot in consequence of the failure be put to the intended use. The reduction shall be computed for each day between the Time for Completion and the actual date of completion.

The reduction shall in no case exceed the maximum percentage of the Contract Price of such part stated in the Preamble.

Except as provided in Sub-Clause 27.2, such reduction shall be to the exclusion of any other remedy of the Employer in respect of the Contractor's failure to complete within the Time for Completion.

27.2 Prolonged Delay

If the Employer has become entitled to the maximum reduction under Sub-Clause 27.1 for any part of the Works, he may by notice require the Contractor to complete. Such notice shall fix a final time for completion which shall be reasonable.

If the Contractor fails to complete within such time, and this is not due to a cause for which the Employer or some other contractor employed by him is responsible, the Employer may by further notice to the Contractor either:

(a) require the Contractor to complete, or

(b) may himself complete at the Contractor's cost provided that he does so in a reasonable manner, or

(c) terminate the Contract.

If the Employer terminates the Contract, he shall be entitled to recover from the Contractor any loss he has suffered up to the maximum amount stated in the Preamble. If no maximum amount is stated, the Employer shall not be entitled to recover more

than that part of the Contract Price which is attributable to that part of the Works which cannot by reason of the Contractor's failure be put to the intended use.

The Employer shall give credit for the value of any part of the Works which he retains.

Tests on Completion

28.1 Notice of Tests

The Employer shall give to the Engineer twenty one (21) day's notice of the date after which he will be ready to make the Tests on Completion (the Tests). Unless otherwise agreed, the Tests shall take place within fourteen (14) days after the said date on such day or days as the Engineer shall notify the Contractor.

28.2 Time for Tests

If the Engineer fails to appoint a time after having been asked to do so, or does not attend at the time and place appointed, the Contractor shall be entitled to proceed with the Test in his absence. The Tests shall then be deemed to have been made in the presence of the Engineer and the results of the Tests shall be accepted as accurate.

28.3 Delayed Tests

If the Tests are being unduly delayed by the Contractor the Engineer may by notice require the Contractor to make the Tests within twenty one (21) days after the receipt of such notice. The Contractor shall make the Tests on such days within that period as the Contractor may fix and of which he shall give notice to the Engineer.

If the Contractor fails to make the Tests within twenty one (21) days the Engineer may himself proceed with the Tests. All Tests so made by the Engineer shall be at the risk and cost of the Contractor and the cost thereof shall be deducted from the Contract Price. The tests shall then be deemed to have been made in the presence of the Contractor and the results of the Tests shall be accepted as accurate.

28.4 Facilities for Tests on Completion

Except where otherwise specified, the Employer shall provide free of charge such labour, materials, electricity, fuel, water, stores, apparatus and feedstock as may be reasonably required by the Contractor to carry out the Tests.

28.5 Retesting

If the Works or any Section fails to pass the Tests, the Engineer or the Contractor may require such Tests to be repeated on the same terms and conditions. All costs to which the Employer may be put by the repetition of the Tests under this Sub-Clause or under Sub-Clause 30.7 shall be deducted from the Contract Price.

28.6 Disagreement as to Result of Tests

If the Engineer and the Contractor disagree on the interpretation of the Test results, each shall give a statement of his views to the other within fourteen (14) days after such disagreement arises. The statement shall be accompanied by all relevant evidence.

28.7 Consequences of Failure to Pass Tests on Completion

If the Works or any Section fails to pass the Tests on the repetition thereof under Sub-Clause 28.5, the Engineer, after due consultation with the Employer and the Contractor, shall be entitled to:

(a) order one further repetition of the Tests under the conditions of Sub-Clause 28.5, or

(b) reject the Works or Section in which event the Employer shall have the same remedies against the Contractor as are provided under Sub-Clause 30.5 (c), or

(c) issue a Taking-Over Certificate, if the Employer so wishes, notwithstanding that the Works are not complete. The Contract Price shall then be reduced by such amount as may be agreed by the Employer and the Contractor or, failing agreement, as may be determined by arbitration.

28.8 Use by the Employer

In considering the results of Tests carried out under Sub-Clauses 29.3, 29.4 and 30.7, the Engineer shall make allowances for the effect of any use of the Works by the Employer on the Certificate to the performance or other characteristics of the Works.

28.9 Test Certificate

As soon as the Works or any Section thereof has passed the Tests, the Engineer shall issue a Certificate to the Contractor and the Employer to that effect.

Taking Over

29.1 Taking Over

The Works shall be taken over by the Employer when they have been completed in accordance with the Contract, except in minor respects that do not affect the use of the Works for their intended purpose, have passed the Tests on Completion and a Taking-Over Certificate has been issued or deemed to have been issued in accordance with Sub-Clause 29.2.

29.2 Taking-Over Certificate

The Contractor may apply by notice to the Engineer for a Taking-Over Certificate not earlier than fourteen (14) days before the Works will in the Contractor's opinion be complete and ready for taking over under Sub-Clause 29.1.

The Engineer shall within twenty eight (28) days after the receipt of the Contractor's application either:

(a) issue the Taking-Over Certificate to the Contractor with a copy to the Employer stating the date on which the Works were complete and ready for taking over, or

(b) reject the application giving his reasons and specifying the work required to be done by the Contractor to enable the Taking-Over Certificate to be issued.

If the Engineer fails either to issue the Taking-Over Certificate or to reject the Contractor's application within the period of twenty eight (28) days he shall be deemed

to have issued the Taking-Over Certificate on the last day of that period.

If the Works are divided by the Contract into Sections the Contractor shall be entitled to apply for separate Taking-Over Certificate for each such Section

29.3 Use before Taking Over

The Employer shall not use any part of the Works unless a Taking-Over Certificate has been issued in respect thereof.

If nevertheless the Employer uses any part of the Works, that part which is used shall be deemed to have been taken over at the date of such use. The Engineer shall on request of the Contractor issue a Taking-Over Certificate accordingly. If the Employer uses any part of the Works before taking over the Contractor shall be given the earliest opportunity of taking such steps as may be necessary to carry out the Tests on Completion.

The provisions of Sub-Clause 27.1 shall not apply to any part of the Works while being so used by the Employer. Clause 30 shall apply as if the part had been taken over on the date it was taken into use.

29.4 Interference with Tests on Completion

If the Contractor is prevented from carrying out the Tests on Completion by a cause for which the Employer or the Engineer or other contractors employed by the Employer are responsible, the Employer shall be deemed to have taken over the Works on the date when the Tests on Completion would have been completed but for such prevention. The Engineer shall issue a Taking-Over Certificate accordingly.

The Works shall not be deemed to have been taken over if they are not substantially in accordance with the Contract.

If the Works are taken over under this Clause the Contractor shall nevertheless carry out the Tests on Completion during the Defects Liability Period. The Engineer shall require the Tests on Completion to be carried out by fourteen (14) days notice and in accordance with the relevant provisions of Clause 28.

Any additional costs to which the Contractor may be put in making the Tests on Completion during the Defects Liability Period, shall be added to the Contract Price.

Defects after Taking Over

30.1 Defects Liability Period

Where any part of the Works is taken over separately from the Works the Defects Liability Period for that part shall commence on the date it was taken over.

30.2 Making Good Defects

The Contractor shall, subject to Sub-Clause 30.9, be responsible of making good any defect in or damage to any part of the Works which may appear or occur during the Defects Liability Period and which arises from, either:

(a) any defective materials, workmanship or design, or

(b) any act or omission of the Contractor during the Defects Liability Period.

The Contractor shall make good the Defects or damage as soon as practicable and at his

own cost.

30.3 Notice of Defects

If any such defect appears or damage occurs, the Employer or the Engineer shall forthwith notify the Contractor thereof.

30.4 Extension of Defects Liability Period

The provision of this Clause shall apply to all replacements or renewals carried out by the Contractor as if the replacements and renewals had been taken over on the date they were completed.

The Defects Liability Period for the Works shall be extended by a period equal to the period during which the Works cannot be used by reason of a defect or damage. If only part of the Works cannot be used by reason of a defect, the Defect Liability Period shall be extended only for that part.

In neither case shall the Defects Liability Period be extended by more than one year.

When erection or delivery of Plant has been suspended under Sub-Clause 23.1, the Contractor's obligations under this Clause shall not apply to any defects occurring more than three years after it would have been delivered but for the suspension or such period as may be stated in Part II.

30.5 Failure to Remedy Defects

If the Contractor fails to remedy a defect or damage within a reasonable time, the Employer may fix a final time for remedying the defect or damage.

If the Contractor fails to do so, the Employer may:

(a) carry out the work himself or by others at the Contractor's risk and cost, provided that he does so in a reasonable manner. The costs properly incurred by the Employer in remedying the defect or damage shall be deducted from the Contract Price, but the Contractor shall have no responsibility for such work, or

(b) require the Contractor to grant the Employer a reasonable reduction in the Contract Price to be agreed or fixed by arbitration under Clause 50, or

(c) if the defect or damage is such that the Employer has been deprived of substantially the whole of the benefit of the Works or a part thereof, he may terminate the Contract in respect of such parts of the Works as cannot be put to the intended use. The Employer shall to the exclusion of any remedy under Clause 45 be entitled to recover all sums paid in respect of such parts of the Works together with the cost of dismantling the same, clearing the Site and returning Plant to the Contractor or otherwise disposing of it in accordance with the Contractor's instructions.

30.6 Removal of Defective Work

If the defect of damage is such that repairs cannot be expeditiously carried out on the Site, the Contractor may with the consent of the Engineer or the Employer remove from

the Site for the purposes of repair any part of the Works which is defective or damaged.

30.7 Further Tests on Completion

If the replacements or renewals are such that they may affect the performance of the Works the Employer may request that Tests on Completion be repeated to the extent necessary. The request shall be made by notice within twenty eight (28) days after the replacement or renewal. The Tests shall be carried out in accordance with Clause 28.

30.8 Right of Access

Until the Final Certificate of Payment has been issued, the Contractor shall have the right of access to all parts of the Works and to records of the working and performance of the Works.

Such right of access shall be during the Employer's normal working hours at the Contractor's risk and cost. Access shall also be granted to any duly authorised representative of the Contractor whose name has been communicated in writing to the Engineer.

Subject to the Engineer's approval, the Contractor may also at his own risk and cost make any tests which he considers desirable.

30.9 Defects in Employer's and Engineer's Designs

The Contractor shall not be liable for any defects resulting from designs furnished or specified by the Employer or the Engineer.

30.10 Contractor to Search

The Contractor shall, if required by the Engineer in writing, search for the cause of any defect, under the direction of the Engineer. Unless the defect is one for which the Contractor is liable under this Clause, the cost of the work carried out by the Contractor in searching for the cause of the defect shall be added to the Contract Price.

30.11 Defects Liability Certificate

When the Defects Liability Period for the Works or any part thereof has expired and the Contractor has fulfilled all his obligations under the Contract for defects in the Works or that part, the Engineer shall issue within twenty eight (28) days to the Employer and the Contractor a Defects Liability Certificate to that effect.

30.12 Exclusive Remedies

Except in the case of Gross Misconduct, the Employer's remedies under this Clause shall be in place of and to the exclusion of any other remedy in relation to defects whatsoever.

Variations

31.1 Engineer's Right to Vary

The Engineer may by Variation Order to the Contractor at any time before the Works are taken over, instruct the Contractor to alter, amend, omit, add to or otherwise vary any part of the Works.

The Contractor shall not vary or alter any of the Works, except in accordance with a Variation Order from the Engineer. The Contractor may, however, at any time propose variations of the Works to the Engineer.

31.2 Variation Order Procedure

Prior to any Variation Order under Sub-Clause 31.1 the Engineer shall notify the Contractor of the nature and form of such variation.

As soon as possible after having received such notice, the Contractor shall submit to the Engineer:

(a) a description of work, if any, to be performed and a programme for its execution, and

(b) the Contractor's proposals for any necessary modifications to the Programme according to Sub-Clause 26.1 ro to any of the Contractor’s obligations under the Contract, and

(c) the Contractor's proposals for adjustment to the Contract Price.

Following the receipt of the Contractor's submission the Engineer shall, after due consultation with the Employer and the Contractor, decide as soon as possible whether or not the variation shall be carried out.

If the Engineer decides that the variation shall be carried out, he shall issue a Variation Order clearly identified as such in accordance with the Contractor's submission or as modified by agreement. If the Engineer and the Contractor are unable to agree the adjustment of the Contract Price, the provisions of Sub-Clause 31.3 shall apply.

31.3 Disagreement on Adjustment of the Contract Price

If the Contractor and the Engineer are unable to agree on the adjustment of the Contract Price, the adjustment shall be determined in accordance with the rates specified in the Schedule of Prices.

If the rates contained in the Schedule of Price are not directly applicable to the specific work in question, suitable rates shall be established by the Engineer reflecting the level of pricing in the Schedule of Prices.

Where rates are not contained in the said Schedule, the amount shall be such as is in all the circumstances reasonable. Due account shall be taken of any over-or under-recovery of overheads by the Contractor in consequence of the variation.

The Contractor shall also be entitled to be paid:

(a) the cost of any partial execution of the Works rendered useless by any such variation,

(b) the cost of making necessary alterations to Plant already manufactured or in the

course of manufacture or of any work done that has to be altered in consequence of such a variation,

(c) any additional costs incurred by the Contractor by the disruption of the progress of the Works as detailed in the Programme, and

(d) the net effect of the Contractor's finance costs, including interest, caused by the variation.

The Engineer shall on this basis determine the rates or prices to enable on-account payment to be included in certificates of payment.

31.4 Contractor to Proceed

On receipt of a Variation Order, the Contractor shall forthwith proceed to carry out the variation and be bound to these Conditions in so doing as if such variation was stated in the Contract.

The work shall not be delayed pending the granting of an extension of the Time for Completion or an adjustment to the Contract Price under Sub-Clause 31.3.

31.5 Records of Costs

In any case where the Contractor is instructed to proceed with variation prior to the determination of the adjustment to the Contract Price in respect thereof the Contractor shall keep records of the cost of undertaking the variation and of time expended thereon. Such records shall be open to inspection by the Engineer at all reasonable times.

Ownership of Plant

32.1 Ownership of Plant

Plant to be supplied pursuant to the Contract shall become the property of the Employer at whichever is the earlier of the following times:

(a) when Plant is delivered to Site, or

(b) when by virtue of Sub-Clause 24.2 the Contractor becomes entitled to payment of the value of the Plant.

Certificates and Payment

33.1 Terms of Payment

The terms of payment shall be as stated in the Preamble.

33.2 Method of Application

Unless otherwise specified in Part II applications by the Contractor for payment shall be made to the Engineer as follows:

(a) in respect of the progress of the Works accompanied by such evidence of the

value of the work done as the Engineer may require, and

(b) in respect of Plant shipped and en route to the Site identifying the Plant concerned and accompanied by such evidence of shipment and of payment of freight and insurance and by such other documents as the Engineer may require, and

(c) for additional payment in accordance with Clause 34.

Any other application for payment shall state the amounts claimed and the detailed particulars in respect of which the application is made.

33.3 Issue of Certificate of Payment

Within fourteen (14) days after receiving an application for payment which the Contractor was entitled to make the Engineer shall issue a Certificate of Payment to the Employer showing the amount due, with a copy to the Contractor.

A certificate of payment, other than the Final Certificate of Payment, shall not be withheld on account of:

(a) defects of a minor character which are not such as to affect the use of the Works, or

(b) any part of the payment applied for being disputed. In such case a certificate of payment for the undisputed amount shall be issued.

33.4 Corrections to Certificates of Payment

The Engineer may in any certificate of payment make any correction or modification that should properly be made in respect of any previous certificate.

33.5 Payment

Unless otherwise specified in Part II, the Employer shall pay the amount certified within twenty eight (28) days from the date of issue of each certificate of payment to the Contractor at his principal place of business.

33.6 Delayed Payment

If payment of any sum payable under Sub-Clause 33.5 is delayed, the Contractor shall be entitled to receive interest on the amount unpaid during the period of delay. Unless otherwise stated in Part II the interest shall be at the annual rate three percentage points above the discount rate of the central bank in the Contractor's country. The Contractor shall be entitled to such payment without formal notice and without prejudice to any other right or remedy.

33.7 Remedies on Failure to Certify or Make Payment

The Contractor shall be entitled to stop the Works by giving fourteen (14) days notice to the Engineer and the Employer, if either:

(a) the Engineer fails to issue a certificate of payment upon proper application by the Contractor, or

(b) the Employer fails to make any payment as provided in this Clause.

The cost to the Contractor together with profit occasioned by the stoppage and the subsequent resumption of work, shall be added to the Contract Price.

The Contractor shall also be entitled to terminate the Contract by giving twenty eight (28) days notice to the Engineer and the Employer in any case where the Engineer has failed to issue a certificate of payment upon proper application by the Contractor.

33.8 Payment by Measurement

For any part of the Works which is to be paid according to quantity supplied or work done, the provisions for measurement shall be stated in Part II.

33.9 Application for Final Certificate of Payment

The Contractor shall make application to the Engineer for the Final Certificate of Payment within twenty eight (28) days after the issue of the Defect Liability Certificate, or if more than one, the last Defect Liability Certificate.

The application for the Final Certificate of Payment shall be accompanied by a final account prepared by the Contractor. The final account shall give full details of the value of all Plant supplied and work done under the Contract together with:

(a) such additions to or deductions from the Contract Price as have been agreed, and

(b) all claims for additional payment to which the Contractor may consider himself entitled.

33.10 Issue of Final Certificate of Payment

The Engineer shall issue to the Employer with a copy to the Contractor, the Final Certificate of Payment within 28 days after receiving an application in accordance with Sub-Clause 33.9.

If the Contractor has not applied for a Final Certificate of Payment within the time specified in Sub-Clause 33.9 the Engineer shall request the Contractor to do so within a further period of 28 days. If the Contractor fails to make such an application, the Engineer shall issue the Final Certificate of Payment for such amount as he deems correct.

33.11 Final Certificate of Payment Conclusive

A Final Certificate of Payment shall be conclusive evidence of the value of the Works, that the Works are in accordance with the Contract and that the Contractor has performed all his obligations under the Contract.

Payment of the amount certified in the Final Certificate of Payment shall be conclusive evidence that the Employer has performed all his obligations under the Contract.

A Final Certificate of Payment or payment shall not be conclusive:

(a) to the extent that fraud or dishonesty relates to or affects any matter dealt with in the certificate, or

(b) if any arbitration or court proceedings under the Contract have been commenced by either party before the expiry of 84 days after the issue of the Final Certificate of Payment.

Claims

34.1 Procedure

In any case where under these Conditions there are circumstances which the Contractor considers entitle him to claim additional payment, the Contractor shall:

(a) if he intends to make any claim for additional payment give to the Engineer notice of his intention to make such claim within twenty eight (28) days after the said circumstances became known to the Contractor stating the reasons for his claim, and

(b) as soon as reasonably practical after the date of such notice submit to the Engineer full and detailed particulars of his claim but not later than one hundred and eighty two (182) days after such notice unless otherwise agreed by the Engineer. In any event such particulars shall be submitted no later than the application for the Final Certificate of Payment. The Contractor shall thereafter promptly submit such further particulars as the Engineer may reasonably require to assess the validity of the claim.

34.2 Assessment

When the Engineer has received full and detailed particulars of the Contractor's claim in accordance with Sub-Clause 34.1 and such further particulars as he may reasonably have required he shall after due consultation with the Employer and the Contractor determine whether the Contractor is entitled to additional payment and notify the parties accordingly.

The Engineer may reject any claim for additional payment which does not comply with the requirements of Sub-Clause 34.1.

Foreign Currency and Rates of Exchange

35.1 Payment in Foreign Currencies

Arrangements for payment in foreign currencies shall be as stated in the Preamble.

35.2 Currency Restrictions

The Employer shall reimburse the Contractor for any loss arising from:

(a) currency restrictions, and

(b) restrictions on the transfer of currency in which the Contractor is to be paid which are imposed by the government or authorized agency of the government of the country from which any payments under the Contract are to be made.

This Sub-Clause only applies to restrictions imposed after the date 28 days prior to the latest date for submission of tenders for the Works.

35.3 Rates of Exchange

Where the Contract provides for payment in Foreign Currency the rates of exchange between the currencies shall be fixed for the purpose of the Contract and shall be as stated in the Preamble.

If such rates of exchange are not stated in the Preamble the rates to be used shall be those quoted by the central bank of the country whose currency is to be sold 28 days or the nearest day thereto prior to the latest date for submission of tenders for the Works.

Provisional Sums

36.1 Use of Provisional Sums

A Provisional Sum shall only be used, in whole or in part in accordance with the Engineer's instructions.

The total sum paid to the Contractor shall include only such amounts in respect of work, supplies or services to which such Provisional Sums relate as the Engineer shall have instructed.

36.2 Ordering Work against Provisional Sums

In respect of every Provisional Sum the Engineer may after due consultation with the Employer and the Contractor order:

(a) work to be executed, including goods, materials or services to be supplied by the Contractor. The value of such work executed, determined in accordance with Clause 31, shall be paid to the Contractor in accordance with Clause 33, and

(b) goods and materials to be purchased by the Contractor, for which payment will be made in accordance with Sub-Clause 36.4.

36.3 Invoices and Receipts

The Contractor shall, when required by the Engineer, produce quotations, invoices, vouchers and accounts or receipts in connection with expenditure in respect of Provisional Sums.

36.4 Payment against Provisional Sums

For all work executed or goods, materials or services supplied or purchased by the Contractor under Sub-Clause 36.2(b), there shall be included in the sums paid to the Contractor:

(a) the actual price paid or due to be paid by the Contractor, and

(b) in respect of all other charges and profit, a percentage of the actual price paid or due to be paid. Such percentage shall be as stated in the Preamble.

Risk and Responsibility

37.1 Allocation of Risk and Responsibility

The Risks of loss of or damage to physical property and of death and personal injury which arise in consequence of the performance of the Contract shall be allocated between the Employer and the Contractor as follows:

(a) the Employer: the Employer's Risks as specified in Sub-Clause 37.2

(b) the Contractor: the Contractor's Risks as specified in Sub-Clause 37.3.

37.2 Employer's Risks

The Employer's Risks are:

(a) war and hostilities (whether war be declared or not), invasion, act of foreign enemies,

(b) rebellion, revolution, insurrection, military or usurped power or civil war insofar as it relates to the country in which the Works are located or countries through which plant must be transported,

(c) ionising radiation or contamination by radio-activity from any nuclear fuel, or from any nuclear waste from the combustion of nuclear fuel, radio-active toxic explosives or other hazardous properties of any explosive nuclear assembly or nuclear components thereof,

(d) pressure waves caused by aircraft travelling at sonic or supersonic speed,

(e) riot, commotion or disorder, unless solely restricted to the employees of the Contractor or of his Subcontractors,

(f) use or occupation of the Works or any part thereof by the Employer,

(g) fault, error, defect or omission in the design of any part of the Works by the Engineer, Employer or those for whom the Employer is responsible,

(h) the use or occupation of the Site by the Works or any part thereof, or for the purposes of the Contract; or interference, whether temporary or permanent with any right of way, light, air or water or with any easement, wayleaves or right of a similar nature which is the inevitable result of the construction of the Works in accordance with the Contract,

(i) the right of the Employer to construct the Works or any part thereof on, over, under, in or through any land,

(j) damage (other than that resulting from the Contractor's method of construction) which is the inevitable result of the construction of the Works in accordance with the Contract,

(k) the act, neglect or omission or breach of contract or of statutory duty of the Engineer, the Employer or other contractors engaged by the Employer or of their respective employees or agents,

and all risks which an experienced contractor could not have foreseen or, if foreseeable, against which measures to prevent loss, damage or injury from occurring could not reasonably have been taken by such contractor.

37.3 Contractor's Risks

The Contractor's Risks are all risks other than those identified as the Employer's Risks.

Care of the Works and Passing of Risk

38.1 Contractor's Responsibility for the Care of the Works

The Contractor shall be responsible for the care of the Works or any Section thereof from the Commencement until the Risk Transfer Date applicable thereto under Sub-Clause 38.2.

The Contractor shall also be responsible for the care of any part of the Works upon which any outstanding work is being performed by the Contractor during the Defects Liability Period until completion of such outstanding work.

38.2 Risk Transfer Date

The Risk Transfer Date in relation to the Works or a Section thereof is the earliest of either:

(a) the date of issue of the Taking-Over Certificate, or

(b) the date when the Engineer is deemed to have issued the Taking Certificate or the Works are deemed to have been taken over in accordance with Clause 29, or

(c) the date of expiry of the notice of termination when the Contract is terminated by the Employer or the Contractor in accordance with these Conditions.

39.1 Passing of Risk of Loss of or Damage to the Works

The risk of loss of or damage to the Works or any Section thereof shall pass from the Contractor to the Employer on the Risk Transfer Date applicable thereto.

39.2 Loss or Damage Before Risk Transfer Date

Loss of or damage to the Works or any Section thereof occurring before the Risk Transfer Date shall:

(a) to the extent caused by any of the Contractor's Risks, be made good forthwith by the Contractor at his own cost, and

(b) to the extent caused by any of the Employer's Risks, be made good by the Contractor at the Employer's expense if so required by the Engineer within twenty eight (28) days after the occurrence of the loss or damage. The price for making good such loss and damage shall be in all circumstances reasonable and shall be agreed by the Employer and the Contractor, or in the absence of agreement, shall be fixed by arbitration under Clause 50.

39.3 Loss or Damage After Risk Transfer Date

After the Risk Transfer Date, the Contractor's liability in respect of loss of or damage to any part of the Works shall, except in the case of Gross Misconduct, be limited:

(a) to the fulfillment of the Contractor's obligations under Clause 30 in respect of defects therein, and

(b) to making good forthwith loss or damage caused by the Contractor during the Defects Liability Period.

Damage to Property and Injury to Persons

40.1 Contractor's Liability

Except as provided under Sub-Clause 41.1, the Contractor shall be liable for and shall indemnify the Employer against all losses, expenses and claims in respect of any loss of or damage to physical property (other than the Works), death or personal injury occurring before the issue of the last Defects Liability Certificate to the extent caused by:

(a) defective design, material or workmanship of the Contractor, or

(b) negligence or breach of statutory duty of the Contractor, his Subcontractors or their respective employees and agents.

40.2 Employer's Liability

The Employer shall be liable for and shall indemnify the Contractor against all losses, expenses or claims in respect of loss of or damage to any physical property or of death or personal injury whenever occurring, to the extent caused by any of the Employer's Risks.

41.1 Accidents

The Contractor shall be liable for and shall indemnify the Employer against all losses, expenses or claims arising in connection with the death of or injury to any person employed by the Contractor or his Subcontractors for the purposes of the Works, unless caused by any acts or defaults of the Engineer, the Employer, or other contractors engaged by the Employer or by their respective employees or agents. In the latter cases the Employer shall be liable for and shall indemnify the Contractor against all losses, expenses and claims arising in connection therewith.

Limitations of Liability

42.1 Liability for Indirect or Consequential Damage

Neither party shall be liable to the other for any loss of profit, loss of use, loss of production, loss of contracts or for any other indirect or consequential damage that may be suffered by the other, except:

(a) as expressly provided in Clause 27, and
(b) those provisions of these Conditions whereby the Contractor is expressly entitled to receive profit.

42.2 Maximum Liability

The liability of the Contractor to the Employer under these Conditions shall in no case exceed the sum stated in the Preamble or, if no such sum is stated, the Contract Price.

42.3 Liability after Expiration of Defects Liability Period

The Contractor shall have no liability to the Employer for any loss of or damage to the Employer's physical property which occurs after the expiration of the Defects Liability Period unless caused by Gross Misconduct of the Contractor.

42.4 Exclusive Remedies

The Employer and the Contractor intend that their respective rights, obligations and liabilities as provided for in these Conditions shall alone govern their rights under the Contract and in relation to the Works.
Accordingly, the remedies provided under the contract in respect of or in consequence of:

(a) any breach of contract, or

(b) any negligent act or omission, or

(c) death or personal injury, or

(d) loss or damage to any property

are, save in the case of Gross Misconduct, to be to the exclusion of any other remedy that either may have against the other under the law governing the Contract or otherwise.

42.5 Mitigation of Loss of Damage

In all cases the party claiming a breach of Contract or a right to be indemnified in accordance with the Contract shall be obliged to take all reasonable measures to mitigate loss or damage which has occurred or may occur.

42.6 Foreseen Damage

Where either the Employer or the Contractor is liable in damages to the other these shall not exceed the damage which the party in default could reasonably have foreseen at the date of the Contract.

Insurance

43.1 The Works

The Contractor shall insure the Works in the joint names of the Contractor and the Employer to their full replacement value with deductible limits not exceeding those stated in the Preamble.

(a) from the Commencement Date until the Risk Transfer Date against any loss or damage caused by any of the Contractor's Risks and any other risks specified in the Preamble, and

(b) during the Defects Liability period against any loss or damage which is caused either:

(i) by the Contractor in completing any outstanding work or complying with his obligations under Clause 30, or

(ii) by any of the Contractor's Risks which occurred prior to the Risks Transfer Date.

43.2 Contractor's Equipment

The Contractor shall insure Contractor's Equipment for its full replacement value whilst in transit to the Site, from commencement of loading until completion of unloading at the Site and while on the Site against all loss or damage caused by any of the Contractor's Risks.

43.3 Third Party Liability

The Contractor shall insure against liability to third parties for any death or personal injury and loss of or damage to any physical property arising out of the performance of the Contract and occurring before the issue of the last Defects Liability Certificate.

Such insurance shall be effected before the Contractor begins any work on the Site. The insurance shall be for not less than the amount specified in the Preamble.

43.4 Employees

The Contractor shall insure and maintain insurance against his liability under Sub-Clause 41.1.

43.5 General Requirements of Insurance Policies

The Contractor shall:

(a) whenever required by the Employer produce the policies or certificates of any insurance which he is required to effect under the Contract together with receipts for the premiums,

(b) effect all insurances for which he is responsible with an insurer and in terms approved by the Employer,

(c) make no material alterations to the terms of any insurance without the Employer's approval. If an insurer makes any material alteration to the terms the Contractor shall forthwith notify the Employer, and

(d) in all respect comply with any conditions stipulated in the insurance policies which he is required to place under the Contract.

43.6 Permitted Exclusions from Insurance Policies

The insurance cover affected by the Contractor may exclude any of the following:

(a) the cost of making good any part of the Works which is defective or otherwise does not comply with the Contract provided that it does not exclude the cost of making good any loss or damage to any other part of the Works attributable to such defect or non-compliance,

(b) indirect or consequential loss of damage including any reductions in the Contract

Price for delay,

(c) wear and tear, shortages and theft, or

(d) risks relating to vehicles for which third party or other insurance is required by law.

43.7 Remedies on the Contractor's Failure to Insure

If the Contractor fails to produce evidence of insurance cover as stated in Sub-Clause 43.5 (a) then the Employer may effect and keep in force such insurance. Premiums paid by the Employer for this purpose shall be deducted from the Contract Price.

43.8 Amounts not Recovered

Any amounts not recovered from the insurers shall be borne by the Employer or Contractor in accordance with their responsibilities under Clause 37.

Force Majeure

44.1 Definition of Force Majeure

Force Majeure means any circumstances beyond the control of the parties, including but not limited to:

(a) war and other hostilities, (whether war be declared or not), invasion, act of foreign enemies, mobilization, requisition or embargo,

(b) ionizing radiation or contamination by radio-activity from any nuclear fuel or from any nuclear waste from the combustion of nuclear fuel, radio-active toxic explosives, or other hazardous properties of any explosive nuclear assembly or nuclear components thereof,

(c) rebellion, revolution, insurrection, military or usurped power and civil war,

(d) riot, commotion or disorder, except where solely restricted to employees of the Contractor.

44.2 Effect of Force Majeure

Neither party shall be considered to be in default or in breach of his obligations under the Contract to the extent that performance of such obligations is prevented by any circumstances of Force Majeure which arise after the date of the Letter of Acceptance or the date when the Contract becomes effective, whichever is the earlier.

44.3 Notice of Occurrence

If either party considers that any circumstances of Force Majeure have occurred which may affect performance of his obligations he shall promptly notify the other party and the Engineer thereof.

44.4 Performance to Continue

Upon the occurrence of any circumstances of Force Majeure the Contractor shall

endeavour to continue to perform his obligations under the Contract so far as reasonably practicable. The Contractor shall notify the Engineer of the steps he proposes to take including any reasonable alternative means for performance which is not prevented by Force Majeure. The Contractor shall not take any such steps unless directed so to do by the Engineer.

44.5 Additional Costs caused by Force Majeure

If the Contractor incurs additional costs in complying with the Engineer's directions under Sub-Clause 44.4, the amount thereof shall be certified by the Engineer and added to the Contract Price.

44.6 Damage Caused by Force Majeure

If in consequence of Force Majeure the Works shall suffer loss or damage the Contractor shall be entitled to have the value of the work done, without regard to the loss or damage that has occurred, included in a Certificate of Payment.

44.7 Termination in Consequence of Force Majeure

If circumstances of Force Majeure have occurred and shall continue for a period of one hundred and eighty two (182) days then, notwithstanding that the Contractor may by reason thereof have been granted an extension of Time for Completion of the Works, either party shall be entitled to serve upon the other twenty eight (28) days' notice to terminate the Contract. If at the expiry of the period of twenty eight (28) days Force Majeure shall still continue the Contract shall terminate.

44.8 Payment on Termination for Force Majeure

If the Contract is terminated under Sub-Clause 44.7 the Contractor shall be paid the value of the work done.

The contractor shall also be entitled to receive:

(a) the amounts payable in respect of any preliminary items so far as the work or service comprised therein has been carried out and a proper proportion of any such item in which the work or service comprised has only been partially carried out,
(b) the cost of materials or goods ordered for the Works or for use in connection with the Works which have been delivered to the Contractor or of which the Contractor is legally liable to accept delivery. Such materials or goods shall become the property of and be at the risk of the Employer when paid for by the Employer and the Contractor shall place the same at the Employer's disposal,
(c) the amount of any other expenditure which in the circumstances was reasonably incurred by the Contractor in the expectation of completing the whole of the Works,
(d) the reasonable cost of removal of Contractor's Equipment from the Site and the return thereof to the Contractor's works in his country or to any other destination at no greater cost, and
(e) the reasonable cost of repatriation of the Contractor's staff and workmen employed wholly in connection with the Works at the date of such termination.

44.9 Release from Performance

If circumstances of Force Majeure occur and in consequence thereof under the law governing the Contract the parties are released from further performance of the Contract, the sum payable by the Employer to the Contractor shall be the same as that which would have been payable under Sub-Clause 44.8 if the Contract had been terminated under Sub-Clause 44.7.

44.10 Force Majeure Affecting Engineer's Duties

The provisions of Clause 44 shall also apply in circumstances where the Engineer is prevented from performing any of his duties under the Contract by reason of Force Majeure.

Default

45.1 Notice of Default

If the Contractor is not executing the Works in accordance with the Contract or is neglecting to perform his obligations thereunder so as seriously to affect the carrying out of the Works, the Engineer may give notice to the Contractor requiring him to make good such failure or neglect.

45.2 Contractor's Default

If the Contractor:

(a) has failed to comply within a reasonable time with a notice under Sub-Clause 45.1, or

(b) assigns the Contract or subcontracts the whole of the Works without the Employer's written consent, or

(c) becomes bankrupt or insolvent, has a receiving order made against him or compounds with his creditors, or carries on business under a receiver, trustee or manager for the benefit of his creditors or goes into liquidation.

The Employer may, after having given seven (7) days notice to the Contractor, terminate the Contract and expel the Contractor from the Site.

Any such expulsion and termination shall be without prejudice to any other rights or powers of the Employer, the Engineer or the Contractor under the Contract.

The Employer may upon such termination complete the Works himself or by any other contractor.

45.3 Valuation at Date of Termination

The Engineer shall, as soon as possible after such termination, certify the value of the Works and all sums then due to the Contractor as at the date of termination in accordance with Clause 33.

45.4 Payment after Termination

The Employer shall not be liable to make any further payments to the Contractor until

the Works have been completed. When the Works are so complete, the Employers shall be entitled to recover from the Contractor the extra costs, if any, of completing the Works after allowing for any sum due to the Contractor under Sub-Clause 45.3. If there is no such extra cost the Employer shall pay any balance due to the Contractor.

45.5 Effect on Liability for Delay

The Contractor's liability under Clause 27 shall immediately cease when the Employer expels him from the Site without prejudice to any liability thereunder that may have already occurred.

46.1 Employer's Default

The Contractor may, by giving fourteen (14) days notice to the Employer and the Engineer, terminate the Contract if the Employer:

(a) fails to pay the Contractor the amount due under any certificate of the Engineer within twenty eight (28) days after the amount became payable, or

(b) interferes with or obstructs the issue of any certificate of the Engineer, or

(c) becomes bankrupt or insolvent, has a receiving order made against him, compounds with his creditors, or carries on business under a receiver, trustee or manager for the benefit of his creditors or goes into liquidation, or goes into liquidation, or

(d) consistently fails to meet his contractual obligations, or

(e) appoints, a person to act with or in replacement of the Engineer without the Contractor's consent.

Any such termination shall be without prejudice to any other rights of the Contractor under the Contract.

46.2 Removal of Contractor's Equipment

On such termination, the Contractor shall be entitled to remove immediately all Contractor's Equipment which is on the Site.

46.3 Payment on Termination for Employer's Default

In the event of such termination the Employer shall pay the Contractor an amount calculated in accordance with Sub-Clause 44.8.

The Employer shall pay in addition the amount of any loss or damage, including loss of profit which the Contractor may have suffered in consequence of termination. The additional amount shall, however, not exceed the limit specified in the Preamble.

Change in Cost and Legislation

47.1 Labour, Materials and Transport

Where the Contract Price is to be adjusted for changes in the cost of labour, materials,

transport or other costs of execution of the Works, the method for calculating such adjustment shall be specified in the Preamble.

When calculating the adjustment no account shall be taken of any increased cost which results from the Contractor's default or negligence.

47.2 Statutory and Other Regulations

The Contract Price shall be adjusted to take account of any increase or decrease in cost resulting from changes in legislation of the country where the Site is located or in its generally accepted interpretation.

Legislation means any law, order, regulation or bye-law having the force of law, which affects the Contractor in the performance of his obligations under the Contract, made after the date 28 days prior to the latest date for submission of tenders for the Works.

The Engineer shall certify the amount of the resulting increase or decrease in cost, which shall be added to or deducted from the Contract Price.

Customs

48.1 Customs and Import Duties

Unless otherwise stated in Part II the Employer shall pay all customs, import duties and taxes in consequence of the importation of Plant. If the Contractor is required to pay such customs, import duties and taxes, the Employer shall reimburse the amount thereof.

48.2 Clearance through Customs

The Employer shall assist the Contractor in obtaining clearance through the customs of all Plant and Contractor's Equipment and in procuring any necessary government consent to the re-export of Contractor's Equipment when it is removed from the Site.

Notices

49.1 Notices to Contractor

All certificates, notices or written orders to be given to the Contractor by the Employer or the Engineer under these Conditions shall be sent by airmail post, cable, telex or facsimile transmission to or left at the Contractor's principal place of business or such other address as the Contractor shall nominate for that purpose, or may be handed over to the Contractor's representative.

49.2 Notice to Employer and Engineer

Any notice to be given to the Employer or to the Engineer under these Conditions shall be sent by airmail post, cable, telex or facsimile transmission to or left at the respective addresses nominated for that purpose in the Preamble, or handed over to the Engineer's or the Employer's representative authorised to receive it.

49.3 Minutes of Meetings

Instructions or notices to the Contractor and notices from the Contractor to the Engineer

or the Employer recorded in a minute or protocol signed by the authorized representatives of the giver and recipient of such notice or instruction shall be valid notice or instruction for the purposes of the Contract.

Disputes and Arbitration

50.1 Disputes concerning Engineer's Decisions

If either party is dissatisfied with a decision or instruction of the Engineer as confirmed, reversed or varied in accordance with Clause 2 he may refer the matter to arbitration pursuant to Sub-Clause 50.2.

Unless the dissatisfied party has notified the other party and the Engineer within fifty six (56) days of such decision or instruction of his intention to refer the matter to arbitration, he shall be deemed to have accepted the decision as final.

Reference to arbitration shall not relieve the Contractor of his obligation to proceed with the Works in accordance with the Engineer's decision or instruction, nor relieve the Employer of any of his obligations under the Contract.

The Contractor shall in any such arbitration be at liberty to rely on reasons additional to the reasons stated in the notice given under Sub-Clause 2.7.

50.2 Arbitration

If at any time any question, dispute or difference shall arise between the Employer and the Contractor in connection with or arising out of the Contract or the carrying out of the Works either party shall be entitled to refer the matter to be finally settled by arbitration in accordance with the Rules of Conciliation and Arbitration of the International Chamber of Commerce by one or more arbitrators appointed in accordance with those Rules, or by arbitration in accordance with such other rules as are specified in Part II.

The Arbitrators(s) shall have full power to open up, review and revise:

(a) any decision or instruction of the Engineer referred to arbitration pursuant to Sub-Clause 50.1, and

(b) any certificate of the Engineer related to the dispute.

50.3 Works to Continue

Performance of the Contract shall continue during arbitration proceedings unless the Employer shall order suspension. If any such suspension is ordered the reasonable costs incurred by the Contractor and occasioned thereby shall be added to the Contract Price.

No payments due or payable by the Employer shall be withheld on account of pending reference to arbitration.

50.4 Time Limit for Arbitration

Formal notice of arbitration must be given to the other party, and where required to the

appropriate arbitration body, no later than eighty four (84) days after the issue of the Final Certificate of Payment

Law and Procedure

51.1 Applicable Law

The law which is to apply to the Contract and under which the Contract is to be construed is stated in the Preamble.

51.2 Procedural Law

The law governing the procedure and administration of any arbitration instituted pursuant to Clause 50 is stated in the Preamble.

51.3 Language

The language and place of the arbitration are stated in the Preamble.

Part-5

Particular Conditions of Contract

TABLE OF CONTENTS

PARTICULAR CONDITIONS OF CONTRACT 172
PART-II: PARTICULAR CONDITIONS OF CONTRACT 173
1.1 Definitions 173
Sub-Clause 1.1.3 173
Sub-Clause 1.1.5 173
Sub-Clause 1.1.11 173
Sub-Clause 1.1.15 173
Sub-Clause 1.1.16 174
Sub-Clause 1.1.23 174
Sub-Clause 1.1.41 174
Sub-Clause 1.1.42 175
Sub-Clause 1.1.43 175
Sub-Clause 1.1.44 175
Sub-Clause 1.1.45 175
Sub-Clause 1.1.46 175
Sub-Clause 1.1.47 175
Sub-Clause 1.1.48 175
Sub-Clause 1.1.49 175
Sub-Clause 1.1.50 176
Sub-Clause 1.6 Costs, Overhead Charges and Profit 176
Sub-Clause 2.1 Project Manager/ Engineer's Duties 176
Sub-Clause 2.6 Confirmation in Writing 176
Sub-Clause 2.8 Replacement of Project Manager/ Engineer 177
Sub-Clause 2.9 Project Manager/ Engineer Not Liable 177
Sub-Clause 4.2 No Contractual Relation between Subcontractor and the Employer 177
Sub-Clause 4.3 – Interface Management and Third Party Coordination 177
Sub-Clause 5.3 Priority of Contract Documents 178
Sub-Clause 5.4 Documents Mutually Explanatory 178
Sub-Clause 6.2 Consequences of Disapproval of Contractor's Drawings 178
Sub-Clause 6.6. Operation and Maintenance Manuals 178
Sub-Clause 6.9 Manufacturing Drawings 179
Sub-Clause 6.10 "As–Built" Drawings 179
Sub-Clause 6.11 Shop Drawings 180
Sub-Clause 6.12 Interface Drawings 180
Sub-Clause 7.2 Errors by Employer or Engineer 180
Sub-Clause 8.1 General Obligations 180
Sub-Clause 10.1 Performance Security 181
Sub-Clause 10.3 Claims under Performance Security 181
Sub-Clause 10.4 Performance Security Binding on Variations and Changes 181
Sub-Clause 11.1 Site Data 181
Sub-Clause 12.1 Programme to be Furnished 181
Sub-Clause 12.4 Monthly Progress Report 182
Sub-Clause 12.5 Daily Job Record 182
Sub-Clause 13.1 Contractor's Representative 183
Sub-Clause 13.3 Language Ability of Superintending Staff of Contractor 183
Sub-Clause 13.4 Employment of Local Personnel 183
Sub-Clause 14.1 Contractor's Equipment 183
Sub-Clause 14.2 Safety Precautions 183

Sub-Clause 14.3 Electricity, Water and Gas 183
Sub-Clause 14.4 Employer's Equipment 184
Sub-Clause 14.8 Information for Import Permits & Licenses 184
Sub-Clause 15.2 Compliance with Laws 184
Sub-Clause 16.4 Photographs of Works and Advertisement Prohibited 184
Sub-Clause 16.5 Training of Employer's/ Consultant's Staff 184
Sub-Clause 16.6 Protection of the Environment 184
Sub-Clause 17.4 Consents and Way Leaves 185
Sub-Clause 17.5 – Import Permits and Licences 185
Sub-Clause 18.1 – Engagement of Labour 185
Sub-Clause 18.5 Employment of Persons in the Service of Others 185
Sub-Clause 18.6 Alcoholic Liquor or Drugs 185
Sub-Clause 18.7 Arms and Ammunition 185
Sub-Clause 18.8 Festivals and Religious Customs 185
Sub-Clause 18.9 Disorderly Conduct 185
Sub-Clause 18.10 Records of Safety and Health 185
Sub-Clause 18.11 Reporting of Accidents 186
Sub-Clause 18.12 Compliance by Subcontractors 186
Sub-Clause 18.13 Housing for Labour 186
Sub-Clause 18.14 Epidemics 186
Sub-Clause 18.15 Supply of Water 186
Sub-Clause 18.16 Compliance by Subcontractors 186
Sub-Clause 19.1 Manner of Execution 186
Sub-Clause 19.3 Uncovering Work 186
Sub-Clause 19.4 Use of Pakistani Materials 187
Sub-Clause 20.6 Witnessing of Factory Acceptance Tests (as applicable): 187
Sub-Clause 24.1 Cost of Suspension 187
Sub-Clause 24.4 Resumption of Work 187
Sub-Clause 25.1 Time for Completion 187
Sub-Clause 26.1 Extension of Time for Completion 188
Sub-Clause 26.3 Earlier Completion 188
Sub-Clause 26.4 Rate of Progress 188
Sub-Clause 27.1 Delay in Completion 188
Sub-Clause 28.7 Consequences of Failure to Pass Tests on Completion 189
Sub-Clause 30.4 Extension of Defects Liability Period 189
Sub-Clause 30.5 Failure to Remedy Defects 189
Sub-Clause 30.13 Unfulfilled Obligations 190
Sub-Clause 31.1 Project Manager/ Engineer's Right to Vary 190
Sub-Clause 31.5 Records of Costs 190
Sub-Clause 31.6 Daywork under Variation Order 190
Sub-Clause 31.7 Value Engineering 190
Sub-Clause 33.1 Terms of Payment 190
Sub-Clause 33.1.1 Retention of Payment 193
Sub-Clause 33.1.2 Payment Where Taking-Over Certificate Issued for Section or Part of Works 193
Sub-Clause 33.1.3 Extra Payment 193
Sub-Clause 33.1.4 Breakdown of Lump Sum Items 193
Sub-Clause 33.1.5 Retention Money 193
Sub-Clause 33.2 Method of Application. 193
Sub-Clause 33.3 Issue of Certificate of Payment 194
Sub-Clause 33.5 Payment 194
Sub-Clause 33.6 Delayed Payment 194
Sub-Clause 33.8 Payment by Measurement 194

Sub-Clause 33.11 Issue of Final Certificate of Payment 194
Sub-Clause 33.12 Withholding of Payment 195
Sub-Clause 33.13 Payment Schedule 195
Sub-Clause 35.2 Currency Restrictions 195
Sub-Clause 35.3 Rates of Exchange 195
Sub-Clause 36.4 Payment against Provisional Sums 195
Sub-Clause 37.2 Employer's Risks 196
Sub-Clause 39.2 Loss or Damage before Risk Transfer Date 196
"Sub-Clause 39.4 Duty to Minimize Delay 196
Sub-Clause 40.2 Employer's Liability 197
Sub-Clause 42.6 Foreseen Damages 197
Sub-Clause 43.1(a) The Works (Insurance) 197
Sub-Clause 43.1.1 Marine Insurance for LOT-2 (Electrical & Mechanical Works) 197
Sub-Clause 43.1.2 Erection/ Construction All Risks Insurance 198
Sub-Clause 43.1.3 General 199
Sub-Clause 43.2 Contractor's Equipment 199
Sub-Clause 43.7 Remedies on the Contractor's Failure to Insure 199
Sub-Clause 43.9 Currency of Insurance 199
Sub-Clause 43.10 Contractor to Notify 199
Sub-Clause 43.11 Procurement of Insurance Policies 199
Sub-Clause 43.12 Insurance Company 199
Sub-Clause 44.6 Damage Caused by Force Majeure 199
Sub-Clause 44.8 Payment on Termination for Force Majeure 199
Sub-Clause 45.2 Contractor's Default 200
Sub-Clause 45.4 Payment after Termination 200
Sub-Clause 45.6 Integrity Pact 200
Sub-Clause 46.1 Employer's Default 200
Sub-Clause 46.3 Payment on Termination for Employer's Default 200
Sub-Clause 47.1 Labour, Materials and Transport 200
Sub-Clause 48.1 Local Taxation-Custom and Import Duties 201
Sub-Clause 48.3 Port Charges and Port Congestion 201
Sub-Clause 49.1 Notices to Contractor 201
Sub-Clause 50 Disputes & Arbitration 201
Additional Conditions 203
52. Liens 203
53.1 Payment of Income Tax, Etc. 203
53.2 Personnel, Taxes and Duties 203
53.3 Income Taxes Provisions in Subcontracts 203
54. Liability of the Contractor 203
55. Joint and Several Liability 203
56. Details to be Confidential 204

PARTICULAR CONDITIONS OF CONTRACT

PART-II: PARTICULAR CONDITIONS OF CONTRACT

These Conditions of Particular Application Part-II are additions, deletions and amendment to General Conditions of Contract Part-I. Clause Nos., if similar as of Part-I are amendments therein otherwise these are additional clauses or sub-clauses thereto.

This Contract is a single responsibility EPC Contract limited exclusively to Lot-2 Electrical & Mechanical Works as defined in the Employer's Requirements. Any mentions or descriptions and intents in this Contract Agreement which are contrary to the spirit of EPC Contract shall be ignored.

Any reference in the Contract Documents to "EPC", "Plant", "commissioning", "commercial operation", "overall performance", or similar expressions shall be interpreted and applied strictly to the extent applicable to Lot-2 Works only, and shall not create any obligation, liability, or performance responsibility for Works executed under Lot-1 (Civil, Ancillary Services and Hydraulic Steel Work), which shall be procured and executed under separate contract.

The Contractor's Lot-2 obligations include required interface provisions and coordination only, as expressly stated in this Contract.

1.1 Definitions

The text of Sub-Clause 1.1.1 is deleted and substituted by the following:

"Commencement Date" means the date specified in the Preamble to Conditions of Contract. The text of

Sub-Clause 1.1.2 is deleted and substituted by the following:

"Conditions" means the Preamble to Conditions of Contract, General Conditions of Contract (GCC) and Particular Conditions of Contract (PCC).

Sub-Clause 1.1.3

At the end of Sub-Clause, the following is added:

"Any subsequent document mutually agreed and signed by the Employer and the Contractor, shall be the part of the Contract."

Sub-Clause 1.1.5

The text of Sub-Clause 1.1.5 is deleted and substituted by the following:

"Contract Price" means the sum stated in the Letter of Acceptance as payable to the Contractor for the design, execution and completion of the Works subject to such additions thereto or deductions therefrom as may be made under the provisions hereinafter contained and remedying of any defects therein in accordance with the provisions of the Contract".

Sub-Clause 1.1.11

The Defects Liability Period is the period mentioned in the Preamble to Conditions of Contract.

Sub-Clause 1.1.15

The following is added at the beginning of this Sub-Clause:

"For the purpose of this EPC/Turnkey Contract (Lot-2), based on two party agreement, the term Engineer is construed as Project Manager/ Engineer. The Project Director is a Person appointed by the Employer to act on behalf of the Employer for the purpose of the Contract whereas the Engineer has the same meaning as defined in GCC Sub-Clause 1.1.15 hereof."

The following is added at the end of the Sub-Clause:
"or any other competent person appointed by the Employer as his replacement."

Sub-Clause 1.1.16

The term "Engineer's Representative" is replaced with the term "Project Manager/Engineer's Representative".

Sub-Clause 1.1.23

The following paragraph is added:

"For the purposes of Lot-2 only, "Goods/Plant" means Electrical & Mechanical equipment, embedded parts, operating mechanisms and associated materials supplied under Lot-2. It shall not include Hydraulic Steel Structures to be executed under Lot-1".

The text of **Sub-Clause 1.1.27** is deleted and substituted by the following:

"Schedule of Prices" means the completed and priced Schedule of Prices, or any part or individual schedule thereof, submitted by the Contractor with his Bid or revised and mutually agreed and forming a part of the Contract Documents.

Add the following at the end of Sub-Clause 1.1.33:

The word "Tender" is synonymous with the word "Bid" and the word 'Tender Documents' with "Bidding Documents" including technical bid is also part of it.

The following new Sub-Clauses 1.1.38 to 1.1.50 are added:

1.1.38 **"Month"** means calendar month according to Gregorian calendar.

1.1.39 **"Operation and Maintenance Manuals"** has the meaning described in Sub-Clause 6.6."

1.1.40 **"Warranty Certificate"** means the certificate against specified Plant/equipment, for the period mentioned in the Preamble to Conditions of Contract, to be issued by the Contractor that the Plant/equipment supplied under the Contract are new, unused and incorporate all recent improvements in design and materials unless provided otherwise in the Contract and that the Contractor will be responsible for making good or replacing any defective Plant/equipment during the Warranty Period specified in the Preamble to Conditions of Contract which should commence after expiry of Defect Liability Period.

Sub-Clause 1.1.41

The word 'Part II' wherever appearing in FIDIC Conditions of Contract is synonymous with the words "Particular Conditions of Contract".

Sub-Clause 1.1.42

The words 'Local Goods' is synonymous with the words "Indigenous Goods" and the word 'Installation' with "Erection".

Sub-Clause 1.1.43

"EPC/Turnkey Basis" means where the Contractor takes total responsibility for design and execution of the project. The Contractor carries out all the Engineering, Procurement and Construction (EPC) providing a fully equipped facility ready for operation.

Total responsibility of the Contractor include; but not limited to; design, supply, installation and commissioning of all E&M Works necessary for the completion and commercial operation of the Plant and shall include all such items of Plant and equipment or work, whether mentioned in the Specifications, Bid drawings, Schedule of Prices or not, which are required to make the Plant operationally complete in accordance with the guarantees prescribed under the Contract.

Sub-Clause 1.1.44

"Constructional Plant" means all appliances or things of whatsoever nature (other than Temporary Works) required for execution and completion of the Works and the remedying of any defects therein but does not include Plant, materials or other things intended to form or forming part of Permanent Works. The word 'Constructional Plant' is synonymous with "Contractor's Equipment".

Sub-Clause 1.1.45

"Contractor's Agent" means the person for the time being or from time to time appointed by the Contractor pursuant to the provisions of Clause 13. The word "Contractor's Agent" is synonymous with" Contractor's Representative".

Sub-Clause 1.1.46

"Performance Tests" means tests intended to demonstrate the attainment of guaranteed performance in the Contract to be conducted in accordance with the requirement of the Specifications.

Sub-Clause 1.1.47

"Reliability Test" means such test or tests as are provided for in the Contract, or as may be agreed upon, which shall be successfully completed as a pre-requisite to Taking Over.

Sub-Clause 1.1.48

"Temporary Works" means all temporary works of every kind (other than Contractor's Equipment) required in or about the execution and completion of the Works and the remedying of any defects therein.

Sub-Clause 1.1.49

"Permanent Works" means the permanent works to be executed (including Plant) in accordance with the Contract.

Sub-Clause 1.1.50

Wherever the terms "Plant", "commissioning", "performance", "operation" or similar expressions appear in the Contract Documents, they shall be construed strictly as applicable to Lot-2 Works only, unless the Contract expressly states otherwise.

Sub-Clause 1.6 Costs, Overhead Charges and Profit

The last sentence "Any profit entitlement shall be added to cost at the percentage stated in the Preamble" is deleted.

Sub-Clause 2.1 Project Manager/ Engineer's Duties

The text of Sub-Clause 2.1 is deleted and substituted by the following:

"The Project Manager/ Engineer shall carry out the duties specified in the Contract.

The Project Manager/ Engineer may exercise the authority attributable to the Project Manager/ Engineer as specified in or necessarily to be implied from the Contract. The Project Manager/ Engineer is required to obtain the specific approval of the Employer before carrying out his duties in accordance with the following Clauses of General Conditions of Contract (GCC):

(a) approval of Subcontractor under Sub-Clause 4.1,

(b) certifying additional sums under Sub-Clause 5.4,

(c) certifying additional costs under Sub-Clauses 11.3 & 12.3,

(d) certifying any cost under Sub-Clause 14.6,

(e) approval of extension of time under Clause 26,

(f) issuing a Taking–Over Certificate under Sub-Clause 29,

(g) issuing a Defects Liability Certificate under Sub-Clause 30.11,

(h) issuing a Variation Order under Clause 31,

(i) fixing rates or prices under Clauses 31 and 34,

(j) certifying additional costs under Sub-Clause 44.5 and

(k) certifying additional costs under Sub-Clause 47.2;

Except for such variations pursuant to Sub-Clause 31.1 of the GCC which may be necessary in an emergency affecting safety of life, the Works or of adjoining property.

Except as expressly stated in the Contract, the Project Manager/ Engineer shall have no authority to relieve the Contractor of any of his obligations under the Contract."

Sub-Clause 2.6 Confirmation in Writing

(i) In line 3 after the words "undue delay" the following is added:
"but not after the number of days mentioned in the Preamble to Conditions of Contract from the instruction or decision".

(ii) At the end of Sub-Clause 2.6, the following is added:

"The Project Manager/ Engineer shall confirm or otherwise within the period mentioned in the Preamble to Conditions of Contract from the receipt of requirement(s) from the Contractor".

Sub-Clause 2.8 Replacement of Project Manager/ Engineer

The text of Sub-Clause 2.8 is deleted in its entirety and substituted by the following:

"If the Employer intends to replace the Project Manager/ Engineer, the Employer shall, not less than fourteen (14) days before the intended date of replacement, give notice to the Contractor/Engineer, of the name, address and relevant experience of the intended replacement Project Manager/ Engineer. The Employer shall not replace the Project Manager/ Engineer with a person against whom the Contractor raises reasonable objection by notice to the Employer, with supporting particulars within 14 days of Employer's written notice."

The following new Sub-Clause 2.9 is added:

Sub-Clause 2.9 Project Manager/ Engineer Not Liable

Approval, reviews and inspection by the Project Manager/ Engineer of any part of the Works does not relieve the Contractor from his sole responsibility and liability for the supply of remaining materials and equipment for the Works and parts thereof and complete the remaining erection works and testing and commissioning in accordance with the Contract and neither the Project Manager/ Engineer's authority to act nor any decision made by him in good faith as provided for under this Contract whether to exercise or not to exercise such authority shall give rise to any duty or responsibility of the Project Manager/ Engineer to the Contractor, any Subcontractor, any of their representatives or employees or any other person performing any of the Works.

The following new Sub-Clause 4.2 & 4.3 are added:

Sub-Clause 4.2 No Contractual Relation between Subcontractor and the Employer

Nothing contained in the Contract Documents shall create any contractual relation between any Subcontractor and the Employer."

Sub-Clause 4.3 – Interface Management and Third Party Coordination

The Contractor acknowledges that the Project is executed under multiple contracts, including:

(a) Lot-1: Civil, Auxiliary Services and Hydraulic Steel Structures;

(a) Lot-2: Electrical & Mechanical Works (This Contract).

The Contractor shall coordinate its Works with all third parties, authorities, and other contractors whose works or facilities interface with the Works of other contractors to the extent necessary for proper interface, including provision of embedded parts, openings, reference points, tolerances, and access required for integration.

No act of coordination, cooperation, or interface assistance shall be construed as assumption of responsibility for the design, supply, installation, testing, commissioning, or performance of Works under other Lot.

The Contractor shall prepare and implement an Interface Management Plan within twenty-eight (28) days of the Commencement Date, detailing all interface points, responsibilities, coordination procedures, and communication protocols.

Failure to properly coordinate or protect third-party facilities shall be deemed a Contractor's Risk, and no Extension of Time or additional Cost shall be payable on this account.

Sub-Clause 5.3 Priority of Contract Documents

The text of Sub-Clause 5.3 is deleted and substituted by the following:

"Unless otherwise provided in the Contract, the priority of the Contract Documents shall be as follows:

1. The Form of Contract Agreement.
2. Minutes of Pre-Award Meeting.
3. The Letter of Acceptance
4. Performance Security / Undertaking by the Contractor
5. Completed Letters of Technical and Price Bids
6. Preamble to Conditions of Contract.
7. The Particular Conditions of Contract.
8. The General Conditions of Contract.
9. The Employer Requirements.
10. Specifications.
11. Drawings.
12. The corrected priced Schedule of Prices.
13. The completed Schedules to Bid (A to L)
14. Clarification replies during the Bidding Process.
15. Any other document forming part of the Contract.

In case of discrepancies between drawings, those of larger scale shall govern unless they are superseded by drawing(s) of a later date regardless of scale. All drawings and specifications shall be interpreted in conformity with the Contract Agreement and these conditions."

Sub-Clause 5.4 Documents Mutually Explanatory

The text appearing in the last line after the words "the Contract Price" is deleted and the following text is added:

"The Technical Specifications are taken to be correct, but complete accuracy is not guaranteed. Any error or ambiguity must be reported to the Employer and the Project Manager/ Engineer before starting the work affected. In the event of any dispute arising as to the true intended meaning of Technical Specification, the Project Manager/ Engineer shall interpret the same and his interpretation shall be accepted as final and binding upon all parties concerned, except to the extent provided for in the Arbitration provisions hereof."

Sub-Clause 6.2 Consequences of Disapproval of Contractor's Drawings

Full stop in the last line is deleted and the following words are added at the end of the Sub-Clause:

"for the approval of the Project Manager/ Engineer. However, the Contractor shall not be entitled for time extension on this account".

Sub-Clause 6.6. Operation and Maintenance Manuals

Paras 2 & 3 are deleted and the following text is added at the end of Para 1 of Sub-Clause:

"The Operation and Maintenance Manuals shall include full instructions for the operation, servicing and

maintenance of the Plant, not only during the period of the Contractor's liability but more particularly during its operating life.

The directions shall be set out simply, clearly and systematically. This may be divided into two volumes if desirable, one for operation and the second for servicing and maintenance (in sub– volumes for major items of Plant).

The operational data shall include a complete physical and functional description of the Plant (in sub–volumes for major items of Plant) and step–by–step procedures for inspection, checking and adjustments for proper operation of the Plant.

The maintenance data shall include complete instructions for routine checks, servicing, maintenance and repair of all parts and for dismantling, handling and re–assembly of all equipment, sub–assemblies and all separate components. The maintenance data shall also include where possible parts catalogues. The lists shall provide all necessary information for identifying the parts and for re–ordering the parts including name of part, part number and catalogue references where applicable, name of manufacturer, size, capacity and other characteristics .

General arrangements, single line diagrams and detailed drawings shall be provided for ready reference in the operation and maintenance instructions.

The manuals shall be printed on ISO paper size A4 (210 x 297 mm) with offset or equivalent printing strongly bound in a durable stiff cover bearing the title in approved legend. Drawings shall be folded or reduced to 297 mm height. All volumes shall bear on the spine an approved shortened version of the title.

The Contractor shall submit three (3) draft copies for approval of the Project Manager/ Engineer prior to producing finished volumes.

The Contractor shall provide seven (7) copies of the approved Operation and Maintenance Manuals prior to Taking Over by the Employer. Supplementary Operation and Maintenance Manual shall be provided by the Contractor, if required, to incorporate changes resulting from experience during the operation and maintenance period. The work shall not be considered to be completed for the purpose of taking over until such manual and drawings have been supplied to the Employer." All documents will be provided in hard copies and in editable/non editable versions of soft copies as required by the Engineer.

Sub-Clause 6.9 Manufacturing Drawings

The words "Unless otherwise specified in Part-II" are deleted and the following is added at the end of Sub-Clause:

"However, the Contractor is required to disclose to the Project Manager/ Engineer or the Employer any confidential information necessary to justify the reliability, the efficiency and the operation and maintenance of the Plant supplied by him."

The following new Sub-Clauses 6.10 and 6.11 & 6.12 are added:

Sub-Clause 6.10 "As–Built" Drawings

The Contractor shall furnish to the Project Manager/ Engineer O&M Manual and six (6) copies and one (1) reproducible of approved quality of all "As–Built" drawings within the period mentioned in the Preamble to Conditions of Contract. All drawings shall also be provided in an electronic form (CD/ DVD/ USB).

Sub-Clause 6.11 Shop Drawings

The Contractor shall submit to the Project Manager/ Engineer for review three (3) copies of all shop and site erection work drawings in 1:4 scale seeking approval of the Project Manager/ Engineer.

Review and approval by the Project Manager/ Engineer shall not be construed as a complete check but will indicate only that the general method of construction and detailing is satisfactory and that the Project Manager/ Engineer's review or approval shall not relieve the Contractor of any of his responsibilities under the Contract."

Sub-Clause 6.12 Interface Drawings

The Contractor shall prepare and submit interface drawings identifying dimensions, loads, tolerances, and embedded requirements after the necessary coordination with Lot-1 Works.

Approval of such drawings shall not transfer responsibility for the design or performance of Works under other Lots.

Sub-Clause 7.2 Errors by Employer or Engineer

The text of Sub-Clause 7.2 replaces and supersedes in its entirety with the following:

The Contractor shall be solely responsible for the design, accuracy, adequacy, stability, safety, and fitness for purpose of the Works under Lot-2, including all Electrical and Mechanical Works, whether such design is prepared by the Contractor or based on any drawings, data, concepts, or information provided by the Employer or the Project Manager/Engineer.

Any drawings, specifications, reports, surveys, investigations, data, or information provided by the Employer or the Project Manager/Engineer are provided for reference only and shall not relieve the Contractor of any design responsibility. The Contractor shall independently verify all such information and shall remain solely responsible for the design and execution of the Works.

No error, omission, ambiguity, or inadequacy in any information provided by the Employer or the Project Manager/Engineer shall entitle the Contractor to any Extension of Time, Cost, compensation, or other relief.

Sub-Clause 8.1 General Obligations

The text of Sub-Clause 8.1 is deleted and substituted by the following:
The Contractor's obligations under this Contract (Lot-2) are limited exclusively to Electrical & Mechanical Works as defined in the Employer's Requirements.

"(a) The Contractor shall commence the work on the date specified in the Preamble to Conditions of Contract and shall proceed with the same with due expedition and without delay.

(b) The Contractor shall, in accordance with the Contract, with due care and diligence, complete the Works and test and commission the Plant and carry out the Works within the Time for Completion. The Contractor shall also provide all necessary Contractor's Equipment, superintendence, labour and except as stated herein below, all necessary facilities therefor.

The Employer will permit use of the Erection and Testing Equipment and Maintenance Tools if given any in the Preamble to Conditions of Contract.

The above facilities shall be provided at no cost to the Contractor but he shall procure at his cost all required consumable materials and any other items necessary for the proper execution of the Works. These shall be properly used and maintained by the Contractor and returned to the Employer upon handing over of the Works in good condition, fair wear and tear excepted. In case of any damage, loss or theft, the items shall be replaced by the Contractor at his own cost."

Sub-Clause 10.1 Performance Security

The text of Sub-Clause 10.1 is deleted and substituted by the following:

"The Contractor shall provide a Performance Security in the prescribed Form annexed to these Documents. The said Security shall be furnished by the Contractor within twenty eight (28) days after the receipt of Letter of Acceptance. The Performance Security shall be of an amount equal to
10 percent of the Contract Price in the currency (ies) of the Contract in the form of Bank Guarantee from any Scheduled Bank of Pakistan or from a bank located outside Pakistan duly counter-guaranteed by a Scheduled Bank of Pakistan.

The performance security shall be valid for twenty eight (28) days beyond defect liability period.

The cost of complying with the requirements of this Sub-Clause shall be borne by the Contractor".

Sub-Clause 10.3 Claims under Performance Security

Sub-Clause 10.3 is deleted in its entirety. The following new Sub Clause 10.4 is added:

Sub-Clause 10.4 Performance Security Binding on Variations and Changes

"The Performance Security shall be binding irrespective of variations and changes in the quantities of the Works or extensions in completion time of the Works, which are granted or agreed upon under the provisions of the Contract."

Sub-Clause 11.1 Site Data

The following paragraphs are added at the end of Sub-Clause:

"The Contractor shall satisfy himself as to the nature of the ground, the hydrological and climatic conditions, the form and nature of the Site, the quantities and nature of the Work and materials necessary for the completion of the Works, and the means of access to the Site, the accommodation he may require and in general shall himself obtain all necessary information as to risks, contingencies, and other circumstances which may influence or affect his Bid.

The Employer does not guarantee the correctness of any data/information/drawings either verbal and/or written provided herein nor any interpretations, deductions or conclusions relative to conditions at Site. The Contractor must form his own opinion of the character of the work and of the materials to be excavated etc. He must make his own interpretations, and satisfy himself by his own investigations and research regarding all conditions affecting the work to be done. The Contractor must assume all responsibility for deductions and conclusions as to the nature or conditions of the materials to be excavated and of doing other work affected by the geology at the Site."

Sub-Clause 12.1 Programme to be Furnished

(1) The text of Sub-Clause 12.1(a) is deleted and substituted by the following:

"(a) the order in which the Contractor proposes to carry out the Works (including preliminaries, required material ordering, delivery to Site, construction, erection and rectifications work, testing, commissioning of the Plant including design and construction of associated works and taking–over by the Employer). The programme on critical activity based format and resource planning schedule shall be prepared. The programme shall also include the following:

(i) Employment of local and expatriate labour of various categories;

(ii) Local material procurement; and

(iii) Material imports, if any.

(iv) Details of the programme for the Works from the Start Date, including a complete resource allocation showing the number of units and allotted times for each unit of Constructional Plant, materials and labour allocated to each part of the Works;

(v) The programme shall be prepared using proprietary software using latest Primavera version. It shall identify key milestones including all milestones defined within the Contract. All activities shall be coded by a Work Breakdown Structure (WBS)."

(2) The text of Sub-Clause 12.1(c) is deleted and substituted by the following:

"(c) The time by which the Contractor requires the Employer:

(i) to furnish any Employer's approval of Contractor's Drawings;

(ii) to provide access to the Site by Employer; and

(iii) to have obtained consents, way leaves and approvals necessary for the purpose of the Works (if required under the Contract)."

(3) The second last sentence of Sub-Clause 12.1 is deleted and substituted by the following:

"The programme is to be furnished by the Contractor within forty two (42) days from the date of receipt of Letter of Acceptance. Rs. 100,000/- per day as delay damages shall be deducted for delay beyond this period. "The Project Manager/ Engineer" proposed changes/modifications shall be incorporated and revised program shall be submitted within fifteen (15) days."

The Programme shall include reasonable interface milestones with Lot-1 Contractor as notified by the Engineer.

However, delay, disruption, or non-performance by Contractor under Lot-1 shall not entitle the Contractor to Extension of Time or additional Cost unless such delay directly prevents execution of Lot-2 Works and notice requirements under Clause 26 are strictly complied with."

The following new Sub-Clauses 12.4 and 12.5 are added:

Sub-Clause 12.4 Monthly Progress Report

During the period of the Contract, the Contractor shall submit six (6) sets of monthly progress report to the Project Manager/Engineer not later than the 8th day of each month including:

(i) the progress achieved vs targeted progress as per approved programme during the preceding month;

(ii) Description of all work carried out since the last report;

(iii) Description of the work planned for the next forty-two (42) days sufficiently detailed to enable the Project Manager/ Engineer to determine his programme of inspection and testing;

(iv) Summary of daily job record for the preceding month;

(v) Colour digital photographs to illustrate progress.

(vi) Overall planed VS actual progress with S-Curves

Sub-Clause 12.5 Daily Job Record

"During the period of the Contract, the Contractor shall keep a daily record of the work progress, which shall be made available to the Project Manager/Engineer as and when requested.

The daily record shall include particulars of weather conditions, number of men working in different categories, deliveries of materials, quantity, location and assignment of equipment."

Sub-Clause 13.1 Contractor's Representative

At the end of the Sub-Clause, the following is added:

"The Contractor's Representative shall be a competent and skilled person approved by the Project Manager/Engineer (which approval may at any time be withdrawn). He shall be present on the Site during all working hours and shall not be transferred from the Site without the consent of the Project Manager/ Engineer. The Contractor's Representative shall be a registered professional engineer as defined in the Pakistan Engineering Council Act 1975 (V of 1976)."

The following new Sub-Clauses 13.3 and 13.4 are added:

Sub-Clause 13.3 Language Ability of Superintending Staff of Contractor

A reasonable proportion of the Contractor's superintending staff shall have a working knowledge of the English language.

Sub-Clause 13.4 Employment of Local Personnel

"The Contractor shall, to the extent practicable and reasonable, employ staff and labour from sources within Pakistan."

Sub-Clause 14.1 Contractor's Equipment

Replace the word "or" at the end of Sub-paragraph (a) by "and" and insert the following at the end of Sub-paragraph (b):

"Which shall not be unreasonably withheld."

Sub-Clause 14.2 Safety Precautions

At the end of the Sub-Clause, the following is added:

"In order to provide for the safety, health and welfare of persons, and for prevention of damage of any kind, all operations for the purposes of or in connection with the Contract shall be carried out in compliance with the safety requirements of the Government of Pakistan with such modifications thereto as the Project Manager/ Engineer may authorize or direct and the Contractor shall take or cause to be taken such further measures and comply with such further requirements as the Project Manager/ Engineer may determine to be reasonably necessary for such purpose.

The Contractor shall make, maintain, and submit reports to the Project Manager/ Engineer concerning safety, health and welfare of persons and damage to property as the Project Manager/ Engineer may from time to time prescribe.

Sub-Clause 14.3 Electricity, Water and Gas

The text of Sub-Clause 14.3 is deleted and substituted by the following:

"The Contractor shall be responsible for making his own arrangements for the adequate supply of electricity, water and gas required for the effective performance of his obligations under the Contract.

Subject to the aforesaid, the Contractor shall be entitled to use for the purposes of the Works such supplies and services as may be available on the Site. The Contractor shall, before the commencement of the work at Site, seek the approval of the Project Manager/Engineer as to his detailed requirements of electricity, water and gas for the entire Contract period. The Contractor shall pay the Employer at the rates/cost incurred by the Employer. The Contractor shall at his own cost provide any apparatus necessary for such use". The contractor will bear the cost of distribution network for electricity, potable water, telephone, gas and their consumption by his own personnel for the purpose of the work."

Sub-Clause 14.4 Employer's Equipment

The text of Sub-Clause 14.4 is deleted.

Sub-Clause 14.8 Information for Import Permits & Licenses

The text of Sub-Clause 14.8 is deleted and substituted by the following:

"The Contractor shall submit to the Employer in good time such details of all Plant and Contractor's Equipment to be imported into Pakistan and identify as to what assistance of the Employer is required for obtaining by the Contractor of all necessary import permits or licenses".

Sub-Clause 15.2 Compliance with Laws

The text of Sub-Clause 15.2 is deleted and substituted by the following:

"The Contractor shall comply with the Laws of country of manufacture and the Laws of Pakistan where the Plant is to be erected".

The following new Sub-Clauses 16.4, 16.5 and 16.6 are added:

Sub-Clause 16.4 Photographs of Works and Advertisement Prohibited

Except with the prior written authorization of the Employer the Contractor shall not exhibit or permit to be exhibited any photographs or advertisement on the Works. Any authorized exhibition shall be immediately removed if the Employer so requires.

Sub-Clause 16.5 Training of Employer's/ Consultant's Staff

The Contractor shall provide such facilities for the training of such numbers of Pakistani engineers, engineering students, apprentices and trade apprentices on such sections of the Works at the Site or on the Contractor's premises or Contractor selected plant manufacturer's premises and factories, or wherever else work is in hand, as specified or directed by the Project Manager/ Engineer. The Employer shall direct what sums by way of wages and allowances are to be paid by the Contractor to such persons and shall reimburse the Contractor for such sums as are so directed to be paid and are paid. The Contractor shall also provide medical expenses or medical insurance and travelling expenses for trainees if required by the Employer which shall be reimbursed by the Employer.

The language of training at the above stated premises shall be English and Urdu."

Sub-Clause 16.6 Protection of the Environment

The Contractor shall comply with all applicable national and local environmental regulations and guidelines as defined in Employer's Requirement.

Sub-Clause 17.4 Consents and Way Leaves

The text of Sub-Clause 17.4 is deleted and substituted by the following:

"The Employer shall issue permissions, letters, certificates and provide such other assistance to the Contractor for his obtaining permits-to-work, way leaves and approvals from any other department/ authority and right of way from private owners, if required. The Contractor will bear the cost of logistics, fees, etc. for such activities. The Employer, will reimburse the Contractor only the payments made by him in respect of any land compensation for obtaining such way leaves, required for the Works."

Sub-Clause 17.5 – Import Permits and Licences

The word "Employer" is deleted and substituted by the word "Contractor" and the following is added at the end of Sub-Clause 17.5:

"The Employer will provide assistance for this purpose."

Sub-Clause 18.1 – Engagement of Labour

At the end of the Clause the following is added:

"in accordance with the regulations, orders and requirements of the Government of Pakistan".

The following new Sub-Clauses 18.5 to 18.16 are added:

Sub-Clause 18.5 Employment of Persons in the Service of Others

The Contractor shall not recruit or attempt to recruit his staff and labour from amongst the persons in the service of the Employer or the Project Manager/ Engineer and vice–versa, unless mutually agreed between the Employer/ Project Manager/ Engineer and the Contractor.

Sub-Clause 18.6 Alcoholic Liquor or Drugs

The Contractor shall not, otherwise than in accordance with the statutes, Ordinances and Government Regulations or Orders for the time being in force, import, sell, give, barter or otherwise dispose of any alcoholic liquor or drugs, or permit or suffer any such importation, sale gift, barter or disposal by his Subcontractors, agents, employees or labour.

Sub-Clause 18.7 Arms and Ammunition

The Contractor shall not give, barter or otherwise dispose of to any person or persons, any arms or ammunition of any kind or permit or suffer the same as aforesaid.

Sub-Clause 18.8 Festivals and Religious Customs

The Contractor shall in all dealings with his staff and labour have due regard to all recognized festivals, days of rest and religious or other customs.

Sub-Clause 18.9 Disorderly Conduct

The Contractor shall at all times take all reasonable precautions to prevent any unlawful riotous or disorderly conduct by or amongst his staff and labour and for the preservation of peace and protection of persons and property in the neighborhood of the Works against the same.

Sub-Clause 18.10 Records of Safety and Health

The Contractor shall maintain such records and make such reports concerning safety, health and welfare of persons and damage to property as the Project Manager/Engineer may from time to time prescribe.

Sub-Clause 18.11 Reporting of Accidents

The Contractor shall report to the Project Manager/ Engineer details of any accident as soon as possible after its occurrence. In the case of any fatality or serious accident, the Contractor shall, in addition to appropriate action required under the law, notify the Project Manager/ Engineer immediately by the quickest available means.

Sub-Clause 18.12 Compliance by Subcontractors

The Contractor shall be responsible for compliance by his Subcontractors of the foregoing provisions.

The Contractor shall be responsible for compliance of Rates of Wages and Conditions of Labour as per international standard laws and labour laws of Employer's country.

Sub-Clause 18.13 Housing for Labour

Save insofar as the Contract otherwise provides, the Contractor shall provide and maintain such housing accommodation and amenities as he may consider necessary for all his supervisory staff and labour, employed for the purposes of or in connection with the Contract including all fencing, electricity supply, sanitation, cookhouses, fire prevention, water supply and other requirements in connection with such housing accommodation or amenities. On completion of the Contract, these facilities shall be handed over to the Employer or if the Employer so desires, the temporary camps or housing provided by the Contractor shall be removed and the Site reinstated to its original condition, all to the approval of the Project Manager/Engineer.

Sub-Clause 18.14 Epidemics

In the event of any outbreak of illness of an epidemic nature, the Contractor shall comply with and carry out such regulations, orders and requirements as may be made by the Government, or the local medical or sanitary authorities, for purpose of dealing with and overcoming the same.

Sub-Clause 18.15 Supply of Water

The Contractor shall, so far as is reasonably practicable, having regard to local conditions**,** provide on the Site, to the satisfaction of the Project Manager/ Engineer or his representative, adequate supply of drinking and other water for the use of his staff and labour including Engineer/Employer's site staff.

Sub-Clause 18.16 Compliance by Subcontractors

The Contractor shall be responsible for compliance by his Subcontractors of the foregoing provisions of Clause-18."

Sub-Clause 19.1 Manner of Execution

The following is added at the end of Sub-Clause:

"The Contractor shall submit for approval of the Project Manager/Engineer, his detailed method statement(s) for the execution of such items of work as may be desired by the Project Manager/ Engineer. Approval of such method statement(s) shall neither relieve the Contractor of his responsibilities under the Contract nor form any basis for claiming additional costs."

Sub-Clause 19.3 Uncovering Work

The following is added at the end of second paragraph of Sub-Clause 19.3:

"In any other case, all costs shall be borne by the Contractor."

The following new Sub-Clause 19.4 is added:

Sub-Clause 19.4 Use of Pakistani Materials

"The Contractor shall so far as may be consistent with the Contract make the maximum use of materials, supplies and equipment indigenous to or produced in Pakistan and services available in Pakistan or operated in Pakistan provided such materials, supplies, equipment and services shall be of required standard."

The following new Sub-Clause 20.6 is added:

Sub-Clause 20.6 Witnessing of Factory Acceptance Tests (as applicable):

Factory Acceptance tests shall be undertaken in the following manner:

(a) Factory acceptance tests shall be arranged by the contractor through a reputable third party agency having presence in the country of origin of the equipment approved by the Employer, witnessed by the personnel of the Employer and the Project Manager/Engineer. All costs in connection with witnessing of the factory acceptance tests by the Employer and the Project Manager/Engineer shall be borne by the Contractor. These shall include the costs of air travel (economy class) from Pakistan to place of inspection/ testing and back, hotel accommodation/boarding/ lodging (as per actual), inland transportation and daily allowance @ US Dollars 200 per day per person for inspection/testing to be conducted outside Pakistan and Rs. 15,000/- per day per person [besides other costs of traveling and lodging etc. (as above)] for inspection/testing to be conducted inside Pakistan for each visit of every person to witness these tests.

(b) Under the special circumstances, The Employer, if deems appropriate, may require, carrying out the inspection/testing of all works or part of the works through the approved 3rd Party agency. The cost thus incurred shall be responsibility of the Contractor.

Sub-Clause 24.1 Cost of Suspension

At the end of the second paragraph after the word "Contractor" the following is added:

"or for the proper execution or for the safety of the Works or Plant unless such necessity results from any act or default of the Project Manager/ Engineer or the Employer or in consequence of any of the Employer's Risks under Sub-Clause 37.2."

Sub-Clause 24.4 Resumption of Work

First paragraph of Sub-Clause 24.4 is deleted and substituted by the following:

"If the Contractor chooses not to treat prolonged suspension as an omission or termination under Sub-Clause 24.3, the Employer shall, upon the request of the Contractor, take over the responsibility for protection, storage, security and insurance of the suspended Works and of the Plant which has been delivered to the Site and which is affected by suspension and the risk of loss or damage thereto shall thereupon pass to the Employer".

Sub-Clause 25.1 Time for Completion

The text of Sub-Clause 25.1 is deleted and substituted by the following:

"The Works at the place of the project mentioned in the Preamble to Conditions of Contract shall be completed tested and commissioned within the period mentioned in the Preamble to Conditions of Contract."

Sub-Clause 26.1 Extension of Time for Completion

Sub-Clause 26.1 (c) & (h) is deleted.

Sub-Clause 26.3 Earlier Completion

(i) At the end of Sub-Clause 26.3(a) the following text is added and Clause is re- designated as 26.3.

"The extra sum to be paid to the Contractor for Completion of Works prior to the date of Completion established under Sub-Clause 25.1 shall be computed on the basis of the sums mentioned in the Preamble to Conditions of Contract."

(ii) Sub-Clause 26.3 (b) is deleted.

The following new Sub-Clause 26.4 is added:

Sub-Clause 26.4 Rate of Progress

"If for any reason, which does not entitle the Contractor to an extension of time, the rate of progress of the Works or any Section is at any time, in the opinion of the Project Manager/ Engineer, too slow to comply with the Time for Completion, the Project Manager/ Engineer shall so notify the Contractor who shall thereupon take such steps as are necessary, subject to the consent of the Project Manager/ Engineer, to expedite progress so as to comply with the Time for Completion. The Contractor shall not be entitled to any additional payment for taking such steps. If, as a result of any notice given by the Project Manager/ Engineer under this Clause, the Contractor considers that it is necessary to do any work at night or on locally recognized days of rest, he shall be entitled to seek the consent of the Project Manager/ Engineer so to do. Provided that if any steps, taken by the Contractor in meeting his obligations under this Sub-Clause, involve the Employer in additional supervision costs, such costs shall, after due consultation with the Employer and the Contractor, be determined by the Project Manager/ Engineer and shall be recoverable from the Contractor by the Employer, and may be deducted by the Employer from any moneys due or to become due to the Contractor and the Project Manager/ Engineer shall notify the Contractor accordingly, with a copy to the Employer."

Sub-Clause 27.1 Delay in Completion

The text of Sub-Clause 27.1 is deleted and substituted by the following:

"If the Contractor fails to deliver the Works, or any part thereof, within the time stated in Sub- Clause 25.1, or fails to complete the whole of the Work, or, if applicable, any Section within the relevant time prescribed by Sub-Clause 25.1, then the Contractor shall pay to the Employer the relevant sum stated herein below as liquidated damages for such default (which sum shall be the only moneys due from the Contractor for such default) for every day or part of a day which shall elapse between the relevant time for Delivery or Time for Completion and the actual date of delivery at site or the date stated in a Taking–Over Certificate of the whole of the Works or the relevant Section, as the case may be, subject to the applicable limit stated herein below.

The Employer may deduct the amount of such damages from any monies due or to become due to the Contractor. The payment or deduction of such damages shall not relieve the Contractor from his obligation to complete the Works, or from any other of his obligations and liabilities under the Contract.

The liquidated damages for each day of delay and the maximum amount of liquidated damages shall be the amounts mentioned in the Preamble to Conditions of Contract."

Sub-Clause 28.7 Consequences of Failure to Pass Tests on Completion

The words "by arbitration" appearing at the end of the Sub-Clause 28.7(c) are deleted and substituted by the words "by the Project Manager/ Engineer".

Add the following new Sub Clause 28.10
"The Employer/ Engineer shall verify the functional guarantees of the offered Facilities/ Plant. The Contractor guarantees are as follows:

1. Turbine & Generator Efficiencies
Turbine and generator efficiencies shall be subject to performance guarantees and shall be verified by site efficiency tests in accordance with the standards and procedures detailed in the Technical Specifications. The Weighted Average Efficiencies of the turbine and generator shall not be less than the values offered in Technical Bid.

2. Failure to Attain Functional Guarantees and Liquidated Damages
If the values attained in the corresponding guarantees tests are less than the guaranteed figures specified in the Technical Bid, and the Contractor elects to pay liquidated damages to the Employer in lieu of making changes, modifications and/or additions to the Facilities, then the Contractor shall pay liquidated damages due to the shortfalls, as ruled by accepted international standards, at the rate of;

- US$ 10,000 per each 0.01% of the Weighted Average Efficiency of Turbine below the guaranteed value.
- US$ 10,000 per each 0.01% of the Weighted Average Efficiency of Generator below the guaranteed value.

3. Minimum Levels
Notwithstanding the provisions of this paragraph, if as a result of the guarantee test(s), the following minimum levels of performance guarantees are not attained by the Contractor, the Contractor shall at its own cost make good any deficiencies until the Facilities reach any of such minimum performance levels;
(a) Turbine efficiency guarantee: If the weighted average efficiency of the turbine is 88% or less, then the Employer has the right to reject the turbine(s).
(b) Generator efficiency guarantee: If the weighted average efficiency of generator is 92% or less, then the Employer has the right to reject the generator(s).

4. Limitation of Liability
The Contractor's aggregate liability to pay liquidated damages for failure to attain the functional guarantees shall not exceed fifteen percent (15 %) of the Contract Value of Lot-2."

Sub-Clause 30.4 Extension of Defects Liability Period

At the end of 4th paragraph of Sub-Clause the following is added:

"or a mutually agreed period."

Sub-Clause 30.5 Failure to Remedy Defects

In first line after the words "reasonable time" the following is added:

"fixed by the Project Manager/ Engineer".

The following new Sub-Clause 30.13 is added:

Sub-Clause 30.13 Unfulfilled Obligations

"After the Defects Liability Certificate has been issued, the Contractor and the Employer shall remain liable for the fulfillment of any obligation which remains unperformed at that time. For the purposes of determining the nature and extent of any such obligation, the Contract shall be deemed to remain in force."

Sub-Clause 31.1 Project Manager/ Engineer's Right to Vary

The following is added at the end of second paragraph:

"No such variation shall in any way vitiate or invalidate the Contract, but the effect, if any, of all such variations shall be valued in accordance with Clause 31. Provided that whether the issue of an instruction to vary the Works is necessitated by some default of or breach of Contract by the Contractor or for which he is responsible, any additional cost attributable to such default shall be borne by the Contractor".

Sub-Clause 31.5 Records of Costs

The word "Engineer" in 4th line of Sub-Clause is deleted and substituted by "Project Manager/ Engineer".

The following new Sub-Clauses 31.6 is added:

Sub-Clause 31.6 Daywork under Variation Order

A Variation Order may provide that work done pursuant thereto shall be executed as Daywork, if applicable in the opinion of the Project Manager/Engineer. In such case the Contractor shall be paid for such work under the conditions and the rates and prices set out in the Day Work Schedule.

Sub-Clause 31.7 Value Engineering

The Contractor may, at any time, submit to the Project Manager/Engineer a written proposal which in the Contractor's opinion will reduce the cost of constructing, maintaining or operating the works, or improve the efficiency or value to the Employer of the completed Works or otherwise be of benefit to the Employer. Any such proposal shall be prepared at the cost of the Contractor. However Employer is not bound to accept such proposal."

Sub-Clause 33.1 Terms of Payment

The text of Sub-Clause 33.1 is deleted and substituted by the following: "The EPC/Turnkey Contract shall be payable for the following items:

A. Mobilization Advance

1. **Advance Payment**
   The Employer shall provide the Contractor with an advance payment equivalent to ten percent (10%) of the total Contract Price for mobilization purposes.

2. **Conditions for Release**
   The advance payment shall be released upon:
   a. Submission of a formal written request by the Contractor; and
   b. Provision of an irrevocable advance payment security (Bank Guarantee) of an equivalent amount, issued in favor of the Employer.

3. **Recovery of Advance**
   The advance payment shall be recovered at the rate of ten percent (10%) from each interim payment certificate/invoice submitted by the Contractor.

4. Reduction of Security

The advance payment security may be reduced proportionally in accordance with the value of work completed and certified.

B. Schedule No. 1 - Plant and Mandatory Spares Supplied from Abroad

In respect of Plant and Mandatory Spares supplied from abroad, payments shall be made in accordance with Sub Clause 33.5 as follows:

1. Seventy Percent (70%) of the total or pro rata CIP amount upon Incoterms "CIP" under the L/C, shall be paid upon delivery to the carrier.

2. Twenty Percent (20%) of the total or pro rata CIP amount upon delivery of the Goods at the project site, inspected, stacked and stored and adequately protected until commencement of installation activities.

3. Ten Percent (10%) of the total or pro rata CIP amount upon successful installation, testing & commissioning.

Note: All Costs, Charges, Commissions, Bank fees and expenses related to the opening of Letter of Credit shall be borne entirely by the contractor. Furthermore, any cost arising from the amendments, revisions or extensions of the Letter of Credit including but not limited to validity extensions required, shall also be born solely by the contractor.

C. Schedule No. 2 - Plant and Mandatory Spares Supplied from Pakistan

In respect of Plant and Mandatory Spares supplied from Pakistan, payments shall be made in accordance with Sub Clause 33.5 as follows:

1. Seventy Percent (70%) of the total or pro rata EXW amount shall be paid at the Ex-Factory stage.

2. Twenty Percent (20%) of the total or pro rata EXW amount upon delivery of the Goods at the project site, inspected, stacked and stored and adequately protected until commencement of installation activities.

3. Ten Percent (10%) of the total or pro rata EXW amount upon successful installation, testing & commissioning.

D. Schedule No. 3 Design Services

In respect of Design Services for both the foreign currency and the local currency portions, payments shall be made in accordance with Sub Clause 33.5 as follows:

1. Level-1 Design Payment

Fifteen percent (15%) of the total Design Services quoted amount shall be paid upon acceptance of the Level-1 Design by the Employer/Engineer.

2. Level-2 Design Payment

Twenty five percent (25%) of the total Design Services quoted amount shall be paid upon acceptance of the Level-2 Design by the Employer/Engineer.

3. **Construction/Erection Drawings Payment**
   Fifty percent (50%) of the total Design Services quoted amount shall be paid on a pro rata basis upon acceptance of the Construction/Erection Drawings by the Employer/Engineer.

4. **As-Built Drawings and O&M Manuals Payment**
   Five percent (5%) of the total Design Services quoted amount shall be paid upon acceptance of the As-Built Drawings and Operation & Maintenance Manuals by the Employer/Engineer.

5. **Completion Report Payment**
   Five percent (5%) of the total Design Services quoted amount shall be paid upon acceptance of the Completion Report by the Employer/Engineer.

E. Schedule No. 4 – General Items (Local Currency)

In respect of General Items payable in local currency, payments shall be made in accordance with Sub Clause 33.5 as follows:

1. **Transport Facility**
   The payments for the provision, operation and maintenance of transport facilities, as required by the Employer, shall be made on a monthly basis for the period during which the transport facilities actually provided and maintained to the satisfaction of the Employer.

2. **Training of Employer's O&M Staff**
   Payment for the training of the Employer's Operation and Maintenance (O&M) staff shall be made on a lump-sum, milestone basis, in accordance with the approved payment schedule.

3. **HSE and Environmental Compliance**
   a) Payment for compliance with Health, Safety, and Environmental (HSE) provisions shall be made on an actual cost basis.
   b) Such payment shall be subject to on site verifications and inspections, and submission of supporting documentation including payment vouchers, laboratory reports, purchase bills, and other relevant evidence.

4. **Progress Construction Movie and Pictures Facility**
   Payment for the provision of progress construction movie and photographic documentation facilities shall be made on a lump-sum, milestone basis, in accordance with the approved payment schedule.

F. Schedule No. 5 – Transportation from Karachi port/ EXW to project site including taxes, port charges, local taxes, insurance, etc. together with Erection, Testing and Commissioning

In respect of Schedule No. 5 for both foreign and local currency portions, payments shall be made in accordance with Sub Clause 33.5 as follows:

1. One Hundred Percent (100%) of the amount for Transportation to Site (including taxes, duties, port changes, local taxes, insurance, etc.) shall be paid upon delivery of equipment at site, subject to certification by Engineer's Representative.

2. Eighty Five Percent (85%) of the Erection, Installation, Testing & Commissioning amount or the pro rata amount, shall be paid upon completion of erection and installation works, subject to certification by the Engineer's Representative.

3. Fifteen Percent (15%) of the Erection, Installation, Testing & Commissioning amount or the pro rata amount, shall be paid upon successful completion of Testing & Commissioning, subject to certification by Engineer's Representative.

Advance Payment Security

The Contractor will submit advance payment security for all advance payments in the form of Bank Guarantee issued by a Scheduled Bank of Pakistan or from a bank located outside Pakistan duly counter-guaranteed by a Scheduled Bank in Pakistan in favor of the Employer valid for a period of twenty-eight (28) days beyond the issue of taking over the certificate.

The following new Sub-Clauses 33.1.1 to 33.1.5 are added:

Sub-Clause 33.1.1 Retention of Payment

"If at any time any payment would fall due for Works or part of Works and, if there shall be any defect in a part of such Works in respect of which such payment is proposed, the Employer may retain the whole or any part of such payment. Any sum retained by the Employer pursuant to the provisions of this Clause shall be paid to the Contractor after the said defect is removed /rectified."

Sub-Clause 33.1.2 Payment Where Taking-Over Certificate Issued for Section or Part of Works

"If any section or part of the Works shall be taken over separately under Clause 29 (Taking-Over) hereof, the payments herein provided for on or after Taking-Over shall be made in respect of the section or part taken over and reference to the price shall mean such part of the price as shall, in the absence of agreement, be apportioned thereto by the Project Manager/ Engineer"

Sub-Clause 33.1.3 Extra Payment

No extra payment in respect of overtime, additional materials, or special conditions or hardship shall be claimed by the Contractor unless otherwise provided in the Contract or such payments have been previously authorized in writing by the Project Manager/ Engineer or the Employer.

Sub-Clause 33.1.4 Breakdown of Lump Sum Items

For the purposes of statements to be submitted in accordance with Sub-Clause 33.1 hereof, the Contractor shall submit to the Project Manager/ Engineer, within twenty-eight (28) days after the receipt of the Letter of Acceptance, a breakdown for each of the lump sum items contained in the Bid. Such breakdowns shall be subject to the approval of the Project Manager/ Engineer."

Sub-Clause 33.1.5 Retention Money

Deduction of Ten (10%) percent shall be made from each payment (interim payment certificate) made to the Contractor except advance payment, which will be kept as retention money. The first half of this amount shall be paid to the Contractor after issuance of the Taking Over Certificate. The remaining half of this amount shall be paid to the Contractor after issuance of the Defect Liability Certificate in Final Certificate of Payment.

Sub-Clause 33.2 Method of Application.

The following paragraphs are added:

"The Contractor shall submit to the Employer/ Project Manager/ Engineer six (6) copies of the Application for Certificate of Payment (invoices) each signed by the Contractor and in such form as the Employer/ Project Manager/ Engineer may from time to time prescribe.

The Employer/Project Manager /Engineer shall examine such invoices within the times stated in Sub-Clauses 33.3 and 33.5. After such time each invoice will be deemed to have been accepted. If the invoice amount is not accepted by the Employer/ Project Manager/ Engineer, the disputed amount which is retained, shall be communicated, giving the reasons in writing, to the Contractor within the same time. If the objections of the Employer/Project Manager/ Engineer are not acceptable to the Contractor he will justify his claims with necessary documentation and include left over amounts / items in the next invoice. However, the portions of such invoices accepted by the Employer/Project Manager/ Engineer shall be paid as per Sub-Clause 33.5."

Sub-Clause 33.3 Issue of Certificate of Payment

The text 'Within fourteen (14) days' in the start of Sub-Clause 33.3 is substituted by the following:
"Within twenty eight (28) days".

Sub-Clause 33.5 Payment

The text of Sub-Clause 33.5 is deleted and substituted by the following:

"The amount due to the Contractor under any Interim Payment Certificate issued by the Project Manager/ Engineer pursuant to this Clause, or to any other term of the Contract, shall, subject to Clause 27, be paid by the Employer to the Contractor within Fifty six (56) after such Interim Payment Certificate has been issued by the Project Manager/ Engineer, or, in the case of the Final Certificate (referred to in Sub-Clause 33.10) within Ninety (90) days after such Final Payment Certificate has been issued by the Project Manager/ Engineer;

Deduction shall be made from the net amounts payable to the Contractor of any sum(s) in accordance with the prevalent Federal and/or Provincial laws, provided that no such deduction shall be made from those payments in respect of which the Contractor has obtained exemption under the Law."

Sub-Clause 33.6 Delayed Payment

The text of Sub-Clause 33.6 is deleted and substituted by the following:

"In the event of the failure of the Employer to make payment within the times stated in Sub-Clause 33.5, the Employer shall pay to the Contractor compensation at the rate of KIBOR + 1 percent for local currency (Schedule 4 & 5 only) per annum upon all local currency sums unpaid from the date by which the same should have been paid. The provisions of this Sub-Clause are without prejudice to Contractor's entitlement under Sub-Clause 46.1."

Sub-Clause 33.8 Payment by Measurement

The work shall be measured for the units mentioned in the Schedule of Prices according to the Contract as determined by the Project Manager/ Engineer from approved drawings, Specifications and Contract Documents.

Sub-Clause 33.11 Issue of Final Certificate of Payment

The following paragraph is added at the end:

"The final certificate of payment is also subject to the production of "As-Built Drawings, O&M Manual and Completion Report" by the Contractor as per Sub-Clause 6.10 of particular Conditions of Contract.

The following Sub-Clauses 33.12, 33.13 & 33.14 are added:

Sub-Clause 33.12 Withholding of Payment

If the Works or any parts thereof are not being carried out to the Project Manager/ Engineer's satisfaction and in order to protect the Employer from loss on account of:

(a) Defective work not rectified
(b) Guarantees not met
(c) Claims filed against the Contractor
(d) Failure of the Contractor to make payments due for Plant procured or labour employed by him
(e) Damage to any other contractor employed by the Employer
(f) Contractor's non–compliance with the Contract
(g) Any Government dues recoverable from the Contractor if notified by the Government

The Project Manager/ Engineer may notify withholding of such payments or part thereof as may, in his opinion, be related to the aforesaid reasons/ grounds. When the reasons/grounds for withholding the payment are removed by the Contractor, the Project Manager/ Engineer shall upon being satisfied to that effect issue Certificate of Payment in respect of withheld amounts.

Sub-Clause 33.13 Payment Schedule

Within thirty (30) days after receipt of the Letter of Acceptance, the Contractor shall submit a proposed payment schedule indicating the estimated payment throughout the currency of the Contract. This schedule shall be in a format satisfactory to the Employer and the Project Manager /Engineer, shall be consistent with the Program of Works, the advance, progress and final payment provisions included herein, and shall be in sufficient detail to permit preparation of cash flow projections for use by the Employer."

Sub-Clause 35.2 Currency Restrictions

The text of Sub-Clause 35.2 is deleted and substituted by the following:

"Any required foreign currency transactions shall be met by the Contractor at his cost from his own resources."

Sub-Clause 35.3 Rates of Exchange

The text of Sub-Clause 35.3 is deleted and substituted by the following:

Payment of foreign currency will be made at the Ready exchange rate for Mark to Market published/authorized by the State Bank of Pakistan, for actual Work-done or as per approved schedule under Clause PCC 12.1, whichever is lower, if the Works are delayed by the Contractor.

Sub-Clause 36.4 Payment against Provisional Sums

The text of Sub-Clause 36.4 is deleted and substituted by the following:

"Provisional Sum if specified in the price schedules will be expended wholly, partially or not at all for the actual expenditure on the direction of the Project Manager/ Engineer which would be valued in accordance with the provisions of Clause 31 Conditions of Contract while payment for Item for Price Adjustment will be expended in accordance with provisions of Clause 47."

Sub-Clause 37.2 Employer's Risks

The text of Sub-Clause 37.2 is deleted and substituted by the following: "The Employer's Risks are:

(a) (Insofar as they relate to Pakistan) war and hostilities (whether war be declared or not), invasion, act of foreign enemies;

(b) (Insofar as they relate to Pakistan) rebellion, revolution, insurrection, military or usurped power or civil war;

(c) ionizing radiation or contamination by radioactivity from any nuclear fuel, radio-active toxic explosives or other hazardous properties of any explosive nuclear assembly or nuclear components thereof;

(d) pressure waves caused by aircraft travelling at sonic or supersonic speed;

(e) (Insofar as they relate to Pakistan) riot, commotion or disorder, unless solely restricted to the employees of the Contractor or of his Subcontractors.

(f) use or occupation of the Work or any part thereof by the Employer;

(g) fault, error, defect or omission in the design of any part of the Works by the Project Manager/ Engineer, Employer or those for whom the Employer is responsible for which the Contractor has disclaimed responsibility in writing within a reasonable time after the receipt of such design;

(h) the use or occupation of the Site by the Works or any part thereof, or for the purposes of the Contract: or interference, whether temporary or permanent with any right of way, light, air or water or with any easement, wayleaves or right of a similar nature which is the inevitable result of the construction of the Works in accordance with the Contract;

(i) the right of the Employer to construct the Works or any part thereof on, over, under, in or through any land;

(j) damage (other than that resulting from the Contractor's method of construction) which is the inevitable result of the construction of the Works in accordance with the Contract; and

(k) the act, neglect or omission or breach of contract or of statutory duty of the Project Manager/ Engineer, the Employer or other contractors engaged by the Employer or of their respective employees or agents."

Sub-Clause 39.2 Loss or Damage before Risk Transfer Date

The words "by arbitration under Clause 50" are deleted and substituted "by the Project Manager/ Engineer".

The following new Sub-Clause 39.4 is added:

"Sub-Clause 39.4 Duty to Minimize Delay

Each Party shall at all times use all reasonable endeavors to minimize any delay in the Performance of the Contract as a result of Risks.

The Contractor shall give notice to the Employer and vice versa the Employer shall give notice to the Contractor in case of foreseeable delay by the Risks."

Sub-Clause 40.2 Employer's Liability

The text of Sub-Clause 40.2 from the words "death or personal injury" to the end of the Sub- Clause, is deleted and substituted by the following:

"(other than the Works) or of death or personal injury to the extent caused by those of the Employer's Risks listed in paragraphs (f), (g), (h), (i), (j), and (k) of Sub-Clause 37.2 but not otherwise."

Sub-Clause 42.2 Maximum Liability

The words "the sum stated in the Preamble to Conditions of Contract or if no such sum is stated" appearing in 2nd line of Sub-Clause are deleted.

Sub-Clause 42.6 Foreseen Damages

Sub-Clause 42.6 is deleted in its entirety.

Sub-Clause 43.1(a) The Works (Insurance)

The other risks to be insured are:

(i) Fire, smokes, explosion, falling objects, earthquake, perils of the sea, tempest, impact by aircraft or land vehicle, aircraft and other aerial devices or articles dropped therefrom, lightning, strike, riot, civil commotion, escape of water, inundation, rain, snow, land slides, flood, act of God, vandalism or malicious damage, windstorm or hail storm.

(ii) Collision, upset, overturn, derailment, stranding or sinking of an automobile or any conveyance of a common carrier by land, water or air in which the Plant or any part thereof is being carried including overland transportation in Pakistan from port of entry to the Site.

(iii) Theft, burglary or attempted theft or burglary.

(iv) Any loss or damage during pre-erection storage.

(v) Faults in construction and erection, lack of skill, lack of experience, negligence, malicious act.

(vi) any other sudden and unforeseen event such as loss or damage due to collapse etc. on site, transport of items to be erected.

(vii) Actions of the Employer in the operation of plant or part thereof on behalf of the Contractor.

The following further Sub-Clauses are 43.1.1, 43.1.2 and 43.1.3 are added:

Sub-Clause 43.1.1 Marine Insurance for LOT-2 (Electrical & Mechanical Works)

(1) The Contractor shall in the joint names of the Contractor and the Employer, obtain Marine Cargo All Risks Insurance to cover loss or damage to the Plant or part thereof during transport.

(2) The insurance for each consignment of Plant or part thereof shall attach from the time the Plant or part thereof leave the warehouse or place of storage and terminate after ninety (90) days on its completion of unloading at the Site or until insurance survey whichever occurs first. Upon arrival of each consignment at the Site, the Contractor shall, immediately arrange insurance survey by the insurance company.

(3) The sum insured for imported Plant or part thereof shall be for its full replacement value at the Site i.e. 100 % CIF value at the Site for each consignment of the Plant or part thereof plus not less than 30 % of CIF value at the Site to cover any additional costs resulting from loss or damage thereof.

(4) The Insurance Policy for imported Plant etc. shall be on "All Risks" basis and shall not be limited to the attachment/endorsement of following clauses:

(a) Institute Cargo Clauses (A)

(b) Institute War Clauses (Cargo)

(c) Institute Strikes Clauses (Cargo)

(d) Institute Cargo Clauses (Air) excluding sending by Post

(e) Institute War Clauses (Air Cargo) excluding sending by Post.

(f) Special Replacement Clauses (Air)

(g) Institute Theft, Pilferage and Non-delivery Clauses

Sub-Clause 43.1.2 Erection/ Construction All Risks Insurance

(1) The Contractor shall insure the Works or part thereof in the joint names of the Contractor and the Employer.

(a) from the date following the completion of the first unloading at the Site of the Plant or part thereof and other materials (to be used for construction or erection) and from commencement of Works at Site until the Risk Transfer Date against any loss or damage caused by any of the Contractor's risks and any other risks specified in Sub-Clause 43.1.(a) above and

(b) during the Defects Liability Period against any loss or damage which is caused either:

(i) by the Contractor in completing any outstanding work or complying with his obligations under Clause 30, or

(ii) by any of the Contractor's risks and any other risks specified in Sub- Clause 43.1(a) above, which occurred prior to the Risk Transfer Date.

(2) The sum insured shall be the full replacement value at the Site, which includes:

(a) (i) FOB value of imported Plant to be erected

(ii) Ex-factory value of Indigenous Plant to be erected, if any

(b) freight and insurance including local transport

(c) customs duties and taxes etc.

(d) cost of erection

Plus 30% to cover any additional costs resulting from loss or damage thereof.

Sub-Clause 43.1.3 General

Should a loss be sustained, the Contractor shall replace or repair any loss or damage at his own cost and complete the Works in accordance with the Contract as soon as possible after occurrence of such loss or damages, without waiting for the settlement of the insurance claim."

Sub-Clause 43.2 Contractor's Equipment

The text of Sub-Clause 43.2 is deleted and substituted by the following:

"The Contractor shall insure the Contractor's Equipment for its full replacement value while on the Site against all loss or damage caused by any of the Contractor's Risks."

Sub-Clause 43.7 Remedies on the Contractor's Failure to Insure

In 3rd line after the word, "purpose", the expression "and reasonable costs including the man- hours costs of Employer's Personnel" is added.

The following new Sub-Clauses 43.9 to 43.12 are added:

Sub-Clause 43.9 Currency of Insurance

All policies of Insurance of the Plant shall provide for payment of indemnity to be made in such amounts as will allow making good of loss of or damage to the whole or any part of the Works.

Sub-Clause 43.10 Contractor to Notify

It shall be the responsibility of the Contractor to notify the insurance company of any changes in nature and extent of the Works and to ensure the adequacy of the insurance coverage at all times in accordance with the provisions of the Contract.

Sub-Clause 43.11 Procurement of Insurance Policies

The Contractor shall procure and submit the insurance cover under this Clause within a period of twenty-eight (28) days from the date of receipt of Letter of Acceptance from the Employer.

Sub-Clause 43.12 Insurance Company

The policies of marine insurance and all other insurances with respect to Contractor's operations in Pakistan shall be effected with any of the insurance company acceptable to the Employer operating in Pakistan with financial strength rating of AA approved by Pakistan Credit Rating Agency (PACRA) or JCR including National Insurance Corporation (NIC) of Pakistan."

Sub-Clause 44.6 Damage Caused by Force Majeure

At the end of the Sub-Clause 44.6 the following is added:

"However the Contractor shall put up his claim to the Employer / Project Manager/Engineer with full details and justification with a copy to the Employer."

Sub-Clause 44.8 Payment on Termination for Force Majeure

Text in sub-Para (c) is deleted and Paras (d) and (e) are re-numbered as (c) and (d).

Sub-Clause 44.10 Force Majeure Affecting Project Manager/Engineer's Duties

Sub-Clause 44.10 is deleted in its entirety.

Sub-Clause 45.2 Contractor's Default

The following paragraph is added at the end of Sub-Clause 45.2.

"The Employer or such other contractor may use for such completion any Contractor's Equipment which is upon the Site as he or they may think proper, and the Employer shall pay the Contractor a reasonable compensation for such use".

Sub-Clause 45.4 Payment after Termination

The text of Sub-Clause 45.4 is deleted and substituted by the following:

"The Employer shall not be liable to make any further payments to the Contractor until the Works have been completed. When the Works are so complete, the Project Manager/Engineer shall certify the total cost of such completion of Works.

The Employer may recover the extra cost of such completion, as certified by the Project Manager/Engineer, from any sums otherwise due and payable to the Contractor and/or by disposing of the Contractor's Equipment and stores taken over by the Employer under this Clause or as otherwise provided by law. If there is no such extra cost the Employer shall pay any balance due to the Contractor."

The following new Sub-Clause 45.6 is added:

Sub-Clause 45.6 Integrity Pact

If the Contractor, or any of his Subcontractors, agents or servants is found to have violated or involved in violation of the Integrity Pact signed by the Contractor as Schedule-J to his Bid, then the Employer shall be entitled to:

(a) recover from the Contractor an amount equivalent to ten times the sum of any commission, gratification, bribe, finder's fee or kickback given by the Contractor or any of his Subcontractors, agents or servants;
(b) terminate the Contract; and
(c) recover from the Contractor any loss or damage to the Employer as a result of such termination or of any other corrupt business practices of the Contractor or any of his Subcontractors, agents or servants.

The termination under Sub-Para (b) of this Sub-Clause shall proceed in the manner prescribed under Sub-Clauses 45.2 to 45.5 and the payment under Sub-Clause 45.4 shall be made after having deducted the amounts due to the Employer under Sub-Paras (a) and (c) of this Sub- Clause.

Sub-Clause 46.1 Employer's Default

The comma and the word "or" at the end of paragraph (d) of Sub-Clause 46.1 are deleted and substituted by period (.) Paragraph (e) of Sub-Clause 46.1 is deleted.

Sub-Clause 46.3 Payment on Termination for Employer's Default

The words "including loss of profit" in the second paragraph of Sub-Clause 46.3 are deleted.

Sub-Clause 47.1 Labour, Materials and Transport

The procedure for price adjustment is expressed in Annex 2 – Attachment to PCC Sub Clause 47.1

Sub-Clause 48.1 Local Taxation-Custom and Import Duties

The text of Sub-Clause 48.1 is deleted and substituted by the following:
The rates and prices quoted by the Contractor in the Schedule of Prices shall be deemed to have included (i) business taxes, income tax, super tax, customs, import duties and other taxes on income, and (ii) fees charged for services provided under this Contract. The taxation is leviable as per income tax ordinance 2001 and amendments thereto issued by FBR Government of Pakistan & the taxation laws/rules of AJK Government (which also includes education CESS tax) including adjustment in prices as per clause 47.

The Employer shall not reimburse the amount thereof.

The following Sub-Clause 48.3 is added:

Sub-Clause 48.3 Port Charges and Port Congestion

"The Contractor shall be deemed to have obtained all the information regarding facilities and charges, in respect of port clearance, loading and unloading, storage, transportation, congestion and confirmed the requirements thereof at his own responsibility and all such costs and charges are deemed to be included in the rates and prices of the Schedule of Prices."

Sub-Clause 49.1 Notices to Contractor

The following paragraph is added at the end of Sub-Clause 49.1:

"For the purposes of Sub-Clause 49.1, the Contractor shall, immediately after receipt of Letter of Acceptance, intimate in writing to the Employer and the Project Manager/ Engineer by registered post, the address of his principal place of business or any change in such address during the period of the Contract."

Sub-Clause 50 Disputes & Arbitration

Clause 50 is deleted and in its place the following Sub-Clauses 50.1 to 50.5 are inserted:

"50.1 If a dispute of any kind whatsoever arises between the Employer and the Contractor in connection with, or arising out of, the Contract or the execution of the Works, whether during the execution of the Works or after their completion and whether before or after repudiation or other termination of the Contract, including any dispute as to any opinion, instruction, determination, certificate or valuation of the Project Manager/ Engineer, the matter in dispute shall, in the first place, be referred in writing to the Project Manager/Engineer, with a copy to the other party. Such reference shall state that it is made pursuant to this Clause. No later than the fifty sixth (56) day after the day on which he received such reference, the Project Manager/ Engineer shall give notice of his decision to the Employer and the Contractor. Such decision shall state that it is made pursuant to this Clause.

Unless the Contract has already been repudiated or terminated, the Contractor shall, in every case, continue to proceed with the Work with all due diligence, and the Contractor and the Employer shall give effect forthwith to every such decision of the Project Manager/ Engineer unless and until the same shall be revised, as hereinafter provided in an amicable settlement or in an arbitral award.

50.2 If either the Employer or the Contractor be dissatisfied with a decision of the Project Manager/ Engineer or if the Project Manager/ Engineer fails to give notice of his decision on or before the fifty sixth (56) day after the day on which he received the reference, then either the Employer or

the Contractor may, on or before the twenty eighth (28) day after the day on which the said period of fifty six (56) days expired, as the case may be, give notice to the other party to commence arbitration, as hereinafter provided, as to the matter in dispute. Such notice shall establish the entitlement of the party giving the same to commence arbitration, as hereinafter provided, as to such dispute and, subject to Sub- Clause 50.5, no arbitration in respect thereof may be commenced unless such notice is given.

If the Project Manager/ Engineer has given notice of his decision as to a matter in dispute to the Employer and the Contractor and no notification of intention to commence arbitration as to such dispute has been given by either the Employer or the Contractor on or before the twenty eighth (28) day after the day on which the parties received notice as to such decision from the Project Manager/ Engineer the said decision shall become final and binding upon the Employer and the Contractor.

50.3 Where notice of intention to commence arbitration as to a dispute has been given in accordance with Sub-Clause 50.2, arbitration of such dispute shall not be commenced unless an attempt has first been made by the parties to settle such dispute amicably through mutual negotiation within ninety (90) days from the date of notification of Project Manager/ Engineer's decision.

50.4 Any dispute in respect of which:

(a) the decision, if any, of the Project Manager/Engineer has not become final and binding pursuant to Sub-Clause 50.1; and

(b) amicable settlement has not been started/reached within the period stated in Sub-Clause 50.3, shall be finally settled, unless otherwise specified in the Contract, under the Rules of Pakistan Arbitration Act, 1940 (Act No. X of 1940) and Rules made thereunder as amended, by one or more arbitrators appointed under such Rules.

The said arbitrator/s shall have full power to open up, review and revise any decision, opinion, instruction, determination, certificate or valuation of the Project Manager/ Engineer related to the dispute. Neither party shall be limited in the proceedings before such arbitrator/s to the evidence or arguments put before the Engineer for the purpose of obtaining his said decision pursuant to Sub-Clause 50.1. No such decision shall disqualify the Project Manager/ Engineer from being called as a witness and giving evidence before the arbitrator(s) on any matter whatsoever relevant to the dispute.

Arbitration may be commenced prior to or after completion of the Works, provided that the obligations of the Employer, the Engineer and the Contractor shall not be altered by reason of the arbitration being conducted during the progress of the Works

The venue of arbitration proceedings shall be the place in Pakistan as mentioned in the Preamble to Conditions of Contract.

50.5 Where neither the Employer nor the Contractor has given notice of intention to commence arbitration of a dispute within the period stated in Sub-Clause 50.1 or 50.2 and the related decision has become final and binding, either party may, if the other party fails to comply with such decision, and without prejudice to any other rights it may have, refer the failure to arbitration in accordance with Sub-Clause 50.4. The provisions of Sub-Clauses 50.1 to 50.2 shall not apply to any such reference."

Additional Conditions

52. Liens

Each contractor, for himself and for any persons directly or indirectly responsible to him, and for his or their material, equipment and employees, and for all other persons performing any labor or furnishing any labor or material for any/or all of the Work covered by his Contract, will be required to release or waive, to the full extent permitted by law, all mechanical and other liens, for or on account of the Work done or equipment and material furnished hereunder and the improvements or structures herein same may be incorporated, and the land to which they are appurtenant shall at all times be free and clear of all such liens.

53.1 Payment of Income Tax, Etc.

The Contractor shall be responsible for the payment, if any is required, of all Pakistani & AJK Govt. Income Tax, Super Tax, and other taxes on income arising out of the Contract, and the rates and prices stated in the priced Schedule of Prices shall be deemed to cover all such taxes.

53.2 Personnel, Taxes and Duties

The Contractor or his personnel shall pay all personal income tax or other taxes due in Pakistan, if any, for the personnel employed by the Contractor for implementing the work or any other activity required by the Contract. The Contractor shall obtain, at his own cost, work permits from competent authorities to enable any foreign personnel to work in Pakistan. The Contractor shall be responsible for all formalities in connection with passports, obtaining visas, police permits, and expenses for customs duties, if any, related to personal goods of foreign personnel employed on the Project. However, the Employer will, if requested, assist the Contractor in obtaining visas and work permits.

53.3 Income Taxes Provisions in Subcontracts

Provisions to the like effect as those contained in this Clause shall be incorporated in Subcontracts.

54. Liability of the Contractor

The Contractor or his Subcontractors or assigns shall follow strictly, all relevant labour laws including the Workmen's Compensation Act and the Employer shall be fully indemnified for all claims, damages etc. arising out of any dispute between the Contractor, his Subcontractors or permitted assigns and the labour employed by them.

55. Joint and Several Liability

If the Contractor is a joint venture of two or more persons, all such persons shall be jointly and severally bound to the Employer for the fulfilment of the terms of the Contract and shall designate one of such persons to act as leader with authority to bind the joint venture. The composition or the constitution of the joint venture shall not be altered without the prior consent of the Employer.

56. Details to be Confidential

The Contractor shall treat the details of the Contract as private and confidential, save in so far as may be necessary for the purposes thereof, and shall not publish or disclose the same or any particulars thereof in any trade or technical paper or elsewhere without the prior consent in writing of the Employer or the Project Manager/Engineer. If any dispute arises as to the necessity of any publication or disclosure for the purpose of the Contract, the same shall be referred to the decision of the Project Manager/Engineer whose award shall be final.

Annex 2 - Attachment to PCC Sub Clause 47.1 – Price Adjustment

Price Adjustment

Not Applicable

Part-6

Standard Forms

TABLE OF CONTENTS

STANDARD FORMS 206
STANDARD FORMS 207
FORM OF BID SECURITY 208
FORM OF CONTRACT AGREEMENT 210
FORM OF PERFORMANCE SECURITY 212
FORM OF BANK GUARANTEE FOR ADVANCE PAYMENT 214

STANDARD FORMS

STANDARD FORMS

Standard Forms include the following:

- Form of Bid Security (Bank Guarantee)
- Form of Contract Agreement
- Form of Performance Security (Bank Guarantee
- Form of Bank Guarantee for Advance Payment

FORM OF BID SECURITY

(Bank Guarantee)

Guarantee No._____
Executed on _____
Expiry date _____

Name of Guarantor (Bank) with address: _____

Name of Principal (Bidder) with address: _____

_____

Penal Sum of Security (express in words and figures):_____

_____

Bid Reference No._____Date of Bid Opening_____

KNOW ALL MEN BY THESE PRESENTS, that in pursuance of the terms of the Bid and at the request of the said Principal, we the Guarantor above-named are held and firmly bound unto the _____, (hereinafter called the "Employer") in the sum stated above, for the payment of which sum well and truly to be made, we bind ourselves, our heirs, executors, administrators and successors, jointly and severally, firmly by these presents.

THE CONDITION OF THIS OBLIGATION IS SUCH, that whereas the Principal has submitted the accompanying Bid numbered dated as above for _____ (Particulars of Bid) to the said Employer; and

WHEREAS, the Employer has required as a condition for considering the said Bid that the Principal furnishes a Bid Security in the above said sum to the Employer, conditioned as under:

(1) that the Bid Security shall remain valid for a period 28 days beyond the period of validity of the Bid,

(2) that in the event of;

- (a) the Principal withdraws his Bid during the period of validity of Bid, or
- (b) the Principal does not accept the correction of his Bid Price, pursuant to Sub-Clause 24.2 of Instructions to Bidders, or
- (c) failure of the successful Bidder to
  - (i) furnish the required Performance Security, in accordance with Clause 34 of Instructions to Bidders, or
  - (ii) sign the proposed Contract Agreement, in accordance with Clause 35 of Instructions to Bidders,

then the entire sum be paid immediately to the said Employer as liquidated damages and not as penalty for the successful Bidder's failure to perform.

NOW THEREFORE, if the successful Bidder shall, within the period specified therefor, on the prescribed form presented to him for signature enter into a formal Contract with the said Employer in accordance with his Bid as accepted and furnish within twenty eight (28) days of his being requested to do so, a Performance Security with good and sufficient surety , as may be required, upon the form prescribed by the said Employer for the faithful performance and proper fulfilment of the said Contract or in the event of non-withdrawal of the said Bid within the time specified for its validity then this obligation shall be void and of no effect, but otherwise to remain in full force and effect.

PROVIDED THAT the Guarantor shall forthwith pay to the Employer the said sum stated above upon first written demand of the Employer without cavil or argument and without requiring the Employer to prove or to show grounds or reasons for such demand notice of which shall be sent by the Employer by registered post duly addressed to the Guarantor at its address given above.

PROVIDED ALSO THAT the Employer shall be the sole and final judge for deciding whether the Principal has duly performed his obligations to sign the Contract Agreement and to furnish the requisite Performance Security within the time stated above, or has defaulted in fulfilling said requirements and the Guarantor shall pay without objection the sum stated above upon first written demand from the Employer forthwith and without any reference to the Principal or any other person.

IN WITNESS WHEREOF, the above bounden Guarantor has executed the instrument under its seal on the date indicated above, the name and seal of the Guarantor being hereto affixed and these presents duly signed by its undersigned representative pursuant to authority of its governing body.

Guarantor (Bank)

Witness: Signature ----------

1. ---------- Name ----------

---------- Title ----------
Corporate Secretary (Seal)

2. ---------- ----------

---------- ----------
(Name, Title & Address) Corporate Guarantor (Seal)

FORM OF CONTRACT AGREEMENT

THIS CONTRACT AGREEMENT (hereinafter called the "Agreement") made on the_____day of _____(month) 20_____ between _____ (hereafter called the "Employer") of the one part and _____ (hereafter called the "Contractor") of the other part.

WHEREAS the Employer is desirous that certain Works, viz_____should be executed by the Contractor and has accepted a Bid by the Contractor for the execution and completion of such Works and the remedying of any defects therein.

NOW this Agreement witnesseth as follows:

1. In this Agreement words and expressions shall have the same meanings as are respectively assigned to them in the Conditions of Contract hereinafter referred to.

2. The following documents after incorporating addenda, if any except those parts relating to Instructions to Bidders shall be deemed to form and be read and construed as part of this Agreement, viz:

    1. The Form of Contract Agreement.
    2. The Letter of Acceptance/ Letter to Commence.
    3. Performance Security/ Undertaking by Contractor
    4. Minutes of Pre-Award Meeting.
    5. Completed Form of Bid (Letters of Technical & Financial Bids).
    6. Preamble to Conditions of Contract.
    7. The Particular Conditions of Contract.
    8. The General Conditions of Contract.
    9. Corrected Priced Schedule of Prices.
    10. The completed Schedules to Bid (A to L).
    11. Clarification replies during Bidding Process.
    12. The Employer Requirements.
    13. The Specifications.
    14. The Drawings.
    15. Any other document forming part of the Contract.

3. In consideration of the payments to be made by the Employer to the Contractor as hereinafter mentioned, the Contractor hereby covenants with the Employer to execute and complete the Works and remedy defects therein in conformity and in all respects with the provisions of the Contract.

4. The Employer hereby covenants to pay the Contractor, in consideration of the execution and completion of the Works as per provisions of the Contract, the Contract Price or such other sum as may become payable under the provisions of the Contract at the times and in the manner prescribed by the Contract.

IN WITNESS WHEREOF the parties hereto have caused this Agreement to be executed on the day, month and year first before written in accordance with their respective laws.

Signature of the Contactor	Signature of Employer
_____	_____
(Seal)	(Seal)
Signed, Sealed and Delivered in the presence of:	
Witness:	Witness:
_____	_____
(Name, Title and Address)	(Name, title and Address)

FORM OF PERFORMANCE SECURITY
(Bank Guarantee

Guarantee No._____
Executed on _____
Expiry date _____

Name of Guarantor (Bank) with address:_____

Name of Principal (Contractor) with address:_____
_____

Penal Sum of Security (express in words and figures)_____
_____

Letter of Acceptance No._____Dated _____

KNOW ALL MEN BY THESE PRESENTS, that in pursuance of the terms of the Bidding Documents and above said Letter of Acceptance (hereinafter called the Documents) and at the request of the said Principal we, the Guarantor above named, are held and firmly bound unto the _____ (hereinafter called the "Employer") in the penal sum of the amount stated above for the payment of which sum well and truly to be made to the said Employer, we bind ourselves, our heirs, executors, administrators and successors, jointly and severally, firmly by these presents.

THE CONDITION OF THIS OBLIGATION IS SUCH, that whereas the Principal has accepted the Employer's above said Letter of Acceptance for _____ _____ (Name of Contract) for the _____ _____ (Name of Project).

NOW THEREFORE, if the Principal (Contractor) shall well and truly perform and fulfill all the undertakings, covenants, terms and conditions of the said Documents during the original terms of the said Documents and any extensions thereof that may be granted by the Employer, with or without notice to the Guarantor, which notice is, hereby, waived and shall also well and truly perform and fulfill all the undertakings, covenants terms and conditions of the Contract and of any and all modifications of said Documents that may hereafter be made, notice of which modifications to the Guarantor being hereby waived, then, this obligation to be void; otherwise to remain in full force and virtue till all requirements of Clause 30, Defects after Taking Over, of Conditions of Contract are fulfilled.

Our total liability under this Guarantee is limited to the sum stated above and it is a condition of any liability attaching to us under this Guarantee that the claim for payment in writing shall be received by us within the validity period of this Guarantee, failing which we shall be discharged of our liability, if any, under this Guarantee.

We,_____(the Guarantor), waiving all objections and defences under the Contract, do hereby irrevocably and independently guarantee to pay to the Employer without delay upon the Employer's first written demand without cavil or arguments and without requiring the Employer to prove or to show grounds or reasons for such demand any sum or sums up to the amount stated above, against the Employer's written declaration that the Principal has refused or failed to perform the obligations under the Contract which payment will be effected by the

Guarantor to Employer's designated Bank & Account Number.

PROVIDED ALSO THAT the Employer shall be the sole and final judge for deciding whether the Principal (Contractor) has duly performed his obligations under the Contract or has defaulted in fulfilling said obligations and the Guarantor shall pay without objection any sum or sums up to the amount stated above upon first written demand from the Employer forthwith and without any reference to the Principal or any other person.

IN WITNESS WHEREOF, the above-bounden Guarantor has executed this Instrument under its seal on the date indicated above, the name and corporate seal of the Guarantor being hereto affixed and these presents duly signed by its undersigned representative, pursuant to authority of its governing body.

_____
Guarantor (Bank/)

Witness:

1. _____ Signature _____

_____ Name _____
Corporate Secretary (Seal)

Title _____

2. _____

_____ _____
Name, Title & Address Corporate Guarantor (Seal)

FORM OF BANK GUARANTEE FOR ADVANCE PAYMENT

Guarantee No._____
Executed on_____
Expiry date _____

WHEREAS the_____(hereinafter called the Employer) has entered into a Contract for _____ _____ _____ (Particulars of Contract), with _____ _____ (hereinafter called the Contractor).

AND WHEREAS the Employer has agreed to advance to the Contractor, at the Contractor's request, an amount of_____(Rs._____) which amount shall be advanced to the Contractor as per provisions of the Contract.

AND WHEREAS the Employer has asked the Contractor to furnish Guarantee to secure advance payment for performance of his obligations under the said Contract.

AND WHEREAS _____ (Bank) (hereinafter called the Guarantor) at the request of the Contractor and in consideration of the Employer agreeing to make the above advance to the Contractor, has agreed to furnish the said Guarantee.

NOW THEREFORE the Guarantor hereby guarantees that the Contractor shall use the advance for the purpose of above mentioned Contract and if he fails, and commits default in fulfillment of any of his obligations for which the advance payment is made, the Guarantor shall be liable to the Employer for payment not exceeding the aforementioned amount.

Notice in writing of any default, of which the Employer shall be the sole and final judge, as aforesaid, on the part of the Contractor, shall be given by the Employer to the Guarantor, and on such first written demand payment shall be made by the Guarantor of all sums then due under this Guarantee without any reference to the Contractor and without any objection.

This guarantee shall come into force as soon as the advance payment has been credited to the account of the Contractor.

This guarantee shall expire not later than _____
by which date we must have received any claims by registered letter, telegram, telex or telefax.

It is understood that you will return this Guarantee to us on expiry or after settlement of the total amount to be claimed hereunder.

_____
Guarantor (Bank)

Witness:

1. _____ Signature _____

_____ Name _____
Corporate Secretary (Seal)

Title _____

2. _____

_____ _____
Name, Title & Address Corporate Guarantor (Seal)

POWER DEVELOPMENT ORGANIZATION
GOVERNMENT OF AZAD JAMMU & KASHMIR

EPC/ TURNKEY BIDDING DOCUMENT
FOR
ENGINEERING, PROCUREMENT AND CONSTRUCTION
OF
22 MW JAGRAN-IV HYDROPOWER PROJECT

LOT-2: ELECTRICAL & MECHANICAL WORKS

Volume-II Employer Requirements and Specifications

Contract No.: JRN-IV/Lot-2/2026 **July 2026**

Associated Consulting Engineers ACE Limited
36-Civic Centre, M Bloc, Model Town Extension, Lahore – Pakistan. Tel: +92 42 35759417 – 19

Rehman Habib Consultants
160 Khayaban-e-Jinnah, Airline Society, Lahore

Saudconsult Saudi Consulting Services
11451 Sheikh Mubarak Al-Sabah, Sulaymaniyah Riyadh, Saudi Arabia

Volume-I Bidding Documents

Part-1 - Instructions to Bidders and Appendices

Part-2 - Letters of Technical & Price Bid and Schedules to Technical & Price Bid

Part-3 - Schedule of Prices

Part-4 – General Conditions of Contract

Part-5 – Particular Conditions of Contract

Part-6 – Standard Forms

Volume-II Employer Requirements & Specifications

Part-A – Employer Requirements

Part-B – Mechanical Specifications

Part-C – Electrical Specifications

Volume-III Bidding Drawings

Supplementary Information

1 Tender Design Report, Feb 2026
2 Feasibility and Design Review Report, Nov 2025
3 Third Party Validation Report, July 2021
4 Feasibility Study Report, 2010

PART-A: EMPLOYER'S REQUIREMENT

TABLE OF CONTENTS

SECTION 1: GENERAL 1
1.1 Scope of Work 1
1.1.1 General 1
1.1.2 Detailed Design and Planning of the Project Components 5
1.1.3 Contractor's Facilities for the Employer and Engineer Staff 8
1.1.4 Security, Health and Safety 9
1.1.5 Quality Assurance/ Quality Control 9
1.1.6 Environmental Compliance 13
1.1.7 Training Programme 15
1.1.8 Electrical and Mechanical Equipment 15
1.1.9 Documentary Film 15
1.1.10 Joint Operation and Defect Liability Period 15
1.1.11 Mobilization and Demobilization 16
1.1.12 Operation and Maintenance Manuals 16
1.1.13 Project Completion Report 16
1.2 Basic Design Criteria 16
1.2.1 General 16
1.2.2 Design Responsibility 17
1.3 Bid Submissions 17
1.3.1 Bid Level Design 17
1.3.2 Bid Drawings for Electrical and Mechanical Equipment 17
1.4 Contractor's Documents 18
1.4.1 General 18
1.4.2 Procedure 18
1.4.3 Basic and Level–1 Design 19
1.4.4 Detailed Design (Level–2) 19
1.4.5 Inspection and Test Plans 19
1.4.6 Erection and Testing Manuals 19
1.4.7 Operation and Maintenance Manuals 19
1.4.8 As-Built Drawings 19
1.4.9 Commissioning Reports 20
1.5 Environmental Aspects 20
SECTION 2: PROGRAMME & PROGRESS REPORTS 21
2.1 Programme 21
2.2 Progress Reports 21
2.3 Fortnightly Progress Meetings 21
2.4 Photographic Records 22
SECTION 3: SUBMITTALS 23
3.1 Description 23

3.2 General Aspects of Submittal and Review 23
3.3 Design Liability 24
3.4 Special Requirement for Site Installation 24
3.5 Level 1 Review 24
3.6 Level-2 Review 25
3.7 Review Process 25
SECTION 4: QUALITY ASSURANCE/ QUALITY CONTROL 27
4.1 Description 27
4.2 The Contractor's Quality Assurance Plan 27
SECTION 5: ENVIRONMENTAL PROTECTION & MISCELLANEOUS 28
5.1 Environmental Management 28
5.2 Water Quality 28
5.3 Waste Management 28
5.4 Avoidance of Nuisance 28
5.5 Notice to Service Authorities 29
5.6 Utilities and Other Services 29
5.7 Prohibition of Advertising 30
5.8 Explosives 30
SECTION 6: EQUIPMENT PRESERVATION AND STORAGE AT SITE 31
6.1 General 31
6.2 Localized Climate Control 31
6.3 Power Infrastructure Optimization 31
6.4 Packing and Preservation Mandates (Vendor-Level Preservation) 32
6.5 Contractor Liability for Improper Preservation and Moisture Damage 32
6.5.1 Maintenance and Monitoring Obligations 32
6.5.2 Definition of Preservation Failure 32
6.5.3 Liability for Damage, Rust, and Moisture Ingress 32
6.5.4 Financial Penalties and Liquidated Damages 33
6.6 Employer Liability 33
6.7 Measurement & Payment 33
SECTION 7: PROJECT SIGNS 34
7.1 Project Sign Boards 34
SECTION 8: COMPLETION 35
8.1 Site Clearance 35
8.2 Project Records 35
8.2.1 Project Record Documents and Samples 35
8.2.2 Submittals 36
SECTION 9: INTERFACE BETWEEN C&HH AND E&M CONTRACTORS 37
9.1 General 37
9.2 Scope of Interface Management 37

9.3 Interface Coordination Responsibilities 37
9.3.1 Responsibilities of the Civil Contractor (Lot 1) 37
9.3.2 Responsibilities of the Electrical & Mechanical Contractor (Lot 2) 37
9.4 Interface Identification and Register 37
9.5 Design Coordination 38
9.6 Embedded Parts and Installation Provisions 38
9.7 Construction Sequencing and Access 38
9.8 Inspection and Verification 38
9.9 Protection of Installed Works 38
9.10 Interface Meetings and Coordination 39
9.11 Documentation and Reporting 39
9.12 Dispute Resolution 39

SECTION 1: GENERAL

1.1 Scope of Work

1.1.1 General

The Jagran-IV Hydropower Project, with a proposed installed capacity of 22 MW, is planned on left bank of Jagran River in District Neelum, AJK. Its proposed powerhouse location near Thunian forest / Rest House is 260 m just upstream to existing weir / intake structure of Jagran-I Hydropower Project. The diversion weir is proposed approximately 70 meters downstream of the confluence of Baihkl Nullah with the Jagran River near Shaal Village.

The Contractor shall design, procure the necessary equipment and materials, construct, install, test, start-up, commission and impart training to the staff according to the scope of work. This Section describes the Scope of Work, to be performed by the Contractor under EPC Contract for Lot-2 for delivering the Employer with fully commissioned and operative 22 MW (Capacity mentioned above) Hydropower Project Jagran-IV. The Contractor will maintain and jointly operate the plant on Commercial basis for training of the Employer staff during the (01) one year Defect Liability Period (DLP) from commercial date of operation.

- Minimum temperature limit of 5°C, depending upon the season prevails generally w.e.f end March to end November. The temperature goes down in the project area from -1°C to -5°C from December first to end of March.
- Where ever the term "or equivalent International Standards" is mentioned; that is subject to approval of the client and valid for successful bidder only after award of the contract.
- Where ever the term "The Engineer" or "Employer/Engineer" is mentioned; that means The Project Manager/Engineer as defined in **Sub Clause 1.1.15 of the preamble to the conditions of contract.**
- The Mechanical, Electrical and any other Designs included in the tender level design report are only for the information of the Bidders to understand the Project. The bidder shall review all such designs and may firm up their **bid level designs and drawings** in view of the Employer's requirements, standards and specifications to fulfill their responsibility as an EPC Contractor.
- The Bidder shall accordingly estimate, all of the plants and equipment including all other works essential to furnish the complete facility of 22 MW Hydropower Project, ready to generate.
- The bidder shall offer the prices against the major components of the works and Plant & Equipment or supply of tools and plants etc. in line with the Bid Forms and associated details.
- The Bidder also represents that all items of Works required for completion of various components of the Project and their prices have been accounted for in the offered Bid Price and Priced Schedules. Further the cost of miscellaneous or minor items, not mentioned in the Employer's Requirements and Schedules of Prices, shall be deemed included in the offered Bid Price / Priced Schedules and Contractor shall be liable to provide the required items at no additional costs to the Employer and shall ensure successful completion of the Project for its intended Use. This shall also include but not

limited to any work that are not covered within the Schedule of Prices, but might neccessry be needed to be done, in order to achieve the "Performance Gaurantees.

The Contractor shall be responsible for all aspects of design and construction of the Project **pertaining to Lot-2 Works in accordance with the design criteria and specifications furnished herein,** and in accordance with additional and supplementary design criteria and specifications prepared by the Contractor and accepted by the Engineer. The scope of work to be carried out by the Contractor will include, but not limited to:

The Permanent Works shall comprise, but shall not be limited to, the following components:

- Three (03) vertical shaft Francis turbines of rated capacity of 7.16 MW each and one (01) vertical shaft Francis Turbine with rated capacity of 2.24 MW along with all auxiliary equipment, Inlet valve, Howel Bunger type pressure relief values, draft tube etc. the capacity will be according to the data given in the design requirement & specifications or as per EPC design with the requirement that the total design flow of 16 m^3/s & unit flow of 4.83 m^3/s each for larger units and 1.51 m^3/sec for the smaller unit will not be changed. The net head of the Plant is 166.1 meters as per consultant assessment which may be finalized during detailed design.
- Four (04) Governors (PID-Type) including power pack and all requisite equipment and accessories.
- Power house auxiliary systems i.e., cooling water system, dewatering and drainage system, fire fighting system, compressed air system, oil handling system, oil purification system, Fire detection and alarm system and HVAC system including all type of sensors required for successful completion of the hydropower project.
- Powerhouse Bridge Crane (45/10 ton).
- Gantry crane to lift draft tube bulk head gates at powerhouse.
- Workshop equipment and tools.
- Three (03) 6.8 MW (8.5 MVA) vertical shaft Generators including excitation system, automatic voltage regulators, along with all control panels, switch gears, cables, alarm system, generator protection etc.
- One (01) 2.13 MW (2.66 MVA) vertical shaft Generators including excitation system, automatic voltage regulators, along with all control panels, switch gears, cables, alarm system, generator protection etc.
- Three (03) 10/13 MVA, 11/132 kV Step-up Power Transformers at Switchyard.
- One (01) 3.5 MVA, 11/132 kV Step-up Power Transformers at Switchyard.
- Local supply and station service Transformers.
- MV Switchgears in Powerhouse.
- AC/DC auxiliary distribution system for Powerhouse, batteries and battery chargers, UPS etc. complete.
- 11/132 kV Switchyard at Jagran-IV Powerhouse including four Transformer bays, two-line bays and one PT bay along with HV switchgear equipment, control & protections, Steel Structure, and all ancillary equipment and cable connection from MV switchgear to Terminal pole of distribution feeders with termination kits. The Switchyard civil works shall be carried out by Lot-1 Contractor for Civil Works.

- Earthing system and lightning protection systems for Powerhouse, switchyard, weir and intake along with connection to equipment and all metal parts.
- Control and protection, Alarm system, telecommunication system including PABX with carrier system for data and voice communication, (SCADA system), VHF local radio communication system for Powerhouse and Switchyard.
- Plant Control and Automation and security system.
- Emergency Diesel Generator for power plant.
- Cables for MV, LV, telecommunication, control and protection with cable tray, cable ducts, complete.
- Internal and external electrification of Power plant, switchyard, intake, substations.
- 11 kV Transmission line complete in all respect with Rabbit Conductor from the powerhouse to intake structure, through colony and office area, with 11 kV lattice steel structures and LV distribution having an approximate length of 3.5 Km:
- 132 kV Transmission line complete in all respect with self-supported galvanized lattice steel towers (132kV), ACSR Lynx conductor and stock bridge dampers, for conductor and galvanized steel shield wire for the interconnection of the Project having an approximate length of 4.0 Km
- Supply, Installation and Connection of all Types and sizes of Cables including Power, Instrumentation, Control and Communication complete in all respect
- Firefighting system in power plant, weir/intake, Switchyard, PPEs and instruments etc. complete in all respects.
- 132 kV Switchgear, control & protection equipment etc for 132 kV outdoor Switchyard complete in all respect.
- AC auxiliary distribution system for powerhouse and switchyard.
- Control & alarm system, protection and earthing systems, telecommunication with carrier telephone for powerhouse and switchyard.
- SCADA and Telecommunication system complete in all respect.
- Spare parts, tools and plants.
- Ancillary, health, safety and environmental protection works necessary during implementation of the Project.
- Spare parts, tools and plants.
- Training of engineers and O&M staff on job and abroad

The Contractor shall **design, procure the necessary equipment and materials, manufacture, construct, install, test, start-up, commission and connect the 22 MW Jagran-IV Hydropower Project pertaining to Lot-2 Works**.

The Contractor shall be responsible for all aspects of design, construction of works, procurement/supply and transport of all plant and equipment, storage, installation, testing and commissioning of the Project pertaining to Lot-2 Works in accordance with the design criteria and specifications furnished herein, and in accordance with additional and supplementary design criteria and specifications prepared by the Contractor and accepted by the **The Engineer.**

In addition to Works describe herein above the scope of work to be carried out by the Contractor will also include, but not be limited to:

- Contractor will be responsible to mobilise a strong design team for design and detailed supervision during Construction of the project components at the site.
- Preparation of a comprehensive detailed design report including design criteria, design analysis, design calculations, construction specifications, detailed erection and shop drawings, quality control procedures and plans, and Environmental Management Plans, necessary for the complete construction of the project together with Operation and Maintenance (O&M) Manuals, and as built record drawings.
- Design, planning and scheduling of the Works.
- Provision and construction of Temporary Works, including offices, Field Cabins and required accommodation for Contractor's staff, steel fabrication workshop, plant maintenance workshops, storage facilities, First Aid, utilities etc. and other temporary equipment and plant required for construction.
- Finalization of overall layout of the project.
- Equipment layout in the Power House, Switchyard, Transmission lines and other ancillaries to be finalized in coordination with Lot-1 Contractor.
- Preparation of detailed construction / erection drawings, necessary shop drawings, and erection sequence drawings for E & M Equipment.
- Telecommunication and Internet Facility for the Contracotr's own use.
- Quality Assurance Plan, Safety Plan and QC system.
- Preparation of Construction Program along with resource levelling.
- Production, fabrication, delivery to site, storage, erection, testing and commissioning of specified Plants and all other equipment.
- Health, Safety and environmental protection Plan.
- As-built drawings for record.
- Project completion Report.
- Provision of latest edition/publication of international standards in English language used for design of this project both soft and hard form.
- Provision of Operation and Maintenance (O&M) Manuals in English language.
- Training of Employer's O&M staff.
- Testing and Commissioning of the Works.
- After successful testing & commissioning, the Contractor will maintain and jointly operate the plant on commercial basis for training of the Employer's staff during one year defect liability period.
- Remedying of defects during the Defects Liability Period.

The descriptions given in **Part A Employer's Requirements (this part)** are outlined descriptions only. Such descriptions do not include or give full description of all materials or other items to be supplied or all Works and services to be executed by the Contractor in order to fulfil its

obligations in compliance with the Contract. Once completed the Works shall include all that is necessary to satisfy the Project Requirements, or is implied by the Contract and all Works (which although not mentioned in the Contract) are necessary for stability or for the completion, or safe and proper operation, of the Works suitable and fit for the purposes for which Works are intended as set out in the Contract.

1.1.2 Detailed Design and Planning of the Project Components

A. The Contractor shall be responsible for the detailed design and planning of the Works in accordance and consistent with Contract.

B. The Contractor shall further establish and implement Quality Control and Quality Assurance Plan to ensure and verify that it's Work is in accordance with the requirements of the Contract. The plan should depict deployment of the supervisory Engineers and staff including the testing and commissioning methods and Procedures.

C. The Contractor will prepare a Basic Design as part of preparation of its proposal for construction of Works. The Contractor shall be fully responsible to develop the detailed design for implementation of the Project, including consideration of all requirements stated in Technical Specifiction (Part-B & Part-C of Volume-II) and (Tender Drawings – Volume-III). Any details or information shown in the Basic Design shall be confirmed by the Contractor before incorporation in the Detailed Design of the Works. Any deviations from the requirements stated in Employer's requirements shall be brought to the attention of the Engineer in writing and shall be subject to the Engineer's approval.

1.1.2.1 Detailed Design

All Designs shall be performed in accordance with the requirements given as follows:

A. Design shall be performed in accordance with the Project Requirements and requirements of the Contract.

B. The Project shall be designed, constructed and operated to comply with the terms and conditions of the Contract, which shall be considered as a minimum standard of performance and operating characteristics required to be delivered under this Contract.

C. The Contractor shall not commence procurement of Plant and Materials until the relevant submittals as mentioned in Contract have been reviewed and approved by the Engineer.

D. The Contractor shall prepare the Detailed Design for the Plant. The Contractor shall submit to the Engineer for his review, a Detailed Design report and supporting documentation (the "Detailed Design"), which shall include as a minimum the following. The Contractor shall submit any additional calculation or supporting documentation that the Engineer deems necessary to demonstrate the proposed design.

   i. A description of each major part of the Plant.

   ii. A description of assumptions and design philosophies adopted.

   iii. Design criteria, loads and load cases used.

   iv. A short description of each method of analysis used such as computer programs.

   v. Calculations and main results of the detailed design analysis.

vi. The Contractor shall prepare the Detailed Design and construction drawings of the necessary Temporary works to be performed under this Contract.

vii. The Contractor shall prepare the Detailed Design and Shop Drawings of the Hydro-mechanical, Electrical & I&C equipment to be installed under this Contract.

viii. Contractor shall prepare the detailed designs, technical specifcations and shop drawings of transmission line and connection facilities etc.

The activities to be performed under the detailed design are outlined below:

I. Expansion and clarification of design criteria and parameters.

II. Design Memoranda.

III. Detailed Design calculations.

IV. Transmission lines, switch yard SLDs, Schematic diagrams and drawings etc.

V. E&M equipment assembly drawings, shop drawings, installation drawings, circuit diagrams, SLDs, etc.

VI. Providing and/or incorporating Manufacturer's Drawings of E&M equipment.

VII. Manufacturing and delivery Schedule for major equipment.

VIII. Layout drawings for all temporary works.

IX. Principal items of Processing, Production & Construction plants to be used.

X. Detailed information of site offices and camp facilities.

XI. Quality Control and Quality Assurance plans and procedures for Installation, construction, fabrication, storage, erection, testing and commissioning.

XII. Environmental Management Plan including measures for rehabilitation of work areas.

XIII. Construction, Security, Health and Safety plans.

XIV. Drafting & preparation of the Operation and Maintenance Manuals and proposed Training Program.

1.1.2.2 Temporary Site Installations

A. Provision of furnished field camps and offices, temporary accommodations complete with all basic facilities for his staff shall be made by the Contractor positively within four (04) months of issuance of notice to proceed in accordance with Engineer's prior approval and requirements.

B. The Contractor shall provide all consumable items, spares, replacements etc., and shall maintain throughout the execution of the work all his temporary camp and office facilities required for the Works.

C. The Contractor shall provide un-interrupted Electricity supply for lightening and heating purposes to his temporary camps and offices through diesel/petrol generators of appropriate capacity.

D. The Contractor shall be responsible for ensuring that, during the construction period, there should be no adverse impact on the operations of any structures owned by government of Pakistan, Government of Azad Jammu & Kashmir and Private sector.

E. Contractor shall provide appropriate No's of Security personnel for internal security and watch & ward of the project area along with all necessary security equipment's and tools.

1.1.2.3 Temporary Facilities to be Handed over to the Employer

At the Completion date, selected temporary facilities or part thereof shall be handed over to the Employer if and as the Employer requires. These facilities shall be handed over to the Employer at no additional cost in good and serviceable conditions so that these can be utilized by the Employer without any further treatment or renovation.

1.1.2.4 Construction Power and Water Supply

A. The Contractor shall be responsible for the arrangement of temporary power supply, necessary for operating its construction machinery and other tools & plants to execute all works and fabricate, erect or install and testing/commissioning of the Plant.

B. The Contractor shall provide all arrangements for the supply of potable water as well as treatment of wastewater and acceptable disposal.

C. The Contractor may draw and use water from the Jagran River for normal construction activities with due consideration to environmental and other governmental regulations.

1.1.2.5 Water Supply System

A. The water supply system shall be designed and installed by the Contractor and shall be maintained during the entire duration of the Project Construction, Defect Liability Period and Period during which the Contractor rectifies the defects.

B. Prior to execution, the Contractor shall submit all necessary layouts and detailed drawings to the Engineer for approval.

C. Every two (2) weeks, the Contractor shall, at his cost, furnish analysis of the potable water. The quality of water shall comply with Pakistan Regulations for drinking water. If the water produce is not suitable for consumption, then the Contractor is to provide mineral water.

1.1.2.6 Sewerage and Water Treatment Disposal System

A. The Contractor shall design, execute and maintain a sewerage system for all of his site installations and facilities to the approval of the Engineer during the entire time for Completion, Defect Liability Period and Period during which the Contractor remedies the defects.

B. The sewerage system shall be in accordance with the capacity of the sewerage system comprising sewer pipes in all dimensions, manholes, complete sewage treatment plants and all other installations and civil works to put the complete system into operation.

C. The treated wastewater shall be discharged downstream of water intake structures located in the vicinity of the site installation area.

D. At all workshops and other areas where losses of lubrication oil can occur, the Contractor shall provide oil traps, oil separators or other measures to avoid environmental pollution. The oil shall be properly disposed at location and method approved by the relevant authorities/Engineer.

1.1.2.7 Contractor's Site Office

A. The Contractor shall establish the site office and its facilities which he requires for the Project.

B. The Contractor is foreseen to have one main office.

C. The Contractor shall establish its site office at its own cost.

D. Unless otherwise instructed by the Engineer, at the end of the Construction period, all site office buildings and storage buildings (including the foundations), electric services, buried utilities, and fencing shall be removed, and the site restored to the condition found before the camp was developed.

E. The provision and maintenance of the facilities and equipment shall be continued during time of Completion, Defect Liability Period and the period during which the defects shall be rectified.

1.1.2.8 First Aid Facilities

A. A first aid station shall be provided to serve all personnel at the site. The first aid station (Dispensary) shall be equipped as required by applicable Pakistani and Government of Azad Jammu & Kashmir laws.

B. A qualified emergency medical officer shall be on duty at the first aid station (Dispensary) on each working shift and day.

C. One Ambulance with driver fully equipped to handle the emergency shall be on duty at site for working day

D. The Contractor shall furnish proof to the Engineer that he has a continual arrangement with an approved hospital and Medicare arrangements for the emergency evacuation and admittance at any time and subsequent medical and hospital care for injured employees.

1.1.3 Contractor's Facilities for the Employer and Engineer Staff

A. The Contractor shall furnish two (02) Nos single cabin (4 x 4) automobiles for the exclusive use of the Management Consultants. These vehicles shall be registered with the consent of the Employer and fully insured for use throughout Pakistan. Vehicles shall be factory equipped with safety equipment, seat belts, air conditioning, radios, spare tires and standard tool kit in accordance with manufacturer's specifications:

B. These vehicles will be used for consultant's supervisory staff. The Contractor shall be responsible for provision of vehicles including POL, repair & maintenance, insurance, and all related costs. In addition, the Contractor shall assign two (02) licensed and experienced drivers to the vehicles to cover working hours and overtime where necessary. The Contractor shall maintain and keep vehicles in good running condition at all times till expiry of DLP. Any of the vehicles if needed to be repaired and then be away from the works for more than one (1) day, the Contractor must provide a substitute vehicle of equivalent standard until such time as the original vehicle is back in service. The vehicles shall be returned to the Contractor on expiry of DLP.

C. The Payment to the Contractor for the provision of vehicles and other facilities shall be made as per the relevant BoQ Item included in Part 3 – Price Schedules, Volume-I of the Bidding Documents for Lot-2.

1.1.4 Security, Health and Safety

The Contractor will be responsible for the security, safety & health and Group insurance of his Employees. The Contractor will provide the Employer with a Security, Safety and Health Manual within one month of Notice to Proceed, covering all aspects mentioned in relevant clauses of the EPC Contract, Laws and Regulations of Government of Pakistan and Government of Azad Jammu & Kashmir, relevant international standards (ISO 18000:2018 procedures for safety), traditions and customs of Azad Jammu & Kashmir.

1.1.5 Quality Assurance/ Quality Control

The Contractor shall implement quality assurance plan in accordance with the requirements of ISO 9001:2015 procedures.

A. The Bidder is required to demonstrate by documentation its proven capability to design, manufacture, supply, install and commission all equipment specified herein.

B. The documentation shall be based upon the requirements set forth in ISO 9001:2015, "Quality systems, Model for quality assurance in design/development, production, installation and servicing". Copy of current certificate shall be presented to the Engineer/Employer.

C. The Contractor shall be completely responsible for implementing a Quality Assurance Plan covering all the Works contained in the Contract. The Quality Assurance Plan will be prepared by the Contractor and reviewed and authorized by the Engineer and will be implemented by the Contractor. Specifically, it will be managed by the Contractor's Quality Assurance Manager. The Contractor's Quality Assurance Plan is the means by which the Contractor ensures the control and quality of all design functions, all fabrication by his suppliers and subcontractors and all construction activities carried out by his forces and his subcontractors, all work by equipment installation engineers and the testing and commissioning activities associated with all the mechanical and electrical equipment.

1.1.5.1 Contractor's Quality Assurance Plan

A. The Contractor's Quality Assurance Plan shall meet all the requirements of ISO9001- 2015. As appropriate the Contractor will impose on his designers, suppliers, fabricators and subcontractors the requirements of ISO 9002, ISO 9003 and ISO 9004. The Quality Assurance Plan will be prepared and presented in three different volumes namely:
    - o Volume 1 Quality Plan
    - o Volume 2 Quality Assurance Procedures; and
    - o Volume 3 Quality Control Procedures

B. Collectively the three Volumes shall comprise the Contractor's Quality Assurance Plan (PLAN). Each volume will address the issues enumerated in the following articles of this Section. The Quality Assurance Plan shall recognize and include the potential necessity for revision during the project at which time reauthorization shall be sought from the Engineer. Within thirty (30) days of the date of the Letter of Acceptance, the Contractor shall produce and submit to the Engineer an outline of the Plan. Within a further 30 days of the above submittal date, the Contractor will submit the detailed Plan incorporating the comments made by the Engineer. The authorized detailed Plan will be supplemented by comprehensive details for specific work activities at least 28 days prior to their commencement. The Contractor's Quality Assurance Plan will be managed and directed by a dedicated Quality Assurance (QA) Manager who will be physically present on the Project Site throughout the implementation and will report directly to both the Contractor's Site Project Manager and independently and directly to the Contractor's Home Office Senior Management. The QA Manager shall represent and be authorized by the company to manage quality assurance activities and to implement the Contractors QA system.

1.1.5.2 Requirements of Contractor's Quality Assurance Plan

This section of the Contractor's Quality Assurance Plan will address the following topics:

- Purpose and Scope
- Policy

1.1.5.3 Volume 1 "Quality Plan"

The purpose, scope and policy chapters will establish the general philosophy and parameters that the Contractor's Senior Management requires for the Quality Assurance Plan. Organization and Responsibilities will clearly present the detailed Contractor's Organization as it pertains to Quality Assurance and Quality Control activities. A description of assigned responsibilities is required. Project Management Review will address the Contractor's procedures for addressing quality issues raised by the Quality Manager to the Site Project Manager and Head Offices Senior Management. The standards that will be used to support the Contractor's Quality Assurance Plan are required to be listed. These will include all applicable industry codes, standards and practices and specifically those referenced in the Contract Documents and the Technical Specifications. For clarification in the use of the Contractor's Quality Assurance Plan document by Contractor's personnel it is required that a glossary of specific terms used in the documents be itemized (Definitions).

- Organization and Responsibilities
- Project Manager Review

- Applicable Standards; and
- Definitions.

1.1.5.4 Volume 2 "Quality Assurance Procedures"

This Volume will present clearly the Quality Assurance (QA) procedures developed by the Contractor to provide a planned and disciplined approach for the achievement of project quality objectives. The procedures, in general, require the prompt detection and correction of deviations, which are or may be, detrimental to quality or safety and generate documentation necessary to provide objective evidence of achievement of quality and safety objectives during design, fabrication, construction /erection and commissioning phases of the project. As a minimum the QA procedures will include but not limited to:

- Contractor's quality statement
- Contractor's organization structures including quality control organization
- Contractor's quality procedures addressing requirements of ISO 9001
- Principal staff and its tasks and responsibilities
- Contractor's plant management procedures
- Construction programme management
- Progress reporting procedures
- Contractor's design procedures
- Contractor's procedures for selecting and appointing Subcontractors and Suppliers including independent testing laboratories
- Contractor's procedures for obtaining, reviewing and approving Subcontractors and Suppliers quality procedures and for quality auditing of Subcontractors and Suppliers
- Contractor's risk assessments and method statements reporting in detail the proposed safe methods of working and measures to reduce risks or hazards to as low as reasonably practicable
- Control of construction /erection procedures with emphasis on:
- Plant control and approval; and Method statements, including transportation and handling of Plant.
- Verification, testing and reporting procedures for design, equipment, materials and workmanship in the office, factory or on site
- Document control procedure
- Health and safety procedures
- Environmental Management plan
- Site operational control procedures
- Contractor's internal quality audit control procedures
- Non-conformance reporting (NCR) procedures
- Closing out NCR for the Taking-Over procedures

- Training procedures
- Interim measurements and payment procedures
- Final measurement procedures
- As-built information and operation and maintenance manuals; and
- Change control of project quality procedures.

The plan shall include organization charts illustrating the main task and their sub-division, the reporting structure and:

- Interface between the Contractor, the Engineer and the Employer
- Interface within the Contractor's internal project team
- The Contractor's coordination with local and statutory authorities; and
- The Contractor's internal quality management arrangement including quality assurance and auditing personnel.

The QA Procedures are the requirement for the Quality Assurance Manager to formulate an audit plan, designate organizational elements subject to audits and establish a schedule for providing regular auditing activities. The Contractor's internal quality audit control procedures will be written and submitted to the Engineer for review and approval and as a minimum will contain the following items:

- Audit title and number
- Organization affected
- Purpose
- Scope
- Activities to be audited
- Performance standards
- Audit team members overall schedule
- Any interfaces
- Review and
- Approval authority and
- Schedule of audits.

The Contractor's internal quality audit control procedures and schedule of audits will be forwarded to the Site Project Manager and other key members of his organization. Engineer shall have the right to require revision of the Contractor's internal quality audit control procedures during the project.

1.1.5.5 Volume 3 "Quality Control Procedures"

A. This volume will present the procedures and systems that the Contractor will perform to maintain an effective Quality Control (QC) program. In general, the Contractor will perform sufficient checks, inspection and tests on all items of the Work including:

    - Design engineer

- Suppliers
- Subcontractors and
- Contractor's site work activities.

B. The Contractor shall ensure conformity with respect to the design, materials, workmanship, construction, finish and functional performance. The Quality Control Plan shall include adequate provision for access by the Engineer to inspect any and all facilities of the project and facilities required to implement the plan. Specifically, Volume 3 will address the following items as a minimum:

- The QC organization
- The number and qualifications of personnel to be used
- Authority and responsibility of QC personnel
- Methods and procedures of QC control for all the work including design, suppliers and subcontractors
- Inspection and Testing Plan
- Details of any off-site laboratory testing
- Offsite testing of manufactured items and type testing
- Procedures that will ensure that the latest applicable Drawings, shop drawings, the Employer's Requirements and instructions required by the Contract Documents, as well as authorized changes, are used for fabrication, construction/erection, inspection and testing and
- Procedure for the issuance, tracking and closeout of NON-Conforming Reports (NCR's) and Deviation Reports (DR's). This procedure shall prioritize the NCR's and ensure the closeout of such matters in a timely manner to the satisfaction of the Engineer.

1.1.6 Environmental Compliance

1.1.6.1 General

The EPC Contractor shall comply with all applicable national and local environmental regulations and guidelines, specifically the Azad Jammu & Kashmir Environmental Protection Act, 2000. The EPC Contractor shall strictly adhere to the mitigation and monitoring measures outlined in the Environmental Impact Assessment Report, the Environmental Management Plan (EMP), and the conditions that will be laid down in "No Objection Certificate (NOC)" that will be issued by the government of Azad Jammu & Kashmir, Environmental Protection Agency (EPA).

Reference is made to the environmental requirements given in;

A. The Law and Regulation of Government of Pakistan and Government of Azad Jammu & Kashmir, and relevant international standards (14001:2015 procedures).

B. Government of Azad Jammu & Kashmir Environmental Protection Act, 2000 and other applicable environmental rules and standards

C. Employer's Requirements for Environmental Protection given in subsequent Sections of Bidding Documents

D. Sub-clauses of General Condition of Contract and any other clause or sub-clause having any relevance to Environment

E. Local traditions and customs of Azad Jammu & Kashmir.

F. The EPC Contractor shall within one month of receipt of Notice to Proceed, appoint an Environmental Specialist/HSE Officer for the Works, whose broad responsibilities are to guide the construction personnel on environmental matters, to communicate and to make liaison with the Employer Engineer, Government of Azad Jammu & Kashmir, local stake holders, relevant departments such as Environmental Protection Agency (EPA), Fisheries Department, Forest Department, Wildlife Department and other relevant departments

G. The EPC Contractor shall (a) establish an operational system for managing environmental impacts, (b) carry out all the monitoring and mitigation measures set forth in the Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) for the project, and (c) allocate the budget required to ensure that such measures are carried out, and all cost for the implementation of such measures shall be borne by the Contractor. The EPC Contractor shall submit to the Engineer/Employer monthly and quarterly environmental reports on the carrying out of such measures.

The EPC Contactor needs to prepare the Site-Specific Environmental Management Plan (SSEMP) site-specific environmental plans as suggested in the EMP within the bidding documents and subsequent EIA Report. The EPC Contractor will also update the EMP as when required and submit to the Engineer/Employer for review and approval. No physical works shall commence until a Site-Specific Environmental Management Plan (SSEMP) is approved by the Engineer/Employer.

1.1.6.2 Environmental Compliance & Miscellaneous

The Contractor shall within one month of receipt of Notice to Proceed, appoint an Environmental Inspector for the Works, whose broad responsibilities are to guide the construction personnel on

environmental matters, to communicate and to make liaison with the Employer, Management Consultants, Government of Azad Jammu & Kashmir and local elders.

The Contractor shall provide Environment Management Plan of the Site as defined in Sub-section 16.6 of "Particular Conditions of Contract", Volume-I of Bidding Documents.

If the EPC Contractor erects any structure in the river bed which can break the supply of perennial river flow for irrigation or drinking purposes to downstream riparian or inhabitants, the Contractor shall ensure a regular supply of perennial river discharge to downstream riparian and inhabitants in accordance with their traditional rights.

Any breach of these environmental requirements or the approved SSEMP will result in a fine, which shall be deducted from the corresponding Environmental BOQ item(s). Furthermore, the Engineer reserves the right to withhold payment for these items during the period of non-compliance and issue a Work Stoppage Order for any significant breach until the issue is rectified at the Contractor's sole cost and to the satisfaction of the Engineer.

1.1.7 Training Programme

The Contractor's Training Progromme for the Employer's staff shall include the following provisions:

1. Comprehensive Operation and Maintenance training shall be provided to Employer's staff (Max 5 no.) from WAPDA approved Institutes.
2. On job training shall be provided to PMU and Employer staff during installation, testing and Commissioning of Electro-Mechanical equipment.
3. Managerial and advanced technical training abroad shall be arranged for Employer's nominated persons (Max 4 No) for 2 weeks. Training shall focus on Advanced O&M practices, case studies of similar hydropower projects etc.
4. The Payment to the Contractor for the Training (Local & Abroad) of Employer's O & M Staff shall be made as per the lump sum BoQ Item included in Part 3 – Price Schedules, Volume-I of the Bidding Documents for Lot-2.

1.1.8 Electrical and Mechanical Equipment

The Employer/Engineer may inspect the manufacturing and testing of electrical & mechanical equipment and workshop facilities at manufacturer's shop. The Contractor shall give at least six (06) to eight (8) weeks' notice to the Employer/Engineer for all important shop tests.

1.1.9 Documentary Film

The Contractor will prepare a documentary film showing all important events of assemblies, sub-assemblies and erection of all the equipment. The documentary will provide a commentary giving full details of events. Three (03) copies of the documentary Film will be provided to the Employer before completion of the Project. The Contractor will present the Employer the updated documentary film on three (03) month basis for his review and approval.

1.1.10 Joint Operation and Defect Liability Period

Contractor shall successfully complete one (01) year joint operation of the project during DLP Contractor will deploy well qualified staff for Works to work with the local staff of the Employer and

train them in the routine O&M activities. The medium of interaction between the contractor staff and the Employer staff will be English.

1.1.11 Mobilization and Demobilization

A. The Contractor shall also furnish all the labour, materials, equipment and shall perform all work required for mobilization to and demobilization from the project Site.

B. Mobilization shall include, but not be limited to, moving personnel, plant, and equipment to the Site; arranging for necessary Site utilities; establishing camps, shops, offices and administrative facilities; construction of storage yards and facilties for the plant and obtaining all required permits, licenses, and other regulatory authorizations required by the Contractor for the construction of the project.

C. Demobilization shall include, but shall not be limited to, removing all plant, equipment, and temporary facilities from the Site; disconnecting temporary utilities; relocating personnel from the Site; cleaning-up and restoring all areas occupied by the Contractor; closing out permits, licenses, and other regulatory authorizations; and disposal of all waste materials and excess construction materials which are not the property of the Employer.

D. Cost of mobilization and demobilization shall be deemed to cover in other items of the Price Schedules. No separate payment shall be made to the Contractor on account of mobilization and demobilization in accordance with the contract provisions and as instructed by the Project Manager.

1.1.12 Operation and Maintenance Manuals

The Contractor shall provide operation and maintenance manuals, for all equipment and plant which must be in English.

The Contractor shall provide to the Employer tools and spare parts sufficient for five (5) years of operation together with a recommended priced list of spare parts. The foreseen mandatory spares are included in the Part 3 – Schedule of Prices, Volume-I of the Bidding Documets. The Contractor shall construct proper and sufficient storage facilities for such tools and spare parts.

1.1.13 Project Completion Report

The Contractor shall provide Project Completion Report, for all electrical & mechanical equipment including all references, which must be in English.

1.2 Basic Design Criteria

1.2.1 General

1.2.1.1 Design Criteria

The Plant shall be designed according to the latest version of international standards. The completed Plant shall be safe, durable and adequate for intended purpose under most severe loading conditions where there are differences between the various standards; the most conservative standards shall be adopted. Whichever standard shall be applied, the latest revision or edition in effect at the time of the invitation of bidders shall be preferred and the Contractor must make available two copies of such standards in English language. If other standards shall be

chosen, the contractor shall supply copies of those standards in English language only, clearly identifying or making reference to the particular chapters or sections that shall be applied. The other standards must be international level will be only accepted if and only if these must fulfil the criteria of equivalent or better. The approval for adoption of such standards must be necessary from the Employer /Engineer.

The detailed design shall be based upon the design criteria stated herein, the Design Memoranda submitted with his Bid, and additional Design Memoranda and design analysis as necessary to complete the design of the Plant.

Temporary works shall be designed to be safe, reliable, and adequate for all loads and uses.

1.2.1.2 Compliance with Local Regulations

In addition to the Basic design criteria, the design shall also conform to the requirements of all relevant local, state and federal authorities where approvals for that section of works is needed from the relevant authorities.

1.2.1.3 Economic Life of Works

The design shall be based upon a useful economic life of not less than 30 years for plant and equipment, assuming the Employer will operate the works and perform normal routine maintenance in accordance with the works operation and maintenance manuals.

1.2.2 Design Responsibility

The design of Civil, Anciliary Services and Hydraulic Steel Works shall be the responsibility of EPC Contractor for Lot-1. The design of Mechanical, Electrical and associated Works shall be resposnbility of EPC Contractor for Lot-2.

1.3 Bid Submissions

1.3.1 Bid Level Design

The Bidder shall submit as a minimum to define its offer, the Bid Drawings, Bid Level Design Criteria, Data and Design Briefs and Construction /Erection Specifications. The Design Briefs shall be intended to represent the essential information required to evaluate the Bids and to highlight:

a) Design parameters and Methodology

b) Design Criteria

c) Power and Energy Calculations

d) Construction Work Schedule

e) Operating characteristics of the Project and its component parts.

1.3.2 Bid Drawings for Electrical and Mechanical Equipment

As a minimum the following drawings shall be necessary to define the project Electro-mechanical, Mechanical and I&C equipment;

Drawings showing the general arrangement of the equipment Plans, Elevations and Sections (including principal dimensions).

1.4 Contractor's Documents

1.4.1 General

The Contractor's Documents to be submitted to the Employer / Engineer for review as defined in Conditions of Contract **(Clause 6.1, 6.5, 6.6 & 6.7) comprise:**

Table 1: Contractor's Documents to be submitted

Description	Review Period	No of Copies for Review	No of Copies for Final Issue	Digital Copy
Detailed Design Criteria	28 days	4	5	**2**
Detailed Design Specifications	28 days	4	5	**2**
Conceptual Design (Level–1)	28 days	4	5	**2**
Detailed Design (Level–2)	28 days	4	5	**2**
Construction /Erection drawings	28 days	4	5	**2**
Manufacturer's shop drawings	28 days	4	5	**2**
Inspection and Test Plans	28 days	4	5	**2**
O&M Manuals	28 days	4	5	**2**
Erection and Testing manuals	**28 days**	**4**	**5**	**2**

1.4.2 Procedure

1. The sequence in which documents are submitted shall follow a logical progression such that all information is available to the Employer/ Engineer to facilitate review of each submittal when it is received. The programme for detailed design shall allow the required time for review by the Employer/ Engineer.
2. All submittals shall include two copies in Digital form as well as the prescribed number in hard copy. In general design submittals shall be in:
    - MS Word format for all text and reports
    - MS Excel format for tables and design calculation sheets
    - MS Power Point format for all types of presentations
    - AutoCAD latest release or as advised for all drawings
3. The Contractor shall provide on each submittal a clear space for the Employer / Engineer's review stamps and comments.
4. Drawings and all supporting data, catalogues, or similar information shall be prepared by the Contractor or his suppliers and sub-contractor, but shall be submitted as instruments of the Contractor.
5. The Employer / Engineer will review submittals only for conformance with the design concept of the Project and for compliance with the contract. Contractor shall make all necessary corrections.
6. After the Employer / Engineer has performed his review of submittals, he will return one print to the Contractor with one of the following notations:
7. Approved. (A)

8. Approved except as noted. (AEN)
9. Revise and resubmit. (RC)
10. Rejected. (R)
11. When submittals are returned marked with either RC or R, the Contractor shall make such revisions and/or corrections and resubmit the drawings or other material in the same manner as specified.
12. When drawings and submittals are returned with authorization to proceed with the work, Contractor shall provide the number of prints or copies of drawings as is required for field distribution.

1.4.3 Basic and Level–1 Design

The basic design of the Works shall be the Tender Design together with any agreed modifications incorporated in the Contract Agreement. The Level–1 design shall comprise development of the Basic Design to the level of detail necessary for fabrication and construction/erection.

1.4.4 Detailed Design (Level–2)

Detailed designed will be submitted just after the approval of Level–1 design. Detailed design submissions shall include design memoranda, analyses, drawings, instructions, and specifications in accordance with the requirements of the specifications and as outlined herein. The sequence of submission shall progress as per approved schedule.

1.4.5 Inspection and Test Plans

Inspection and test plans shall be submitted for factory Tests and Tests on Completion. Tests on Completion shall be carried out in two stages: Dry tests followed by wet testing, commissioning and reliability tests.

1.4.6 Erection and Testing Manuals

Detailed erection and testing procedures shall be submitted along with instructions regarding handling and storage of all equipment at least two months before the start of erection of the first unit.

1.4.7 Operation and Maintenance Manuals

Three (3) months prior to scheduled commissioning of the Project, the Contractor shall provide detailed manuals (in English) with drawings and schematics setting out the operations and maintenance procedures for all mechanical and electrical works and equipment, including specifications, equipment data sheets, vendor data and shop drawings.

1.4.8 As-Built Drawings

The Contractor shall provide five (5) copies of detailed "as-built" drawings for the Project, including all mechanical, and electrical general arrangements, and shop drawings of major equipment. These are to be based on the Contractor's "approved shop" drawings and field information.

All drawings shall be provided in hard copy, and the Contractor shall also provide "AutoCAD" files..

1.4.9 Commissioning Reports

Within one month after the Completion Date the Contractor shall issue to the Employer the Commissioning reports including copies of all test records.

1.5 Environmental Aspects

All aspects of the Contractors Site Installation shall conform to the requirements of Sub Clause **16.6, of "Particular conditions of contract", Volume-I of the Bidding Documents.**

SECTION 2: PROGRAMME & PROGRESS REPORTS

2.1 Programme

The Contractor shall submit the proposed programme for the design and execution of the Works in accordance with **Clause 12.1 of the Conditions** of Contract in a format and media approved by the Employer / Engineer. The proposed programme shall be in two levels of details as follows:

- The Overall Programme which shows the major work items of the Works.
- The Detailed Working Programme which shows further breakdown of the major work items into activities involved in the sub-items.
- The Contractor shall identify critical activities and key dates and shall present the programme in bar chart form indicating activities and dates critical to completion of the Work on time.

The Contractor shall submit an explanatory report covering any aspect of the chart or network that the Contractor cannot show on the chart. The Contractor shall agree with the Employer's Representative on the work section, activities, sub-activities, interface and other critical dates, which the Contractor has to identify in the programmes. Upon agreement by the Employer / Engineer, the proposed Overall Programme shall become the Overall Works Programme based on which the Contractor shall complete the Works on time. This Overall Works Programme shall not be changed unless agreed with the / Engineer.

The Detail Working Programme shall contain the items, which are breakdowns of the major items, such that no activity shall have a duration not exceeding 30 days. The programme shall identify any interface requirements affecting the work, the main quantities of material and other agreed relevant information.

2.2 Progress Reports

Each month the Contractor shall report on a day in a format and media approved by the Engineer, the progress and financial status of the Works of the previous month. The report shall accurately estimate the work completed on each activity including the design activities shown on the accepted Overall Works Programme and the Working Programme. The Contractor's progress report shall include relevant progress photographs. The Contractor shall agree with the Employer / Engineer and shall implement progress control procedures.

The Contractor's execution of the construction work shall not deviate from the sequence shown in the approved overall Work Programme without prior written permission from the Employer / Engineer.

2.3 Fortnightly Progress Meetings

Fortnightly progress meetings will be held with the Employer and Engineer. Bottlenecks will be discussed and resolved. Special meetings will be held as and when required.

The Fortnightly Detailed Working Programme shall be submitted to the Employer / Engineer for approval fortnightly and must show at least previous Fortnightly progress and the future two (2) Fortnightly planned works.

2.4 Photographic Records

The Contractor shall take progress photographs in digital camera during progress of work, which shall be attached to the monthly progress report. Each of these photos shall be submitted in 3-fold as paper copies in colour. The sizes of the photos shall be 10 x 15 cm. Every month at least twenty (20) colour photos for each report shall be supplied.

The Contractor shall also prepare movie up to international standard of all the activities occurred on the project, from date of starting to end of the project.

SECTION 3: SUBMITTALS

3.1 Description

The Employer shall undertake a comprehensive review of the design submitted by the Contractor for the Project pertaining to the information described. To facilitate this review, submission requirements noted in this section shall be met by the Contractor.

3.2 General Aspects of Submittal and Review

1. Review of designs for the Project by the Engineer shall be carried out in two stages whereby the proposed conceptual design is reviewed at "Level 1", after which the detailed design drawings, fabrication drawings, technical specifications, etc. shall be submitted for review at "Level 2". With respect to custom engineered and manufactured items, Level 2 reviews shall take place prior to commencement of manufacturing. Thereafter, the Contractor may proceed with schedules, etc., for construction, fabrication and erection.
2. All criteria, design statements, design calculations, computer input and output, specifications, method statements, drawings, catalogue cuts, and any other information submitted, shall be individually numbered on each sheet, indexed, collated, bound, and with summary sheets for discrete portions of the records so that adequate monitoring of revisions, modifications, and the general flow of the design process can be easily understood. Text shall include both line numbering and pagination, and computer programs used shall be explained in a summary statement of the input output and analytical process. The Contractor shall make available, at the Employer's / Engineer's request, any and all information upon which the Project design is based - suitably collated and indexed - including, but not limited to the results of hydraulic and other model test results and manufacturers' data.
3. In order to facilitate the design review process, the Contractor shall make accommodation for full-time representatives of the Employer in any or all of the Contractor's design offices, and such representative shall be given full and complete access to the development of design concepts, and detailed design process.
4. Schedules of all proprietary components proposed for use in the Project shall be provided at Level 2 and shall fully describe each component. The proposed use of components with poor availability and/or service support may be rejected at the discretion of the Employer.
5. Five (5) copies of all detailed construction/erection and fabrication drawings shall be issued to the Employer not later than 21 days before construction/erection, fabrication or procurement of any particular aspect of the work is commenced. The Employer will not carry out a formal review of final construction / erection drawings, details and schedules but reserves the right to require revisions where design aspects do not comply with those reviewed at Level 2.
6. When drawing up the construction schedule, the Contractor shall make adequate allowance for the twenty-eight (28) days design review period by the Engineer in accordance with Clause 12.1 of the Conditions of Contract and other authorities concerned with the design and environmental impact aspects of the Work.
7. The following table represent the numbers of submittals required:

Table 2: Submittals Required

Documents	Hard Copy	Digital Copy
Detailed Design criteria	5	2
Detailed Design specifications	5	2
Detailed Cv's and Docs. of design team	3	2
Detailed Work Plan	5	2
Detailed EMP	5	2
Detail QA and QC Plans	5	2
Level 1	5	2
Level 2	5	2
Detailed Construction /Erection Documents	5	2
As built	7	2
Project Completion Report	7	2

The Employer reserves the right to request additional, (both hard copy and digital) of submittals where necessary to facilitate the work progress

8. Within 30 days of notice to proceed the Contractor shall submit a schedule of Level 1 and Level 2 submissions that matches the overall work program.

3.3 Design Liability

Notwithstanding any review carried out by the Employer, the Contractor shall accept full responsibility for all aspects of the design, procurement, construction /erection, testing and commissioning of the Project.

3.4 Special Requirement for Site Installation

The Contractor shall submit, with his tender, drawings showing the overall layout of the proposed site installation. This layout shall be compatible with the general layout included in the Tender Drawings. The final layout of site installation shall be agreed with the Employer's Representative prior to award of the Contract.

The Contractor shall present at least twenty-eight (28) calendar days in advance of the starting date of the works, drawings and specifications sufficiently detailed to enable the Employer's Representative to check the suitability of the proposed construction and installation and their conformity with this Specification.

3.5 Level 1 Review

The Contractor shall, within approximately three (3) months, but not more than four (4) months, of the Notice to Proceed, submit general arrangement drawings showing the conceptual layout of the plant, together with outline commentaries giving design philosophy, construction /erection standards, and criteria, principal design data, project procedures, quality assurance systems, and the proposed construction schedule.

The Employer shall review and agree **in principle or otherwise respond in accordance with the requirements of Clause 6 of the Conditions of Contract. Reviews may be carried out section by**

section following discussions on particular aspects of the design proposals. Information required by Employer for Level 1 Review shall include but not necessarily be limited to:

Drawings - Site layout; general arrangements of plants to be instllateed at the powerhouse, switchyard and transmission line route long with construction schedules.

Design Statements - Overall design concept, stability and detailed design criteria for plant, loading conditions, etc.

Project Procedures Manual - Procedures for design, approvals, procurement, construction/erection, scheduling, progress reports, etc.

Quality Assurance (QA) Manual - Description of QA system. As part of Contractor's QA Procedures, all equipment installed in the Project shall be tested and inspected during manufacture in accordance with relevant International and/or other national standards acceptable to the Employer. At appropriate stages during manufacture, trial assembly prior to shipping from the manufacturer's plant and final assembly on site, the manufacturer's facilities shall be made available for inspection by the Employer. Adequate notice shall be given so that arrangements may be made for such tests and such plant inspections.

3.6 Level-2 Review

Following agreement in principle to the Level 1 design concepts, the Contractor shall submit detailed general arrangement drawings, specifications and calculations of all principle component parts of the Project for review by the Employer. The Contractor shall also submit a schedule of all inspections and tests to be carried out on major equipment and a list of drawings and documents together with a schedule for submission of same. The drawings and document list and schedule shall be updated and resubmitted at intervals throughout the Level 2 review period. Drawings and documents shall be submitted in a logical sequence and in a structured manner to provide an even flow of material, and the Employer will review and comment in accordance with the requirements of Clause 6 of the Conditions of Contract.

3.7 Review Process

1. The Contractor shall provide on each submittal a clear space for the Employers review stamps and comments.
2. After the Employer has performed his review of submittals, he will return one print to the Contractor with one of the following notations:
    a. Proceed without change.
    b. Proceed as corrected.
    c. Revise and resubmit.
    d. Rejected.
3. When submittals are returned marked with either (c) or (d), the Contractor shall make such revisions and/or corrections and resubmit the drawings or other material in the same manner as specified.
4. When drawings and submittals are returned with authorization to proceed with the work, Contractor shall obtain and provide such number of prints or copies of drawings as is required for field distribution.

5. The Employer will review submittals only for conformance with the design concept of the project and for compliance with the Contract Documents
6. Contractor shall make any and all corrections required.
7. Drawings and all supporting data, catalogues, or similar information shall be prepared by the Contractor or his suppliers and sub-contractor, but shall be submitted as instruments of the Contractor.
8. Contractor shall check the submittals of his suppliers and sub-contractor, as well as his own submittals, before submitting them to the Employer. In particular, Contractor shall ascertain that the submittals meet all requirements of the Contract Drawings and Specifications and conform to all structural and space conditions.
9. All submittals shall be accompanied by a written statement, signed by the Contractor, that they have been checked by him and found to be in accordance with the Contract Drawings and Specifications and that proper provision has been made to accommodate ail abutting work. This statement may be in the form of a rubber stamp bearing the Contractor's signature.
10. Contractor shall be fully responsible for observing the need for and making any changes to the arrangement of piping, connections, wiring, manner of installation, and the like, which may be required by the equipment.
11. Submittals, including manufacturers' literature, catalogue cuts, or other printed material, shall be entitled with the name of the project on each sheet and shall otherwise be identified by listing the particular Division, Section, Article, or reference of the Work and Contract Documents pertaining thereto. Differing items shall not be submitted on the same sheet.

SECTION 4: QUALITY ASSURANCE/ QUALITY CONTROL

4.1 Description

The Contractor shall be completely responsible for implementing a Quality Assurance Plan covering all the Works contained in the Contract including the design. The Quality Assurance Plan will be prepared by the Contractor and reviewed and authorized by the Employer's Representative and will be implemented by the Contractor. Specifically, it will be managed by the Contractor's Resident Quality Assurance Manager. The Contractor's Quality Assurance Plan shall ensure the control and quality of all design functions, all fabrication by the vendors and sub-contractors and all construction activities carried out by work forces and sub-contractors.

4.2 The Contractor's Quality Assurance Plan

The Contractor's Quality Assurance Plan shall meet all the requirements of the International Standards Organizations. As appropriate the Contractor shall impose on his designers, vendors, fabricators and sub-contractors the requirements of latest IS0 9001, 14001and 18000.

SECTION 5: ENVIRONMENTAL PROTECTION & MISCELLANEOUS

5.1 Environmental Management

The Contractor shall comply with all legal duties and obligations regarding the protection of the environment as laid down Laws and Regulation of Governments of Pakistan and Azad Jammu & Kashmir.

5.2 Water Quality

The Contractor shall submit proposals for the Employer's Representative's approval for all waste water and foul effluent from offices, workshops and site accommodation to be collected and treated at a waste treatment plant prior to discharge into open water courses or into ground water.

Where construction methods involve pumping of ground water, the Contractor shall submit proposals for monitoring and the disposal of water discharges.

5.3 Waste Management

The Contractor is fully responsible for the day-to-day management on waste collection and disposal. The Contractor must make arrangements for waste management for the collection and the disposal of domestic and industrial refuse, by handling, transport or storage of schedules wastes outside the premises and its safe disposal at a location approved by the Employer Representative.

The Contractor must ensure that all the necessary utensils such as proper storage containers or bins for refuse and kitchen wastes, special storage containers for scheduled wastes, temporary sewerage plants or toilet facilities are provided at the premises.

The Contractor must also comply with the following environmental conditions throughout the construction stage:

1. All effluents produced must be treated to comply Law and Regulation of Government of Pakistan before discharge into area approved by the Employer's Representative. The effluent shall never be discharged into river/ canal without treatment;
2. Temporary sewage treatment for toilet facilities in accordance with the specifications as prescribe by the Law and Regulation must be provided at the Contractor's site office and worker's camps before the commencement of any works;
3. Open burning of solid wastes including biomass waste and construction debris is strictly not permitted;
4. Handling and disposal of scheduled wastes must comply with the requirements of the Law and Regulation of Government of Pakistan;
5. Waste oil and grease arising from the construction activities must not be disposed into any nearby watercourse. These wastes must be stored in proper drums/containers and either reused or disposed at the site as approved/licensed by the Director General of Environmental Quality.

5.4 Avoidance of Nuisance

The Contractor shall take all reasonable precautions to avoid causing a nuisance with dust noise or vibrations arising from his operations. This provision is in addition to but not in substitution for the

provisions of the Conditions of Contract. The Contractor shall ensure that all emissions and noise levels strictly comply with the National Environmental Quality Standards (NEQS) of Pakistan adopted by the AJK-EPA.

The Contractor shall not obstruct, as far as possible, the normal rights of way of the users of the public roads and where this is necessary and unavoidable, he shall provide barriers, roads signs, warning lights, etc. required for proper traffic control including getting the necessary permits from the Police Department and other local authorities and paying all fees in connection therewith.

The Contractor shall be responsible for clearing and cleaning all existing streets, roads, drains, etc. at regular intervals, or when directed by the Employer's Representative and keep the approaches to the site clear of mud and obstruction.

The Contractor shall be liable and shall indemnify the Employer in respect of any claims or proceedings arising out of his neglect in taking care to avoid creating a nuisance when carrying out the Works.

5.5 Notice to Service Authorities

The Contractor shall make at his own expense all necessary arrangements for notifying the service authorities of required connections, removals and relocations of all public utilities and services affected by the Works.

Sufficient time shall be allowed for such notification as may be required by the relevant authorities so that appropriate action can be taken regarding the execution of the removals and relocation.

5.6 Utilities and Other Services

The Contractor shall be responsible for locating the position of all utilities, including mains, overhead and underground cables, pipes, sewers and drains, and where necessary shall adopt such methods of excavation as may be required by the appropriate authorities or Employers to ensure that no damage is caused to them.

The Contractor shall make good, at his own expense, any damage what so ever to existing utilities to the complete satisfaction of and in accordance with the instructions of the relevant authority or Owner concerned, and shall keep the Employer indemnified at all times from all claims, costs and expenses which may be brought against or incurred by the Employer for or on account of any damage (whether permanent, temporary or recurring) to the said utilities. All utilities, which are encountered in the course of the Works, shall be adequately supported, slung up, strutted or otherwise protected from damage to the satisfaction of the persons or authority in which they may be vested.

Due allowance shall be made by the Contractor for the effect on the phasing of the Works of relocations to existing public and private mains and utilities necessitated by the Works. The Contractor shall ensure that such existing mains and utilities are not interrupted without the written consent of the relevant authority or the owner of the utilities concerned.

If any privately owned utilities for water, electricity, telephone, drainage. etc., passing through the Site are affected by the Works, the Contractor shall provide an approved equivalent alternative service in full working order to the satisfaction of the Employer of the utility and the Employer's Representative, before the cutting of the existing utility, and until the completion of the permanent replacement of the utility.

5.7 Prohibition of Advertising

The Contractor shall treat the Contract and everything written as private and confidential. In particular, the Contractor shall not publish any information, advertisement, drawing or photograph relating to the Works and shall not use the Site for advertising purposes, except with the written consent of the Employer and subject to such conditions as he may prescribe.

5.8 Explosives

The Employer's Representative shall have the power to regulate, restrict or prohibit the use of explosives, explosive powered tools, or the like in the Works if in his opinion it is necessary to do so for the safety of persons or property or to safeguard the Works.

No blasting shall be carried out in any part of the Works without the written permission of the Employer's Representative. Such permission shall not absolve the Contractor from any of his obligations or liabilities under the Contract and he shall take all necessary precautions including the use of blasting nets or mats to avoid damage, loss or injury to persons and to public or private property.

The Contractor shall keep the Employer's Representative fully informed at all times when blasting is proposed to be carried out and of any details that may be required by the Employer's Representative concerning strength of charges and their positions.

Explosives shall not be used within 30 m, or such greater or lesser distance as the Employer's Representative may direct, of concrete placed in the Works, of any existing structure, pipeline, electric cable or overhead power or telephone lines, etc.

The Contractor shall obtain at his own expense the necessary licenses from the concerned Government Authorities for the use, handling, transporting and storage of explosive and shall comply at all times with the requirements of the Police Department, and other authorities having jurisdiction in the area of the works, as may be conditional upon the granting of such licenses.

SECTION 6: EQUIPMENT PRESERVATION AND STORAGE AT SITE

6.1 General

The Jagran-IV hydropower Project, due to its location at high altitude, sever now fall, negative temperature and excusive humidity for months, requires special facility for safe storage of sensitive plant and equipment at site, prior to its installation.

- **Special Storage Facility:** The Contractor may construct a single warehouse split into two distinct structural zones, or two separate adjacent blocks to minimize the sever climate aspects at site of Jagran-IV Hydropower Project as described below:
    1. **Zone 1 (Premium Conditioned Space – max 20% of total area):** A highly insulated, tightly sealed room constructed of 100 mm polyurethane sandwich panels specifically for control systems, SCADA, and excitation panels.
    2. **Zone 2 (Basic Covered Space – max 80% of total area):** A lightly insulated (50 mm) pre-engineered steel building (PEB) with corrugated sheets for heavy turbine components, casings, runners, and structural steel.
- **Optimized Roof Pitch:** The steel frame of the truss to be used at site, shall have a 1:1 slope of the roof for excellent snow shedding and to minimize the snow accumulation. Since snow may still accumulate due to ice formation, partial melting and refreezing, therefore consideration of minimum snow loads shall still be required in view of the relevant codes e.g. ASCE 7, Euro code EN 1994-1, National building codes for such cases.
- **Civil Works Economy:** Instead of a single ultra-thick concrete slab across the entire facility, the floor slab may be optimized. A limited portion of the pedestrian shall be of standard reinforced concrete slab of 200 to 250 mm thick, whereas remaining shall be of 150 mm. Before placing the pedestrian, the firm and mountainous ground shall be leveled and well compacted, may have layer of 75 mm of lean concrete under the pedestrian slabs. The outer perimeters of the storage PEB building block to be protected with a suitable foundation of suitable depth, to protect against scouring during rains or flow caused by snow melt. All such designs or drawings are subject to review of the Engineer and approval of the Employer.

6.2 Localized Climate Control

- **Internal Strip Heaters:** The factory-installed internal anti-condensation space heaters inside the generator stators and large electrical cubicles must be continuously energized.
- **Targeted Tarpaulin Tents:** If external electrical panels must sit in Zone 2, they must be clustered together, draped in heavy-duty thermal tarpaulins, and kept warm using small, localized 500W electric space heaters under the canvas.
- **Passive Moisture Control:** In place of high-power commercial industrial dehumidifiers in the large Zone 2, moisture control shall be managed passively via heavy application of desiccant (Silica Gel bags) placed inside the equipment's original sea-worthy packing crates, replaced or baked dry every 4 weeks.

6.3 Power Infrastructure Optimization

- **Optimized Standby Generator Sizing:** By limiting continuous space heating to Zone 1 and utilizing localized strip heaters in Zone 2, the total peak electrical load of the facility is heavily

reduced. The standby Diesel Generator (DG) set shall be sized strictly for this optimized load, eliminating the need for a massive, expensive power plant.

- **Utilization of the Contractors Equipment:** The Contractor is encouraged to utilize the same Contractor's equipment (mobile crane or heavy-duty forklift) intended for permanent powerhouse installation to execute the initial warehouse offloading and positioning.

6.4 Packing and Preservation Mandates (Vendor-Level Preservation)

The Contractor shall ensure that all equipment received at site remains in its original, multi-layer export sea-worthy packing. Machined surfaces (shaft journals, runner flanges) must be coated with heavy, weather-resistant rust-preventative compounds (e.g., Tectyl or outdoor-grade grease) and vacuum-sealed in heavy VCI (Vapor Corrosion Inhibitor) plastic sleeves. This reduces the cleanroom requirements of the physical building.

6.5 Contractor Liability for Improper Preservation and Moisture Damage

6.5.1 Maintenance and Monitoring Obligations

The Contractor shall assume full, unbroken custody and care of all electro-mechanical equipment from the moment of physical handover or arrival at the project site storage facility. Where passive desiccant preservation, localized tarpaulin heating tents, or internal equipment space heaters are deployed as an economized preservation strategy, the Contractor shall strictly maintain, monitor, and log these systems.

Desiccant silica gel bags must be inspected, weighed, and replaced or baked dry every four (4) weeks (or more frequently if indicated by moisture color indicators). Internal space heaters must be monitored daily to verify continuous power connectivity and thermal function.

6.5.2 Definition of Preservation Failure

A "Preservation Failure" shall be defined as any occurrence where:

- The Contractor fails to update the physical or digital moisture inspection logs for any individual equipment crate or enclosure for a period exceeding seven (7) calendar days past the scheduled inspection date.
- Relative humidity inside an equipment enclosure or vacuum-sealed shroud exceeds seventy percent (70% RH) due to saturated, spent, or un-rotated desiccant materials.
- Localized anti-condensation strip heaters or tarpaulin heating tents experience unaddressed power failures exceeding twenty-four (24) continuous hours.

6.5.3 Liability for Damage, Rust, and Moisture Ingress

In the event of a Preservation Failure resulting in surface rust, corrosion, insulation degradation, mold, fungus, micro-pitting of machined surfaces, or moisture ingress into windings and electronic panels, the Contractor shall be held exclusively liable.

Upon identification of such damage by the Employer or the Engineer, the Contractor shall, at their own expense and with no impact on the project schedule, immediately execute the following remedial actions:

1. **Specialist Evaluation:** Hire the original equipment manufacturer (OEM) or an approved third-party technical specialist to inspect the severity of the degradation and issue a formal restoration protocol.
2. **Rectification and Refurbishment:** Execute all required sandblasting, chemical rust removal, re-coating, rewinding of stator/rotor sections, or replacement of corroded components strictly in accordance with the OEM's certified standards.
3. **Replacement of Corrupted Elements:** If digital control systems, SCADA blocks, electronic relays, or precision turbine components are deemed compromised or unreliable by the Engineer due to moisture exposure, the Contractor shall procure brand-new OEM replacement units at their own cost.

6.5.4 Financial Penalties and Liquidated Damages

- **Direct Rectification Deduction:** If the Contractor fails to immediately initiate repairs within forty-eight (48) hours of damage identification, the Employer reserves the right to engage the OEM or an independent Contractor to rectify the damage. All associated costs, including airfare for international OEM engineers to visit Neelum Valley, shall be deducted directly from the Contractor's running invoices or retention money.
- **Preservation Negligence Penalty:** In addition to repair costs, a non-refundable penalty of USD 500 per affected equipment unit per week shall be levied against the Contractor for every week the equipment remains in a compromised state due to documented negligence of passive preservation protocols. Such additional penalties of specifc part of the work shall be additional to the routine penalties clauses.
- **Project Delay Liability:** Any delay to the overall commercial operation date (COD) of the hydropower plant resulting from the rectification or replacement of moisture-damaged components shall be subject to the standard Project Liquidated Damages for Delay clause, without prejudice to the specific equipment repair costs outlined herein.

6.6 Employer Liability

Employer liability in this regard shall be limited only to the extent of providing land for the site storage facility upto maximum of 4000 sft in its original available Natural state in consultation with Project Manager. If more land is required, the Contractor shall acquire land on lease or rental basis. The Contractor is liable to provide the design drawings and necessary layout of site storage facility immediately based upon the approved design of equipment before starting manufacturing process enabling Employer and Consultants to jointly identify and approve the site storage facility land.

6.7 Measurement & Payment

Cost of equipment preservation and storage at site shall be deemed to cover in relevant Price Schedules. No separate payment shall be made to the Contractor on account of construction of storage facilities, climate control measures, power supply, preservation of equipment, etc. in accordance with the contract provisions and as instructed by the Project Manager.

SECTION 7: PROJECT SIGNS

7.1 Project Sign Boards

The Contractor shall design, supply, erect and maintain one signboard, approximately 2 m wide by 1.5 m high, at the entrance of the Site or at a location to be agreed by the Employer. The Employer's Representative shall review and agree the Contractor's design. The Contractor shall employ an experienced sign-writer to prepare the signboard.

The Contractor shall remove the signboard and associated footings on completion of the Works and leave the site in the specified condition.

The Contractor shall not display any advertisements within or around the Site without the prior written approval of the Employer's Representative.

SECTION 8: COMPLETION

8.1 Site Clearance

After completion of the Works, the Contractor, with prior approval of the Employer's Representative, shall:

- Remove all Contractor's buildings, installation and temporary facilities,
- Shall fill with earth all basements and underground areas, clean up and restore the terrain to its original condition, and
- Treat the excavations executed for his own convenience, such as temporary roads, in a way acceptable to the Employer's Representative.

If the Contractor shall fail to remove the buildings, plant, equipment and installations or if the operation shall not be made as specified within two (2) months from completion of the Works, such buildings, plant, equipment and installations may be removed by the Employer and the removal costs shall be deducted from the Contractor's final payment.

The Employer shall have the right to take-over a part or all of such buildings and installations at no extra cost. All buildings and installations shall be handed over in good condition.

Temporary roads constructed for the Contractor's use, the Employer's Representative shall indicate in which condition the areas shall be left, and the Contractor shall establish this condition at his own cost.

8.2 Project Records

8.2.1 Project Record Documents and Samples

Contractor shall maintain one record copy of:

1. Contract Drawings
2. Specifications
3. Addenda
4. Change Orders and Other Modifications to the Contract
5. Approved Shop Drawings, Product Data and Samples
6. Approved Construction Drawings & Erection Sequence Drawings for E&M Equipment.
7. Approved control, protection and instrumentation Drawings
8. Field Test Records
9. Inspection Certificates
10. Manufacturer's Certificates

Record Documents and samples shall be stored in Contractor's Field Office apart from documents used for construction. Files, racks, and secure storage for Record Documents and samples shall be provided.

Record Documents shall be maintained in a clean, dry and legible condition. Record Documents shall not be used for construction purposes.

Record Documents and samples shall be available for inspection by Employer's Representative.

8.2.2 Submittals

On completion of works, Contractor shall deliver Record Documents to Employer's Representative including the Contracts Drawings in reproducible ink-on-mylar sheets that match the contract documents (size, sheet content and title block).

Accompany submittal with transmittal letter, in duplicate, containing:

1. Date
2. Project title and number
3. Contractor's name and address
4. Title and number of each record document
5. Certification that each document as submitted is complete & accurate
6. Signature of Contractor, or his authorized representative.

SECTION 9: INTERFACE BETWEEN C&HH AND E&M CONTRACTORS

9.1 General

Interface management between the Civil & Hydraulic Steel Structure Works (C&HSS) Contractor and the Electrical and Mechanical (E&M) Works Contractor shall be implemented to ensure proper coordination, compatibility of works, and timely execution of the project components. The interface management system shall cover all physical, technical, and operational interactions between the civil & hydraulic steel structures and the installation of electrical and mechanical equipment. Both Contractors shall cooperate closely to ensure that civil works such as foundations, embedded parts, openings, and structural provisions are constructed in accordance with the requirements of the E&M installations. Effective communication and coordination shall be maintained to avoid conflicts, delays, or rework during construction and installation activities.

9.2 Scope of Interface Management

The scope of interface management shall include coordination of design information, construction sequences, embedded components, installation requirements, testing procedures, and commissioning activities related to C&HSS and E&M works. Particular attention shall be given to areas where the works of the two Contractors interact, such as powerhouse structures, intake and gate systems, pressure conduits, crane systems, cable routes, drainage systems, and equipment foundations. The Contractors shall ensure that all interface requirements are clearly identified and implemented during the design review, construction, and installation stages.

9.3 Interface Coordination Responsibilities

9.3.1 Responsibilities of the Civil Contractor (Lot 1)

The C&HSS Contractor shall construct all civil structures required for the installation and operation of electrical and mechanical equipment in accordance with approved drawings and specifications. This includes the provision of equipment foundations, anchor bolt pockets, embedded plates, sleeves, cable trenches, equipment openings, and structural supports required for E&M installations. The C&HSS Contractor shall ensure that all dimensions, levels, and tolerances of civil and hydraulic works comply with the requirements provided by the E&M Contractor.

9.3.2 Responsibilities of the Electrical & Mechanical Contractor (Lot 2)

The E&M Contractor shall provide all necessary technical information required for the civil & hydraulic works, including equipment loads, foundation requirements, anchor bolt layouts, clearances, cable routes requirements, and installation tolerances. The E&M Contractor shall submit these requirements sufficiently in advance to allow incorporation into C&HSS construction works. The E&M Contractor shall supply all embedded parts, anchor bolts, inserts, sleeves, and equipment support components that must be installed within the C&HSS structures. During equipment installation, the E&M Contractor shall ensure that installation activities are coordinated with the C&HSS Contractor to avoid damage to completed civil works.

9.4 Interface Identification and Register

An Interface Register shall be developed and maintained jointly by the Contractors and the Engineer. The Interface Register shall identify all interfaces between C&HSS and E&M works,

including structural provisions, embedded components, equipment installation zones, and access requirements. The register shall define responsibilities, schedules, and documentation requirements for each interface item. The Interface Register shall be regularly updated during project execution and shall form part of the project coordination documentation.

9.5 Design Coordination

Design coordination between the C&HSS Contractor and the E&M Contractor shall be carried out through regular review meetings and submission of coordinated drawings. The E&M Contractor shall submit equipment layout drawings, load data, and installation requirements for review and incorporation into C&HSS design drawings. The C&HSS Contractor shall verify that all structural provisions required for E&M equipment are included in the C&HSS works design. Any discrepancies or conflicts between C&HSS and E&M designs shall be resolved in consultation with the Engineer prior to execution of works.

9.6 Embedded Parts and Installation Provisions

Embedded parts required for E&M installations shall be supplied, installed and aligned by the E&M Contractor in accordance with the approved design and installation drawings. The C&HSS contractor shall only be responsible for providing the required Civil works as per drawings issued by E&M Contractor and approved by Engineer. The E&M Contractor shall also ensure proper positioning, alignment and securing of these components prior to and during concrete operations, in coordination with the C&HSS Contractor.

9.7 Construction Sequencing and Access

The construction schedule shall be coordinated to ensure that C&HSS works required for equipment installation are completed in time for the E&M installation activities. Adequate access shall be provided for the transport, lifting, and installation of equipment such as turbines, generators, valves, cranes, and control panels. Temporary openings, lifting arrangements, and installation platforms may be required and shall be coordinated between the Contractors to facilitate safe and efficient equipment installation.

9.8 Inspection and Verification

All interface works shall be subject to joint inspection by the C&HSS Contractor, the E&M Contractor, and the Engineer. Inspections shall verify that civil works meet the requirements specified by the E&M Contractor. Any deviations identified during inspection shall be corrected prior to equipment installation.

9.9 Protection of Installed Works

After installation of embedded parts or E&M equipment, appropriate protection measures shall be implemented to prevent damage during subsequent construction activities. The C&HSS Contractor shall ensure that installed equipment, anchor bolts, and other interface components are protected from impacts, contamination, or corrosion. Similarly, the E&M Contractor shall take necessary precautions to avoid damage to completed C&HSS structures during equipment installation.

9.10 Interface Meetings and Coordination

Regular interface coordination meetings shall be held between the C&HSS Contractor, the E&M Contractor, and the Engineer to review progress, resolve technical issues, and update interface requirements. These meetings shall address construction schedules, equipment delivery, installation planning, and any coordination issues affecting project progress. Minutes of the meetings shall be recorded and circulated among all relevant parties.

9.11 Documentation and Reporting

Both Contractors shall maintain complete documentation related to interface management activities. This documentation shall include interface registers, coordinated drawings, inspection reports, installation records, and meeting minutes. All interface related documentation shall be submitted to the Engineer for review and approval as part of the project quality assurance system.

9.12 Dispute Resolution

In the event of any disagreement regarding interface responsibilities or technical requirements, the matter shall be referred to the Engineer for resolution. The decision of the Engineer regarding interface matters shall be binding on both Contractors. Both parties shall cooperate to resolve issues promptly to avoid delays in project execution.

PART-B: MECHANICAL SPECIFICATIONS

TABLE OF CONTENTS

SECTION 1: GENERAL MECHANICAL REQUIREMENTS 1

1.1 General 1
1.1.1 General Design Requirements 1
1.1.2 Standards and Codes 2
1.1.3 Equivalent Standards 4
1.1.4 Revisions to Standards 4
1.1.5 Matierials and Equipment 4
1.1.6 Workmanship 7
1.1.7 Working Stresses 8
1.1.8 Special Design Criteria 11
1.2 Welding 11
1.2.1 General 11
1.2.2 Edge Preparation 13
1.2.3 Welding Qualifications 13
1.2.4 Welding of Stainless Steel 13
1.2.5 Field-Weld-Filler Metal 14
1.2.6 Heat Treatment 14
1.2.7 Quality- and Procedure Control 14
1.2.8 Documentation 14
1.2.9 Non-Destructive Testing 14
1.2.10 Machine Work 15
1.2.11 Steel Forgings 16
1.3 Casting 16
1.3.1 General 16
1.3.2 Steel Castings 16
1.3.3 Cast Iron Castings 17
1.3.4 Aluminium Bronze Castings 17
1.4 Corrosion Resistant Elements 18
1.5 Nameplates 18
1.6 Foundation Materials 18
1.6.1 General 18
1.6.2 Anchor Bolts 18
1.7 Fasteners and Anchor Bolts 19
1.7.1 General 19
1.7.2 References 20
1.7.3 Fasteners 21
1.7.4 Anchor Bolts 22
1.8 Coupling Guards 22
1.9 Locks 22
1.10 Lubrication 23

1.11 Handling Devices 23
1.12 Platforms, Stairways, Ladders and Hand Railing 23
1.12.1 General 23
1.12.2 Flooring 24
1.12.3 Hand Railing & Protective Barriers 24
1.12.4 Stairways 24
1.12.5 Fixed Access Ladders 25
1.13 Pumps 25
1.13.1 General 25
1.13.2 General Requirements of Centrifugal Pumps 26
1.13.3 Technical Requirements for Centrifugal Pumps 27
1.13.4 Shafts, Seals and Couplings 28
1.13.5 Pump Materials 28
1.14 Hydraulic Systems 28
1.14.1 Oil Pumps 28
1.14.2 Oil Pressure Tanks 28
1.14.3 Sump Tanks 28
1.14.4 Hydraulic Oil Piping 29
1.15 Piping 29
1.15.1 General 29
1.15.2 Identification of Piping 30
1.15.3 Welding 30
1.15.4 Hydrostatic Testing 30
1.16 Pipe Supports and Anchors 31
1.16.1 Flanges 31
1.16.2 Jointing Material 31
1.16.3 Internal Cleaning of Pipes 31
1.16.4 Pipe Terminations and Connections 31
1.16.5 Fluid Velocities in Pipes 32
1.16.6 Embedded Pipe Work 32
1.17 Valves 32
1.17.1 General 32
1.17.2 Parallel Slide, Gate and Sluice Valves 33
1.17.3 Spherical Valves 34
1.17.4 Safety Relief Valves 34
1.17.5 Butterfly Valves 34
1.17.6 Float Valves 35
1.17.7 Non-Return Valves 35
1.17.8 Pressure Reducing Valves and Relief Valves 35
1.17.9 Power Operated Valve General Requirements 36
1.17.10 Compressed Air Systems 36

1.18 Noise Level 37
1.19 Vibration and Balance 38
1.20 Painting and Protection 39
1.20.1 General Design for Protective Coatings 39
1.20.2 Painting 39
1.20.3 Metallic Coating 40
1.21 Witnessing of Shop Assembly and Tests 41
1.22 Tools and Spare Parts 41
1.22.1 Tools, Wrenches and Lifting Devices 41
1.22.2 Spare Parts 41
SECTION 2: TURBINES 43
2.1 Scope 43
2.2 Design Standards and Reference 43
2.3 Type and Rating 44
2.3.1 Number of Start/Stop Cycles 45
2.3.2 Life of Plant, Maintenance Cycles and Reliability 45
2.3.3 Protective Coating 46
2.4 Speeds and Balance 46
2.5 Vibration 46
2.6 Resonance 47
2.7 Regulation 47
2.7.1 Speed Regulation 47
2.7.2 Pressure Regulation 47
2.8 Air Admission System 48
2.9 Efficiency 48
2.10 Guarantees 49
2.10.1 General 49
2.10.2 Turbine Output Guarantees 50
2.10.3 Cavitation Guarantees 50
2.10.4 Cracking Guarantees 51
2.11 Torque Fluctuations 51
2.12 Stresses and Materials 51
2.13 Oil Type and Grade 53
2.14 Turbine Model Tests 53
2.14.1 General 53
2.14.2 Demonstration of Turbine Performance Parameters 54
2.14.3 Programme 55
2.14.4 Model Design, Construction and Similitude with Prototype 56
2.14.5 Scope of Tests 56
2.15 Runner 59
2.16 Turbine –Generator Shaft 60

2.17 Wearing Rings and Facing Plates 61
2.18 Bearings and Oil Lubrication System 61
2.19 Stuffing Box 61
2.20 Spiral Casing, Stay Ring and Gate Operating Mechanism 62
2.21 Front and Rear End Covers 62
2.22 Servomotor 62
2.23 Draft Tube and Discharge Ring 63
2.24 Walkways Stairways and Handrails 63
2.25 Spare Parts 63
2.26 Rating Plates and Nameplates 63
2.27 Painting, Piping Material and Valve Schedule 64
2.27.1 Painting 64
2.27.2 Piping Materials and Valves 65
2.28 Testing and Commissioning 66
2.28.1 Works Tests 66
2.28.2 Material Tests On Component Parts 66
2.28.3 Runner 66
2.28.4 Wearing Rings and Facing Plates 67
2.28.5 Main Shaft 67
2.28.6 Stay Ring and Spiral Casing 67
2.28.7 Draft Tube and Discharge Ring 67
2.28.8 Guide Vanes 67
2.28.9 Regulating Ring 67
2.28.10 Servomotors 67
2.28.11 Pressure Accumulator and Receivers 67
2.28.12 Pipework and Associated Fittings 68
2.28.13 Valves 68
2.28.14 Check Assembly of Turbine 68
2.28.15 Shear Pin Tests 68
2.28.16 Electrical Tests 68
2.28.17 Site Assembly Tests 68
2.28.18 Stage Testing During Erection and Commissioning 69
2.28.19 Draft Tube and Discharge Ring 69
2.28.20 Spiral Casing and Inlet Section 69
2.28.21 Runner and Shaft 69
2.28.22 Bearing 69
2.28.23 Guide Vanes and Regulating Gear 69
2.28.24 Commissioning Tests 69
2.28.25 Site Efficiency/Performance Tests 71

SECTION 3: HOWELL BUNGER TYPE PRESSURE RELIEF VALVES 72

SECTION 4: GOVERNORS AND AUXILIARIES 73

4.1 Scope 73
4.2 Structure of The Governor 73
4.3 Hazop Studies 73
4.4 Digital Governor 73
4.4.1 Precedence and Type 73
4.4.2 Location 74
4.4.3 Wiring and Cabling 74
4.4.4 Electrical Supplies 74
4.4.5 Input and Output Signals 74
4.4.6 Network Detection and Parameter Selection 74
4.4.7 Frequency/Power Control 75
4.4.8 Guide Vane Limit 75
4.4.9 Compensation for Water Column Inertia 76
4.4.10 Start/Stop Commands 76
4.4.11 Points of Control 76
4.4.12 Operating Requirements 76
4.4.13 Control Functions Whilst The Unit Is at Standstill 77
4.4.14 Rapid Shut Down 77
4.4.15 Partial Shut Down 77
4.4.16 Internal Monitoring 78
4.4.17 Human-Machine Interface 78
4.4.18 Operating Requirements 80
4.4.19 Software 80
4.4.20 Digital Governor Panel 80
4.4.21 Speed Sensing Equipment 80
4.5 Electrohydraulic Equipment 81
4.5.1 Location 81
4.5.2 Electrohydraulic Amplifier Control System 81
4.5.3 Electronic Interface 82
4.5.4 Emergency Shut Down 82
4.5.5 Hand Control 82
4.5.6 Position Feedback 82
4.6 Pressure Pumping System 82
4.6.1 Location 82
4.6.2 Sump Tank 83
4.6.3 Pumps 83
4.6.4 Pressure Accumulator 84
4.6.5 Nitrogen System 84
4.6.6 Piping 84
4.7 Special Tools 84
4.8 Spare parts 84

4.9 Inspection and Testing 85
4.9.1 Particular Inspection and Testing During Manufacture 85
4.9.2 Testing During Erection and Commissioning 86
SECTION 5: MAIN INLET VALVES 89
5.1 Scope 89
5.2 Location 89
5.3 Operation 89
5.4 Submittals 89
5.5 Guarantees 89
5.5.1 Performances 89
5.5.2 Tolerances, Penalties, Rejection 90
5.6 MIV-Type and Construction 90
5.6.1 Scope 90
5.6.2 Type of Valves 90
5.6.3 Hydraulic Power Unit for MIV 90
5.6.4 Thrust Forces 91
5.6.5 Dismantling Joint 91
5.6.6 Bypass Valve 91
5.6.7 Foundation Plates 92
5.6.8 Valve Body 92
5.6.9 Valve Disc / Plug 92
5.6.10 Stem, Guides and Bearings 93
5.6.11 Operating Servomotors 93
5.6.12 Operating Mechanism 93
5.6.13 Pressure Balanced Disc / Plug 93
5.6.14 Emergency Closing and Operating Time 94
5.6.15 Pressure Oil System and Control Equipment 94
5.7 Instrumentation 94
5.8 Spare Parts 95
5.9 Inspection and Testing 95
5.9.1 Particular Inspection and Testing During Manufacture 95
5.9.2 Inspection and Test of Raw Materials and Mass Produced Equipment 95
5.9.3 Inspection of Welds 95
5.9.4 Shop Erection 96
5.9.5 Operating Test 96
5.9.6 Hydrostatic Test 96
5.9.7 Leakage Test 96
5.9.8 Testing During Erection and Commissioning 96
5.9.9 General 96
5.9.10 Dry Test 96
5.9.11 Final Test 97

SECTION 6: POWERHOUSE CRANE 98
6.1 General 98
6.1.1 General Requirements 98
6.2 Extent of Supply 99
6.2.1 Powerhouse Crane, Auxiliary Hoists 99
6.2.2 Spare Parts 99
6.2.3 Tools and Appliances 99
6.3 Technical Requirements 99
6.3.1 General Requirement 99
6.3.2 Space Requirements 100
6.3.3 Adjustments 100
6.3.4 Crane Girders 100
6.3.5 Crane Drive 100
6.3.6 Trolley Frame 100
6.3.7 Trolley Drive 100
6.3.8 Hoist and Gear 101
6.3.9 Auxiliary Hoists 101
6.3.10 Crane Tracks 101
6.3.11 Lighting and Power Points 101
6.3.12 Hooks and Wires Ropes 102
6.3.13 Motors 102
6.3.14 Power Supply and Electrical Wiring 102
6.3.15 Control Equipment 102
6.4 Erection 103
6.5 Tests 103
6.5.1 Factory Tests 103
6.5.2 Tests at Site 103
SECTION 7: COOLING WATER SYSTEM 104
7.1 Scope 104
7.2 Description 104
7.2.1 Primary Cooling Water Circuit 104
7.2.2 Secondary Cooling Water Circuit 105
7.2.3 Shaft Seal Cooling Water 105
7.3 Detailed Requirements for Cooling Water Services 105
7.3.1 Duplex Basket Type Strainers 105
7.3.2 Automatic Filters 106
7.3.3 Expansion Joints 106
7.3.4 Motor Operated Valves 106
7.3.5 Orifice Plates 107
7.3.6 Filters for Shaft Gland Supply 107
7.3.7 Standby Cooling Water Pump 107

7.4 Spare Parts 107
7.5 Testing & Commissioning. 108
7.5.1 Inspection and Testing During Manufacture 108
7.5.2 Pressure Tests 108
7.5.3 Pumps 108
7.5.4 Automatic Strainers 108
7.5.5 Stage Testing During Erection and Commissioning 108
7.5.6 Commissioning Tests 109
SECTION 8: DRAINAGE AND DEWATERING SYSTEMS 110
8.1 Scope 110
8.1.1 For Drainage System 110
8.1.2 For Dewatering System 110
8.2 Drainage Scheme 110
8.2.1 Drainage Pump 110
8.2.2 Drainage Pump Motor 111
8.2.3 Drainage Pump Starters 111
8.2.4 Sump and Pump Control Equipment 111
8.3 Dewatering Scheme 111
8.3.1 Dewatering Pump 111
8.3.2 Dewatering Pump Motor 112
8.3.3 Dewatering Pump Starters 112
8.4 Layout of Drainage and Dewatering Sump 112
8.5 Spare Parts 112
8.6 Erection 112
8.6.1 General 112
8.6.2 Welded Construction 112
8.6.3 Sound Isolation 112
8.6.4 Lubrication 112
8.6.5 Ease of Maintenance 113
8.6.6 Painting, Retouching & Re-Finishing 113
8.7 Tests 113
8.7.1 Particular Inspection and Testing During Manufacture 113
8.7.2 Pressure Tests 113
8.7.3 Drainage and Dewatering System Pumps 113
8.7.4 Stage Testing During Erection and Commissioning 113
8.7.5 Commissioning Tests 114
SECTION 9: COMPRESSED AIR SYSTEM 115
9.1 Scope 115
9.2 Description of Compressed Air System 115
9.3 Detailed Requirements for Compressed Air System 115
9.3.1 Compressors 115

9.3.2 Receivers 115
9.3.3 Control Equipment 116
9.3.4 Motors Control Panels, Motors and Starters 116
9.4 Spare Parts 116
9.5 General Requirements 116
9.5.1 Pipework and Valves 116
9.5.2 Lubricators 117
9.5.3 Air Temperatures 117
9.6 Erection 117
9.6.1 General 117
9.6.2 Welded Construction 117
9.7 Control, Indications Alarm and Trip Schedules 118
9.8 Rating Plates and Nameplates 118
9.9 Painting 118
9.10 Inspection and Testing 118
9.11 Particular Inspection and Testing During Manufacture 118
9.11.1 Compressed Air System 119
9.12 Testing During Erection and Commissioning 119
9.12.1 General 119
SECTION 10: FIRE FIGHTING SYSTEM 121
10.1 Scope 121
10.2 Design Standards 121
10.3 Organization of Fire Safety Facilities 121
10.4 Portable Fire Extinguishers 122
10.4.1 General 122
10.4.2 Mounting 122
10.4.3 Refilling and Recharging Materials 122
10.4.4 Local Available Resources 122
10.5 Fire Water Supplies for The Powerhouse 123
10.5.1 Scope 123
10.5.2 Fire Water Scheme and Limits of Supply 123
10.5.3 Detail Requirements for Fire Water Supplies 124
10.6 Mobile Fire Extinguishing Units 125
10.7 Fire Safety Signs 126
10.8 Painting 126
10.9 Inspection and Testing 126
10.9.1 Particular Inspection and Testing During Manufacture 126
10.9.2 Testing and Commissioning 127
10.9.3 Pre-Start and Commissioning Tests 128
SECTION 11: OIL PURIFICATION SYSTEM 129
11.1 Oil Purification System 129

11.1.1 Scope 129
11.1.2 Detailed Requirements 129
11.1.3 Oil Purifier 129
11.1.4 Vacuum Pump 129
11.2 Governor and Lubricating Oil Purification System 129
11.2.1 Scope 129
11.2.2 Oil Purifier 129
11.3 Painting 130
11.4 Inspection and Testing 130
11.4.1 Particular Inspection and Testing During Manufacture 130
11.4.2 Oil Purifiers 130
11.4.3 Testing and Commissioning 130
11.4.4 Equipment 131
11.4.5 Electrical Equipment 131
11.4.6 Commissioning Tests 131
11.4.7 Performance Tests 131
SECTION 12: HEATING, VENTILATION AND AIR-CONDITIONING (HVAC) 132
12.1 Scope of Supply 132
12.1.1 General 132
12.1.2 HVAC Scope of System in General 132
12.1.3 Machine Halls 133
12.1.4 Control Room and Offices 133
12.1.5 LV and MV Switchgear Room 134
12.1.6 Design Conditions and Design Data 134
12.1.7 Design Conditions 134
12.1.8 Smoke Ventilation 134
12.1.9 Equipment/Material Selection 135
12.1.10 Codes and Standards Requirements 135
12.1.11 Major Equipment Description 136
12.1.12 Documents/Information Required for Approval 136
SECTION 13: WORKSHOP EQUIPMENT 137
13.1 Scope 137
13.2 Location and Layout 137
13.3 Machine Tools and Equipment 137
13.4 Powerhouse Workshop 137
13.4.1 High Precision Bench Lathe 137
13.4.2 Equipment to be Provided with Lathe: 137
13.4.3 Drill Stand 138
13.4.4 Equipment to be Provided with Grinder 138
13.4.5 Bench Mounted Grinder 138
13.4.6 Equipment to be Provided with Grinder: 138

13.4.7 Electric Welding Machines 139
13.4.8 Electrode Ovens 139
13.4.9 Oxy-Acetylene Welding Equipment 139
13.4.10 Tool Cabinets 139
13.4.11 Tool Room Racks 140
13.4.12 Lockers 140
13.4.13 Metal-Working Benches 140
13.4.14 Electrical-Working Bench 140
13.4.15 Hand Tools 140
13.5 Standard of Accuracy 141
13.6 Motors Control Panels, Motors and Starters 141
13.7 Painting 142
13.8 Inspection and Testing 142
13.8.1 Scope 142
13.8.2 Particular Inspection and Testing During Manufacture 142
SECTION 14: FIRE DETECTION & ALARM SYSTEM 143
14.1 Scope 143
14.2 Standards 143
14.3 General Technical Requirements 143
14.4 Functional Description 144
14.5 System Layout 145

LIST OF TABLES

Table 3: List of Standards 2
Table 4: Material for General Purpose 5
Table 6: Bolt and Nut References 20
Table 7: Maximum Allowable Flow Velocity in Pipes 32
Table 8: Use of Parallel Slide and Gate Valves 33
Table 9: Equipment Noise Level 38
Table 10: Radiating Surface Vibration Limits 38
Table 11: Applicable Requirements from Standards 43
Table 15: Average Weightages for Different Flows 48
Table 16: Stresses and Materials 52
Table 17: Painting Requirement 64
Table 18: Piping Materials and Valves 65
Table 14: Key Parameters for Pressure Relief Valves 72
Table 19: Proximity Transducer Details 81
Table 20: Key Parameters for Main Inlet Valve 91
Table 21: Class Requirement of Crane 98
Table 22: HVAC Design Requirement 134
Table 23: Code & Standard Requirements 135
Table 24: Equipment Description 136

SECTION 1: GENERAL MECHANICAL REQUIREMENTS

1.1 General

This Section covers the general mechanical requirements and requirements that are common between the various Sections of the Specification. This Section provides general specifications that apply equally to all other sections of the specification, to the extent that more stringent requirements are not provided in detailed specification sections. Unless otherwise expressly specified, the requirements of this Section, even when written in the singular form for one piece of equipment, shall apply equally to all equipment provided or supplied.

The Bidder shall furnish all Plant, Contractor's Equipment and services required to design, manufacture, factory test, and deliver new equipment and/or components to the Site, install, carry out testing & commissioning.

1.1.1 General Design Requirements

Tenderer shall design, manufacture, supply, install, test, commission and maintain all works including all required accessories for a reliable continuous operation, even if all details are not explicitly stated in the technical specification and/or contract documents.

The equipment shall be designed and manufactured to provide most optimum functional value and neat appearance. All major assemblies or equipment shall be designed to facilitate easy and quick surveillance, maintenance and optimum operation. All control sequences shall be simple and rational.

All live, moving and rotating parts shall be adequately secured in order to avoid danger to the operating staff. All electrical components shall be electrically earthed.

Suitable lifting eyes and forcing off bolts shall be provided where required or where they will be useful for erection and dismantling.

Any changes of the design of any part of the equipment, which may become necessary after signing the contract have to be submitted in writing to the Purchaser for approval, being sufficiently substantiated and justified.

The Supplier shall assume full responsibility for a coordinated and adequate design of all equipment specified and shall ensure that such equipment conforms to the best engineering practice for the operating conditions specified. When requested by the Purchaser, the Supplier shall furnish complete information as to the maximum stress and other criteria used in the design.

Factors of safety of not less than 2.0 shall be used throughout the design and especially in the designs of all parts subject to alternating stresses of shock. For the rotating parts of the generator and exciters, the maximum unit stresses due to runaway speed of turbine shall not exceed two–thirds of the yield point.

As far as possible the equipment shall be of the Contractor's standard design, provided that this design is in accordance with the requirements of the Technical Specifications. Components used shall have proven satisfactory service.

All equipment performing similar duties shall be of the same type. All identical machined parts shall be interchangeable.

1.1.2 Standards and Codes

All equipment and parts related to this section and concerning choice of materials, main dimensions and function shall conform to the appropriate standards mentioned in the Bidding Documents. For this purpose, the Bidders shall be requested to specify in their Bids the relevant standards for the main items of their supply and clearly identify the parts, phases, operations, etc. to which each particular standard shall be applied. For example, the bidder must indicate the standards to be applied for design, calculations, materials, and fabrication of the supply.

The Works shall be made to the following general groups of Standards. The Contractor shall refer to Standards within these general groups in defining the characteristics of the Plant in his supply, as required by the schedules enclosed with these Specifications. These groups of Standards shall be referenced in the contractual information presented for approval by the Contractor:

Table 1: List of Standards

Standards	Abbreviation
American Concrete Institute	ACI
American Institute of Steel Construction	AISC
American Iron and Steel Institute	AISI
American National Standards Institute	ANSI
American Petroleum Institute	API
American Society of Mechanical Engineers	ASME
American Society for Testing of Materials	ASTM
American Water Works Association	AWWA
American Welding Society	AWS
Anti-Friction Bearing Manufacturers Association	AFBMA
British Standards Institute	BS
Canadian Electrical Association	CEATI
European Standards	EN
Fédération Européenne de la Manutention	FEM
German standards, Deutsches Institut für Normung e.V.	DIN
Hydraulic Institute	HI
Institute of Electrical and Electronics Engineers	IEEE
International Electrotechnical Commission	IEC

International Standards Organization	ISO
Insulated Cable Engineer's Association	ICEA
Japanese Industrial Standard	JIS
Joint Industrial Council	JIC
(American) National Bureau of Standards	NBS
(American) National Electrical Code	NEC
(American) National Electrical Manufacturers Association	NEMA
National Electrical Safety Code	NESC
(American) National Fire Protection Association	NFPA
Steel Structures Painting Council	SSPC
(American) Underwriter's Laboratory	UL
United States Bureau of Reclamation	USBR
American Bearing Manufacturers Association	ABMA
American Gear Manufacturers Association	AGMA
American Society of Heating, Refrigeration & Air Conditioning Engineers.	ASHRAE
Crane Manufacturers Association of America.	CMAA
German standards, Deutsches Institut für Normung e.V.	DIN
Uniform Plumbing Code of International Association of Plumbing & Mechanical Officials.	IAPMO
Manufacturers Standardization Society of the Valve and Fillings Industry.	MSS
National Fluid Power Association.	NFP (A)

The latest revision or edition in effect at the time of the Invitation of Bidders shall apply.

All equipment and materials related to this contract shall conform to the requirements of the Technical Specifications and to the designated standards. In case of discrepancy between the designated standards and the Specifications, the latter shall rule.

All drawings, calculations, data, nameplates, and other information shall be presented in the English language. Drawings and other documents shall be prepared with metric units.

1.1.3 Equivalent Standards

If the Bidder wishes to use standards which it deems equivalent to either the American standard or the alternate IEC standards system, or to deviate from the above-cited standards, it shall be handled as part of design submittals. Individual questions will not be entertained during the Bidding period. If equivalency can be demonstrated to the satisfaction of the Engineer, alternative standards may then be used by the Contractor during manufacturing. The intent is to allow equivalent standards, not alternative standards. The decision of the Engineer in the matter of equivalency of alternate standards shall be final.

Standards utilized other than those specified shall be made available to the Engineer and the Employer in the English language. The latest revision or edition in effect at the Issue of Bidding Documents shall apply.

1.1.4 Revisions to Standards

The Bidder shall base its Bid on those laws, standards, and codes referenced in the Specification which are in effect at the time of submission of Bid, and on any additional laws, standards and codes stated in its Bid, that apply to the design detailing and shop detailing by the Bidder, and which are in effect at time of submission of Bid.

The Contractor shall, throughout the duration of this Contract, bring to the attention of the Engineer any revisions to any laws, standards, and codes which occur after the submission of the Bid, which may merit adoption.

Notwithstanding the provision of any standard or code applicable to the Works, the Contractor shall be exclusively responsible for proper design, manufacture, inspection and testing of the Works to assure that it meets all requirements of the Contract.

1.1.5 Matierials and Equipment

- General

The material shall be of highest grade free from defects and imperfections, of recent manufacture and unused.

All materials incorporated in the equipment supplied shall be of quality, grades and conditions as set forth in the approved Standards.

Materials not specifically designated herein shall be subject to the approval of the Engineer, shall be suitable for their purpose and shall as far as practicably comply with the latest issue or revision of the designated standards or their approved equivalent.

Materials for general purposes shall be delivered according to the following standards given in table below, or their equivalent. The grade' used will depend on stress levels, environmental conditions, resulting material thickness and manufacturing and inspection procedures.

The material grade shall unless otherwise specified be proposed by the Contractor but are subject to the Engineer’s approval.

Table 2: Material for General Purpose

Material	Specification
Structural Aluminum	ASTM B308/B308M, “Specification for Aluminum - Alloy 6061-T6 Standard Structural Profiles”.
Carbon Steel Castings	ASTM-A27, "Specification for Mild to Medium-Strength Carbon-Steel Castings for General Application," Grade 65-35, Grade 70-36, and Grade 70-40.
Low-Alloy Steel Castings	ASTM-A148, "Specification for High-Strength Steel Castings for Structural Purposes," Grade 80-50.
Corrosion-Resistant Steel Castings	ASTM-A743/A 743M, "Specification for Casting, Iron- Chromium, Iron-Chromium-Nickel, and Nickel Base (Corrosion-Resistant) Alloy Castings for General Application," Grade CA-15, Grade CF-8 and Grade CA-6NM.
Corrosion-Resistant Steel Plate	ASTM-A167, "Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip."
	ASTM-A176, "Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip."
	ASTM-A240, "Specification for Stainless and Heat-Resisting Chromium and Chromium-Nickel Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels," Type 405 and Type 410.
Corrosion-Resistant Steel Bars	ASTM-A582, "Specification for Free-Machining Stainless and Heat-Resisting Steel Bars, Hot-Rolled or Cold-Finished," Type 303 and Type 416.
Nickel-Copper Alloy Plate (Monel)	ASTM-B127, "Specification for Nickel-Copper Alloy Plate, Sheet, and Strip (UNS No. 4400)."
Iron Forgings	ASTM A48/A48M, “Specification for Gray Iron Castings”, Class 30
Carbon and Alloy Steel Forgings	ASTM-A668, "Specification for Steel Forgings, Carbon and Alloy for General Industrial Use," Class D.
Carbon Steel Forgings (for pipe flanges, fittings, etc.)	ASTM-A181, "Specification for Forged or Rolled Steel Pipe Flanges, Forged Fittings, and Valves and Parts for General Service," Grade I and Grade II.
Carbon Steel Plates (for low-stressed parts)	ASTM-A283, "Specification for Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality (Plates 50 mm and Under in Thickness)," Grade A and Grade B.
	ASTM-A36, "Specification for Structural Steel."
Carbon Steel Plates	ASTM-A285, "Specification for Low and Intermediate Tensile Strength Carbon Steel Plates for Pressure Vessels (Plates 2 in and Under in thickness)," Grade B and Grade C.
Intermediate Strength Steel	ASTM-A516, "Specification for Carbon Steel Plates for Pressure

Material	Specification
Plates (for important stress-carrying parts)	Vessels for Moderate and Lower Temperature Service," Grade 60 or better, except that all plates thicker than one inch shall be normalized to produce grain refinement.
High Strength Steel Plates (for highly stressed parts)	ASTM-A517, "Specification for High Strength Alloy Steel Plates, Quenched and Tempered, for Pressure Vessels."
Bronze Castings	ASTM B584, “Specification for Copper Alloy Sand Castings for General Applications”, UNS Alloy Nos. C90300 and C92300.
Bronze Castings, Bronze (for bearings, wearing plates, etc.)	ASTM-B584, "Specification for Copper Alloy Sand Castings for General Applications, UNS Alloy Nos. C93200 and C93700."
Bronze (for bolting)	ASTM-B21, "Specification for Naval Brass Rod, Bar, and Shapes," Alloy No. 464.
Copper Tubing	ASTM-B88, "Specification for Seamless Copper Water Tube," Type K.
Copper Pipe	ASTM-B42, "Specification for Seamless Copper Pipe, Standard Sizes."
	ASTM B88/B88M, “Specification for Seamless Copper Water Tube”, Type K.
Bronze Pipe	ASTM B43, “Specification for Seamless Red Brass Pipe, Standard Sizes”, UNS Copper Alloy No. C23000.
Steel Pipe	ASTM-A53, "Specification for Welded and Seamless Steel Pipe."
	ASTM A106, “Specification for Seamless Carbon Steel Pipe for High - Temperature Service”.
	ASTM A120, “Specification for Pipe, Steel, Black and Hot – Dipped Zinc - Coated (Galvanized) Welded and Seamless, for Ordinary Uses”.
Stainless Steel Pipe	ASTM A312, Type 304 "Specification for Seamless and Welded Austenitic Stainless Steel Pipe."
	ANSI B36.19M “Stainless Steel Pipe”, seamless, Grade TP316N.
Stainless Steel Pipe Fittings	ASTM A282, Type 304 "Forged Stainless Steel Fittings, Socket-Welding and Threaded."
	ASTM A403, Type 304 "Specification for Wrought Austenitic Stainless Steel Pipe Fittings."
Stainless Steel Tubing	ASTM A269 or ASTM A213, Grade TP304 "Specification for Soft Annealed Stainless Steel Tubing."
Titanium Tubing	ASTM B338, “Specification for Seamless and Welded Titanium and Titanium - Alloy Tubes for Condensers and Heat Exchangers”.
Stainless Steel Tube Fittings	Compression type stainless steel flareless tube fittings, suitable for

Material	Specification
	1200 psi working pressure.
Steel Pipe Flanges and Flanged Fittings	ANSI-B16.5, "Steel Pipe Flanges and Flanged Fittings."
Wire Rope and Strand	U.S. Fed. Spec. RR-W-410 C, “Wire Rope and Strand”, IWRC, Regular stranded, Type 1, Class 2 and Class 3.
Brazing Filler Metal	ANSI/AWS A 5.8, “Specification for Brazing Filler Metals”.
Welding Electrodes	AWS A 5.1, “Specification for Carbon Steel Covered Arc-Welding Electrodes”.
Zinc Lining	ASTM A123/A123M, “Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products”.
	ASTM A153/A153M, “Specification for Zinc Coating (Hot - Dip) on Iron and Steel Hardware”.
Motors	NEMA MG 1, “Standards for Motors and Generators”.
Tanks and Metal Pressure Tanks	ASME “Boiler and Pressure Vessel Code”, Section VIII, Division 1.

- Test of Materials

I. General

Unless otherwise agreed by the Employer/Engineer, all materials or parts shall be new and shall be tested by the material supplier, in conformity with applicable methods prescribed by the ASTM, or such other equivalent international standards organizations approved by the Engineer. For mass produced equipment, the supplier shall indicate that material testing is part of its quality program.

II. Test Certificates (Mill Certificates)

Certified material test reports shall be submitted by Contractor to the Engineer as soon as possible after the tests are made. The test certificates shall identify the component for which the material is to be used and shall contain all information necessary to verify compliance with the Contract.

1.1.6 Workmanship

Except where the manner of design, manufacture or execution is otherwise specifically set forth in this Contract, the Works shall be designed and executed in a proper and workmanlike manner, all in accordance with prudent industry practice for such Works. All work shall be done by personnel skilled in the related professions and trades.

All parts shall be made accurately to a standard gauge, so as to facilitate replacement and repairs. All bolts, nuts, screws, rivets, threads, pipe, gauges, gears, and measurements or dimensions shown on the Contractor’s Drawings shall conform to customary standards.

The Contractor shall provide and maintain in storage for at least ten (10) years, free of cost to the Employer, sufficient templates, gauges, patterns, and other records to enable the Employer to make

repair and replacement parts. All special gages and templates necessary for field erection shall be furnished and shall become the property of the Employer. Patterns shall remain the property of the Contractor.

1.1.7 Working Stresses

A. Loading

Ample factors of safety shall be used throughout the design of the equipment, especially in the design of parts and components subject to alternating stresses, vibration, impact or shock.

In general, the loading shall be divided into 3 different classes according to the following typical examples.

1. Normal loading
    a. Loading due to dead loads
    b. Hydrostatic loads, from vacuum to design water pressure
    c. External pressure
    d. Hydrodynamic loads, design values for surges and pressure rise
    e. Friction loads
    f. Forces due to temperature variations
    g. Environmental loads with a return period of 50 years
    h. Dynamic loads due to normal operation
    i. Vibration loads caused by flowing water or by ordinary operation

2. Unusual loading
    a. Sediment loading. Construction shall be appropriate for an increased load due to sedimentation
    b. Un-symmetric loading due to uneven frictional forces
3. Extreme loading
    a. Earthquake loading
    b. Loading due to transportation and erection
    c. Pressure testing at 50 % above design pressure
    d. Loading due to maximum (PMF) floods
    e. Loading due to transportation and erection
    f. Emergency situations, complete short circuit forces in generator
    g. Emergency hoisting
    h. Continuous run away of the generating unit

The various loads shall for normal loading be combined if physically possible, and the most severe shall determine the design conditions. At unusual and extreme loading, each unusual or extreme

load cases shall be combined with the most severe normal loading. Unusual or extreme load cases do not need to be combined.

B. Design Conditions

1. Normal Design Conditions

The following stress levels at the different load cases are the maximum allowable values. Lower stress levels may be prescribed in the particular specifications for the individual sections of work, or under Construction Elements in these General Specifications, or in the various design standards used for particular components.

Under design conditions, the combined stress levels calculated according to Von Mieses theory shall not exceed what is allowed according to the approved standards but shall in no case exceed the values in Table below unless otherwise stated by the Contractor and approved by the Engineer.

Table 3: Normal Design Condition Stress Limits

Material	Stress condition	Stress limit
Structural steel materials	Maximum general stress level	60% of the yield strength
Structural steel materials	Average stress at points with local stress concentrations, calculated according to methods approved be the Engineer	75% of the yield strength, provided the quality of material can be confirmed by approved methods at the point with stress concentration.
Other materials	Maximum stress in tension or compression	33% of the yield strength or 20% of the ultimate strength of the material
Cast steel	Maximum general stress level	50% of the yield strength
Cast steel	Average stress at point with local stress concentrations, calculated according to methods approved by the Engineer	67% of the yield strength provided the quality of material can be confirmed by approved methods at the point with stress concentration.
Cast iron	Maximum general stress level	20 N/mm^2
Ductile materials in general	Shear stresses	57% of allowable stresses in tension
Ductile materials in general	Hydrostatic pressure testing	90% of the yield strength
Vertical pump, turbine and generator shafts	Maximum torsion shear stress	40 N/mm^2
Vertical pump and turbine shafts exposed to water	Maximum torsion shear stress	35N/mm^2

- Ratio between ultimate strength and yield strength minimum 1.2
- Elongation, A, test length 5.65. √So minimum 17%
- Impact Strength, KV, at design temperature minimum 27 J

The minimum properties shall be tested in the direction of highest principal stress of any component, including weld zones.

The yield strength shall mean the guaranteed, minimum yield strength. For materials not having a defined yield point, the 0.2% proof stress shall be used.

All components shall be designed for a lifetime of 30 years under normal running conditions, and components subject to fatigue shall have a theoretical safety factor of 2 against failure unless otherwise stated. Due consideration shall be made to dynamic stresses, which shall be kept within the stress limits stated above. The effects of corrosion, stress concentrations, notches, etc., shall be duly considered.

The maximum general stress levels shall be calculated in accordance with the elastic theory, considering all main stress components.

The resulting effect of peak stresses, due to secondary bending moments, may be calculated using a non-linear theory, provided that the material is not subject to fatigue, the ductility allows limited yielding without danger of cracking and that the quality control procedures during production with a satisfactory degree of probability shall detect cracks well below the critical crack size.

Materials for pressure vessels, spiral casings, larger valve housings, penstocks and similar which are heat treated after manufacture, shall have a critical crack length which will cause the crack depth to penetrate the vessel, thus causing the vessel to leak without bursting at its lowest operation temperature and at the general maximum stress level. For vessels not heat treated, the same shall apply for stresses equal to the yield stress.

2. Unusual Design Conditions

For structural steel materials the general maximum stress level may be increased to 75 % of the yield strength, and up to 80 % of yield strength for the maximum stress at points with local stress concentrations.

For other materials, the stresses may be increased accordingly.

3. Extreme Design Conditions

For structural steel materials the general maximum stress level may be increased to 80 % of the yield strength, and up to 90 % of yield strength for the maximum stress at points with local stress concentrations.

For other materials, the allowable stresses may be increased accordingly subject to the Engineer's approval.

a. Pressure Testing

Before pressure testing of larger components, the critical crack size shall be calculated and compared with the crack detection level. The general membrane stress in any part shall not exceed 80% of the yield stress.

b. Runaway Conditions

Under maximum runaway conditions, the increasing forces due to deformations under loading shall be considered.

Earthquake loading shall be calculated using the specified Vertical and vertical acceleration. The method of calculation shall be subject to approval of the Engineer.

1.1.8 Special Design Criteria

a. Shaft bending frequency

The following criteria shall be observed for main shaft systems (turbine/generator, pump/motor, diesel-engine/generator etc.):

- The first order shaft natural bending frequency shall exceed the maximum transient runaway speed by 25% or more. The shaft natural bending frequencies shall have a separation of 25% or more to the operating speed, to the line frequency (50 Hz) and to other predominant system frequencies.
- The first order shaft natural torsion frequency shall exceed the maximum transient runaway speed by 25'% or more. The shaft natural torsion frequencies shall have a separation of 25% or more to the operating speed, to the line frequency (50 Hz) and to other predominant system frequencies.

For auxiliary motors, pumps and other rotating equipment, the shaft speed shall not exceed 90% of the first order shaft natural frequencies at a temporary line frequency or 75 Hz.

Standardized electrically driven equipment rated less than 6 kW shall, after approval by the Engineer, be exempted from these criteria.

The deformations shall at all loads be within acceptable limits according to the best engineering practice.

The Contractor shall assume full responsibility for an adequate design and shall use lower stresses wherever necessary.

1.2 Welding

1.2.1 General

All welding shall be performed by the electric-arc method, by a process that excludes the atmosphere from the molten metal, and, by automatic machines, however, manual welding shall be performed on the welds where automatic welding cannot be performed due to access issues. After being deposited, all welds shall be cleaned of slag by shotblasting, unless otherwise approved by Engineer, and shall be uniform, smooth, showing good fusion with the base metal, and free of voids, crack, and clinkers. Machined surfaces of parts affected by welding shall be machined to final dimensions after welding. Machined surfaces of parts requiring stress relief shall be machined to final dimensions after the parts have been stress relieved. Localized stress relieving shall not be permitted for shop-welded parts. All principal load-carrying welds shall be full penetration type welds. Strength of welded joints shall be based upon the allowable stress of the parent materials. Welding methods shall be such that residual stresses shall be reduced to a minimum. The weld seams shall, as far as possible, be positioned outside zones of stress concentration.

All joining of plates in the principal stress direction shall be carried out using double welded butt joints. Adjacent plates, carrying high stresses, shall in general not differ more than 3 mm in thickness. If the difference is greater, the thicker plate shall be chamfered maximum 1: 4.

Principal welds shall be ground as specified in the approved welding procedure. Besides, all welds exposed to water having a velocity of 10 m/s or more, shall be ground flush with the plates unless otherwise approved by the Engineer.

I. Cracked or defective tacks shall be removed before welding.

For double welded butt joints, the root must be completely removed by grinding or back gauging before proceeding with the welding on the other side in order to prevent the presence of residues.

Where auxiliary structural members are welded to components for the purpose of assembly and installation, the connecting welds shall be given particular care. Once an installation has been completed, these auxiliary structural members shall be removed by burning them off, followed by grinding the affected areas flush with the plate, without introducing additional local thermal stresses. Knocking off of such members shall not be permitted.

The electrodes for arc welding shall be classified on the basis of mechanical properties of the as welded deposited weld materiel, type of covering, hydrogen absorption, welding position of the electrodes and type of current.

Electrodes shall be used only in the positions and under the conditions of intended use in accordance with instructions with each container. Electrodes for manual welding shall be suitable for welding in any position.

During the welding operations the electrodes shall be stored and dried in electric heaters prior to welding, according to the instructions from the manufacturer/Employer.

The ignition of welding-electrodes shall not be initiated at the steel surface adjacent to the weld, but at the groove flanks to prevent detrimental increments of local hardness. Where ignition points of electrodes are discovered, they shall be ground appropriately.

II. Designs shall be such as to minimize Site welding.

Unless otherwise stated the qualification of welding procedures, welders, and welding operations, including weld repairs of castings shall conform to Section IX of the ASME "Boiler and Pressure Vessel code".

Unless otherwise stated all welded parts shall be designed, fabricated, inspected and tested in accordance with Section VIII of the ASME "Boiler and Pressure Vessel code" and shall be stress relieved prior to machining in accordance with the requirements of the same code. No Site welds shall require stress relieving.

For certain structural items welding, welders and weld procedure shall be in accordance with AWS Standards. These items shall be identified in these Specifications. All pressure vessels and items subject to penstock pressure shall be welded to ASME "Boiler and Pressure Vessel code".

Welds shall in general be treated so that they shall display good appearance and a surface suitable for painting. Structural welds shall be ground and blended to avoid stress raisers. All welds which require non-destructive examinations shall be dressed by chipping and grinding as required for good interpretation by the selected weld examination methods.

III. All welds shall be continuous, watertight and free from voids.

Welded-on fabrication aids shall be kept to a minimum. They shall be attached only by approved welders and shall be removed by flame cutting not less than 1.5 mm above the parent plate surface and then by subsequent grinding and crack detection of the weld area.

IV. All plate butt welds shall be full penetration back gouged and welded from both sides.

The minimum size of fillet welds shall be 6.5 mm measured on the leg. Undercutting not exceeding 1 mm shall be removed by grinding. Undercutting exceeding 1 mm shall be filled by welding.

The edges of surfaces (up to the thickness of the metal) to be welded shall be of sound metal free from visible defects such as laminations or defects caused by cutting operations and free from rust, oil grease and other foreign matter.

1.2.2 Edge Preparation

Members to be joined by welding may be cut to shape and size by mechanical means such as shearing, machining, grinding, or by gas or arc cutting, to suit the conditions. Design of welded joints and selection of weld filler metal shall allow thorough penetration and good fusion of the weld with the base metal. The edges of surfaces to be welded shall be sound metal free of visible defects, such as laminations or defects caused by cutting operations, and free from rust, oil, grease and other foreign matter.

1.2.3 Welding Qualifications

The qualification welding procedures, of welders, and of welding operators shall conform to standards at least equal to ISO 9606 or Sections VIII and IX of the ASME Boiler and Pressure Vessel Code. The Contractor shall furnish the facilities and all equipment, materials, and other articles required to perform qualification tests of its welders and welding operators. The Contractor shall prepare the procedure for qualification testing of the field welders, and the qualification tests shall be witnessed and accepted by the Contractor. All welders' and welding operators' test certificates shall be submitted to the Engineer. Welders for on-site work shall be tested no earlier than 3 months prior to commencing site work. Contractor shall replace any welder or welding operator deemed unacceptable by Engineer or Employer.

WPS and Welder Qualification Tests shall be in accordance with the relevant welding standard and shall be performed by the Contractor and witnessed by the Engineer.

1.2.4 Welding of Stainless Steel

All welding of stainless steel shall be carried out using the inert gas method (TIG/MIG). Pipes shall be locally filled with inert gas during welding.

Butt welds on thin-walled pipes shall have a smooth, fully penetrated weld seam inside and outside. Partly penetrating, drops or metal sputter shall not be accepted.

All welds and heat affected zones shall be carefully descaled and cleaned with a suitable cleaning paste and fresh water if inert gas has not been applied or if the inert gas method has failed. Carbon steel tools shall not be used.

1.2.5 Field-Weld-Filler Metal

The calculated quantity of weld-filler electrodes or wire required for field-welded joints plus twenty percent (20%) additional shall be furnished. The Contractor shall select the proper filler material for all field-welded connections and shall specify it on the applicable Contractor's Drawings submitted for the Employer's approval, together with the detailed design of the field-weld joint.

1.2.6 Heat Treatment

The need for heat treatment shall be determined in accordance with the approved Design Standard and/or Boiler and Pressure Vessel Code, taking into account the stress levels and design temperature, material properties including notch toughness, material thickness and forming, welding and inspection procedures. The shop heat treatment of welded components shall be performed on the completed component prior to final machining.

Procedures for heat treatment shall be submitted to the Engineer for approval.

Heat treatment of site welding shall be performed according to the specifications for the welding procedure for the corresponding parts, which shall be submitted to the Engineer for approval.

1.2.7 Quality- and Procedure Control

Quality testing and inspection methods, e.g., inspections by non-destructive testing (NDT) means, shall be carried out in accordance with the appropriate manufacturing code. However, the Contractor shall indicate clearly on the drawings the extent to which these methods shall be used.

1.2.8 Documentation

The Contractor shall maintain a strict quality control program for the welding work performed in the shop. Weld procedure specifications (WPSs) shall be submitted for review and approval by the Engineer prior to starting the fabrication work. All welds shall be identified on the Contractor's Drawings by numbers. All welding work shall be performed by qualified welders and welding operators and shall be properly documented.

1.2.9 Non-Destructive Testing

a) General

Unless otherwise indicated, all non-destructive tests shall be in accordance with the applicable section of ASTM Standards, Part III, Metallography Non-destructive Tests or approved equivalent. The Contractor's Drawings submitted to the Engineer for review and approval shall define the areas, extent, and type of non-destructive examination employed.

b) Examination of Welds

All welds on weld-fabricated parts, except minor parts or low stressed parts, shall be given complete non-destructive examination by Contractor. Weld examination shall be by TOFD (Time-of-Flight Diffraction), dye penetrant and magnetic particle methods, supplemented by radiographic examination. Supplemental radiographic examination shall include examination of critical high-stressed areas where interpretations of other methods are unclear, or where the integrity of the weld is doubtful. All butt-welded joints exposed to headwater pressure, or to significant stress levels shall be given a one hundred percent (100%) radiographic or TOFD inspection by Contractor, accompanied by a one hundred percent (100%) magnetic particle or liquid penetrant inspection. At

least, 25% of Butt Welds at Site shall be radiographic tested. The Employer shall have the right to request random spot-check examination of welds, including radiographic examination, as part of its inspection of the equipment. The Employer shall have the right to review films of previously performed radiographic examinations. The non-destructive examination scope, procedures and acceptance standards of welds shall be clearly indicated on the Contractor's Drawings. The detailed program for non-destructive examination of welds shall be submitted by Contractor for review and approval by the Engineer.

1.2.10 Machine Work

i. General

Sufficient machining stock shall be allowed on all parts to be machined to ensure true finished surfaces of solid material. Finished contact or bearing surfaces shall be true and exact to secure full contact. Journal and sliding surfaces shall be polished, and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. No machining shall be done on working surfaces of self-lubricating bushings or washers.

ii. Finished Surfaces

In addition to the machined surfaces indicated on the Contractor's Drawings, all surfaces that require machining for their intended function and those surfaces that are normally machined in good shop practice shall be machined.

iii. Unfinished Surfaces

All work shall be laid out to secure proper matching of adjoining unfinished surfaces. Where there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth, or machined, to secure proper alignment. Unfinished surfaces shall be true to the lines and dimensions shown on the Contractor's Drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in an approved manner. Corrosion-resistant-steel, seal plate surfaces in contact with seals shall be thoroughly cleaned to have a smooth and even surface.

iv. Pins and Pin Holes

Pin holes shall be drilled smooth and straight and at right angles to the axis of the member. The drilling shall be done after the member is securely fastened in position.

v. Assembly

Before assembly, all bearing surfaces, journals, and grease and oil grooves shall be carefully cleaned and lubricated with an approved oil or grease. Solvents shall not be used on self-lubricating bearings. After assembly, each lubricating system shall be filled with an approved lubricant. Self-lubricating bearings shall not be greased and shall be assembled dry according to the manufacturer's instructions.

vi. Surface Finish

The quality of all surface finishes shall be selected with due regard for the nature and function of the surface and in accordance with conservative design practice. Surface finish shall be subject to approval.

1.2.11 Steel Forgings

The Contractor shall supply a list of all important forgings and draw up material specifications for each forging. Copies of this list and specifications shall be supplied to the Engineer for his use.

Steel forgings shall be in accordance with the requirements of BS Standards, the equivalent ISO Standards, or agreed national Standards.

Test blocks from which mechanical test pieces will be machined shall be cut from forgings at positions to be agreed by the Engineer. On large and important forgings several test pieces shall be taken from radial and longitudinal directions.

Forgings shall be free from cracks externally or internally, extensive non-metallic inclusions and surface defects. The Contractor shall carry out non-destructive testing of forgings during machining to verify that no unacceptable defects are present.

Repairs by welding or other means shall not be undertaken on forgings at any stage of the production cycle.

Each forging shall be suitably branded with an identification number which shall be transferred throughout all final machining stages. The identification number shall be marked on all documents and test certificates related to the forging.

1.3 Casting

1.3.1 General

Test bars shall be provided from medium and large castings for all necessary material and chemical tests which are to be witnessed by the Engineer. If required by the Engineer any castings for rotating or highly stressed parts are to be subjected to non-destructive testing by approved methods including radiographic and ultrasonic means, the cost of which shall be borne by the Contractor.

All castings shall be homogeneous and free of shrinkage, pipes, under sizing, porosity or voids. "Burn in" repairs are not acceptable and no welding, filling, interlocking or plugging of defective parts shall be done without the Engineer's approval in writing. All repairs shall be subjected to non-destructive examination (ultrasonic, X-rays, gamma rays) after heat treatment.

1.3.2 Steel Castings

The Contractor shall prepare material purchasing specifications for all important castings. Each document shall indicate fully the quality and inspection requirements for the component casting covered. Copies of the Specification shall be issued to the Engineer for his approval.

Castings shall be repaired by welding providing the approval of the Engineer is first obtained. The Contractor shall submit drawings, sketches or photographs and metallurgical test reports showing the location and principal dimensions of the defect together with the proposed weld repair procedure. The maximum size of defect for which weld repair shall be permitted is:

- Maximum length of defect 20 mm
- Maximum width of defect 10 mm
- Maximum depth of defect no greater than 10% of the wall thickness but in no case greater than 20mm

Only welders who have passed an appropriate qualification test shall be employed on the repair of castings. All repairs shall be carried out by the metal arc process.

Ultrasonic inspection shall be applied to all important castings to locate the extent of sub surface defects and to check the wall thickness.

All castings shall be identified by stamped or cast on reference marks which shall be entered on all relevant documents and test certificates.

The Engineer may require that certain castings shall be examined using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Engineer's instructions when issued.

1.3.3 Cast Iron Castings

Cast iron shall not be used for any part of equipment which is in tension or which is subjected to impact, or to a working temperature exceeding 200 °C unless specifically approved by the Engineer.

Weldable grades of Ni resist austenitic cast iron castings shall be repaired by welding provided the approval of the Engineer is first obtained. The Contractor shall submit full details of the proposed weld repair procedure and weld procedure qualification test prior to making any weld repairs. The maximum size of defect for which weld repair shall be permitted is:

- Maximum length of defect 20 mm
- Maximum width of defect 10 mm
- Maximum depth of defect no greater than 10% of the wall thickness.

Test blocks shall be integrally cast on all medium and large castings.

The Engineer may require that certain castings shall be checked using radiographic techniques. The Contractor shall include for this eventuality and shall comply with the Engineer's instructions when issued.

1.3.4 Aluminium Bronze Castings

The Contractor shall prepare material purchasing specifications for all important castings. Each document shall indicate fully the quality and inspection requirements for the component casting covered. Copies of the Specification shall be issued to the Engineer for his use.

The inspection and quality requirements shall include an analysis of each cast, mechanical testing of test bars from each cast, pressure testing, penetrant flaw detection and radiographic examination of selected critical areas.

Weldable grades of aluminium bronze shall be repaired by welding provided the written approval of the Engineer is first obtained. The Contractor shall submit full details of the proposed weld repair procedure and weld procedure qualification test prior to making any weld repairs. The maximum size of defect for which weld repair shall be permitted is:

- Maximum length of defect 20 mm
- Maximum width of defect 10 mm
- Maximum depth of defect no greater than 10% of the wall thickness but not more than 20mm

On completion of repairs, welded areas shall be ground smooth and carefully blended into the parent material. The repaired areas shall be examined for defects using penetrant flaw detection and radiography. Crack like linear defects shall not be permitted.

1.4 Corrosion Resistant Elements

All new bolts, nuts, studs, dowels, pins and other elements provided as part of the Works that are used for the adjustment or disassembly of the components or pieces shall be of corrosion resistant steel or bronze. All exposed outdoor bolts shall be of high strength stainless steel.

1.5 Nameplates

Each major and auxiliary item of upgraded equipment shall have a nameplate permanently affixed thereto showing in a legible and durable manner the serial number, name and address of the manufacturer, ratings, characteristics, weight, manufacturing date and other significant information, as applicable. Nameplates of distributing agents only shall not be acceptable.

Additional nameplates shall be provided to indicate main operating instructions, caution or warning for personnel and operational safety. In addition, each panel-mounted instrument, position indicator, pushbutton, switch, light, or other similar device shall be identified by a permanently affixed nameplate that describes the control functions. Electrical wiring and instruments including relays shall also be labeled to correspond to the numbers assigned on the electrical control schematics.

The above general nameplate requirements shall be used in preparing nameplate lists and drawings shall be submitted to the Engineer for review and approval. Contractor's Drawings for nameplates, as they will appear on the finished equipment, shall be submitted to Engineer for review and approval.

All nameplates shall be in English and shall be suitably engraved and shall be weather-resistant. All nameplates shall be permanently attached to the respective parts, components, or equipment items in clearly visible locations. Nameplates for control equipment shall be screw-mounted laminated plastic, white with black cores, with engraved capital letters 6.4 mm minimum height.

1.6 Foundation Materials

1.6.1 General

All permanent foundation materials including all anchor bolts, jacks, tie rods, turnbuckles, anchor loops, leveling screws, supporting columns made of pipe or structural steel, soleplates, embedded anchor plates, bracing, and all other foundation materials required for anchoring and/or supporting the parts during concreting, shall be provided with all equipment.

1.6.2 Anchor Bolts

All anchor bolts and anchoring materials, for anchoring the equipment and accessories, shall be provided. Calculations showing the stresses in the anchor bolts for the, shall be submitted for review and approval by the Engineer.

1.7 Fasteners and Anchor Bolts

1.7.1 General

All bolts, studs, nuts, etc., shall have a standard metric threading and conform to the relevant standards as regards shape and tolerance. They shall be marked by the manufacturer's symbol and class of strength.

Nuts and bolt-heads shall be hexagonal in shape and truly faced. Bolts and screws with sunk heads such as Hexagon Socket Head Cap Screws or Hexagon Socket Countersunk Head Cap Screws shall be made from stainless steel only unless approved by the Engineer.

All bolts, studs, nuts, washers, screws, etc., above size M10, shall, if not in stainless steel or other corrosion resistant material, be hot dip galvanized, except for bolts above Strength Class 8.8, for which corrosion resistant materials or electrolytic zinc-coating shall be preferred.

All bolts and nuts used in bolted and screwed joints in hydraulic steel structures shall have a minimum dimension of M16.

Expansion bolts shall have a minimum dimension of M16 and shall be stainless steel.

Bolts, nuts, studs and screws which require frequent tightening and unbolting during inspection or maintenance procedures shall be of stainless steel.

For equipment within closed cabinets, in oil sumps and similar locations the Engineer shall approve other types of corrosion protection.

All bolts, nuts and screws shall be secured in an approved manner against their becoming loose during operation.

The Contractor shall supply the net quantities plus 5% spare of all permanent bolts, screws and other similar items and materials required for installation of the works at the site. Any such bolts, screws, etc., which are surplus after the installation of the equipment has been completed shall become spare parts and shall be wrapped, marked and handed over to the Employer.

Washers, locking devices and anti-vibration arrangements shall be provided and shall be subject to the approval of the Engineer. Taper washers shall be fitted where necessary.

Nuts, bolts and screws that might become loose during operation shall be locked in fastened position by means approved by the Engineer.

Bolts shall be designed so that with the nuts fully tightened, the stress intensity at the bottom of the thread shall not exceed half the yield stress of the material under all conditions.

All torque values shall be stated on the Contractor’s Drawings or torque value listing.

All existing fasteners in contact with water shall be replaced. All existing fasteners, which exhibit corrosion, or are not reusable, shall be replaced.

Bolts, nuts and studs, except for fitting-up bolts and shaft coupling bolts.

1.7.2 References

Table 4: Bolt and Nut References

American Society for Mechanical Engineers	
B1.1	Unified Inch Screw Threads (UN and UNR Thread Form)
B1.15	Unified Inch Screw Threads (UNJ Thread Form)
B1.13M	Metric Screw Threads (M Profile)
B1.21M	Metric Screw Threads (MJ Profile)
B18.2.1	Square and Hex Bolts and Screws (Inch Series)
B18.2.3.1M	Metric Hex Cap Screws
B18.2.3.2M	Metric Formed Hex Screws
B18.2.3.3M	Metric Heavy Hex Screws
B18.2.3.4M	Metric Hex Flange Screws
B18.2.3.5M	Metric Hex Bolts
B18.2.3.6M	Metric Heavy Hex Bolts
B18.2.3.7M	Metric Heavy Hex Structural Bolts
B18.2.3.8M	Metric Hex Lag Screws
B18.2.3.9M	Metric Heavy Hex Flange Screws
B18.2.2	Square and Hex Nuts
B18.2.4.1M	Metric Hex Nuts, Style 1
B18.2.4.2M	Metric Hex Nuts, Style 2
B18.2.4.3M	Metric Slotted Hex Nuts
B18.2.4.4M	Metric Hex Flange Nuts
B18.2.4.5M	Metric Hex Jam Nuts
B18.2.4.6M	Metric Heavy Hex Nuts
B18.3	Socket Cap, Shoulder, and Set Screws, Hex and Spline Keys (Inch Series)
B18.6.2	Slotted Head Cap Screws, Square Head Set Screws, and Slotted Headless Set Screws
B18.3.1M	Socket Head Cap Screws
B18.6.3	Machine Screws and Machine Screw Nuts

B18.6.7M	Metric Machine Screws
B18.21.1	Lock Washers (Inch Series)
B18.22M	Metric Plain Washers
B18.22.1	Plain Washers
Society of Automotive Engineers:	
SAE J429	Mechanical and Material Requirements for Externally Threaded Fasteners
SAE J1199	Mechanical and Material Requirements for Metric Externally Threaded Steel Fasteners

1.7.3 Fasteners

A. Threads

1. All bolts, studs, machine screws, nuts and tapped holes shall be threaded in accordance with ASME B1.13M, B1.21M for metric forms.
2. Fine pitched threads shall be made to Class 3 tolerances for U.S. Customary forms and to Class 4H and 5H for metric bolts and nuts respectively.
3. Fasteners subjected to fatigue loads shall have rolled UNJ or MJ thread forms.

B. Bolts

1. Bolts shall be finished hex bolts conforming to either ASME 18.2.1 for U.S. Customary or ASME B18.2.3.xM for metric.
2. Carbon steel bolts shall be SAE J429 Grade 2 or higher and/or SAE J1199 Grade 5.8 or higher.

C. Nuts

1. Nuts shall be finished hex nuts conforming to either ASME B18.2.2 or ASME B18.2.4.xM for metric.
2. Nuts and tapped holes shall be selected/designed to support more load than the bolt, and to minimize galling.

D. Cap and Set Screws

1. Cap and set screws shall conform to the applicable requirements of ASME B18.3 and/or to ASME B18.3.1M for metric screws.
2. The hardness of socket head cap screws utilized in load carrying members shall not exceed Rockwell C40.

E. Machine Screws and Nuts

1. Machine screws and nuts shall conform to the requirements to ASME B18.6.7M for metric screws.

F. Washers

1. Plain washers shall be hardened and conform to the requirements of ASME B18.22M for metric.

2. Lock washers shall conform to the requirements of ASME B18.21.1 for helical spring type.

1.7.4 Anchor Bolts

A. General Requirements

1. Anchor bolts shall be supplied in accordance with the anchor manufacturer's recommendations for the equipment design, details shown on the approved Contractor's Drawings and with the requirements of the Specification unless otherwise directed.

2. The anchor bolts specified herein are intended for anchorage of equipment to new concrete foundations or existing concrete structures. Such items include but are not limited to anchorage of the connection ring liner prior to welding, anchorage of sump tanks, accumulator tanks, equipment skids, pipe hangers and supports.

3. Anchor bolts shall be of the dimension, size and grade as indicated in the Contract documents. Nuts and washers shall be as specified for grade, type and style.

4. Chemical anchors with past due expiration dates shall not be used and shall be properly discarded.

5. Anchors for lighter static loads shall be of the drilled, wedge type of 303 or 304 stainless steel.

6. After anchor bolts have been embedded, Contractor shall protect threads by applying grease and by having the nuts screwed on until the time of installation of the equipment or metalwork.

B. Embedment Depth

Minimum depth of embedment of drilled mechanical anchors shall be as recommended by the manufacturer, but no less than six and one-half bolt diameters.

1.8 Coupling Guards

All rotating shafts and couplings shall be fitted with rigid guards of wire mesh or plate so designed that accidental contact with the rotating parts is not possible.

1.9 Locks

Locks shall be supplied for all normally closed valves and for electrical cabinets and cubicles. Three keys shall be supplied for each lock and all keys shall be non-interchangeable. All padlocks shall be of brass.

A key cabinet shall be supplied to accommodate the keys. The keys shall have an engraved identification tag and the key hooks in the cabin shall also have engraved labels.

1.10 Lubrication

Grease, oil and hydraulic fluid for all Plant and systems shall be provided by the Contractor for initial filling of all the equipment, plus an additional fifty percent. The types of lubricants and hydraulic fluids to be used shall be coordinated with the Engineer so that the same types shall be used throughout the Project. Upon completion of the design, the Contractor shall provide a schedule showing the types, the quantities of oil, hydraulic fluid and grease required for the initial filling of each item of Plant.

Lubricants and greases shall be of types readily available in Pakistan.

During erection, use shall be made of an approved anti scuffing lubricant, such as molybdenum-di sulphide, on threads of bolts and nuts for items requiring subsequent routine dismantling.

1.11 Handling Devices

The Contractor shall furnish any required special handling and lifting devices for handling all newly furnished components.

Lifting lugs, brackets, and eyes as required for attaching lifting devices shall be provided on all of the major components of new equipment.

All equipment over 50 kg weight shall be equipped with lifting lugs or screwed sockets for eye bolts conveniently located for ease of handling. Sufficient eye bolts shall be supplied for the equipment to be handled and these shall be handed over to the Employer at the end of the erection period in good working condition. The lugs and eye bolts shall meet the requirements of FEM or other approved recognized international Standards. Lugs and eye bolts shall have a factor of safety of 5 in relation to the load being handled and shall be ultrasonically examined before use.

1.12 Platforms, Stairways, Ladders and Hand Railing

1.12.1 General

The Contractor shall provide all platforms, galleries, stairways and ladders necessary to give access to the various sections of the plant being supplied under this Contract. The Contractor shall provide adequate means of access for all operation, inspection and overhaul purposes and shall be of sufficient strength to support workmen, tools and portions of plant which shall be placed on them during maintenance and inspection periods.

Platforms, stairways and ladders shall be designed generally for a load of 250 kg/m², but where loads in excess of this are likely to be imposed during operation or maintenance, the Contractor shall ensure due allowance in the design. All necessary supports shall be supplied under this Contract.

Platforms and galleries shall have a minimum width of 850 mm clear passageway and shall be enclosed by hand railing on both sides. In cases where there is a space not exceeding 200 mm on one side of a passageway hand railing need be supplied for one side only but an edging strip shall be provided on the other side. The minimum headroom on platforms and galleries shall be 2100 mm.

Ladders shall only be permissible where stairways are both impractical and access is required for maintenance purposes or for emergency purposes.

1.12.2 Flooring

Floors of all platforms, staircase treads and ladders shall be of galvanized mild steel open grid except in those cases where chequer plate is specified. Platforms shall have edging strips extending to a height of not less than 150 mm above the platform. Any opening in the open grid flooring or chequer plate shall be finished off with a similar edging strip. Handrails shall be provided on platforms and ladders as necessary for safety of operating personnel. These shall be of formed steel plate with plastic covers.

Where chequer plate is supplied it shall be galvanized mild steel. No chequer plate shall be less than 10 mm thick over the chequer and all plates shall be secured to the supporting steel by galvanized countersunk screws.

Open grid floor panels shall be not less than 25 mm in depth and shall be fitted neatly between Krebs and clamped with nuts and bolts in such a manner as to permit ready removal or replacement. The design of the clamps shall be to approval and only minimal protrusion above the floor level shall be permitted.

1.12.3 Hand Railing & Protective Barriers

Hand railing and protective barriers shall be provided wherever necessary to protect operation or maintenance personnel from hazards and shall comply with BS 6180.

Double hand railing shall be provided unless otherwise specified. Each length shall be joined by internal ferrules and all joints shall be neatly finished by the removal of all burrs. The top rail shall be not less than 30 mm diameter and a height of not less than 1100 mm from the gallery or platform level. The intermediate rail shall be not less than 25 mm diameter and at a height of not less than 535 mm from the gallery or platform level. Handrails over stairways shall have the top level at a height of not less than 900 mm and a lower rail at not less than 420 mm above the stairway pitch line.

Tubular or solid forged stanchions shall be provided, spaced at a maximum distance of 1,750 mm, and to which hand railing shall be firmly attached.

The stanchions shall be firmly attached to the platform, gallery, stairway or ladder steelwork, but not toe plates, or civil works by bolting, and when erected shall be vertical.

In designing hand railing and the supporting stanchions particular attention shall be paid to the provisions of BS 6180 relating to design loads and to permissible deflections and flexibility.

1.12.4 Stairways

Main stairways shall have a minimum stair tread width of 1100 mm; other stairways shall have a minimum width of 750 mm. Wherever possible, the angle of slope of stairways shall be standardized. Angles exceeding 42° shall not be used.

No flight of stairs shall have more than 16 risers. Where a stairway requires more than 16 risers, each flight shall have an approximately equal number of risers and shall be separated by a landing. Risings shall be between 190 mm and 210 mm, and goings shall be between 220 mm and 250 mm in width. Minimum headroom shall be 2.3 m.

1.12.5 Fixed Access Ladders

Ladders shall comply with BS 4211. The minimum width of ladders shall be 500 mm and shall have an inclination of not less than 70°, or more than 80° to the Vertical.

1.13 Pumps

1.13.1 General

All pumps to be supplied for the Works shall be of a reputable make and of a type best suited for their purpose. They shall be furnished complete with electrically driven motors of ample capacity to provide safe and continuous service under all operating conditions of the respective system. Each pump shall be supplied with a common base plate or support, as the case shall be for its drive motor.

The main dimensions shall as far as possible be standardized, as an example according to ISO 2858 or similar relevant standards.

Pumps rated less than 100 kW, shall in general be delivered with guarantees according to ISO 2548 Class C, unless otherwise specified.

Pumps rated above 100 kW shall in general be delivered with guarantees according to ISO 3555 Class B, unless otherwise specified.

Pump bodies of larger pumps (above 30 kW rating) or maximum pressure above 6 bar, shall be of nodular cast iron quality not less than 400-12 ISO 1083 (GGG 40 DIN 1693), or cast steel 45.3 DIN 1681.

Pump bodies of smaller pumps (less than 6 kW) may be of cast iron of a quality not less than GG 25 DIN 1691 or approved equivalent.

All wearing parts, sealing faces and shafts, etc., shall be of a corrosion proof material and easy to replace. The shafts shall have wear collars where required. Mechanical shaft seals shall be preferred. Shafts sealed by stuffing boxes shall be fitted with sleeves. Seals shall be exchangeable without extensive disassembly of the pump. Leakage water shall be led to suitable canals/gutters. Each pump shall have air and drain valves.

Pump impellers and labyrinth rings shall be of Ni Al - bronze or stainless steel. For standard pumps being supplied with more than one impeller diameter, the proposed impeller shall not be of the maximum nor the minimum size for the selected pump.

Pumps intended for continuous operation with water with suspended sediments shall have materials and surface coating for impeller, labyrinths and shaft seal specially designed for such service.

Pumps shall not require frequent lubrication of the shaft bearings.

All pumps shall be fitted with a suitable manometer, as specified hereafter. The pressure tapping for this item as well as other instruments required in the Specifications shall be arranged so as to ensure a correct indication of the value to be measured, as indicated in ISO 3555 or DIN 1944. All instruments shall be easily visible. Should transfer pipes be required, they shall be of a corrosion proof material with an isolating valve at the connecting point.

The size of the pump motor forming part of the supply of pumps shall be:

$$Pm = 1.10 \times Pp$$

Pm = rated motor power

Pp = maximum required power at the rated pump capacity

The pumps shall withstand corrosion and wear by abrasive matters within reasonable limits.

For submersible pumps, pump and motor shall be contained in the same casing and designed as a package unit with incorporated suction strainer. The impeller shall be of bronze or with rubber lining or of stainless steel. For dirt water pumps, the flow channels shall be rubber or epoxy lined.

Dirt water submersible pumps with the motors mounted on top of the pump shall be suitable for running dry continuously, without damage to seals, bearings, or motors.

For any pump, the overall pump/motor efficiency for the specified rated head and discharge shall not be less than 60%.

If requested by the Engineer, one out of three pumps with Pp larger than 30 kW shall pass a performance test to ISO 2548 Class C (DIN 1944, Class II), with measurements taken at discharges of 0%, 50%, 80%, 100% and 110% of nominal capacity at rated speed. The results have to be certified in a Workshop certificate. For pumps with Pp larger than 100 kW, these tests shall be compulsory.

Prior to the test, the Contractor shall provide certified motor performance curves.

All pumps shall have a pressure rating, guaranteed by the manufacturer, of minimum 50% above the normal system working pressure.

Acceptance test of oil pumps shall be performed according to relevant standards approved by the Engineer at the manufacturer's shop or at the Site.

1.13.2 General Requirements of Centrifugal Pumps

Preventive and routine maintenance time shall be minimized by the selection of appropriate design of pumps, preferably those that leave casing to piping joints intact, i.e., Vertical split-casing types for large centrifugal pumps and Vertical, back pull out types for smaller units.

Where a significant saving in floor space or improvement of layout can be demonstrated, a vertical pump may be acceptable.

All pumps above 150 kW shall be provided with temperature sensors on the bearing of the pump and the motor. Vibration sensors shall also be fitted on pumps above 150 kW.

Pumps shall be capable of continuous operation with minimum maintenance over the operating range from minimum flow to maximum flow. The Contractor shall define this range.

The rating of the driver and the pumps net positive suction head (NPSH) requirements shall be such that the pump is capable of a flow rate 10% in excess of the maximum flow rate required.

In addition, pumps shall be designed to have a reasonable margin on head (normally 5% on head for clean fluids, 10% for solids bearing fluids) to compensate for normal wear of pump components. There shall be an adequate margin on NPSH, normally greater than 1 m for values of NPSH required and between 2 m and 12 m with flow rates up to the stated maximum.

When pumps are installed to operate in parallel, they shall be capable of equal load sharing throughout the operating range. This implies a pump head flow characteristic that falls continuously from shut valve to duty point by at least 10%. The pump unit shall, when operating over its normal range of flow rates, comply with the noise emission requirements stated in this section.

All pump motor units shall be installed on a substantial base plate, with isolating valves, a discharge non return valve, air release valves (for both pump casing and seal chamber), drain valves, suction and discharge pressure gauges unless otherwise stated. The supplier should review the minimum flow rates stated and advice if a leak off system is necessary, in which case all minimum flow detection devices, diversion valves and pipe work shall be supplied.

1.13.3 Technical Requirements for Centrifugal Pumps

In selecting bearing type, account should be taken of possible vibration damage to the bearing surfaces while the machine is stationary. Where sleeve bearings are used, bearing shells shall be replaceable without removing pump or motor shaft. Bearing housings shall be effectively sealed against loss of lubricant and ingress of fluid or dirt. Oil seals shall be replaceable without major dismantling of the pump.

All oil lubricated bearings shall have housings fitted with means of drainage, visual oil level indicator and capped filler or a constant level oiler which is accessible whilst the unit is operating. Grease lubricated bearings shall be connected to readily accessible greasing points either singly or at a battery plate. Lubrication should be by means of a pressure gun.

Where rolling contact bearings are used, they shall be sized to provide a minimum L10 life of 16,000 hours (as per ISO Standard 281/1) under conditions of maximum load on the bearings.

In the case of a close coupled pump, this requirement applies to the motor bearings. Replaceable case wear rings shall be fitted where diameters exceed 150 mm and replaceable impeller neck rings where diameters exceed 250 mm. All wear rings shall be a press fit on or in their respective component and positively locked against rotation.

Casing design pressure shall be at least 1.1 times the pump shut valve pressure with the pump operating at maximum possible inlet pressure. The pump casing and base plate shall be capable of withstanding all hydraulic forces, together with externally applied pipe moments and loads as stated in the technical particulars. The supplier shall state the pump's pipe load limitations.

The pump unit and all removable components greater than 10 kg in weight shall be fitted with suitable lifting lugs and eyes to facilitate all erection and maintenance tasks. Any special lifting tackle shall be supplied.

Suitable means, such as jacking screws, shall be provided to aid the separation of pump components; these shall be arranged so that no damage can be done to mating or sealing faces by their use.

The method of fitting the impeller to the shaft shall adequately center the component but allow its removal without risk of damage to either component. Torque shall be transmitted to the impeller by keying, other than in the case of a multistage vertical pump for which a collect drive may be acceptable. The main impeller nut or screw shall not have its thread exposed to the pumped fluid and must either be locked or maintained tight by virtue of the normal direction of rotation.

The pump shafts shall be designed such that the first critical speed of the pump is at least 20% higher than the maximum speed encountered in service.

All rotating components shall be dynamically balanced and the complete pump shall comply with the requirements of the vibration section of this section.

Where two pumps are connected in parallel, the units shall be capable of reverse rotation under full pump head without sustaining any damage.

1.13.4 Shafts, Seals and Couplings

The pump shall be fitted, depending on its duty with a packed gland or mechanical seals of a reputable manufacturer, preferably of a pressure balanced type. The design of the unit shall allow the mechanical seal to be replaced or the gland to be repacked without disturbing the pump or driver.

Any leakage at the gland shall be intercepted by a flinger.

All pump glands shall be provided with trays and guards to catch leakage. Piping shall be fitted for drainage to an approved location. Other than on small pumps (i.e., with driver less than 50 kW) auxiliary pipe work for seal harnesses, drains, etc., shall be not less than 20 mm bore.

Couplings shall be dynamically balanced and the couplings shall be match marked. Where a spacer coupling is used, the spacer shall similarly comply.

1.13.5 Pump Materials

Materials of construction shall be selected with due regard to the corrosive nature of the pumped fluid and risk of corrosion, cavitation, and metal to metal galling that can occur within a pump in all its modes of operation. It is the Contractor's responsibility to select materials that shall provide an adequate service life.

1.14 Hydraulic Systems

Hydraulic systems shall fulfill the general safety requirements set forth in EN 983 or other relevant standards.

1.14.1 Oil Pumps

Pumps for hydraulic systems shall be of the displacement type. Parallel to each pump or group of pumps operating in parallel, a relief valve of sufficient capacity to by-pass the full delivery of the pumps at a pressure only 10% above the maximum allowable working pressure shall be provided as a safety measure.

The pumps shall be provided with check valves and pressure switches for actuating the starting equipment. Hand operated valves shall be provided to isolate any pump from the hydraulic system and permit its removal without losing oil pressure.

1.14.2 Oil Pressure Tanks

Oil pressure tanks shall be of welded construction, designed, constructed and tested in accordance with the ASME Boiler and Pressure Vessel Code, Section VIII, part 1, for 1.5 times the maximum system operating pressure.

The welded joints of the tank shall be finished smooth. The welds shall not be ground to the extent that the tank is weakened structurally, but it shall be free of irregularities that would throw highlights when painted.

1.14.3 Sump Tanks

The capacity of the sump tank shall, unless otherwise specified, not be less than that required to contain all of the oil that can be discharged back into the sump by completely discharging the oil in

the system. The oil Volume-III the sump tank shall be sufficient to maintain the oil level within an adequate working level during operation.

- Oil sump tanks shall be provided with:
- Suitable access openings
- Fine mesh strainer(s) combined with a magnetic filter/plug which all oil returning shall pass. The strainer(s) shall be readily removable for cleaning.
- Humidity separating air filter.
- Flush mounted oil level indicator(s), covering most of the tank height.
- Capped filler hole with a suitable strainer
- Drain connection with hand operated shut off valve.

Sump tanks must be installed so that the bottom of the tank and the drain connection are at least 400 mm above the floor.

The interior of the tank shall be free of crevices, open joints, or dead end holes, and all welds inside the tank shall be continuous. Oil sumps shall be made from stainless steel. The interior and exterior surfaces of any sump tanks not made from stainless steel shall be cleaned and painted as specified in these General Technical Specifications.

1.14.4 Hydraulic Oil Piping

All main piping shall be seamless tubing with welded joints, approved couplings or steel flanges for bolted connections. All piping shall be thoroughly cleaned (removing all mill scale, weld deposits, etc.), oiled inside, painted on the outside as specified in these General Technical Specifications, and protected for shipment by protectors on all flanges and plugs on pipe ends. If stainless steel piping is used, no painting is required, such piping requires couplings and fittings of identical material. All gate valves in the pressure lines shall be of the cast steel, solid wedge, rising stem, type with close guide clearances to minimize vibration of the gates when operating at partial opening. Piping shall be shop fabricated to the maximum extent possible, consistent with erection, handling and shipping requirements, so as to reduce field work.

Oil piping shall be completed with taps for oil sampling and pressure testing.

Adequate pipe supports shall be provided to prevent vibration and movement of the oil piping during sudden pressure changes. All necessary studs, bolts, nuts, washers, oil resisting seals, pipe supports, and hangers for field assembly of the oil pressure system shall be furnished.

1.15 Piping

1.15.1 General

Pipe work drawings shall be in accordance with ISO 6412.

Piping shall be arranged to facilitate access for maintenance and such that removal or replacement of Plant can be achieved with the minimum dismantling of piping. The design of piping shall be such as to minimize Site welding.

All pipes work 25 mm and below shall be stainless steel. All piping for cooling water system shall be Stainless steel unless otherwise specified or approved by the Engineer. The piping shall have material combinations which avoids galvanic corrosion.

Provision shall be made for the draining and release of air in systems. Plugged drain and air release bosses shall be welded to pipes at appropriate points to facilitate hydraulic testing.

All interior water pipes shall be lagged with fiber glass lagging not less than 1" or equivalent as approved by the Engineer.

Embedded pipe should be kept to a minimum. In preference to running pipe in covered floor trenches it shall be supported from walls and ceilings.

Floor collars or wall box shall be provided at all points where pipes pass through floors and walls. The floor collars shall have raised Krebs not to be less than 75 mm in height. All wall boxes shall be sealed and flush fitting.

The Contractor shall provide all necessary fittings for the passage of pipes through external walls and roofs, together with all necessary components for the protection against weather.

In the case of flanged pipe work, boxes shall be large enough to permit the passage of the flange.

1.15.2 Identification of Piping

The Contractor shall furnish and apply pipe identification markers on all piping systems. The markers shall be applied after all insulation and painting work has been completed. Each pipe shall be identified at each valve, at every point of pipe entry or exit where two or more lines go through a wall, at each tee joint, and on continuous lines, at least once in every unit block. A direction of flow marker shall be affixed downstream of each pipe identification marker. Markers shall be applied on the two lower quarters of the pipe where the view is unobstructed. The markers shall be of adhesive-coated vinyl cloth which shall be applied in accordance with the manufacturer's instructions and shall be white with black letters. Letters shall vary between 10 mm and 40 mm in height to suit the piping size. Pipe marker legends shall be designated by the Engineer.

1.15.3 Welding

Pipe work welding, testing and inspection shall conform to the appropriate ASME and ASTM Standards and where applicable AWS.

1.15.4 Hydrostatic Testing

Except as precluded by shipment in parts for Site welding due to size, hydrostatic works tests shall be carried out by the Contractor on all casings, vessels, valves, pipes and other pressure fittings. Such tests shall be at 50% above the maximum operating pressure. The test pressure and date shall be stamped on all parts tested and certificates or written particulars of each test shall be supplied to the Engineer.

In each case the pressure shall be maintained for a period of thirty minutes, the item under test remaining tight under the specified pressure.

All valves shall be tested for both "open end" and "closed end" conditions.

All piping systems shall be hydrostatically tested at Site.

1.16 Pipe Supports and Anchors

Pipe work and accessories shall be supported and mounted in accordance with ANSI B31.1 Power Piping. All necessary slings, saddles, structural steelwork, foundation bolts, foundation inserts and plates, fixing bolts, locks and all other attachments shall be supplied.

No point of passage of pipes through floors or walls shall be used as a point of support.

1.16.1 Flanges

All pipe flanges shall be in accordance with ISO 7005 Standard as applicable for the appropriate condition. Threaded pipe shall be in accordance with ISO 7 and ISO 228 as applicable.

1.16.2 Jointing Material

Complete jointing material, bolts, nuts and washers shall be provided for flanged pipes, valves and fittings supplied under this Contract. Threads and other details of fasteners shall comply with ISO Standards. The quantities supplied shall include twenty percent excess to allow for wastage.

1.16.3 Internal Cleaning of Pipes

The Contractor shall ensure that the internal surfaces of all pipelines are thoroughly clean.

All internal surfaces prior to erection shall be cleaned to remove accumulations of dirt, rust, scale, and welding slag due to Site welding before erection.

Prior to and during erection, all parts shall be inspected to make sure that they are clean, and adequate steps shall be taken to prevent entry of foreign matter both during and after erection. Each section erected shall be cleaned out before the next section is connected to it. All headers shall be cleaned before closing up.

All ferrous oil pipe work shall be acid pickled and flushed with oil prior to erection.

All pipe work after erection shall be flushed using the same fluid as for the system.

The Contractor shall provide all necessary facilities in the pipe system for cleaning including any temporary pipe work.

1.16.4 Pipe Terminations and Connections

The Contractor shall co-operate fully with other Contractors and the Engineer to establish agreement on the jointing technique at terminal points.

All pipe connections shall be fusion welded except where flange connections are required or specified to facilitate erection or maintenance, or where pipe materials used preclude welding.

Screwed pipe work shall only be permitted for pipes of less than 50 mm bore in non-critical air or water services.

Below 25 mm bore connections shall be of flared connectors or welded cone nipple in positions where leakage shall not introduce any hazard and the type of coupling and particular application has been approved by the Engineer.

Pipe work flanges shall comply with the requirements of the code to which the pipe work is designed. Flanges having ratings less than 10 bar g shall not be permitted except where agreed with the Engineer.

All metallic pipe flanges either for high or low pressure or for high or low temperature shall be in accordance with ANSI/ASME B16.5, and other approved standards, as applicable for the appropriate condition.

All plastic pipe flanges shall be in accordance with ISO 2536 and 3663 and the other standards issued by Technical Committee 138 (TC138) of the International Organization for Standardization.

Jointing material, bolts, nuts and washers shall be provided where necessary for flanged pipes, valves and fittings supplied under this Contract.

In the case of cast iron flanges full face gaskets shall be used so that bending stresses shall not be induced in the flange by bolt tightening.

Jointing of thermoplastic piping shall be carried out in strict accordance with the Manufacturer's recommendation.

1.16.5 Fluid Velocities in Pipes

The maximum allowable velocity of flow in pipes shall be as listed in the following table.

Table 5: Maximum Allowable Flow Velocity in Pipes

Service	Maximum Allowable Velocity (m/s)
Compressed air	15
Cooling water	3
Lubricating Oil	2
All other pipe work	0.6 m/s per 25 mm bore up to a maximum of 4.2

1.16.6 Embedded Pipe Work

All service pipe work embedded in concrete shall be of stainless steel.

1.17 Valves

1.17.1 General

All valves shall comply with the relevant ISO Standards.

All valves shall be arranged so that the hand wheel moves in a clockwise direction to close the valve. The face of each hand wheel shall be clearly marked with the words "open" and "closed" and shall be provided with an arrow to indicate direction for opening and closing. As far as possible, valves shall not be fitted in an inverted position.

All valves shall be readily accessible for both operating and maintenance and, where necessary for ease of manual operation, the spindles shall be extended and an approved form of pedestal hand wheel provided at convenient operating floor or intermediate floor level. Pedestals shall not be mounted on checkered plate cover or floor gratings.

All hand operated valves shall be capable of being opened or closed against their maximum working pressure with a force at the hand wheel not exceeding 200 N.

Valves of 100 mm nominal bore and above shall be provided with valve position indicators. All valves shall be fitted with labels showing duty and identification number.

All hand wheels shall be of metal. Bonnets and valve covers shall be bolted in position, not screwed.

Valves used for isolation purposes shall not be smaller than the pipeline size.

Where appropriate all valves of 250 mm bore and above other than drain valves shall be provided with by-passes connected to the valve body.

A complete valve schedule for each pipe work system shall be provided for approval.

Parallel slide or gate valves shall be used for isolation purposes for water, oil and gas services. In general valves shall not be used for throttling service. Flow control shall be achieved by stainless steel orifice plate mounted between flanges for ease of adjustment. To the approval of the Engineer needle valves shall be used for throttling services in special cases. Butterfly valves shall be used for application of 200 mm diameter and above.

Parallel slide or gate valves shall be such that the bore of the fully open valve is unobstructed by any part of the gate.

Non return valves shall be of the non-slam type. Safety relief valves shall be of the pop action type.

1.17.2 Parallel Slide, Gate and Sluice Valves

Parallel slide and gate valves shall be used generally for isolating purposes. The valves shall be of the full way open type unless approved to the contrary and when in the fully open position, the bore of the valve shall not be obstructed.

Where applicable bypasses and equalizing pipes shall be fitted to parallel slide and gate valves in accordance with the following table.

Table 6: Use of Parallel Slide and Gate Valves

Valve type	Pressure Range	Valve Size
Parallel slide only	0 to 19 bar g	250 mm and above
Parallel slide and gate valves	19 to 65 bar g	200 mm and above

For potable water supplies, sluice valves shall be cast iron wedge gate valves with bronze trim in accordance with BS 5163 or equivalent approved standard. The valves shall be of solid wedge gate type. The valve bodies shall be of the best quality cast iron complying with BS 1452 (Grade 14). Valve seals and facing rings shall be zinc free bronze or gunmetal and spindles of manganese bronze. The valve gates shall be provided with bronze guide shoes and locating channels where necessary to oppose unbalanced forces during opening and closing. The spindles of valves subject to unbalanced pressures during operation shall also be provided with ball thrust collars to reduce the turning effort required. The ball bearings shall be contained within totally enclosed grease packed housings with seals to prevent the ingress of dust and moisture.

Large bore wedge gate valves are to be provided with easing screws and a suitable flushing connection, complete with valve, which shall be fitted at the valve sealing to facilitate removal of any dirt preventing complete closure.

Gate valves to be used for seawater shall have the body and internals manufactured from materials as specified in this Specification.

1.17.3 Spherical Valves

Spherical valves shall generally be used for regulating purposes. The valve shall have radiused or spherical sealings and the disc shall be free to revolve on the spindle. An arrow indicating the direction of flow through the valve shall be clearly cast or embossed on the body of each valve.

Spherical valves shall comply with BS 5154 or BS 5160 or equivalent as might be applicable to the particular installation requirement.

1.17.4 Safety Relief Valves

Pressure relief valves shall be of the spring-loaded type unless otherwise specified, or unless the Engineer has given written permission for the use of a different type of valve actuation.

Safety valves shall comply with BS 6759 or equivalent.

Spring loaded valves shall be fitted with easing gear which shall not be extended.

Where necessary relief valves shall be supplied with vent pipes, silencers and drains, and with gagging equipment for hydraulic testing following erection and in the long term maintenance of the plant.

1.17.5 Butterfly Valves

Butterfly valves shall have bodies of either the flanged or lugged wafer type. The actuator/manual gearbox shall be mounted direct to the valve body, other than where both actuator and body are fitted with feet for pedestal mounting; no actuator loads shall be transmitted via the pipe work. The valve should be mounted with spindle set Vertical. If the valve is designed for unidirectional flow, an arrow shall be cast or embossed in a prominent position on the valve body to indicate that direction.

The valve must be capable of positive shut off in both directions against full system pressure. Unless an alternative type is proposed by the Contractor and approved by the Engineer as being fully suitable for the particular duty, the seating of the disc shall be positive (that is, the disc must not be capable of passing through the shut position); a stop fitted on the actuator/operating level is not adequate for this purpose.

Unless the Contractor can demonstrate that some alternative design is capable of adequate long term sealing, the design shall be such that the shaft is offset from the seal ring. That is, there shall be an unbroken peripheral seal when the valve is shut.

Internal shaft bearings must be capable of operating dry, that is, not dependent on the presence of the pumped fluid.

In the case of butterfly valves for potable water supply mains, they shall be of cast iron resilient seal construction and in accordance with BS 5155 or an equivalent approved standard.

Each valve body shall be of best quality cast iron conforming to BS 1452 (Grade 14 or 17) with a closure sealing of bronze or stainless steel, or the resilient seal material. The valve disc shall be of high quality cast iron with the seat facing of bronze, stainless steel or the resilient seal material.

The disc shaft is to be of stainless steel to ASTM 316L. Shaft bearings shall preferably be of the self-lubricating type, with "O" ring seals.

The actual position of the valve disc shall be clearly shown by an external indicator.

Besides mechanical operation tests, each valve shall be subjected to a body pressure/leakage test and strength/leakage test.

1.17.6 Float Valves

Float valves should be of the equilibrium ball float type. Floats for cold water duty shall be plastic, of a grade that does not deteriorate in sunlight. All operating rods, guides, brackets and covers shall be of non-ferrous material.

Float valves operating in liquids other than fresh water shall be of materials to the Engineer's approval. Float valve shall comply with BS 1212 or equivalent and be complete with float rods, guides, covers and brackets where required.

1.17.7 Non-Return Valves

For severe service conditions, cushioned check valves shall be used. Cushioning piston and valve disc area shall be as nearly equal as possible to produce balance and obviate valve clatter.

Swing check valves shall have facilities for quickly examining the clack. The body seat shall be inclined at such an angle from the vertical as shall facilitate closing and prevent clatter, and the clack shall be arranged to possess a movement in favor of closure increasing in the final stages of the swing. The clack shall be secured to the hinge in a manner which allows for the self-seating of the clack. Counterpoise devices and dashpots shall not be used except when specifically approved by the Engineer. Where solids are liable to hazard operation of the valve, due precautions shall be taken.

All non-return valves shall be provided with means of draining the space between the valve and its adjacent isolating valve. The design shall preclude the possibility of the valve jamming in the open position; the effect of solid particles settling out in dead spaces within the valve should be recognized in this respect. Where screw down non-return valves are supplied, they shall provide a demonstrable leak tight joint.

Unless stated to the contrary, non-return valves should be rapid closing. Power assisted closing is acceptable where necessary for rapid shut off. For large non-return valves on air and water services, consideration shall be given to the consequences of valve slam and the possible requirements for a hydraulic snubber to minimize slam effects.

1.17.8 Pressure Reducing Valves and Relief Valves

Pressure reducing valves shall be of the external pilot valve operated type capable of passing the required total flow while operating over the same head range as the turbine. The minimum discharge head shall include a generous margin to overcome the total losses of the raw water system and discharge to the tailrace. It shall be complete with all necessary fittings. The pressure

reducing valve shall be designed to close reliably on cessation of flow. A relief valve shall be provided, designed to open at 10% overpressure and pass full flow at 25% overpressure.

1.17.9 Power Operated Valve General Requirements

Valves, dampers and similar devices requiring abnormal physical effort to operate or high speed operation, shall be provided with powered actuation. Hand operating equipment shall also be fitted for closing and opening, which is effectively decoupled during power operation.

The following criteria are preferred in the selection of the power source for the servo mechanism:

Isolation and other duties not subject to operation of more than once in 10 minutes - electrical, compressed air.

Continuous or intermittent modulation - compressed air, electrohydraulic.

Continuous or intermittent modulation involving heavy control forces likely to produce fluttering or hunting - electrohydraulic, electrical.

Emergency control or isolating duties - compressed air, spring loaded, or electrohydraulic with sufficient reservoir capacity to complete the operation without an external source.

Electric actuators for on/off duties shall be fitted with travel limiting devices capable of accurate and positive adjustment. Torque limiting or other devices shall be provided to prevent damage to the mechanism in the event of jamming of the driven device.

All powered valve or damper mechanisms shall be provided with accurate indication of the position of the driven device.

Electrically operated devices shall be provided with integral or separate switch/control equipment in accordance with the requirements of the Control and Instrumentation Specification. Provision shall be made for the inclusion of interposing relays and volt free contacts to suit modern control systems, including digital control systems.

Power supplies shall be in accordance with those specified in Electrical General Design Specifications.

Direct solenoid operation of valves shall comply with the requirements of the Control and Instrumentation Specification.

Reversing contactors and limit switches, used to control electric power driven mechanisms, shall be robust and of proven reliability by both type test and commercial operation. Solid state switching shall be accepted when temperature conditions permit.

1.17.10 Compressed Air Systems

Compressed air systems shall fulfill the safety requirements set forth in EN-983 or other relevant standards.

Vessels shall be of the cylindrical, vertical type. The vessel shall be mounted on a structural steel base. Each vessel shall be equipped with the following provisions:

- Inlet sockets with valves
- Outlet sockets with valves
- Pressure safety valve

- Dial pressure gauges, one with four electric contacts or separate pressure switches
- Manhole or inspection hole
- Drain valve

In case the pressure vessel is used for pressurized oil or water systems, the vessel shall further be equipped with:

- One (magnetic) level gauge with shut off valves
- Level indicators with electric contacts in a number as required or specified

Each vessel has to pass a pressure test at 1.5 x nominal pressure lasting for 8 hours in the manufacturer's Workshop before coating is applied.

Each vessel shall be furnished with a test certificate of an independent, internationally reputable underwriters' society.

Compressors shall be provided with:

- Automatic lubrication
- Air intake filter and silencer
- Thermometer for measuring temperature of the compressed air
- Automatic shut down if the discharge air temperature exceeds a predetermined adjustable value
- Unloading valves
- Water drain valves
- Water and oil separator
- Pressure safety valve
- Cooler for compressed air
- Non return valve
- Inlet pressure valve
- Outlet pressure valve

The water and oil separator shall be equipped with an automatic solenoid operated drain valve to achieve automatic draining during standstill. Both compressor stages shall be equipped with unloader valves, which shall close time delayed after start to avoid compressor start against full pressure.

The compressors shall be delivered as package units on common frame with the appropriately sized AC squirrel cage motor and the respective motor control center ready for operation.

If requested by the Engineer, each compressor shall pass a performance test in the manufacturer's Workshop according to ISO 1217 (DIN 1945), without extra cost. The ready assembled compressors, controls and switchgear have to pass a functional test.

1.18 Noise Level

Maximum noise level at any of the operating conditions (unless otherwise mentioned in the technical specification) shall be as per the following figures indicated in Table below.

Table 7: Equipment Noise Level

S. No.	Equipment	Noise level dB (A)	Measured distance (m)
1	Turbine	<85	1.0 m away from the operating part of the equipment
2	Generator	<85	1.0 m away from the operating part of the equipment
3	Main Transformer	<67	3.0 m away from the equipment
4	Station Transformer (200 kVA)	<64	3.0 m away from the equipment
5	Aux. Transformer	<48	3.0 m away from the equipment
6	Diesel Generator	<75	1.0 m away from the equipment
7	Ventilation system	<45	in the control room, office and toilet
		<60	in the other rooms and areas

All rotating parts shall be designed to operate without undue vibration. Special precaution is to be taken to run the machines smoothly. The vibration level of the machines shall be within the limits specified in the relevant IS specifications (IS: 14773 / ISO 7919) or equivalent international standard. Full balancing shall be done at works. Fine balancing shall be carried out at site to bring down vibration level to acceptable limits if required.

1.19 Vibration and Balance

The amplitude of vibration of rotating Plant when measured on the bearing housings under steady state conditions at the designed operating speeds shall not exceed the values given by the 2.8 mm/s criterion of ISO 3945.

Provision shall be made for the reduction of vibration transmitted to covers, cladding, platforms and structures that are liable to vibrate. The vibration of any such radiating surface shall not exceed the values shown in Table below:

Table 8: Radiating Surface Vibration Limits

Frequency (Hz)	Amplitude (mm) (Peak-to-peak)
5	0.40
10	0.20
25	0.08

Frequency (Hz)	Amplitude (mm) (Peak-to-peak)
50	0.04
100	0.02
120	0.017

1.20 Painting and Protection

1.20.1 General Design for Protective Coatings

Unless otherwise specified all Plant shall be painted using lead-free paints. The design and layout of the Plant shall be such that all surfaces can be recoated after erection.

Where corrosion resistant materials (e.g., concrete, galvanizing, copper, aluminum) are used no decorative finish shall be applied unless otherwise specified.

Surface preparation and protective coatings shall conform to SSPC.

1.20.2 Painting

a. Surface preparation

After fabrication, the Contractor shall clean and paint the Plant in accordance with this Clause and the paint schedule given in these Specifications. Painted surfaces shall be protected from abrasion or other damage at all times.

Surfaces to be painted shall be cleaned of all mill scale, dirt and other foreign substances by scraping, chipping, blasting, wire brushing or other effective means in accordance with the applicable sections of SSPC Specification. All oil and grease shall be removed from the surfaces. In the event that rust forms or the surfaces otherwise become contaminated in the interval between cleaning and painting, the surfaces shall be recleaned. Surfaces of stainless steel, bronze and machined surfaces shall be protected by effective masking during the cleaning and painting of adjacent metal work.

b. Application procedures

Paint and coating materials shall be in a thoroughly mixed condition at the time of application. If necessary, to improve application properties, the paint shall be heated by means of a hot water bath to a temperature not exceeding 40°C. Paint other than primer shall not be thinned. Priming paint shall be thinned if necessary to improve application qualities but shall be thinned only with mineral spirits not exceeding 1 part of thinner per 8 parts of paint. Paint shall not be applied when the temperature of the metal or of the surrounding air is below 10°C or is above 40°C. Surfaces shall be free from moisture at the time of painting. The first coat shall be applied immediately after cleaning. All paint shall be applied strictly in accordance with the manufacturer's instructions. When paint is applied by spraying, suitable means shall be provided to prevent segregation during the painting operations. Means shall be provided for removing all free oil and moisture from the air supply lines of all spraying and blasting equipment. Different colors or shades shall be used for each coat. Each

coat of paint shall be free from runs, sags and missed areas and shall be allowed to dry and harden thoroughly before the succeeding coat is applied.

c. Painting schedules

Painting schedules are given in these Specifications. The make of paints to be used shall be selected by the Contractor. The Contractor shall submit his proposed paint schedules together with applicable paint specifications for approval. Surface preparation shall be done in accordance with the methods specified in the paint schedules given in these Specifications.

1.20.3 Metallic Coating

a) Galvanizing

All punching, cutting, drilling, screw tapping and removal of burrs shall be completed before galvanizing.

All galvanizing shall be done by the hot dip process with spelter, not less than 98% of which shall be pure zinc. Subject to the approval of the Engineer, where an item is of a size or shape to render hot-dip galvanizing impracticable, zinc spraying or other approved method of coating shall be adopted. Common bolts shall be completely galvanized including the threads, but the threads shall be left uncoated in the case of nuts. High tensile steel bolts shall not be galvanized.

The zinc coating shall be uniform, clean and smooth. The zinc coating shall weigh not less than 400 g/m² of area covered and be not less than 0.060 mm in thickness.

Galvanized wire shall comply with the requirements of ASTM A641 a. Nuts and bolts and small components shall be coated in accordance with ISO 1461.

All galvanized parts shall be protected from injury to the zinc coating during the periods of transit, storage and erection. Damaged areas of the coating less than 50 mm² shall be cleaned back to bright metal, feathering the edge of the surrounding galvanized coating, and touched up with zinc-rich paint. Parts which have suffered greater damage shall be re-galvanized.

b) Metal spraying

Surface preparation prior to metal spraying shall be dry grit blasting SA 2½.

Immediately after grit blasting the surface shall be cleaned of any traces of blast product on the surface and in pockets, pits, and corners by brushing with clean brushes, blowing with dry compressed air or vacuum cleaning.

The surface shall be coated with the metal spray before discoloration occurs.

c) Chromium plating

The chromium plating shall comply with the requirements of ISO 2081.

d) COLOR

The Contractor shall submit, for the approval of the Engineer, within 266 days after the date of the Letter of Acceptance of the finish colors for the individual items of Plant.

Pipework shall be identified by a color banding code. The Contractor shall submit, for the approval of the Engineer, of the code as it is applicable to this Contract within 266 days of the Letter of Acceptance.

1.21 Witnessing of Shop Assembly and Tests

The shop assemblies and tests specified for the various items of equipment shall be witnessed by the Engineer, a representative(s) of the Employer and the Contractor and the completed shop inspection and test forms showing the results shall be signed by both parties. Copies of all shop inspection and test records shall be furnished to the Employer. No equipment shall be shipped from the shop until it has been inspected and tested, or the Employer has waived the inspection in writing. However, the waiver of any test or the witnessing of shop assemblies and tests by the Employer shall not constitute a release of the Contractor's responsibility to meet fully the requirements of this Contract. A minimum of sixty (60) days prior to major shop assemblies and tests, the Contractor shall submit an outline of the procedures and tests it plans, to demonstrate fulfillment of the requirements specified in subsequent Sections of the Specification for the equipment. Target dates for shop assembly and tests shall be included in the Program, projecting dates for shop tests far into the future. Shop assembly and test dates shall be narrowed to within a two (2) week time frame, not less than six (6) weeks in advance, to enable the Employer and Engineer to obtain any required visas. The Contractor shall finalize the dates within that two (2) week window and notify the Employer in writing, prior to any shop assembly or test, a minimum of four (4) weeks in advance for out of Pakistan shops or two (2) weeks in advance for domestic (Pakistan) shops.

1.22 Tools and Spare Parts

1.22.1 Tools, Wrenches and Lifting Devices

Prior to shipment Contractor shall furnish and deliver to the Employer/Engineer a complete set of any specialized tools, fixtures, devices, slings, lifting devices, appurtenances, or other equipment that shall be required or convenient for the most expeditious assembling, dismantling and maintenance of the equipment supplied under this Contract.

The Contractor shall permanently label all specialized tools and devices to indicate their purpose and the equipment on which they are to be used. All custom tools and devices shall be accurately machined to fit the parts to be handled. The tools shall be supplied in a neat metal toolbox or cabinet or on a neat tool board with each item marked clearly for identification.

Special installation tools, fixtures, lifting devices, jacks, spiders and appurtenances for parts which cannot be removed after installation shall be furnished as part of the Contract.

1.22.2 Spare Parts

All spare parts shall be interchangeable with and be of the same materials and workmanship as the corresponding parts of the original equipment furnished.

All mandatory spare parts for the equipment shall be provided as mentioned in the relevant sections of these specifications. However, the bidder shall submit list of any other spare parts (which in the opinion of the bidder) are necessary for plant as per recommendation of the equipment supplier(s).

All spares furnished shall be new and interchangeable with the corresponding original parts. They shall also be of the same material and workmanship and shall have all the features and provisions of the corresponding original parts. Second-hand spare parts shall be rejected.

All spares are to be suitably treated and packed for long storage under conditions prevailing at the Site. Each spare shall be clearly marked or labelled on the outside of its packing with description

and purpose, and, when more than one spare is packed in a single case, box or container, an inventory is to be shown on the outside of same, and a detailed list enclosed inside. All cases, containers, boxes and other packages shall be suitably marked and numbered for purposes of identification.

The Contractor shall manufacture the spare parts and deliver them to Site at the same time as the rest of the Plant. Spares shall be handed over to the Employer not later than at the date 30 days prior to the start of the final performance tests.

Spare parts catalogues and/or necessary drawings with item lists shall be supplied giving all necessary data for ordering spare parts directly from the manufacturers. The spare parts catalogues shall include data on complete modules and assemblies as well as sub-modules, sub-assemblies and individual components. The drawings shall show the location, main dimensions and the ways of disassembly or assembly of the various spare parts.

Additionally, the Contractor shall propose recommended spare parts with itemized prices. The Employer shall have the option of ordering or omitting any of the spares listed.

SECTION 2: TURBINES

2.1 Scope

This section specifies the requirements for the design, turbine model testing, manufacture, factory testing, packing for transport, supply, insurance, transportation to site, storage at site, erection, site testing, commissioning, guarantee and making good defects of 3 Francis type Vertical shaft water turbines with rated capacities of 7.16MW each and one Francis type Vertical shaft water turbine with rated capacity of 2.24MW.

.

2.2 Design Standards and Reference

The turbines shall conform to the applicable requirements of the latest edition of the following Standards or to recognized and equal standards applying 28 days before the tender date.

Table 9: Applicable Requirements from Standards

Subject	Standard
Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless	ASTM A 53 M
Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application	ASTM A 743 M
Standard Specification for Seamless Red Brass Pipe, Standard Sizes	ASTM B 43
Standard Specification for Seamless Copper Water Tube	ASTM B 88
Rotating electrical machines - Multiple parts	IEC 60034
Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines	IEC 60041
Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests	IEC 60193
IEEE Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Coupling and Shaft Runout Tolerances	IEEE 810
Industrial liquid lubricants - ISO viscosity classification	ISO 3448
Hydraulic turbines, storage pumps and pump-turbines-Cavitation pitting evaluation	IEC 60609-1
Guide to specification of hydraulic turbine control systems	IEC 61362

2.3 Type and Rating

In Jagran-IV, the flow pattern of the available discharge over the whole year suggests to use a mix of 3 large and 1 small Turbines to extract maximum annual energy and maintain optimal plant factor.

Three Vertical shaft Francis turbines will deliver a continuous output of 7.16MW each while operating at the rated discharge of 4.83m3/s and rated speed of 500rpm whereas one small unit with similar configuration e.i vertical shaft Francis turbine will be capable of providing 2.24MW output when running at rated discharge of 1.51m3/s and rated speed of 750rpm with rated net head of 166.1m.

Table 10: Key Turbine Parameters

Parameter	Quantity	Unit
Number of Turbines	4	No
Turbine type	Vertical Shaft Francis	-
Rated Gross Head (Intake to tailrace)	180.75	m
Average Intake Operating Level (NWL)	2252.00	m
Maximum Weir Level (Spill over)	2254.00	m
Maximum Tailrace Water Level	2076.36	m
Minimum Tailrace Water Level	2073.25	m
Turbine centerline elevation	2072.25	m
Net Head	166.1	m
Rated Flow per Unit for large turbines	4.83	m^3/s
Rated Flow per Unit for single small turbine	1.51	m^3/s
Rated Output of each of the large Units	7.16	MW
Rated Output of the single small Unit	2.24	MW
Rated Speed of Large Units	500	rpm
Runaway speed of Large Units	796	rpm
Rated Speed of the Small Unit	750	rpm
Runaway Speed of the Small Unit	1179	rpm

The rated gross head and number of units entered in the above Table is the value chosen to obtain maximum annual energy. The Contractor must ensure that the turbine can operate satisfactorily over the complete range of heads and flows specified.

The output shall be guaranteed to be not less than 7.16 MW for main turbines and 2.24MW for auxiliary turbine (small unit) at the rated net head of 166.1under normal circumstances and power limits from the governor shall be provided to limit the turbine output accordingly. However, when operating with the net head below the rated net head value the guide vane opening can be greater to allow operation up to appropriate power and cavitation limits at lower heads. Such limits shall be shown on the hill chart required in the following paragraph.

Continuous generation at the guide vane opening corresponding to rated head and output shall be guaranteed within the minimum and rated head with the tailwater levels. The guarantees shall be indicated on a Hill-Chart.

Within the limits stipulated above the turbine shall be guaranteed to operate within the requirements of these Specifications on the rated speed from no load to maximum output for a particular head.

The turbine runner blades, guide vanes, wearing rings, facing plates, discharge ring, and any other parts that may be prone to erosion after contact with sediment shall be fully coated with abrasive erosion resistant coating (High Velocity Oxygen Fuel-HVOF, hard coating) as protection against abrasion from suspended sediment in the river, allowing the turbine to perform a trouble free operation with only minor maintenance for at least 10 (ten) years, along with guarantee.

The turbine condition should be assessed by the Contractor after the first flooding or completion of first year of operation (whichever comes first) to investigate abrasive wear of the hard (HVOF) coating or metal erosion intensity if any (if the coating is breached). The Contractor shall repair any damages which might occur as a result of the flooding.

The reduction in turbine efficiency (or any other unit performance parameter) due to the full application of hard (HVOF) coating shall be presented along with the guaranteed values in Guaranteed Characteristics.

QA/QC documents for hard coating (HVOF) shall be submitted to the Engineer for Approval. The document shall include the details of quality, coating procedure, coating maintenance procedure with corresponding manuals and the tests for the reliability of coating. The Engineer shall have the right to request, at any moment during the project, additional testing of coated samples, to be performed by the Supplier or by a third party testing service selected by the Engineer. Should the results of the test cast doubt on the quality of the coating, and its ability to perform at the Jagran-IV Hydroelectric Project site, the Engineer shall have the right to request a change of the hard coating supplier.

2.3.1 Number of Start/Stop Cycles

It is envisaged that each unit will be subjected to a maximum of three start/stop cycles per day, timed to suit generation requirements. It should be noted that the purpose of the power intake/penstock gates is protection and therefore they will not be closed at each unit stop. However, the Main Inlet Valve shall be closed as part of the unit shutdown sequence.

2.3.2 Life of Plant, Maintenance Cycles and Reliability

The Plant shall be designed for a 30-year operating life under the operating conditions indicated above. Maintenance on each unit will be done annually on a rotational basis. Between annual maintenance periods the units will be expected to operate with 100% availability.

The design shall be such that dismantling shall not be necessary in the first 10 years of operation.

Starting reliability shall be at least 99% as logged by the Control and Indication System. If "Failure to Start" events in excess of 1% due to defective components or systems supplied by the Contractor occur during the defects liability period, the components shall be replaced with more reliable equipment.

Forced outages shall not be greater than 2 per annum after commencement of Commercial Operation. Where any defective component or system supplied by the Contractor can be identified for forced outages in excess of this it shall be replaced with more adequate equipment.

Any auxiliary equipment or components whose life expectancy is less than 30 years shall be identified and the predicted life stated.

2.3.3 Protective Coating

The Contractor shall be required to carry out his own water, petrographic and sedimentation analysis where necessary for verification and confirmation of contractual guarantees. The Contractor is required to take sedimentation into consideration in the design while suggesting the protective coating for anti-abrasion and cavitation protection

2.4 Speeds and Balance

The synchronous speed for vertical shaft francis turbines shall be 500 rpm for large units and 750 rpm for small unit. Alternative bids may be made for a horizontal configuration of the turbine (horizontal shaft) and different synchronous speeds if this is considered to be beneficial to the Employer with no additional cost of Civil and Electromechanical works. The unit shall be designed for continuous operation over the speed range ±5% of synchronous speed.

The direction of rotation shall be clockwise when viewed from Generator Side (top side).

The complete rotating assembly (turbine and generator) shall be designed to accommodate the maximum runaway speed which can occur under any steady or transient condition. Such conditions shall include the failure of the guide vanes and the Main Inlet Valve to close on load rejection. Friction and windage losses of the generator shall be allowed for in the calculation of runaway speed. All parts of the turbine shall be designed to withstand safely this speed within the stress limitations specified in this section.

The first critical speed of generator and turbine combined shall be at least 30% above the maximum runaway speed. The Contractor shall check the critical speed and torsional vibration characteristics of the combined turbine and generator rotating system after determining the necessary generator data from the generator manufacturer. In the calculations higher harmonics and combined critical speeds shall be considered. Calculations shall be presented in an easily understandable and concise manner. Amplitudes of vibration as measured on the turbine or generator bearing housings shall be in accordance with ISO 10816 and ISO 7919.

2.5 Vibration

The number of guide vanes, stay vanes, and runner blades shall be such as to ensure vibration-free operation

2.6 Resonance

Based upon the results of the hydraulic model tests and the Contractor's experience of similar units in size, operating head range and output, the Contractor shall conduct resonance studies covering the complete range of normal operation of the turbines up to and including full load rejection. These studies shall include but not be limited to:

a. Penstock hydraulic resonance due to excitation from part load and full load draft tube pressure pulsations.

b. Power swings due to excitation from part load and full load draft tube pressure pulsations and governor oscillations coupled with the generator natural frequency.

c. Resonances due to unfavourable coupling of the passing frequencies of runner blades, guide vanes and stay vanes.

d. Resonance caused by rotating pressure waves in the vaneless space between runner and guide vanes.

e. Resonance of the stay vanes and runner blades due to Karman vortex shedding from the blade trailing edges.

f. Resonances caused by wearing ring pumping.

2.7 Regulation

The total stored energy of the combined turbine and generator shall be the minimum necessary for stable governing and the attainment of the specified and guaranteed pressure and speed regulation.

2.7.1 Speed Regulation

The maximum transient speed which can occur during a power station load rejection at any head and output shall not exceed 150% of rated synchronous speed.

2.7.2 Pressure Regulation

Under all conditions of normal and transient operation:

a. The maximum pressure which can occur in the waterway system during any transient event shall not exceed 2.5 MPa at the spiral casing inlet of any unit.

b. The water column in the draft tube shall remain intact or be controlled by air valves such that the maximum head under the runner on column return does not exceed the guaranteed value.

The transient conditions shall include:

a. Instantaneous rejection of any load of which the unit or station is capable at any possible operating or transient condition in the reservoir and tailrace.

b. Acceptance of any load which the unit is capable at any possible operating or transient condition in the reservoir and tailrace.

c. The Contractor shall submit calculations for all transient conditions showing compliance with the above requirements. The transient analysis shall calculate the variation of pressure

throughout the complete waterway from intake to draft tube exit, the speed rise of the turbine.

The controlling conditions are expected to be:

- Full load station load rejection at maximum reservoir level
- Full load station load rejection at rated net head.
- Acceptance of any load which the unit is capable at any possible operating or transient condition in the PRVs (pressure relief valves) toward tailrace.
- The Contractor shall submit calculations for all transient conditions showing compliance with the above requirements. If air valves are required to control draft tube under pressure, then their opening shall be controlled by the regulating gear. The valves shall act as a check valve or they shall be provided with a separate check valve.

2.8 Air Admission System

The turbine shall be designed to operate without air admission over the complete operating range. However, in the event that during Turbine Model test it is found that the machines are not stable and this issue can only be corrected by admitting air to the machines then the turbines shall be designed such that an air admission system is included. No additional payments shall be made for the supply of this equipment and an allowance for any power consumption will be made when computing the guaranteed efficiency of the turbine-generator.

2.9 Efficiency

In addition to pure hydraulic losses, turbine efficiency shall include mechanical and volumetric losses attributed to the turbine supply.

For the bearings the distribution of losses attributed to the generator and to the turbine will be proportioned in accordance with IEC 60041. Calculations of guide bearing losses will initially be in accordance with IEC 60041 and subsequently measured at site in accordance with IEC 60034.

Turbine efficiency shall be subject to performance guarantees for the entire turbine operating range and shall be verified by site efficiency tests in accordance with IEC 60041 by the acoustic or thermodynamic method. The test method shall be subject to the Employer's/Engineer's approval.

The prototype efficiencies shall be guaranteed over the entire range of discharges at a nearly constant speed factor as defined by IEC, corresponding to the design data of tile prototype turbine.

The efficiencies guaranteed shall be stated in the Technical Bids and shall be tabulated versus the specific range of discharge from 50 to 100% of rated discharge in steps of 10%. The efficiency shall also be graphically presented in an enclosure.

A weighted average efficiency shall be guaranteed using the following weights.

Table 11: Average Weightages for Different Flows

Relative Flow Rate	Weightage
100%	52
90%	5

Relative Flow Rate	Weightage
80%	4
70%	5
60%	6
50%	28
	100

The minimum guaranteed weighted average efficiency of each prototype turbine shall not be less than 89.5%.

The turbine efficiency for each such turbine power value shall be determined by measurement and computation in accordance with IEC 60041. The measured turbine weighted efficiency shall be determined by applying the weighting factors to the efficiency values determined by the site tests.

The guaranteed turbine efficiency for each of the turbine power values nominated in the above table shall be determined from the guaranteed turbine prototype performance diagrams (Hill Chart), for the net head and relative flow conditions applying at the time of the site efficiency tests.

The guaranteed turbine weighted efficiency shall be determined by applying the weighting factors nominated above to the respective guaranteed efficiency values.

The measured turbine weighted efficiency shall be compared to the guaranteed turbine weighted efficiency, and the amount that the measured value is less than the guaranteed value, if any, shall be the Turbine Weighted Efficiency Shortfall, and shall be subject to liquidated damages pursuant to the Conditions of Contract.

If the Shortfall in Weighted Avaerage Efficiency exceeds 1.5 %, , then the Employer may reject the associated turbine ; in which case the Contractor shall design, model test, construct, supply and install free of charge to the Employer a new turbine with satisfactory performance. Further, in this case the Contractor shall carry out site efficiency tests of all units.

2.10 Guarantees

2.10.1 General

Guarantees for each turbine shall be given for rated conditions based upon the levels, heads and turbine settings specified herein.

The guarantees for efficiency, maximum load and cavitation as well as axial hydraulic load, runaway speed, guide vane torque, vibration levels etc., shall be verified by site commissioning tests according to IEC 60041 and related standards.

The Contractor shall carry out model tests on a turbine model to demonstrate a satisfactory design and the validity of the guarantees given. The tests shall be conducted in accordance with IEC Publication no 60193, latest revision including amendments and supplements.

The Contractor shall contain all relevant technical information about prototype tests that is used for demonstrating the validity of the guarantees and technical information given.

The Engineer will have the right to request additional documentation which he deems necessary to demonstrate to his satisfaction the Contractor's compliance with the pertinent parts of the Specifications.

2.10.2 Turbine Output Guarantees

The turbine output shall be guaranteed in the sense that the Contractor shall be bound to modify the turbine within a period of six months after the site completion test, in order to achieve the guaranteed output, if the measured turbine output is below the corresponding guaranteed output value. If, after modifications have been carried out, the turbine still fails to achieve the guaranteed output, or if it is mutually agreed to waive the modifications or if modifications are not possible, a sum equal to that stated in the Particular Conditions of Contract shall be deducted from the Contract Price.

The output test results shall be converted to the design net head values and compared with the guaranteed value. All measurements shall be conducted in accordance with IEC Publication no 60041 "Code for Field Acceptance Test of Hydraulic Turbines" (latest revision). Output values shall be stipulated on basis of net heads measured at the downstream side of the inlet valve and at tailrace level measured in the draft tube access shaft.

The guide vane mechanism, as well as servomotors, shall mechanically allow an 10 % over-opening compared with the theoretical rated flow opening.

The possible partly or fully utilization of the over-opening will be decided during the commissioning tests, depending on the operational experience, and might be limited by tailwater levels or sediment basin efficiency.

2.10.3 Cavitation Guarantees

The Contractor shall guarantee the runners and discharge rings against cavitation pitting or erosion due to suspended solids for 8,000 operating hours from the date each unit is placed in commercial operation. Testing will be undertaken in accordance with IEC 60609.

The method of measuring the loss of material due to cavitation shall be volumetric as determined by IEC Code 60609.

Should the loss of material in grams per operating hour during the basic guarantee period (Defect Liability Period) be ≤ 0.002 D^2 g/h (where D is runner throat diameter in meters) or the runner blade thickness at any point be reduced by 15% or more the Contractor shall repair and rectify by welding, grinding and polishing. If after a further period of 8,000 operating hours the runner or discharge ring shall again have suffered loss of material in excess of 0.002 D^2 g/h grams per operating hour or runner blade thickness be reduced by 15% at any point, the runner may be rejected in which case the Contractor shall design, model test, construct and supply free of charge to the Employer a new runner with satisfactory cavitation performance.

The cavitation guarantee period shall commence upon successful commissioning of each Unit and the start of its Commercial Operation.

Any repairs required under the Contractor's guarantee as above described shall be performed entirely at the expense of the Contractor except that the Employer will provide necessary compressed air, electric power and proper access.

The cavitation guarantee shall apply to any new runners supplied under the above requirements.

2.10.4 Cracking Guarantees

The Contractor shall guarantee the runners and discharge rings against crack formation for a period of not less than 8,000 operating hours from the date each Unit is placed in Commercial Operation. The Contractor's guarantee shall be based on operation for not more than 50 hours at output greater than the guaranteed maximum output at a given head.

Cracks shall be detected by ultrasonic, magnetic particle and/or dye penetrant inspection in accordance with applicable ISO standards (including ISO 17638, ISO 17640 and ISO 23277) and generally accepted hydro turbine inspection practices.

The acceptance criteria shall distinguish between acceptable indications, repairable cracks, and rejectable defects as follows:

(a) Repairable cracks shall be limited to surface-breaking cracks not exceeding 3 mm depth or 10% of local wall thickness (whichever is less) and not exceeding 50 mm in length, provided they are not located in high-stress regions such as blade leading edges, trailing edges, or hub/fillet transition zones and show no evidence of propagation.

(b) Rejectable cracks shall include any through-thickness crack, any crack exceeding the above limits, any crack exhibiting propagation after repair, or any crack located in structurally critical zones.

The Contractor shall repair all repairable defects in situ at its own expense using approved welding, grinding, and post-repair finishing procedures. The Employer shall provide compressed air, power, and access facilities as required.

Upon completion of repair works, the guarantee period shall recommence for the affected Unit. If cracks exceeding the acceptance criteria are again detected after 8,000 cumulative operating hours (or 24,000 hours total service, as applicable), the Engineer reserves the right to reject the runner, in which case the Contractor shall supply and install a new runner free of charge.

The Contractor shall investigate the root cause of cracking and submit corrective design modifications for approval, which shall be implemented at the Contractor's expense.

2.11 Torque Fluctuations

Torque fluctuations measured at the turbine shaft shall not exceed the following:

a. Between 50% and maximum output for a particular head 3% peak to peak
b. Below 50% maximum output for a particular head 5% peak to peak

2.12 Stresses and Materials

Liberal factors of safety shall be used throughout the design and especially in the design of all parts subject to alternating stresses or shock. The design of equipment shall include an allowance for the OBE earthquake loading stipulated in General Mechanical Design Requirements. Under the most severe loading conditions expected in normal operation (including load rejection), stresses in the materials shall not exceed the values listed in the table below.

Table 12: Stresses and Materials

Material	Tension	Compression	Shear
Cast iron	10% of ultimate strength	70 MN/m^2	21 MN/m^2
Cast mild steel	83 MN/m^2	83 MN/m^2	50 MN/m^2
Alloy cast steel	20% of the ultimate strength or 33% of the yield point, whichever is less	20% of the ultimate strength or 33% of the yield point whichever is less	60% of the allowable tensile stress
Plate steel for spiral case or other principal parts	25% of the ultimate strength but not to exceed 100 MN/m^2	25% of ultimate strength but not to exceed 100 MN/m^2	60% of the allowable tensile stress

For materials not listed in the table the maximum stresses in tension or compression under the most severe normal and transient operating conditions shall not exceed 33.3% Yield or 20% Ultimate Tensile Strength (UTS).

Maximum shear stresses in other ferrous materials shall not exceed 60% of the allowable stresses in tension, except that the maximum torsional shear stresses in the turbine main shaft shall not exceed 50% of the allowable stress in tension in normal operation including load rejection. Maximum combined stresses in the shaft under generator short circuit conditions shall not exceed 50% of the material yield stresses.

Under maximum runaway speed or under the hydrostatic test conditions, stresses shall not exceed 66.67% Yield.

Stresses at the junction of the runner vanes and crown shall not exceed 25% Yield under any operating condition. To the calculated thickness for this condition shall be added an allowance of 3 mm for attrition.

Stresses in the guide vanes, guide vane stems and guide vanes stem levers at the breaking point of the shear pin friction device combination shall not exceed 66.67% Yield.

The exception to the above will be pre-tensioned bolts. These shall be stressed to the extent necessary to ensure that the joint face remains closed under all operating conditions.

Calculations shall be presented by the Contractor to prove their proposed pre-tensioning for all pre-tensioned bolts and means shall be provided for monitoring the pre-tensioning.

Finite element calculations shall be submitted to show compliance with the above requirements for all major components.

The material for all important stressed parts including stay ring, spiral case, top cover, bottom cover, shaft, and runner shall have adequate impact value and the Contractor shall submit details of such critical components for approval by the Engineer. All steel plates for these items shall be ultrasonically tested at the mill in accordance with the General Mechanical requirements.

2.13 Oil Type and Grade

As a general specification all lubricating oil shall typically be to either ISO VG46 or ISO VG68 at 40°C according to ISO 3448 and shall be readily available in Pakistan. The make and grade of lubricating oil shall be coordinated by the Contractor and his subcontractors so that oil of the same specification is used for lubrication of all bearings, the governor, MIV and actuators.

2.14 Turbine Model Tests

The model test as defined below will be preferred. Alternatively reliable model test data duly certified by relevant forums may also be accepted.

2.14.1 General

If contractor offers a turbine system which not has already been tested and no certification is available then contractor will perform model testing of the prototype turbine. The prototype turbine hydraulic design and guaranteed performance values shall be based upon a homologous turbine scale model, tested and witnessed, in accordance with IEC 60193 Hydraulic Turbines, Storage Pumps and Pump Turbines - Model Acceptance Tests, Second Edition, Nov. 1999, and from which the model test results are stepped up to the prototype values. The Supplier shall design, construct and conduct tests on a new homologous scale model turbine in order to verify the contractual guarantees for prototype turbine power outputs, discharge, efficiency, cavitation, maximum steady state runaway speed and shall perform any additional tests requested by Employer.

The model testing (which shall include a developmental test portion and the model acceptance test portion) shall be conducted in accordance with IEC Publication no. 60193, latest revision, and shall include a model test procedure, a CFD study and a witnessed model acceptance test and a final model test report.

The hydraulic laboratory and instrumentation, the model, the conduct of the tests, the evaluation of the test results for the model and prototype shall be in accordance with the latest edition of IEC 60193.

The model acceptance tests shall establish the turbine hydraulic characteristics, including the model measurements and the stepped-up prototype characteristics for the following items: the turbine efficiency and output characteristics, the cavitation limits, the hydraulic thrust and counterthrust (steady state and calculated transient characteristics), runaway speed and accompanying discharge, and the wicket gate torque characteristics. Additional details are given below, concerning these testing requirements.

The Contractor shall provide a hydraulic test engineer(s) to direct the model acceptance tests in the hydraulic laboratory, shall perform the necessary calculations and shall provide all of the reports that are described herein.

The model acceptance tests shall include model dimensional checks and model test stand calibrations. The model acceptance test procedure shall be prepared by the Contractor and will be subject to review and approval by the Engineer.

Prediction of the expected prototype performance and the determination of the new guaranteed stepped-up prototype efficiencies, flows and power outputs shall be based on the model acceptance test data with zero tolerance for uncertainties of measurement.

If the prototype performance, converted from the model characteristics, does not meet the original guaranteed values or if the model acceptance test results should indicate any unfavorable conditions that would prevent satisfactory operation within the continuous operating range, the Supplier shall modify the model and shall conduct the model acceptance test once again. All expenses caused by the additional design, engineering, model modification and retest shall be borne by the Contractor. If such a retest results in a delay in equipment delivery, such delays will be handled in accordance with the Contract.

Prior to the model tests the Contractor shall conduct a 3-dimensional fluid dynamic analysis of the turbine flow to be used in development of the model. The results of the 3-dimensional analysis shall be presented for discussion with the Engineer's representatives as well as the Employer's representatives who will attend the witnessed model tests. The results of the 3-dimensional analysis shall be included as an Appendix to the final model test report, together with any discussion and conclusions reached with the attending the representatives of the Engineer as well as the Employer during the model tests.

2.14.2 Demonstration of Turbine Performance Parameters

Considering the relatively small unit rating and the non-economical nature of physical model testing, model tests in accordance with IEC 60193 can be omitted on the sole discretion of the Employer.

Instead, the Bidder/Contractor shall demonstrate hydraulic performance compliance through validated Computational Fluid Dynamics (CFD) analysis supported by verification against prototype or model-tested reference turbines of similar specific speed, head range, runner geometry, and operating regime.

The submitted documentation shall include certified performance characteristics (efficiency, cavitation inception behaviour, and part-load stability) of such reference units, established through prior model testing or full-scale commissioning experience in accordance with IEC 60193 and field validation principles of IEC 61116.

The Employer/Engineer reserves the right to review, verify, and request substantiation of the similarity criteria, scaling assumptions, and validation basis for the proposed turbine design.The Contractor shall provide a hydraulic scale turbine model for this project, the hydraulic laboratory and instrumentation, and shall carry out the tests and prepare the test reports, and their costs shall be included in the Contract price. The Employer and Engineer will witness these tests. The model test scope shall include the Contractor's performance of Computational Fluid Dynamics (CFD) flow analyses, optimization of the hydraulic design (including optimization to improve flow conditions in turbine water passages that are prone to erosion abrasive wear, so as to minimize such wear), fabrication of the model components, performance of developmental model tests and of model acceptance tests, provision of all model test reports and data, during the turbine model tests. The developmental testing and the witnessed model acceptance testing shall be conducted at the Contractor's hydraulic laboratory or in a laboratory that is under subcontract to the Contractor, subject to Engineer's approval.

If any model test results indicate that the performance of the prototype turbine would fail to comply with the Contract turbine performance guarantees or be unsatisfactory in other respects, the model shall be modified and retested as necessary at the Supplier's cost.

The model, test installation and instrumentation shall remain the Contractor's property. However the model shall be kept available without modification until the expiry of the Defects Notification period.

2.14.3 Programme

Within 60 days after Commencement Date the following information shall be submitted to the Employer/Engineer for approval:

Arrangement drawings of the model turbine complete with dimensions and statement of the intended scale ratio.

Detailed description of the test stand, with schematic diagrams of the hydraulic circuit.

Detailed description of instrumentation for all quantities and methods of calibration, calibration certificates, and any additional information the Employer/Engineer deems necessary to demonstrate the accuracy of the measurements to be performed.

- Test items.
- Measuring methods.
- Measuring points, test range.
- Instrument errors, individual uncertainties.
- Calculation methods.
- Table of Contents of proposed test report.
- Other information requested by Employer/Engineer.

Promptly upon receiving the Notice to Proceed for the model testing, the Contractor shall proceed with the developmental model test work. Upon reaching mutual agreement with the Engineer as to the test program, the Contractor shall proceed with developmental model tests. It is expected that the developmental tests will include some initial internal tests that would allow the Contractor to refine its program for the testing of various alternatives. The Contractor shall provide the Engineer with weekly updates concerning the progress of the developmental testing. These updates shall include Excel files with the data that define the performance of each tested alternative.

The Contractor shall submit the draft developmental model test report to the Engineer for review prior to the start of the model acceptance tests. Within the established schedule after receiving Engineer’s comments, the Contractor shall incorporate these comments, finalize the developmental model test report and submit to Engineer. After receiving Engineer’s comments, the Contractor shall perform and complete the model acceptance tests under the witness of the Employer and Engineer’s Representative within the established schedule.

Within the established schedule after completing the model acceptance tests, the draft model acceptance test report shall be submitted to the Engineer for review. The model acceptance test report shall contain conclusions emerging from the model tests with respect to guaranteed prototype design and operation. Prototype performance data as described in detail hereinafter shall be included in the report. After receipt of the Engineer’s review comments, the final model acceptance test report shall be submitted to Employer/Engineer. Six printed and electronic copies of the final acceptance model test report, including a compilation of all of the model test data in Excel format, shall be submitted to the Engineer.

The manufacturing of the prototype Francis turbine runners shall not be started until after the results of the model acceptance tests have been approved by the Employer/Engineer.

2.14.4 Model Design, Construction and Similitude with Prototype

The model turbine shall be a geometric scale model of the intended prototype with respect to all water passages and wetted surfaces, including those between the running and the adjoining fixed parts. The model shall include the complete draft tube (including the Concrete portion).

Permissible deviations from model similarity between scaled up model dimensions and prototype dimensions shall be in accordance with IEC 60193.

The model turbine runner blades shall have clearly marked grid patterns, to facilitate accurate sketches of cavitation locations. The model discharge ring, draft tube cone and other required components shall be completely made of transparent materials and shall be provided with stroboscopic lighting. Means shall be provided for viewing runner cavitation via these transparent components and through other necessary observation windows, which shall be included in the model.

Following successful completion of the model acceptance tests, all model parts shall be precisely measured for all dimensions, angles, profiles and shapes and any deviations from the design drawings shall be noted. Runner and guide vane profiles and finish shall be measured with a 3-dimensional electronic arm, or other approved method. All measurements shall be repeated following any modifications resulting from test work.

Drawings of the prototype turbine water passage wetted components shall be dimensioned to reflect the true stepped-up model turbine water passage wetted component dimensions.

The Contractor shall provide a hydraulic test engineer(s) to direct the model acceptance tests in the hydraulic laboratory, shall perform the necessary calculations and shall provide all of the reports that are described herein.

The model acceptance tests shall include model dimensional checks and model test stand calibrations. The model acceptance test procedure shall be prepared by the Contractor and will be subject to review and approval by the Engineer.

Prediction of the expected prototype performance and the determination of the new guaranteed stepped-up prototype efficiencies, flows and power outputs shall be based on the model acceptance test data with zero tolerance for uncertainties of measurement.

If the prototype performance, converted from the model characteristics, does not meet the original guaranteed values or if the model acceptance test results should indicate any unfavorable conditions that would prevent satisfactory operation within the continuous operating range, the Contractor shall modify the model and shall conduct the model acceptance test once again. All expenses caused by the additional design, engineering, model modification and retest shall be borne by the Contractor. If such a retest results in a delay in equipment delivery, such delays will be handled in accordance with the Contract.

2.14.5 Scope of Tests

a) Turbine Performance and Efficiency Tests

Flow, torque, head and speed shall be measured for a maximum of 10% increments of guide vane opening from 10% to 110% and for at least 12 speeds for each gate opening, all at nominally constant head. Around the point of best efficiency, they should be taken at a maximum of 5% guide vane increments. The speeds shall cover the range locked runner to nominally 2% above runaway

speed for each gate opening with at least 5 points defining the range equivalent to prototype head range and rated speed. These tests shall be conducted at non-cavitating conditions.

The maximum and minimum power output capability tests shall be performed at each guaranteed net head. The calculation results shall include, separately for each type of test, the possible deviations between the prototype and the model, including the expected majoration of performance due to scale effects.

The model results shall be plotted as unit torque and unit flow against unit speed with constant efficiency lines plotted.

The prototype results shall be plotted on a Hill Chart of flow against head showing lines of constant efficiency, constant guide vane opening and constant turbine output, all at nominal speed.

b) Prototype results from the model results

Scale up for efficiency and power shall be in accordance with IEC Code 60193 Annex F “Scale-up of the hydraulic efficiency of reaction machines”, with full allowances for volumetric losses in the model compared with the prototype and for mechanical losses in the prototype turbine. The Supplier shall also calculate the turbine majoration adjustments.

c) Cavitation Tests

Cavitation tests shall cover the same range of guide vane opening as the output and efficiency tests and shall be conducted for at least 7 unit speeds for each guide vane opening corresponding to the range 90% of minimum head to 110% of maximum head with specific test points corresponding to normal maximum and normal minimum net heads. For each guide vane opening/unit speed combination and with nominally constant head flow, the absolute head at the runner outlet shall be reduced until at least 2% of efficiency drop and onset of visible cavitation both occur.

The incipient cavitation Thoma number (σi) and the Thoma number one (σ1) for each different condition shall be determined by the model tests. The plant Thoma number (σpl) shall also be stated for each operating condition. The Contractor’s design shall be such that the incipient cavitation Thoma number (σi) is below the plant Thoma number (σpl) for the operating conditions at each guarantee point. All values of Thoma number shall be referenced to the centerline of the distributor.

The incipient cavitation Thoma number is defined as the corresponding cavitation factor at which the visible bubbles begin to form repeatedly on the surfaces of two runner blades, as the suction head diminishes. Random bubbles are not considered as incipient cavitation. The Thoma number one is defined as the corresponding cavitation factor at which the efficiency is 1% less than the efficiency at Thoma number zero (σ0). The Thoma number zero (σ0), as defined in IEC 60193, shall be identified on each sigma break curve along with the incipient cavitation Thoma number (σi), the plant Thoma number (σ pl), and the Thoma number one (σ1).

The results shall be plotted as curves of efficiency against sigma, with a scale of suction head also.

The extent of visible cavitation shall be indicated on sketches or photographs. Frequency and amplitude measurements shall be taken of draft tube pressure fluctuation throughout the operating range. Signs of vortex shedding from the runner blades and pulsating of the inner vortex cone shall be noted.

Cavitation tests will be acceptable if for all conditions, 1% efficiency drop occurs at not more than 90% of minimum plant sigma and visible cavitation on the exit suction side does not occur at or above minimum plant sigma.

Should any blade(s) exhibit better cavitation performance (both inlet and discharge) than the other blades, then the profile of these blades shall be exactly measured and compared with the others. To the approval of the Engineer, differences thus obtained shall be transferred to the prototype via more stringent manufacturing tolerances than required by IEC 60193.

Air admission tests shall be conducted.

d) Pressure Fluctuations Tests

Pressure fluctuations related to flow instabilities or vortices in the model shall be measured by the use of pressure taps or transducers located in the model water passages, including the draft tube, at points most likely to detect pressure fluctuations. The measurements of pressure fluctuations shall be carried out over the full operation range, under the conditions with the plant Thoma number. The pressure fluctuations shall be recorded and analyzed and the results shall be presented in graphic charts. The fluctuations shall be recorded in such manner that their amplitude and frequency are defined throughout the entire operating range, including the overload range. The peak-to-peak equivalent amplitude curve of pressure pulsations with mixing frequencies shall be clearly marked on the performance curve of the model turbine. The data shall be collected for frequency analysis, to determine the main frequency and amplitude of vibration. The Contractor shall provide an interpretation of these data to indicate the expected prototype conditions. Signs of vortex shedding from the runner blades and pulsating of the inner vortex cone shall be noted.

e) Runaway Speed

The runaway speed characteristics, associated discharge and associated hydraulic axial thrust shall be determined on the model for both on-cam and off-cam operation, to verify the expectation of compliance with the maximum runaway speed guarantee of the prototype.

f) Radial Thrust Tests

The magnitude, direction and frequency of radial thrust on the model runner shall be measured by 3 transducers and for the range of conditions covered by the performance tests and also for the condition of all but three adjacent guide vanes fully closed the three being fully open.

The radial thrust results for all operating conditions shall be taken into account in the design of all affected components, including runner, shaft, bearing, bearing support and runner seals.

g) Guide Vane Torque Tests

a. The torque on 3 adjacent guide vanes shall be measured by transducers for:
b. The range of conditions for the performance tests with all guide vanes in their normal correlation
c. 10% increments of guide vane opening of all vanes, except the central instrumented vane which shall be fully open for all tests for unit speed corresponding to the following conditions:
    - Maximum head and rated speed
    - Rated head and rated speed
    - Minimum head and rated speed
    - Load rejection speed and pressure rise
    - Runaway speed at maximum head

The results thus obtained shall be used for design of the guide vane shear pin/friction device and the guide vane servomotor system.

h) Dynamic Pressure Tests

The magnitude and frequencies of the dynamic pressures on the runner blade and band surfaces shall be measured in the range of conditions for the performance and the cavitation tests at minimum plant sigma.

The results thus obtained shall be converted to prototype conditions with formulae previously approved by the Engineer and shall be used as input to the runner three dimensional finite elements dynamic stress analysis.

i) Re-Model Tests

Should the prototype exhibit any unacceptable vibrations, resonance or operational characteristic which necessitates a modification to the hydraulic passage of the turbine which is outside the dimensional tolerances of IEC 60193, then the model shall be modified accordingly and retested. The retest of the model shall be done before the prototype is modified and shall cover all parameters measured in the original model test. Modifications to the prototype shall only be accepted if the performance of the retested modified model is totally within all the guaranteed values.

All modifications of the model and prototype and re-testing of the model shall be at no cost to the Employer.

2.15 Runner

The turbine runner shall be of martensitic stainless-steel grade CA6NM to ASTM A743M, Francis type, one piece casting or shop assembled construction. If fabricated, runner parts shall be integral castings or formed plate. All shop welds shall be stress relieved. Material and the method of construction shall be to the approval of the Engineer. The welding filler for runner blades with crown and bands shall be Martensitic. CNC milling machines shall be used for the turbine runner manufacturing.

The fully heat-treated runner material shall have a minimum Charpy “V” notch energy of 55 J at -200C.

The runner shall be designed to withstand the forces encountered during all normal and abnormal conditions up to and including the guaranteed runaway speed. It shall also be designed to support its own weight and that of the turbine rotating parts including the shaft when resting on the shoulder of the discharge ring.

The Contractor shall use the results of the Dynamic Pressure Tests to conduct a three dimensional finite element dynamic stress analysis of the runner. The analysis shall be conducted at minimum plant sigma for the following conditions:

a. Minimum net head and maximum output and 50% output.
b. Design net head and maximum output and 50% output.
c. Maximum net head and maximum output and 50% output.

The above conditions for the calculations are subject to change by the Engineer, subject to the results of the model tests.

Dynamic stresses thus calculated shall be below those for infinite fatigue life of the runner material and welded joints in water.

The runner of the first unit shall be strain-gauged and the dynamic stresses measured. Should the stresses thus measured be above those for infinite fatigue life (allowing for measuring tolerances as agreed with the Engineer) then the Engineer reserves the right for modifications to be made to this and the runners of all subsequent units. Such modifications shall be made by the Contractor at no cost to the Employer.

The hydraulic shape of the runner shall be homologous, within the tolerance with the model on which performance was proved. Templates shall be provided by the Contractor and retained by the Employer for checking the runner before acceptance and for future checking of the profile in the event of repair welding.

All surfaces exposed to the flow of water shall be finished smooth over the entire plane by grinding or other means so as to be free from hollows, depressions, cracks and projections. The average surface finish shall be 4 microns or finer in areas subject to possible cavitation as shown in the model tests. All other areas shall be finished to 10 microns or less. Surface undulations shall not cause S/L to exceed 0.01 where S is the deviation from the design profile measured normal to the surface and L is the distance along the surface over which S occurs.

The trailing edges of the runner blades may be chamfered to reduce the dynamic stresses.

The runner shall be statically balanced in the shop to a precision of at least 100 kg-m. Lead filled boxes shall not be used for balancing purposes. The balancing method shall be submitted for approval of the Engineer.

All runners shall be interchangeable among all the units covered by these Specifications.

The outside diameters of the runner crown and band will be machined to form the rotating wearing ring to provide a close fit with the fixed wearing rings.

The Contractor shall demonstrate by calculation that there is no possibility of the fixed and rotating wearing rings contacting for all speeds up to and including runaway.

2.16 Turbine –Generator Shaft

The complete shaft assembly shall be designed to operate safely at any speed up to the maximum runaway speed without detrimental vibration or distortion.

The maximum torsional shear stress shall not exceed 50% of the allowable stress in tension.

The turbine shaft shall be of steel as an integral forging. The central material shall be machined out to allow examination of the full length of the bore.

The shaft shall have an integrally forged flange to match with the flange on the flywheel and shall conform to IEEE 810 OR ANSI Standard B-49-1 “Shaft Couplings integrally forged type for hydraulic units”.

The Contractor shall furnish metal templates so that the turbine and generator couplings can be accurately machined in the works prior to before delivery to site.

The Contractor shall furnish all tools and equipment necessary for the coupling. A hydraulic device shall be used for pre tensioning the coupling bolts.

The accuracy of machining of the face of the flange shall be within the limits of + 0.013 mm.

The shaft shall be accurately and smoothly machined all over and polished where it passes through the guide bearing. The amount of shaft-runout shall be checked by rotating the finished shaft in a lathe or aligning device in the Manufacturers shop, and shall not exceed the tolerances recommended for shafts in the relevant Standards for Vertical Hydraulic Turbine Generator Shaft Runout Tolerances or as approved by the Engineer.

The stuffing box shall be made of corrosion-resistant steel of suitable resistance to abrasion accurately machined and polished, split and securely fasted to the shaft.

Shaft run out as checked in the works shall not exceed the recommendations of IEEE 810 OR NEMA “A” Standard for Vertical Hydraulic Turbine Generator Shaft Run out.

The same Standard shall be used for checking the coupled shaft run out at site.

2.17 Wearing Rings and Facing Plates

At points of small clearance between the runner and stationery parts of the turbine, at the runner crown and the band, removable and renewable stainless steel wearing rings shall be provided and securely fastened by screws and tack welding. The stainless steel selected for the wearing rings shall be of a different hardness from that of the runner so as to prevent galling or tearing of the metal in case of rubbing. The wearing rings shall be so located that the clearances may be readily measured with the turbine assembled.

Removable and renewable facing plates of suitable stainless steel shall be provided in the throat section of the distributor, on the front and rear covers adjacent to the ends of the guide-vanes. The facing plates shall be attached by screws so as to permit their removal. The screws shall be flush with the finished surface and tack welded to prevent loosening during operation.

2.18 Bearings and Oil Lubrication System

The turbine shall be provided with a radial axial thrust bearing installed on the same common bottom frame with two radial bearings of generator. It shall bear not only axial hydraulic thrust force but also the weight of the unit rotating parts and radial force due to hydraulic in equilibrium and magnetic pull of generator together with the radial bearings of generator. The bearing shall be of self-lubrication type. The lubricating oil shall be brought up by shaft collar. Cooling pipes shall be mounted in the oil basin cold water shall be led out from the spiral casing via filter and it shall enter the cooling pipes absorb the heat in oil basin and finally flow into the draft tube.

Two thermometers shall be provided for in the radial axial thrust bearing. One of them shall be a pressure type thermometer with electric contacts and the other shall be a thermometer with fixed thread type copper thermistor. These shall be used to indicate the existing temperature and to give stopping, protective signals when bearing temperature exceeds normal value.

2.19 Stuffing Box

A stuffing box, designed so that it can be replaced or adjusted without disturbing the main guide bearing, shall be provided where the main shaft passes through the front cover. The stuffing box shall be designed either for compression type packing, including a lantern ring restrained against rotation, a split bronze or aluminium packing gland with corrosion-resistant bolts, and suitable high grade hydraulic packing, or shall be designed for multiple carbon-ring type seals.

2.20 Spiral Casing, Stay Ring and Gate Operating Mechanism

Spiral casing sectors made of steel plates shall be welded to the cast annealed steel stay ring. There shall be eight profile shaped fixed guide vanes on the stay ring. On the top of the casing there shall be a valve, used to release air when filling the casing with water during initial starting. On the bottom, a drain valve is provided, used to drain out water during maintenance or long time of stoppage. A bent pipe is connected to the spiral casing entrains. The outlet diameter of the pipe penstock shall be matched with that of the inlet valve.

Design pressure of the spiral casing shall be 2.5 MPa. Spiral casing design and testing shall be in accordance with the Rules of Construction of Unfired Pressure Vessels. Section VIII of the ASME Boiler and Pressure Vessel Code. Support from the surrounding concrete shall not be considered in the calculations.

The spiral casing shall be pressure tested to 1.5 times design pressure at the centre line of the spiral. Water for the pressure test will be supplied by the Contractor.

Gate operating mechanism shall be used to regulate the load and to stop the machine at normal or emergency conditions. It shall consist of guide vanes, rocker arms, link plates, shearing pins, regulating ring, pull - push rods, etc. The guide vanes shall be made of cast steel and the surface of each vane shall be accurately machined smooth and free of waviness, projections, or other surfaces irregularities. The bushing for guide vane shall be of self-lubricating type. In order to prevent leakage, Y - shaped sealing ring shall be used at the top part of the guide vane stems and ordinary O-rings at the middle part. Shearing pins shall be provided on the link plates. In case any foreign object is blocked in between any two of the vanes, one of the shearing pins shall be broken and a signal shall be given to the control room. Relief valve will be used to avoid over pressure in case of sudden unit shutdown.

2.21 Front and Rear End Covers

The front and rear end covers shall be made of annealed cast steel in one piece and have anti-frictional lining plates on the surface which are in the flow path. On the surface of the front end cover facing the runner crown, stabilizing ribs are provided to hold the water from whirling in that chamber, seriously eroding the surfaces of both the crown back and the front end cover. The front and rear end cover shall be fixed to the stay ring by means of bolts.

2.22 Servomotor

The regulating ring shall be actuated by two double-acting servomotors conveniently arranged with respect to accessibility and oil piping.

The servomotors shall be amply dimensioned for the maximum regulating forces occurring. The baseplate shall be fixed to the concrete structure or to the spiral casing. The servomotors shall be supported to avoid unnecessary wear on the piston rods.

One servomotor shall be equipped with a linear (mm) scale indicating the servomotor stroke conveniently legible when the turbine operates.

An orifice built in the servomotor cylinder wall shall determine the maximum closing rate of the guide vanes. Once adjusted to the correct diameter and installed, it shall be secured properly so that it cannot be removed unintentionally during overhauls, neither shall it become loose if the pipe coupling is broken.

The servomotors shall have pressure tapings for venting or measuring the pressure on both sides of the piston during operation. The pressure measuring equipment, not being a part of the supply, shall be provided by the Contractor during commissioning.

The oil pipes shall preferably be flanged directly to the servomotors, with long leg oil pipes to ensure the necessary flexibility during servomotor movements.

The stroke of the servomotors, including the guide vane apparatus, shall mechanically be designed for a 10% higher opening than the theoretical opening corresponding to rated conditions.

2.23 Draft Tube and Discharge Ring

Leaving the runner, water shall enter the bent pipe through the discharge ring to elbow type draft tube and finally reaches tailrace. The function of the draft tube shall be to regain most part of velocity energy remaining in the flow at the runner exit. The discharge bent pipe and draft tube shall be of cast or welded steel plate structure. One end of the bent pipe shall be connected to rear end cover and the other shall be attached to the draft tube. An air supply device shall be provided on the bent pipe to automatically supply air for draft tube and reduce the vibration of the unit and improve the operating condition of the unit at the condition of lesser load, larger vacuum. After the bent pipe is removed the runner could be easily disassembled.

2.24 Walkways Stairways and Handrails

Walkways, platforms, stairs, ladders and handrails shall be provided for safe and convenient access to all equipment supplied under the Contract They shall comply with General Mechanical Design Requirements

2.25 Spare Parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for turbines deemed necessary for trouble free operation of all 04 turbines units for at least 05 years of commercial operation.

2.26 Rating Plates and Nameplates

A permanent stainless steel rating plate shall be mounted at a visible location on the wall at the machine hall floor. It shall be approximately 1000 mm wide and 700 mm high and shall have the following Information in bold letters:

a. Manufacturer's name and address
b. Turbine's serial number and date of manufacture
c. Rated turbine output in MW
d. Rated net head in meters
e. Rated turbine discharge in m3/s
f. Normal operating speed in rpm

The wording shall be in English. A drawing showing the proposed nameplate. its size and wording shall be submitted for approval.

2.27 Painting, Piping Material and Valve Schedule

2.27.1 Painting

Painting of the turbine and auxiliaries shall be generally in accordance with General Mechanical Design Requirements and the following paint Schedule.

Table 13: Painting Requirement

Surface	Surface preparation	Treatment
Exterior surface of the draft tube, spiral case, and all surfaces to be embedded in concrete	Mechanical cleaning as required (SSPC SP-2 or 3)	None
Wetted surfaces of the spiral case, discharge ring and draft tube	Mechanical cleaning SSP SP-2 or 3) and commercial blast cleaning (SSPC SP-6) as required	2 coats of coal tar epoxy SSPC Paint 16 each coat to have 200 microns dry film thickness
All nonmating surfaces of removable parts exposed to water	Near white blast cleaning (SSPC SP-10)	2 coats of coal tar epoxy SSPC Paint 16 each coat to have 200 microns dry film thickness
Edge preparations for field welding and/or prefabrication priming of parts to be field welded and painted	As required	One coat of zinc chromate vinyl butyra wash primer. SSPC Paint 27 or similar protective coating
All finished surfaces of ferrous metals. including screw threads that will be exposed during shipment or while awaiting installation	Solvent cleaning (SSPC SP-1)	Heavy coating of rust preventing compound removable with solvent
All parts exposed to atmosphere except machine surfaces	Near white blast cleaning (SSPC SP-10) or pickling (SSPC SP-8)	Zinc rich primer undercoat minimum dry film thickness 80 microns followed by 2 gloss finish coats of water base epoxy or acrylic dry film thickness each coat 50 to 80 microns. Total dry film thickness not less than 220 microns
Interior of bearing and parts in contact with oil	Near white blast cleaning (SSPC SP-10) or pickling (SSPC SP-8)	4 coats of white oil resistant vinyl paint total dry film thickness 150 microns
Exterior surfaces of Electrical cubicles. control and instrument cubicles and excitation cubicle etc.	Near white blast cleaning (SSPC SP-10) or pickling (SSPC SP-8)	Treatment 4 coats of vinyl paint SSPC-Paint 9, for total of 150 microns dry film thickness. finish colour as directed
Interior surfaces control cubicles of cabinets. etc.	Commercial blast cleaning (SSPC SP-6)	Manufacturer's standard

Auxiliary items of equipment such as compressors, air receivers. pumps etc.	Standard commercial cleaning	Manufacturer's standard finish with finish colours at site as directed
Walkways and stairs	Commercial blast cleaning (SSPC SP-6)	Galvanize
Platforms and walkways	Commercial blast cleaning (SSPC SP-6)	Galvanize then 1 coat etch primer. 2 coats zinc rich primer total dry film thickness 100 microns then 1 coat nonskid epoxy paint dry film thickness 30 microns

2.27.2 Piping Materials and Valves

Piping material and valves for turbines and auxiliaries shall be generally in accordance with General Mechanical Design Requirements and the following materials and valve schedules.

Table 14: Piping Materials and Valves

Service	Piping Material	Sch. & Finish	Joints	Valves
Cooling water in sizes 65 mm and smaller	Stainless Steel. A312/A312M, Type 304L, seamless	Sch. 40.	Screwed	Brass or Bronze. rising
Cooling water piping in sizes 75 mm and larger	Stainless Steel. A312/A312M, Type 304L, seamless	Sch. 40.	Welded & Flanged	Cast steel body stem & trim
Compressed air (5 bar and brake air station service) and drain piping in sizes 65 mm and smaller	Stainless Steel. A312/A312M, Type 304L, seamless	Sch. 40.	Welded & Flanged	Brass or Bronze. rising
Lubricating oil piping	Stainless Steel. A312/A312M, Type 304L, seamless	Sch. 40.	ISO 8434 flared pipe fittings or flanged	Brass or bronze. rising stem
High pressure oil piping	Stainless Steel. A312/A312M, Type 304L, seamless	Sch. 80. Black	Welded & flanged	Steel. rising stem
Compressed air piping	Stainless Steel. A312/A312M, Type 304L, seamless	Sch. 80. Black	Welded & flanged	Steel rising stem

2.28 Testing and Commissioning

2.28.1 Works Tests

a) Scope

All equipment covered by these Specifications shall be subject to inspection and testing in accordance with relevant Clause of the Contract. The tests listed in this Section are the minimum requirements.

The tests shall be performed to an agreed inspection and test plan using acceptance criteria approved by the Engineer.

b) Test equipment

The Contractor shall provide all the test equipment and test sets required for carrying out the inspection and tests. All equipment shall have current calibration certification.

c) Mechanical tests

This section specifies inspections and tests required and shall be included in the inspection and test plan to be submitted for approval. This shall not preclude the Engineer's right to call for modification or further inspections and tests if he considers these necessary in order to ensure compliance with these Specifications, whether under test conditions or in ordinary working, or to cover materials and methods of construction different from those indicated in the scheduled inspections.

2.28.2 Material Tests On Component Parts

Material tests are required on all materials in accordance with General Mechanical Design Requirements. Materials for all stressed items and those in contact with water shall be impact tested in accordance with General Mechanical Design Requirements.

All test specimens shall be tested to the satisfaction of the Engineer to conform compliance with the Specifications. All mechanical test certificates shall include full details of chemical analysis and heat treatment.

The material used shall in all cases conform to the requirements of these Specifications including chemical analysis and mechanical properties to be tested.

2.28.3 Runner

At the foundry - general ultrasonic examination and magnetic particle inspection and witnessing and testing of cast test specimens, at least one being from each casting of the crown and the skirt. The blade dimensional tolerance shall be plus 10% minus 0% and a minimum grinding allowance of 1 mm shall be left on each side of each vane.

At the Contractor's works - dimensional check before runner is removed from boring mill. On completion of grinding inspection shall include ultrasonic examination measurement of surface finish, measurement of leading dimensions. Check using template and pantograph that water passages are geometrically similar to those of the model within the tolerances specified.

Check of templates against drawings. The balance of the runner shall be demonstrated by an approved method.

2.28.4 Wearing Rings and Facing Plates

Ultrasonic examinations shall be carried out for wearing rings and facing plates.

2.28.5 Main Shaft

Forgings shall be subject to a complete ultrasonic survey, whilst all welds shall be subjected to radiographic examination backed up by an ultrasonic survey.

The micro finishes on the shaft shall be checked for conformity.

The shaft runout shall be checked in the Contractor's factory in accordance with the requirements of this specifications.

Borescope examination of finished bore.

2.28.6 Stay Ring and Spiral Casing

All plates to be ultrasonically examined to 75 mm back from weld preparations and all changes in section. Crack detection of all weld preparation edges. Check of contour and fit up on base plates. Radiographic examination of all spiral casing welds.

2.28.7 Draft Tube and Discharge Ring

All welds on suction cone and elbow liner to be checked by magnetic particle or dye penetrant inspection. Suction cone to be assembled in the works to the discharge ring to ensure correct fitting. Component parts of liner and splitter nose to be assembled to prove fit.

2.28.8 Guide Vanes

If cast, surfaces shall be crack detected and all vanes ultrasonically or radiographically examined with special attention to junction between stem and vane. If fabricated all welds 100% ultrasonically tested.

Guide vane contours shall be checked by templates to the tolerances stipulated on approved drawings.

2.28.9 Regulating Ring

Thirty percent ultrasonic examination of welds.

2.28.10 Servomotors

The servomotor cylinders shall be ultrasonically examined. The servomotors shall be tested with a pressure equal to 1.5 times the maximum working pressure for a period of at least thirty minutes.

2.28.11 Pressure Accumulator and Receivers

Ultrasonic or radiographic examinations to prove complete soundness of the vessel in accordance with ASME Code.

2.28.12 Pipework and Associated Fittings

Pipework welds shall be non-destructively tested with dye penetrants. Hydraulic pressure tests shall also be carried out. All compressed air piping shall be tested at a pressure of twice the maximum working pressure of the system.

2.28.13 Valves

Valves subject to cooling water pressure shall be hydraulically tested to the requirements stated in the relevant Section. Unless otherwise approved by the Engineer all valves shall be hydraulically tested before the application of any coating.

2.28.14 Check Assembly of Turbine

For the first machine, the guide vanes, runner, shaft, shaft seals, bearing, regulating ring and draft tube shall be assembled to the extent practicable to prove the design, construction and machining for proper fits and clearances. Parts shall be properly match-marked, identified and dowelled to ensure correct assembly and alignment at the Site, except that, where necessary, suitable dowels shall be furnished for insertion after Site assembly and drilling. The guide vanes shall be operated through their full movement or full servomotor stroke, as may be required, to demonstrate that the guide vanes and regulating mechanism function properly without interference or binding.

Shop assembly of the subsequent machines will not be required unless the assembly of the first machine demonstrates a requirement for improving quality control procedures.

Controlling dimensions and small clearances of the assembly shall be measured and recorded on the inspection and test plans, showing both the design drawing dimensions and the actual measured dimensions. Copies of the inspection and test plans shall be submitted to the Engineer for review prior to the first shop assembly. The assembly shall be assembled plumb and level and the bottom ring and top cover, including the mating surfaces for the guide bearing and shaft seal, shall be checked for concentricity.

2.28.15 Shear Pin Tests

The guide vane shear pin with friction device shall be subjected to a break test performed in the shop using equipment to simulate the actual operating conditions. All friction devices shall be set at Site using a calibrated servomotor. Description of the test rig and the test procedure shall be submitted to the Engineer prior to such tests.

2.28.16 Electrical Tests

Insulation and high voltage tests shall be conducted on all electrical equipment in accordance with the relevant IEC Standards.

2.28.17 Site Assembly Tests

During assembly on Site tests shall be carried out as specified in the approved quality plan. Tests on each turbine shall include but not be limited to the following:

2.28.18 Stage Testing During Erection and Commissioning

Commissioning tests and procedures shall be in accordance with IEC Publication 60545, "Guide for Commissioning, Operation and Maintenance of Hydraulic Turbines", in combination with the tests and procedures detailed herein. Dimensions to be measured during erection and witnessed by the Engineer shall include those tabulated and illustrated in the Appendix to IEC Publication 60545 entitled "Measurements".

2.28.19 Draft Tube and Discharge Ring

Ultrasonic checks on 30% of full penetration welds. Dimensional checks, including elevation and concentricity and circularity of conical section.

2.28.20 Spiral Casing and Inlet Section

All field joints including joint to stay ring shall be 100% checked by radiography and/or ultrasonic examination. In the region of tee junctions all circumferential joints shall be double checked by radiography and ultrasonics for a distance of at least 300 mm from the tee junction. The following checks and tests shall be conducted:

- Dimensional checks including accuracy of stay ring setting, concentricity and level.
- Pressure tests in accordance with the requirements of these specifications.
- On the first unit strain gauge measurements shall be recorded during pressure tests to the approval of the Engineer.

2.28.21 Runner and Shaft

Elevation, level and concentricity of runner and shaft shall be measured and recorded to the satisfaction of the Engineer.

2.28.22 Bearing

Bearing clearances shall be checked during installation and verified during shaft alignment check.

2.28.23 Guide Vanes and Regulating Gear

The governor and regulating gear shall be adjusted to give the guide-vane total opening and closing times previously approved by the Engineer.

A curve of servomotor stroke against guide vane opening shall be prepared. The guide vane openings plotted shall be the mean of three readings taken at equidistant levels.

2.28.24 Commissioning Tests

a) Turbine Generator tests

Prior to placing each unit into commercial operation, commissioning tests shall be performed on the completed generator and turbine unit. These tests will be coordinated by the Engineer but the Contractor shall assume full responsibility for the testing operation and safety of his Plant. The Contractor shall cooperate with the Engineer and others to permit all necessary tests to be performed. The Contractor shall provide all necessary labour and instruments to perform the tests on his Plant. The test instruments shall be of the latest model and type available with the precision

required to conduct the specified tests. The Contractor shall be required to follow the Engineer's agreed operating procedures. The commissioning tests shall be in accordance with IEC 60041, IEC 60545, IEC 60994 and Special Provisions if any and shall include, but not be limited to, the following:

b) Alignment and rotation check in the dry condition.

1 Mechanical run.

2 Governor operation.

3 Timing tests including measurement of guide vane openings.

4 Proving of interlocks and indications/alarms

5 Initial wet run to ensure satisfactory operation.

6 Measurement of shaft throw and runout over complete range of speeds and loads

7 Bearing temperature checks

8 Braking tests

9 Proving, and if necessary, adjusting over-speed switches

10 Mechanical tripping tests for turbine

11 Generator tests in accordance with IEC 60034 including electrical tests, mechanical tests of heating and cooling system

12 Braking tests on all units and also following tests

13 Open and short circuit loss tests

14 Efficiency tests

15 Harmonic injection tests

16 Load and overload tests.

17 Load rejection and load acceptance tests.

18 Investigation of any objectionable vibrations, pressure surges, power swings, or noise under any operating conditions

19 Closure of the Main Inlet Valve with guide vanes blocked at 100% opening

20 Leakage checks on closed MIV

21 MIV closing and opening times

22 Reliability Tests

c) Runaway Speed Tests

A runaway speed test may be made on one turbine-generator unit to demonstrate that all parts of the turbine will successfully withstand the stresses incident to its operation at the runaway speed. This test shall be conducted by opening the turbine guide vanes in suitable steps, allowing the speed to level off at each step so that readings of steady-state speed and guide vane position can be obtained, until no-load speed at maximum guide vane opening is attained. The unit will be operated at this speed for a period of not more than five minutes.

These tests shall be started with the excitation field breaker closed, the voltage regulator be started with overspeed contacts set to remove the regulator from service and open all excitation field circuits at approximately 150% speed.

Should the overspeed test show deficiencies in the turbine, the deficiencies shall be corrected and the runaway test shall be repeated. The Engineer reserves the right to direct the Contractor to conduct a runaway test run on any other or all turbines furnished.

2.28.25 Site Efficiency/Performance Tests

a) General

The efficiency/ performance tests at Site shall be carried out after the units have been satisfactorily put into commercial operation and within the specified period of guarantee of the turbines and governors.

Efficiency/performance tests shall be conducted on at least one turbine. The Engineer reserves the right to make such performance tests on one or all of the other turbines, as may be in the best interest of the Employer. The points at which performance is measured shall include but will not be restricted to the Guaranteed conditions and shall be agreed between the Engineer and the Contractor prior to commencement of testing. The tests for the turbine shall be conducted in accordance with the applicable provisions of the International Code for Field Acceptance Tests of Hydraulic Turbines, IEC Publication 60041.

Flow shall be measured by the acoustic flow meter specified in these specifications.

b) Provision of tapings, measurements, instruments and personnel

The Contractor shall make all necessary provisions at the design and manufacturing stages for tapping points according to IEC 60193 and IEC 60041 on all turbines so that such tests may be carried out accurately on any one of them.

Measurements of the dimensions of the test sections of the hydraulic system shall be made by the Contractor and witnessed and agreed by the Engineer before the penstocks are filled.

Generator output will be measured electrically at the generator terminals by the contractor.

The tests are to be conducted at a date when the weir stands at such a level as to give, as nearly as it may be possible to arrange, the design head on the turbine.

c) Conduct of tests and records

Copies of all log sheets and test readings shall be given to the Engineer as the tests proceed.

After the conclusion of the tests, the Contractor shall compile a comprehensive Test Report to the approval of the Engineer. This report shall include copies of all log and calculation sheets and all necessary tables and curves to record the results of the tests. The Contractor shall supply the Engineer with six copies of the report.

SECTION 3: HOWELL BUNGER TYPE PRESSURE RELIEF VALVES

As described in the beginning of this chapter under 1.1 General, total four (04) Howell Bunger (Fixed cone and movable sleeve type) pressure relief valves shall be provided. These valves will be flanged connected on a branch pipe directly welded with each spiral casing of the respective sizes. These valves will be operated with hydraulic actuators and pressure sensing units designed on the basis of transient studies to be conducted by EPC Contractor. The fixed cone size shape shall be proposed by the Contractor such as to relieve the water pressure on tail race side without harming any equipment or components in the vicinity.

The Howell-Bunger (fixed cone) valve shall be designed specifically for high-head hydropower service and shall comply with the latest editions of the following standards:

- IEC 60545 (Hydraulic turbines – auxiliary equipment)
- USBR Design Standards and Engineering Monograph for fixed-cone valves
- ASME B31.1 / ASME B16.34 for pressure design
- EN 12516 for valve strength
- ISO 5208 for pressure testing
- AWWA standards for fabrication and actuators
- AWS D1.1 for welding

Where conflicts occur, hydropower-specific standards shall govern.

The relief valves shall be provided with vent piping, silencers and drain connections, as well as suitable gagging and locking devices for hydraulic testing after erection and for long-term maintenance of the plant.

Table 15: Key Parameters for Pressure Relief Valves

Total No of Valves	**4**
Valve type	Fixed cone, Howell Bunger
Design Pressure	22 Bar
Pressure Rating	PN40
03 valves with Nominal Diameter	DN500
01 valve with Nominal Diameter	DN300
Operating system	Hydraulic Actuator with pressure sensing units
Connection with Branch pipe	Flanged type with damper sleeves
Connection of branch pipe with Spiral Casing	Welded

SECTION 4: GOVERNORS AND AUXILIARIES

4.1 Scope

This Section covers the Particular Specifications for design, engineering, manufacture, transport, erection, shop and site testing and commissioning of 4 sets of speed governing units and their auxiliaries for the Francis type turbines to be furnished complete in accordance with these specifications.

This specification is written mainly considering a digital control system. The governing system shall be designed, installed, tested and commissioned in accordance with the following standards and codes:

- IEC 60308 International Code for Testing of control system for Hydraulic Turbines.
- ANSI/ASME PTC 29-1980 Speed governing systems for Hydraulic Turbine Generator Units
- IEEE Std. 1207-2004 IEEE Guide for the application of Turbine Governing Systems for Hydroelectric Generating Units

4.2 Structure of The Governor

The governor shall comprise three separate but interconnected elements as follows:

- Digital Governor
- Electrohydraulic Amplifier
- Pressure Pumping System

The general location of these items of equipment is shown on the Specification Drawings.

4.3 Hazop Studies

The Contractor will conduct in conjunction with the Engineer's representative a full Hazard and Operability (HAZOP) study covering the complete turbine, turbine governor and Main Inlet Valve systems. The study will review the proposed designs and examine their performance and reliability under all possible conditions including machine start up, operation under the complete range of operating conditions of load and head and also under runaway conditions and shutting down under normal and fault conditions.

The purpose of the study is to ensure that the designs will provide safe plant operation and shut-down even if parts of the system were to fail to work normally.

4.4 Digital Governor

4.4.1 Precedence and Type

The Digital Governor (DG) shall consist of a solid-state programmable microprocessor system suitable for operation over the full range of ambient conditions. It shall be made to the highest equipment and manufacturing specifications and incorporate dual redundancy. The Digital Governor proposed shall be the most current model in a substantial line of governors designed and manufactured by the digital governor supplier and shall have previously been installed and used successfully on a number of Francis turbine hydro schemes.

4.4.2 Location

The Digital Governor shall be located in a metallic panel (Digital Governor Panel (DGP)) alongside the Unit Local Control Panel (ULCP) located on the Machine Hall Floor as shown on the approved drawing.

4.4.3 Wiring and Cabling

The Contractor will wire from all the local panels to the Marshalling Panel of the ULCP. The Contractor will also wire all necessary connections from the Marshalling Panel of the ULCP to ports at the DGP.

4.4.4 Electrical Supplies

Electrical supplies shall be in accordance with General Electrical Requirements. Should the Digital Governor require electrical supply at voltages and frequencies different to those available then the Contractor shall provide the necessary conversion equipment. Such conversion for the main supply shall be duplicated such that, in the event of failure, switch over to the alternate conversion system is automatic. In the event of failure and switch over a "Digital Governor Fault" alarm shall be given.

4.4.5 Input and Output Signals

During on-line operation, remote commands to the Digital Governor will be from the station Distributed Control System (DCS) specified in Control System Specifications. Therefore, start/stop and synchronizing commands will either be from the hard wired protection/tripping scheme or from the control system in the ULCP (local manual/auto) or from the DCS (remote auto) depending on which mode has been selected at the ULCP. The form of input signals provided by the DCS and ULCP at the Digital Governor and those required from the Digital Governor to the DCS and ULCP for Control and Indication are given in General Control and Instrumentation Requirements of these Specifications. Should the Digital Governor require or give signals and indications in a different form to those specified then the Contractor shall provide all the necessary conversion equipment within the Digital Governor.

The connection details and signals between the Digital Governor, ULCP and DCS will be subject to approval by the Engineer.

4.4.6 Network Detection and Parameter Selection

The Digital Governor shall have the facility to hold separate adjustable permanent speed droop, proportional gain, integral and derivative time constants for the following modes of operation:

- No load operation
- Steady State Network operation
- Isolated operation

by selection from the DGP Control Panel and DCS or when frequency changes exceed those for Steady State Network operation.

Switching from Steady State Network operation to and from Isolated operation shall be automatic depending on the system conditions. The changeover shall be bump less. If Isolated operation has

been selected at the DGP Control Panel or from the DCS, then the Digital Governor shall remain in this mode regardless of system conditions.

The permanent speed droop for steady state operation shall be adjustable from DCS and at the DGP.

The variables shall be adjustable at least within the following ranges:

- Permanent Speed Droop 0 to 10%
- Proportional Gain 0.2 to 10
- Integral Time Constant 1 to 20 seconds
- Derivative Time Constant 0 to 2 seconds

4.4.7 Frequency/Power Control

Under DCS command the Digital Governor shall respond to frequency with PID response and to each of the following digital inputs via PI response (or under PID response with reduced derivative gain):

- Generator Active Power set point (MW)
- Turbine Flow set point (m3/s)

The type of set point to be received by the Digital Governor will be selected from the DCS and the Digital Governor shall respond accordingly. Having reached the set point the Digital Governor shall automatically maintain the unit at this value regardless of variations in system parameters, to the limits of permitted maximum guide vane opening.

Set point control shall from algorithms for generator power and turbine flow. These algorithms shall be generated internally in the Digital Governor from matrices based upon turbine model test results, prototype commissioning tests and data obtained from the generator contractor.

Under commands from the DGP, with the DCS selected to "Local" operation, the Digital Governor shall respond to frequency with PID response and to guide vane opening raise/lower pulses via PI response (or PID response with the derivative gain reduced).

Frequency shall be controlled by the Digital Governor to a signal from the network and, when selected, from an internally generated signal within the governor. The source of the frequency signal shall be selectable at the Digital Governor. The internal frequency signal shall be adjustable from 0% to 200% normal speed to enable testing of the generating unit.

The governor shall incorporate feed forward arranged such that the rate of change of guide vane opening/power or flow shall follow a pre-determined law when the respective set points are changed, or the guide vane raise/lower pulses are received from the DGP. The laws shall be adjustable locally at the DGP. Feed forward shall be enabled only for Steady State Network operation. It shall be deactivated under Isolated operation.

4.4.8 Guide Vane Limit

The Digital Governor shall be equipped with a maximum guide vane limit adjustable from DCS and at the DGP. The Digital Governor shall also be programmed with guide vane and power limits which, based upon the turbine model and prototype test results, will alarm operation in regions of rough running and will inhibit operation in regions outside those established under the Contract.

The guide vane limiter travel time shall be adjustable between 20 to 80 seconds for full travel of the servomotor.

4.4.9 Compensation for Water Column Inertia

The Digital Governor shall be equipped with internal sensing and compensation circuitry which shall compensate to the maximum practical extent for water column inertia during change in loading of the unit.

4.4.10 Start/Stop Commands

Under start up command from the DCS or ULCP the Digital Governor shall automatically run up the unit, give the DCS control system a permissive synchronized signal in the case of start from the DCS or accept synchronizing pulses from the ULCP when started from there. When the ULCP or DCS puts the unit on line (in the case of control from the DCS) the Digital Governor shall load the unit to the selected digital set point. In the case of a Local start from the ULCP, loading shall be done from guide vane raise/lower pushbutton commands at the DGP.

The Contractor or his sub-contractor shall prepare hard wired and microprocessor start/stop logic for the unit.

4.4.11 Points of Control

At the DGP, switching shall be provided for the following points of control and operations:

Remote Control - under Remote Control the Digital Governor shall receive on line commands from the station DCS system.

Local Control - under Local Control the Digital Governor shall receive on line commands from the DGP Control Panel and start/stop and synchronizing commands from the hard wired ULCP system.

4.4.12 Operating Requirements

i. Starting

On receipt of a start signal from the DCS the Digital Governor shall be programmed to:

1 Send the guide vanes and the guide vane limiter to the start up position. This position shall be a function of net head to ensure a constant start up acceleration.

2 Speed govern to current network frequency with a positive slip appropriate for synchronizing. Or a pre-set speed (nominally 50 Hz but adjustable). The start-up mode shall be selectable.

3 Give a "ready to synchronize" signal to the DCS.

4 When synchronized load the turbine to the preset level provided by the DCS" Starting from the ULCP will be identical to starting from the DCS except that synchronizing will be done by an auto or manual synchronizer, selectable at the ULCP, pulsing the Digital Governor.

ii. Control functions during generation under DCS command

During generation the Digital Governor shall:

Accept set points from the DCS for:

- Generator Active Power (MW)

- The choice of parameter for set point control shall be selected from the DCS and correspondingly changed in the Digital Governor.
- Switch over to isolated operation and back to Steady State Network operation settings as necessary for stability of the Network.
- Maintain unit speed.
- Check the efficiency of turbine operation and alarm when it exits preset limits.
- Alarm when turbine operation is in known rough operating zones as indicated by the turbine model tests and prototype commissioning.
- Alarm when set points cannot be maintained because of net head limitations
- Alarm when the operating net head and tailwater levels are outside the normal range
- Limit guide vane openings and powers to those stipulated in the Contract.

iii. Control functions during generation under DGP Command

Under local operation from the DGP the operation shall be the same as under DCS command except that inputs for Power and Flow shall be substituted by guide vane raise/lower commands from the DGP.

Manual control of the guide vanes which by passes the governor control loop shall also be available at the DGP.

iv. Normal stops

On receipt of a normal stop command from the ULCP or the DCS the Digital Governor shall:

- Lower power in accordance with the pre-set unloading law.
- Close the guide vanes to their fully closed position.
- On receipt of a permissive from the ULCP or the DCS activate the unit creep detection system.

4.4.13 Control Functions Whilst The Unit Is at Standstill

Whilst the unit is at standstill the Digital Governor shall monitor the creep detection system and, if creep is detected give the ULCP or DCS system a signal to apply the generator brakes.

4.4.14 Rapid Shut Down

The hardwired T1 and T2 Rapid Shut Down signals defined in SCADA & Control System specifications shall feed directly into the Rapid Shut Down circuits of the Digital Governor. On receipt of the Rapid Shut Down signal from the ULCP hardwired control system the pilot servomotor Actuator shall pressurize the closing side of the guide vanes such that they close in accordance with the pre-determined law required to meet the pressure and speed rise guarantees. At the same time the Digital Governor shall run down the guide vane limiter to zero.

4.4.15 Partial Shut Down

On receipt of a T3 Partial Shut Down signal defined in SCADA & Control System specifications the Digital Governor the Digital Governor shall rapidly close the guide vanes and run the guide vane limiter to the speed no load position and await further signals from the ULCP.

4.4.16 Internal Monitoring

At all times during standstill, starting, generation and stopping the Digital Governor shall monitor its internal system and supplies to ensure that they are healthy. In the event of a failure or fault the Digital Governor shall provide a "Digital Governor Fault" alarm to the DCS and ULCP and shall be programmed to automatically switch to safely control the opening of the distributor. The indications on the Digital Governor Control Panel or via a externally connected control module shall be detailed enough to clearly indicate the reason for the fault.

4.4.17 Human-Machine Interface

a. Facia control and indication panel

On the facia (front) of the DGP there shall be a panel which shall have facilities for all necessary Control and Indications relating to day to day operation of the Unit. Minimum necessary Control and Indication facilities on the facia control panel are:

Control

- Local/Remote select
- Manual/governor guide vane control select
- Guide vane raise/lower
- Permanent speed droop setting raise/lower
- Network Frequency/Set Frequency select
- Set Frequency raise/lower
- Guide vane limit raise/lower
- Isolated operation/Network operation select

Indication

- Speed (rpm)
- Guide vane Position (%)
- Permanent Speed Droop (%)
- Guide Vane Limit %
- Set Frequency/Network Frequency selected
- Set Frequency setting
- "Digital Governor Fault" alarm
- Unit operating at guide vane limit
- Unit operating at power limit
- Unit operating outside acceptable efficiency range.
- Unit operating in rough running region
- Digital Governor under DGP Command
- Digital Governor under DCS Command

- Operating net head outside Normal range.
- Tailwater outside the Normal range.
- Electrical supplies fault
- Digital Governor input fault
- Creep detected
- Isolated operation selected
- Network operation selected
- Manual operation of the Guide Vanes selected
- Guide vanes operation under governor control selected
- Digital Governor On No Load operation settings
- Digital Governor On Steady State Network operation settings
- Digital Governor On Isolated operation settings

These requirements are indicated on the Control and Indication Schedules. They shall be supplemented as necessary by the Contractor to reflect the actual equipment supplied.

b. Internal control and indication panel

Located inside the DGP and permanently connected to the Digital Governor shall be a Control and Indication panel which shall contain the following minimum control and indication functions for day to day operation:

Control

- Permanent droop default settings for No Load, Steady State Network, and Isolated operation.
- P,I and D settings for No Load, Steady State Network, and Isolated operation.
- Head, tailwater and guide vane limits for start of forced draft tube air admission (if provided).
- Head, tailwater and guide vane limits for alarm of out of normal operation.
- Head, tailwater and guide vane limits for alarm of rough running operation.
- Ramp settings for power, flow and guide vane raise lower (MW/min, m^3/s/min and % of maximum guide vane opening/min)

Indication

- P,I and D settings for No Load, Steady State Network, and Isolated operation.
- Head, tailwater and guide vane limits for start of forced draft tube air admission (if provided).
- Head, tailwater and guide vane limits for alarm of out of Contract operation.
- Head, tailwater and guide vane limits for alarm of rough running operation.
- Ramp settings for power and guide vane raise/lower (MW/min, m^3/s/min and %/min)
- Other reasons for "Digital Governor Fault" alarm.

Being part of the governor programming these requirements are not indicated on the Control and Indication Schedules. However, they shall be provided and they shall be supplemented as necessary by the Contractor to reflect the actual equipment supplied.

4.4.18 Operating Requirements

The magnitude of the sustained speed oscillations attributable to the Governor shall not exceed plus or minus 0.1 % of the normal speed with a permanent speed droop setting between 2% and 5% inclusive.

The magnitude of power and flow oscillation attributable to the Governor shall not exceed plus or minus 0.2% of the rated value with a permanent speed droop setting between 2% and 5%.

Dead time from speed no load to maximum guide vane opening under all net heads shall not exceed 0.2 seconds for a 10% load change.

Dead Band for speed control from speed no load to maximum guide vane opening under all net heads shall not exceed 0.4% of the rated speed, to be demonstrated during shop test.

4.4.19 Software

It shall be possible to adjust all variable parameters with the unit online. Application programs shall be arranged in functional blocks. They shall be written in a high level language industry standard format. Update times shall be commensurate with the importance and the rate of change of the control parameters and shall be adjustable.

Custom made application programs (matrices etc.) shall be accessible from a plug-in key board and monitor and shall be readily changeable. The Contractor shall supply two plug in key boards and monitors each mounted on a rubber wheeled trolley. Also mounted on each trolley shall be a dot matrix printer on which hard copy of the programs can be printed.

4.4.20 Digital Governor Panel

The Digital Governor Panel (DGP) shall be generally in accordance with General Electrical Requirements of these specifications. The functional modules shall be rack mounted inside the panel and shall be arranged for ease of access and testing. There shall be 20% extra racks.

The DGP shall be identical to that of the panels of the ULCP.

4.4.21 Speed Sensing Equipment

The frequency signal shall be taken from a voltage Transformer supplied as part of the generator circuit breaker (GCB). In addition, a separate toothed wheel/proximity transducer system shall be supplied by the Contractor for mounting on the generator shaft. The design and installation of speed sensors and the voltage Transformer shall be coordinated by the Contractor and his sub-contractors. Cabling to and from these items to the generator marshalling box shall be undertaken by the Contractor. The toothed wheel system shall be used for operating speed sensing devices. The toothed wheel signal from one of the sensors shall also be used as an automatic backup frequency signal should the supply from the voltage Transformer fail.

The toothed wheel system shall have three separate proximity transducers, two for over speed sensing and one for speed switching of auxiliaries. A third over speed device of the centrifugally

weight operated pilot hydraulic valve type shall be supplied by the Contractor and mounted on the shaft within the turbine pit. The proximity transducers shall generate the following contacts.

Table 16: Proximity Transducer Details

Speed Switch	Action	Settings % of Normal Speed	
		Operate	Reset
Overspeed No. 1	Partial Shut Down then go to speed no load (T3)	115	105
Overspeed No. 2	Emergency Shut Down (T5)	140	Manual Reset
Overspeed No.3 (mechanical)	Emergency Shut Down (T6)	150	Manual Reset
Interlock Switch	Generator Brakes	Auto	-
	Excitation	Auto	Auto
	Spare		

All speed signals shall be feed directly to the hard wired control system in the ULCP and to the DCS for action.

The creep detection system to be supplied and installed by the Contractor shall be capable of detecting a 2 degree rotation of the shaft or less. The setting for annunciation of creep shall be adjustable between the minimum detectable and 10 degrees. The measuring system shall be insensitive to vibration. Upon detection of creep, a creep alarm shall be annunciated and a signal shall be given to the ULCP or the DCS to apply the generator brakes.

4.5 Electrohydraulic Equipment

4.5.1 Location

The Electro-hydraulic equipment, including the electro-hydraulic proportional valve, all solenoids and accessories shall be mounted on the top of governor sump tank located in the Machine Hall as shown on the approved drawing. Contained within the governor sump tank shall be, but not limited to, the Electrohydraulic Actuator, Main Distributing Valve together with all necessary accessories.

4.5.2 Electrohydraulic Amplifier Control System

The Electro-hydraulic control system shall position the guide vane servomotors in response to a set point signal transmitted from the Digital Governor. The servomotor position shall match the set point signal from the Digital Governor with an accuracy of plus or minus 0.2 % of servomotor stroke or better. The forward gain of the servomotor control system shall be adjustable.

A standard servo/proportional valve with integrated amplification steps shall be supplied according to standard concepts and experience. The dynamic response requirements for the complete hydraulic control system are to be met. The pilot stages of hydraulic amplification shall be tolerant of contamination levels consistent with oil filtered to 10 microns filtration of the pressure pumping system.

Unless approved by the Engineer standard CETOP hydraulic components shall be used.

4.5.3 Electronic Interface

The electronic interface of the Electro-hydraulic equipment shall receive the position set signal from the Digital Governor and shall position the Actuator which in turn, via hydraulic circuits, shall position the guide vane servomotors or Main Inlet Valve servomotors as appropriate. The electronic interface shall be designed to be fail-safe, such that loss of either the power source or the set signal shall cause a shutdown of the unit. Fail-safe operation shall be by spring loaded or weight-operated action.

4.5.4 Emergency Shut Down

The Electro-hydraulic equipment shall have an independent Emergency Shut Down system, to be activated for all T5 Emergency Shutdowns identified in C&I and SCADA System Specifications of these Specifications. It shall be located on the governor sump tank. This shut down system shall act directly upon the hydraulic circuit, bypassing the governor.

The emergency shutdown system shall be activated remotely via a solenoid operated valve which can also be manually operated at the valve. The solenoid shall be activated directly from the hard wired protection system which will simultaneously trip the generator circuit-breaker and shut the main inlet valve. The solenoid operated valve shall be arranged on the governor sump tank such that the manual actuation is easily accessible. The manual actuation shall be clearly marked in red. An Emergency Shut Down pushbutton will be provided at the ULCP.

There shall also be a hand operated emergency shutdown valve in another convenient location away from the tank.

Another independent shut down valve located in the turbine pit shall be actuated by the mechanical over speed device. The signal from this shall be hardwired to the ULCP for appropriate further action by the hard wired control system.

4.5.5 Hand Control

There shall be means for manually actuating the guide vanes from the GHP for maintenance purposes. This shall take the form of a lockable valve in the oil system which by passes the Digital Governor. The handle shall be accessible from the front of the GHP and the open and closed positions shall be clearly marked.

4.5.6 Position Feedback

Position feedback from the guide-vane servomotor shall be from a position transducer mounted as close to the servomotor as is practical. If the connection to the servomotor is under tension, it shall be arranged such that breakage of this connection will result in a closure of the guide vanes.

4.6 Pressure Pumping System

4.6.1 Location

The operating pressure of the pressure pumping system will be no more than 160 Bars.

The pressure pumping system for each unit comprising sump tank with pumps, pressure accumulator, and all accessories and pipe work shall be at Machine hall floor.

4.6.2 Sump Tank

The capacity of the sump tank shall be not less than 110% of the total quantity of the oil in the governor, piping and turbine servomotor systems. The sump tank shall be provided with sealed access openings for inspection and cleaning.

The interior of the tank shall be free of open joints or crevices in which foreign matter in the oil could lodge. All welds inside the tank shall be continuous. The tank shall be designed with a system of baffles such that all oil returning from the servomotors will take the longest practical path before reaching the pump suction lines.

The bottom of the sump tank shall have a slope of at least 0.5%. A drain fitting shall be provided at or near the low point of the sump tank.

Duplicate fine mesh screen strainers with a permanent magnet in their bases shall be provided through which all oil returned from the servomotors shall pass. The strainer shall be readily removable for cleaning.

The sump tank shall be equipped with a flush-mounted oil level indicator/transmitter, temperature indicator/ transmitter, filler connection, drain connection, and connections for the oil purifier. The filler pipe shall be provided with a strainer, which shall be readily removable for cleaning.

An easily accessible and cleanable cooler shall be provided should the Contractor’s calculations show this necessary to keep oil temperature within limits. The water discharge side of the cooler shall be provided with a regulating valve and flow indicator with contacts.

A sump air filter/breather complete with 10 micron filter shall be mounted on the sump tank. The filter shall be of the replaceable element type.

A drain gutter shall be provided around the perimeter of the sump tank. A drain point shall be provided to empty this gutter.

4.6.3 Pumps

Each Governor Pressure Pumping System shall have two electric motor-driven oil pumps, complete with starters, having a combined capacity per minute of not less than three times the total oil volume of the turbine guide vane servomotors. The pumps and motors shall be mounted on the oil sump tank. Each oil pump shall be of the rotary or screw type, and shall be self-priming. The pumps shall be directly connected to squirrel cage, low-starting current induction type motors, designed for full-voltage across the line starting.

One pump shall run continuously when the generating unit is in operation. The second pump shall start and stop in response to the governor accumulator pressure. An unloading valve shall be provided for each pump to bypass the oil when the governor accumulator pressure has reached maximum normal working pressure. Automatic pressure operated controls shall be provided, which, when the generating units are at standstill, will start the pumps when oil pressure in the governor accumulator is less than minimum operating pressure and will stop the pumps when oil pressure rises to maximum operating pressure. The pumps shall start unloaded under all conditions. The two oil pumps shall be interconnected and provided with "failure to start" "cut-out" and "alarm" features so that they can be operated independently or together. When operating together, the interconnection and automatic control of the two pumps shall permit the use of either pump in lead operation with the second serving as the backup.

Each pump shall have a relief valve set to open at 10% over pressure with capacity to pass the full delivery of the pump at 20% above the maximum governor accumulator pressure. The necessary hand operated valves shall be provided to isolate either pump from the oil pressure system and permit its removal, without loss of oil pressure.

A portion of the oil flow from the oil pumps shall be diverted through a 20 micron filter element and returned to the sump tank. The filter shall be equipped with a high differential pressure alarm.

The sump shall have a very low oil level sensor which shall prevent operation of the pumps.

4.6.4 Pressure Accumulator

The governor system shall be provided with piston type accumulators fully equipped for operation on a high integrity turbine governor system. The accumulator shall be equipped with systems to determine any loss of nitrogen including the position of the piston.

Connections between oil pressure gauges and the pressure vessel shall have isolation valves.

Pressure instrumentation shall be mounted in a piped connection to the pressure vessel. This connection shall be unaffected by oil flow in the main line. At least three pressure switches shall be provided on the connection with sufficient contacts to control the pumps and provide control alarm and tripping functions.

4.6.5 Nitrogen System

Nitrogen shall be supplied from gas bottles ideally mounted in the same frame as the oil/Nitrogen pressure vessel. All piping, valves, moisture traps between this system and the pressure vessel shall be supplied and installed by the Contractor. Nitrogen admission to the oil/Nitrogen pressure vessel shall be automatic in response to pressure vessel oil level.

All required controls, non-return valves and devices for emptying and filling the accumulator in a safe and efficient manner shall be supplied and installed by the Contractor.

4.6.6 Piping

All piping, tubing, flanges, fittings, valves, hangers, brackets, fasteners, and all necessary items for a complete, self-contained hydraulic pressure and actuator system shall be designed, manufactured and installed by the Contractor. The piping will preferably manufactured from standard “off the shelf” stainless steel components with appropriate high-pressure fittings.

4.7 Special Tools

The Contractor shall supply all special tools & software required for operation, setting, maintenance and testing for governor system.

4.8 Spare parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for turbines governors deemed necessary for trouble free operation of all 04 units for at least 05 years of commercial operation

4.9 Inspection and Testing

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

In general, all the equipment shall be tested in accordance with the requirements of applicable clauses of IEC 60193, IEC 60308 and EC 61116

4.9.1 Particular Inspection and Testing During Manufacture

The governor unit, including servomotors shall be assembled complete in the Contractor's works and tested to demonstrate that it meets the performance requirements of the Specifications in respect of stability, dead time, dead band, speed of response and control requirements. The type tests shall be in accordance with the latest edition of IEC 60308 International Code for Testing of Speed Governing Systems for Hydraulic Turbines.

In particular, the following shall be established:

- Range of external command signals
- Dead band
- Dead time
- Inaccuracies
- Range of permanent speed droop
- PID settings and range
- Stroke of main regulating valve
- Servomotor closing and opening time
- Servomotor cushioning time
- Servomotor response time
- "Fail safe" features
- Insensitivity to changes in hydraulic pressure
- Performance of guide vane and power limiting devices
- Response to external Power set points
- Response to external Flow set points
- Response to guide vane raise and lower commands from the DGP
- Simulated start, stop and emergency shut down sequences
- Indication of rough running bands
- Simulated efficiency evaluation

Each tank shall be tested for oil tightness after fabrication and before shot blasting and painting. For the test the tank shall be filled with a suitable non-corrosive fluid and inspected for leaks.

Each pumping set shall be completely assembled in the Contractor's factory with its pressure vessel and accumulator. The pumping units shall be run continuously for a period of four hours to demonstrate the satisfactory operation of the pumps, unloading valves, relief valves, pressure

switches and other ancillary equipment. The pumps shall also be run for ten minutes at a pressure thirty percent above the maximum normal operating pressure.

At least sixty days prior to the type tests the Contractor shall provide for approval of the Engineer a detailed description of the procedures and equipment to be used in the tests.

4.9.2 Testing During Erection and Commissioning

The test procedure shall include but shall not be limited to the following tests:

4.9.2.1 General

The Contractor shall submit to the Engineer, one month prior to the date of commencement of the tests, six (6) copies of the complete test procedure. The procedure, method and points of measurement shall be approved by the Engineer before any test is carried out. Six (6) copies of the test results shall be furnished to the Engineer for his approval.

The complete governor system will be subjected to inspection and testing in accordance with applicable clauses of the codes and standards of IEC.

Tests on compressed air system will include Preliminary tests, Pre-start and Commissioning test and Performance test as described below

4.9.2.2 Preliminary tests

All items of equipment will be tested individually to determine the specified and scheduled data, and conformance to specified requirements, when operated independent of overall system for noise, vibration, electrical data, air temperatures, pressures and capacities.

- Equipment

  All compressed air equipment will be inspected for proper operation, noise and vibration. Tests will be carried out with readings of temperature, pressure, rpm, ampere, voltage, etc. to determine the specified data.

- Electrical equipment

  All electrical equipment will be cleaned and adjusted on Site before supply of power.

The following tests will be carried out:

- Wire and cable continuity tests
- Insulation resistance tests, phase to phase and phase to earth, on all circuits and equipment, using 500 V megger. The megger reading shall not be less than one megohm.
- Earth resistance between metallic conduit systems and earth shall not exceed half (0.5) ohm.
- Phasing out and phase rotation tests.
- Operating tests on all protective relays to prove their correct operation before energizing the main equipment.
- Operating tests on all starters, circuit-breakers, etc.

4.9.2.3 Pre-start and commissioning tests

i. Governor

- Check of control motor operation
- Adjustment and setting of rated speed
- Adjustment and setting of limit switches
- Characteristics test of valves
- Adjustment and setting of guide vane closing and opening times
- Adjustment and setting of valves
- Adjustment and setting of servomotor strokes for turbine starting and no load running
- Measurement of differential pressure at servomotors
- Setting and checking of adopted times for turbine guide vane
- Turbine no-load operation test

ii. Pressure Oil Supply System

- Measurement of oil pump discharge pressure
- Adjustment and setting of unloader valve
- Continuous operation test of oil pump (heat run)
- Automatic start and stop test of oil pump with stand-by oil pump
- Measurement of relation between oil level and pressure value in pressure oil tank
- Measurement of oil build-up time by N2 gas pressure
- Capacity test of pressure oil tank
- Adjustment and setting of safety valve
- Check of oil level control system
- Leakage test of oil and air (tank and all pipe lines)
- Setting of oil level switch and pressure switches
- Insulation resistance measurement of motors

iii. During commissioning of generating Unit:

- Adjustment and setting of rated speed
- Initial response test
- Turbine speed-SSG characteristic test
- Automatic start and stop operation test
- Emergency stop test
- Quick stop test
- No-load and excitation operation test
- Load rejection tests at 25, 50, 75 and 100% of the rated load

- Heat run test
- Relation between guide vane servomotor opening and generator output (output test) with vibration measurement
- Quick load increase test
- Permanent speed droop measurement
- Over speed test for checking over speed relay

SECTION 5: MAIN INLET VALVES

5.1 Scope

The scope covers the design, manufacture, supply and installation of four Main Inlet Valves (MIVs) and operating equipment, suitable for use with each of the four turbine units.

5.2 Location

The location of the Main Inlet Valves is indicated on the Specification drawings.

5.3 Operation

The inlet valves shall be capable of closing against the maximum flow that can occur under any turbine operating condition including runaway. The inlet valves shall be operated in the opening direction by an oil pressure servomotor. Closure shall be by counterweight. In the closed position the counterweights shall not restrict access on the valve floor.

The inlet valves opening and closing times shall be independently adjustable but the adjustments shall be of a form that cannot be readily or inadvertently altered. In the interests of minimizing the time necessary to shut down in an emergency, the closing times shall be the minimum consistent with safe operation.

The valves shall be closed after each turbine shut down. Valve operation shall be controlled by the normal start up and shut down sequences of the generating units. The valves shall be opened under balanced conditions provided by opening of their bypass valve. Normal closure is at no flow, except possible turbine guide vanes leakage. Valve closure under this exceptional discharge shall not generate a transient head higher than that the maximum design pressure.

The oil pressure accumulator system shall be dimensioned to handle three (3) full strokes of the valve (close-open-close) with the remaining pressure during the last stroke sufficient to close the valve.

5.4 Submittals

On completion of valve design and before the commencement of manufacture, the Contractor shall submit to the Engineer for approval a technical note on the analysis of valve closure under exceptional discharge. The assumptions shall be clearly presented and shall make reference to previous tests or measurements if possible. This note shall establish the basis for the guaranteed pressure surge.

5.5 Guarantees

5.5.1 Performances

A. Leakage

There shall be no leakage of the valve when new.

B. Opening / Closing time

The Contractor shall guarantee that complete valve opening / closing shall occur in less than 45 s; this time is from the signal opening until complete disc opening.

C. Pressure surge

The Contractor shall guarantee that, under the assumption of free flow through the valve, the maximum transient head generated by the closure is less than the design pressure. This guarantee shall be supported by the technical note mentioned under 'Submittals'.

5.5.2 Tolerances, Penalties, Rejection

I. Leakage

If the guarantee is not met, the Contractor shall modify the valve within 30 days of the test. The Engineer reserves the right to reject a valve should the Contractor fail to meet the guaranty within 45 days of the test.

II. Operating time (valve opening)

This time is guaranteed without tolerances. The Engineer reserves the right to reject the valve should the Contractor fail to meet the guarantee within 30 days following completion of the test.

5.6 MIV-Type and Construction

5.6.1 Scope

Three (03) Spherical type Main Inlet Valves (MIVs) with diameter 1100mm and one Spherical type Main Inlet Valve with diameter of 610 mm shall be supplied along with operating equipment, suitable for use with each of turbine unit as part of Mechanical supply.

5.6.2 Type of Valves

Each turbine unit will be equipped with the corresponding 1100 mm and 610mm in diameter Spherical type main inlet valves which should be closed during longer stand-still periods and in emergency cases against the full water flow. Before the valve is opened, the pressure at upstream and downstream should be equalized via a bypass valve. The bypass valve should be firm flanged to the bypass line connected beyond the outer lines of the disc on upstream and downstream side. The foundation should enable a longitudinal displacement of the valve and should carry no forces in the axial direction

5.6.3 Hydraulic Power Unit for MIV

Separate mono-block compact type hydraulic power unit synchronized with the unit governor is recommended for smooth operation of Main Inlet Valve with hydraulic oil pumping system and pressure accumulators filled with Nitrogen on one side of the piston and oil on the other side.

The MIV hydraulic oil pressure systems are foreseen to operate at about 60 bars and Nitrogen is required to maintain the oil pressure at certain value and keep the pressure available for MIV hydraulic cylinders.

The control shall be possible as per following conditions:

- From the main control board for starting, synchronizing, loading and stopping of the unit.
- From the control room for supervising the function and operating of a unit when connected to the main grid or for the local network.

The MIVs will be provided with two double acting hydraulic cylinders for opening and closing, both operated by the commands from turbine governors but powered with separate accumulator. A counterweight for closing the valve in an emergency situation is recommended. The use of the headwater pressure for valve operation is not recommended due to the sediment content in the water.

Table 17: Key Parameters for Main Inlet Valve

Total No of Valves	**4**
Valve type	Spherical type
Design Head	250 mWC
03 valves with approximate diameter	1100 mm
01 valve with approximate diameter	610 mm
Sealing system	Stainless Steel
Expansion joint location	Down stream
Operating system	Pressurized oil

5.6.4 Thrust Forces

The downstream end of the penstock shall be located within a thrust block that shall provide axial restraint against hydraulic forces. Any residual expansion of the short penstock between the thrust block and the MIVs shall cause the valve to move axially. The main inlet valve foundation and the dismantling joint connect to the turbine inlet shall accommodate this small movement.

5.6.5 Dismantling Joint

A flanged dismantling joint complete with nuts, bolts and jointing shall be provided, located immediately on the turbine side of the valve. The dismantling joint shall permit installation and removal of the valve and, when in position, shall form a positive connection which shall allow sliding movement of the valve relative to the spiral casing.

The dismantling joint shall be provided with lifting lugs to facilitate removal and installation.

5.6.6 Bypass Valve

The main inlet valve shall be provided with bypass valves of a maximum diameter of DN 200. These bypass valves shall be of the needle type. The bypass valve, when opened, shall be such as to ensure substantially balanced pressure across the inlet valve, when the guide vanes and the inlet valve are closed. It shall be sized to obtain full upstream pressure within the spiral casing in a time not exceeding 30 seconds from commencement of bypass opening. The bypass valve(s) shall be complete with a pipe connection(s) to the isolating valve(s) mounted directly on to the penstock. The bypass valve shall be motorized to allow automatic operation by the control system, alternatively the bypass valve can be actuated by the governor hydraulic system. Manual operation provision shall also be provided.

The bypass valve discharge shall be suitably angled so that a cushion of water shall minimize the effects of erosion on surfaces within the spiral casing.

All wearing parts of the bypass valve(s), including those susceptible to erosion or cavitation, shall be renewable, and those in contact with water shall be of stainless steel or bronze.

The bypass shall be formed to avoid cavitation damage to the valve and piping.

The inlet to the maintenance valve shall be rounded; the bypass valve shall have a replaceable stainless-steel needle and a replaceable stainless-steel seat, also protecting the bore in the expansion pipe. The operating / closing time of the bypass shall be adjusted by orifices built into the cylinder wall.

The bypass valve shall have two limit switches to operate in the closed position and one for 100 % opening.

5.6.7 Foundation Plates

The foundation plates shall be provided with the necessary devices to facilitate level and position adjustments of MIVs. The sliding faces shall preferably be equipped with self-lubricating bearing surfaces but if appropriate materials are not available then they shall be provided with grease grooves and greasing nipples.

5.6.8 Valve Body

The valve body shall be cast steel or fabricated in boiler plate quality steel. It shall be rigidly built and adequately ribbed to minimize distortions. The body shall be divided into two parts with connecting flanges downstream to the expansion joint and upstream to the transition pipe.

Cast or welded valve body parts shall be normalized before machining.

The body shall include two Vertical trunnion bearings. The bearing housings shall be integral with the valve body.

The supporting feet shall be designed, machined and surface treated to allow movement of the valve within the elastic extension of the upstream manifold pipe.

The valve body shall be provided with suitable flange connections for the bypass and the dewatering line(s).

5.6.9 Valve Disc / Plug

The valve disc (plug) shall be of cast steel or welded steel construction and shall be designed for throttling and tight shut-off service under the specified operating conditions. The disc/plug shall be guided to ensure stable operation and accurate alignment with the valve seat. Replaceable sealing components shall be provided to ensure reliable upstream and downstream sealing performance.

The valve seat ring and disc seating surfaces shall be of stainless steel or other approved corrosion and erosion resistant material, suitable for operation with silt-laden water. The seating surfaces shall be replaceable or renewable.

Due to transport limitations, the valve body may be manufactured in two or more sections and assembled on site. The design of the disc/plug and internal flow passages shall minimize head losses and turbulence while ensuring smooth flow through the valve.

The valve position shall be clearly indicated on a scale of adequate size. Valve position shall also be transmitted to the control system.

5.6.10 Stem, Guides and Bearings

The valve stem shall be manufactured from forged stainless steel of adequate strength and corrosion resistance. The stem shall be designed to safely transmit the operating forces from the actuator to the valve disc/plug without excessive deformation.

The stem shall operate within suitable guides and bearings to maintain precise alignment of the disc/plug with the seat during operation. The guides and bearing surfaces shall be made of corrosion-resistant material suitable for operation in silt-laden water.

The replaceable guide bushes and bearing components shall support radial and axial loads and shall be designed for easy replacement without dismantling the valve body. The bearings shall be self-lubricated or provided with an appropriate lubrication system. Stem sealing arrangements shall be optimized to ensure reliable sealing and long service life under silt-laden water conditions.

5.6.11 Operating Servomotors

The servomotors shall be adequately sized to ensure reliable opening and closing of the valve under the minimum operating pressure and the most adverse hydraulic conditions.

The piston rods shall be chrome plated or otherwise protected against corrosion and wear.

The servomotors and their mountings, pressure piping and control valves shall be designed to withstand the maximum pressures developed in the servomotor system under the most unfavorable operating conditions.

A manually operated mechanical locking device shall be provided to secure the main inlet valve in the closed position and, where required, in the open position. The locking device shall be designed to withstand the actuator thrust and hydraulic forces acting on the valve. Provision for padlocking in both inserted and withdrawn positions shall be provided.

The initiation of opening of the inlet valve shall be interlocked with the establishment of a pressure in the spiral casing substantially equal to the penstock pressure.

The piping arrangement shall ensure that the servomotor cannot depressurize or lose control under any operating condition.

5.6.12 Operating Mechanism

The operating mechanism shall be hydraulic oil at 160 Bars or less. The pressure oil shall be taken from the MIV pump unit provided for each MIV. Separate Nitrogen accumulators and Nitrogen/oil pressure vessel shall be provided for each main inlet valve operation. The pressure vessel and accumulator design and equipment shall be similar to those for the hydraulic governor pumping set.

The main inlet valves shall normally be automatically opened and shut by the station control system. However, a main inlet valve control panel shall also be provided to allow local control of the valve, bypass, as well as indication of system oil and Nitrogen pressures.

5.6.13 Pressure Balanced Disc / Plug

The valve shall be provided with a pressure-balanced disc (plug) design in order to minimize the operating forces required for opening and closing under high differential pressure conditions.

The pressure balancing arrangement shall ensure that hydraulic forces acting on the disc/plug are reduced to the extent that the valve can be reliably operated by the servomotor under all operating conditions, including maximum penstock pressure and full differential pressure across the valve.

The balancing system shall be designed to prevent instability, vibration or uncontrolled movement of the disc/plug during operation. Any balancing chambers, passages or auxiliary components shall be designed to prevent clogging or malfunction due to silt-laden water.

The design shall ensure that the valve remains stable and controllable throughout the entire operating range.

5.6.14 Emergency Closing and Operating Time

The valve and its operating system shall be designed to permit controlled closing under emergency conditions in order to protect the turbine and associated equipment.

The closing time of the valve shall be adjustable and shall be selected to avoid excessive pressure surges or water hammer in the penstock system. The Contractor shall determine and propose the appropriate closing characteristics based on hydraulic transient analysis of the waterway system.

The operating system shall permit smooth and controlled valve movement throughout the opening and closing cycle.

Provision shall be made for emergency closure of the valve in the event of loss of electrical power, control system failure or turbine emergency shutdown. The design shall ensure reliable closure under all operating conditions.

The Contractor shall submit detailed calculations and operating characteristics of the valve and actuator system for review and approval.

5.6.15 Pressure Oil System and Control Equipment

The pressure oil supply system and the control equipment shall be accommodated in one cabinet located adjacent to each valve. consisting of the following.

1. Oil reservoir tank
2. Two oil pumps
3. One hand operated piston oil pump for emergency operation
4. Control instruments and limit switches
5. Oil pressure accumulator system
6. Connecting tube between valve, pumps and control cabinet
7. Internal electrical wiring of the control panel

5.7 Instrumentation

The valve shall be provided with the limit switches or other devices to provide the control system with information on the valve position.

A pressure gauge with an isolating tap shall be provided on the valve upstream flange.

5.8 Spare Parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for MIVs deemed necessary for trouble free operation of all 04 units for at least 05 years of commercial operation

5.9 Inspection and Testing

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

In general, all the equipment shall be tested in accordance with the requirements of applicable codes, standards and best engineering practices All the electrical equipment shall also be tested in accordance with Testing Clauses of the Technical Provisions of Electrical Equipment.

5.9.1 Particular Inspection and Testing During Manufacture

Over and above the dimensional checks and other routine tests, at least the following tests shall be witnessed by the Engineer, for all the equipment supplied under this part of the Contract:

5.9.2 Inspection and Test of Raw Materials and Mass Produced Equipment

Supply of certificates for:

i. Mechanical testing and chemical analyses on raw materials used in the manufacture of the equipment,

ii. Routine tests on mass produced equipment.

5.9.3 Inspection of Welds

1. Welds

The valve body shall be submitted to ultrasonic inspection to check defects in welds and metal soundness and to dye penetrate inspection on all fillets.

2. Forgings

The trunnions shall be submitted to ultrasonic or magnetic particle inspection.

3. Hydraulic Cylinders

If the cylinder is fabricated with welded elements, the welds shall be submitted to 100% radiographic inspection before the pressure test is carried out.

5.9.3.1 Dimensional Inspection

All the functional dimensions of machined parts shall be measured and reported on sketches or drawings for easy comparison with the theoretical values. This inspection shall extend especially on:

1. Valve body
2. Valve disc
3. Seals
4. Valve actuator.

5.9.4 Shop Erection

The valve shall be assembled in the shop before shipment. Shop assembly shall include the valve itself with the operating levers on the disc trunnions.

5.9.5 Operating Test

After shop erection is completed, the valve shall be subjected to a full closure and opening cycle to check for proper operation of the disc and of the seals.

5.9.6 Hydrostatic Test

The test equipment shall be provided by the Contractor but shall remain his property.

1. Valve body and dismantling coupling

The valve body, dismantling coupling and hydraulic cylinders shall be submitted on completion of machining to a pressure test at 150% of design pressure. The hydrostatic test of the dismantling coupling can be waived provided a 100% ultrasonic inspection of the welds is carried out. The ultrasonic inspection shall be supplemented by radiographic examination when deemed necessary.

2. Valve disc/plug

The sliding disc / plug shall be submitted to a pressure test at 150% of the pressure corresponding to the hydrostatic head as specified hereunder:

a. The test pressure shall be applied between a test head on the upstream side of the valve body and the seals

5.9.7 Leakage Test

On completion of above-mentioned test, the pressure shall be reduced to 100% of the pressure corresponding to the hydrostatic head and the leakage through the valve seal shall be measured.

5.9.8 Testing During Erection and Commissioning

The test procedure shall include but shall not be limited to the following tests:

5.9.9 General

The Contractor shall submit to the Engineer, one month prior to the date of commencement of the tests, six (6) copies of the complete test procedure. The procedure, method and points of measurement shall be approved by the Engineer before any test is carried out. Six (6) copies of the test results shall be furnished to the Engineer for his approval.

The complete Main inlet valves shall be subjected to inspection and testing in accordance with Testing Clause of the Employer requirement volume.

Tests on main inlet valves include dry and final tests as described below:

5.9.10 Dry Test

On completion of erection and before the penstock is filled with water, the Contractor shall check the valves for correct operation on a complete opening and closing cycle. Opening and closing time shall be measured and adjusted.

5.9.11 Final Test

1. Test in dead water

The penstock shall be filled with the main inlet valve and turbine guide vanes closed. On completion of filling, a complete opening and closing cycle shall be carried out. The opening and closing time shall be measured and adjusted if required.

2. Closure under full flow

After the normal load rejection tests are carried out on the generating units, a test of valve closure at 100% of full turbine flow shall be carried out with the turbine guide vanes kept open. Valve operating time shall be measured and adjusted if required.

The pressure surge shall be measured.

The date of commencement of the above said tests shall be subject to agreement with the Engineer.

SECTION 6: POWERHOUSE CRANE

6.1 General

This section covers the particular specifications for design, manufacture, transport, erection, shop and site testing and commissioning of the Electric Overhead Travelling /Bridge crane (EOT) to be furnished complete in accordance with these Specifications.

6.1.1 General Requirements

The powerhouse crane will be used for unloading, assembly, erection and future maintenance of the turbines, generators, inlet valves and other mechanical and electrical equipment. The crane shall travel within the powerhouse serving all four units. It shall be operated from an open cabin hanging under the bridge at the downstream wall. In addition, it shall be possible to operate the cranes from any location in the powerhouse by means of a portable radio control panel. The Contractor shall determine the capacity of the Crane during his basic design which shall be subject to the Engineer's approval. The capacity of the power cranes shall be 110% of the heaviest part.

The bridge crane shall be designed and tested in accordance with the requirements of Federation European deLa Manutention (FEM).

FEM classes for the cranes shall be as follows for appliance as a whole.

Table 18: Class Requirement of Crane

Crane	**Class**
Powerhouse Main Crane	A4

For the Mechanism

Crane	**Main**			**Auxiliary Hoist**
	Hoist	Traverse	Travel	
Main	M4	M4	M4	M6

For the Individual Components

Crane	**Main**	**Auxiliary**
Main	E3	E6

6.2 Extent of Supply

The supply under this Chapter shall include but not be limited to:

6.2.1 Powerhouse Crane, Auxiliary Hoists

- 1 (one) powerhouse bridge crane (EOT) with lifting capacity of the main hoist shall be 45 tons or 110% of the heaviest assembly to be handled, whichever is the highest, with appropriate factor of safety; also determining the lifting height.
- 1 (one) 10 tons auxiliary hoists traveling under one of the main girders.
- 1 (one) complete set of crane rails for the crane.
- 1 (one) open operator's cabin with access ladders, along with a radio operating unit (wireless operating console)
- 1 (one) set of electrical control equipment.
- All necessary anchors, bolts, screws, framing, pipes, handrails, oil, grease, temporary and permanent devices for alignment and fixing.
- All components, accessories, items and equipment not specifically mentioned above, but necessary for the safe and proper manufacture, transportation, testing, commissioning operation and maintenance of the supply.

6.2.2 Spare Parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for Powerhouse crane deemed necessary for trouble free operation of all 04 units for at least 05 years of commercial operation

6.2.3 Tools and Appliances

a. 1 (one) set of lifting tackles needed for the erection of crane.

b. 1 (one) set of all other special tools, required for the operation, repair and maintenance of the supply.

c. 1 (one) set of hydraulic jacks for changing the crane wheels.

6.3 Technical Requirements

The design and principles for the design shall be in accordance with the General Mechanical Design Requirements and the requirements given in this section. Reference is also made to General Mechanical Design Requirements regarding seismic loads.

6.3.1 General Requirement

The crane shall be of the overhead travelling type with hook, rails for the runway, and each shall be equipped with one hoist with gear and one auxiliary hoist travelling under one of the girders. The crane will run on a set of rails extending throughout the length of the powerhouse. The crane shall be provided with a cabin of simple, open design for one person, and shall be equipped with chair, controllers and electric socket for 230 V., lighting and fan, and a foot operated horn/bell.

6.3.2 Space Requirements

In general the hook approach distances from the lateral and end walls as well as the space requirements above the crane beams should be kept as small as possible, to obtain maximum working area for the crane.

The Bidder shall submit information about space requirements, hook approaches, lifting heights, etc.,.

6.3.3 Adjustments

If, for some reason, the length or width of the powerhouse will be adjusted during final design, the length of the crane runways and crane girders will be adjusted correspondingly. No price adjustments will be made for changes of crane span or runway length.

6.3.4 Crane Girders

The crane girders shall be strong, welded steel construction. Standard size girder rails and trolley stops shall be provided on each girder. Bumpers shall be provided on the trolley. The crane girder shall be provided with the necessary walkways with hard rails, platforms etc., to permit easy access for lubrications, inspection and maintenance. Access to the walkway and the powerhouse crane operator's cabin shall be allowed by ladders as shown on Drawings.

6.3.5 Crane Drive

The crane traveling drives shall be variable frequency drive type, and the number of driving wheels shall be in accordance with FEM Standards. The driving and control mechanisms shall be designed and constructed so that the crane travel will be steady and free from undue noise, vibration or rocking in any parts of the structure at rated speed and load. An electrical release, spring set, friction shoe brake with a capacity of at least 150% of the full load torque of the crane drive motor shall be provided.

The brake shall operate immediately after the power of the driver motor is cut off and shall be equally effective in both directions of travel.

6.3.6 Trolley Frame

The trolley frame shall be of rigid welded steel construction and shall provide equal load on all wheels without undue deflection. Bumpers shall be placed at the ends of the trolley frame. The frame shall be equipped with supports allowing maximum sag of 20 mm in the event of any one wheel assembly breaking.

6.3.7 Trolley Drive

The trolley drive shall be designed so that the travel under all operating conditions will be steady and free from undue noise, vibration or rocking in any part. At least one wheel on each rail shall be connected to the trolley drive. An electrically released, spring-set, friction shoe type brake, having the same characteristics as stipulated for the crane drive, shall be provided.

6.3.8 Hoist and Gear

The hoist and gear shall be mounted on the trolley frame and be driven by suitable electric motors to obtain the required hoisting speeds. Drums and sheaves shall be designed according to approved standards. The reduction gear shall be fitted with ball/roller bearings, running in oil baths within an oil and dust-tight gearbox, equipped with level sight glasses.

All rotating and moving parts shall be protected by sheet metal guards or other convenient protection devices. Limit switches shall be provided to prevent the hook traveling beyond the predetermined highest and lowest positions.

The hoist shall be equipped with an electrical release, spring-set friction shoe type holding brake with a capacity not less than 150% of the full load torque of the motor.

The load blocks shall be designed to protect the hoisting ropes and prevent them from leaving the sheaves under operating conditions.

6.3.9 Auxiliary Hoists

The auxiliary hoist shall be mounted under a traveling carriage driven by a suitable electric motor and gears to obtain the required speeds. Drums and sheaves shall be designed according to approved standards. The reduction gear shall be fitted with ball/roller bearings, running in oil baths within an oil and dust-tight gearbox.

All rotating and moving parts shall be suitably protected by sheet metal guards or other convenient protection devices Limit switches shall be provided to prevent the hook and carriage traveling beyond the predetermined limits of position. The carriage shall be provided with suitable end bumpers.

The hoist shall be equipped with an electrical release, spring-set friction type holding brake with a capacity not less than 150% of the full load torque of the motor.

The load block shall be designed to protect the hoisting ropes and prevent them from leaving the sheaves under operating conditions.

6.3.10 Crane Tracks

The crane tracks shall be mounted on the concrete beams along the powerhouse.

The columns will be provided with brackets for support and attachment of the girders. Bolts and accessories for fixing the girders to the columns as well as alignment and erection of the girders is part of this Contract.

The complete track with rails, rail fixtures, backplates, end buffers, bolts and nuts shall be included in the supply. The design shall allow for future adjustment of the lateral position of each rail by using clamps for fixing the rails to the concrete beam as shown on drawings or by other approved means.

6.3.11 Lighting and Power Points

Four mercury vapour lamps complete with reflectors shall be furnished for crane. These shall be conveniently located and be adjusted from the gangway. The lamp capacity shall be 400 Watts. A power supply with three sockets shall be provided in convenient places along the crane gangway for light, hand tools etc.

6.3.12 Hooks and Wires Ropes

The hooks shall be made of forged annealed alloy or carbon steel in accordance with the General Mechanical Design Requirements. The hooks shall swivel freely on grease lubricated ball or roller bearings. The bearings shall be totally enclosed, dust-tight and constructed to prevent grease leakage.

The wire ropes shall have sufficient length to provide three turns of each end on the drums with the hook at the lowest position. The wire ropes shall be galvanized, permanently lubricated and of heavy duty, fiber core, twist-free design.

The main hook of the powerhouse crane shall have a perfect, vertical lift.

6.3.13 Motors

The motors shall be of the slip-ring or squirrel cage type with sufficiently smooth start characteristics and with sufficient capacity to handle the maximum loads They shall be rated for at least 40% relative duty factor and shall have class B or better insulation. Motors of relatively low speed will be preferred. The motor protection shall correspond to IP 54, IEC 144.

The bidder shall offer thyristor based variable speed motors for crane and trolley drive and/or hoisting machinery.

6.3.14 Power Supply and Electrical Wiring

The power supply is 400 V AC, 50 Hz. Connection boxes will be situated next to the crane rail. For the powerhouse this connection box will be located at the top floor of the service bay.

Power shall be supplied to the trolleys and to the auxiliary hoists and the cable hall monorail crane through flexible suspended cables.

All wiring shall be furnished and shall be installed in galvanized steel conduits.

Separate conduit systems shall be provided for power and control circuits. All wiring, unless otherwise specified, shall be of the stranded conductor type and shall be brought to terminal blocks to facilitate external power connection. All wires shall be tagged or marked for permanent identification to facilitate erection and maintenance.

6.3.15 Control Equipment

All functions of the main and auxiliary crane hoists of the powerhouse crane shall be controlled from the operator’s cabin specified above.

Additionally, the crane shall have a radio control panel for control from the machine hall.

The electrical equipment and installation shall be complete and comprise all control and protective devices, particularly:

a. Limit switches controlling the end travel of hoist hooks.

b. Limit switches controlling the end travel of traveling carriages.

c. Limit switches controlling the end travel of cranes and trolleys.

d. Load switches that cut the power supply in the event of overloading the hoists.

Two emergency stop switches, each stopping both powerhouse crane, shall be provided at the machine hall floor, near the generating units. The switches and necessary cabling is part of this Contract.

All electrical equipment supplied shall be in accordance with the standards and requirements specified in General Electrical Design Requirements.

The control cubicle for the crane/hoist shall include all necessary fuses, circuit breakers, relays, switches, etc., as required for the proper and safe operation of the equipment. The supply shall also include all necessary limit switches, motor protection devices, cables, cable racks, etc.

6.4 Erection

All transport and work for the positioning, alignment, erection, testing and commissioning shall be part of the supply. The Contractor shall furnish all necessary tools and instruments.

6.5 Tests

The equipment shall be subject to the relevant tests specified in the General Mechanical Design Requirements, concerning materials, manufacture and function both in the workshop and at site. Further to the test specified above the following shall apply:

6.5.1 Factory Tests

a. Electrical tests
b. Functional tests

6.5.2 Tests at Site

a. Electrical tests
b. Functional tests
c. Checking of the hook approach distances
d. Brake tests
e. Static and Dynamic Load tests on Crane at 125% of the rated lifting capacity.
f. Maximum load and overload test

The Contractor shall provide the loads as required for the load tests of the cranes. The Contractor shall provide the cages/slings required for lifting the loads.

Maximum load shall be observed first time this occurs by authorized persons from the Contractor and the Engineer. Maximum deflection shall be observed at the same time. Hoist brakes shall be checked for any chip of.

SECTION 7: COOLING WATER SYSTEM

7.1 Scope

This section specifies the requirements for the design, manufacture, works testing, erection, Site testing and setting to work of the cooling water system for the turbine and generator units.

7.2 Description

Closed circuit cooling water systems shall be adopted. One complete system shall be provided for each generating unit.

Closed circuit cooling water systems comprise a primary cooling water circuit and a secondary cooling water circuit.

Each cooling water system must provide cooling water to the following equipment:

- generator air coolers
- generator bearing coolers
- turbine bearing coolers
- governor oil coolers (if needed)
- unit excitation rectifier
- unit excitation transformer
- unit transformer oil coolers

Usually cooling water is a once through system drawing water from the penstock or tailrace channel and discharging it into the tailrace channel. It is known however that sediment in the Jagran River may be higher and during the flood season could become very high. Therefore there is a danger that small particles can become trapped in pipe work, filters and tubes of heat exchangers and associated fittings blocking the water ways and reducing the cooling efficiency of the system.

Based on above facts the Contractor shall submit his own design to minimize the chances of any blockages with sedimentation through efficient filtration approach adopted for enhancing the service life of the equipment to the optimum level.

A description of each circuit is outlined below

7.2.1 Primary Cooling Water Circuit

Primary Cooling Water circuit shall be an open loop circuit that shall draw water from tail race and drain it back to the tail race after heat transfer from closed loop (Secondary cooling water circuit) through heat exchangers. Suitable sized auto strainers and hydro cyclones shall be provided in the open loop cooling circuit before heat exchangers to diminish the blockage of tubes. To minimize the

length of pipe work associated with the primary cooling water circuit, the primary cooling water pumps shall be located on the Main inlet Valve Floor or other suitable place proposed by the Contractor and accepted by the Project Manager. Duplicate (standby) pumps and heat exchangers shall be provided to enhance reliability.

To facilitate cleaning, the heat exchangers shall include removable or hinged headers so the internal tubes of a heat exchanger can be 'bared' out. Bends and fittings shall be minimized so as to minimize the potential clogging.

7.2.2 Secondary Cooling Water Circuit

Each secondary cooling water circuit shall include two pumps (duty and standby). The pumps shall be located on the Turbine Floor and after the water passes through the duty heat exchanger it shall be reticulated to the equipment listed above.

Internal corrosion of pipe work and equipment in the secondary cooling water circuit shall be inhibited by chemical dosing. Make-up water for the circuit shall be drawn from a header tank located on a suitable height where gravity flow can be utilised. This tank shall be replenished from the potable water tank also located on the top of the offices block Building. The make-up water tank shall be periodically dosed with requisite chemicals to inhibit corrosion.

7.2.3 Shaft Seal Cooling Water

Cooling water must also be reticulated to each turbine shaft seal. This must be a once through water system and hence water cannot be taken from the secondary cooling water circuit. It is recommended that this water be taken from Service Water Network; accordingly to ensure this water is free of debris and excessive sediment. The cooling water for the shaft seal shall pass through twin auto-operated strainers and duplicate hydro-cyclone separators before being injected into the seal.

7.3 Detailed Requirements for Cooling Water Services

7.3.1 Duplex Basket Type Strainers

The duplex strainers in the system shall with-held larger organic particles and other matters. They are not intended to with-hold suspended sediments and shall be of a design allowing the large amount of sediments to pass without interrupting the operation.

The baskets shall be in stainless steel, and for baskets in the main cooling circuit located at appropriate level, mechanically designed for differential pressure not less than 2 bars.

The switching valve shall enable operation of both filters in parallel, as well as individual operation. The switching over and replacement of filter baskets for cleaning shall be easily done without the use of wrenches or other tools.

A bottom drain may, if required, be used to prevent larger accumulation of sediments.

7.3.2 Automatic Filters

Each filter shall be of the automatic self-cleaning and purging motorized or air pressure actuated type. If air pressure actuated, it shall have a separate air receiver sized for at least 5 cleaning cycles and be suitable for operation with the powerhouse service air supply. The filters shall be capable of removing particles of dia. 0.7 mm and above from the raw water. The process of cleaning and purging shall not interrupt the raw water supply and not give rise to pressure fluctuations greater than ± 5% downstream. A differential pressure relay and pressure gauge shall be provided across the strainer to give visual indication of blockage of the filter, initiate automatic cleaning and purging and, on abnormal high pressure differential, initiate an alarm and switchover to the standby system supply. Equipment shall also be provided so that the filters are cleaned and purged on a time cycle irrespective of the change in differential, pressure. This time cycle shall be easily variable between wide limits and capable of being adjusted to suit seasonal requirements.

Each filter shall be of steel construction designed to the ASME Boiler and Pressure Vessel Code for the maximum static head. The filter elements and internal support structure shall be of stainless steel.

Debris from the filter shall be automatically discharged to the tailrace during each cleaning cycle. The discharge pipe shall be stainless steel and equipped with a non-return valve. Sharp bends or other traps which would be prone to blockage shall be avoided.

7.3.3 Expansion Joints

Two stainless steel bellows type expansion joints shall be provided in each of the raw water and strained water headers at the two isolating valves.

7.3.4 Motor Operated Valves

The motor operated valves shall be gate or ball type and shall be fitted both with hand operating gear and motor. They shall be complete in all respects including the motor, reversing starter and isolator and the necessary controls for automatically stopping the motor when the valve has reached the "full open" or "full close" position without slamming. The mechanism shall be designed so that in the event of a valve jamming, the motor will not be overloaded.

The operation of closing or opening the valves shall be controlled by means of three pushbuttons labelled respectively "Open", "Close" "Stop". The control shall be so arranged that the motor can be stopped with the valve in any position by means of the "Stop" pushbutton and after having been stopped can be re-started in either direction by the "Open" or "Close" pushbutton. The pushbuttons shall be mounted together on or adjacent to the valve in such a position that the valve indicator is readily visible to the operator. If for any reason the valve indicator is not readily visible from the operating position, a further indicator of approved type shall be provided and mounted near the control pushbuttons. In addition to the local control at the valves, control equipment shall be arranged so that the valve operation is initiated remotely, as part of an automatic control sequence. Switchover to the standby system shall also be provided by the Contractor. Electrical contacts shall be provided for inclusion in automatic control and indication circuits as indicated in the Control and Indication Schedules.

The valve motor and starter may be a composite unit fitted to the valve, the isolator being separately mounted. Alternatively, the motor only may be fitted to the valve, the starter and isolator being separately mounted. Valves which are pedestal operated shall have the motor mounted at the

pedestal. All electrical equipment shall be mounted in such positions relative to the valve that there is no possibility of water from the valve joints or glands reaching the equipment.

The hand operating gear shall be so arranged that it must be disengaged before the operating motor can be energized. The motor operated valves shall be provided with hand-wheels having plain polished rims.

All motor operated valves and their associated control equipment shall be suitable for operation by three phase ac supply.

7.3.5 Orifice Plates

Orifice plates used for balancing the flow to each element shall be made of stainless steel and held between flanges for ease of adjustment.

7.3.6 Filters for Shaft Gland Supply

The fine filters for the shaft gland supply shall be of the Duplex type with provision for manual changeover. A differential pressure gauge and pressure-switch shall be provided for indication of pressure drop and high differential alarm.

7.3.7 Standby Cooling Water Pump

The operating range of cooling water pump shall also cover the required cooling water demand in the case only one turbine is in operation. The delivery head of the pump shall be designed to allow for a safety margin to all cooling water consumers.

The pump shall be standard units of a reputable manufacturer and shall conform to the requirements of the standards as prescribed in this Specification. Pump performance curves shall be submitted during basic design.

The pump shall have a Vertically split casing and shall be of centrifugal type with a fully balanced impeller and at least two bearings. The driving motor shall be mounted on the extension of the pump bed plate and shall drive the pumps directly through flexible coupling, provided with removable coupling guard. The driving motor is component of the supply.

The casing and other cast parts of the pump shall be of ductile cast iron with both, suction and discharge connections flanged. The supporting frame shall provide suitable support for the casing and bearings and shall be designed to allow easy access to the shaft seal.

Shaft seal shall be of multiple packing ring type, water sealed from the pump discharge casing.

Impeller and shaft as well as shaft sleeves shall be of stainless steel. Bearings shall be of oil or grease lubricated ball type.

7.4 Spare Parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for cooling system deemed necessary for trouble free operation of all 04 units for at least 05 years of commercial operation.

7.5 Testing & Commissioning.

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

The equipment shall be subject to relevant tests as specified under.

7.5.1 Inspection and Testing During Manufacture

Over and above the dimensional checks and other routine tests, at least the following tests will be witnessed by the Engineer, for all the equipment supplied under this part of the Contract:

7.5.2 Pressure Tests

All equipment shall be pressure tested in the works to 1.5 time maximum design pressure for at least thirty minutes.

7.5.3 Pumps

The full range of performance of the pump shall be demonstrated in the works to the Engineer and performance curves submitted for approval.

7.5.4 Automatic Strainers

Each automatic strainer shall be completely assembled in the works and its operation demonstrated on satisfactory completion of the pressure test, which shall be conducted at 1.5 time maximum design pressure.

7.5.5 Stage Testing During Erection and Commissioning

The test procedure shall include but shall not be limited to the following tests to be conducted by the Contractor.

a) General

The complete cooling water system shall be subject to inspection and testing in accordance with approved Specifications.

Tests on cooling water system shall include Preliminary tests, Pre-start and Commissioning test, as described here under:

b) Preliminary tests

All items of equipment shall be tested individually to determine conformance to specified requirements, for vibration, electrical data, water flow rates, pressures and capacities.

c) Piping system

Pressure tests shall be applied to piping only before connection to equipment and appliances. In no case shall piping, equipment or appliances be subjected to a pressure exceeding their rating. Tests shall be performed in the presence of and to the satisfaction of the Engineer. The prescribed pressure shall be maintained for thirty (30) minutes.

d) Equipment

All the equipment shall be inspected for proper operation, noise and vibration. Tests shall be carried out with readings of pressure, rpm, ampere, voltage, flow rates, etc to determine the specified data.

e) Electrical equipment

All electrical equipment shall be cleaned and adjusted on site before supply of power. The following tests shall be carried out:

1. Wire and cable continuity tests
2. Insulation resistance tests, phase to phase and phase to earth, on all circuits and equipment, using 500 V megger. The megger reading shall not be less than one megohm.
3. Earth resistance between metallic conduit systems and earth shall not exceed half (0.5) ohm.
4. Phasing out and phase rotation tests.
5. Operating tests on all starters, circuit-breakers, etc.

7.5.6 Commissioning Tests

When the system is complete and ready for operation as specified, the Contractor shall carry out Commissioning tests.

Equipment tests as stated under Preliminary tests shall be repeated during commissioning tests for the whole system.

SECTION 8: DRAINAGE AND DEWATERING SYSTEMS

8.1 Scope

This section describes the requirements for the design, manufacture, works testing, erection, Site testing and setting to work of the powerhouse drainage and dewatering systems. The scope of supply is shown on the Specification Drawings and shall generally be as follows:

8.1.1 For Drainage System

Two submersible centrifugal-type drainage pumps complete with mountings, discharge pipework, electrical connections and controls.

Isolation valves with shaft extensions and operating headstocks, non-return valves, pipework within the pits and discharge pipe with flap valve up to the tailrace.

Float control system for the drainage and dewatering pumps in drainage and dewatering sump together with a float operated alarm system.

All supporting steel work for the pumps and motors, valve headstocks, access ladders, chequered plates at appropriate level with supporting steelwork. Pipe and valve supports required to install and subsequently inspect and maintain the equipment specified in this Section.

8.1.2 For Dewatering System

Two vertically mounted volute-type centrifugal dewatering pumps complete with shafts, motors, electrical connections and controls. Capacity of the pumps shall be such that it must be greater than the largest possible discharge required in case of rupture of any penstock or draft tube connection.

Isolation valves with shaft extensions and operating headstocks, one for each unit in valve pits.

All interconnecting pipework from the draft tubes to manifold in the drainage and dewatering sumps and interconnecting pipework and valve between the sumps.

Valves with shaft extensions and operating headstocks, non-return valves, strainers and pipework within the sumps and discharge pipe with flap valve into the tailrace.

8.2 Drainage Scheme

The powerhouse shall have one common drainage and dewatering sump. Sump shall be equipped with one submersible centrifugal type drainage pump and one volute type centrifugal dewatering pumps. The discharge pipes from the sump shall be terminated at a suitable elevation above maximum flood level into the tailrace.

The dewatering pumps shall be piped and their controls arranged for it to serve as emergency drainage pumps when not being used for dewatering duty.

8.2.1 Drainage Pump

The submersible drainage pumps shall be the centrifugal-type. The pump shall be electrically driven, with its suction positioned in a 2 meter deep pit below the sump floor. The pump shall be connected to a delivery pipe (The Contractor shall calculate the size of the pipes during basic design stage which shall be subject to the approval of the Engineer) with non-return and isolation valves. The pump shall be capable of handling impurities. It shall be arranged for mounting in the

sump with a guide bar system for maintenance purposes. The pump shall have stainless steel impellers and suction strainers.

8.2.2 Drainage Pump Motor

The motor for the submersible drainage pump shall be arranged for ease of maintenance of both motors and bearings. Motor shall have the degree of protection IP 68. The thrust bearing shall be arranged such as to avoid overheating of the bearing resulting from silt accumulation in the sump.

8.2.3 Drainage Pump Starters

The drainage pump starter shall be located in a drainage pump starter and control panel located at the machine hall which shall be supplied with ac supply.

Running hour meters shall be supplied and mounted on the starter panel.

8.2.4 Sump and Pump Control Equipment

The drainage pump shall respond to water level control equipment of float type. The same water level equipment shall start and stop the dewatering pump at a higher water level when on emergency drainage duty and also give a first stage high level alarm. An independent float switch shall be provided to give a second stage high level alarm.

There shall be a water level control system for the sump.

Facilities for manual operation of all pumps shall be provided.

Manual operation of drainage pump shall be possible to just below the sump floor level such as to provide a dry floor area for maintenance. Each drainage and dewatering pump shall have a flow switch which shall stop the pump in the event of no flow (dry pump condition).

8.3 Dewatering Scheme

Dewatering of the units will be required during scheduled or unforeseen maintenance of any of the unit and in case of leakages from valve on bypass line connecting upstream of inlet valve to draft tube.

Each spiral case and draft tube shall be connected to a dewatering suction header by means of an isolating valve. The centrifugal volute type pump shall discharge through discharge pipes (The Contractor shall calculate the size of the pipes during basic design stage which shall be subject to the approval of the Engineer) to tailrace above maximum flood level.

The suction bus shall run between all the units and with isolating valves at the spiral case and draft tube dewatering outlets in valve pits and at the dewatering pump suction and discharge. Non-return valves shall be provided at the discharge end of the pump.

8.3.1 Dewatering Pump

The pumps shall be vertically mounted volute-type centrifugal (The Contractor shall calculate the ratings of the pumps during basic design stage which shall be subject to the approval of the Engineer). Pumps shall have stainless steel impellers capable of handling impurities. Maintenance facilities shall be as for drainage pumps.

8.3.2 Dewatering Pump Motor

Pump motor shall be supplied. It shall be vertically mounted.

8.3.3 Dewatering Pump Starters

The dewatering pumps starters shall be included in a dewatering pump starter panel located at appropriate level. This will be supplied ac electrical supply. For dewatering duty the pump shall be manually operated. For emergency drainage duty it shall automatically respond to the drainage pit level switches. The pump controls shall be arranged such that either pump can be selected for lead or backup operation.

8.4 Layout of Drainage and Dewatering Sump

The Contractor shall submit to the Engineer a detailed layout of all the equipment in the drainage and dewatering sumps.

Open mesh flooring shall be provided at intermediate levels to provide access for maintenance purposes. Opening with a hatch cover shall be provided at appropriate level and all beams, channels, brackets, etc., required for these floors and the pumping equipment shall be included in the supply.

8.5 Spare Parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for drainage and dewatering system deemed necessary for trouble free operation of all 04 units for at least 05 years of commercial operation.

8.6 Erection

8.6.1 General

The installation of drainage and dewatering system equipment including its electrical installations shall comply with applicable standards, manufacturers' instructions and recommendations.

8.6.2 Welded Construction

Welded construction shall be provided for installation of drainage and dewatering system wherever bolted connections are not required for subsequent removal or for normal operation, adjustment, inspection, maintenance, or replacement of worn parts. Welding workmanship and qualification of welding operators shall comply with American Welding Society (AWS) standards or approved equivalent.

8.6.3 Sound Isolation

Rotating and vibrating equipment and components shall be mounted on vibration - absorption mounts designed to effectively prevent the transmission of vibrations of the structure, and thereby eliminate the sources of structure - borne noise.

8.6.4 Lubrication

Operating parts of the system shall be lubricated as per manufacturer's recommendation.

8.6.5 Ease of Maintenance

Proper co-ordination of installation of pumps, valves and piping shall be such that these can be maintained with easiness and maintenance staff can move freely.

8.6.6 Painting, Retouching & Re-Finishing

After completion of installation and testing to the satisfaction of the Engineer, the Contractor shall carryout all finishing, retouching and refinishing operation on the entire equipment accessories and installation matching the original finish in an approved way. All auxiliary works carried out by the Contractor as the finished installation shall also be painted in the approved standard

8.7 Tests

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

8.7.1 Particular Inspection and Testing During Manufacture

Over and above the dimensional checks and other routine tests required as per Special Provisions, at least the following tests will be witnessed by the Engineer, for all the equipment supplied under this part of the Contract:

8.7.2 Pressure Tests

All equipment shall be pressure tested in the works to 16 bars for at least thirty minutes.

8.7.3 Drainage and Dewatering System Pumps

The full range of performance of the drainage and dewatering system pumps shall be demonstrated in the works to the Engineer and performance curves submitted for approval.

8.7.4 Stage Testing During Erection and Commissioning

The test procedure shall include but shall not be limited to the following tests to be conducted by the Contractor.

a) General

The complete drainage and dewatering system shall be subject to inspection and testing in accordance with applicable codes and standards.

Tests on drainage and dewatering system shall include Preliminary tests, Pre start and Commissioning test, as described here under:

b) Preliminary tests

All items of equipment will be tested individually to determine conformance to specified requirements, for vibration, electrical data, water flow rates, pressures and capacities.

c) Piping system

Pressure tests will be applied to piping only before connection to equipment and appliances. In no case will piping, equipment or appliances be subjected to a pressure exceeding their rating. Tests will be performed in the presence of and to the satisfaction of the Engineer. The prescribed pressure will be maintained for thirty (30) minutes.

d) Equipment

All the equipment will be inspected for proper operation, noise and vibration. Tests will be carried out with readings of pressure, rpm, ampere, voltage, flow rates, etc to determine the specified data.

e) Electrical equipment

All electrical equipment will be cleaned and adjusted on site before supply of power. The following tests will be carried out:

1. Wire and cable continuity tests
2. Insulation resistance tests, phase to phase and phase to earth, on all circuits and equipment, using 500 V megger. The megger reading shall not be less than one megohm.
3. Resistance from metallic conduit systems to earth shall not exceed 0.5 ohms.
4. Phasing out and phase rotation tests.
5. Operating tests on all starters, circuit-breakers, etc.

8.7.5 Commissioning Tests

When the system is complete and ready for operation as specified, the Contractor will carry out Commissioning tests.

Equipment tests as stated under Preliminary tests will be repeated during commissioning tests for the whole system.

SECTION 9: COMPRESSED AIR SYSTEM

9.1 Scope

This section specifies the requirements for the design, manufacture, works testing, packing ready for transport, installation and testing & commissioning of the compressed air system for station general services.

9.2 Description of Compressed Air System

The compressed air plant shall be located in one room at Turbine floor

A low pressure compressed air system shall be provided in the powerhouse for air supply to the following:

- Power tools of workshop and hand tools (grinders operation during runner cavitation area)
- Generator Brakes
- Station Air Taps on Each Floor as well as on Transformer Deck and Draft Tube Deck

9.3 Detailed Requirements for Compressed Air System

9.3.1 Compressors

The two air compressors shall be electric motor driven, water seal rotary type, each to deliver 100 cubic meters per hour of free air. The air compressors shall have provision of automatic start/stop control, and shall deliver air at a pressure of 10bars when installed at an altitude of 2375 m above sea level. The compressors shall be fitted with automatic unloading equipment such that full speed of the compressor is attained before air delivery commences.

The air inlet of each compressor shall be provided with a suction silencer and a cleanable air filter. Provision shall be made for indication when the filter is clogged. The total unit shall be enclosed. Each compressor and motor shall be mounted on a common bedplate in the enclosure.

The power supply for drive motors shall be three-phase, 400 V ac, 50 Hz. The drive motors shall generally comply with standard Electrical Requirements.

The quality of the compressed air delivered shall be according to the following minimum requirements:

- Maximum particle size 5 microns
- Maximum particle concentration 5 mg/m3
- Pressure dew point maximum 2°C
- Maximum oil content 1.0 mg/m3

The design, construction and installation of the compressors shall comply with ISO 5388.

9.3.2 Receivers

Each compressor shall be provided with its own air receiver of suitable capacity with supports. All the receivers shall be cylindrical and installed vertically adjacent to their respective air compressors.

Separate Air receiver shall be provided with each Unit for Generator Brakes.

The pressure air receivers shall be designed and manufactured to ASME Boiler and Pressure Vessel Code, Section VIII.

The receivers shall be supported at sufficient height for installation of automatic moisture traps and drain piping supplied by the Contractor. They shall be complete with safety valves, pressure switches/pressure gauges with low pressure alarm contacts and inspection manhole with cover.

9.3.3 Control Equipment

The station service air compressors shall be controlled from a control, indicating and alarm panel located in their respective compressor areas. Compressors shall be arranged for automatic start/stop operation in response to pressure switches. A local selector switch shall permit selection of either "automatic" or "manual" control. Motor starters, control switches and push-buttons shall be in accordance with stadard Electrical Requirements. 1 compressor shall be selected "Lead" or at the control panel standby. When operating on "automatic control" pressure switches shall start the lead compressor at 9 bars and stop it at 10 bars. The standby air compressor shall start at 7 bars and stop at 10 bars. Before stopping, the compressors shall unload and maintain this condition for five minutes (adjustable), loading again should a demand require it. The compressor shall start unloaded and then load when full speed is reached. The lead and standby compressors shall be interchangeable and selected at the local panel. The local panel shall be complete with pressure gauges, normal start/stop buttons and a remote alarm to the station DCS system.

The safety valves on air receivers shall be set to operate at 11.5 bars and reset at 11.0 bars.

9.3.4 Motors Control Panels, Motors and Starters

The motor control panels supplied by the Contractor shall have all the necessary contactors for starting the motors and be complete with motor protection. Motor duty switching shall be integral within the Contractor’s supply. Local panels as indicated herein shall be supplied complete with terminal strips for connection by others as indicated in the attached Control and Indication Schedule. All electrical equipment supplied shall be in accordance with the relevant clauses of General Electrical Requirements of these Specifications.

Motors and starters shall conform to the General Electrical Requirements of these Specifications. Full load operation of the motor shall not, under any circumstances, exceed its nameplate kW rating.

9.4 Spare Parts

In addition to the spareparts lists provided in the relevant price schedules, the contractor may propose a set of spare parts for compressed air system deemed necessary for trouble free operation of all 04 units for at least 05 years of commercial operation.

9.5 General Requirements

9.5.1 Pipework and Valves

Air velocities

The velocity of air in the compressed air pipework shall not exceed 15 meters per second under all operating conditions. The internal diameter of the branches for hose coupling shall not be less than 20 mm.

Pipework

The pipework, pipe supports, and anchors, flanges and jointing material shall comply with General Mechanical Design Requirements.

All piping connections to and from the compressors shall be made via flexible couplings.

Piping shall be routed by making maximum use of the plant, steel and concrete structure for hanging and support. Overhead piping shall have a minimum vertical clearance of 2.3 m above walkways and working areas. No pipework shall be embedded in concrete.

Integral pipework layout and compressor connections shall avoid straight pipes of such lengths that the column of air inside the pipe would vibrate at the same frequency as the pulsation, if any, from the air compressors.

Valves

The arrangement of all valves shall comply with General Mechanical Requirements.

9.5.2 Lubricators

Lubricators of proven design shall be provided at all hose line terminals in the workshop, erection bay, turbine floor and draft tube access gallery.

9.5.3 Air Temperatures

Air temperatures in the delivery lines up to the air receivers shall not exceed 45°C under extreme working conditions.

9.6 Erection

9.6.1 General

The installation of compressed air system equipment including its electrical installations shall comply with applicable standards, manufacturers' instructions and recommendations.

The scope of installation and civil works shall include the following:

- Providing and/or cutting all necessary holes, chases and openings and making good after installation of equipment.
- Supplying and fixing all supports, ladders, platforms etc. necessary for the installation of the machinery, pipes, etc.
- Furnishing all necessary cement and/or concrete for 'grouting-in' brackets, bolts, etc.
- Providing and fixing suitable scaffolding and protection of work in progress.

9.6.2 Welded Construction

Welded construction shall be provided for installation of compressed air system wherever bolted connections are not required for subsequent removal or for normal operation, adjustment, inspection, maintenance, or replacement of worn parts. Welding workmanship and qualification of welding operators shall comply with American Welding Society (AWS) standards or approved equivalent.

1. Sound Isolation

   Rotating and vibrating equipment and components shall be mounted on vibration - absorption mounts designed to effectively prevent the transmission of vibrations of the structure, and thereby eliminate the sources of structure - borne noise.

2. Lubrication

   Operating parts of the system shall be lubricated as per manufacturer's recommendation.

3. Ease of maintenance

   Proper co-ordination of installation of compressors, valves and piping shall be such that these can be maintained with easiness and maintenance staff can move freely.

9.7 Control, Indications Alarm and Trip Schedules

For control, indications, alarm and trip schedules refer to standard Electrical Requirements.

9.8 Rating Plates and Nameplates

Compressor rating plates shall state rated capacity in cubic meters of free air per minute (m3/h) or litters per sec. (l/s), rated speed in revolution per minute (rev/min), and rated pressure in bars.

All the compressors shall have a plate installed in a visible place, conveying following message in English and Urdu languages:

DANGER

THIS COMPRESSOR IS REMOTELY CONTROLLED

AND MAY START WITHOUT WARNING.

These warning plates shall be written with thick black letters on a yellow background.

9.9 Painting

All the surfaces requiring paint treatment shall be painted in accordance with the General Mechanical Requirements.

9.10 Inspection and Testing

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

In general, all the equipment shall be tested in accordance with the requirements of applicable codes and standards. All the electrical equipment shall also be tested in accordance with applicable codes and standards. for Electrical Equipment.

9.11 Particular Inspection and Testing During Manufacture

Over and above the dimensional checks and other routine tests at least the following tests shall be witnessed by the Engineer, for all the equipment supplied under this part of the Contract:

9.11.1 Compressed Air System

a. Air compressors

Each compressor shall be fully assembled in the works along with the associated control cabinet and subjected to performance tests and calibration. All devices provided shall be checked for range of adjustment and then adjusted so that the minimum of further adjustment shall be required after installation at Site

b. Air receivers

Inspection of manufacture and final testing of the pressure receivers shall comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII.

c. Electrical equipment

Routine tests shall be carried out on all motors and type tests on one of each type.

9.12 Testing During Erection and Commissioning

The test procedure shall include but shall not be limited to the following tests:

9.12.1 General

The Contractor shall submit to the Engineer, one month prior to the date of commencement of the tests, six (6) copies of the complete test procedure. The procedure, method and points of measurement shall be approved by the Engineer before any test is carried out. Six (6) copies of the test results shall be furnished to the Engineer for his approval.

The complete compressed air system shall be subjected to inspection and testing in accordance with applicable codes and standards.

Tests on compressed air system shall include Preliminary tests, Pre-start and Commissioning test and Performance test as described below:

a. Preliminary tests

All items of equipment shall be tested individually to determine the specified and scheduled data, and conformance to specified requirements, when operated independent of overall system for noise, vibration, electrical data, air temperatures, pressures and capacities.

b. Equipment

All compressed air equipment shall be inspected for proper operation, noise and vibration. Tests shall be carried out with readings of temperature, pressure, rpm, ampere, voltage, etc. to determine the specified data.

c. Electrical equipment

All electrical equipment shall be cleaned and adjusted on Site before supply of power.

The following tests shall be carried out:

i. Wire and cable continuity tests

ii. Insulation resistance tests, phase to phase and phase to earth, on all circuits and equipment, using 500 V megger. The megger reading shall not be less than one megohm.

iii. Earth resistance between metallic conduit systems and earth shall not exceed half (0.5) ohm.

iv. Phasing out and phase rotation tests.

v. Operating tests on all protective relays to prove their correct operation before energizing the main equipment.

vi. Operating tests on all starters, circuit-breakers, etc.

d. Pre-start and commissioning tests

Upon completion of compressed air system, the Contractor shall carry out Commissioning tests.

e. Performance tests

All compressed air equipment shall be tested for performance after successful completion of Commissioning tests to determine the Specified and Guaranteed Data at Specified Operating Conditions as shown in Equipment Schedule and Specifications.

The date of commencement of the above said tests shall be subject to agreement with the Engineer.

SECTION 10: FIRE FIGHTING SYSTEM

10.1 Scope

This section specifies the requirements for the design, manufacture, works testing, packing ready for transport and supply of the firefighting equipment for the powerhouse, intake control building and Transformers located near the switchyard.

10.2 Design Standards

The design, manufacture, testing and inspection of firefighting equipment shall comply with the following standards and codes (latest editions):

NFPA 10	Standard for Portable Fire Extinguishers.
NFPA 12	Standard on Carbon Dioxide Extinguishing Systems
NFPA 13	Standard for the Installation of Sprinkler Systems
NFPA 14	Standard for the Installation of Standpipe and Hose Systems.
NFPA 15	Standard for Water Spray Fixed Systems for Fire Protection
NFPA 20	Standard for the Installation of Stationary Pumps for Fire Protection.
NFPA 22	Standard for Water Tanks for Private Fire Protection.
NFPA 24	Standard for the Installation of Private Fire Service Mains and Their Appurtenances.
NFPA 170	Standard for Fire Safety and Emergency Symbols
NFPA 851	Recommended Practice for Fire Protection for Hydroelectric Generating Plants
NFPA 1981	Standard on Open Circuit Self Contained Breathing Apparatus
NFPA 1975	Standard on Emergency Services Work Clothing Elements
ASME	Boiler and pressure Vessel code, Section VIII

10.3 Organization of Fire Safety Facilities

Reference the Specification Drawings the Plant in the powerhouse and in the control buildings shall be organized in following firefighting zones:

a. Machine hall
b. Control building
c. Service bay floors and workshop
d. Intake Control Building

In addition, these zones shall be divided into sub-zones, and sectors for rapid identification of a fire alarm.

A plan layout of each fire safety zone/sub-zone to a scale of 1:200, with boundaries of the fire safety zone clearly indicated and with each area clearly coded and named, shall be provided. This shall be

located adjacent to the local control and indicating unit of the fire safety zone/sub-zone and shall be protected by glass in a metal frame.

10.4 Portable Fire Extinguishers

10.4.1 General

Portable fire extinguishers of three types shall be provided:

a. Water (Stored Pressure)

b. Dry powder

c. Carbon dioxide

All portable fire extinguishers shall comply with NFPA 10. The charge (extinguishing medium) to be by means of a lever-operated valve provided with a safety pin. The extinguisher shall be capable of controlled part discharge.

All extinguishers shall be of Minimax, Germany make or approved equal and be marked with clear instructions for use in the English and Urdu languages.

10.4.2 Mounting

All internal extinguishers shall be wall mounted and attached in a manner affording quick release from the supporting bracket. They shall be installed so that the top of the extinguisher is not more than 1500 mm above the floor and in no case shall the clearance between the bottom of the extinguisher and the floor be less than 100 mm. The extinguishers shall be positioned so that the instructions for operation face outwards.

All external extinguishers shall be located in a weatherproof cabinet secured in the closed position by a lead seal. The cabinet shall be painted red and marked in white with the words "Fire Extinguisher" in the English and Urdu languages.

10.4.3 Refilling and Recharging Materials

Refilling and recharging materials sufficient to recharge 200% of all the dry powder portable fire extinguishers supplied shall be provided. These materials shall be suitably packed for prolonged storage.

One set of refilling equipment for carbon dioxide portable fire extinguishers shall be provided. This equipment shall be sufficient to recharge all the carbon dioxide portable fire extinguishers provided and shall be capable of being recharged.

Instructions in English and Urdu for charging shall be provided.

10.4.4 Local Available Resources

The Contractor shall identify and inform the Engineer the facilities available in Pakistan for the recharging of portable fire extinguishing cylinders and servicing of smoke/heat detectors and related equipment.

10.5 Fire Water Supplies for The Powerhouse

10.5.1 Scope

The fire water system for the powerhouse to be provided by the Contractor includes the following:

a) Two (2) self-cleaning automatic filters drawing water from the raw water header to supply water to overhead water tank located on Powerhouse Roof.

b) One standby back-up fire water pump with strainers drawing water from tailrace.

c) One (1) fire main, running up to overhead fire water tank.

d) One main fire water pump and one jockey pump will be installed on the outflow line from the tank.

e) Pipework and valves for supplying fire water to the deluge system for generator Transformer bays.

f) Hydrants and hoses with nozzles for service bays.

g) Hose reels with nozzles for the office lobbies, workshop area etc.

h) Fire hose and equipment cabinets and mounting anchors.

i) All pipework, isolating valves, non-return valves, strainers, control valves, flow switches, pressure gauges with contacts, expansion joints, pipe supports and fittings and any other equipment necessary for the complete operation of the system.

10.5.2 Fire Water Scheme and Limits of Supply

Water shall be drawn from raw water header to feed the water to overhead firefighting tank located on powerhouse roof. From the Fire-Fighting Water Overhead Tank, the water would be fed to sprinkler heads. One main fire water pump and one jockey pump will be installed on the outflow line from the tank in order to achieve the pressure of 10 bars at all times. The water shall be filtered to pre-vent blockage of the sprinkler heads. According to National Fire Protection Agency (NFPA) standards fire water flow must be provided for a minimum of two hours at a minimum pressure of at least 1MPa (10 bar) at all times.

Water from this fire main shall be distributed to supply the following fire protection systems:

a. Fire protection system for the generator Transformers in switchyard.

b. Fire hydrants at:

The unloading bay	1 No.

c. Hose reels at:

The workshop at	1 No.

d. The office corridors :

1 No.

e. Machine Hall

4 Nos.

10.5.3 Detail Requirements for Fire Water Supplies

a) Standby back-up Fire water pumps

The electric motor driven; centrifugal type pump shall be supplied to deliver water to the overhead water tank. The Contractor shall determine pump capacities during basic design which shall be deemed to the Engineer's approval. The pumps shall draw water from the tailrace. The pump shall be located at a suitable place identified during detailed design stage by EPC contractor.

The pump and motor shall be vertically mounted on a common base frame. The starter shall be located close to the pump. Provision of manual control from the local control panel shall also be provided.

b) Fire main and distribution pipework

The stainless-steel fire main, on the powerhouse main hall floor shall be approximately 50 m long (The Contractor shall calculate pipe size and length during its basic design which shall be deemed to the Engineer's approval). The fire main shall have two stainless steel expansion joints. The fire main shall be provided with tee-offs and strainers for connecting all fire water facilities.

The fire main and the connected piping shall be designed for a maximum pressure of 11 bars.

Supports for the fire main shall be provided at no more than 6.5 m spacing. Supports shall be provided adjacent to valves, tee-offs and expansion joints. All supports for the pipework including anchors shall be included in the supply.

c) Transformer fire water system

The Contractor shall supply a water supply pipe (The Contractor shall calculate pipe size and length during its basic design which shall be deemed to the Engineer's approval) to terminate at the deluge valves of Transformer fire protection system. Upstream of the deluge valves the Contractor shall supply isolation valves with provisions for positive locking in both the open and closed position.

d) Fire hydrants, hoses and hose reels

Hydrants shall be wall mounted, simple outlet type with easy instantaneous coupling 65 mm bore conforming to NFPA 24, and isolating valves, full flow gate type, generally located as shown on the Specification Drawings.

The hoses for use with hydrants shall be non-kink, single jacket, synthetically lined and shall be 30 m long with a nominal diameter of 65 mm. Hoses shall be provided with one male and one female instantaneous coupling to NFPA 24.

The fire hose nozzles shall be made in gunmetal or high-grade light alloy and be adjustable to deliver water in the following three alternative modes:

a. Solid jet.

b. Spray, with adjustment of droplet size.

c. Fog, delivered in a cone-shaped configuration.

Hose reels shall comply with NFPA 14. Hose reels shall be of the swing arm type and each shall contain 40 m of 19 mm nominal dia. hose. They shall be of the type in which the water is turned on when the reel is rotated. The discharge shall be controlled by a jet/spray nozzle.

e) Fire hose and equipment cabinets

The fire hose cabinets shall be constructed of galvanized mild steel plates at least 1.2 mm thick with suitable internal reinforcement. The cabinets shall be wall mounted so that the base of the cabinets are 1.2 m above ground level.

The cabinets shall have outward-opening solid steel doors or a demountable body, be secured in the closed position by means of a wire and lead seal breakable by hand without excessive force or difficulty. They shall enclose the following equipment:

a. Two (2) 30 m lengths of fire hose of 65 mm nominal diameter.
b. Two (2) combined jet/fog/spray nozzles having an equivalent nozzle orifice diameter of 15 mm in the "jet" setting.
c. One (1) fire hose cradle capable of storing 30 m of 65 mm dia. fire hose. The fire hose cradle shall be finished in red enamel.

The fire hose and equipment cabinets shall be finished in red enamel with the words "FIRE HOSE" in English and Urdu languages, marked in white.

10.6 Mobile Fire Extinguishing Units

Five (5) dual agent units shall be provided.

The units shall consist of one powder container and one aqueous film forming foam making liquid container both of which shall be attached to a container of compressed inert gas for use as the propellant of both extinguishers. The powder and aqueous film forming foam making liquid shall be fed to individual discharge nozzles controlled by triggers through twinned flexible hoses. This equipment shall be mounted on a metal frame with wheels and a handle and located one in unloading bay and one in 11 kV switchgear room of powerhouse, one at machine hall, one at intake building, and one in the control building of powerhouse.

The extinguishing agent containers shall be of steel construction and shall be pressure-tested to twice the operating pressure. The individual containers shall hold a minimum 90 kg of dry powder and at least 130 litters of an aqueous film forming foam making liquid pre-mix. These two agents shall be such that neither adversely affects the effectiveness of the other. The unit shall have two wheels which shall have rubber or synthetic tyres and a minimum overall diameter of 300 mm.

All steel components of the extinguisher shall be galvanized or otherwise protected against corrosion.

The twinned hoses conducting the extinguishing agents to the discharge nozzle shall be at least 15 m long. The twinned hoses shall be permanently connected to the extinguishing agent containers in a manner allowing easy removal for use. A single easily accessible valve shall be used to release the pressurizing gas into the containers.

The nozzles shall control discharge of the extinguishing agents and shall be designed for controlled part delivery so that the aqueous film forming foam making liquid is released in a jet and the dry powder is sprayed in a cone. The unit shall be capable of discharging all the extinguishing agents in a maximum time of 120 seconds and shall be effective to extinguish fires from a distance not less than 15 m.

The extinguisher shall be painted red and shall be marked in the English and Urdu languages with clear instructions for use. The unit shall be provided with 100% refilling materials suitably packed for prolonged storage. Instructions both in English and Urdu languages shall be provided for refilling.

10.7 Fire Safety Signs

Fire safety signs shall comply with NFPA 170. Indoor fire safety signs shall be of a robust material capable of being securely fixed by two or more screws. The demarcation between adjacent colours shall be a sharp line without any discernible colour overlap or merging. The surface of the sign shall remain unaffected by all common office cleaning materials and the colours shall be fast and not fade with time or when subjected to sunlight, rain and wind.

The signs shall be 500 mm x 300 mm in size and display warnings of "No Smoking" and "No Open Flame" in English and Urdu languages. The signs shall be provided at locations to be notified by the Engineer.

External fire safety signs shall meet the requirements above in addition to being fully resistant to sunlight, rain and wind.

The fire safety signs shall be positioned with fixing screws or other fixing devices such that the sign is fixed and no movement occurs when a force is applied by hand to the sign in any direction.

10.8 Painting

All the surfaces requiring paint treatment shall be painted in accordance with the General Mechanical Requirements.

10.9 Inspection and Testing

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

In general, all the equipment shall be tested in accordance with the requirements of Testing Clause of the contract. All the electrical equipment shall also be tested in accordance with Testing Clause of the Technical Provisions. All testing shall be conducted by the Contractor according to Engineer’s agreed/approved procedure.

10.9.1 Particular Inspection and Testing During Manufacture

Over and above the dimensional checks and other routine tests required in accordance with General Mechanical Requirements, at least the tests mentioned below shall be witnessed by the Engineer, for all the equipment supplied under this part of the Contract.

All fire safety equipment shall be subjected to inspection at the works in accordance with the British Standards.

The Contractor shall submit a schedule of proposed tests for approval before testing. The Contractor shall complete functional tests on all fire safety equipment excluding a typical portable fire extinguisher and submit a report to the Engineer.

All smoke detectors shall be subjected to test fires.

All sprinkler systems shall be subjected to functional tests involving the normal discharge of water. The water discharge patterns shall be recorded by the Contractor.

The Contractor shall provide a comprehensive check list for all tests.

10.9.2 Testing and Commissioning

The test procedure shall include but shall not be limited to the following tests to be conducted by the Contractor.

a) General

The Contractor shall submit to the Engineer, one month prior to the date of commencement of the tests, six (6) copies of the complete test procedure. The procedure, method and points of measurement shall be approved by the Engineer before any test is carried out. Six (6) copies of the test results shall be furnished by the Civil Contractor to the Engineer for his approval.

The complete firefighting system shall be subject to inspection and testing in accordance with General Mechanical Design Requirements.

Tests on firefighting system shall include Preliminary tests, Pre-start and Commissioning test and Performance test, as described here under:

b) Preliminary tests

All items of equipment shall be tested individually to determine the specified and scheduled data, and conformance to specified requirements, when operated independent of overall system for noise, vibration, electrical data, water flow rates, temperatures, pressures and capacities.

c) Piping system

Pressure tests shall be applied to piping only before connection to equipment and appliances.

In no case shall piping, equipment or appliances be subjected to the pressure exceeding their rating.

Tests shall be performed in the presence of and to the satisfaction of the Engineer.

The prescribed pressure shall be maintained for four (4) hours.

d) Equipment

All firefighting equipment shall be inspected for proper operation, noise and vibration. Tests shall be carried out with readings of temperature, pressure, rpm, ampere, voltage, etc. to determine the specified data.

e) Electrical equipment

All electrical equipment shall be cleaned and adjusted on Site before supply of power.

The following tests shall be carried out:

a. Wire and cable continuity tests.

b. Insulation resistance tests, phase to phase and phase to earth, on all circuits and equipment, using 500 V megger. The megger reading shall not be less than one megohm.

c. Earth resistance between metallic conduit systems and earth shall not exceed half (0.5) ohm.

d. Phasing out and phase rotation tests.

e. Operating tests on all protective relays to prove their correct operation before energizing the main equipment.

f. Operating tests on all starters, circuit-breakers, etc.

10.9.3 Pre-Start and Commissioning Tests

a) Commissioning tests

Upon completion of the firefighting system the Contractor shall carry out Commissioning tests.

b) Performance tests

All the firefighting equipment shall be tested for performance after successful completion of Commissioning tests to determine the Specified and Guaranteed Data at Specified Operating Conditions as per technical plant data and applicable codes and standards.

The following items of the firefighting system shall be tested:

a. One (1) hydrant & hose reel system.

b. One (1) automatic spray system for Transformers.

c. One (1) dual agent unit/foam hose unit.

d. One (1) portable fire extinguisher (one of each type).

The date of commencement of the above said tests shall be subject to agreement with the Engineer.

SECTION 11: OIL PURIFICATION SYSTEM

11.1 Oil Purification System

11.1.1 Scope

This sub-section specifies the requirements for the design, manufacture, works testing, packing ready for transport of the Transformer oil purifying plant.

11.1.2 Detailed Requirements

The Plant shall be capable of treatment of oil to IEC. 296 and IEC. 422 "Maintenance Guide for Insulating Oil in Service".

The Plant shall be designed for oil treatment with a water extraction capability down to 10 ppm. Reduction of dissolved gas contents shall be to one percent by volume or less.

11.1.3 Oil Purifier

The oil purification unit shall be mobile oil purifier provided with a thermostat-controlled heating system, a filter and all necessary accessories and instrumentation. The purifier shall have the capacity of at least 4,000 l/h.

11.1.4 Vacuum Pump

The vacuum pump shall be electric motor driven, direct drive, capable of producing a vacuum of 40 kPa in Transformer or oil sump of bearings & hydraulic systems,. The pump shall be capable of handling air with suspended oil vapours. The pump shall be provided with an unloader and check valve. A non-return valve shall be provided in the suction line to retain vacuum in the Transformer in case of power failure.

Drive motor shall be totally enclosed type and generally in accordance with General Electrical Requirements. Supply voltage for the motor shall be three-phase, 400 V, 50 Hz, ac.

A control panel shall be provided. All the start/stop and protection devices shall be mounted on this panel. A vacuum gauge calibrated in mm of Hg and kPa shall also be provided to indicate the amount of vacuum achieved in the Transformer tank.

11.2 Governor and Lubricating Oil Purification System

11.2.1 Scope

This sub-section specifies the requirements for the design, manufacture, works testing, packing ready for transport of the following lubricating oil handling and purifying equipment.

11.2.2 Oil Purifier

The oil purification unit shall be of mobile type provided with a thermostat-controlled heating system, a filter and all necessary accessories and instrumentation. The purifier shall have a capacity of 4,000 l/hr at 70°C.

11.3 Painting

All the surfaces requiring paint treatment shall be painted in accordance with the

General Mechanical Requirements.

11.4 Inspection and Testing

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

In general, all the equipment shall be tested in accordance with the applicable codes and standards. All the electrical equipment shall also be tested in accordance with applicable codes and standardsof the Electrical Equipment.

11.4.1 Particular Inspection and Testing During Manufacture

Over and above the dimensional checks and other routine tests required in accordance with General Mechanical Requirements, at least the following tests shall be witnessed by the Engineer, for all the equipment supplied under this part of the Contract:

11.4.2 Oil Purifiers

The oil purifier shall be tested in the manufacturer's works in the presence of the Engineer. The test on lubricating oil purifier shall consist of purifying new lubricating oil at an entrance temperature of approximately 55°C and water content of between 0.5 % and 1.0 % by volume and containing 0.1 % of solids by volume, at the specified rate, to no more than 0.1 % of moisture by volume and not more than 0.005 % of solids by volume. This test shall continue without interruption for one hour. Under no circumstances shall the separated water contain more than 0.5 % of oil by volume.

The Transformer oil purifier shall be tested to check ability to purify the dirty Transformer oil to a quality to pass the tests specified in IEC 296.

The oil handling and purification system shall, as far as is practicable, be fully assembled in the works along with the associated control cabinet and subjected to performance tests to demonstrate conformity with the Specifications and approved drawings. All devices provided shall be checked for range of adjustment and then adjusted so that the minimum of further adjustment shall be required after installation at Site.

11.4.3 Testing and Commissioning

The test procedure shall include but shall not be limited to the following tests:

a) General

The Contractor shall submit to the Engineer, one month prior to the date of commencement of the tests, six (6) copies of the complete test procedure. The procedure, method and points of measurement as well as the method of calculation shall be approved by the Engineer before any test is carried out. Six (6) copies of the test results shall be furnished to the Engineer for his approval.

Tests on oil handling equipment shall include Preliminary tests, Commissioning test and Performance test, as described here under:

b) Preliminary tests

All items of equipment shall be tested individually to determine the specified and scheduled data, and conformance to the specified requirements for vibration, electrical data, flow rates, temperatures, pressures and capacities.

11.4.4 Equipment

All the equipment shall be inspected for proper operation, noise and vibration. Tests shall be carried out with readings of temperature, pressure, rpm, ampere, voltage, flow rates, etc. to determine the specified data.

11.4.5 Electrical Equipment

All electrical equipment shall be cleaned and adjusted on site before supply of power.

The following tests shall be carried out:

a. Wire and cable continuity tests

b. Insulation resistance tests, phase to phase and phase to earth, on all circuits and equipment, using 500 V megger. The megger reading shall not be less than one megohm.

c. Earth resistance between metallic conduit systems and earth shall not exceed half (0.5) ohm.

d. Phasing out and phase rotation tests.

e. Operating tests on all protective relays to prove their correct operation before energizing the main equipment.

f. Operating tests on all starters, circuit-breakers, etc.

11.4.6 Commissioning Tests

When the oil handling equipment is complete and ready for operation as specified, the Contractor shall carry out Commissioning tests.

11.4.7 Performance Tests

All oil handling equipment shall be tested for performance after successful completion of Commissioning tests.

SECTION 12: HEATING, VENTILATION AND AIR-CONDITIONING (HVAC)

12.1 Scope of Supply

12.1.1 General

All materials, components units and equipment of HVAC systems shall be designed, furnished, installed, tested and commissioned in accordance with the relevant highest verifiable codes and standards as well as the requirements specified in this section. The specifications state the minimum requirements for the equipment, which shall be valid unless a higher standard of quality is required or specified otherwise in the other sections of the entire Bidding Documents.

If there are deviating specifications in the Bidding Documents from the following specifications under this section, the higher standard and quality as well as the more extensive, complete and suitable equipment shall be taken as the basis for the calculations, design, delivery, installation and settlement.

12.1.2 HVAC Scope of System in General

The scope of work comprises designing, engineering, preparation of shop drawings, procurement, manufacture, testing, transport, erection, installation, obtaining approvals and completion of the HVAC works including relevant electrical and civil works. The work covered by this part of the specification shall include but shall not be limited to the following items:

1. Submission of HVAC Load calculation on HAP, ventilation & static pressure calculation and design of HVAC systems for approval,
2. Heating, ventilation and air-conditioning (HVAC) equipment including DX split air conditioners, VRF Units, Fans with all components and accessories,
3. Sound baffles, attenuators and vibration eliminators,
4. Access and entrance doors for all air chambers and moving parts,
5. Watertight duct and pipe passages through roofs, outside walls and air-conditioning units,
6. Earthing of all metal parts of the complete air conditioning plant,
7. Protecting coats of paint and coating against corrosion and other damage for all not galvanized steel components such as steel structures,
8. Installation of protection guards, stairs, ladders, service platforms, gratings and railings for all maintenance purposes,
9. Fire dampers shall be provided and installed in supply and return ducts between floor slabs and where fire zones are crossed,
10. Low voltage (LV) power distribution and cabling,
11. Draining system for all HVAC equipment extending to the next possible connection to the sewage system, including all necessary accessories,
12. Functional test, starting-up, initial operation, reliability test and performance test by qualified personnel of the Contractor in the presence of the Employer or his representative,
13. Provision of all necessary documents for review and approval by the Employer/Engineer before starting up,

14. Working, operation and servicing manuals, spare part lists,
15. Clearing of faults and damage during the Warranty Period,
16. All necessary spare parts, tools, devices, working and substitute material such as refrigerants, etc for an uninterrupted, trouble-free operation.
17. The delivery and installation shall not be limited to the above-mentioned parts. All deliveries and installations not particularly specified shall be added to ensure fully functioning systems and to meet the latest technical experiences and standards.
18. Heat insulation, vapour insulation and fire protection.
19. Setting, adjusting, balancing of all HVAC equipment and system.
20. Submission of equipment submittal as per approved calculation including selection sheet, manufacturer catalogues, certificates etc. All information must be in English. All procurement shall be made as per approved technical submittal only.
21. Preparation and submission of shop drawing (coordinated detail design drawings after coordination with all services) for approval.
22. Provide all security and safety measures during installation phase and O&M period.
23. All relevant civil works including cutting, patching, repairing, masonry and concrete works, foundations, etc is in scope of contract.
24. All relevant electrical works for main LT Panel to downstream of HVAC system including cabling, panels, conduits, breakers etc.
25. For all control rooms, electrical equipment rooms and emergency stair case smoke ventilation system shall be separately designed and isolated from the rest of HVAC system.
26. Provision of emergency electricity generator for HVAC equipment installed in critical areas in case of plant shut down.
27. Submission of installation drawings of every HVAC equipment and material for approval and reference at site.
28. Submission of equipment schedule showing all types of HVAC equipment and material along with capacities and design conditions
29. Submission of As-built drawings showing all variations as per site installation.

12.1.3 Machine Halls

Ventilation system shall be provided for machine halls. The air shall be distributed by reversible fan to turbine halls and then released to outside through fans.

12.1.4 Control Room and Offices

The control room and offices shall be air-conditioned by Reversible Type Variable Refrigerant Flow (VRF) system with minimum fresh air rate as per ASHRAE Standards.

The HVAC system shall be designed for 50% capacity in the Control Room.

HVAC System load of Control Room shall be consider in Emergency load and feed by Emergency Diesel Generator in case of power failure.

12.1.5 LV and MV Switchgear Room

The ventilation system including fan units and filter section, except the air duct system, shall be designed for LV and MV Switchgear room.

12.1.6 Design Conditions and Design Data

a) Design Ambient Condition

The design ambient conditions at the site are;

- Summer 36° C Max.
- Winter -10° C Min.

12.1.7 Design Conditions

The design conditions of the HVAC systems shall be carried out in consideration of the basic design concept which is mentioned this section and entire specifications.

a) Design Indoor Conditions

The entire HVAC systems shall be carried out in consideration of the design indoor criteria which are mentioned in this section and as per following HVAC room lists.

b) Indoor Conditions

The Contractor shall guarantee the following indoor conditions.

Table 19: HVAC Design Requirement

Area	Temp. °C	Rel. Humidity	Control by A/C	Air Change Rate (Min)	Noise Level dB(A)
Machine Hall	+22	80%	Ventilation	10	85
Control Rooms	+22	50%	Air Conditioning (Cooling + Heating)		40
Offices	+24	50%	Air Conditioning (Cooling + Heating)		35
Electrical or Switchgear room	Max +28	50%	Ventilation	6	65

Note: After finalization of layout by the EPC Contractor, any area that has not been specifically mentioned in the HVAC specifications, shall be subject to Employer / Engineer's approval / consent.

12.1.8 Smoke Ventilation

For all Control, Electrical equipment rooms and emergency stair cases in all building of the project, smoke ventilation system shall be separately designed and isolated from the rest of HVAC system. The smoke ventilation shall be designed as per ASHRAE standards.

12.1.9 Equipment/Material Selection

For all proposed equipment manufacturer shall meet minimum following criteria:

- Ten (10) years of international experience for same equipment /material.
- Minimum five (5) years national experience with same brand and after sale services in Pakistan
- Compliance with international standards/codes
- Availability of all technical data in English
- High ambient compatibility
- Most energy efficient equipment/model available in market
- Verifiable list of projects of last five (05) years in Pakistan

12.1.10 Codes and Standards Requirements

Following codes and standards shall be fully complied by Contractor and their offered equipment/material.

Table 20: Code & Standard Requirements

S.#	Codes	Standards
a)	ASME	American Society of Mechanical Engineers
b)	ASTM	American Society for Testing & Materials
c)	ASHRAE	American Society of Heating, Refrigerating and Air- conditioning Engineers
d)	NFPA	National Fire Protection Association, USA
e)	ARI	Air-conditioning and Refrigeration Institute, USA
f)	SMACNA	Sheet Metal and Air-conditioning Contractors National Association, USA
g)	I.E.E.	Institute of Electrical Engineers, London
h)	NEMA	National Electrical Manufacturers Association,
i)	AHRI	Air Conditioning, Heating and Refrigeration Institute
j)	USA.	United State of America
k)	AMCA	Air Moving and Control Association Inc.,USA
l)	P.S.	Pakistan Standards.
m)	B.S.	British Standards.
n)	TIMA	Thermal Insulation Manufacturer's Assoc. USA

12.1.11 Major Equipment Description

Table 21: Equipment Description

Sr. No	Type of System/Material	Major Equipment
1.	VRF Units	• High Ambient, Heavy Duty • (AHRI & Eurovent Certified)
2.	Ventilation	• Propeller Fans • Centrifugal Fans • Inline Centrifugal Fans • Tube Axial Fans • Explosion proof/corrosion proof (as required)

Notes:

i. For all equipment mentioned above, highly efficient latest model with all safeties, controls and advanced optional features as per project requirement approved by the Employer/Engineer.

ii. All equipment shall be provided with two (02) year spare parts.

iii. Warranty period for all equipment shall be as specified in Bidding Documents.

iv. HVAC equipment shall be capable to provide rated load at Outdoor Design Conditions.

12.1.12 Documents/Information Required for Approval

The document for approval shall include minimum following;

a. Design calculations for all areas.

b. Technical submittal for VRF units, fans etc.

c. Testing protocols

d. Samples of HVAC material

e. As built drawings

SECTION 13: WORKSHOP EQUIPMENT

13.1 Scope

This section specifies the requirements for the design, manufacture, works testing, packing and delivery of workshop machine tools and other equipment.

13.2 Location and Layout

The powerhouse workshop equipment shall be installed in the workshop of the powerhouse.

13.3 Machine Tools and Equipment

The equipment shall be new, of latest design and shall be of standard commercial quality.

Individual motor drives shall be provided to all machine tools. Lathe, drilling machine, and grinder shall be provided with work-lights. Motors shall be squirrel cage, full voltage start for operation on 400 V, three-phase, 50 Hz or 230 V, single-phase supply.

All machine tools with electric drives shall be provided with individual control and protection panels.

13.4 Powerhouse Workshop

13.4.1 High Precision Bench Lathe

The precision bench lathe shall be quick-change gear-type, light duty, general purpose bench lathe. The dimensions and facilities of the lathe shall be approximately as follows:

a.	Swing over cross-slide	370 mm
b.	Swing over bed	560 mm
c.	Height of centers	280 mm
d.	Bed length between centers	1500 mm
e.	Width of bed	400 mm
f.	Spindle bore	102 mm
g.	Spindle speeds	UJ1250
h.	Thread cutting facilities	Metric

13.4.2 Equipment to be Provided with Lathe:

a. 500 mm, 4 jaw, self-centering chuck.

b. 315 mm, 3 jaw, self-centering chuck.

c. Coolant equipment and splash guard.

d. Two (2) tapered centers No. 3 Morse or equivalent.

e. Emergency stop button.

f. One (1) square tool post, one pair of dead centers, one taper sleeve.

g. Set of spanners and keys, instructions and spares manual, accuracy chart.

h. Low voltage machine lighting for standard ac supply.

i. Chip guard.

j. Large faceplate, manufacturer's standard.

k. Ten (10) assorted cutting tools complete with a selection of cutting bits and tips.

l. Collet chuck with a set of collets, manufacturer's standard.

13.4.3 Drill Stand

The drill stand shall be of floor-standing type with pulley drive, adjustable depth stop, graduated in metric calibrations and fitted with safety foot switch. The dimensions and facilities shall be approximately as follows:

Drilling capacity	50 mm
Power input	200 Watt
No load speed	350/450 rpm
Cutting holder	19 mm Weldon Shank (3/4 inch)
Maximum cutting depth with cutters	50 mm
Maximum cutting dia with cutters	50 mm
Drill power pressure	317 kg
Motor	3-Phase, 400 V, 50 Hz

13.4.4 Equipment to be Provided with Grinder

- 15 mm drill chuck and arbor.
- One (1) set of high speed straight shank twist drills from 5 mm diameter to 15 mm in 0.25 mm steps.

13.4.5 Bench Mounted Grinder

Bench grinder shall be heavy duty industrial type with pushbutton starter, shatter proof wheel guards and robust work rests. The approximate sizes and dimensions shall be as follows:

a. Wheel size 200 x 25 x 20 mm

b. Wheel centers 350 mm

c. Motor speed 3000 rev/min.

d. Motor 3-phase, 400 V, 50 Hz

13.4.6 Equipment to be Provided with Grinder:

- Twelve (12) 200 x 25 x 20 mm grinding wheels, comprising 3 sets of 4 wheels, each set having different grit sizes.

13.4.7 Electric Welding Machines

Each portable arc welding machine shall be of multi process GTAW/GMAW/SMAW inverter type sets. At least one large for the workshop and one small portable one shall be supplied. Each unit shall be equipped with an overload protection. The entire assembly shall be attached to a steel platform and shall be mounted on four mould-on rubber wheels. The following standard accessories shall be furnished with each unit:

a. 10 m of extra flexible rubber covered electrode cable with electrode holder attached.
b. 10 m of extra flexible rubber covered ground cable, with ground clamp.
c. One (1) head shield with lens and cover glass
d. One (1) wire scratch brush
e. One (1) cone and chisel head hammer

Each welding unit shall be furnished complete with 12 m of four conductor rubber covered power cable.

In addition, a triple panel, vinyl coated fiber glass, green coloured screen having each panel 2 m wide and 2 m high shall be provided. The unit shall include three connected steel frames, platform legs, a single curtain that covers all three frames and ties.

13.4.8 Electrode Ovens

Two portable electrode ovens, of capacities approx. 7 kg. and 25 kg., shall be provided. Ovens shall be suitably insulated capable to heat up to 135°C and to hold about 46 cm long electrodes. Units shall have handles for ease of handling for transportation, supplied with 3 m length of cables and rated at 220 volts ac.

13.4.9 Oxy-Acetylene Welding Equipment

The oxy-acetylene combination welding and cutting outfit shall consist of:

a. One (1) welding blow-pipe with 5 tips, lighter and wrench
b. One (1) oxygen regulator with 0.7 to 21.0 MPa gauges and wrench
c. One (1) acetylene regulator with 2 to 2.5 MPa gauges
d. 8 m of 5 mm green oxygen hose.
e. 8 m of 5 mm red acetylene hose.
f. Four (4) 5 mm hose ferrules
g. One (1) cutting attachment with 2 nozzles
h. One (1) pair no. 16 goggles
i. One (1) instruction manual

13.4.10 Tool Cabinets

Tool storage cabinets shall be of steel construction and each shall be approximately 600 mm deep and 1,000 mm wide. Each shall be complete with shelves and drawers and lockable doors as required for most efficient storage.

13.4.11 Tool Room Racks

The metallic racking and shelving for hand tools, air operated tools and precision instruments normally used in station workshops, shall be approximately 1.8 m high and 600 mm deep. The metallic racking shall consist of shelves vertically adjustable. The racks shall be supplied for assembly at Site.

13.4.12 Lockers

Five (5) lockers shall be supplied, and each shall have approximate dimensions of 450 x 500 x 1,800 mm and shall have shelves, drawers and hanging space to accommodate the personal effects of workshop and maintenance personnel.

13.4.13 Metal-Working Benches

Two (2) metal-working bench shall be approximately 800 mm wide by 4,000 mm long, each with a 1,000 mm diameter welder's bench. The legs of the benches shall be designed so that the benches can be attached to the floor by means of expansion bolts. Each workbench shall be complete with a strong clamping base for four 200 mm swivel bench vices furnished with the benches.

13.4.14 Electrical-Working Bench

The wooden-topped bench for electrical work shall be supplied approximately 800 mm wide by 2,500 mm long. The legs shall be designed so that the bench can be attached to the floor by means of expansion bolts. The bench shall be complete with strong clamping bases for two 200 mm swivel bench vices furnished with the bench.

13.4.15 Hand Tools

a) General

The following basic hand tools and gauges shall be supplied:

a. One (1) cased set of metric hand taps and dies - range 6 to 24 mm.
b. One (1) boxed set of BSP taps and dies - range 1/8 inch to 1¼ inch.
c. One (1) boxed set of BSP highspeed steel taps - range 1/8 inch to 1¼ inch.
d. One (1) LCD digital external micrometer to read 0-25 mm and one to read 0-1 inch, both shall be fitted with friction thimble.
e. One (1) external micrometer with extension rods and setting gauge to read 0 - 150 mm with accuracy of 0.01 mm.
f. One (1) external micrometer with range of anvils and setting gauge to read 150-300 mm.
g. One (1) cased set of internal micrometers reading 25-50 mm.
h. One (1) cased set of internal micrometers reading 50-300 mm.
i. Two sets of socket wrenches 6 mm to 60 mm.
j. Two sets of end wrenches from 6 mm to 42 mm.
k. One pipe wrench.

l. Pliers

m. One set of screw drivers

n. One set of small files

o. Hammers

p. One set of medium size files

q. Two (2) standard dial gauges with magnetic bases and cross bar assembly to suit reading 0.01 mm over a total travel of 12 mm.

r. 300 mm engineer's level with main, cross and plumb facilities and sensitive to 0.1 mm over 300 mm.

s. One (1) micrometer depth gauge, range 0-150 mm, with six measuring rods.

t. Three (3) inside calipers, sizes 100, 150 and 200 mm.

u. Three (3) outside calipers, sizes 100, 150 and 200 mm

v. One (1) dial calipers, range 0-150 mm, accuracy 0.01 mm.

w. Two (2) electric drilling machines, suitable for 230 V, 50 Hz electric supply, different size from 08 mm to 16mm. One (01) Drill machine shall be supplied suitable for concrete and One (01) suitable for steel.

b) Air operated tools

The following air operated tools and appliances shall be supplied:

a. One (1) worm drive nut-runner suitable for bolts up to 12 mm dia.

b. One (1) ratchet wrench for nuts in the range 10-15 mm across flats.

c. Two (2) straight grinders suitable for 75 x 25 mm wheel.

d. One (1) surface grinders with 15 mm spindle with metric thread.

e. One (1) spray gun suitable for low and medium viscosity fluids, e.g., water, solvents, paints etc.

f. Three (3)10 m lengths of hose suitable for use with above items along with couplings and fittings.

13.5 Standard of Accuracy

All machine tools supplied under this section shall conform to the standards of straightness, flatness, parallelism, squareness and rotation laid down in the latest edition of ISO 230-1: Acceptance code for machine tools.

13.6 Motors Control Panels, Motors and Starters

The motor control panels supplied by the Contractor shall have all the necessary contactors for starting the motors and be complete with motor protection. Motor duty switching shall be integral within the Contractor’s supply. Local panels as indicated herein shall be supplied complete with terminal strips for connection by others as indicated in the attached Control and Indication Schedule. All electrical equipment supplied shall be in accordance with the relevant clauses of General Electrical Requirements of these Specifications.

Motors and starters shall conform to the General Electrical Requirements of these Specifications. Full load operation of the motor shall not, under any circumstances, exceed its nameplate kW rating.

Wherever possible, three-phase, 400 V, 50 Hz motors shall be supplied with the machine tools specified.

Loose starters complying with the requirements of General Electrical Requirements shall be supplied under this section for those machine tools which do not embody starters in their structure. Loose starters shall be to the approval of the Engineer and shall be equipped with a suitable starter stand.

13.7 Painting

Painting shall be the manufacturer's standard system.

13.8 Inspection and Testing

13.8.1 Scope

This section specifies the requirements for the inspection and testing of all the equipment specified in the preceding sections.

13.8.2 Particular Inspection and Testing During Manufacture

In the case of machine tools, the manufacturer shall demonstrate the performance of each to the Engineer and carry out the practical, geometrical and special checks set out in ISO 230-1: Acceptance code for machine tools.

SECTION 14: FIRE DETECTION & ALARM SYSTEM

14.1 Scope

The Contractor shall design, manufacture, delivery and erection, testing and commissioning of an electrically supervised addressable non-coded fire detection and alarm system for the entire powerhouse structure.

The fire detection and alarm system shall be based on intelligent detectors, manual call points, alarm sounders and auxiliary devices etc. as required.

Intelligent detectors, manual call points, alarm sounders/flashing lights and fire telephones are to be connected in pre-defined circuits in the entire power plant. Some of the manual call points and the alarm bells shall be installed outdoor.

All equipment shall be manufactured and tested in accordance with the latest revision of the relevant IEC and NFPA standards.

14.2 Standards

The fire alarm and detection system shall conform to the applicable requirements of the latest edition of the following standards or to recognized equal:

Subject	Standard
• National Electric Code	NFPA 70
• National Fire Alarm Code	NFPA 72
• Recommended Practice for Fire Protection for Hydroelectric Generating Plants	NFPA 851
• Fire Detection & Alarm Systems	BS EN 54
• Control Units and Accessories for Fire Alarm Systems	UL 864

14.3 General Technical Requirements

The fire alarm system shall be based on an analogue and addressable fire detec¬tion and alarm system with detectors, manual call points and alarm sounders. External auxiliary devices shall be connected.

The fire alarm system shall consist of a main fire alarm panel (MFAP), printer, LED type VDU and a mimic annunciating panel in the central control room, local fire alarm panel and annunciators in the powerhouse, GSU Transformers area, machine hall, switchgear room, offices and other rooms. Fire detectors and manual call points, alarm sounders/flashing lights shall be connected in pre-defined circuits in the entire power plant.

The equipment shall be digital and the fire detectors limit values shall be programmable from the alarm panels, and it shall be possible to program the values in the field after installation. The equipment shall be modular with possibilities for future extensions and keep necessary stocks and spares to a minimum.

The Contractor shall perform detailed engineering of the complete installations, including the configuration of the fire alarm and associated equipment, detailed engineering of connections and

interfacing to the power plant control systems, detailed engineering of the connections to the station power supplies and supplemented engineering as required.

The number of fire alarm detectors, detector loops and alarm sounders included in the supply shall be calculated by the Contractor according to the standards as part of his engineering work. The quantity and the location of the smoke detectors, duct smoke detectors, heat detectors, manual call points, fire telephones, strobe lights and horns etc. and the layout arrangements of all equipment included in the supply shall be the responsibility of the Contractor and has to be approved by the Engineer. The Contractor shall submit the complete fire detection and alarm system design drawings to the Employer/Engineer for review and approval prior to installation.

All junction boxes shall be sprayed red and labeled “Fire Alarm” both in English and Urdu.

Wiring color code shall be maintained throughout the installation. All equipment which belongs to the fire alarm system shall have red colour.

14.4 Functional Description

One set of complete centralized fire alarm system shall be provided, with one set of fire detection and alarm controller arranged for each turbine-generator and generator step-up Transformer. The GSU Transformers and the turbine-generators shall have separate fire alarm and detection system linked to the plant control system (PCS) and the main fire alarm panel (MFAP).

The fire alarm and control system shall send alarm signal and coordinated control command for fire control automatically or manually based on the fire alarm signal sent by the detectors distributed in the powerhouse once a fire disaster occurs, with information related to the fire disaster recorded, displayed and printed. Interface shall be reserved on host machine of the fire alarm system so as to transmit the fire alarm signal to the Plant Control System (PCS) in central control room (CCR). All equipment shall be UL listed and shall conform to the requirements of IEC and all applicable provisions of NFPA 72, as well as applicable state and local requirements.

The activation of any non-coded manual pull station or automatic smoke or heat detector shall display the appropriate zone description (custom label) on the Main Fire Alarm Panel (MFAP). In addition, the condition shall cause all audible and visual signaling devices to activate.

The Contractor shall ensure that the fire detection system interfaces with the Plant Control System (PCS).

Any abnormal condition, such as power failure, open circuit, or a grounded conductor shall cause the system warning signal to sound and the warning LED to glow indicating the type of fault that exists. The warning signal may be silenced by momentarily pressing the warning silence switch, but the warning LED shall glow until the fault condition has been corrected. If a second fault condition should arise the warning signal shall be resounded.

The fire detectors shall be easy to remove from its mounting base. A warning signal shall be initiated if a detector is removed from its mounting socket, but the remaining detectors of the zone shall remain operative.

Alarm sounders shall be installed in all areas. The minimum alarm level in any part of the power plant shall be 15 dBA related to the normal background noise. In areas with high noise levels, flashing lights shall be used in addition to the alarm sounders.

The system shall normally operate from a single 230 VAC, 50 Hz source. Standby batteries shall be provided to operate the system during power outages. Batteries shall be sized to operate the

system in the standby mode for a minimum of 24 hours and in the alarm mode for a minimum of 5 minutes at the end of 24 hour period.

According to division of fire zones in the whole powerhouse, monitoring range of the fire detection and alarm system covers the erection area, turbine-generator floor of powerhouse and important rooms such as MV and LV distribution room, central control room (CCR) and offices etc. in the powerhouse.

14.5 System Layout

The fire detection and alarm system shall adopt bus mode. With the functions of receiving all fire alarm input, the main fire alarm panel (MFAP) and coordinated controller are arranged inside the central control room. Fire telephone control equipment is arranged inside the central control room and can be used for receiving the fire alarm message that is sent manually and the fire communication and command in a fire accident.

Each turbine generator is provided with one set of special fire detection and alarm controller. Intelligent heat detectors and optical smoke detectors that can resist power frequency electromagnetic field shall be installed. The detectors shall be bus-mode encodable product. The fire alarm controller shall be supplied by the generator manufacturer, with its quantity, installation site and installation method determined by the generator manufacturer. Water spray fire extinguisher of the turbine generator can be operated manually or automatically, as required.

The turbine-generator floor in main powerhouse and other important rooms shall be provided with optical smoke detectors and intelligent thermal detectors. A certain number of manual fire alarm buttons are set at such places as stair head and access. The alarm signal is transmitted to the main fire alarm panel (MFAP) in the CCR. The audible and visual alarm and smoke exhaust fan are started under coordinated control of the fire alarm signal to stop ventilation and electric pad at related position.

Cable type linear temperature detectors shall be used for cable interlayer, cable trenches and cable trays in powerhouse, laid by sections at each layer.

One set of fire telephone system shall be provided in the central control room. Fixed extension fire telephones shall be provided at the location of firefighting equipment.

PART-C: ELECTRICAL SPECIFICATIONS

TABLE OF CONTENTS

SECTION 1: GENERATORS 1

1.1 Scope of Work 1
1.2 Reference to Other Chapters 1
1.3 Design Requirements 1
1.3.1 Insulation and Temperature Rise Limits 3
1.3.2 Short Circuit Withstand Capability 3
1.3.3 Stability and Performance 4
1.3.4 Runaway Speed Withstand Capability 4
1.3.5 Structural Design and Steel Work 4
1.4 Generators Terminal Equipment 5
1.4.1 Busbar Equipment 5
1.4.2 Stator Core and Frame 5
1.4.3 Stator Winding 5
1.4.4 Rotor Rim and Poles 6
1.4.5 Field Winding 6
1.4.6 Shaft 7
1.4.7 Bearings 7
1.4.8 Generator Brakes 8
1.4.9 Fire Protection System 8
1.4.10 Control and Instrumentation 8
1.4.11 Anti-Condensation Heaters 9
1.4.12 Generator Cooling System 9

SECTION 2: EXCITATION SYSTEM 10

2.1 General 10
2.2 Scope of Work 10
2.3 Design Requirement 10
2.3.1 General 10
2.3.2 Excitation Transformer 11
2.3.3 Excitation Rectifier 11
2.3.4 Excitation Circuit Breakers 12
2.3.5 De-Excitation System 13
2.3.6 Field Suppression System 13
2.3.7 Over Voltage Protection 13
2.3.8 Automatic Voltage Regulator (AVR) 13
2.4 Measuring, Indication and Protection 14
2.4.1 Lighting 14
2.4.2 Piping and Wiring 14
2.4.3 Erection Equipment /Special Tools: 15
2.5 Spare Parts 15
2.6 Tests 15

2.6.1 Factory Test 15
2.6.2 Site Tests 17
SECTION 3: TRANSFORMERS 19
3.1 Scope of Work 19
3.2 Applicable Standards 19
3.3 Technical Data 20
3.4 Station Auxiliary Service 22
3.5 Design Requirements 22
3.5.1 General 22
3.5.2 Bushings and Bushing Current Transformer 22
3.5.3 Cores 23
3.5.4 Windings 24
3.5.5 Tap Changers 24
3.5.6 Tanks and Accessories 25
3.5.7 Flanged Wheels 26
3.5.8 Drain and Filter Valves 26
3.5.9 Transformer Oil 27
3.5.10 Oil Conservator Tank 27
3.5.11 Measuring and Supervision 27
3.5.12 Water Spray Fire Protection of Power Transformers 29
3.6 Tests 30
3.6.1 Factory Tests 30
3.6.2 Routine Tests on all Transformers 31
3.6.3 Additional Tests on the Main Transformers and Local Grid Transformer 31
3.6.4 Site Tests upon Completion 32
3.7 Tools and Appliances 32
3.8 Spare Parts 33
SECTION 4: SWITCHGEARS 34
4.1 General 34
4.2 High Voltage (HV) Switchgear 34
4.2.1 Scope of Work 34
4.2.2 Spare Parts 35
4.2.3 Design Requirement 35
4.2.4 Tests 47
4.3 MV Switchgears 49
4.3.1 Scope of Work 49
4.3.2 Design Requirements 50
4.3.3 MV Switchgear Tests 57
4.3.4 Spare Parts 57
4.4 LV Switchgear 58
4.4.1 Extent of Supply 58

4.4.2 Design Requirements 58
4.4.3 LV Switchgear Tests 59
4.4.4 Spare Parts 60
4.4.5 Low Voltage Circuit Breaker 60
SECTION 5: DC SUPPLY SYSTEM 61
5.1 General 61
5.2 Scope of Work 61
5.2.1 Powerhouse and Switchyard 61
5.2.2 Weir Intake 61
5.3 Design Requirement 62
5.3.1 Station Batteries System 62
5.3.2 Batteries 63
5.3.3 Battery Chargers and Inverter 63
5.3.4 Inverters 64
5.3.5 D.C./D.C. Converters 64
5.3.6 Switchboards 65
5.3.7 Metering and Signalling 65
5.4 DC System Tests 66
5.4.1 Works Tests 66
5.4.2 Site Tests 66
5.5 Spare Parts 67
5.6 Reference Standards 67
SECTION 6: PLANT CONTROL AND AUTOMATION SYSTEM 68
6.1 General 68
6.2 Scope of Work 68
6.3 Design Requirements 70
6.3.1 System Concept 70
6.3.2 System Architecture 70
6.3.3 System Main Features 71
6.3.4 Unit Control Systems (UCS's) 72
6.3.5 Generating Units (UCS 1-4) 72
6.3.6 Auxiliary Systems (UCS-5) 73
6.3.7 Intake (UCS-6) 73
6.3.8 HV Switchgear (UCS-7) 73
6.3.9 Power Plant–Substations, National/Regional Grid Remote Control Communication System (UCS-8) 73
6.3.10 Control Levels Functions 73
6.4 Computer Control System Tests 74
6.4.1 Workshop Tests 74
6.4.2 Site Tests 75
6.5 Consumables 75

6.6 Spare Parts 75
SECTION 7: PROTECTION SYSTEM 76
7.1 General 76
7.2 References Standards 76
7.3 Scope of Work 76
7.4 Design Requirements 77
7.4.1 Protection system for Generator Unit Components 77
7.5 Design Requirements 79
7.5.1 Protection Devices 80
7.5.2 Protection System Tests 84
7.5.3 Spare Parts 85
SECTION 8: MAIN EARTHING SYSTEM AND LIGHTNING PROTECTION 86
8.1 General 86
8.2 Standards 86
8.3 Scope of Work 86
8.3.1 Lightning Protection System 87
8.4 Design Requirements 87
8.4.1 General 87
8.4.2 Installation of Earthing System 88
8.4.3 Earthing Points 89
8.4.4 Earthing Conductors 89
8.4.5 Earthing Points for Intake and forebay 90
8.4.6 Lightning Protection 90
8.4.7 Accessories 90
8.4.8 Drawings and Information 90
8.5 Earthing System Tests 91
8.6 Earthing System Spare Parts 91
SECTION 9: CABLES AND CABLE TRAYS 92
9.1 General 92
9.2 References Standards 92
9.3 Scope of Work 93
9.4 Design Requirements 94
9.4.1 Main Technical Characteristics 94
9.4.2 Medium Voltage Cable 95
9.4.3 Low Voltage Cable 95
9.4.4 Control Cable 96
9.4.5 Metering and Protection Circuit Cables 96
9.4.6 Measuring Cable 96
9.4.7 DC Cables 97
9.4.8 Cable Supports and Other Steelwork 97
9.4.9 Erection of Supports 97

9.4.10 Installation on Racks 97
9.4.11 Installation on Trays 98
9.4.12 Cable Ducts 98
9.4.13 Cable Markers 98
9.4.14 Core Identification 98
9.5 Testing and Commissioning 98
9.5.1 Factory/Works Tests 99
9.5.2 Site Tests 100
9.6 Spare Parts 101
SECTION 10: EMERGENCY DIESEL GENERATOR SET 102
10.1 Scope of Work 102
10.2 Reference Standards 102
10.3 Design Requirements 103
10.3.1 Diesel Engine 104
10.3.2 Operations, Interlocking and Synchronization 104
10.3.3 Generator 105
10.3.4 Control Panel 106
10.3.5 Fuel Oil System 106
10.3.6 Lubricating Oil System 106
10.3.7 Starting Battery 106
10.4 Diesel Generating Unit's Tests 107
10.4.1 Workshop Tests 107
10.4.2 Site Tests 107
10.5 Spare Parts 108
SECTION 11: TELECOMMUNICATION SYSTEM 109
11.1 General 109
11.2 Reference Standards 109
11.3 Scope of Supply 109
11.4 Design Requirements 112
11.4.1 EPABX System 113
11.4.2 Radio Communication System 114
11.4.3 Repeater Station, VHF Band. 114
11.4.4 Power Supply Units 114
11.4.5 Communication Cable System 114
11.4.6 Closed Circuit Television System (CCTV) 115
11.4.7 Communication and Security Systems Tests 115
11.4.8 Public Address System 115
11.5 Tests 116
11.5.1 Workshop Tests 116
11.5.2 Site Tests 117
11.6 Spare Parts 118

SECTION 12: ELECTRIFICATION WORK 119
12.1 General 119
12.2 Reference Standards 119
12.3 Electrification of Power Plant 120
12.3.1 Scope of Supply 120
12.3.2 Design Requirements 120
12.3.3 Testing 123
12.3.4 Spare Parts 123
SECTION 13: TECHNICAL SPECIFICATIONS OF TRANSMISSION LINE 124
13.1 Transmission Lines 124
13.1.1 Applicable Standards 124
13.1.2 Site Conditions 124
13.1.3 Units of Measurement 125
13.1.4 Design and Document Submission 125
13.1.5 Design Calculations 125
13.2 Selection of Line Route and Tower Structure 125
13.3 Lattice Steel Tower Structure 126
13.3.1 General Requirement of Steel Tower (132 kV) 126
13.3.2 Material 127
13.3.3 Steel Properties 127
13.3.4 Chemical Composition 127
13.3.5 Tensile Properties 127
13.3.6 Bolt Size and its Spacing 128
13.3.7 General Requirements of Steel Tower (11 kV Lattice Poles) 128
13.4 Survey and Right of Way 129
13.5 Foundation Requirements 129
13.5.1 General 129
13.5.2 Structural Design of Foundation 129
13.5.3 Design Loads 130
13.5.4 Types of Foundations to be used 130
13.6 Tower Erection 131
13.6.1 Equipment and Method 131
13.6.2 Damage to Galvanizing 131
13.7 Stringing of Conductor and Earthwire 131
13.8 Tower Signs and Mark of Warning 132
13.9 Anti-Climbing Devices 132
13.10 Grounding of Towers 132
13.11 Conductors and Insulators for Transmission Lines 132
13.11.1 Technical Data 133
13.11.2 Overhead Shield Wire 133
13.12 Insulators 134

13.12.1 Disc Type Insulators for 132 kV Line 134
13.12.2 Pin Type Insulator (11kV) 135
13.13 Stringing of Conductor and Overhead Shield Wire 135
13.13.1 Conductor Sagging 136
13.13.2 Erection of Vibration Dampers 136
13.13.3 Splices and Dead Ends 136
13.14 Tests 142
13.14.1 General 142
13.14.2 Manufacture's Tests 142
13.14.3 Acceptance Tests 143
13.14.4 Acceptance and Rejection Test 143
13.14.5 Assembly Test 144
13.14.6 Test Method 144

LIST OF TABLES

Table 1: Weighted Average Efficiencies 2
Table 2: Technical Data for Power Transformers 20
Table 3: Technical Data for Station Service Transformers 21
Table 4: Minimum Creepage Distance 23
Table 6: Clearances for High Voltage Switchgears 36
Table 7: Specification of Earth wire 44
Table 8: Specifications for Disc Type Porcelaine Insulator 45
Table 9: Rated Currents for Panels 51
Table 10: Ratings for Circuit Breakers 52
Table 11: Characteristics for the Winding 53
Table 12: Characteristics for Voltage Transformers 54
Table 13: Ratings for Surge Arresters 55
Table 14: Characrteristics for Batteries 63
Table 15: System Data 126
Table 16: Types of 132 kV Line Towers 126
Table 17: Chemical Composition of Steels 127
Table 18: Tensile Properties of Steel 127
Table 19: Minimum Edge Distances of Bolts 128
Table 20: Minimum Spacing of Bolts 128
Table 21: Conductor Specifications 133
Table 22: Technical Specification of Porcelain Disc Insulator Data 134
Table 23: Technical Data of Pin Insulator 135
Table 24: Minimum Number of Samples for testing Chemical Composition 144
Table 25: Limits for Chemical Composition 145
Table 26: Bend Test Requirements 145
Table 27: Tensile Test Requirements 145

SECTION 1: GENERATORS

1.1 Scope of Work

This chapter specifies the requirement for the design, supply, installation, tests and commissioning of four vertical shaft, Salient pole, three-phase A.C. Synchronous Generators having capacity of 6.8 MW (3 Nos) and 2.13 MW (1 No), for direct coupling to Francis turbines, complete with excitation and auxiliary equipment. The generators shall be supplied with the main components as a complete functional unit including but not limited to the following:

1.2 Reference to Other Chapters

As regards climatic conditions, elevation, physical infrastructures such as access roads, bridges capacity for transportation of rotor and Transformer, reference is made to the Instructions to Bidders.

1.3 Design Requirements

a) Generator Main Data

No. of Generators/Rated Speed/No. of Poles (Main Units)	3/500/12	No/rpm/No
No. of Generators/Rated Speed/No. of Poles (Aux.Unit)	1/750/08	No/rpm/No
Rated unit output (Main)	8.5	MVA
	6.8	MW
Rated unit output (Aux)	2.66	MVA
	2.13	MW
Total Capacity of Plant	22.53 MW / 28.16 MVA	
Rated Current	446 & 139	A
Rated Power Factor	0. 80	p.f
Rated Voltage	11	kV
Power Frequency	50	Hz
No. of Phases	3	phases
No. Poles	12-8	No.
Rated Speed	500-750	rpm
Runaway Speed at rated head	616-924	rpm
Continuous overload	10	%
Efficiency	95	%
Winding Connection:	Star connect, nutral grounded	
Ambient temperature (Max)	40	°C
Cooling of stator and rotor	Air/water heat exchanger	
Cooling of Guide and thrust bearing oil	Oil/water heat exchangers (if necessary)	

Maximum cold cooling water temperature	24 °C
Protection Class	IP 44
Insulation class	F
Excitation	Static
Rotor weight	40 Ton

The values specified above, relate to tender level design. All parameters will be finalized by Designer of EPC Contractor in compliance with the Employer's requirements, standards and specifications.

The bidder shall also Aquent himself of the access condition such as roads Culverts and bridge capacities for transportation of the heaviest part to their respected sites before signing the contract.

Each generator shall have the following auxiliary equipment:

b) Generator Rated Output and Efficiency

The efficiency shall be in accordance with latest IEC publication 60034-2 but shall not be less than 95 %. The rated and average weighted efficiency shall take into account the losses of the excitation system. The thrust bearing losses shall not be included in the efficiency calculation. The permissible Tolerances shall be in accordance with latest IEC Publication 60034-1. The maximum continuous output within Class F temperature rise with all heat exchangers operational will be stated in the Tender.

Guaranteed Output, Efficiency, Penalty and Price Adjustments

The continuous rating of generators after final installation, measured at the rated values of frequency, power factor and terminal voltage will be 8.5 MVA (3) & 2.66 MVA (1), with temperature rises within guaranteed limits.

Guaranteed Efficiency

The Contractor shall state, Technical Guarantees in the technical bid the generator efficiency at rated frequency, rated voltage, PF 0.80 and 1.00 and at the following outputs:

- 100 %
- 75 %
- 50 %

The weighted average efficiency shall be calculated by applying the following weight factors:

Table 1: Weighted Average Efficiencies

S/SN %	Power Factor		Sum
	0.80	1.00	
100	35	15	50
75	25	10	35
50	10	5	15
Sum	70	30	100

The minimum guaranteed weighted average efficiency of each generator shall not be less than 93.5%.

The efficiency shall be declared according to IEC Publication 60034-2 (1972) and shall take into account the losses of the excitation system. The thrust bearing losses shall not be included in the efficiency calculation. Tolerances shall be permitted according to IEC Publication 60034-1.

If the Shortfall in Weighted Average Efficiency exceeds 1.5 %, then the Employer may reject the associated generator ; in which case the Contractor shall design, construct, supply and install free of charge to the Employer a new generator with satisfactory performance. Further, in this case the Contractor shall carry out site efficiency tests of all units.

Penalty

The guaranteed output and the guaranteed efficiency shall be used to determine the Contract price reduction to be imposed in case the generators deviate from the performance guarantees. Deductions applied for each generator shall be calculated as stipulated.

1.3.1 Insulation and Temperature Rise Limits

The stator and rotor pole winding insulation will be of epoxy type Class F.

The stator and rotor winding temperature rise, while delivering continuously the rated plant power output, at any voltage and frequency in the specified operating range will not exceed the following temperature rises over the temperature of the cooling air not exceeding 40°C:

- Stator 80 K
- Rotor 90 K

The cooling raw water temperature is expected not to exceed 20°C. The Contractor will guarantee the above temperature rise limits and suitable means for their measurement will be provided in the stator and rotor.

The maximum temperature rise, measured by embedded temperature detectors (ETD), of any part of the stator core not in contact with insulated windings, including the clamping and flux-shielding arrangements, will not exceed the permitted temperature rise for parts in contact with insulated windings by more than 10 K at maximum continuous rated load and at lagging and leading power factors. The detectors shall be suitable distributed throughout the winding and the number of detectors installed shall not be less than six per phase.

All reasonable efforts, consistent with safety, shall be made to place the detectors at the points where the highest temperatures are likely to occur, in such a manner that they are effectively protected against contact with the primary coolant.

1.3.2 Short Circuit Withstand Capability

The generator and all accessories shall be capable of withstanding without permanent deformation, mechanical or electrical damage, or dangerous temperature rise while operating at any load under following fault conditions without exceeding material yield stress.

- Single-phase or phase to phase short circuits for two minutes.
- Full voltage sudden three-phase short-circuits at its terminals for 3 seconds.

1.3.3 Stability and Performance

The generators will operate satisfactorily in parallel with each other, units connected to the grid as well as in isolated mode. The generators will be capable of operating on sudden application or loss of maximum load and during momentary short circuits and sustained earth faults without causing any abnormal vibration or resonant conditions. The generators shall be designed for stable operation at rated voltage connection with the system via the generator Transformer with a maximum phase angle displacement of 120 electrical degrees.

1.3.4 Runaway Speed Withstand Capability

The generators will be designed and constructed to safely withstand, without incurring damage, the maximum runaway speed of the turbine for a duration of 2 min, with cooling water flow available. The runaway speed test shall be considered as satisfactory if no permanent abnormal deformation is apparent subsequently, and no other deformation is detected which would prevent the machine from operating normally and provided that the rotor windings after the test comply with the required dielectric tests. After this test the generator will withstand the high voltage test at 80% of the dielectric test voltage. The duration of any overspeed test will not be less than 2 min.

1.3.5 Structural Design and Steel Work

The generators shall be three-phase synchronous machines with horizontal layout and shall satisfy the requirements of the latest publication of IEC Standard No. 60034 for synchronous machines. The design should be for 30 years minimum operating lifetime.

Only such materials that are appropriate for the respective purpose and have been checked for their reliability and fatigue endurance shall be used for the construction of the synchronous machines. Due to the climatic conditions at site, small pieces shall be made of corrosion-resistant materials, while large parts may be made of corrosion- protected materials.

For screws and nuts and parts subject to severe strain, only materials with guaranteed characteristics and ageing resistance shall be used. When selecting the materials for screws and nuts, the mode of operation of the generally used, compressed air-driven hammering screwdrivers shall be observed.

Cast-steel parts shall be stress-relief annealed. After stress-relief annealing, no welding is permitted. Type and performance of thermal treatment shall be described and be proven by annealing certificate.

The generator shall be designed and constructed so that all disturbing vibrations and avoidable noises are eliminated. The noise level shall not exceed 85 dB measured after installation. In case the specified values are exceeded, the Contractor shall take additional measures to satisfy the specifications. Any material being used for noise suppression shall be flameproof. The designed shall also facilitate all repair works, maintenance and inspection of the generator and turbine parts with a minimum of disassembly work.

The generators shall be designed to withstand all fault situations that can be experienced during operation without any displacement of its windings or mechanical damage to any of its parts or to the generator foundations due to the following conditions:

- Short circuit between two or three phases at its terminals
- Faulty synchronization

- Magnetic unbalance due to pole winding failure
- Runaway conditions

Temperature rise of the windings shall not exceed the values stated in IEC Standard No. 60034 for insulation class F, measured by ETD (embedded temperature detectors) for the stator winding and by the resistance method for the rotor winding.

1.4 Generators Terminal Equipment

The stator winding shall be terminated by means of six bushings on the stator housing, three for the phase outlets and three for the neutral end outlets.

The neutral end equipment shall have the same insulation level as the phase terminal equipment.

The neutral point shall be connected to earth through a resistor, dimensioned to limit the maximum earth fault current and shall withstand this current for minimum 5 Seconds. The resistor shall have a removable link for disconnecting the resistor. Inside the generator pit, the phases and neutral point bus bars shall have safety provisions against accidental touching.

1.4.1 Busbar Equipment

All busbars and equipment shall be designed to withstand, without any damage whatsoever, all stresses caused by the maximum asymmetrical short circuit (peak) current corresponding to the symmetrical values.

1.4.2 Stator Core and Frame

Stator frame shall be of welded plate construction, and the stator housing shall include all necessary access for inspection and maintenance purposes.

The stator core shall be built up with high-grade, non-ageing, thin laminated, oriented magnetic steel with a thickness of 0.5 mm. The loss coefficient shall not be more than 1.15 W/kg at 1 Tesla. After punching, each lamination shall be checked to ensure that burrs do not exist. The laminations shall be coated on both sides after punching with non-ageing, temperature resistant insulating varnish or other suitable material to minimize eddy current losses.

The stator core laminations shall have a uniform tightness and the ventilation air ducts shall be properly supported, to avoid core vibration and deformation. Special care shall be taken to avoid short-circuit of the insulating coating at any point.

The fastening of stator core to stator housing shall be described and shown by drawings. Mode of transfer of forces arising in the stator core (weight, torque, short-circuit forces and thermal expansion forces) to the stator housing shall be described and shown by drawings. Special attention shall be given to the stator joints, which shall be illustrated by drawings. Erecting mode of this special part shall be described for the synchronous machine offered. All above-mentioned illustrations shall be submitted with the Bid.

1.4.3 Stator Winding

The stator winding shall be made of insulated stranded copper conductors, stacked and form pressed to the design cross section. Each coil shall be insulated for the full generator voltage. The insulation shall consist of multiple layers of vacuum-pressure impregnated mica tapes or with a cast resin insulation system. Coil insulation shall be applied continuously throughout the coils with equal

thickness to both the slot and end-turn portions. All coils of the same type shall be of uniform dimensions to be completely interchangeable.

The stator winding insulation shall be of a non-flammable type and conform to Class F as defined by IEC Publication 60085. Full description of the composition and make of the insulation system shall be submitted with the Bid.

The coils shall fit in to the stator slots with narrow tolerances and be secured against loosening during operation by spring type wedges, or other approved method. The winding voltage withstand levels shall comply with IEC 60071.

Removal of the stator bars shall be possible without deformation of the bars or damage to the main insulation.

The coils shall be protected against surface partial discharges (corona) outside the stator iron by applying a semi-conductive varnish. The method for corona suppression and voltage gradient control shall be described in the Bid.

The end portions of the winding shall be rigidly supported to prevent movement and distortion under the most unfavourable (short-circuit) conditions. All support structures shall be made of non-magnetic material.

The stator winding line ends, and neutral ends shall be brought out to six terminals on the stator frame. Neutral end terminals shall have the same insulation level as the phase terminals.

1.4.4 Rotor Rim and Poles

The magnetic circuit of the rotor shall be made of thin low loss silicon steel sheets varnish coated, the sheets shall be stacked up and separated by cooling channels; they shall be press fitted and shall be firmly maintained with the help of tightening clamps located at both ends. The rotor shall be built according to the best practice and design to withstand safely all overloads and other stresses encountered during abnormal operation or runaway speed conditions.

All rotor parts such as shaft, rotor spider, rotor rim, pole cores and pole windings shall be guaranteed to withstand the maximum unit stresses at any speed up to and including the maximum runaway speed without exceeding 70% of the respective material yield strength and 50% of the rupture strength.

Fan blades shall be fitted at each end of the rotor body. The design of the fan blades shall be such as to avoid loosening during operation. In case of laminated rim, a ventilated rim can be used. Suitable air guides shall be provided for the correct distribution of the ventilation air and to minimize air friction losses.

The poles shall be built of thin steel laminations, bolted under high pressure and furnished with dovetails for fastening to the rotor rim. Rotor design shall allow dismantling of the poles without any disassembly of the stator, rotor or spider brackets.

1.4.5 Field Winding

The field winding shall be insulated with Class F insulation in accordance with IEC publication No. 60085 comprising thermoset epoxy resin. The coil of the induced circuit shall be made of electrolytic insulated copper conductors, which are placed into the slots where they are maintained with the help of Insulation wedges at the level of the magnetic circuit.

Insulation shall be realized with the help of class F quality materials according to the thermo-hardening process. Conductors shall be insulated with the help of a mica tape winding. After the rotor has been placed, the whole unit shall be treated under vacuum before being impregnated with varnish.

An interconnected damper winding shall be provided in the pole faces to minimize the difference between the quadrature and direct axis sub-transient reactance and improve stability under fault conditions. The cage dimensions shall be such as to maximize rotor damping of hydraulic transients generated by the turbine

1.4.6 Shaft

The shaft shall be of ample size to operate safely at any speed up to and including the maximum runaway speed without detrimental vibration or distortion and to carry the turbine torque at maximum power, PF = 1.0. The shaft shall be machined accurately all over and polished at the bearing regions.

The shaft shall have a central hole of adequate diameter bored axially throughout the shaft length. Bore finish shall be sufficiently smooth to allow visual inspection of the central material.

The shaft shall include:

- A non-driving-end bearing race
- Welded arms which receive the rotor magnetic circuit
- A Driving-End bearing race (if any)

The rotor shall be carefully balanced and shall easily accept a runaway speed for a duration of 2 minutes without undergoing any damage.

1.4.7 Bearings

The bearings shall be of the sleeve type located in end shielded supported by the frame.

The bearings shall be completely self-lubricated, incorporating their own oil circulating systems without external motor-driven pumps. The housings shall have ample storage volume for the oil. Top covers shall have ample inspection openings.

Each bearing shall be provided with oil drainage valve(s) with fittings for connection to an oil-emptying hose and fittings with a valve and a replaceable strainer for connection to an oil-filling hose.

The mechanical protection shall be ensured by a casing unit composing the "bearing box". Lubrication shall be by oil ring system with a water coil inserted in the oil basin in order to keep the Babbitt temperature within its suitable capacity of any condition, which may occur.

Each bearing oil system shall be equipped with oil level indicator with minimum and maximum contact, flow indicator with signal contact for minimum flow to external heat exchangers (if applicable), Pt-100 element for the oil reservoir for remote indication and pressure switch for low oil pressure shall also be provided

Oil/water heat exchangers shall be provided. In the case of external heat exchangers, flow detectors shall be mounted in the piping for monitoring the oil flow.

1.4.8 Generator Brakes

Each generator shall be provided with pneumatically operated mechanical brake with air to be supplied from station compressed air system.

The air receiver shall be of sufficient capacity for at least five complete braking operations without make-up air.

Pneumatical brake will be applied at 10% of rated speed. The brakes shall remain applied when the machine is stationary.

The braking system shall be electrically interlocked with the turbine guide-vane locks and the generator main circuit breaker so that the brakes cannot be applied either automatically or from the manual control switch, unless the guide-vanes are closed, and the generator circuit breakers are open. Each brake pad shall be provided with at least two interlock and alarm position switches.

The brake linings shall be suitable for 25,000 braking operations before they require to be renewed.

1.4.9 Fire Protection System

The powerhouse shall be provided with a fire extinguishing system of water spray type.

The water for the water spray system shall be taken from the powerhouse fire fighting water main supply/from penstock upstream of Inlet valve.

The Contractor shall supply all equipment for the water fire extinguishing system inclusive of pipes, spray heads, valves, locks, key cabinet, and notice.

The fire protection system shall comply with standards and codes of NFPA 851 National Fire Protection Association (and additional NFPA regulations).

Firefighting water supply will be drawn directly from the penstock upstream of unit inlet valve. The pressure in the penstock is sufficient to provide an adequate head for water for firefighting. The system includes piping, valves, flexible hoses, box cabinets and fire hydrant for outside use.

The firefighting system for Electrical equipment of the power plant shall be based on CO2 fire extinguisher system. Trolley mounted and portable fire extinguishers in accordance with ISO standard shall be installed/placed at all key locations of the project

1.4.10 Control and Instrumentation

The Contractor shall supply and install all the necessary auxiliary equipment, pipework, tubing, fittings, orifice plates, flanges, pockets and other items to provide the complete control and instrumentation for each unit.

The bearings shall be equipped with necessary instrumentation i.e. flowmeters, oil level indicators, water level indicator, etc.

Temperature detectors shall be located in the area of maximum predicted temperature, in each component or part. Where limitations imposed by electrical safety or mechanical integrity at the measuring point dictate otherwise, measuring point locations shall be subject to the Engineer's approval.

Temperature detectors other than those in the windings and core shall be housed in suitable pockets, and in all cases a second pocket with a screwed protection cap shall be provided alongside to accommodate a liquid-in-glass thermometer for temperature detector calibration.

Resistance-type temperature detectors (PT-100) shall have a resistance of 100 ohms at 0°C and shall be permanently wired to a marshalling box outside the generator housing. The detector and bridge circuits shall be wholly insulated. Common point connections may be used in the detector circuit wiring for any one resistance thermometer, but there shall be no common point between separate resistance thermometers. The spare embedded temperature detectors in the core and windings shall be permanently wired to the above marshalling box.

1.4.11 Anti-Condensation Heaters

To avoid water condensation during long non-operative periods of the machine, heating elements shall be installed in the air circuit and in the excitation cubicles. These elements shall be connected to the 400/230 V A.C., 50 Hz power source, via contactors.

The number of these heating elements and their energy requirements are to be stated in the Technical Schedules.

Necessary contactors for switching the heating power on and off, as well as the necessary internal wiring, shall be part of the generator supply. Terminal blocks for external connections of power shall be located centrally.

1.4.12 Generator Cooling System

The generators shall be based on a closed-circuit ventilation system with air-water heat exchangers. The circulation of air being by means of fans attached to the rotor or by a ventilated rim shall dissipate the machine losses, to limit the temperatures to the values defined by the class of temperature rise. Manually operated valves must be provided to allow isolating of the individual coolers from the cooling water system for removal and cleaning of the coolers.

The heat exchangers shall have sufficient capacity to maintain the temperature of the air entering the generator at or below 40°C under the required maximum load conditions. The water coolant temperature at the inlet to a machine or heat exchanger shall not exceed +25 °C nor be less than +5 °C

The surface air/water heat exchangers arranged around the periphery of the stator frame shall be mounted in a simplified manner to allow easy access for maintenance, repair and dismantling. The heat exchangers shall be of straight through design to facilitate cleaning.

Heat exchangers, pipes, strainers, valves and measuring devices shall be placed so that each element can be easily removed for inspection and cleaning. An isolation valve shall be available in the inlet and in the outlet connection between each heat exchanger and header so that any heat exchanger can be readily removed without interfering with the operation of the remaining heat exchangers.

Approved means for draining and for releasing entrapped air of all heat exchangers and pipe work shall be provided. The heat exchangers shall be equipped with a collecting and drainage system for condensed vapour.

SECTION 2: EXCITATION SYSTEM

2.1 General

The excitation system shall be of the static, constant-voltage type with controlled thyristors. It shall feature a very sensitive, quick acting control of the generator voltage and reactive power respectively. The system shall be of reliable design with an adequate record of satisfactorily working reference plants. The excitation systems with the related parameters, performances, scope and methods of testing and the excitation system components will be in conformity with respective to IEEE 421.

2.2 Scope of Work

The supply of four sets of generator static excitation system shall include the main components for complete functional system but not limited to the following:

- Dry-insulated Excitation Transformers encapsulated, or cubicle mounted, with L.V. and M.V. connections
- Field breaker, de-excitation, over voltage protection, protection and control devices
- Field flashing and field suppression equipment
- A.C. /D.C circuit breaker, cubicle mounted
- A.C./D.C. converter with controlled thyristors assembly
- Electronic Automatic Voltage Regulator (AVR)
- Control and supervisory system for manual and automatic operation.
- Equipment for Remote communication
- HMI panel mounted on excitation panel for local control, supervision, and testing
- All necessary indicating equipment
- All necessary protective and alarm devices
- One set of maintenance tools

The equipment shall be arranged in cubicles and installed in main Control Room.

2.3 Design Requirement

2.3.1 General

The excitation system shall be of the static, constant-voltage type with controlled thyristors. It shall feature a very sensitive, quick acting control of the generator voltage and reactive power respectively. The excitation cubicles shall be metal enclosed, rigid, self-supporting, free-standing panels and shall provide easy access to the equipment for installation and maintenance.

Excitation power shall be taken directly from the generator terminal and supplied to the excitation rectifier via the excitation Transformer. The excitation system shall be independent of any outside power supply except short-time external supply for voltage build-up. The excitation system shall be of well-proven design with operational records from similar installations and service conditions. The excitation systems with the related parameters, performances, scope and methods of testing the excitation system components will be in conformity with IEEE 421.

The excitation system shall operate correctly and continuously even if the excitation Transformer is supplied with unbalanced voltages.

The rectifier assemblies will be directly fed from the excitation Transformer connected to the generator terminal through MV cable. The excitation equipment will be designed for supplying without exceeding the continuous rating, ample excitation for the generator operating at its maximum capability at rated frequency, rated power factor and at 105% rated voltage. Separate current and voltage transducers will be provided in the excitation cubicles to transmit the generator and excitation current/voltage values to the Plant Control Unit.

The control features will include Local/Remote/Manual/Automatic control of the systems from the excitation control cubicle, the Unit Control Board and the Plant Control system.

The excitation system shall have built-in protection and supervision equipment. All fault signals shall be displayed on the AVR front panel. Potential-free signal contacts for alarm and unit shutdown shall be provided. The excitation system shall include but not limited to the following:

- AC exciter (Excitation Transformer)
- Thyristor Rectifier bridges
- Draw-out AC circuit breaker
- DC over voltage and discharge circuit
- Field Flushing Circuit
- Equipment for Remote Communication
- HMI panel mounted on excitation cubicle for control supervision and testing
- Automatic Voltage Regulation (AVR) Features
- All necessary indicating equipment
- All necessary protective and alarm devices

2.3.2 Excitation Transformer

The excitation Transformer shall be Air Cooled (AN) cooled and of dry insulated type using non-flammable Class B insulating material. It shall be encapsulated/cubicle mounted or installed in a cage, to achieve personnel safety. Embedded temperature detectors (Pt-100) for monitoring winding temperatures shall be included.

Rated secondary voltage and rated output of the excitation Transformer shall be determined by the Contractor to conform to the required rectifier ceiling voltage and current during dynamic load conditions.

2.3.3 Excitation Rectifier

The excitation rectifier shall be of solid-state type with controlled silicon power thyristors for both polarities. It shall be capable of reversing its output voltage to obtain fast response in case of load rejection and unit over speed. Each rectifier branch shall consist of at least two sets of thyristors mounted in parallel as redundant, so that one set of thyristors can be removed during operation. The remaining thyristors shall have capacity for unrestricted operation of the generating unit, and be capable of enduring a short circuit on the generator terminals from 120% of nominal field current.

The rated continuous output of the excitation rectifier shall correspond to not less than the excitation power required for continuous operation of the generator at rated output and power factor and 105% of rated voltage.

The excitation rectifier shall preferably be of the self-ventilated type. If forced ventilation is offered, redundancy of the cooling system must be provided to avoid shut- down of the generator in the event of breakdown of the fan motors. Description of the operation and monitoring of the cooling system must be included in the Bid.

The thyristors shall be protected against D.C. short circuits with high-speed fuses. Each thyristor shall be equipped with a PT100 temperature sensor so that individual thyristor temperatures can be monitored. Each thyristor fuse shall be equipped with a micro-switch for blown fuse indication. Each phase shall be equipped with current measuring and the HMI shall display the different phase currents.

Complete monitoring of the thyristor bridge shall be available on the HMI. The HMI shall provide a graphical representation of each thyristor bridge, with display of temperatures, fuse monitoring, current monitoring, and fan monitoring. The following annunciation and control shall be available:

- Blown fuse indication providing information regarding exact location of failed fuse
- Temperature monitoring with user adjustable alarm and trip setting
- Temperature and current trending of each thyristor in order to predict failures
- Indication of current flowing through each phase of the bridge
- Indication of failed fan
- Control for switching fans

Two independent thyristor trigger pulse units shall be installed, one for the automatic voltage regulator, the other for manual excitation control.

2.3.4 Excitation Circuit Breakers

The excitation system shall comprise one A.C. circuit breaker and one D.C. circuit breaker. The breakers shall be cubicle mounted with approved position indicators on the cubicle front. The cubicles shall include complete internal wiring. All external connections for signalling and remote control of the breakers shall be terminated at easily accessible terminal strips.

The A.C. circuit breaker shall operate during normal start and stop of the unit, as well as during clearing of fault conditions. The D.C. circuit breaker shall be in closed position during normal start and stop of the unit but shall disconnect the rectifier during electrical fault conditions.

The circuit breakers shall be able to break the field current under the most unfavourable fault conditions, i.e., short circuit of the generator from full load or loss of synchronization, without causing damage to the breakers or adjacent equipment.

Each circuit breaker shall be furnished with one closing coil, two separate opening coils and anti-pumping device. Four position-indicating switches for signalling "Breaker Open" and four switches signalling "Breaker Closed" shall be furnished as a minimum. The construction of the breaker shall be such as to allow easy inspection, maintenance, and testing.

2.3.5 De-Excitation System

Opening of the A.C. circuit breaker shall perform de-excitation during normal shutdown of the unit. Simultaneously, the AVR shall trigger all thyristors simultaneously to fully open state, thereby providing a "free-wheeling" circuit for the field current.

2.3.6 Field Suppression System

The field suppression system shall consist of voltage-dependent resistors, dimensioned to withstand the excessive field currents resulting from fault conditions. The equipment shall withstand a slip-out of synchronism or a 3-phase short circuit at the generator terminals from full rated output and 105% of rated voltage.

For the conditions of tripping the unit under rated load and 105% of rated voltage, the Bidder shall state the maximum slip-ring voltage and the de-energizing time from 105% to 5% of rated generator voltage.

Tripping of the D.C. circuit breaker shall instantaneously put the field suppression system into operation.

2.3.7 Over Voltage Protection

An over voltage protection against induced over voltages in the field circuit must be provided. The Bidder shall include details of the protection characteristics with the Bid.

2.3.8 Automatic Voltage Regulator (AVR)

The control of generator voltage shall be achieved by comparing continuously the generator voltage with a reliable reference voltage. Adjustment of the reference voltage, set point shall be performed locally by a switch on the AVR front and remote by a voltage signal. Switches for remote adjustment of set points for the regulator will be installed in the respective Local Control Units. The Automatic Voltage Regulator shall have the following features

- Local, Remote, Auto and Manual control mode
- Reactive Power/Power Factor control mode
- Power System Stabilizer
- Over Excitation Limiter
- Under Excitation Limiter
- Over/under Voltage limiter
- Over/under frequency Limiter
- Reactive compensation
- Arrangement for remote communication
- Voltage adjustment for synchronizing.

The AVR shall respond quickly and accurately to any fluctuations in generator load including sudden application or throw-off of load. The static accuracy shall lie within tile range of + 0.5% of the set value of the generator voltage at normal operating conditions. The generator voltage shall be

maintained at or below 110% of rated value with the generator disconnected and at maximum over speed condition.

Over- and under-excitation limiters shall be included. The under-excitation limit shall match the static and dynamic stability curves for the generator.

On over-voltage resulting from sudden loss of load or over-speed up to 140 % of normal speed, the regulating equipment shall limit the instantaneous output voltage change to plus thirty percent (30 %) of the voltage held before the over-voltage and/or over-speed occurred, and shall bring back the voltage to normal value in about 1 sec. The regulating equipment shall be provided with a minimum excitation limiter with adjustable setting to automatically prevent a decrease in generator excitation which would result in a pull out from synchronism under operation between no-load and 100 % load.

2.4 Measuring, Indication and Protection

The generator will be provided with instruments, control and protection devices and switches as necessary for operation with high degree of safety, reliability, and continuity of service. A list of instruments will be furnished for each generator, providing local and remote indication.

All signal contacts shall be potential-free, normally open contacts, rated for 220 V D.C. Dial indicators and gauges shall be mounted together in a common instrument panel, as far as possible.

A tachometer shall be provided for monitoring speed and detecting set values for stopping, synchronizing and over-speed. The system shall include set of electronic modules with 220 V DC power supply. Wiring between sensor and modules shall be shielded and earthed at the module.

All resistance type temperature detectors (R.T.D.) shall be of the 3-wire Pt-100 type. Each generator stator winding shall be provided with RTDs for temperature measurement of stator winding.

Mercury dial type thermometers shall be equipped with minimum two adjustable signal contacts for high temperature, for alarm and tripping respectively.

Fire detectors may be either temperature sensitive switches or smoke detectors, according to the manufacturer's well-proven practice.

The Contractor will consider these items in his scope and will also include any additional item not included in the list but necessary for reliable operation and safety of the personnel and the equipment. Generator related temperatures and other necessary data will be displayed on the UCB

2.4.1 Lighting

For the generator pit a complete lighting and single-phase socket outlet installation with a sufficient number of lamps shall be provided. The scope of works shall include the lamps, socket outlets, switches, cables, the fixing and the installation material.

The lighting circuit shall be switched at various locations inside of the generator pit by means of light push buttons. There shall be at least one waterproof outlet located in the space between each air cooler

2.4.2 Piping and Wiring

The generator supplier shall supply and install all necessary piping, wiring, etc., between the various generator and excitation equipment and between the generator equipment and the external connections as specified under the articles above. The instrument leads from the stator, bearings,

water and air temperature detectors etc. shall be brought in a neat and well protected manner to easily accessible terminal boxes outside the stator housing, for connection to external wiring. Separate terminal boxes shall be used for the leads from Pt-100 elements

2.4.3 Erection Equipment /Special Tools:

- Lifting devices for stator, spider brackets and rotor/shaft
- Tools and equipment for stator coils
- Tools and equipment for bearing assemblies
- Tools and equipment for rotor and poles
- Set of slings
- Any other special erection tools

2.5 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

2.6 Tests

The principal, requirements of generator testing procedure and conditions shall be governed by the IEC Standards 60034.

The manufacturer shall provide a schedule for all relevant tests for approval by the Engineer.

2.6.1 Factory Test

a) Material Tests

All materials shall be tested and/or test results verified by signed test reports, according to requirements stated in the specifications.

I. Magnetization Tests

The stator core shall be subject to magnetic flux tests. The test shall be performed before commencement of the stator winding installation. The flux density in the core during the test shall correspond to the operational flux density. The test duration shall be at least 60 minutes.

II. Dielectric Tests

The coils or bars of the stator winding shall be subject to several sample tests during manufacturing and prior to insertion in the slots of the stator core. All such tests shall be performed according to the applicable IEC recommendations.

The test to be performed shall include but not be restricted to:

- Voltage withstand test between elementary conductors using 110 V, 50 Hz, on all bars before applying main insulation.

- High voltage withstands tests of the bar main insulation on all bars before loss angle measurement. The test voltage shall be 120% of the stator winding test voltage as specified in IEC Standard 60034- 1, for 1 min.
- Dielectric loss angle measurement at room temperature for the slot portion and end turn portion of all stator bars.
- Insulation breakdown test (performance test) for the slot portion of the stator bars. The test shall be performed on 5% of the total number of bars, randomly selected.
- High voltage withstands test of the winding of each stator segment after assembly.
- All generator components or parts containing electrical insulation shall be subject, in the assembled state, to appropriate dielectric tests according to the provisions of the applicable IEC publication.

III. Auxiliaries and Accessories

- All generator auxiliaries and accessories shall be tested individually according to the provisions of the applicable standards.
- Certified test data covering each part of the generator accessories and auxiliaries shall be submitted for the Engineer's approval.

IV. Excitation System

- The set of excitation and voltage regulating equipment shall be subject to a full series of performance tests at the factory, unless the manufacturer can present a comprehensive report on performance based on tests with the same type of excitation system with approximately the same rating.
- All excitation equipment components or parts containing electrical insulation shall be subject, in the assembled state, to appropriate dielectric tests according to the provisions of the applicable IEC publication.

b) Workshop Acceptance Tests

Before any part of the supply can leave the factory, the test specified under article “Material test and test performed by the manufacturer” shall be accepted by the Engineer. In addition, the following tests shall be performed:

- Power frequency high voltage withstand test on assembled stator windings.
- Measurement of stator, winding insulation resistance and polarization factor.
- High voltage insulation test on embedded temperature detectors and their connections.
- Resistance checks on embedded temperature detectors.
- High voltage withstand test on all individual rotor poles of the rotor winding main insulation. The insulation shall withstand a one-minute, 50 Hz voltage test according to IEC Standard No. 60034- 1.
- High frequency, interturn insulation test on all individual rotor poles.

2.6.2 Site Tests

a) Pre-Commissioning Tests

Before the generator is put into normal operation, tests shall be carried out by the Contractor in the presence of the Employer and/or the Engineer to determine whether the generator and generator equipment meet the guarantees and other technical requirements set forth in the Contract Documents.

The Contractor according to the requirements specified in the specifications shall provide testing equipment and technical personnel for the tests.

The site tests of the generator and the accessories shall be made according to the provisions of the applicable IEC publications.

The site tests shall include but not necessarily be restricted to those specified hereunder:

- Pressure tests of- water, air or oil systems
- • Rotational check for turbine and generator alignment Checking of the complete control, protection and indication system for correct operation and correct wiring
- Dielectric insulation tests (high voltage withstand tests) for one minute at power frequency (50 Hz) of the stator winding after final installation.
- Dielectric insulation test, 1 minute, 3.0 kV, 50 Hz of the rotor winding
- Dielectric insulation test, 1 minute, 2.0 kV, 50 Hz, of all parts and accessories, low-voltage and measuring circuits and apparatus
- Dielectric insulation test of the excitation system equipment according to procedure and standards proposed by the Contractor and approved by the Engineer.
- Resistance measurements of generator windings (stator and rotor)

b) Commissioning Test on Completion

- Over speed test to check and adjust the over speed protection
- Function tests on the generator equipment (excitation system, signalling and protective devices, braking, etc.)
- Checking of phase sequence and phase angle
- No-load characteristic
- Short-circuit characteristic (3-phase)
- Load rejection tests
- Bearings heat run test

Tests for determining the maximum temperature rises of the various generator parts, including the excitation system under full rated load conditions

The following tests shall be made on one generator only if the tests have verified that the generator characteristics are practically identical:

- Sudden short-circuit tests at 75% of nominal voltage for the determination of transient and sub transient reactance and time constants. The conditions and time for executing the test shall be finally agreed on Site.

- Sustained short-circuit tests, two-phase (line to line) and single- phase (line to neutral) to determine the negative sequence and zero sequence reactance.
- Over excitation test at zero power factor (lagging) to determine the complete excitation diagram.
- Tests to verify the generator capability of supplying the required MVAR output at zero leading power factor (line charging capacity).
- Reactive load rejection tests to check the excitation system capability.
- Measurement of losses to determine the generator's efficiency.

The Engineer shall have the right to decide which of the generators to be subject to the above tests. Should the generator fail to meet the technical requirements because of the test, similar tests shall be carried out on the other generator free of charge. A generator will only be accepted if it passes all tests to the satisfaction of the engineer.

SECTION 3: TRANSFORMERS

3.1 Scope of Work

This chapter covers the requirements for design, Engineering, manufacture, assembly, inspection & test at manufacturer's works, packing, delivery including loading, transportation, unloading at site, storage at site, installation, test, and commissioning complete with all fittings, accessories, associated equipment's spares, required for satisfactory and trouble-free operation of the power plant. The supply shall include the following:

a) Power Transformers (Three Phase)

- Three Nos.,10/13 MVA, 11/132 kV Step up Transformer at Switchyard
- One No., 3.5 MVA 11/132 step up Transformer at Switchyard

b) Station Service Transformers

- Two Nos. 250 kVA, 11/0.4 kV Station Service Transformers at Powerhouse switchyard
- One No. 200 kVA,11/0.4 kV station service Transformer at weir intake
- Four Nos.150 kVA,11/0.4 kV dry type Excitation Transformers at Powerhouse
- One No. 200 kVA, 11/0.4 kV Transformer as spare.

The power and station service Transformers shall be pad mounted to be installed in the open-air switchyard/substations and the excitation Transformer shall be dry type installed indoor.The Contractor shall provide foundation, pads and other concrete works for the Transformers of powerplant, intake complete in all respect including cable trenches, necessary recesses for pipes and cables, etc., delivery and installation of the transportation rails on the foundation, grouting and finishing works, all in accordance with the Contractor's drawings and instructions approved by the Engineer.

3.2 Applicable Standards

WAPDA	Specification P-46: 82, Power Transformers
IEC 60076	Power Transformers
IEC 60214	On-load tap-changers
IEC 60296	Specification for unused mineral insulating oils for Transformers and switchgear
IEC 60185	Bushing type current Transformer
IEC 60354	Loading guide for oil-immersed power Transformers
IEC 60542	Application guide for on-load tap-changers
IEC 60551	Determination of Transformer and reactor sound level
IEC 60599	Interpretation of the analysis of gases in Transformers and other oil-filled electrical equipment in service
IEC 60606	Application guide for power Transformers
IEC 60616	Terminal and tapping markings for power Transformers

IEC 60722 Guide to the lightning impulse and switching impulse testing of power Transformers and reactors

3.3 Technical Data

The technical detail of Power Transformers to be installed in the powerhouse's switchyard are given as under.

I. Power Transformers (Three Phase)

Table 2: Technical Data for Power Transformers

Nomenclature	Unit	Switchyard
		Step-up
Rated Power (3 Main Units)	MVA	10/13
Rated Power (1 Aux Unit)	MVA	3.5
Voltage Levels	kV	11/132
No. of Units	No	4
Rated Voltage LV	kV	11
Rated Voltage HV	KV	132
Highest system voltage LV	kV	12
Highest system voltage HV	kV	145
Rated power frequency withstand voltage LV	kV	275
Rated Lightning Impulse withstand voltage HV	kV	650
System Frequency	Hz	50
Voltage variation at full load	%	10
Vector Group	-	YNd 11
Cooling type	-	ONAF
Tape Changer (on HV side)	-	Off load
Tapping Range (in 11 steps)	%	± 10
Max. Temperature rise (winding)	^{0}C	55
Max. Temperature rise (Top oil)	^{0}C	50
Neutral earthing (HV side)		solidly
Maximum noise level	dB	70/80
Impedance voltage	%	9
Altitude	masl	2100
Max. Transport weight (Approx)	Ton	32

II. Station Service Transformers

Table 3: Technical Data for Station Service Transformers

Nomenclature	Unit	Powerhouse, switchyard		
		Station Service	Excitation	Intake weir
Rated Power	kVA	250	150	200
Voltage Levels	kV	11/0.4	11/0.4	11/0.4
No. of Units	No	2	4	1
Rated Voltage LV	kV	0.4	0.4	0.4
Rated Voltage HV	KV	11	11	11
Highest system voltage LV	kV	0.415	0.415	0.415
Highest system voltage HV	kV	12	12	12
Rated power frequency withstand voltage LV	kV	34	34	34
Rated Lightning Impulse withstand voltage HV	kV	95	95	95
System Frequency	Hz	50	50	50
Voltage variation at full load	%	10	10	10
Vector Group	-	DYn 11	YNd11	DYn 11
Cooling type	-	ONAN	AN	ONAN
Tape Changer (on HV side)	-	Off load	off load	Off load
Tapping Range (in 11 steps)	%	± 10		± 10
Max. Temperature rise (winding)	0C	55	55	55
Max. Temperature rise (Top oil)	0C	50	50	50
Neutral earthing (HV side)		solidly	solidly	solidly
Maximum noise level	dB	70/80	70/80	70/80
Impedance voltage	%	4	4	4

Each Transformer shall be equipped with all accessories but not restricted to the following:

- Oil conservator with level gauge
- Dehydrating breather with silica gel
- Gas relay (for Power Transformers)
- Resistance-type temperature detectors for oil and winding temperatures

- Contact thermometers for oil and winding temperatures
- Oil/water heat exchangers
- A ladder for access to the gas relay of Power Transformers
- Flanged wheels

3.4 Station Auxiliary Service

The station auxiliary supply system of Power Plant shall be fed by two station service Transformers (SST), each rated for 100% of the station load. For the power supply at the weir intake, one distribution Transformer will be provided. One Transformer shall be kept as spare.

The Transformers shall be dry type air cooled for indoor installation and 200 kVA shall be hermetically sealed tank construction with air cushion with bolted cover and shall be suitable for pole/pad mounting installation. The 250 kVA Transformer shall be of conservator type tank construction fitted with breather bolted cover and shall be suitable for pad mounting installation.

3.5 Design Requirements

3.5.1 General

The Transformers shall be designed to supply full rated output at rated frequency, rated terminal voltage and at any tapping shall be confirmed to the nominal capacity in MVA /kVA at p.f 1.00-0.80 lagging as specified for each Transformer under the specified climatic conditions. The temperature rise of the Transformers shall not exceed the values specified in IEC 60076-2, 60289 and WAPDA Specifications P-46:82

3.5.2 Bushings and Bushing Current Transformer

The HV bushings shall be suitable for interface between the Transformer and nude conductor. On the LV-side, cables shall be connected. Final design details shall be elaborated by the Contractor and be subject to approval by the Engineer. The bushings shall comply with IEC Publication No.60137 and WAPDA Specification P-46:82.

The 132 kV bushings shall be oil filled or of the condenser type and shall be manufactured and tested in accordance with the IEC Publication 60137 and the 11 kV bushings shall be in accordance with German Standard DIN 42533.

The Transformer bushings shall withstand accidental arcing or flashover without damage to seals or other vital parts. Stresses due to expansion and contraction in any part of the bushing shall not lead to development of bulges, hairline cracks or other defects. Suitable connecting clamps shall be able to absorb shocks due to vibration of the connecting jumpers. All the bushings of any Transformer shall have a rated current of at least 120% of the rated current of the winding to which they are connected.

The Transformers and the bushings shall be for outdoor erection and the necessary precautions have to be taken. Bushings shall be mounted in such a manner as to minimize the accumulation of fouling material. The design of sheds and body shall be such that bushings may be easily cleaned and present a long-protected leakage path. Bushings shall not depend on insulation of oil drawn up from the Transformer tank.

All bushings shall be wet process porcelain, homogeneous, free from laminations, cavities or other physical flaws and shall be well vitrified, tough, and impervious to moisture. Bushings shall be glazed, brown coloured. Fittings made of steel shall be galvanized.

The minimum creepage distance from line to earthed part shall be as follows:

Table 4: Minimum Creepage Distance

Voltage (kV)	Max. System Voltage (kV)	Normal Creepage (mm)	Extended Creepage (mm)
132	145	2900	3800
33	36	720	900
11	12	240	350

3.5.3 Cores

Transformer core shall be made of high grade, non-ageing, cold-rolled electrical silicon steel. Laminations shall have low losses and high permeability. After the laminations are cut and sharp projections removed, they shall be annealed to relieve shearing stresses. All laminations shall be machine coated to ensure a thin uniform coating. The coating material shall be heat resistant, inert to the action of the hot oil and shall be baked on.

The core shall be rigidly clamped with insulated clamping bolts, or by other approved method, into a one-piece steel structure which will retain its shape under the most severe stresses encountered during shipment and handling and under short-circuit conditions. Insulation packet of the core shall be connected so that potential difference will not exist between them. Flux distortion will be minimized to reduce noise level. Cooling ducts will be provided in ample number throughout the core to eliminate hot spots

The design of the magnetic circuit shall be such as to avoid static discharges, development of short-circuit paths within itself or to the earth clamping structure and the production of flux components at right angles to the plane of the laminations which may cause local heating.

All joints between laminations shall be of the interleaved type and the laminations shall be clamped firmly and securely with non-magnetic straps. Butt joints will not be accepted. The laminations shall be separated by hot-oil proof insulation, and the fastening to the frame shall be firm to prevent undue vibrations or noises.

The core straps shall be efficiently insulated from the cores and tested by applying 2 kV, 50 Hz during 1 minute between straps and earth (or core). The core shall be designed and built up in such a manner as to avoid accidental or slow development of short circuit paths through the iron and framework.

Each part of the core shall be electrically earthed to the Transformer tank. The internal earth connection shall be of the detachable link type and shall be located in an accessible position.

3.5.4 Windings

The windings shall consist of high-quality copper or aluminium, wound on frames to form circular coils. All conductors used in the coil structures shall be copper free from scale, burrs, and silvers. All permanent current carrying joints or splices shall be brazed or compressed.

The insulation of the end turns of each winding adjacent to the Transformer terminals shall be reinforced between turns to protect the windings satisfactorily against surges and transients. Details of the reinforcements shall be specified in the Bid.

All windings and all fibrous and hygroscopic materials used in the construction of the Transformer shall be dried under vacuum and impregnated with hot oil.

It is essential that the windings shall be subject to a thorough shrinking and seasoning process, so that no further shrinking of windings occurs at site. Clamping arrangements shall be provided to compensate for any possible shrinking of coils when in service. None of the materials used shall shrink, disintegrate, carbonize or become brittle under the action of hot oil, when the Transformer is operated continuously at the maximum specified temperature.

The windings, connections and tapings of all Transformers shall be clamped in position and braced so as to withstand shocks or undue stresses during transport, short circuit conditions, and other transient causes.

Adequate provision shall be made for circulation of oil around and between the winding so that a low temperature gradient between the conductors and the oil is assured and any risk of excessive local heating is avoided.

The Transformers shall be designed and constructed to withstand, without damage or mechanical movement, the effects of external short circuit under the conditions as specified in IEC 60076-5, Power Transformers.

The Bidder shall furnish a fully detailed description of the windings as well as the drying out and vacuum treatment.

3.5.5 Tap Changers

The Switchyard Power Transformer (step up) shall be provided with off load tap changer whereas the grid Transformers shall equipped with On load tap changers as given in above Tables.The off-load tap changer shall be manually operated from the ground level. The tap changer shall include an operation crank or hand wheel, tapping position indicator and means for locking the tap changer in any tapping position. The locking device shall be arranged to prevent blocking of the tap changer in an intermediate or off-tapping position.

The on-load tap changers shall be of the vacuum type design vessel fitted inside the Transformer tank, motor operated mechanism and controls in accordance with IEC Publication 60214 and preferably be located inside the Transformer tank, so that only the drive shaft end of the load breaker is protruding. The load breaker shall be mounted in a separate oil container to prevent contamination of the insulating oil.

The motor drive shall be mounted outside the tank and have suitable shafts and gears up to the drive shaft end. The motor drive assembly shall be complete with motor protection, limit switches, position indicator and electrical connection terminals. A detachable crank handle for emergency operation shall be provided.

All contacts and connections shall allow at least 120% current loading, compared to the Transformer rated current.

3.5.6 Tanks and Accessories

The active part shall be housed in a conventional type of tank. Transformer tanks shall be of electrically welded mild steel construction, and all components shall be designed and constructed to withstand an internal pressure without leakage or permanent distortion and also permit the handling of the entire weight of the completely filled Transformer. Pulling eyes shall be provided to allow for the attachment of a pulling rig and moving the Transformer horizontally on wheels or rollers in either direction.

Jacking pads shall be available at convenient locations on the Transformer tanks to allow the jacking of the completely filled Transformer. The same set of jacks shall be used for all the main Transformers.

Each Transformer tank shall have at least two earthing terminals of adequate dimensions. These shall be welded near the tank bottom, at opposite sides.

The necessary number of pockets for thermometers and temperature detectors shall be provided on the tank cover. On each Transformer an additional pocket (spare and for portable thermometer) shall be provided.

After installation (positioning) of the Transformers on their final foundations, the wheels or rollers shall be anchored in position by approved means furnished for this purpose by the Contractor.

The Transformers shall be provided with at least the following accessories as per WAPDA Specification P- 46:2008.

- Oil level indicators magnetic type, (one each for main and OLTC conservators)
- Oil temperature indicators
- Winding temperature indicator(s)
- Thermometer pockets
- Buchholz relay (with valves on both sides)
- Fans and controls
- Auxiliary panel
- Control cabinet
- Lifting eyes for cover only (optional for Transformers other than 10/13MVA)
- Facilities for lifting the core and coil assembly
- Lugs for lifting complete Transformer
- Moving facilities/flanged roller wheels
- Jacking facilities
- Oil conservator with silica gel breather
- Drain and filter valves comprising:
- One drain valve

- Two filter valves of about 30 mm dia
- Two sampling valves of about 20 mm dia
- Air release plug
- Oil filling plug
- Pressure relief devices
- Earthing terminals for tank
- Inspection facilities
- Rating plate
- Terminal marking plate

3.5.7 Flanged Wheels

Flanged wheels shall be bi-directional, for moving the fully assembled Transformer in perpendicular directions on rails.

The bi-directional movement shall be obtained by means of a swivel arrangement, capable of being locked in any of the two positions. Necessary jack and other allied tools, for use when altering the wheel positions, shall be supplied.

The flanged wheels shall be so located that a tommy bar can be used without fouling any part of the Transformer tank, tubes or radiators.

Suitable dimensioned manholes, with bolted covers, shall be provided wherever required to afford easy access to the lower ends of the bushings, terminals, etc. All flanged joints shall be provided with gaskets, preferably set in grooves or held in position by stops to prevent over compression of the gaskets.

All bearings shall be of roller or ball type, with suitable arrangement provided for lubrication.

Suitable means shall be provided to enable the wheels being locked to the rail firmly when the Transformer is in service.

3.5.8 Drain and Filter Valves

The Transformers shall be fitted with the following valves:

- The drain valve of adequate size so situated that the tank can be drained of oil as far as practicable. The size of the valve shall be 75 to 100 mm diameter for smaller Transformers but shall be greater as required for the larger Transformers.
- Two filter valves of about 40mm diameter, one at the top and other at the bottom of the tank, diagonally opposite to each other for connection to the oil circulating system. The flanges shall have four holes on a bolt circle diameter of 110mm. The hole size shall be 14mm.
- Devices of 20mm diameter for sampling the oil at the bottom and middle or top of the tank but independent of the specified filter valves and situated so as to be readily accessible with the Transformer live and in service.
- Globe valves shall be provided on each side of the Buchholz relay. The coupling of the valves shall be made by means of flanges for easy replacement of the relay.

All valves opening to atmosphere shall be fitted with blank flanges. All valves shall be of iron body with bronze or stainless-steel trim. They shall be the globe or other approved type. Means shall be provided for locking the valves. Each valve shall be provided with an indicator clearly showing its position. Manufacturer's catalogue/literature shall be submitted the bid and for approval before installation.

3.5.9 Transformer Oil

The Transformer oil shall be of the standard mineral, uninhibited type oil class-I conforming to IEC-60296 and shall be free from synthetic additives of all types and shall be of the same make and type for all Transformers.

Sufficient quantity of oil shall be supplied with each Transformer for its filling to proper level. Insulating oil shall be straight run mineral oil obtained from fractional distillation of crude petroleum, refined specially for use as insulating and cooling medium in oil immersed Transformers. It shall be free from water, sediments, foreign materials, PCB and petroleum fractions which may be injurious to equipment or to any of its components, such as insulation, paint, varnish and metallic or other parts.

The Transformer oil shall be un-inhibited oil class-I conforming to IEC-60296 and shall be free from synthetic additives of all types.

The Transformer shall be suitable for use with the oil specified above and for satisfactory service shall not require oil of dielectric strength above 40 kV, when tested with 2.5 mm standard gap.

The Contractor shall submit the information regarding the make, type and properties of the Transformer oil in due course for the Engineer's approval.

3.5.10 Oil Conservator Tank

The conservator shall preferably be of the diaphragm scaled type, complete with all necessary fittings.

Oil conservators shall have a capacity of at least 10% of the Transformer oil volume. The conservator assembly shall be complete with drain cock and shut off valve on the feed pipe to the Transformer tank. The tank shall be installed with its minimum oil level higher than the highest oil filled part of the Transformer in order to avoid air pockets.

Each conservator shall have a dehydrating breather assembly, complete with glass observation window fitted with silica gel, and necessary connecting piping to the conservator. The silica gel drum shall be easy to operate with regard to emptying and refilling.

3.5.11 Measuring and Supervision

All Instruments and Plates must be easily accessible and readable from the ground.

a) Oil Level Gauges

Oil level gauges shall be of the dial type fitted to the conservator chamber. The indicating pointer shall be magnetically coupled to the float inside the chamber so that fracture of the glass cover of the gauge shall not result in loss of oil.

The gauges shall be of such size that they can be easily read directly or by means of a mirror arrangement, from the ground vertically below. The gauges shall have alarm and tripping contacts for high and low oil level.

b) Gas Relay

Gas relays shall be installed in the pipe between the Transformer tank and the conservator. The relay shall have separate contacts for alarm and for shutdown, at low speed and high gas development respectively. The relay shall have valves for taking gas samples and for air impression for testing the relay.

The relay shall be placed in such a way that inspection, testing and dismantling is possible when the Transformer is under operation.

c) Resistance Temperature Detectors

Resistance temperature detectors shall be of the three-wire Pt-100 type. They shall be located in specially designated oil filled measuring pockets in the Transformer tank cover. Detectors for remote measurement of winding temperature shall be connected to a thermal image circuit including current Transformer placed inside the tank on one of the bushings and heating coil with wiring to constitute a complete system. They shall be located in specially designated oil filled measuring pockets in the Transformer tank cover.

One temperature detector shall be used for remote Transformer top oil temperature detection for power Transformers.

d) Dial Type Thermometers

Dial type thermometers shall be mounted on the Transformer tank at a convenient height from ground level. The thermometers shall be provided with at least 2 sets of adjustable contacts for alarm and trip circuits.

e) Auxiliary Wiring and Terminal Cabinets

All auxiliary wiring used on each Transformer shall be carried in suitably supported steel conduit or metal protective channel and brought to an adequately dimensioned terminal cabinet with gasket cover of equivalent design. The terminal cabinet shall be situated at convenient height on the Transformer. All wiring shall be stranded conductor with oil resistant insulation.

f) Cooling Systems

The ONAN cooling system shall comprise radiators connected to the Transformer tank. Shut-off valves shall be mounted at the oil inlet and outlet so that each radiator can be removed from service or replaced without disturbing major parts of the Transformer and without the need of interruption of the Transformer operation. Lifting lugs, drain and vent plugs shall be provided for each radiator.

The ONAF cooling system shall be used for main power Transformers and the Substation Transformers. The Transformers shall be capable of operating under the natural cooled condition up to the specified load. The forced cooling equipment shall come into operation by pre-set contacts of winding temperature indicator and the Transformer shall operate as a forced cooled unit, as ONAF. Cooling shall be so designed that during total failure of power supply to cooling fans, the Transformer shall be able to operate at full load for at least ten (10) minutes without the calculated winding hot spot temperature exceeding 140 degree centigrade. Also stopping of one or two cooling fans should not have any effect on the cooling system.

Automatic operation control (switching in and out) of fans/pumps shall be provided (with temperature change) from contacts of winding temperature indicator. The supplier shall recommend the setting of Winding Temperature Indicator (WTI) for automatic changeover of cooler control from ONAN to ONAF. The setting shall be such that hunting i.e., frequent start operations for small temperature differential do not occur.

Suitable manual control facility for cooler fans with manual/automatic select or switches and push buttons shall be provided.

3.5.12 Water Spray Fire Protection of Power Transformers

3.5.12.1 General

The Contractor shall design, furnish and install a high-pressure deluge-type water-spray-fire protection system for each of the power Transformers.

The firefighting system for the power Transformers shall be designed for a spray pattern covering the complete Transformer and appurtenances and taking into account localized wind patterns.

The deluge water-spray system shall comply with the applicable requirements of Article 20, Fixed Water Spray Systems, of the NFPA Standard No.15 and as approved by the Engineer. The system shall be designed for a maximum pressure of 7.5 bars. Clearances between the energized conductors or apparatus and the spray system shall be in accordance with IEC 60071-2. The spray system shall be controlled by automatic deluge valves.

The fire protection system shall be complete and ready for trouble free operation when installed. The Contractor shall furnish detailed catalogue, literature and characteristics for every apparatus for the Engineer's approval.

The Contractor shall provide and install the deluge valve, local pipework, sprinkler nozzles and fire detection system under with all firefighting equipment including the priming tank, jockey pump, air compressor, pressure water tank, isolation valves and associated piping etc and water supply up to the priming tank.

3.5.12.2 Equipment

The spray nozzles shall be bronze, screwed, full square spray having a maximum spray angle of 120 degrees. The thermostats shall be rated 80°C to 85°C suitable for operation on 220 V, D.C. The deluge valves shall be of the piston-operated check type with the valve disc held normally closed by upstream water pressure through a three-way solenoid operated pilot valve. In the normal closed position, the de-energized three-way solenoid valve connects the main line upstream pressure to the disc of the main valve, keeping it in the closed position. In case of fire, the solenoid is energized, closing off control water pressure to the disc and opening the cylinder to drain, and allowing the disc of the main valve to open to provide full water flow to the fire loop. An isolating valve upstream of the deluge valve, will have provision for positive locking in both the open and closed positions. The Contractor shall indicate the strainer mesh (to be supplied by others) size required for filtered water supply to the fire fighting system.

Each deluge system shall consist of all necessary component parts and appurtenances including but not limited to the following:

- Sprinkler heads
- Deluge valve

- Fire detection devices
- Piping, valves and fittings
- Hanger and supports
- Control cabinet
- Pressure gauges

The system shall be fully automatic with manual emergency release. A complete pre-wired local control panel with sufficient number of fire detection devices shall be designed to receive the signals from the fire detectors and retransmit it to activate the fire fighting system and all the other necessary alarms and controls

3.5.12.3 Joints and Gaskets:

All joint faces shall be arranged to prevent ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

Nitrile base cork or equivalent shall be used for gaskets. Oil resistant synthetic rubber gaskets are not permissible except where the synthetic rubber is used as a bonding medium for cork or similar material or where metal inserts are provided to limit compression.

Gaskets shall be consistent with the provision of a good seal and full details of all gaskets sealing arrangement shall be shown on the drawings.

3.5.12.4 Rating Plates

A corrosion-resistant nameplate and diagram/rating plate shall be provided on each Transformer. The rating nameplates shall bear the data, specified in IEC 76 Part - I

In addition to the rating nameplate of the Transformers, each major Transformer part shall also carry an identification plate giving serial number and other relevant information needed for identifying the said Transformer component.

3.5.12.5 Shipment

Reference is made to the Instruction to Bidders and the Specifications regarding the transport of heavy equipment to the site.

The Contractor shall endeavour to construct the main Transformers so that the core/winding assembly can be transported in its own tank, oil filled, taking into account the weight limitations of loading facilities and of the roads and rails.

3.6 Tests

3.6.1 Factory Tests

a) Bushings Tests

The Contractor shall submit for approval, the test records, and data for all bushings. These records shall show the tests performed on the bushings including, but not necessarily restricted to the following tests:

- Standard, one minute, 50 Hz, dry withstand tests for all bushings.

- One minute, 50 Hz, wet withstand tests for all bushings.
- Type test of impulse withstand voltage.
- Switching impulse test of the HV bushings.
- Atmospheric pollution characteristics (Salt fog or other approval test).

All recorded test figures shall be given with the bushings serial number.

3.6.2 Routine Tests on all Transformers

- Each Transformer shall be completely assembled at the Contractor's works and shall be subject to the following tests:
- Resistance measurements of all windings for all tapings.
- Ratio tests for all tapings and vector relationship check.
- Measurement of impedance voltages, short circuit impedances and load losses.
- Measurement of no-load loss and currents.
- Induced voltage and separate source voltage withstand power frequency, dielectric tests on all windings and all phases.
- Zero Sequence Impedance
- Oil leakage tests. The complete oil filled Transformer shall be tested at a pressure of 0.7 kg/cm2 gauge (positive) pressure for not less than one hour without showing leaks or drop in pressure.
- Determination of efficiencies

3.6.3 Additional Tests on the Main Transformers and Local Grid Transformer

The following additional tests on the main Transformers and the grid Transformer shall also be carried out

- Measurements of the capacity between the windings and between each three-phase winding and earth.
- Partial discharge measurements (corona testing) during the power frequency dielectric tests. Test procedures shall be agreed between the Contractor and the Engineer.
- Impulse withstands tests and switching impulse test. The Transformer shall be subject to a complete series of full-wave impulse voltage withstand tests. Such tests shall be performed on the high-voltage winding, line terminal of each phase as well as on the neutral terminal.
- Test of on-load / off-load tap changers
- Temperature rise test

The Transformers shall be subject to tests for the determination of the Transformer noise level. Details of the test procedure shall be agreed between the Contractor and the Engineer.

If the temperature rise test does not give a satisfactory result, the Engineer may decide to repeat the test on one of the other Transformers.

The test certificates shall be in conformity with the corresponding IEC standards, especially concerning the capability of the Transformers to withstand thermal and mechanical effects of short circuits.

3.6.4 Site Tests upon Completion

Upon completion of erection work of the Transformers at site, the Contractor shall perform the essential site tests to prove compliance with the provisions and guarantees set forth in the Contract. The tests shall be in accordance with IEC standard; however, the following tests shall be included as a minimum:

- Visual inspection.
- Oil quality verification, including:
- Dielectric strength
- Polarity
- Particle content
- Gas analysis
- Insulation resistance
- Water content
- Temperature stability
- Flash point
- PH value

Functional tests on all control and protection equipment.

The oil quality verification shall be repeated after one-month normal operation, as well as at the end of the guarantee period.

3.7 Tools and Appliances

The contractor/supplier shall provide all necessary tools/appliances for maintenance of the equipment including but not limited to the following.

- Three set of slings for lifting of the station Transformers.
- Two lots of slings needed for lifting of accessories, such as conservator of main Transformers, coolers, bushings etc.
- Four sets of manually operated hydraulic jacks for the main Transformers for jacking the complete Transformer in order to place or position its wheels.
- One set of full outfits of tools and special tools, for assembling and dismantling the Transformers with tap changer and for their efficient maintenance and repairs, including racks for holding them. All spanners shall be case hardened and single ended.
- One No., station Supply Transformer of 11/0.4 kV, 200 kVA.
- One No. dehydration plant

3.8 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 4: SWITCHGEARS

4.1 General

This chapter covers all the aspects of design, manufacturing, supply, installation, erection, testing and commissioning of the equipment complete in all respect pertaining to High Voltage (HV), Medium Voltage (MV) and Low Voltage (LV) switchgear equipment and associated auxiliaries. The supply shall comprise all Switchgear apparatus with insulators and requisite accessories, connection cubicles, equipment supports& foundations, all overhead phase conductors and earth conductors, connection loops to all apparatus and to the phase conductors of the transmission lines, tension insulator strings and steel structures, MV and LV switchgear panels with all control , protection and indication equipment which are necessary for the electrical interconnections complete in all respect for satisfactory functioning of the project, to be installed at various locations of the project:

4.2 High Voltage (HV) Switchgear

4.2.1 Scope of Work

- 11/132 kV Switchyard Jagran HPP having duble busbar and single breaker scheme with four (4) Transformer bays, Two (2) Line bays and one PT bay with all switchyard equipment i.e. circuit breakers, disconnectors, earthing switches, CT's, CVT/ PTs, Surge Arrestors, PLC equipment, Gantries, Busses, Clamps conductors insulator all dropouts for interconnection as per WAPDA standards and single line diagram shown on the drawing and covered by the specification.
- 132 kV interconnection between all phase conductor masts and switchyard gantries including all line material i.e. masts, conductor, insulators, hardware etc. Connection of HV side of Transformer with gantries interconnection including all connectors, down-droppers, local control panels, operating mechanism, and all supporting structures etc.
- All civil works including control buildings in Structure foundations, cable trenches, drainage works, Transformer ways, fencing work and all other works related to the HV switchyard.
- Control and Protection Panels for Transmission line and Power Transformer
- Each bay shall include one cable connection cubicle IP 54, with the following equipment:
    - Terminal block for control and measuring cables.
    - One single phase 230 V A.C., three-pole (phase + neutral + earth) power outlet socket for hand lamps and small tools.
    - One three-phase 400 V A.C., power outlet socket for heavy tools and welding.
    - Anti-condensing heating element
    - Internal lighting
- One set of special tools and appliances.

4.2.2 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

4.2.3 Design Requirement

All 132 kV switchgear shall be rated for 145 kV maximum system voltage. All equipment and components shall comply with the design data and latest publication of IEC standards and WAPDA Specifications.

The design current capacity for equipment is assumed to be 2000 A, for Switchyard, however contractor shall work out the maximum rated and short circuit currents for the HV equipment of Switchyard and Substations. The layouts have been shown in their single line diagrams/Drawings, the same may be adjusted as necessary to suit the manufacturers' standard designs.

Equipment and components as well as the total plant should withstand the thermal and mechanical stresses caused by the symmetrical and unsymmetrical short circuits and shall also withstand stresses due to switching, over voltages and seismic acceleration.

The design of the switchgear should also give due consideration to environmental aspects, operational experience, and safety.

The layout of the equipment shall be such as to provide sufficient clearances between phase to earth, phase to phase and between bays and shall offer ease of access for supervision operation and maintenance

4.2.3.1 Ratings and Characteristics

The HV equipment and their accessories shall be so designed as to comply with the following ratings, characteristics and to meet all test requirements with respect to insulation strength, current carrying capacity, making, and breaking currents and mechanical & electrical operations etc.

The equipment shall be suitable for continuous operation on a three-phase, 50 Hz system.

The switchgear shall have rated impulse and power frequency withstand voltages equal to or greater than the levels specified below at the minimum operating SF6 gas density or pressure.

Table 5: High Voltage Switchgear Ratings and Characteristics

Nominal system voltage kV, rms	132
Rated voltage kV, rms	145
Rated insulation level:	
Rated lightning impulse withstand voltage:	
to earth kV, peak	650
across open breaker kV, peak	750
Rated one-minute power frequency withstand voltage	
to earth kV, peak	275

across open breaker kV, peak	315
Rated Current (A)	2000
Short circuit Current (kA)	40

4.2.3.2 Clearances

For the design and erection of the conductors and equipment in the HV outdoor 145 kV switchyard the following minimum distances shall be observed:

Table 6: Clearances for High Voltage Switchgears

Nominal Voltage	132 kV
From ground to un-insulated live parts	4000 mm
From ground to lower end of apparatus insulation	2500 mm
Minimum insulation clearance between phases in air	3500 mm
Min. clearance between bays	4750 mm

Outdoor equipment shall be designed with bushings with creepage path not less than 25 mm/kV.

The control voltage for closing and opening operations shall be 220 V D.C. + 10 % - 20%, unearthed, from battery.

The layout of switchgear and equipment shall provide for ready access for operation and maintenance whilst the remaining sections of equipment are alive. Working clearances provided on the outdoor installations between isolated equipment and the nearest live metal work shall not be less than the specified clearances or if not specified then IEC Standard clearances shall apply.

Full information of the insulation creepage distances for all outdoor insulators, and bushings shall be provided by the Contractor. Creepage distances shall be not less than 31 mm per kV of system highest voltage for outdoor equipment.

The height from the ground or other permanently available means of access and from fixed working platforms to any live part of the equipment which is not in an earthed screened enclosure shall be not less than 2.5 meters plus the length of the supporting insulator or bushing

4.2.3.3 Circuit Breakers

The circuit breakers mounted on steel structure shall be of the SF6 type with puffer type arc interrupter. The circuit breakers shall have individual operating mechanisms for each phase in order to perform single-phase fast enclosures operation. The circuit breakers shall be mounted on steel structures.

The operating mechanism shall be of the motor operated spring loading type, rated for 400/230 V, 50 Hz power supply. Motor control equipment shall be provided for automatic operation. A crank, lever, or other similar suitable device shall be provided to permit charging the operating mechanism by hand in the event of a failure of the auxiliary supplies or in the event of a failure of the energy-storing device.

The complete operating mechanism, including the controls, shall be mounted in watertight and dust-proof cubicles IP 54. All parts shall be easily accessible without dismantling other parts. Openings,

covered with dust filters, shall allow a good ventilation of these cubicles. In order to avoid any moisture, thermostatic controlled heaters shall be built in. A local position indicator shall be mounted in the front panel of the operating mechanism cubicle.

The breakers shall be capable of handling the following operation cycle, according to the IEC recommendations:

O-t-CO-t'-CO t = 0.3 sec, t'= 3 min

The total breaking time (opening time plus duration of the arc) of the breakers shall be as short as possible, but in no case longer than 3 cycles.

The stored energy shall, as a minimum is sufficient to allow a complete O-C-O cycle.

Rate of rise for transient recovery voltage shall be equal to or better than 2000 V/µs. First pole to clear factor shall not be less than 1.5.

The opening device shall be provided with two independent release coils, connected to separate terminal blocks in the terminal cubicle, allowing the connection of two independent opening command circuits. The connection diagram shall be subject to approval by the Engineer.

Sufficient quantity of auxiliary contacts for 220 V D.C. shall be provided for control, interlock, signal and alarm purposes.

The circuit breakers shall have a gas density monitor system. The system shall comprise alarm contacts that close at low and critically low gas densities. At low gas density, the circuit breaker shall be blocked against closing. At a critically low density the circuit breaker shall be blocked against opening.

The circuit-breakers shall have the following ratings

• System nominal voltage	132	kV
• Rated voltage (maximum voltage)	145	kV
• Rated continuous current	2000	A, rms
• Rated short time withstand current	40	kA, rms
• Rated peak withstand current	100	kA, peak
• Rated duration of short circuit	3	sec
• Rated short-circuit breaking current	40	kA
• Rated short-circuit making current	100	kA, peak
• Rated operating sequence	0-0.3 Sec-CO-3min-CO	
• Rated out-of-phase breaking current	8	kA, rms
• Rated D.C. operating voltage	200	V
• Rated duration of short-circuit	3	sec
• First pole to clear factor	1.5	

All wiring shall lead to a terminal strip in the local connection cubicle. 10% of the terminals shall be spare.

4.2.3.4 Isolating and Earthing Switches

The switches shall be mounted on steel structures. Single-phase switches shall be mechanically interconnected to constitute one three-phase unit.

Isolating switches combined with earthing switch shall be assembled in one functional unit. The isolating switch and the earthing switch shall be mechanically interlocked so that the earthing switch cannot be closed unless the disconnection switch is open. In addition, the earthing switch shall be electrically interlocked to prevent earthing of the energized transmission line.

The disconnectors and earthing switches along with steel supporting structures and foundation shall be suitable to withstand the seismic stress/magnitude according to Richer-scale up to 7 (horizontal acceleration up to 4m/s² (0.4g) for safety of equipment under heavy earthquake conditions unless otherwise specified in the tender. The foundation arrangement shall be designed using the soil bearing capacity of 1 kg/cm². Design calculations and guidelines shall also be supplied with the bid

Each three-phase isolating switch and each three-phase earthing switch shall be equipped with its own operating mechanism. The contact surfaces shall be heavily silver-plated. The contact pressure shall be ensured by means of springs.

The operating mechanism for the isolating switches shall be provided for local and remote electrical operation. The earthing switches shall be only locally operated. The auxiliary voltage for closing and opening operation shall be 400/230 V A.C. A sufficient number of auxiliary contacts for 220 V D.C. shall be provided for control and interlock purposes.

In the case of a complete failure of the operating mechanism, operation shall be possible by means of a lever or crank or another manual device.

The complete operating mechanism, including the controls, shall be enclosed in a watertight and dust-proof cubicle, IP 54. The necessary openings for a good ventilation of the cubicles shall be provided. They shall be covered by dust filters. Thermostat controlled heaters shall be provided for each cubicle in order to prevent any moisture by condensation. All parts shall be easily accessible without dismantling.

The technical characteristics of Isolation switches shall be as follow:

- Nominal system voltage 132 kV
- Highest voltage for equipment 145 kV
- Rated frequency 50 Hz
- Lightning impulse withstand voltage
    - Across the isolating contacts 750 kV
    - To earth & between Poles 650 kV
- power frequency withstands voltage (dry and wet)
    - Across the isolating contacts 315 kV
    - To earth & between Poles 275 kV
- Rated normal current 2000 A,
- Rated Short time withstand current 40 kA
- Short peak withstand current 100 kA

- Rated short circuit duration 3 sec
- Power frequency withstand voltage on auxiliary and control circuit 2 kV

All wiring shall lead to a terminal strip in the local connection cubicle. 10 % of the terminals shall be spare.

4.2.3.5 Current Transformers

The outdoor current Transformers shall be single-phase oil-immersed, mounted on steel structure in one insulator.

Each current Transformer shall be equipped with an oil level gauge to be easily readable by a man standing on the ground. The current Transformer oil shall be of the same type as for the power Transformers.

The oil of the current Transformer shall be hermetically sealed against the ambient air. In order to compensate fluctuations of the oil volume owing to temperature changes, flexible metal bellows or oil-resistant rubber covers shall be provided. The scaling method shall be described in the Bid.

The Bidder shall describe the measures for relieving dangerous pressure rises that may develop due to an internal electrical fault.

The primary connections shall be silver-plated. All secondary connections shall be connected to a terminal block, which shall be located in a dust-proof and watertight terminal box (IP 54) and shall be clearly labelled.

An earth connection to the housing shall be provided.

The current Transformers shall be designed to carry continuously a current of 120% of the rated current.

The rated outputs of the current Transformers for measuring and protection purposes shall be determined according to the technical requirements but shall not be less than 125% of the overall computed (design) load of the connected apparatus including cables.

Power frequency test voltage on

The current Transformer to be installed in Switchyard and Substations shall be rates as below

- Nominal Voltage 132 kV,rms
- Highest voltage for equipment 145 kV rms
- Frequency 50 Hz
- Rated voltage factor continuous 1.2
- Rated Lightning Impulse withstand Voltage 650 kV (peak)
- Rated 1 min Power Frequency withstand voltage 275 kV, rms
- One minute Power frequency withstand voltage
    - Secondary windings, 1 min ` 3 kV rms
    - Over voltage Inter turn test, 1 min 4.5 kV peak
- Rated continuous current 2000 A
- Short time thermal current rating 40 kA

- Short time dynamic current rating 100 kA, peak
- Rated duration of short circuit I sec
- Rated primary current (rms) 1200/600/300 A
- Rated secondary current (rms) 5 A,
- Accuracy Class:
    - o measuring core 0.5
    - o Metering 0.1
    - o Protection core 10P
- Maximum radio interference voltage (RIV) at nominal voltage 2.5 mV
- Flashpoint temperature 135 oC
- Maximum winding temperature rise above an ambient of 50oC 55 oC
- Maximum top oil temperature rise above an ambient of 50oC 45 oC
- Minimum Creepage distance 3900 mm

4.2.3.6 Voltage Transformers

The outdoor single-phase voltage Transformers shall be oil-immersed, mounted in one insulator. They shall be mounted on steel structures.

Each voltage Transformer shall be equipped with an oil level gauge to be readable from the ground. The voltage Transformer oil shall be of the same type as for the power Transformers.

The oil of the voltage Transformers shall be hermetically sealed against the ambient air. In order to compensate fluctuations of the oil volume owing to temperature changes, flexible metal bellows or oil-resistant rubber covers shall be provided. The scaling method shall be described in the Bid.

The Bidder shall indicate what measures are provided for relieving dangerous pressure rises that may develop due to an internal electrical fault.

The primary connections shall be silver-plated.

All secondary connections shall be connected to a terminal block, which shall be located in a dust-proof and watertight (IP 54) terminal box and shall be clearly labelled.

All primary and secondary connections shall be clearly marked.

An earth connection to the housing shall be provided. Earthing of the cores and the neutrals shall be done on the Transformers and not on the terminal boxes.

Secondary windings for earth fault protection shall be open delta windings with an accuracy according to class 3P and rated secondary voltage 110/√3 V.

The rated outputs of all windings shall not be less than 125% of the overall computed (design) load of the connected apparatus including cables.

Voltage Transformer to be installed in the switchyard and Substations shall be rated as follows.

- Nominal system voltage 132 kV, rms
- Highest voltage for the equipment 145 kV, rms

- Rated frequency 50 Hz
- Rated voltage factor 1.2
- Rated lightning impulse withstand voltage 650 kV, peak
- One minute power frequency withstands voltage 275 kV, rms
- Nominal primary voltage 132/3 kV, rms
- Rated secondary voltage 110/3 V, rms
- 1 minute power frequency withstands voltage secondary circuit 2 kV rms
- No. of secondary windings 2
- Rated output of each secondary winding 50 VA
- Accuracy class:
    - sec. winding-1 (measurement) 0.2
- Carrier frequency requirements:
    - carrier frequency working range 40-500 kHz
    - impedance 200-400 ohms
    - minimum capacitance > 5000 pF
- Minimum Creepage distance 3800 mm
- Maximum winding temperature rise above an ambient of 50oC 55 oC

4.2.3.7 Surge Arresters

The Surge arresters shall be of non-linear, metal-oxide resistors type having no spark gaps. The metal–oxide blocks employed shall have minimum power loss which shall not increase during the life of the arrester when operating under the specified service conditions, especially the elevated ambient temperature, and with the maximum continuous operating voltage.

The metal–oxide resistors assembly shall be housed in a porcelain insulator of sufficient thermal and mechanical strength which shall be hermetically sealed to between the metal–oxide resistors blocks, and the external housing shall be filled with a dry inert gas. Alternatively, this space may be filled with some suitable, field-proven, solid polymeric material such as silicone rubber.

Surge arresters shall be able to withstand the combination of stresses arising in service as demonstrated by the operating duty test. These stresses shall not cause damage or thermal runway

The design of the arrester shall be such that a reasonably uniform potential drop will exist across each section of the arrester when operating under the specified service conditions. Moreover, the arrester will not flash over, and the temperature increase of the arresters remains within the specified maximum temperature during live washing of arrester.

The arresters shall have the following ratings:

- Nominal system voltage 132 kV rms
- Highest system voltage 145 kV, rms
- Arrester Rated voltage 120 V

• Rated Frequency		50	Hz
• Continuous operating voltage		96	kV
• Temporary Over voltage	1 sec	138	kV rms
• Temporary Over voltage	10 sec	130	kV rms
• Nominal Discharge current Peak		10	kA
• Line discharge class		3	
• Short circuit withstand current (0.2 Sec)		40	kA
• Highest current 4/10 µs Impulse withstand		100	kA
• Switching current Impulse withstand (upper value)		1000	A
• Maxim Residual voltage at 10 kA steep impulse			
• Current wave of 1/20 µs.		330	kV
• 1.2/50 µs Lightning Impulse withstand voltage peak (dry)		650	kV
• 1 minute Power frequency with stand voltage (dry)		315	kV
• 1 minute Power frequency with stand voltage (wet)		275	kV

The outdoor surge arresters in the switchyard and grid stations shall be mounted on steel structures and shall be fitted with a pressure relief device.

The earth conductor from the arrester to the counter, as well as the internal of the counter, shall be suitably insulated or screen protected against accidental touching.

4.2.3.8 Line Trap

The line traps shall be broad band tuned by use of a tuning device which shall be arranged to permit interchange without removing the installed line trap. The ohmic resistance shall be 400 ohms or greater over the tuned bandwidth.

Line trap shall be connected in series with HV transmission lines. The line trap shall be capable to present high impedance at the carrier frequency band while providing negligible impedance at the power frequency. The high impedance shall limit the attenuation of the carrier signal within the power system.

The line trap shall have a protective device which utilizes non-linear resistor type arresters, and the nominal discharge current shall be 10 kA.

The line traps shall have the following ratings:

• Rated voltage	132	kV, rms
• Highest system voltage	145	kV, rms
• Power frequency	50	Hz
• Minimum inductance	1	mH
• Rated continuous current	2000	A, rms
• Short-circuit symmetrical current	40	kA, rms
• Rated duration of short circuit current	1	s

- Rated blocking impedance >400 ohm

The equipment shall be in accordance with the recommendations of IEC 60353, in terms of temperature rise, short time traps satisfy the tests current ratings, protective discharge etc., and also the HF rejection bandwidth. The Contractor shall submit complete type test reports.

All line traps shall be provided with corona rings, bird barriers and clearly visible rating plates which shall include the data according to the IEC Standard.

The tuning device shall also be provided with rating plate detailing requirement of IEC Standard.

4.2.3.9 Conductors for Busbar and Dropouts

a) All Aluminium Conductor "Hawthorn"

The conductors shall be concentric-lay stranded, flexible conductors made of round alloy conductors. Two bundle all aluminium "Hawthorn" Conductor (604 mm2) shall be used for main busbars of 132 kV Switchyards and Substations. High level and low-level overhead buses to be used for line/Transformer feeder shall use all aluminium stranded Conductor "Coreopsis" (1075 mm2). The AAC (All Aluminium Conductor) to be supplied shall conform to requirements of ASTM designation B 231-64, latest publication of IEC standard 61089 and WAPDA specification P:63:2007

The conductor shall be constructed of hard-drawn aluminium wire having the mechanical and electrical properties specified herein. The material shall contain not less than 99.5 percent aluminium by weight. The aluminium wires shall be clean, smooth, and free form harmful defects prior to being stranded. The bidder may propose cross-sectional area of the conductors according to the electrical and mechanical requirements after short circuit calculation.

The dimension and characteristics of the conductor is given below.

- Conductor name Hawthorn
- Nominal size of conductor 600 mm2
- Nominal breaking Load 8966 kg
- Overall Diameter 32 mm
- Calculated area of Complete Conductor 604 mm2
- Strand and Wire diameter 61/3.55 mm
- DC Resistance at 20 OC 0.0479 ohm/km
- Weight of Conductor 1668 kg/km

b) All Aluminium "Coreopsis" Conductor

The All-Aluminium Standard Conductor (Coreopsis) shall be used for the high/low level conductors and shall conform to the requirements of ASTM Designation B 231-64.

- Conductor name Coreopsis
- Calculated area of Complete Conductor 1075 mm2
- Nominal breaking Load 13670 kg
- Overall Diameter 37 mm
- Strand and Wire diameter 61/4.11 mm

- DC Resistance at 20 OC 0.0356 ohm/km
- Weight of Conductor 2241 kg/km

c) Shield Wire Conductor

The overhead shield wire shall conform to extra high strength grade, Steel stranded in accordance with ASTM A-363 and WAPDA specification P-12 :or equivalent Standards. The shield wire shall have the following characteristics:

Table 7: Specification of Earth wire

SPECIFICATION OF EARTH WIRE		
Diameter of stranded Galvanized steel wire	mm	9
No of wires	No	7
Nominal Diameter of Single wire	mm	3.0
Area	mm^2	49.48
Overall diameter	mm	9
Weight	Kg/Km	392
Minimum ultimate tensile strength	Kg	5050

4.2.3.10 Insulators

The characteristics of the discs and the number of discs per string shall be chosen according to the electrical and mechanical requirements and shall be proposed in the Bid. The insulation of the bus shall be done at least by a double insulator chain 13 discs for 132 kV, type 146/255 mm or similar.

Each insulator shall be marked with the initials or trademark of the manufacturer and with the guaranteed electromechanical strength. All markings shall be plainly legible and durable.

Each insulator shall be wet-process, homogeneous porcelain, free of laminations, cavities or other flaws affecting the mechanical and electrical strength and shall be well vitrified tough and impervious to moisture.

The insulators shall be carefully glazed in a uniform shade of brown, free of such imperfections as blisters and burns.

The socket shall be galvanized malleable cast iron and the pin of galvanized steel.

Ball and socket connections shall be provided with cotter pins, which effectively lock the connection against accidental uncoupling without detracting from its flexibility. The cotter pin shall be of stainless steel or bronze.

The metal parts shall be designed to transmit the mechanical stresses to the porcelain by compression and to develop maximum and uniform mechanical strength of the insulator.

Socket and pin shall be of such design that they will not yield or distort under the specified mechanical loading in such a manner as to add undue stresses to the porcelain shells.

In general, the contours of the metal and porcelain parts shall be such as to eliminate areas or points of high electrical flux concentration.

All surfaces of metal parts shall be smooth with no projecting points or irregularities.

All ferrous material, which is not made of stainless steel shall be hot dip galvanized in accordance with the Specification.

a) DISC TYPE PORCELAINE INSULATOR

Table 8: Specifications for Disc Type Porcelaine Insulator

Description	**Unit**	**Value**
Disc Diameter	mm	255
Disc Spacing	mm	146
Minimum Creepage Distance	mm	430
Standard Couple Pin Diameter	mm	16
MECHANICAL VALUES		
short time Electromechanical Breaking Load	KN	80
Mechanical Routine Test Load	KN	32
Mechanical Impact Strength	Nm	6.2
ELECTRICAL VALUES		
Power Frequency withstand voltage	kV	85
Wet Power Frequency withstand voltage	kV	50
Impulse withstand voltage	kV	110
Low frequency Puncture Voltage	kV	130
Galvanizing Coating (Cap & Pin):		
RADIO NOISE		
Maximum Radio influence at 1000 kHZ	µV	50
Test Voltage to Ground	kV	10
Galvanization of ferrous parts (hot dipped Zinc coating)	g/m2	1050
Colour of Glaze	Brown	

4.2.3.11 Accessories

For all accessories as clamps, connections, etc., care shall be taken to fulfil all conditions required concerning current carrying capacity, mechanical strength, glow discharge characteristics, corrosion resistivity and easy mounting, etc.

All nuts and bolts shall be hexagonal, either normal or of the round head socket type made of galvanized steel and secured against loosening by appropriate means.

All accessories shall comply with VDE Standard 0210 and 0212 and with the corresponding DIN specifications or with other similar and approved specification and shall be tested according to the same specifications.

4.2.3.12 Outdoor Cable Connection Cubicles

For each outdoor switch bay, a separate dust and waterproof (IP 54), hot-dip galvanized or aluminium cable connection cubicle shall be provided.

All secondary cables coming from the circuit breakers, isolating switches, instrument Transformers, etc., are collected in this cable connection cubicle. From here, a minimum amount of multi-core cables shall lead to the control room.

For this purpose, the cable connection cubicles are equipped with rows of terminals for all potential and current circuits, including the necessary test terminals for bushings and lashes.

Power outlets shall be of the same type and standards as for other socket outlets in the plant. The cubicles shall be ventilated by means of suitable openings, covered with dust filter. Each cubicle shall be equipped with a thermostatic controlled heater in order to avoid any moisture.

All terminals, socket outlets and other parts of the cubicles shall be easily accessible behind the hinged door(s) without dismantling.

4.2.3.13 Steel Structures

The steel structures for the switchyard and sub stations shall be furnished complete with all accessories required for an appropriate erection, and the equipment supplied shall include all work, materials, information, and services, even if not mentioned specifically in these specifications or shown on the drawings, but which are necessary for a proper and satisfactory erection and installation.

Design and admissible stresses shall be according to DIN 1050 VDE Standards 021015.69 "Determinations for the construction of high-voltage transmission lines" or equivalent similar approved standard.

The steel structures shall be hot dip galvanized. All materials incorporated in the supply shall be new and free from defects. They shall conform to the relevant standards. Materials not specially designed shall be suitable for the purpose.

Steel bars and plates shall be of a quality at least equal to Fe 360 B DIN-EN 10025, with a guaranteed yield point of 240 N/mm2. The use of other steel types is permitted, provided their characteristics are at least equivalent. For any other approved steel, the allowable tensile and bending stress will be evaluated proportionally to the guaranteed yield point.

The steel structures shall be of a proven design and construction and shall suit the indicated conditions and load requirements. The assembly of the parts at the site shall be by means of bolts and nuts. All structures shall be provided with the holes, bolts, and fittings necessary to accommodate the insulator and for securing the structures to their foundations. The design of the steel structures shall be submitted to the Engineer for approval prior to manufacture.

The bolts and nuts of galvanized mild steel shall preferably have hexagonal beads. Lock nuts shall be provided in all cases. On level surfaces spring washers shall be used for all bolts and nuts. Drilled holes are preferred to punch holes. The diameter of the bolt holes shall not be more than 1.5 mm larger than the diameter of the bolt.

Welds shall be carefully cleaned of slag before galvanizing. If straightening of steel members is necessary after galvanizing this shall be performed with the utmost care in order to avoid any damage to the coating.

All pieces shall be distinctly stamped with erection marks, corresponding to those on the drawings. Special care shall be taken to avoid obliteration of these marks during transport.

4.2.4 Tests

4.2.4.1 Factory Tests

Tests of HV switchgear equipment shall be made in accordance with the applicable standards and WAPDA specifications. Routine tests shall be made on each unit of all equipment.

Type tests shall be made on one unit of each type of different equipment. Instead of carrying out the type tests the Contractor may submit suitable type certificates issued by accredited independent laboratory made on equipment of the same type. However, the Employer /Engineer reserves the right of accepting these certificates or to reject them partially or totally.

Factory tests shall include but not restricted to the following tests.

a) Circuit Breakers

Routine Tests.

- Power frequency voltage dry withstand tests
- Measurements of the resistance of the main circuits (main contacts)
- Operating tests

Type Tests/Certificates:

- Impulse voltage dry withstand tests
- Temperature rise tests of the main circuits
- Breaking capacity tests
- Making capacity tests
- Short time current tests
- Mechanical endurance tests

The Contractor shall also submit all necessary tests reports of equivalent types of circuit breakers to verify that they comply with all requirements and guaranteed data referring to:

- Clearing of short circuit faults
- Breaking under phase opposition
- Interruption of unloaded lines
- Disconnection of unloaded Transformers

b) Isolating Switches and Earthing Switches

Routine Tests:

- Power frequency voltage dry withstand tests
- Measurement of the resistance of the main circuits
- Operating tests

Type Tests/Certificates:

- Impulse voltage dry withstand tests
- Temperature rise tests of the main circuits
- Tests to prove the capability of the isolating and the earthing switch to carry the rated peak short-circuit current and the rated short-time current
- Mechanical endurance tests

c) Current Transformers

Routine Tests:

- Verification of terminal markings
- Power frequency tests on primary windings
- Power frequency tests on secondary windings
- Over voltage inter-turn tests
- Determination of errors according to the requirements of the specified accuracy classes
- Partial discharge measurements, preceding the power frequency tests and repeated after them

Type Tests/Certificates:

- Impulse voltage dry withstand test
- Temperature rise test
- Short-time current test

d) Voltage Transformers

Routine Tests:

- Verification of terminal markings
- Power frequency tests on primary windings
- Power frequency tests on secondary windings
- Determination of errors according to the requirements of the specified accuracy class
- Partial discharge measurements, preceding the power frequency tests and repeated after them

Type Tests/Certificates:

- Impulse voltage dry withstand test
- Temperature rise test

e) Surge Arresters

Routine Tests:

- Dry power frequency voltage spark-over test on arrester.
- Acceptance tests to be made on three arresters, selected at random:
- Standard lightning voltage impulse spark-over test on complete arrester

- Residual voltage test at the nominal discharge current on complete arrester or sections

f) Conductors, Insulators, Accessories

Tests for physical and electrical properties on conductors shall be made in accordance with ASTM Standard B 398 and 399 or other equivalent and approved standard. The tests on wires shall be made on wires removed from the complete conductor. All wires making up the conductor sample shall be tested.

Sampling, inspection, tests and acceptance of the insulators shall be in accordance with ANSI/NEMA C 29.1, Test Methods of Electrical Power Insulators and C 29.2, Wet Process Porcelain Insulators (Suspension Type).

g) Steel Structures

Testing of the thickness of the galvanizing.

The Contractor shall submit certificates of the chemical and mechanical properties of the steel and/or aluminium materials.

h) Site Tests, Commissioning and Test on Completion

All electrical equipment and installations shall be tested for correct connections of the high-voltage circuits as well as of the control and measuring circuits, installation, insulation, and earthing.

All electrical equipment and installations shall be subjected to a complete operational test to check the correct operation thereof in terms of the operational requirements specified in these Specifications.

4.3 MV Switchgears

4.3.1 Scope of Work

The supply for the indoor Metal Clad trolley mounted horizontally draw out vacuum type MV Switchgear equipment (11 kV, 3 phase ,50 Hz) shall comprise metal-clad cubicle assemblies including all apparatus and requisite accessories, circuit breakers, disconnectors, busbars, conductors, cables insulators, bushings, clamps and connections, lightning arrester, instrument Transformers, earthing devices, internal wiring and terminals, base frames fixing materials, all switching devices and their combination with associated control, measuring, indicating, alarm, protective and regulating equipment and all those components/parts, not mentioned herein but requires for a complete functional system..

The supply shall include but not limited to the following:

a) Powerhouse

- Nine No, 11 kV Panels system (Copper) including Busbar VT Panel.
- Four Nos., Generator Circuit breaker
- Four Nos, switchgears for connection to 11/132 kV, Step-up Transformers LV side.
- One No., 11 kV Switchgears for 11KV Transmission lines to Intake
- Two Nos, 11 kV Switchgears for 250 KVA Station Service Transformers.
- One No., 11 kV switchgear for Busbar Potential Transformer (Metering Panel).
- One No., 11 kV switchgear as colony

- One set of maintenance tools

Each cubicle shall be equipped with an instrument compartment including mimic diagram, indicators, control switches, instrumentation, transducers, and protection relays. Cubicles shall have lockable access doors and it shall always be possible to open the door from the inside. Interior lighting and heaters shall be provided.

4.3.2 Design Requirements

4.3.2.1 MV Switchgear Panel Characteristics

The cubicle shall have the following specification:

- Switchboard Type — Metal clad
- Installation — Indoor
- Service — Continuous, uninterrupted
- Degree of protection — IEC 60529 (As per location i.e. indoor/outdoor)
- Device type — Withdrawable
- Nominal system voltage — 11 kV
- Max. operating voltage — 12 kV
- Earthing system — Stranded Copper Conductor
- Frequency — 50 Hz
- Rated power-frequency short-
- Duration withstand voltage (1 minute) — 28 kV rms
- Rated lightning Impulse withstand
- Voltage, 1.2/50 mms — 95 kV peak

Each cubicle shall be equipped with an instrument compartment including mimic diagram, indicators, control switches, instrumentation, transducers, and protection relays.

Each switchgear panel shall be fitted with a control panel containing the following:

- Local CLOSE and OPEN switch or pushbuttons coloured red and green respectively
- LOCAL – REMOTE (SUPERVISORY) changeover switch
- Electrically operated indicating lights of the LED type
- Set of terminals for the termination of auxiliary wiring

All auxiliary wiring for remote closing and tripping circuits, incoming dc control supplies and all spare auxiliary switches shall be connected to these terminals

The contractor shall workout the actual required quantities, ratings and burden of current and voltage Transformers and shall be subject to approval by the Engineer.

All instruments, transducers, and metering equipment and all indicating instruments shall be flush-mounted industrial type comply with the requirements of the relevant IEC standards. The instruments shall be clearly visible and easily readable from a standing position in front of the panel

Alarm facias or flagged relays shall be provided for indicating the existence of an alarm and trip condition associated with the SF6 gas density pressure monitoring device. Voltage free auxiliary contacts wired to terminals shall be provided for remote alarm and indication functions

4.3.2.2 Types and Short Circuit Strength of Panels

The following types of switchgear shall mainly be used in the project as per WAPDA Specification P-44-05.

- Incoming panel for connecting the 11kV switchboards to the Step-up Transformers.
- Outgoing panel for connecting supply to 11kV feeder.

Each panel shall be designed to carry and withstand thermal and mechanical stresses caused by the following rated currents:

Table 9: Rated Currents for Panels

Sr. No	Description	25 kA panel
1	Rated normal current (for main circuits)	2500 A
2	Rated short time (1 Sec) withstand current (for main and earthing circuits)	25 kA
3	Rated peak withstand current (for main and earthing circuits)	63 kA

Each incoming and outgoing panel of 25 kA breaking capacity shall consist of but not limited to the following equipment:

- Circuit breaker (Vaccum Type)
- Current Transformers for differential protection, overcurrent protection and metering,
- Voltage Transformers
- Surge arrester for outgoing panels
- Instruments
- Energy meters
- Relays
- Hooters
- Cable termination pad
- Signalling lamp

4.3.2.3 MV Circuit Breaker

The circuit-breaker shall be vacuum type-high current breakers for indoor location and shall be capable of continuous operation at an ambient temperature of 40ºC. Each circuit-breaker shall be equipped with disconnector, current Transformers, and earthing switches.

The metal clad circuit-breakers shall have the following ratings:

Table 10: Ratings for Circuit Breakers

Description	unit	Values	
Type of Switchgear (arc interrupter)		Vacuum	
Rated Voltage	kV	33	11
Maximum voltage	kV	36	12
Frequency	Hz	50	50
No. of Phases	No	3	3
Rated Current	A	As per single line diagram	
Short circuit breaking current	kA	32	
Short circuit making current	kA	63	
Voltage and insulation			
Power frequency withstand voltage	kV	75	38
Lighting impulse withstand voltage1.2/50 µsec	kV	95	170

The ratings given above are indicative, the contractor shall make detailed calculations to check these values and may adjust the ratings of 11kV switchgear in accordance with the latest editions of the above IEC standards.

The circuit-breakers shall be draw out preferably vacuum high current, type suitable for indoor use and shall be capable of handling the following operation cycle without external power, according to the IEC standards:

0-t-CO-t'-CO t = 0.3 sec. t'= 3 min.

The total breaking time (opening time plus duration of the arc) of the breakers shall be as short as possible, but in no case longer than 5 cycles.

The operating mechanism shall be of the stored-energy type with electrically driven spring charging and have provision for automatic local and remote control. The breakers shall be capable of continuous operation at an ambient temperature of 40ºC.

A crank, lever, or other similar suitable device shall be provided to permit charging the operating mechanism by hand in the event of a failure of the auxiliary supplies or the energy-storing device. Power supply for spring charging motors shall be 400/230 V A.C.

The opening device shall be provided with two independent release coils, connected to separate terminal blocks in the terminal cubicle, allowing for the connection of two independent opening command circuits. The control voltage for closing and opening operation shall be 220 V D.C.

A local position indicator shall be mounted in the front panel of the operating mechanism cubicle and the circuit breakers shall be mechanically interlocked with the corresponding earthing switch. A manual/automatic control selection switch shall be provided on the front of the circuit breaker cubicle.

In case of SF6 generator circuit breakers, the gas density shall be monitored. Alarm contacts shall close at low and critically low gas densities. At critically low density the circuit breaker shall be tripped automatically and blocked against operation.

Circuit breaker and earthing switch positions shall be indicated on the front of the cubicles, as well as transmitted to the control system for remote indication.

All internal wiring shall lead to terminals. Ten percent of the terminals shall be kept as spare.

4.3.2.4 Breaker Operating Mechanisms

- Circuit-breaker operating mechanism shall be fitted with independent duplicate shunt trip coils suitable for either independent or simultaneous operation.
- Circuit-breaker operating mechanisms may be of the oil-pneumatic, pneumatic, or spring charging types and shall be to the approval of the Engineer.
- Mechanisms shall be capable of fully closing and latching the circuit-breaker against its rated making current and shall be capable of interrupting under all conditions of short-circuit if the circuit-breaker is tripped during closing by the operation of the protection relays.
- Anti-pumping relays shall be provided to prevent reclosing if the closing coil remains energised and the circuit-breaker fails to latch in the closed position or is tripped during closing.
- Where separate operating mechanisms are provided for each phase approved means shall be provided to ensure the simultaneous operation of all three-phases.
- Operation mechanisms shall be capable of storing energy for at least two complete closing and tripping operations local to the equipment and without recharging. The system shall utilize 400/230 V, three-phase ac supplies for recharging duties.

4.3.2.5 Current Transformers

The current Transformers shall be of dry, synthetic cast resin insulated type.

The current Transformers for the generator terminal end and the generator neutral ends shall be of a type especially suitable for installation in the generator terminals and inside the generator busbars.

All secondary connections shall be connected to terminal blocks, which shall be located in a dust-proof and watertight terminal box and shall be clearly labelled.

A protective earth connection to the housing shall be provided.

The current Transformers shall be designed to carry continuously a current of 120% of the rated current. The rated current of the secondary windings shall be 5 A.

The winding for measuring purposes shall have the following characteristics:

Table 11: Characteristics for the Winding

Description	unit	Values	
Type of Switchgear (arc interrupter)		SF6 or Vacuum	
Rated Voltage	kV	33	11
Maximum voltage	kV	36	12
Frequency	Hz	50	50
No. of Phases	No	3	3

Rated Current	A	As per single line diagram	
Short circuit breaking current	kA	31.5	
Short circuit making current	kA	As per single line diagram	
Voltage and insulation			
Power frequency withstand voltage	kV	75	28
Lighting impulse withstand voltage1.2/50 µsec	kV	170	95
Accuracy class:		0.2	0.2
		5P	5P

The burden for the current Transformers for measuring and protection purposes shall be between 25 - 80% of the nominal burden for the measuring Transformers including cables and measuring equipment connected to the measuring Transformer secondaries. The Bidder shall ensure that no damages on equipment connected to current Transformers secondaries or mall-operation of protection relays will occur in case of short circuits on the medium voltage systems.

4.3.2.6 Voltage Transformers

The indoor voltage Transformers shall be of the single-phase dry synthetic resin type. All primary wiring of the PTs shall be protected by suitable H.R.C. fuse and secondary core will be protected by suitable MCB. Secondary connections shall be clearly marked. Three numbers Single phase draw out type PT of ratio 33000/√3; 110/√3 Volts and 11000/√3; 110 √3 with HT/LT fuses/MCB mounted on an independent trolley shall be housed in the same feeder/Transformer panel. This PT shall not get disconnected along with the Circuit Breaker in case the breaker is drawn out from 'SERVICE' position. Bus potential Transformer shall be housed in a separate panel. Arrangement shall be made in such a way that PT primary fuse can be replaced without switching OFF the breaker.

Table 12: Characteristics for Voltage Transformers

Description	unit	Values	
Type of Switchgear (arc interrupter)		SF6 or Vacuum	
Rated Voltage	kV	33	11
Maximum voltage	kV	36	12
Frequency	Hz	50	50
No. of Phases	No	3	3
Rated Current	A	As per single line diagram	
Short circuit breaking current	kA	31.5	
Ratio		33kV/√3/110V/√3 11kV/√3/110V/√3	
Accuracy Class		0.2	
Rated Budden	VA	100	

Power frequency withstand voltage	kV	75	28
Lighting impulse withstand voltage 1.2/50 µsec	kV	170	95

A protective earth connection to the housing shall be provided. Earthing of the cores and the neutrals shall be done on the Transformers and not on the terminal boxes.

The windings for measuring purposes shall be designed for accuracy according to class 0.2.

The voltage Transformers shall have an additional secondary winding for earth fault protection, connected in open delta with a resistive burden. The accuracy class shall be 3P.

For the stator earth fault protection, the Bidder shall propose a Transformer and resistor combination suitable for or matching the stator earth fault relay.

4.3.2.7 Surge Arresters

The lightning arresters shall be of the gapless metal oxide (MOA) type. Their characteristics shall be proposed by the Contractor. The lightning arresters shall be of the metal oxide gapless type, complying with IEC 60099-1.

The lightning arrester shall have the following characteristics just for tendering purposes, however, the Contractor shall check the values by calculations subject to approval of the Engineer

The arresters shall have the following ratings:

Table 13: Ratings for Surge Arresters

Designation	unit	Voltage Level	
Nominal system voltage (rms)	kV	11	33
Highest system voltage (rms)	kV	12	36
Arrester Rated voltage	kV	12	36
Rated Frequency	Hz	50	50
Continuous operating voltage	kV	10.2	28.8
Temporary Over voltage1 sec (rms)	kV	12	36
Temporary Over voltage10 sec	kV	11	33
Nominal Discharge current Peak	kA	10	10
Short circuit withstand current (0.2 Sec)	kA	20	20
Highest current 4/10 µs Impulse withstand	kA	100	100
Switching current Impulse withstand (upper value)	A	250	500
Maxim Residual voltage at 10 kA steep impulse current wave of 1/20 µs	kV	45	110
1.2/50 µs Lightning Impulse withstand voltage peak (dry)	kV	95	170
1 minute Power frequency with stand voltage (dry)	kV	42	80
1 minute Power frequency with stand voltage (wet)	kV	38	70

The final characteristics shall comply with the results of the Contractor's transient over voltage analysis.

4.3.2.8 Synchronising

The unit synchronizing will be carried out at the generator circuit-breakers at 11 kV. The unit synchronizing equipment will be installed with the unit local control panels. Synchronizing will normally be initiated from the power plant control room but local facilities will be provided in the event of a data highway failure.

Indication lamps shall be built into the lines on the mimic panel, and these shall indicate the apparatus and voltages being selected for synchronizing.

Synchronization test facility shall also be provided by the Contractor. In the test position all functions of the system shall be executed without the breaker closing control with indication of closing signal. Provision shall also be made to over-ride the synchronizing check relays for dead bus/line conditions.

The system provided shall be to the approval of the Engineer and shall be such that the synchronizing circuit must be established before the selected circuit-breaker can be closed. Provision shall also be made for manual control of synchronizing. The instruments shall incorporate running and incoming volts, running and incoming frequency and a synchroscope. Synchronism check relays shall be provided to check frequency, phase and magnitude of the voltage difference, with contacts connected to prevent unintentional manual or auto synchronizing outside acceptable limits

4.3.2.9 Protection Relays

Protection relays shall be equipped with two independent adjustable current settings for instantaneous and delayed tripping for each protection relay function. The time delay setting shall be independent of the current setting.

4.3.2.10 Accessories

For all accessories such as clamps, connections, etc., care shall be taken to fulfil all requirements concerning current carrying capacity, mechanical strength, glow discharge characteristics, corrosion resistivity, easy erection, etc.

All nuts and bolts shall be hexagonal, either normal or of the round head socket type and be non-corrosive made of galvanized steel and secured against loosening by appropriate means.

The metal-clad cubicle assemblies for the indoor switchgear shall be of approved and attractive appearance, adequately dimensioned, and shall consist of rigid, steel- plated cubicles enclosed on all sides and open at the top having full-length doors for easy access to the equipment inside. All doors shall be equipped with handles and key locks and windows making inspection easy.

The open busbars shall be carried on support insulators mounted on the top of the partitions between each cubicle. Supporting insulators shall be of the synthetic resin or other approved type. Porcelain insulators will not be accepted.

In case, system of different materials is used, any Cu-Al connections shall be made using special junction pieces.

An earthing bus (copper) of approved size shall be available in each cubicle, with the separate pieces connected to form a continuous bus through the complete length of the cubicle assembly. All framework, devices, neutrals of instrument Transformers, etc., shall be connected to the earth bus that shall have provisions for connection to the station earthing system.

Lighting inside each cubicle shall be provided, mounted in a separate lighting panel. The cubicles shall be vermin proof.

In order to avoid any moisture, thermostat-controlled heaters shall be provided in each cubicle.

4.3.3 MV Switchgear Tests

4.3.3.1 Works shop Tests

Routine tests and electrical type tests shall be carried out in accordance with IEC 62271, IEC 60298, IEC 60439 and IEC 60947 as applicable.

a) Circuit-Breakers

Type tests on one of each type of circuit-breaker supplied and routine tests on all circuit-breakers supplied shall be carried out in accordance with IEC 62271 and IEC 60439.

b) Contactors, Control Gear and Other Apparatus

Testing to conform with the IEC 60947 and as required by these Specifications.

Control and Indicating Panel Instruments, Wiring, Metering Apparatus, etc.

Routine tests as per IEC or equivalent Standards.

4.3.3.2 Site Tests

Following tests shall be carried out on switchgears at the Site:

- Routine high voltage tests,
- Insulation resistance tests,
- Continuity tests,
- Tests to prove correct operation of interlocks, tripping and closing circuits, indication, etc.,
- Operation of all protective gear circuits by primary and secondary injection,
- Protective gear timing tests as necessary,
- Stability check for different protection,
- Operation of alarm devices,
- Rotational tests on all motors, and
- Operation in conjunction with UCS system.

4.3.4 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

4.4 LV Switchgear

4.4.1 Extent of Supply

This specification covers the design supply installation testing and commissioning of the 400 V distribution system for the power plant, the HV switchyard and the weir intake. The supply shall comprise of MCB and MCCB's including all apparatus and requisite accessories, busbars, conductors, clamps and connections, earthing devices, internal wiring and terminals, base frames, and fixing materials.

The scope of supply for the low voltage switchgear shall comprise of 400 V switch boards complete with automatic changeover devices and associated cabling and equipment with the the following components.

- One Set of common services switch board including switchyard supply and supply for battery chargers with bus section.
- Four Sets of Unit auxiliary switch boards with bus section.
- One Set of Weir Intake switch board with bus section.
- One set of special tools and appliances.

4.4.2 Design Requirements

The low voltage A.C. distribution system will be designed as a 400 V, 3-phase four wire plus protective (earth) conductor system.

The Station Service Transformer connected to the 11 kV bus shall normally supply power to the Low Voltage Station Service busbar. If this supply is not available a standby diesel generating set connected to 11 kV bus bar shall start automatically and provide power supply to the essential equipment at Powerhouse and intake.

The powerhouse distribution systems should be designed with a normal main bus and an essential load bus interlocked with a bus-breaker for automatic separation in failure situations. If a black-out occurs in the main system, the feeder connected to the essential load busbar will feed all essential loads from the standby diesel generator.

The essential load distribution system will be continuously energized during normal operation to ensure the system availability. The distribution system will supply low voltage power to all plant service systems, lighting, and battery chargers, including all power cables, local control cabinets with necessary motor starters and sub-distribution panels. From the battery banks D.C./A.C. power converters will provide uninterrupted power to essential control functions.

All motors shall be powered and controlled through motor starter units assembled in motor control centres (MCCs). The starters are assumed to be of withdraw able design where each unit may consist of more than one starter. The number of MCCs would be determined by their lengths and availability to the localisation motors.

The nominal current ratings of the switchgear for incoming feeders, tie breakers and outgoing feeders will be selected in accordance with the nominal rating of the feeding source or with the busbar rating of the distribution board to be fed. The current rating of busbars will be selected in accordance with the current rating of the relevant incoming feeder or tie breaker whichever rating is higher, considering a maximum temperature rise of 45 K. The neutral and PE bars will be rated as the main busbar

4.4.3 LV Switchgear Tests

4.4.3.1 Workshop Tests

Routine tests and electrical type tests shall be carried out in accordance with IEC 60056, IEC 60298, IEC 60439 and IEC 60947 as applicable.

a) Circuit-Breaker

Type tests on one of each type of circuit-breaker supplied and routine tests on all circuit-breakers supplied in accordance with IEC 60056 and IEC 60439.

b) Contactors, Control Gear and other Apparatus

Testing to conform with the IEC 60947 and as required by these Specifications.

c) Current and Voltage Transformers

Routine tests on current and voltage Transformers as required by IEC 60185 and 60186 respectively and type test including impulse tests.

d) Protective Relaying Apparatus

Routine tests as required by IEC 60255 and checking of correct operation of all relays.

e) Control and indicating Panel Instruments, Wiring, Metering Apparatus, etc.

Routine tests as per IEC or equivalent Standards.

4.4.3.2 Site Tests

a) Switch board

The following tests shall be carried out on switchgear at the Site:

- Routine high voltage tests,
- Insulation resistance tests,
- Continuity tests,
- Tests to prove correct operation of interlocks, tripping and closing circuits, indication, etc.
- Operation of all protective gear circuits by primary and secondary injection,
- Protective gear timing tests as necessary,
- Operation of alarm devices, and
- Rotational tests on all motors.

b) Distribution Switchboards

Following tests shall be performed:

- Visual inspection,
- Functional tests,
- Dielectric tests, and
- Setting and functional tests of sequence and protective devices.

4.4.4 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

4.4.5 Low Voltage Circuit Breaker

Parts for each type and rating of low-voltage air circuit-breaker furnished. Each set shall consist of the following items:

- Four Sets of Stationary and moving, main and arcing contacts for a three-pole breaker
- Two Sets of Stored energy operating mechanism.
- One Set of Arc suppressing or extinguishing parts for a three-pole breaker
- One Set of Pole series trip device of each rating furnished
- One Set of Pole set of stationary and moving contact assemblies for a circuit- breaker.
- Two Sets of Stationary and moving auxiliary circuit disconnecting device
- Three Sets of Operating coils, control and auxiliary relays and breaker accessories such as under voltage trip devices.
- Three Sets of Bus insulators, each set to consist of one insulating component of each kind supplied for main buses and connections.
- Two Sets of Each type of meter installed
- Two Sets of Each type of transducer installed
- 10% of each type of MCB installed
- Two Sets of Current Transformers of each type and rating
- Two Sets of Voltage Transformer of each type and rating
- Two Sets of Under voltage relay of each type
- Two Sets of Protection relay of each type
- 10% of each type of Auxiliary relay
- Three Sets of Voltmeter selector switch
- Three Sets of Control switch of each type
- Indication lamp 50% of each type (Minimum 10)
- Indication lamp holder 10% of each type
- Two Sets of Automatic changeover devices complete
- Two Sets of Each type of printed circuit card used in changeover device.

SECTION 5: DC SUPPLY SYSTEM

5.1 General

The DC supply system shall provide uninterruptible power for control, protection, instrumentation equipment, miscellaneous equipment and to power critical DC operated equipment. An uninterruptible AC system has also to be provided to feed uninterrupted, transient free regulated AC power, during all normal and abnormal plant operating conditions, to specific critical AC loads.

For control and protecting equipment and for providing emergency lighting, in case of AC power failure, a bank of lead acid batteries will be used for DC power supply system in the power plant. Voltage level of this system will be 220 V for control, emergency lighting, closing, and opening of circuit breakers and 48 Volts will be used for communication system.

5.2 Scope of Work

The scope of work covered under this specification includes supply, installation and testing of station supply battery, battery chargers and switchboards complete in all respect for the powerhouse, switchyard. The scope shall include but shall not necessarily be restricted to the following.

5.2.1 Powerhouse and Switchyard

- Two sets of lead acid batteries bank with not less than 300 Ah capacity for the 220 V DC auxiliary power requirements for the powerhouse and Switchyard equipment.
- Two sets battery chargers, each one rated for 100% capacity to deliver DC power to the powerhouse equipment requirements and to supply boost charge to one battery when having reached its minimum end voltage.
- Two sets DC/AC inverter (UPS), 220 V DC / 230 V AC for emergency lighting and other AC essential loads etc. under normal and emergency conditions along with static transfer switch with control equipment.
- Two sets of 220/48 Volt, D.C./D.C. converters for the supply of 48 volts from the battery banks.
- One set of special tools and appliances.

5.2.2 Weir Intake

- Two sets of Li-ion batteries with not less than 150 Ah capacity for the 220 V DC auxiliary power requirements for the intake equipment.
- Two sets of battery chargers, each one rated for 100% capacity to deliver DC power to the Intake equipment and to supply boost charge to one battery when having reached its minimum end voltage.
- Two sets of DC/AC inverter (UPS), 220 V DC / 230 V AC to cope with the power demand of emergency lighting and other AC essential loads etc. under normal and emergency conditions along with static transfer switch with control equipment.
- Two sets of 220/48 Volt, D.C./D.C. converters for supply of 48 volts from battery banks.
- One set of special tools and appliances

5.3 Design Requirement

5.3.1 Station Batteries System

The storage batteries shall be of compact design with a small weight to capacity ratio. The construction shall ensure minimum self-discharge and low internal resistance. Adequate measures shall be taken for prevention of internal short circuits and protection of the element against mechanical damage

Material used in construction of the batteries shall be new and free from all defects which may affect the reliability, impair performance shorten their life expectancy or render them unserviceable.

The storage batteries will be of the high performance, low maintenance lead-acid type, suitable for operation at all prevailing conditions. Each cell will be enclosed in a high strength, translucent, heat and impact resistant plastic container. The top cover will be provided with removable labyrinth plugs which enable the measurement of the electrolyte density and the venting of gas and preventing the emission of acid sprays and minimizing the evaporation. A completely sealed type of battery will be preferred if a service life of 15 years can be guaranteed.

The individual cells will be arranged in single rows of single or double tiers mounted on steel racks specially coated for the purpose. The clearance to ground will be approx. 250 mm and the upper tier will be at convenient working height.

Each battery will be protected by a circuit breaker installed outside the battery room. The cables between the battery, circuit breaker and switchboard will be single core type. The connections to the batteries will be carried out with highly flexible cables only. Group connections will be made with rigid copper bars or copper pipes fully insulated over the entire length.

Heavy duty, natural or forced air-cooled charging rectifiers with fully controlled, 6-pulse thyristor bridges will be provided to supply the initial charging, boost charging, float charging and the total power demand of all connected electrical consumers and any other full rate charging that may be required for the specified lead acid batteries.

The battery chargers will be suitable for parallel operation (50 % load-sharing) and for operation with disconnected batteries.

An approved system will be employed to avoid excessive voltages during fast rate charging. The bus voltage will be maintained within the specified limits at all operating conditions.

DC/ AC inverters will employ fully static elements such as single or three-phase transistor inverters or diodes with pulse width modulation. By suitable bias control signals, the direct current will be chopped into a series of rectangular pulses passed through a filter (leakage inductance and capacitor) to obtain a sinusoidal voltage with low content of higher harmonics. By varying the pulse width of the chopped DC blocks, the AC output voltage will be kept constant in a wide range despite varying the DC input voltage on the AC load. Other control principles will also be acceptable if providing the same results; they will be subject to approval of the Employer/Engineer.

The static inverters will be of the natural air-cooled type.

The normal power source to the inverter will be DC from the DC auxiliary supply system.

Besides the normal DC power source, every inverter will be equipped with a stand-by feeder connected to the AC mains with a matching and de-coupling Transformer and a static bypass switch for uninterrupted load transfer.

The requirements specified for the LV AC switchboards will be applicable.

During the construction design the equipment ratings will be adapted to the actual requirements.

5.3.2 Batteries

The main characteristics of the storage batteries will be the following:

Table 14: Characrteristics for Batteries

Type	Lead Acid	
Installation	Stationary Indoor	
System Nominal Voltage	Volts	220
Nominal Voltage of Cell	Volts	2.0
Open circuit voltage of cell at full charge,	Volts	2.055
Number of cells in battery	No	110
End voltage after 10 h discharge at rated current/cell	Volts	1.8
Trickle charging voltage (floating)/cell	Volts	2.2
Maximum self-discharge rate at 40ºC/ month	%	< 5

5.3.3 Battery Chargers and Inverter

The battery charger shall consist of a solid-state static rectifier, designed to supply the power converter at nominal load and to simultaneously recharge the batteries from 10 % to 95 % of full capacity in 24 hours (rated under full load) at low end of input voltage range; 400 V - 1 0%.

The rated current of the chargers shall be selected to allow recharging of a fully unloaded battery in 5 hours, in addition to simultaneously supplying the total connected DC load. The chargers shall be of constant voltage type with current limiting device.

The chargers connected at the terminals of the battery shall be completely suitable for a fully automatic and controlled charging and floating of the battery, by means of a change-over switch, the charger shall be set from normal charging and float charging to fast charging of the battery. Each charger/rectifier unit shall be presented in a sheet steel floor mounted cubicle. Front panel shall be secured by lock and key and include ON/OFF switch, DC Ammeter and Voltmeter, off failure indicator.

The main characteristics of the battery chargers will be the following:

- Charging mode, I/U constant characteristic
- Nominal input voltage V AC 400/230
- Rated output voltage V DC 240 approx.
- Initial and boost charging, adjustable V/cell 2.4
- Float charging operation V/cell 2.23
- Maximum Recharging time from 1.8 V/cell to

	rated capacity	h	12 max.
•	Protection class	IP 41	

5.3.4 Inverters

The main characteristics of the inverters will be the following:

•	Rated input/ output voltage	V DC/V AC	220/230
•	Rated output	kVA	10 / 5
•	Permissible variation of the input voltage	p.u.	0.8 - 1.15
•	AC voltage stability (steady state)	%	± 1
•	AC voltage waveform	Sinusoidal	
•	Harmonic voltage distortion (linear load)	%	< 5
•	Voltage recovery time	ms	< 4
•	Static switch response time	ms	< 5
•	Frequency	Hz	50
•	Frequency variation, maximum	%	± 1
•	Power factor range, minimum		0.8 - 1.0
•	Noise level, minimum	dB	60
•	Permissible overload, minimum for 1 /10 min	%	50/25
•	Protection class		IP 41

5.3.5 D.C./D.C. Converters

The 220/48 V D.C./D.C. converters shall be used for 48 Volts DC power from the station battery system. The Contractor shall calculate the power ratings based on each unit's actual load with 50 % spare capacity for future use, and 100 % redundancy (two converters in parallel).

The converters shall comply with the following technical data and requirements:

•	Nominal Input voltage:	Volts	220
•	Input voltage variation	%	-10
		%	+15
•	Output voltage:	Volts	48
•	Variation for the maximum input voltage		
	from 0 to 100% of rated output current.	%	+1/-1.5

The converter units shall be equipped as a complete unit comprising:

- Internal fuses
- Cabinets
- Protection, D.C. under voltage and internal fuse
- Instruments; D.C. current and voltage

5.3.6 Switchboards

The main characteristics of the DC and UPS switchboards will be the following:

a) DC Switchboards

• Nominal system voltage	V DC	220
• Rated voltage	V	690
• Rated insulation voltage	V	1000
• Power frequency withstand voltage	V rms	2500
• Rated short time withstand current (1 s)	kA rms	20
• Rated peak withstand current	kA peak	50
• Installation		Indoor
• Protection class		IP 42

b) UPS Switchboards

• Nominal system voltage	V	400/230
• Rated voltage	V	690
• Rated insulation voltage	V	1,000
• Power frequency withstand voltage (rms)	V	2,500
• Rated short time withstand current (1 s)	kA rms	20
• Rated peak withstand current	kA peak	50
• Installation		Indoor
• Protection class		IP 42

5.3.7 Metering and Signalling

Information concerning busbar voltage and current in incoming lines, switch board faults and positions of main items of switchgear necessary for correct operation shall be relayed in accordance with the general principles and technology for control systems. Equipment failure shall in addition to a local alarm, also be transferred to the Station Control System. The following protection system shall be provided for each battery as part of the battery charger as a minimum:

- Under voltage relay
- Over voltage relay
- Earth fault relay
- Charger failure relay

The 220/48 Volt, DC/DC Converter shall be provided with under voltage relay, converter failure relay (each converter) and earth fault relay.

5.4 DC System Tests

5.4.1 Works Tests

Routine tests and electrical type, tests shall be carried out in accordance with IEC 60056, IEC 60298, IEC 60439 and IEC 60947 and relevant IEC/IEEE Standards publications as applicable.

a) Contactors, Control gear and other Apparatus

Testing to conform with the IEC 60947 and as required by these Specifications.

b) Control and indicating Panel Instruments, Wiring, Metering Apparatus, etc.

Routine tests and type tests as per IEC or equivalent Standards.

c) Batteries, Chargers, Inverters and Distribution Switchboards

The battery materials shall be subject to appropriate tests and sample tests shall be carried out on cells according to IEC or international Standards.

The charger components shall be tested in accordance with relevant IEC or other international Standards.

Complete chargers, inverters and distribution boards shall be subjected to temperature rise, high voltage insulation resistance and operational tests. The ripple at the output shall be measured with no battery connected and temperature rise and other effects under permanent short-circuit at the output terminals shall be measured.

Chargers and inverters shall also be subjected to radio interference tests.

5.4.2 Site Tests

a) Batteries and Chargers

The insulation to earth of the complete DC installations shall be tested.

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment and the operation of the battery and charger control and alarm systems. Initial charge, controlled discharge and recharge tests shall be carried out to demonstrate the rated capacity of each battery.

Ripple measurement of charger output with battery connected shall be performed.

The specific gravity and cell voltages of the batteries when fully charged shall be recorded

b) Inverters

Following tests shall be carried out:

- Visual inspection
- Functional tests, and
- Insulation test

c) Distribution Switchboards

Following tests shall be performed:

- Visual inspection,
- Functional tests,

- Dielectric tests, and
- Setting and functional tests of sequence and protective devices.

5.5 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

5.6 Reference Standards

The design, manufacturing and testing shall comply with the below listed standards:

IEC Safety	IEC Safety Handbook containing all IEC basic safety standards.
IEC 27	Letter Symbols To Be Used in Electrical Technology.
IEC 38	IEC Standard Voltages
IEC 51	Direct acting indicating analogue electrical-measuring instruments and their accessories
IEC 59	Standard Current Ratings
IEC 73	Colours of Indicator Lights and Push Buttons
IEC 95	Lead-acid starter batteries
IEC 127	Miniature fuses
IEC 144	Degrees of protection of enclosures for low-voltage switchgear
IEC 254	Lead-acid traction batteries
IEC 255	Electrical relays
IEC 257	Fuse-holders for miniature cartridge fuse-links
IEC 259	Classification of degrees of protection provided by enclosures
IEC 269	Low-voltage fuses
IEC 337	Control Switches
IEC 865	Calculation of the effects of short-circuit currents
IEC 896	Stationary Lead-Acid Batteries, General Requirements and Methods of Test.
WAPDA	Specification P-132:88 Station Batteries

SECTION 6: PLANT CONTROL AND AUTOMATION SYSTEM

6.1 General

The overall Control and Monitoring of the entire power plant shall be carried out through a computerized Plant Control and Monitoring System. The capacity of the systems shall be designed to handle future extensions in view of linking the project with the National Grid system.

The Plant Control and Monitoring System for the Power Plant shall comprise a complete functional and state of the art equipment with latest software including SCADA system, capable of carrying out entire control functions of the power plant and substations, even not mentioned in the specification, for efficient operation of the power plant.

a) Plant Control Levels

The Power Plant Automation and Control System shall function in the following three levels of plant control mode.

- The Plant Control System (PCS) shall consist of a computerized system located in the main control room for supervisory control of the entire power plant. The PCS shall monitor and control the complete power plant, and cover the generating units in the powerhouse, the HV switchyard & MV switchgear system and the weir intake
- The local control system shall consist of computerized Unit Control System (UCS) with local mimic board, one for each generating unit, one for the HV switchyard / 11 kV switchgear one for the auxiliary systems. One for Intake weir. The protection relays shall be part of the unit control system but operationally independent from the local computer.
- The manual control system shall function through manual operation from the object control board and Emergency Stop from separate, independent panels. A Local Control Box with Local/Remote selector switch with key and ON-OFF Push Buttons will be provided near the electrical actuators (motors or valves).

Provision shall be made for remote control from NPCC when National Grid is extended to the project area so that the NPCC will be able to start/ stop individual units which were set to automatic control in the central control room

6.2 Scope of Work

The scope of work under this section shall include design, engineering, manufacturing, supply, test and commissioning of complete control and automation system for the power plant, switchyard. The bidder shall perform all calculations required to determine the necessary requirements which is not mentioned in this specification and shall also workout the actual configuration and perform detailed engineering for a complete functional project.

The bidder shall submit detail drawings and documents, shop and site testing, erection, adaptation to related equipment, commissioning and training services for the plant and its components.

The Bidder shall describe the control and automation system hardware and software as to the contents, operation, functions and any special feature in sufficient detail to enable verification of compliance with the plant requirements. Any operational restrictions of the proposed control and protection system or any hardware or software modules required for fully utilizing the facilities of the offered software packages, shall clearly be stated in the bid documents.

The PCS will be fully developed, debugged, commissioned and tested for manual and fully functional automatic control of the power plant. The PCS shall include the following minimum systems, components and ancillaries but not restricted to the following:

a) Plant Main Control Room Equipment

- Mimic panel display system showing the configuration of the complete power plant's operating philosophy.
- Two workstations consisting of two full graphic colour display monitors with alphanumeric keyboard and mouse.
- Two redundant main servers in hot-standby;
- One video surveillance system based on Internet Protocol (IP) technology with four monitors;
- One metering station with two monitors and printer;
- One engineering station with two monitors and high-resolution and high-capacity laser colour printers;
- One redundant gateway for connection to the Regional / National Power Control Centre (NPCC) in future;
- One redundant fibre optic main Gigabit bus system according to IEC 60870-5-104;
- One metering station with two monitors and printer;
- One archiving system for long term and spontaneous data archiving;
- One engineering station with two monitors and laser colour printer
- One interface with firewall to Office LAN and Web Client for remote access;
- One interface to the Automatic Weir Monitoring System;
- One GPS master clock system with interface to secondary system;
- One redundant gateway to the National Power Control Centre (NPCC);
- One redundant fibre optic main Gigabit bus system according to IEC 60870-5-104;
- One redundant fibre optic process Gigabit bus system according to IEC 60870-5-104;
- Set of furniture for the Central Control Room (CCR).

b) Unit Control System (UCS) and Local Control Units (LCU)

- Four redundant unit controllers with field-bus interfaces to sub-controllers;
- One redundant station auxiliary systems controller;
- One redundant common services controller;
- One redundant 132 kV Switchyard controller;

c) Weir Control Room

- One redundant controller for the Weir Site;
- One operator station with three monitors and alarm printers;
- One printer;
- Set of furniture for the Weir Control Room.

The PCS will include all necessary instruments, sensors, adapters, transmitters, wires, cabling, Ethernet repeater stations, and data bus systems as a fully functioning system complete in every respect.

6.3 Design Requirements

6.3.1 System Concept

- The Plant Control System shall be characterized by an innovative system concept, powerful communication capabilities and a scheme-wide unique engineering and configuration tool. The PCS will consist of state-of-the art equipment and components, applying the latest knowledge and achievements in the industrial process automation technology, such as:
- Client-Server/ Master-Slave concepts;
- Object-oriented processing of data;
- Re-usable automation software objects and program modules;
- High-level of hardware modularity and scalability;
- System-wide data management and data access with single data entry;
- Central engineering system to program and configure all system components;
- Long-term availability of components;
- Standard-based communication from field to management level;
- Standardized 10/100/1000 BASE FX Gigabit-Ethernet bus system;
- Application of IEC 60870-5-104 protocol;
- Distributed redundant concept;
- Integrated alarming;
- Time correct processing;
- Effective human-machine interfaces;
- Window-based operation system, process diagrams and sequential controls;
- Total plant efficiency optimization modules and diagnosis functions.

Expansion or software updates of the PCS will be enabled based on an open system architecture concept and by strictly applying international communication standards for the main, process- and field-bus applications.

6.3.2 System Architecture

The PCS will be designed in consistent hierarchical and decentralized structure. Dividing the control scheme into autonomous functional areas will increase the availability and guarantee all time pre-defined and safe operating modes in case of emergency situations. The PCS will be designed to ensure maximum availability by the inclusion of built-in redundancy for both hardware and software. This will include duplicated control processors, bus systems and power supplies with automatic change-over to the standby device upon detection of a fault or failure. Where appropriate, I/O cards will also be duplicated.

Simple and safe operation of the power plant and its components will be enabled by installing touch-panels as human-machine interfaces (HMI) at the UCS and LCU with ergonomically designed graphical user interfaces. The system will be designed for industrial use and withstand permanently the climatic and electro-magnetic environmental conditions in a power plant.

The PCS will contain self-monitoring hard- and software functions. Software self-supervisory and fault diagnosis functions and plausibility checks will lead to an early detection of abnormalities and therefore to a high availability of the plant. Comprehensive system diagnostic facilities will be incorporated also to assist in maintenance and trouble-shooting.

A failure of any single element will not affect the operation of any main system of the power plant in operation. In particular, the duplicated controllers will enable a failure tolerance in order not to affect the plant operation or any control sequences. All process signals will be managed without multiple engineering (single data-entry).

The two operator stations with three monitors, keyboards, printers and peripheral devices and their associated control desks will allow monitoring, control and adjustment of all relevant plant operation tasks with high resolution window-based graphic displays. The main bus system will be arranged as a dual fiber optic ring network and realize the data transfer between the redundant main servers, the control room HMI equipment, and all other related controllers according to the system architecture drawing.

The process bus system will also be arranged as a dual fiber optic ring network and realize the data transfer between the redundant main servers, the unit controllers, and all other related controllers according to the system architecture drawing. Both bus systems will apply IEC 60870-5-104 as protocol standard. Sub-systems like the digital turbine governor, static excitation system, generator circuit breaker and digital protection system will be interlinked by standard field bus systems, arranged in redundant star shape.

The PCS will be connected to a GPS master clock system to guarantee synchronization of all PCS components. The UCS will be equipped with instruments for active and reactive power, stator voltage, stator current, field voltage, field current, turbine discharge, speed measurement, trash-rack differential pressure measurement and wicket gate position indication. The relevant input signals will be taken directly from the transducers. For position indications of the circuit breakers and disconnecting switches, a mimic diagram will be provided on the unit control board. The signals to the position indicators will be supplied from interposing relays.

6.3.3 System Main Features

The PCS will be designed to ensure maximum plant availability and efficiency. In its final configuration, the PCS will be capable of controlling and monitoring the operation of the entire power scheme, the turbine-generating units, individual sub-systems and auxiliary equipment.

Open system standards and international software protocols will facilitate interconnectivity to a wide range of optimization and diagnosis applications as well as asset management systems. A high level of modularity and system scalability will allow optimum process adaptation. The use of standard industrial components will assure long-term availability and reduce spare part costs.

The following installations and essential equipment will be monitored and operated by the PCS:

- Weir Site with intake gate, water level measurement;
- Weir Site auxiliary and service systems;

- Turbines with Butterfly valve (MIV), governors and ancillary equipment;
- Synchronous generators with ancillary equipment;
- Generator main circuits including generator circuit breakers;
- Generator step up Transformers;
- Station auxiliary systems (MV switchgear, station service Transformers, LV switchgear, DC / UPS systems, diesel generating unit);
- Common services (cooling water system, drainage and dewatering system, HVAC, fire protection system, potable water system, and sewage treatment plant);
- 132 kV AIS Switchyard.

The Plant Control System shall also perform the following functions:

- Fully automatic control and monitoring to provide safe start-up, synchronizing, loading, shut-down and emergency tripping of each unit;
- Provision of active and reactive power joint control / joint discharge control;
- Plant operation forecast schedule module (daily / 7 days);
- Plant optimization software module (operation of active units in maximum efficiency point);
- Total discharge calculation module (including spillway and bottom outlet gates);
- Data acquisition from the Generator step up Transformers;
- Provision of facilities for comprehensive monitoring, storage and presentation of information concerning plant conditions and performance and historical archive;
- Energy metering of scheme output and provision of billing data for invoice purposes;
- GPS master clock systems to generate signals to the secondary clock system;
- Life-beat monitoring;
- Provision for black start capability;
- Control and monitoring of the Weir Site facilities including the Sand Trap;
- Interface with the Load Dispatch Centre.

6.3.4 Unit Control Systems (UCS's)

The local control shall consist of 8 UCSs. The UCS's shall have connections to and be interfacing the process equipment and the communication system that interconnects the UCSs and the Plant Control System (PCS).

6.3.5 Generating Units (UCS 1-4)

The UCS's for the generating units shall be programmed for fully automatic start and stop procedures. The initiated procedures shall perform sequentially all command actions. The sequence of operations and the immediate status shall be visualized at the PCS work stations. However the operation and functions of the voltage regulators and the turbine governors will be independent.

All automatic start and trip sequences should be implemented as software in the Programmable Logical Controller (PLC).

The Automatic synchronizing equipment shall control the voltage and frequency of the generating unit.

Manual synchronizing shall be performed with the local synchronizing unit.

The PCS's for the generating units will be located in the floor of machine hall. The cubicles for the protection relays shall be located in the main Control Room.

6.3.6 Auxiliary Systems (UCS-5)

This UCS shall be located in the Power Plant. In addition to the auxiliary power supply this UCS shall supervise the drainage pumps, ventilation system, the cooling water pumps, light, small power and diesel generating units, firefighting system etc.

The UCS shall supervise the Power Plant station power supply system and provide automatic switching to the available power sources according to agreed priority schedule.

6.3.7 Intake (UCS-6)

The UCS shall be located in the intake control building. The UCS shall cover the gate control and water level measurements, the water level gauges/switches, all gates power systems and auxiliary systems. It shall include programs for the gate and turbine governor set-point control, the standby diesel generating unit and the transmission of signals from the gate equipment to the Power Plant.

A local control system for the gates at the intake will be located in the intake control room.

6.3.8 HV Switchgear (UCS-7)

The UCS shall be located in the local control room for the HV switchyard. The UCS shall be interconnected with the local control panels and the relay protection panels for the HV/MV switch gear.

An automatic synchronizing unit or synchronization software module for operation of the circuit breakers shall be provided and shall be accessible when operating in either PLANT or LOCAL operational mode, i.e. the start synchronization signal shall be activated from either the PCS or the UCS.

6.3.9 Power Plant–Substations, National/Regional Grid Remote Control Communication System (UCS-8)

The UCS shall be located in Power Plant control room and shall provide interface for the SCADA requirements between Power Plant and RCC/NPCC.

6.3.10 Control Levels Functions

a) National Power Control Centre (NPCC) when Connected

The commands will operate the joint control set point of the HPP. If the HPP is not set to joint control, the NPCC or the regional Power control center will be able to start/ stop individual units which were set to automatic control in the central control room.

b) Plant Control System (PCS)

The highest control level in the plant will be designed to enable automatic control and supervision. A comprehensive supervision of all units, AIS Switchyard, the station auxiliary equipment and station

services will be provided. The functions in this mode are the same as those of automatic operation mode from the unit control board.

c) Unit Control Board (UCS) and Local Control Units (LCU)

From the UCS the unit can be operated in the manual and automatic mode. The UCS will be installed on machine hall floor level.

From the LCU the related plant components can be operated in the manual and automatic mode. The LCU will be located close to the relevant plant component.

d) Local Control Cubicles (LCC)

On the lowest level in the control hierarchy, individual control cubicles will enable the operation of individual equipment. These control facilities will mainly be used for testing and maintenance purposes. As a back-up of the normal operation or during special operations, it will be possible to operate the different functional groups of the power plant from local control boards.

e) Control Modes

The mode of control will be selected by selector switches to be provided at the LCU and UCS. The CCS will be suitable for the following control modes:

f) Remote Automatic

The normal operation mode of the power plant main and auxiliary equipment will be “remote automatic” by the station control engineer via the operator stations in the PCS.

g) Local Automatic

In the local automatic” mode, operation of the unit equipment will be controlled and supervised by computers in the unit control boards. The computers and controllers of the boards handle indications and monitoring of the equipment. This mode of control may be used during commissioning of the equipment, as well as during setting up of the PCS.

h) Manual

In the manual” mode, control and supervision will be carried out from the UCS and LCU. This mode of control may be used during commissioning, testing or maintenance.

6.4 Computer Control System Tests

6.4.1 Workshop Tests

The equipment shall be fully assembled and tested in the shop according to Contractor’s practice. All shop tests shall be carried as per the relevant IEC recommendations. For this test all equipment shall be hooked up together in the same way and with the same elements as will be used later at site. Included in this test shall be all other equipment for one unit which shall communicate with the control system through bus connections (turbine governor, excitation system, electrical protections, etc.).

A representative of the Employer will witness the functional tests and shall carry out an inspection of the assembled unit and related documents to verify compliance with the requirements of the contract specification. System and application software functions shall be fully verified. All input signals shall be simulated and output signals verified from cubicle input to cubicle output. The manufacturer shall prepare a detailed test procedure and inspection schedule for all shop tests.

6.4.2 Site Tests

The Contractor shall perform comprehensive functional tests for all equipment according to a predefined schedule, suggested by the Contractor and approved by the Employer/Engineer.

a) Preliminary Tests on Site

The following tests shall be performed during and after erection of supply:

- Checks on the wiring of the interconnections;
- Dielectric tests as well as measurement of insulation resistance of each circuit;
- Functional checks of all instruments, auxiliary relays, switches, etc. including calibration of all gauges and instruments;
- Functional check of systems for local and automatic control, interlocking and annunciation, etc. in conjunction with the actual equipment to be protected and/ or controlled;

b) Tests on Completion

Tests of components/ equipment shall be according to the Contractor's quality control procedures.

The tests on the units shall consist of runs in various conditions of load, voltage, speed, switching on and off, starting-up, shutting-down, etc. with local control and automatic control.

The clock system shall undergo tests at site. A system function check shall be executed showing all functions for each equipment in the system as specified including time reset, continuous time setting, day and date changes, individual adjustments.

6.5 Consumables

Consumables of all kinds for the operation of the control systems for an approximate period of one years, including items such as printing paper, tape cartridges, printer ribbon tapes, etc.

- One lot of printer ribbon tapes for the printers and hard copy units.
- One lot of cleaning kits for the printers, hard copy units and tape stations.
- One lot of any other consumables as recommended by the Contractor

6.6 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 7: PROTECTION SYSTEM

7.1 General

The general principle for the protection shall be such that all parts of the installation (Generators, Power Transformers, Auxiliary Transformers and lines etc.) are covered by two high speed protection schemes which shall be independent to avoid common-mode failures. The protection equipment shall be complete with all relay panels, instruments, meters, interposing and auxiliary relays, control switches, interposing current and voltage Transformers, transducers and all auxiliary equipment. The protection scheme shall be provided with cyber security support for compliance to IEC 62351 with Centralized Account Management. Separate cores of current Transformer (CT) and voltage Transformer (VT) shall be used for each protection and metering. Minimum of one (01) core shall be provided as spare for each CT and VT. The protection system shall fulfil the NTDC and National Grid Code 2023 requirements after conducting short circuit, transient and over/under frequency analysis (Software Based).

Protection equipment shall be designed and supplied to provide maximum discrimination between faulty and healthy circuits. All equipment is to remain inoperative during transient phenomena which may arise during switching or other disturbances to the system. All equipment shall conform to IEC recommendations. All equipment shall conform to IEC, NTDC and Grid Code 2023 recommendations.

7.2 References Standards

The equipment shall comply with the standards listed below:

IEC	Safety Handbook containing all basic safety standards
IEC 331	Fire-resisting characteristics of electric cables
IEC 439	Low-voltage switchgear and control gear assemblies
IEC 801	Electromagnetic compatibility for industrial, process measurement and control equipment
IEC 848	Preparation of function charts for control systems
IEC 1131	Programmable controllers

7.3 Scope of Work

The scope of work under this section covers, the design, short circuit calculation, manufacturing, supply, installation testing and commissioning of contractors proven state of the art protection system for the electrical equipment of power plant, switchyard, transmission lines and substations. The scope of work shall include but not limited to the following protection equipment.

a) Power station and Switchyard

- Four No., Unit Protection System to provide the complete range of electrical protection for the generators.
- One No., 132 kV Switchyard bus bar protection system comprising set of relay’s panels complete in all respect.

- Two Nos, 132 kV Transmission Line bays protection system comprising set of relay panels complete in all respect
- Three Nos, 10/13 MVA, 11/132 kV Transformer bays protection system comprising set of relay panels complete in all respect.
- 0ne Nos, 3.5 MVA, 11/132 kV Transformer bays protection system comprising set of relay panels complete in all respect
- Protection systems to provide the complete range of electrical protection for the 11 kV switchgear, 11 kV overhead line, Auxiliary AC/DC systems, local distribution Transformers, station service Transformer and emergency diesel generator set;
- One set of special tools and appliances;

7.4 Design Requirements

7.4.1 Protection system for Generator Unit Components

The following equipment comprising the generating units with the main circuits up to the Switchyard will be adequately protected:

- Synchronous generator;
- Excitation Transformer;
- Neutral earthing cubicle
- GCB Switchgear, Station service and auxiliary Transformers;
- Overhead Interconnection between step up Transformers and Switchyard.

The protection systems for the above listed equipment will be installed in cubicles, arranged in a common assembly with the Unit Control System.

a) Generator Protection

The following protection devices will be considered as the minimum requirement for each of the generating units:

- 27/59 Under/Over voltage relay.
- 81 Over/Under frequency relay
- 51 Over current relay, instantaneous and time delayed
- 32 Reverse power relay.
- 46 Negative sequence current relay.
- 40 Loss of excitation relay (Minimum reactance relay).
- 64 R Rotor (field winding) earth fault relay.
- 87 G Three phase generator differential current protection relay.
- 64 G Stator earth fault relay.
- 49 Winding Temperature Relay
- 25 Synchro-Check relay

- Rotational, speed relay with two individual settings.
- Level 1: 0 - 1% of nominal speed for creep warning.
- Level 2: 100 - 200% of nominal speed for over speed tripping.
- Vibration and shaft movement supervision relay, complete with Circuit breaker failure relay (Generator CB)

b) Transformer Protection

The following protection relays shall be delivered for each of the Power Transformers:

- 51 Three phase over current relay with two independent settings for instantaneous and ime-delayed trip.
- 63 Buchholz gas pressure Relay
- 26 Oil level and temperature control Relay
- 87T Three phase Transformer unit block differential relay.
- 51G Transformer Neutral point earth fault current relay.
- 49 Winding Temperature Protection

c) Transmission Line Protection

For transmission line, the following protection relays shall be included:

- Distance Relay Three-phase minimum impedance relay with at least three zones,
- Zone 1: Setting range, 80 - 120% of the line impedance. Immediate trip.
- Zone 2: Setting range, up to 80% of the line impedance. Time delay according to selectivity requirements.
- Zone 3: Setting range beyond Zone 2. Time delay 0.3 - 5 s.
- 27 Under Voltage Protection
- 59 Over Voltage Protection
- 25 Synchro-check Relay
- 50 BF Breaker Failure Protection
- 51 Time over current protection
- 50 Over current Relay
- 79 Auto Recloser Relay

d) Busbar Protection

- 87 BB Busbar Differential Protection 132 kV Busbar
- 27/59 U/O Voltage Protection
- 25 Synchro-check Relay
- 50/51 Over current Protection
- 50 BF Breaker Failure Protection

e) Station Service and Local Supply Transformer

- 50 Instantaneous Over current Protection
- 51 Time Delay Over Current Protection
- 51 Overload Protection
- 51 N Earth fault Protection

f) Emergency Diesel Generating Unit

- 50 Instantaneous Over current Protection
- 51 Time Delay Over Current Protection
- 51 N Earth fault Protection

g) 11 kV Overhead Transmission Line

- 50 Instantaneous Over current Protection
- 51 Time Delay Over Current Protection
- 67 N Directional Earth Fault Protection

The protection devices will be accommodated in the unit protection cubicles and the LV compartments of the relevant switchgear, respectively.

The protection systems will communicate with the LCU and CCS by means of bus systems.

All other protection devices relays not mentioned above but are necessary for complete and effective functioning of the system, shall be proposed by the bidder and the list and technical data be included in the bid.

7.5 Design Requirements

The protection systems will be complete in every respect and include the specified protection devices, the necessary auxiliary relays, interposing Transformers and power supply units. The protection devices will be of the numerical, microprocessor controlled type of a competent manufacturer with a 5 years proven track record.

The relay assemblies will be grouped in a logical manner to provide a good overview and facilitate the identification. Test plugs for measuring and test injection will be easily accessible from the front side. For the power supply to each relay or group of devices redundant DC/DC converters will be provided.

The cubicles accommodating the devices will facilitate easy access to the wiring inside the cubicle and to the rear side of the devices. Each protection cubicle forming a functional group will have a door mounted signal lamp indicating the trip of any protection device. After manual resetting of the relay the lamp will be off. Trip and reset indications, adjustments and functional operations will be arranged at the front of the protection device or cubicle.

Control circuits including potential and current Transformer secondary circuits, AC/DC auxiliary power supply circuits, supervisory alarms and communication circuits associated with the function of the concerned equipment will be protected against electrostatic and electro-magnetic influences of transients from the neighboring circuits.

All devices will have the necessary quantity of output contacts with sufficient make and break capability, suitable for control, monitoring, supervisory and tripping functions related with the equipment. Switching of contacts in AC/ DC control circuits will not produce harmful over voltages. CT terminals will be shorted automatically when the relay is withdrawn from its casing.

The software for each device function will be accessible for setting values and retrieval of events via a special software package. Each relay module will be equipped with an integrated key pad and display.

A notebook will be included for adapting values/settings of the protection devices.

After response, the tripping contacts of the protection device will reset automatically, however, the signalling contacts will remain in the tripped position until the manual reset by the operator.

All relay setting ranges will fit with the special requirements of the individual circuits. Generally, time delay modules will have a definite time characteristic with a continuous adjusting range. Inverse time relays are likewise acceptable provided they cover a suitably wide adjusting range and ensure sufficient selectivity with other protection devices.

During the construction design a comprehensive protection study will be performed to define the required protection parameters, redundancies, selectivity and relay setting ranges based on the maximum and minimum short-circuit capacity of the network.

Back-up protection functions will be properly coordinated with due consideration of short-circuit durations and appropriate time constants of the related network elements.

The protection relays shall be part of the unit control system but operationally independent from the local computer. The function of the protection relays shall not depend on the control system.

The protection system shall provide selectivity between selected protection zones. Further shall the protection system provide redundancy in two or three steps by careful selection of the parameter settings on the relays for neighbouring zones.

Protection system shall be organized in two groups, so that one group shall provide back-up protection for the other group to obtain optimal redundancy.

7.5.1 Protection Devices

Only relays of a recognized make and of a high quality which has been duly demonstrated in actual service will be accepted. The protection relays and associated auxiliary relays shall be the standard product of an experienced and reliable protection relay manufacturer. The relays shall be electronic or microprocessor based, rack mounted and based on modern technology. The relays shall preferably be of the same make (manufacture) to build a uniformed modular system.

The relay assemblies will be of modular, uniform design, accommodated as plug-in units in standard type electronic cubicles with the systems completely wired and tested in the factory.

All relays shall be provided with at least two separate pairs of independent contacts. Additional contacts for initiating alarms shall be provided. All relays which are connected either to a tripping circuit of a circuit breaker or to the coil of an, auxiliary tripping relay, shall be provided with approved indicators. Unless otherwise required for special purposes, protection relays shall remain in the tripped position until the operator resets the relay manually.

Relays shall be capable of withstanding at least one million operations without any defects. The contacts shall be of silver, platinum or other approved material and shall be capable of repeated operation without deterioration.

Each relay shall have the facility to enable connection to a station network communications using a standard protocol. The line protection shall have the facility to enable telecommunication between the relays on the opposite ends of the line (tele protection channel), and communication redundancy shall be obtained.

The protection systems will preferably be based on a common data bus with digital signal processing and interfaces to the primary sensors such as CT, VT and other digital sensors. For system redundancy in a centralized system two programmable microprocessors will work on-line in parallel. The individual protection functions will be stored in a library of software which may be modified and complemented using a PC with serial interfaces and recorded using a second serial printer interface.

The protection devices may be designed with individual functions or incorporating combined protection functions in several modules, each one designed as a self-contained unit, i.e. with its own interfaces and programmable microprocessor as well as common features such as input/ output interfaces, programming serial port, self-monitoring facilities, event / alarm / tripping relays as well as event and fault recording memories.

Functional descriptions and setting ranges of the specified protection systems are indicative only and will be complemented and adapted by the Contractor according to his production program and to provide fully functioning, reliable protection systems.

Protection devices will be designed and applied to provide selectivity and maximum discrimination between faulty and healthy circuits. All devices will remain inoperative during internal faults and transient phenomena which may arise during switching or disturbances in the system.

The following mechanical requirements will be considered:

- Easy replacement of all plug-in modules, electronic cards and elements;
- Interchangeability of identical units;
- Easy maintenance and fault detection;
- Silver or gold plated contacts of all plug-in units and devices;
- Protection devices will not be affected by mechanical shock or vibrations or by external magnetic fields.

The following electrical requirements will be considered:

- The protection system will be operated with analogue and binary signals by completely digital processing techniques. The input Transformers will provide the galvanic isolation between the CT, VT and other circuits and the protection devices; the signal levels will be adjusted accordingly;
- The protection devices will be insensitive to voltage and current transients;
- Simple setting by means of the integrated operation panel or with serial connected personal computer with menu-guided software;

- The protection systems will be based on data exchange via internal parallel bus with digital signal processing for functions, signal conditioning, analogue and digital inputs, A/D conversion, processing and signal output;
- Communication and data exchange with the PCS will be via serial standard interfaces and protocols in compliance with the IEC standards;
- All protection devices will be suitable for local and remote reset.

The analogue measurement values of the protection functions will be internally processed, displayed and transmitted as follows:

- Measurement value display: at the screen of the protection device or on a serial interface connected personal computer;
- Event recording: the measurement values of the protection functions will be stored as an event with time tagging at the moment of its occurrence;
- Disturbance recording: the measurement values of the protection functions will be stored as raw data or as magnitude and phase data. The data will be sampled at 12 samples per cycle. The disturbance
- The retrieval of the above data will be carried out via the PCS from the CCR.

7.5.1.1 Interfaces

The protection systems will have the following interfaces:

Interfaces to the protection system relevant plant components like CT, VT and other input values will be directly wired.

Interface with the mechanical protection devices which will form an integral part of the overall protection schemes.

Standard serial interfaces with the PCS will be provided. The communication will be via the station bus system, utilizing standard protocols in compliance with the IEC standards. Retrieval of fault protocols and data, parameterization of protection devices and trip reset will be considered.

Interface to the various trip circuits. Selected protection criteria will be directly wired to provide a back-up for emergency tripping.

Interfaces to the telecommunication system will be provided for the communication with the receiving end of the transmission lines and the transmission of tele-protection signals.

7.5.1.2 Test Facilities

The protection systems will include self-monitoring and diagnostics, which will operate continuously. On the occurrence of a defect, and the correct operation of the protection functions are not guaranteed, the relevant protection function will immediately be detected and an alarm given.

The self-monitoring and testing facilities will provide the following routines:

- Self-monitoring of the hardware;
- Cyclically executed testing routines by means of the software;
- Viewing of the system protection parameters and values, analogue inputs and digital I/O signals;

- Injection testing with separate test equipment.

The protection systems will include a built-in testing facility capable of testing the protection functions from the terminal inputs of the CT and VT circuits to the output trip circuit terminals. The test facility will be for manual / automatic operation. The automatic test feature will include interlocks to ensure the protection of the equipment during the test process. Means for simple functional checks of the relay

7.5.1.3 Trip Circuits

Tripping schemes will be realized by a combination of LED plug type matrix, appropriate software and directly wired trip circuits.

External protection functions of the various plant components (e.g. Buchholz relays, temperature devices, level switches, pressure relays, flow switches, etc.) will be integrated and further processed in the tripping scheme.

The tripping signals of the individual protection devices will be transmitted to the relevant tripping devices by means of the software tripping logics, the diode-plug matrix and the directly wired trip circuits. The software tripping logics will be continuously monitored. The diode plug matrix will be easily adaptable to changing requirements by rearranging the diode plugs. Directly wired trip circuits will be provided for selected protection functions to be used as back-up feature for emergency and quick shut-down. The final configuration of the tripping schemes will be defined at the construction design stage.

Trip circuit supervision will be provided for all trip circuits. Each breaker trip coil/trip circuit will be monitored for electrical continuity. Monitoring will be operative with the circuit breaker in the on and off position. The trip circuit supervision relay will feature identification of the faulty circuit and will be time delayed to prevent operation during transient phenomena caused by breaker operation or fault clearing in the DC system.

The trip circuit supervision relay will initiate a delayed alarm after several seconds. This alarm will be activated by the loss of tripping DC and by any interruption in the trip circuit wiring. In the event of a fault in any component, it will not be possible to inadvertently trip the circuit breaker.

7.5.1.4 Auxiliary Power Supply

Auxiliary power for each protection system or individual protection device will be supplied by redundant DC/DC power units connected to the DC auxiliary supply systems.

The DC/DC power units will be natural air cooled;

Adequate voltage monitoring with alarm annunciation will be provided.

7.5.1.5 Protection Cubicles

The protection devices, auxiliary power supply units and all related equipment will be accommodated in freestanding sheet steel cubicles of standard design with adequate space and cooling;

The equipment will be mounted in convenient working height. The cubicles will have lockable front and rear doors. The front doors will be fitted with windows providing a clear view of the interior, especially of the protection device displays;

Main and back-up protection systems will be safely separated from each other. Installation in separate cubicles is preferred;

The unit protection cubicles will be arranged in a common assembly with the UCB;

Protection devices for auxiliary supply systems may be accommodated in the instrument compartments of the relevant switchgear.

7.5.2 Protection System Tests

a) Workshop Tests

All relay assemblies shall be subject to routine and type tests as specified in the relevant IEC 255-5 or other approved standards before board assembly. The test shall include at least the following:

- HV test (insulation test) with power frequency, 2 kV (rms), 1 min. as routine test
- Impulse voltage test (insulation test) 5 kV, 1.250 micro sec., 3 positive and 3 negative shots at intervals of 5 sec. as type test.
- High frequency test (malfunction test) 2.5 kV, 1 MHz. 400 shots/sec., = 15 micro sec., duration 2 sec. as type test.

Type test certificates will be accepted for identical equipment which has successfully passed such tests earlier.

b) Site Tests

I. Preliminary Tests on Site

All relay assemblies shall be subject to site tests. The Contractor's test equipment shall be of satisfactory quality and condition and, where necessary, calibrated by an approved authority.

c) Pre-Commissioning Test

Insulation resistance tests at 500 V DC are to be carried out on all AC and DC protection, control, alarm and indication circuits to ensure that wiring is in satisfactory condition. It is essential that all AC wiring is proved and relay contacts, auxiliary contacts breaker ratings and small panel items such as indicating lamps. Static equipment which may get damaged by the application of the test voltage shall have the appropriate short circuited.

Loop resistance measurement and polarity checks are to be made on all measuring Transformer circuits. In the case of pilot cables across long distances, impedance and phase angle measurement shall be made.

d) Commissioning Tests

Secondary injection shall be carried out on all AC relays using voltage and current of sinusoidal wave and rated power frequency.

For circulation current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance. The fault setting for this type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, settings resistors and CTs connected.

7.5.3 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 8: MAIN EARTHING SYSTEM AND LIGHTNING PROTECTION

8.1 General

The main earthing system shall cover design, supply installation and testing of the earthing system complete in all respect for satisfactory functioning of the power plant, switchyard, and substations. The Contractor shall perform calculations to verify the design of the earthing system. All calculations shall be based on accepted methods and standards. The contractor shall also prepare drawings of earthing system indicating buried and embedded earthing mesh, electrode system with risers, earthing conductors above- ground, and connection to all equipment /structures in respect of the following project components/sites.

- Powerhouse area
- HV Switchyard area
- Intake area
- 11 kV Transmission Line Poles
- 132 kV Transmission Line Poles

The contractor shall measure the earth resistivity at all the sites mentioned above and shall carry out the earthing design calculations to ensure that the touch and step potentials are within the safe acceptable limits. The Contractor shall submit the earthing design calculations to the Engineer for approval. The Contractor shall prepare the layout drawings showing the conductors of the earthing system and accessories in sufficient detail based on the design approved by the Engineer and shall submit the drawings to the Engineer for approval.

The Contractor shall also prepare the design and layout of the lightning protection system for the powerhouse building, the intake and forebay structures, substations and other locations deemed necessary. The design shall be subject to approval by the Engineer.

8.2 Standards

The design, installation and testing earthing and lightning protection system shall comply with the following recommendations:

WAPDA	Specification P-190: 91 Grounding Sets
WAPDA	Specification P-116: 81 Earth Rods
IEC 80:1986	Earthing
IEC	Safety handbook
IEC 950:	Safety of information technology equipment, including electrical business equipment
IEC 364:	Electrical installations in buildings
ANSI/IEEE 665	Generation station grounding

8.3 Scope of Work

The Contractor shall furnish earthing conductor, connectors, earthing rods, thermo-weld /brazing materials and all other materials necessary for satisfactory installation of the earthing systems for

the sites mentioned in this section. The Contractor shall also install the complete system of aboveground earthing conductors in different areas and will connect all metal parts, even if these do not constitute a conducting part 'of an electric system of the works, such as machinery, operating panels, catwalks, piping, sewers, rails, metal tanks, lighting fixtures, cable racks, etc. to the main earthing system.

The scope of work shall include but not limited to the following installations:

- Supply and Installation of subsurface earthing mesh/earthing electrodes with earthing rods, brazing material and earthing conductors, in Powerhouse, switchyard, intake, subsurface connection made through thermos-weld/brazing process.
- The earthing terminal bars and conductors connected to the risers of the buried/embedded earth electrodes in all areas.
- The interconnecting wires between different parts of the earthing electrode system with connection points to the concrete steel armour.
- The above-ground earthing system in the Powerhouse, from the terminal bars to main machinery and equipment, such as turbines, generators, Generator step up Transformers, switchgear, surge arresters etc.
- The aboveground earthing system of the HV switchyard and, with all connections to metal parts and equipment and to the risers of the buried earth electrodes.
- The above-ground earthing system of the Intake Gates with all connections to metal parts and equipment and to the risers of the buried earth electrodes.
- The above-ground earthing system of the substations.
- All interconnections of the different earthing systems.
- Any other work, material and equipment not mentioned here but are required for safe operation of the project shall be proposed by the bidder and included in the bid. .

8.3.1 Lightning Protection System

Appropriate lightning protection shall be provided to all the above installations and for all areas, the earthing system shall extend to all metal parts, even if these do not constitute a conducting part 'of an electric system of the works, such as machinery, operating panels, cat-walks, piping, sewers, rails, metal tanks, lighting fixtures, cable racks, etc.

8.4 Design Requirements

8.4.1 General

The earthing system shall be designed and constructed to protect persons and equipment/material and to allow for the correct service, operation, and maintenance of the installations. The system design shall be based on the maximum earth fault current that is expected to occur during the design life of the station including generating station and transmission system contributions

The Contractor shall be responsible for the design of the complete earthing systems as per IEEE-80-2000 and IEEE 665 for the complete works mentioned above and for the work related to the connection of structures and equipment, to the main earthing system. The Contractor shall deliver and install all materials for connecting all equipment to the risers of the buried/embedded main

earthing electrode along with conductors, earthing rods and jointing materials for the buried/embedded earth electrode. Earthing and lightning protection systems will be provided for the entire power plant with related structures, buildings and the Weir Site.

8.4.2 Installation of Earthing System

The Contractor shall install the complete earthing system of subsurface and aboveground earthing conductors in the different areas in the entire power plant and sub stations, with the interconnections between the different areas of earthing systems and those of the building structures. The powerhouse earthing system will consist of the installation of an earthing mesh embedded at the draft tube level and connections will be made to the metal lining of each draft tube and spiral casing inlet extension to provide earthing points. An earthing grid will be extended to all levels in the powerhouse.

The main earth conductor shall be connected to at least two groups of earthing rods where each group will consist of earth rods of 16 mm diameter, 5.0 m long, driven into the ground. These groups of earth rods shall be located evenly throughout the area or as may the design allow. The connection between the earth rods of each group shall be through 300 sq mm tin coated copper conductor. Subsidiary branch copper connections shall be made between the main earth conductor and the various items of equipment in the building and metal frameworks.

The combined resistance of earthing electrodes for the earthing system at powerhouse shall be 0.5 ohm and at other locations and for substations it should not exceed by 1 ohm under any climatic conditions.

The earth connections to generator and Transformers neutral points will be made through 30 x 5 mm copper strip or 185 mm² stranded copper, PVC covered conductor and all other points shall be connected through 95 mm2 copper conductor.

Where exposed, conductor-to-conductor connections within the earthing network and for taps to all equipment shall be bolted clamp connectors, for easy connection and disconnection to facilitate testing of the electrodes. All connections embedded in concrete or earth shall be brazed (thermo-weld) and shall be wrapped with burlap. The burlap shall be thoroughly saturated with and covered over with asphalt. All exposed connections of earth conductors to non-current-carrying parts and to structural supports for electrical and mechanical equipment shall be of the bolted type, except where otherwise approved by the Engineer.

All embedded connections of earthing conductor to building steel, crane and track rails, fixed handrails, gates and pipe work shall be of bolted type with supplementary brazing. All metallic conduits shall be grounded at one end. Mechanical piping systems not served by motor-driven equipment shall be grounded by exposed conductor from an earth to one point on the piping or associated equipment. Earthing conductor shall be connected to the piping and equipment. Exposed earth conductor shall be clamped to surfaces. Joints of crane and other track rails flanged pipe work and of cable tray shall be bonded together.

All connections between equipment and the earthing network shall be exposed (not embedded) and easily accessible for checking of the transition points. Bare conductors, as part of the open earthing system, embedded directly in the concrete will not be accepted. Similarly, bolted connections of metallic constructions do not form an acceptable earthing connection.

The earth conductors shall be designed for carrying the earth-fault currents of the various parts of the plant for at least 1 (one) second without exceeding a surface temperature of 250ºC.

Buried connections shall be welded, connections above earth shall as a main rule PC clamped and shall be easily accessible for inspection. Welding shall be by the thermos-weld method (Cadweld or equivalent). All connection points shall be protected against corrosion.

8.4.3 Earthing Points

Subject to the design calculations based on the earth resistivity determined by tests at the Site, a minimum of two earthing points shall be installed for intake gate structure. Each earthing point shall consist of 16 mm diameter, copper rod electrodes, of extensible standard length, driven where possible into undisturbed soil. Each electrode shall be complete with an approved non-ferrous terminal clamp for connection to the earthing conductors and with a hardened steel cap and tip for driving by means of a power hammer.

8.4.4 Earthing Conductors

On each floor in the powerhouse, in switchgear rooms and in other rooms containing electrical installations, a main protective earthing bar / strip will be cleated to walls just above the floor level or will be cleated inside cable trenches, to enable connection of all equipment to the earthing electrode system.

All risers from the earthing electrode system shall be connected to the main bars (at appropriate intervals and at least 2 risers to each bar) by removable screw connections. The conductors for the main earthing bars shall be of electrolytic flat copper bar with a cross-section of at least 150 mm2.

With the exception of the earthing bars and internal connections in panels and boards, all other earth conductors shall consist of electrolytic, stranded copper conductors. For connection to other metal parts the ends of such conductors shall be fitted with cable lugs, rigidly fastened to the earth conductor by means of a hydraulic press. Interconnections between earth conductors are to be performed with straight joints or T- joints terminated in the same manner.

Main earthing mesh conductors shall have a minimum section of 120 mm2

The conductors shall be reliably protected against mechanical damage and corrosion.

The following equipment shall be connected directly to the earth electrodes or the risers:

- The penstocks, draft tubes, turbine spiral casing and inlet valves.
- The generator housings. Each housing shall be connected to two separate risers, connected opposite each other.
- All power Transformer neutrals and Transformer tanks. Main Transformer tanks shall be earthed in two points, by different risers.
- All steel structures in the outdoor switch yard.
- All gate structures at intake.
- All, lightning arresters. The earth conductor from the arrester to the counter, as well as the in-terminal of the counter, shall be suitably insulated or screen - protected against accidental touching and shall be of minimum 2 x 95 mm2.
- The fence of the switchyard and substations and other fences for Transformer cells, etc. shall be earthed to the earthing wire at intervals of not more than 20 m and to the earthing electrode system at all corners and gates. Gates shall be connected to earthed gate posts by a flexible copper braided wire or equivalent. Flexible copper braids of minimum 35 mm2

shall also be used for connecting all sections of pipes, metal trays, conduits, rails, cable racks, etc., unless these are welded together or each section is separately earthed.

Earthing conductors for electronic systems shall be insulated and shall be run separately from the systems, panels, etc., directly to a main earthing bus close to a connection to the earthing electrode system. These earthing conductors shall be of minimum 50 mm2 and shall not be branch-off from the earthing of the power systems.

8.4.5 Earthing Points for Intake and forebay

Subject to the design calculations based on the earth resistivity determined by tests at the Site, a minimum of two earthing points shall be installed for intake and forebay gate structure. Each earthing point shall consist of 16 mm diameter, copper rod electrodes, of extensible standard length, driven where possible into undisturbed soil. Each electrode shall be complete with an approved non-ferrous terminal clamp for connection to the earthing conductors and with a hardened steel cap and tip for driving by means of a power hammer.

8.4.6 Lightning Protection

Lighting protection system shall be provided at all locations specified above for the following purposes.

- To protect personnel, electronic and electrical equipment from the effects of lightning strokes the plant will be equipped with a lightning protection system.
- The lightning protection system will be subdivided into lightning protection zones and consist of roof conductors, air terminals and down conductors.
- All materials will especially be suitable and approved for this type of system.
- The lightning protection system will be connected to the station main earthing electrodes as appropriate.

The Contractor shall design and install the lightning protection system in accordance with EN/IEC 62305 such that Structure of Powerhouse, Forebay, intake and Substation areas shall be adequately protected against lightning events. Contractor shall undertake a lightning design using the rolling sphere method or alternative approved method.

8.4.7 Accessories

Brazed connections shall be made by the thermos-weld process. Materials shall be sufficient for each brazed connection to provide a conductivity equivalent to 150 % of the conductivity of the conductor or conductors being brazed

Clamp type connections shall be of approved bolted type and shall have a minimum of two bolts per clamp for all conductor sizes 95 mm2 and greater. Cable support clamps and all other accessories shall be heavy duty and of a material suitable for the application.

Complete materials for connecting all equipment to the risers of the buried/embedded main earthing electrode.

8.4.8 Drawings and Information

The Contractor shall provide as a minimum the following drawings and calculations:

Drawings showing the earthing mesh and electrode system in the Powerhouse, the HV switchyard, substations, and all structures in the Intake and forebay areas

Drawings showing the location of all main earthing bars (mesh and rods) as well as interconnections between the earth electrodes. (plan and sections)

Earthing resistance at each site and the corresponding voltage rise calculations.

Drawings showing the connections from the earthing bars to all equipment and apparatus.

Drawing showing the overhead earth conductor system for the HV switchyard. The drawings shall also comprise information about the connection between the overhead and underground systems.

Short circuit and conductor temperature rise calculations.

Drawing showing the fence earthing

8.5 Earthing System Tests

After the on-site construction, the resistance to earth of each earthing electrode system shall be measured. The earthing system in the Powerhouse, the HV switchyard, and the installations at the Intake shall be measured collectively under operation conditions and shall be disconnected into separate systems for measuring of the separate elements of the system. The Contractor shall suggest the measurement set-up for approval by the Engineer.

The earthing electrode systems shall be checked for resistance and reliable connections.

8.6 Earthing System Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 9: CABLES AND CABLE TRAYS

9.1 General

The scope of work under this section covers Calculations, design, supply, installation, testing and commissioning of cable tray/racks, medium voltage (11& 33 kV) power cables and accessories, low voltage power, control and communication cables and accessories, for all installations including in powerhouse, switchyard, Substations and intake including the 400/220 V cables for ventilation, street lighting, internal and external electrification of powerhouse, switchyard, intake.

The Contractor shall compute the quantities of cables, cable racks, cable routing and length etc. The MV cable, the control and low voltage cables in the power station, the switchyard shall be laid on cable racks in the cable channel and the cable ducts and trenches.

Cable ducts with cover will be provided by the Contractor for the following facilities

- Within the powerhouse
- Between the powerhouse and the HV switchyard.
- Within the HV switchyard
- In the Intake area.

9.2 References Standards

The design, manufacturing and testing shall, comply with the below listed standards:

IEC	Safety Handbook containing all basic safety standards
IEC 60038	Standard Voltages
IEC 60059	Standard Current Ratings
IEC 60228	Conductors, solid or stranded plain copper
IEC 60287	Calculation of the continuous current rating of cables
IEC 600332	Tests on electric cables under fire conditions, Part 3: Tests on Bunched Wires or cables, Category C.
IEC 60446	Colour codes
IEC 60502	Extruded solid dielectric insulated power cables for rated voltages from 1 kV up to 30 kV
IEC 60811	Common test methods for insulating and sheathing materials of electric cables
ASTM A123	Zinc Coating (Hot dip Galvanized) of Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strip
CCITT (ITU-T)	Standard for Telecommunication equipment and System
BS 2484	Straight Concrete and clay ware cable cover.

9.3 Scope of Work

The scope of supply includes all MV/ LV, A.C power cables, control cables and communication cables with all accessories for the power plant, switchyard, substations, and intake complete in all respect as specified, but not restricted to the following.

a) Medium Voltage Power Cables

b) Powerhouse& Switchyard

- 12 kV cable from the terminals of all the four Generators to the main 11 kV switchgear
- 12 kV cable from main Switchgear to the step-up Transformers in switchyard
- 12 kV Cable from 11-kV switchgear to the station service Transformers in switchyard.
- 12 kV Cable from MV switchgear to 5 MVA, Local supply Transformer and to the end pole of 11 kV Feeder lines
- 12 kV Cable from generator terminals to unit excitation Transformers.
- 12 kV cable from 5 MVA Transformer to 11 kV Local supply switchgears
- 12 kV cable from 11 kV local supply switchgear to local supply Feeders
- 12 kV Cable from main local supply to the end pole of 11 kV line to intake
- 12 kV Cable from end pole of 11 kV line to station supply Transformer at intake.

c) Common

- All low voltage cables from Station service Transformers to LV switchboards in the powerhouse, switchyard and intake structures
- All low-voltage A.C. power cables in the powerhouse, switchyard and intake structures, from the 400 V switchboard to the sub distribution boards for lighting, motor starters and other station supply as well as cables from the sub distribution boards to all A.C. powered equipment, including cables for lighting and small power specified in electrification works
- All LV power cables for AC and DC systems.
- Communication, control, and instrument cables.
- Fibre optic cables for external/internal data transfer systems.
- Material for supporting, laying, and terminating of the cables.
- One set of special tool and appliances.
- All other MV/LV /control cables and other accessories that are not mentioned here but required for a complete functional the power station and substations shall be supplied by the bidder.
- Termination material, clamps, cable boxes and all necessary material for installation and erection of the cables.
- Cable racks complete with covers, bolts, clamps, supports and miscellaneous mounting details.
- The cable racks (ladders and trays) shall be designed to carry also the low voltage cables for lighting and small power.

- Protective pipes and tubes where cables must be protected against mechanical damage

9.4 Design Requirements

Power and control cable systems will be provided for the entire hydropower plant, Switchyard with all related buildings and structures. The cable systems will comprise all MV and LV power, communication, control and instrumentation cables, the necessary accessories such as cable terminations, cable trays, conduits, supports, fixing and mounting materials to provide complete, ready for service systems.

The design of cable conductors size for permissible continuous rating will be based on the following:

- Ambient conditions at the different locations but considering 50°C as minimum standard.
- Temperature and grouping correction factors according to cable laying method.
- Cable length with consideration of the permissible voltage drop.
- Permissible short time withstand current.
- Thermal and dynamic stresses at short circuit conditions.

9.4.1 Main Technical Characteristics

The conductor cross section, is calculated according to:

- Rated current at temperature of 90 °C for MV cables and 70 °C for LV cables.
- Short circuit current at temperature of 250°C for MV cables and 250°C or 160°C for LV cables,
- Maximum voltage drop of 5 %
- Ambient temperature of 40°C.

Cables will be insulated and sheathed with materials featuring the following properties:

- Non halogen.
- Inhibition of fire propagation.
- Flame retardant.
- Heat stabilized.
- Not producing corrosive and toxic gases and vapours in case of fire.
- Low smoke generation.
- High dielectric strength and insulation resistance
- Resistant against environmental influences, in particular humidity, fungi, oil and vermin.
- Safe against repeated overloads and short circuits.
- Easy handling.

The design of the cables will prevent water penetration, radial vapour diffusion and longitudinal water propagation.

As appropriate for the location the cables will be laid on cable racks, ladders, ducts or protecting conduits. The cable racks will be designed to allow laying of the cables from the side without pulling

through. The Contractor will provide drawings and embedded inserts in due time to meet the civil construction programme.

All racks and the fixing devices will be hot dip galvanized. No steel fixing devices will be accepted for the single core power cables.

Wherever cables might deteriorate or where the cable laying may otherwise present difficulties, protecting conduits will be used.

These conduits will have adequate cross section and wall thickness and will be made of hot dip galvanized steel or rigid PVC as may be appropriate. Protecting conduits and fixing devices for single core power cables will be made of non-magnetic material.

9.4.2 Medium Voltage Cable

- Medium voltage cables conform to IEC 60502.
- Insulating material PVC or XLPE
- Nominal voltage 12 kV
- voltage grade (Uo/U) 8.7/15 kV for 11 kV cables
- Highest rated temperature 250 ° C
- Conductor Copper
- Class 2
- Semi-conductor Extruded compound
- Screen of cores Copper type
- Assembly of cores
- Inner covering and fillers. Plastic
- Intermediate sheath Polyvinyl Chloride
- Separation sheath Paraffin waxed crepe paper
- Metallic layers for core cables Armour Steel
- Non-metallic outer sheath PVC
- Fire behaviour Flame retardant IEC 332

9.4.3 Low Voltage Cable

Low voltage cables are insulation type with a minimum conductor cross section of 95 mm2for auxiliary power.

- Insulating material PVC or XLPE
- Rated voltage 600/1000 V Conductor Copper Class 1 or 2
- Number of cores 4
- Metallic armour none
- Non-metallic outer sheath PVC

- Fire behaviour — Flame retardant Cables are insulation type with a conductor of appropriate size.
- Insulating material — PVC or XLPE
- Rated voltage — 600/1000 V Conductor Copper Class 1 or 2
- Number of cores — 1
- Metallic armour — none
- Non-metallic outer sheath — PVC
- Fire behaviour — Flame retardant

9.4.4 Control Cable

Control cables are insulation type multi-conductors with a minimum conductor cross-section of 4 mm2 for command and control and conform to IEC standards.

- Insulating material — PVC or XLPE
- Rated voltage — 600/1000 V
- Conductor — Copper
- Class — 1 or 2
- Number of cores — Multi cores
- Outer sheath — PVC
- Fire behaviour — Flame retardant

9.4.5 Metering and Protection Circuit Cables

Metering and protective circuit cables are 600/1000 V insulation type multi-conductors with a minimum conductor cross section of 6 mm2 for voltage circuit and 6 mm2 for current circuit and conform to IEC standards.

- Insulating material — PVC or XLPE
- Rated voltage — 600/1000 V
- Conductor — Copper
- Class — 1 or 2
- Number of cores — 4
- Metallic Armour — none
- Non-metallic outer sheath — PVC
- Fire behaviour — Flame retardant

9.4.6 Measuring Cable

Measuring cables of 500 V insulation are multi pair type with a minimum cross section of 0.88 mm2 or appropriate size. The pairs are individually twisted and conform to IEC standard - PVC Insulated cables of rated voltage 450/750V.

- Insulating material — PVC
- Conductor — Copper
- Class — 2 or 5
- Number of cores — 4
- Shielding — Aluminium tape with spiral plastic
- Metallic Armour — none
- Non-metallic outer sheath — PVC
- Fire behaviour — Flame retardant

9.4.7 DC Cables

D.C. cables between chargers and batteries and between batteries and distribution panels shall be single core type without metallic shield or armour.

9.4.8 Cable Supports and Other Steelwork

All cable supports including racks, trays, sunshields and other steelwork with all necessary fixings, bolts, nuts, screws, and clamps shall be supplied by the Contractor. Metal work shall be galvanized. The Contractor shall take all precautions to prevent damage to the galvanizing. Where steelwork, racks or trays supplied in standard lengths are cut or minor damage has occurred to the galvanizing the exposed steel shall be treated with zinc rich paint or other method approved by the Employer's Representative. Heavily damaged items shall be replaced as directed by the Employer's Representative at no extra cost to the Employer.

The cable trays shall include all accessories like bends, elbows, tees, etc. and shall be of the perforated type for proper ventilation of the cables. The trays shall be made from 2 mm thick mild steel sheets and the trays shall have a minimum 50 mm edge height.

Cable supports, racks and trays shall be erected in accordance with the layout drawings prepared by the Contractor and approved by the Employer's Representative. Any modification found to be necessary for satisfactory installation shall be to the approval of the Employer's Representative.

All cable trays and supporting metalwork shall be bonded to each other and to the station earthing mesh.

9.4.9 Erection of Supports

Expansion bolts shall be used for the fixing of supports and associated steelwork to concrete and masonry.

The fixing of cable supports and associated steelwork to building structural steelwork shall be done with bolted clamps. Weld gun stud fixing will be allowed as approved by the Employer's Representative. The drilling of structural steelwork shall not be allowed except in special circumstances and then only with the prior permission of the Employer's Representative.

9.4.10 Installation on Racks

Heavy single-core and multicore cables shall be clamped directly to the racks with cleats having bores of the correct sizes for the relevant cable diameters. The cleats shall be of silicon aluminium,

glass-filled nylon, or other tough, non-hygroscopic material. Single core cables shall be erected in close trefoil three-phase groups in nonmagnetic clamps. Wooden cleats shall not be used.

The horizontal distance between supporting clamps for all cables having a conductor cross-sectional area greater than 125 mm2 shall be with the approval of the Employer's Representative.

The distance between rack supports for smaller power and multicore control cables shall be one meter for both horizontal and vertical runs. After installation, cables shall be neatly arranged and parallel to each other.

9.4.11 Installation on Trays

Small power cables, protection, control, communication, and data cables shall be run on trays and shall be secured with heavy duty plastic straps and fixings to the approval of the Employer's Representative. After installation, cables shall be neatly arranged and parallel to each other.

9.4.12 Cable Ducts

All required cable ducts will be provided under this section of contract.

The cable ducts shall be of material LSZH. The ducts shall be of suitable sizes to carry required number of cables with 20% of free space.

9.4.13 Cable Markers

Suitable cable markers of Aluminium with punch marks shall be provided and suitably permanently tagged to the cables for easy identification.

9.4.14 Core Identification

Approved numbered ferrules shall be supplied and fitted to every cable core of control and instrument cables at each termination. The ferrules or sleeves shall be of insulating materials which shall have black text engraved on a white background. The ferrules or sleeves shall be unaffected by oil or damp. Adhesive markers shall not be used.

All markings for terminal blocks, cables, cable conductors and wiring shall be located on the corresponding design drawings.

A common system of ferrule numbering shall be adopted such that ferrule numbers at field terminations shall agree with ferrule numbers on the internal wiring of equipment

9.5 Testing and Commissioning

All cables and other equipment and materials covered by these Specifications shall be subject to inspection and tests in accordance with these Specifications. The tests listed in this section are the minimum requirements.

Routine tests at Works shall be carried out as required by these Specifications.

The Contractor shall be required to carry out type tests in accordance with the internationally recognized Standards (IEC, BS etc.) unless authenticated evidence is produced to the satisfaction of the Employer's Representative to show that the type tests have already been satisfactorily carried out on each type of cable being supplied.

The Contractor shall certify that the cables and accessories offered shall be identical in all essential particulars in respect of design, materials and workmanship with the cables and accessories for which type tests are offered in support of his Bid.

9.5.1 Factory/Works Tests

a) 8.7/15 kV XLPE Cables

Routine and special tests to IEC 60502 shall be carried out, to the approval of the Engineer. Following tests shall be included:

Sample Tests

- verification of dimensions,
- conductor resistance test,
- capacity and power factor test,
- ozone resistance test,
- accelerated water absorption test,
- heat distortion test,
- flame resistance test (for outer sheath),
- insulation and sheath physical test,
- insulation and sheath aging tests,
- high voltage test for 4 hours, and
- bending test.

Routine Tests

The following routine tests shall be carried out on entire length of every cable supplied:

- alternating current test,
- direct current test,
- insulation resistance test,
- corona level test, and
- partial discharge test.

b) 600/1000 V Solid Dielectric Power Multicore Protection and Control Cables

Cables shall be subjected to the sample and routine tests as specified in BS 6346 and IEC 60502. The tests shall include but not be limited to, armour tests, measurement of insulation, bedding and overheat.

c) Multipair Control Cables

Routine Tests

Routine tests shall be carried out according to approved standards and as agreed with the Engineer.

The following routine tests shall be carried out:

I. Conductor Resistance

The DC resistance of conductors corrected to 20ºC shall be stated by the Contractor.

II. Insulation Resistance

The insulation resistance shall be measured by the application of 500 V dc for one minute, between each conductor and the other conductors connected to the armour.

III. Voltage Withstand Tests

A test voltage shall be applied between each conductor and the remaining conductors bunched together and earthed and between the conductors of each pair. This voltage shall be maintained for one minute without breakdown. The required test voltages are as follows:

Underground type cables: 3.0 kV AC between conductors and 3.0 kV AC between conductors and armour.

An alternative dc test voltage of twice the ac test voltage applied for one minute will be acceptable.

IV. Mutual Capacitance Test

The mutual capacitance shall be measured between the two conductors of each pair with the other conductors and armour earthed. The measurement shall be made using ac and a suitable bridge, and the mean value shall be stated by the Contractor.

V. Galvanizing Test

Samples of the galvanized armour selected by the Engineer shall be subjected to the galvanizing tests required by BS Standards.

9.5.2 Site Tests

Site tests and commissioning of Works will be carried out by the Contractor.

Cables will be subjected to the following tests in accordance with latest version of applicable IEC and BS standards:

a) 11 kV XLPE Cables

- high voltage test at 37 kV DC for 15 minutes,
- conductor resistance ohms/km, and
- measurement of insulation ohms/km.

b) 600/1000 V Solid Dielectric Power, Multicore Protection and Control Cables

- high voltage test by 2000 V insulation resistance test set, and
- conductor resistance of each core of completed circuit which include through joints will be measured and recorded. The measured value will be corrected to 20ºC in accordance with Clause 5 of IEC 60228.

c) Multipair Control Cables

- Continuity Test
- Voltage Test on Anti-Corrosion Sheath

- Insulation Resistance Test
- Conductor Resistance Test

9.6 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 10: EMERGENCY DIESEL GENERATOR SET

10.1 Scope of Work

Emergency diesel generating units (EDG unit) will be provided at the powerhouse and shall be installed in enclosed and ventilated Emergency Diesel Generator Room adjacent to the Machine hall. The DG set shall be connected to 11 kV System through EDG switchgear which will also supply power to the intake through 11 kV intake line. The DG set will contain the complete installations including the day tank, cooling system, control equipment, starting battery and battery charger.

The scope of work will comprise the following:

- One Emergency Diesel Generating (EDG) Set rated 250 kVA, 11 kV, 1500 rpm for the Powerhouse and Intake complete with all control and protection instruments and accessories.
- One set of special tools and appliances.

All equipment shall be manufactured and tested in accordance with the latest revision of the relevant IEC standards.

The Capacity of emergency diesel generator shall be sufficient to provide “black start” capability for one generating unit in addition to meet essential load requirements of Intake and powerhouse when power from normal or alternate source is not available. The capacity given above is indicative, the bidder shall determine the actual capacity of the diesel generator based on the loads and shall submit to the Engineer for approval. The Supplier shall use the following criteria for specifying the main parameters of the emergency generator set and its control system:

- Voltage level of the system to be supplied from the generator is assumed 11 kV
- Load requirements and duration
- Control and automation

The emergency diesel generator shall be furnished with speed governor, lubricating oil facility, air inhalation, cooling facility, fuel supply facility, exhaust facility, battery starting system, exciter, voltage adjuster and control panel.

The Contractor shall prepare the detailed design of the installations and submit drawings of the equipment for the installation.

The Contractor shall submit certificates of compliance, test reports and/or approval documents for the EDGs to be delivered for this project.

10.2 Reference Standards

The equipment shall conform to the applicable requirements of the latest revisions of the following standards or to recognized and equal DIN/VDE standards:

IEC 60034	Rotating electrical machines
IEC 61869	Current Transformers
IEC 60255	Electrical relays
IEC 61439	Low voltage switchgear and control-gear assemblies

IEC 60529	Degrees of protection provided by enclosures (IP code)
IEC 60947	Low voltage switchgear and control-gear
ISO 3046	Reciprocating internal combustion engines performance
ISO 8528	Reciprocating internal combustion engine driven alternating current generators sets
DEMA	Diesel Engine Manufacturers Association Standards
NEMA MG-1	National Electric Manufacturers Association
IEC 60027	Letter symbols to be used in electric technology
IEC 60050	International electro technical vocabulary

10.3 Design Requirements

The Emergency Diesel Generating Units (EDGs) shall be designed for operation of essential power plant auxiliary services, control room requirements with 20% spare capacity during any outage of the grid connected power system. The EDG of powerhouse shall also provide sufficient power for black start of the power generating units.

The diesel engine and generator shall be interconnected to form a unit. The overload capacity shall be 10% of the rated output for one hour in every 12 hours of operation under the most adverse combination of climatic conditions at site.

The diesel engine shall be equipped with the following:

- Flexible flange coupling to the generator
- Speed governor, electronic
- Filters for air, fuel oil
- Lubricating oil coolant pump
- Starter motor
- Fuel injection stopping coil
- Monitors of oil pressure
- Monitoring of cooling water temperature
- Radiator-type cooler with directly driven fan and ducting to wall opening\
- The generator shall be protected by housing, self-ventilated, drip proof, for tropical climate and equipped with a brushless excitation system with rotating diodes and voltage regulator.
- Temperature rise of the windings shall not be more than 90°C for class-F insulation with an ambient temperature of 40°C under rated conditions.
- The generator shall be designed to withstand speed of 1.2 times the rated speed.
- The control panel shall contain all necessary equipment for control, protection and operation of the units. Facilities for both manual and automatic start/stop shall be available.
- The generator body and control panel shall have provision for earthing. Control panel shall have auto-changeover facility, digital automatic voltage regulators, CTs, PTs, CBs,

protection devices relays, indication alarms. The degree of protection provided by the enclosure for the generator shall be IP-23 as per IEC 60034 – 5.

- The switchover of loads from diesel generating unit to station service supply after starting of one of the four units following a black-start shall be done by automatic changeover.

10.3.1 Diesel Engine

The diesel engine shall be of heavy-duty solid injection, compression ignition, exhaust gas turbocharged with intercooler, water-cooled closed circuit with radiator, air starting, four stroke, multi-cylinder with exchangeable cylinder liners, forced lubrication with lubrication oil cooler, electronic governor, suitable flywheel for flicker-free operation and exhaust silencer with necessary piping etc. all parts shall be easily accessible for inspection and repairs.

The lubricating oil system shall be closed circuit, forced feed type with duplex oil filters with an automatic bypass to avoid stoppage of oil circulation. The generator shall be continuous running duty type (SI) as per IEC 60034 – 1.

The long term fuel oil storage tank shall have a capacity of at least 72 hours of continuous operation. The tank shall have double wall with leakage monitoring equipment and shall be furnished with float switch and fuel level gauge. The fuel oil day tank shall have the capacity for at least 12 hours full load running, with equipment for automatic refilling from the storage tank. Technical Data of Diesel Engine is given as under;

- Type Diesel 4-stroke
- Rated output 200 kW
- Rated speed 1,500 rpm
- Cooling system Closed water circuit, radiator with motor fan
- Fuel supply By gravity or fuel supply pump
- Fuel Commercial diesel
- Starting system 24 V DC, battery, and charger
- Day tank capacity 1,000 L
- Storage tank capacity Suitable for 5 days operation
- Battery Type Lead acid type, or gel-acid type.

10.3.2 Operations, Interlocking and Synchronization

The Emergency Diesel Generator Set shall form part of the Station Supply system and shall be capable of parallel operation with another supply. The EDG set shall provide standby power in case of complete loss of normal power and shall have the facility for auto-start in the event of failure of the normal supplies to the 11 kV switchgear.

The resistor shall be able to withstand the continuous third harmonic current circulated during parallel operation with the auxiliary Transformers. The Contractor shall submit detailed calculations on the size of the earthing resistors for approval by the Employer/Engineer before start of the manufacture.

The DG Set shall be provided with a local control panel which shall include all facilities for remote auto-start and control by the Plant Control System (PCS) as well as facilities for the manual starting and loading. The EDG of powerhouse shall be provided with auto/manual control selection, start-up, synchronizing and sequential loading from the central control room. The Contractor shall supply necessary equipment on the Local Control Cubicle for interfacing with the PCS (Plant Control System) for remote operation from the control room.

On a complete shutdown of the system, the EDGs shall start and supply their respective boards. The synchronizing facility shall also be used for reconnection of the normal supply, following a blackout, before shutting down the EDGs.

The EDGs will be automatically shut down in response to electrical and mechanical fault conditions, in all modes. Faults will operate a lockout system, as required, requiring reset by operator before a start can be initiated.

10.3.3 Generator

The generator shall be protected by housing, self-ventilated, drip proof, for tropical climate and equipped with a brushless excitation system and voltage regulator. The generator terminal voltage level shall be readily adjustable to 10% of rated voltage. The maximum acceptable voltage variations during steady state generation shall be 2.5%, and in the transient state with load fluctuations of up 25%, the maximum acceptable voltage variations shall be 5%. This shall be achieved by incorporating automatic voltage regulator (AVR), the excitation system shall be of brushless type with rotating diodes.

The AC generator shall be of constant voltage, 50 Hz, three phase, four wire, internally air cooled, solidly grounded neutral, self-excited type with a power factor of 0.85. Damper windings shall be uniformly distributed round the rotor. Temperature rise of the windings shall not be more than 90°C for class-F insulation with an ambient temperature of 40°C under rated conditions.

The generator shall be designed to withstand speed of 1.2 times the rated speed.

The generators shall have the following ratings:

- Type 3 Phase synchronous directly coupled with Diesel Engine
- Design Horizontal
- Cooling Air-cooled
- Rated output 250 kVA
- Rated voltage 11 kV
- Rated frequency Hz 50
- Voltage regulation ± % 5
- Rated speed 1,500 rpm
- Power Factor 0.80 lagging
- Insulation Class F
- Protection class IP42
- Excitation System Brushless with rotating diodes, Self-regulating
- Neutral grounding Solidly grounded

10.3.4 Control Panel

The control panel shall be located in the Diesel Generator Room and shall contain all necessary equipment for control, protection and operation of the units. Facilities for both manual and automatic start/stop shall be available.

The generator body and control panel shall have provision for earthing. Control panel shall have auto-changeover facility, automatic voltage regulators, CTs, PTs, CBs, protection devices relays, indication alarms. The degree of protection provided by the enclosure for the generator shall be IP-23 as per IEC 60034-5.

The following instruments shall be provided on local control panel:

- voltmeter and selector switch,
- ammeter,
- wattmeter,
- frequency meter,
- power factor meter,
- synchroscope,
- double voltmeter,
- double frequency meter,
- engine speed indicator,
- hours run indicator,
- lubricating oil temperature and pressure,
- cooling water temperature,
- for turbocharge engines, charge air temperature and pressure,
- tank fuel level gauge

10.3.5 Fuel Oil System

The long-term fuel oil storage tank shall have a capacity of at least 72 hours of continuous operation. The fuel oil day tank shall have the capacity for at least 12 hours full load running. Both tanks shall have double wall with leakage monitoring equipment and shall be furnished with float switch and fuel level gauge

10.3.6 Lubricating Oil System

The lubricating oil system shall be closed circuit, forced feed type with duplex oil filters with an automatic bypass to avoid stoppage of oil circulation. The generator shall be continuous running duty type as per IEC-60034-1.

10.3.7 Starting Battery

The battery shall be of the lead acid type, alternatively gel-acid type. Each cell shall have an individual container preferably of clear plastic. The container shall be completely closed and provided with an acid spray preventing ventilation plug. The number of cells shall be selected, to

prevent that the battery voltage does exceed 110% of rated voltage during the float charging. Bolted or welded interconnections between the cells shall be provided.

10.4 Diesel Generating Unit's Tests

The testing shall be performed in accordance with the IEC recommendations for the actual equipment.

The testing shall consist of a complete functional test and a technical test to verify significant technical specifications.

The test plans and test specifications for both the factory tests and the site tests shall be presented to the Engineer and approved by him in due time before the actual test shall be performed. The Employer and Engineer's Representative are entitled to witness all the factory tests.

All test results shall likewise be presented to the Employer/Engineer for approval.

10.4.1 Workshop Tests

The complete diesel generating set assembled in the workshop shall be subjected to type tests and routine tests according to applicable standards. The tests shall include:

- Five (5) starts of the cold engine;
- Test run of the completely assembled diesel generator set mounted on a common frame for 10 hours in succession, the test run subdivided into:
    - 1 hour warming up.
    - 3 hours100 % rated loads.
    - 1 hour 110 % of rated load.
    - 3 hours100 % rated loads.
    - 30 minutes 75 % of rated load.
    - 30 minutes 50 % of rated load.
    - 1 hour with 25 % of rated load.
- During the test run, water, oil, exhaust gas, etc., temperatures, speeds, speed variations and droops, all pressures and fuel quantities shall be measured.
- Checking of mechanical and electrical protection operation;
- Functional tests of excitation system;
- Checking of automatic and manual start up to full load and stopping, recording frequency, voltage and speed variations;
- Record of vibration at nominal speed at any load; peak-to-peak value shall not exceed 0.05 mm;

10.4.2 Site Tests

The scope of preliminary tests and commissioning tests shall be based on the Contactors standard quality control plan.

A test run lasting 24 hours shall be performed under real operating conditions. During this time all important performance data shall be recorded and the correct functioning of the control equipment shall be verified. Fuel for testing period shall be supplied by the Contractor.

10.5 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 11: TELECOMMUNICATION SYSTEM

11.1 General

This section specifies all telecommunication systems for Jagran-IV hydropower plant, intake.

The contractor shall be responsible for design, manufacturing, testing at manufacturer's work, packing and transportation to site, erection, testing, and commissioning of equipment as specified in this section. All communication equipment shall be suitable for good quality voice and data communication within the power plant and between the power plant and the intake.

An independent Electronic Private Automatic Branch Exchange (EPABX) system and networks will be provided at the power plant for system operations and normal local telephone traffic with connection to the public network.

The telecommunication from the powerhouse to the intake will be provided by fibre-optic link with the VHF local radio as voice communication back-up.

The main communication link between the power station, the grid stations and the regional/ National Control Centre will be provided by PLC system.

11.2 Reference Standards

The equipment shall conform to the following latest I.E.C Standards as given below: -

IEC	60353	Publication No.353 for line trap.
IEC	60950-1,	Publication No safety standard
I.E.C.	60481	for coupling devices.
I.E.C.	60495	power line carrier terminals.
I.E.C.	60663	Planning of SSB PLCC system.
IEC	61000	Immunity requirements and test methods for electrical and electronic equipment
I.E.C.	60099	Surge Arrestors
I.E.C.	61196	HF Cable

11.3 Scope of Supply

The scope of supply covered under this section comprises but not limited to the following:

- Power Line Carrier System (PLC)
- Interface equipment/coupling device for PLC
- VHF local radio system
- Permanent Telephone Equipment and Network
- Closed circuit television system (CCTV).
- Public Address System (PAS)
- One set of special tools and appliances.

a) Power Line Carrier System (PLC)

A PLC link will interconnect the power plant with the intake and provision shall be made for future connection to National/Regional Control Centre, when extended to the project area. The link shall be used for data and voice communication. Contractor shall workout the required quantities of equipment which are necessary for trouble free voice and data communication system.

The PLC System shall comprise the following equipment:

- Four Nos., PLC cubicle (including equipment for opposite end)
- Four Nos., Line Matching Unit (LMU) including equipment for opposite end
- Four Nos., Exchange 8+8
- Four Nos batteries 100 Ah each
- Four Nos Battery Charger with DC/DC distribution
- One lot Coaxial cable, 125 Ohm
- One lot Main Distribution Frame (MDF) with cubicle,
- One lot AC/DC cables
- One lot multipair cables

b) VHF Radio System for Powerhouse and Intake

The VHF local radio system shall comprise the following equipment:

- Two cubicle mounted VHF repeater stations (transponders) operating on two channels, powered by solar panels in combination with battery banks (It might be a dual station or two separate stations).
- Two Sets of power pack including solar panels, charger and battery bank
- Four Sets of antennas including connecting cables, mechanical mounting parts and any other electrical or mechanical parts required for a complete antenna installation, cables and accessories.
- Ten Nos., handheld VHF radio sets including Ni-Cd battery, desktop battery charger, antenna, cover slings. Each set shall have one battery in spare.
- Three Nos. of brackets for vehicle erection of the VHF sets
- One lot of connecting cables, terminal blocks for external connections, mechanical accessories and any other electrical or mechanical parts required for a complete repeater station installation.
- One lot Solar Power System Design Analysis based on the enquiry information.

c) Telephone System

I. Electronic Public Branch Automated Exchange in the powerhouse Control Building

- One cubicle mounted PABX, including software for 3 trunk lines and 15 subscriber lines with a cubicle mounted main distribution frame (MDF) installed in the main control room.

- One power supply with battery back-up with sufficient capacity for operation of the PABX for at least 5 hours, including one integrated automatic charger unit for the battery set fed from the 230 V A.C. mains.
- One lot of interconnection cables and terminal blocks for external connections
- One lot of mechanical accessories and any other electrical or mechanical parts required for a complete PABX installation
- One operator's unit with display and other relevant operator functions.
- Fifteen standard type telephone sets, each including cable and plug, designed both for desktop and wall mounting.
- One desktop telefax set including handset, line connection and plug.
- One lot of Telephone sockets
- One lot of underground cables for the network from the PABX to the distribution cabinets, and from the cabinets to each of the service buildings.
- One lot of Telephone sockets

II. Telephone System at Intake

- Two trunk lines shall be provided
- 5 standard type telephone sets

Any other equipment, component or work not mentioned in the specification but deemed necessary for trouble free operation of telecommunication equipment for speech & data communication shall be considered as covered under the scope of the work. The bidder shall enclose the list of such equipment as part of the bid.

d) CCTV System and Tactical Survaeillance

A Close Circuit Television (CCTV) system will be provided for the surveillance of the power plant and the related structures including the main personnel and vehicle entrances to the Powerhouse building, Switchyard and the intake Weir Site. The Contractor will position the cameras at strategic locations, mounted on buildings or using masts as required keeping in view the environmental conditions as heavy snow-bound zone\sub-zero temperature (-20ºC to 30ºC) and targeted coverage of 400 m perimeter wall protection + 1000 m tactical reconnaissance.

All equipment must be Original Overseas English Retail Models or equivalent.

IP-BASED PERIMETER DOME CCTV SYSTEM

a) Camera Infrastructure Specifications (6 cameras Required)

- **Configuration & Placement:** 6 units uniformly spaced (approx. 65–70m intervals) along the 400m perimeter.
- **Resolution & Imaging:** Minimum 4 Megapixel (2K Ultra HD) progressive scan CMOS sensor with Ultra Low-Light hardware-level enhancement.
- **Cold-Weather Engineering:**
  - Operating threshold rated strictly from -30°C to +60°C.
  - Integrated internal automatic circuit heaters and digital defogging/de-icing routines to melt snow packing and internal condensation.

- **Chassis & Build:** Heavy-duty aluminum alloy base featuring an IK10 vandal-proof bubble and IP67 weatherproof sealing.
- **Mounting Mandate:** Must be deployed on downward-angled wall/pole brackets equipped with integrated deep-base aluminum snow hoods to deflect drift accumulation.
- **Night Vision:** Smart Matrix Infrared (IR) LEDs with an auto-adjusting illumination range of 50+ meters.
- **AI Processing:** Deep-learning engine capable of hardware-level Face Capture & Detection. False-alarm filtering must ignore falling snow and animal footprints, triggering alarms only on human/vehicle profiles.
- **Firmware:** Genuine International / English Version Firmware or equivalent must be strictly enforced. Global region hardware only; cracked regional software is rejected.

b) Network Video Recorder (NVR) & 4-Month Storage Matrix

- **NVR Hardware:** 8-Channel Industrial NVR with a minimum incoming bandwidth throughput of 80 Mbps, supporting native H.265+ smart video compression.
- **Storage Optimization:** AI-driven Variable Bitrate (VBR) setup. The system will record at an economized low-bandwidth timeline until the camera's face/human detection algorithms activate, triggering immediate high-definition capture.
- **Surveillance Hard Drive:** 1 Unit × 10TB Enterprise-Class Surveillance Drive (e.g., Western Digital Purple Pro or Seagate SkyHawk AI) rated for continuous 24/7 high-duty write cycles. This configuration guarantees a full 4 months (120 days) of data retention for the 6-camera pool under H.265+ profiles.

c) Cabling & Power Delivery Infrastructure

- **Primary Networking Cable:** Outdoor Double-Jacketed PE (Polyethylene) Cat6 UTP Cable. Cable must feature a solid 100% Oxygen-Free Copper core filled with a internal Petroleum Gel coating to block freezing moisture and prevent jacket cracking.
- **Conduit Containment:** 1-inch Flexible Liquid-Tight Galvanized Iron (GI) Conduits with a weather-sealed PVC outer jacket to withstand sub-zero structural contraction.
- **PoE Network Switches:** Industrial Managed 8-Port Gigabit PoE Switch supporting IEEE 802.3at (PoE+) standards. The switch must feature a total continuous power budget of 160W to 200W to drive internal camera heaters and IR grids simultaneously during extreme winter freezes.
- **Monitoring Station Display:** Dedicated 24-inch or 27-inch Commercial Security LED Monitor rated for continuous 24/7 duty cycles.

11.4 Design Requirements

The Contractor shall perform all necessary engineering for the telecommunication systems, including the configuration of each system and detailed engineering of the interfaces between the different systems and the connection to the power supply system and shall bear full responsibility that the systems and all equipment has been designed and fabricated in accordance with all codes, standards and applicable government regulations and performs under the conditions and to the specified standards.

All equipment, materials, and parts, which are not specifically mentioned in the specification but are necessarily required for safe operation of the telecommunication and security equipment as a complete functional system shall be identified by the Contractor as part of the bid.

All equipment shall be modular in order to keep necessary stocks and spares to a minimum and shall have possibilities for future extensions.

The equipment will be installed partly outdoor and partly indoor in non-conditioned areas. The layout arrangements of all equipment included in the supply shall be the responsibility of the Contractor and shall be subject to the approval by the Engineer.

The Contractor shall he responsible for interfacing the equipment with the station power supply and the local power supplies.

The equipment cubicles shall be made of smooth steel panels, which shall be properly fastened at the bottom or to the wall. Butt joints on outside surfaces shall not be permitted. The cubicles shall be constructed from a minimum of 3.0 mm sheet steel with edges formed into a rectangular pattern or welded to steel shapes so that each section is rigid and self-supporting and enclosed.

The equipment cubicles shall be ventilated to meet the temperature requirements specified and taken care of the maximum outside temperature, which can be counted on. Vents or louvers shall be provided if necessary. All ventilation openings and all opening in the floor shall be provided with screens to prevent entrance of insects.

The design of the cubicle and arrangement of devices shall be such that adequate space is provided for inspection and maintenance of wiring, terminals and equipment. Sufficient space for future additions and possible future replacement of defective components shall be available. Equipment inside the panels shall be so mounted that the studs of the equipment mounted on the panels will be accessible without removing any device.

The Contractor's engineering work shall include engineering of the cable systems to be supplied by him, comprising the cable plans, terminal diagrams, cable lists, cable schedules and the cable route plans.

The final routing of cables indoor as well as outdoor shall be proposed by the Contractor and shown in the layout drawings. All cable routing and arrangement shall be subject to the Engineer's approval.

The Contractor shall apply for all necessary registrations and be responsible for making all arrangements for required licensing of the different systems.

11.4.1 EPABX System

The PABX System shall be state-of-the-art, digital, non-blocking type utilizing Pulse Code Modulation (PCM) and Time Division Multiplexing (TDM) and Stored Program Control (SPC). It must be field proven and conform to ITU-T standard. It shall at least be equipped with 15 subscriber lines and 3 trunk lines. The system shall allow simultaneous voice and data communication over one twisted pair telephone cable.

The system shall be able to operate in the following environmental operating conditions:

Temperature	:	-10 to 50 ºC
Humidity	:	5 to 95 %

The intercommunication system will be in compliance with the related standards, the requirements of the Local Authorities and will be the well proven product of a competent manufacturer.

The telephone system will comprise the following:

- Digital PABX with software.
- Workstation with monitor.
- Attendant console.
- Main and sub distribution frames.
- Telephone sets for different applications.
- Digital voice recorder.
- Power supply units.
- Telephone cable system.

The PABX will be installed in the telecommunication room. The workstation and the attendant console will be located at the reception in the entrance hall.

The offices, operation and service locations of the power plant will be equipped with push button dial telephone sets of modern approved design, suitable for the different locations.

Sound hoods made of suitable plastic material will be installed for the wall mounted telephone extensions in noisy and outdoor areas.

11.4.2 Radio Communication System

A radio communication system will be provided suitable for the voice communication within and between the power plant and intake, and other related structures within the radius of approximately 8-km. The radio system will consist of a fixed base station with receiver and transmitter, mobile handsets and a PABX interface unit. The system will operate in the VHF band (03 to 0.3 GHZ).

The radio communication system will be in compliance with the related standards and will be the well proven product of a competent manufacturer.

The compliance with the requirements of the Local Authorities will be confirmed.

The radio communication system will comprise the following:

11.4.3 Repeater Station, VHF Band.

- VHF antennas with tower.
- Telephone interconnect system for connection to the PABX.
- Portable VHF radio phones.
- Battery charger station suitable for the VHF portable radio phones.

11.4.4 Power Supply Units

11.4.5 Communication Cable System

The repeater base unit cabinet and the battery charger station will be installed in the electronic equipment room adjacent to the CCR.

The equipment ratings and the location of the antenna towers will be determined by the Contractor, based on the particular features of the proposed system.

11.4.6 Closed Circuit Television System (CCTV)

The CCTV system will permit persons to be clearly seen at any position within the coverage area. The CCTV images displayed on the monitors and recorded on video discs will be of adequate quality to enable clear and unambiguous identification of persons and motor vehicles.

TACTICAL LONG-RANGE SURVEILLANCE OPTICS

Total Quantity required = 6 No.

1 Dual-Spectrum / Multispectral LRF Binoculars (Tactical Patrol Units)

- Operational Intent: 1,000-meter detection and precision ranging through extreme darkness and heavy winter snow.
- Optical Engine Requirements: Dual-Spectrum Fusion or advanced Multispectral design combining a highly sensitive thermal imaging core (minimum 12µm pixel pitch) with a 4K/Full HD low-light CMOS night vision channel.
- Laser Range Finder (LRF): Integrated eye-safe laser module providing continuous real-time distance measurements from 10 meters up to a minimum of 1,000 meters with on-screen data overlay.
- Target Acquisition Range: Human heat signature detection must extend up to 1,500+ meters to ensure visibility through heavy blizzards and fog where standard optical lines fail.
- IR Illuminator: Integrated adjustable 850nm wavelength zoom spotlight. (The 940nm alternative is prohibited due to beam scattering over long distances in snowy climates).
- Cold-Weather Battery Matrix: Device must use easily swappable industrial lithium cells (18650 or 21700 formats). Models with sealed internal batteries are rejected. Device must feature an external USB-C input to run via portable power banks kept inside patrolling guards' insulated uniforms.
- Weather Proofing: Minimum IP66 or IP67 structural dust and water resistance with a working operational range down to -20°C.

11.4.7 Communication and Security Systems Tests

The Contractor shall specify and recommend a test schedule comprising all equipment, covering both factory tests and site tests. The schedule shall include functional test and technical performance tests to verify compliance with specifications and the relevant Standards.

All equipment shall be tested for all functions in normal operation. The equipment shall also be extensively tested for abnormal or faulty conditions by simulating such conditions.

The test schedules and test specifications for both the, factory tests and the site tests shall be presented to the Engineer for approval well before the test schedule.

11.4.8 Public Address System

The PAS system shall be modular in design, flexible and field programmable. The system shall feature an “attention alarm” signal to precede the spoken messages

11.5 Tests

11.5.1 Workshop Tests

Tests on immunity to conducted electromagnetic interference shall be performed in conformity with appropriate internationally approved and accepted tests procedures. Line terminals for externally terminated lines shall be subjected to a dual impulse voltage test series to the following values (over-voltage protection included).

	Series-1	**Series-2**
• Impulse Voltage peak value	1.5	5 kV
• Rise time	1.2	10 micro sec
• Half time value	50	700 micro-sec
• Impulse energy	2	25 joule
• Number of impulse (each pole)	3	3

Other line and signal terminals shall be subjected to an impulse voltage test to the following values (if necessary equipped with separate over-voltage protection which then shall be assumed included in the supply for all similar line and signal terminals):

• Impulse Voltage peak value	5 kV
• Rise time	1.2 micro sec
• Half time value	50 micro-sec
• Impulse energy	o.5 joule
• Number of impulse (each pole)	3

All line and signal terminals shall be subject to tests as follows (This test is normally not performed on power supply input terminals):

a) Power Frequency Test:

• voltage	500 Vrms
• duration	2 min

b) Spark Test:

• spark voltage peak value	2-4 kV
• approx. duration each spark bundle	0.5 ms
• approx. repetition frequency	1 Hz
• test duration (each polarity)	2 min

c) High Frequency Test (1 MHz):

• pulse peak voltage, longitudinal	5 kV
• voltage test (common mode)	2.5 kV
• pulse peak value, transversal	5 kV

- voltage test (series mode) 1 kV
- half time value 3-6 micro-sec
- pulse repetition frequency 300-500 Hz
- test duration 2 s

The equipment shall function without erroneous operation and shall not show visible signs of damages after any of the tests. The Contractor shall document conformity to the test specifications as described above, or to equivalent tests.

11.5.2 Site Tests

The Contractor shall perform comprehensive functional tests for all communication lines according to a pre-defined schedule, suggested by the Contractor and approved by the Employer/Engineer.

a) Cables

The cable schedule to be submitted to the Engineer shall indicate the cable type, cable numbers, cable diameter, voltage, number of conductors, conductor size, termination and connections at each end, and cable route.

b) Telecommunication Cables

The cables shall be twisted pairs, polyethylene-insulated type withstanding without deterioration the conditions prevailing at site.

The color-coding or other identification marks shall be shown on the wiring diagram.

c) Cable Terminations

At all terminations of wires and cables, the insulation shall be neatly stripped without nicking the strands of the conductors. Cable lugs for power cables shall be of adequate size. Cable glands or clamps shall be fitted in all cases to prevent any stress being born by the conductors or the terminals. The scaling compound and sleeves used in terminations should be selected to suit the service temperature conditions under which the cable is to operate.

Where cable terminations are likely to be disturbed in connection with maintenance, some cable slack shall be arranged by looping or similar.

d) Protection of Telecommunication Equipment

All equipment shall be protected from high voltage transients generated by the power plant electrical systems or by external sources. The over voltage protection unit shall consist of varistor based arresters or gas discharge arresters.

The equipment shall function without erroneous operations and shall not show visible signs of damages after any test. The Contractor shall document conformity to the IEC standards.

The installed equipment in open-air conditions, must be specially designed and manufactured to withstand such environmental stresses as can be expected in outdoor installations.

e) Earthing

All equipment shall be earthed using multiwire stranded Cu conductors. The cross-sectional area of the Cu conductor shall be compatible with the current carrying capacity required. The cross section shall in no case be less than 6 mm2. Cable shields shall be earthed in one end only

11.6 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 12: ELECTRIFICATION WORK

12.1 General

This section covers general requirements for furnishing, installation, and testing of items of electrification works consisting of:

- Internal electrification
- External electrification

Electrification works for the power plant, the switchyard, the intake including internal and external lighting fixtures, bracket fans, exhaust fans, wiring, poles, and power outlets complete in all respects.

Cables and supports including all embedded parts and accessories.

The work includes the furnishing and installation of whole of the electrification work/ equipment, which is described in or implied by these specifications.

12.2 Reference Standards

Standards under which items of electrification works covered in this Section are given below.

- ANSI CI National Electrical Code
- ANSI C7.4 Tinned soft or annealed copper wire for electrical purposes
- ASTM B33 Tinned soft or annealed copper wire for electrical purposes
- BS 2484 Straight concrete and clay ware cable covers
- CIBS Codes of practice
- IEE Regulations for electrical equipment of buildings
- IEEE 80 Guide for safety in AC substation grounding
- NEMA WC-30 Colour coding of wires and cables
- ASTM A36 Specification for structural steel
- ASTM A525 Specification for general requirements for steel sheet, zinc-coated (galvanized) by the hot-dip, process
- BS 449 use of cold formed steel sections in building
- BS 5467 Armoured cables with thermosetting insulation for electricity supply
- BS 6346 PVC- insulated cables for electricity supply
- ICEA S-1 Rubber insulated wire and cable for the transmission and distribution of electrical energy
- IEC-207 Aluminium stranded conductors
- WAPDA Specs P-34: Lattice steel poles

12.3 Electrification of Power Plant

12.3.1 Scope of Supply

The Scope of work under this section covers design supply installation testing and completion of electrification work of power station, switchyard and Intake weir, including providing normal and emergency lighting, bracket fans, lighting fixtures, exhaust fans with cables of appropriate sizes, 230 V single-phase, 400 V, 3-phase socket-outlets.

The work shall include supply, installation testing and completion of 10 Nos. LED Flood Lights. The Luminaries of specified wattage and lumens shall conform to IP 66 & IK 08 or above Philips/Osram/Thorn or NEECA approved equivalent manufacturer with corrosion resistant die casted Aluminum housing, minimum 250 WATT & 30,000 lumens, 10kv surge protection rating device, flexible to install on walls and poles, including cost of breakers and power cable (shielded copper) of appropriate design length 600 meters.

The work shall also include Indoor and outdoor lighting systems comprising of various lighting fixtures complete with lamps, supports and accessories, lighting panels, lighting poles complete with distribution boxes, galvanized rigid steel /rigid PVC conduits, lighting wires, G.I. Earth wire, receptacles, tag block & telephone sockets, switchboards, switches, junction boxes, pull out boxes complete with accessories. The entire buildings, switchyard and street lighting shall be done by LED based low power consumption luminaries to achieve desired lux level specified lighting for all components of the Project and the associated roadways as per following.

- Internal and External Lighting and small power installations for the following Project Components.
    - Powerhouse and switchyard area
    - Weir Intake area
- Lighting and small power installations for the service areas and associated roadways, extending up to 1,000 m from the power plant.
- Portable and rechargeable lamps with charging units.
- One set of special tools and appliances.

12.3.2 Design Requirements

The lighting and small power installations will be in compliance with the IEC and National standards. Equipment and materials will be state of art manufacturing and, as far as possible, of a type readily available on the local market.

Lighting will be designed to produce adequate visual performance, safety and amenity, and will be free from excessive glare, stroboscopic effects and flicker from discharge lamps. The system will provide an easily erected installation and be complete with all maintenance, cleaning and lamp replacement equipment.

Lighting apparatus will be of first quality designed to ensure satisfactory operation and service life under all variations of load, frequency and temperature normal to the station. The lighting fixtures will be arranged neatly without interference with other equipment to provide a substantially uniform level of illumination throughout the room or area illuminated, eliminating dark corners.

For rooms with special architectural requirements, type, number and arrangement of the lighting fixtures will be coordinated accordingly.

The control of the lighting circuits will consider the following:

- Switching of individual lighting circuits from suitable points.
- Control by pushbuttons with impulse relays and contactors.
- Automatic control of outdoor lighting circuits with adjustable photoelectric cells, provided with remote control and manual override switches.
- Lighting circuits in the lighting distribution boards, suitable for local manual or remote control.
- Emergency and security lighting circuits do not require individual control.

The lighting sub-distribution boards will be of robust sheet metal, flush fronted design and, depending on size and location, be of the free-standing or surface/flush wall-mounted type. They will be a standard product of an experienced manufacturer. The front doors will be provided with lockable handles.

12.3.2.1 Lighting Installation

a) Main/ Sub Distribution Panels

The contractor shall furnish and install main/sub-distribution panels. Panels with MCCB and MCB's for normal lighting and socket outlets, to be fed from the 400/230 V mains

b) Lighting Fitting Indoor

Indoor lighting will be installed in the entire powerhouse building including control room building, battery room, office, and sanitary facilitates, intake control room and the substations control building.

The control room will have intensity-controlled illumination, so that it might be adapted to special situations.

The following indoor fittings shall be made

I. Lighting

230 V AC light fittings for the powerhouse building, intake, and substations control buildings. 220 V DC emergency lighting fittings for the powerhouse building, intake.

All fittings to be delivered with fluorescent tubes or LED.

II. Socket Outlets

Socket outlets and power points shall be installed in all areas as follows:

III. Normal duty socket outlets

Single phase 230 V, 10 A. All areas shall be reached with cable length of maximum 20 m.

IV. Power outlets

Single phase outlets 230 V, 20 A. All areas shall be reached with a cable length of maximum 10 m. Three phase outlets 440 V, 30 A and 20 A. All areas shall be reached with a cable length of maximum 10 m.

c) Lighting Installations outdoor

The outdoor lighting installations cover luminaries, steel masts/poles in accordance with the requirements of Metal Work specifications, cables, and foundations complete in all respect.

Outdoor lighting shall be, centralized as much as possible, and all lighting shall be controlled from a lighting control panel and all light fixtures are waterproof.

For outdoor lighting, poles of galvanized steel shall be provided. Each pole shall be delivered with steel bracket or a concrete foundation whatever the installation method require. Every pole shall be equipped with a junction box.

d) Wiring and Accessories

For all installations insulated multi-core power cables shall be used for the wiring. Wiring shall be laid on or in the walls and ceilings. The wiring shall be installed in a neat and orderly manner. All cables shall be run either horizontally or vertically.

All installations shall be carried out in accordance with internationally accepted methods to a high standard of workmanship.

Cable and wire termination shall be performed without damage to the conductors; lugs shall be soldered or shrunk with approved tools. Lugs shall be used for all cables above 4 mm2

e) Local Earthing

The Contractor shall be responsible for providing the earthing system required for the electrification works and co-ordinate this with the main earthing system of Respective installations.

f) Types of Lighting Systems

The lighting systems will consist of the following sub-systems:

- Normal Lighting System fed by the AC auxiliary supply system.
- Emergency Lighting System, fed by the emergency DG units in case of AC auxiliary supply failure. The emergency lighting system will be provided for all operational areas to ensure the safe movement of the personnel and to enable essential operations to be carried out at all times. The CCR lighting system will be fed by the UPS system.
- Security Lighting Systems (SLS), fed by the station DC or UPS systems, will adequately illuminate relevant exits and emergency escape ways.

Self-contained, battery-powered lighting fixtures will be used in remote areas. At selected locations portable, automatically recharged lamps, providing 4 h operation, will be installed.

g) Illumination Levels

The lighting systems will illuminate all parts of the power plant at illumination levels in compliance with the DIN and ILE standards, the minimum illumination levels will be the following:

- Roadways and car parks 15 lux
- Cable floors, galleries, shafts, tunnels, outdoor structure 50 lux
- Corridors, stairways, rest rooms, stores 100 lux
- Machine hall and erection bay, turbine and generator floor
- Floors, plant rooms, battery rooms, mechanical and workshop
- Transformer bays 250 lux

- Control rooms, electronic equipment rooms, offices, electrical
- Electronic workshops 500 lux

The lighting calculations will consider ageing factors 1.25 / 1.67 for indoor and outdoor installations, respectively.

The illumination levels of indoor systems will be measured horizontally at a height of 0.80 to 1.00 m above the floor; for outdoor lighting systems at the surface. In new condition of the equipment, the ratio of the minimum to the average illumination level will not be higher than 1:3; the ratio of the minimum to the maximum illumination level will not be higher than 1:6.

12.3.3 Testing

Inspection and testing of all items of electrification work shall be in conformity with the applicable recognized standards for making such tests and inspections.

12.3.3.1 Electrical Equipment and Wiring

All electrical equipment and wiring shall be tested in accordance with the applicable provisions of IEC or other approved Standard.

The test results and plans shall be submitted to the Engineer for approval.

12.3.3.2 Testing Upon Completion

The following tests shall be carried out in the presence of the Engineer's representative.

- Insulation tests between all phases, from each phase to neutral to earth:
- Resistance tests on the earth continuity conductor and on any or all circuits as instructed by the Engineer's representative.
- The resistance to earth of any or all earth electrodes, as the Engineer's representative shall choose; Ref BS-7176 and BS -7430.
- The correct operation of controls, lights, and other outlets.
- Measurement of illumination level.

All tests shall be witnessed by the Engineer and no work will be accepted until the Engineer's representative is satisfied with the installation.

12.3.4 Spare Parts

The Bidder shall supply the mandatory spare parts for the equipment as per requirements stated in the Part 3 - Price Schedules, Volume-1 of the Bidding Documents.

The Bidder shall also enclose with his Bid a detailed list of recommended spare parts for the equipment. The quantity of recommended spares should be sufficient for 5 years of operation.

SECTION 13: TECHNICAL SPECIFICATIONS OF TRANSMISSION LINE

13.1 Transmission Lines

- The technical provision for interconnection of Power generated by 22MW Jagran Hydropower Project specifies the general requirement for self-supported galvanized lattice steel towers (132kV), ACSR Lynx conductor and stock bridge dampers, for conductor and galvanized steel shield wire pertaining to the proposed transmission lines for the interconnection of the Project having an approximate length of 4.0 Km.
- The technical provision for construction of Standard Steel lattice Poles, foundation and stringing work of 11kV single circuit lines with Rabbit Conductor testing and commissioning complete with hardware, disc/pin insulator and Optic fibre Cable (communication) from switchyard to weir intake having an approximate length of 3.5 Km.

13.1.1 Applicable Standards

All equipment, materials, fabrication, and tests under this section shall conform to the latest applicable standards, manuals and specifications contained in the following list or to standards, manuals and specifications approved by the Engineer.

- ACI American Concrete Institute
- ANSI American National Standard Institute, Inc
- ASME American Society of Mechanical Engineers
- ASTM American Society for Testing Materials
- BS British Standard Institution
- IEC International Electro technical Commission
- NEMA National Electric Manufacturers Association
- IEEE Institute of Electrical and Electronics Engineers
- WAPDA Specifications for Transmission Line Equipment

13.1.2 Site Conditions

The information in this section is given solely for the general assistance to Bidders. No responsibility for it will be accepted, nor will any claim based on this Clause be considered by the Client.

The Bidder is advised to survey the sites covered under this Contract to acquaint himself with site conditions particularly regarding the access conditions and bridge capacities. The Contractor shall be responsible for surveying; detailed check survey, geo technical investigation including measurement of soil resistivity at the precise locations as required for foundation and other design of the transmission line and/ or substations.

The Contractor shall locate, and record on the construction drawings, all interfacing utility lines or other obstructions. Damage to existing installations shall be repaired by the Contractor at their own expenses.

13.1.3 Units of Measurement

In all correspondence, technical schedules design calculations and drawings the metric (SI) unit system of measurement shall be used. Angular measurements shall be degrees with 90° comprising a right angle.

13.1.4 Design and Document Submission

In addition to those specifically stipulated in relevant Clause of General and Particular Condition of Contracts regarding drawings, the contractor shall submit all drawings with the Bid in sufficient detail to indicate the type, size, arrangement, dimensions, material description, Bill of Materials, weight of each component break-up for packing and shipment, fixing arrangement required, the dimensions required for installation and any other information specifically requested in these specifications. The Contractor shall submit to the Engineer all design calculation drawings, method statements, test programs and test records of the relevant section of the specification or as otherwise instructed by the Engineer.

13.1.5 Design Calculations

All sets of calculation shall be complete, bound, titled, and given a specific drawing number. The binding shall be in such manner that allows easy introduction of subsequent pages/documents if necessary.

The design information sheets bound into each set shall be fully detailed index incorporating the following details

- The design concept shall be summarized
- Full details of manuals, design papers, or other aids referred to in the next shall be given with photocopies of relevant sheets.
- Full loadings shall be reiterated with their deviations if appropriate.
- Design stresses shall be reiterated.
- Code or standard references should be quoted, and equation written out in full for initial calculation.

Where a computer program is used for design calculations a full explanation in the English language shall be provided to assist the Engineer approval of the calculations for each and every program used. Details must include all references to relevant documentation, checks undertaken on program and list of projects on which the program has been used.

13.2 Selection of Line Route and Tower Structure

The scope of work for 22MW Jagran-IV HPP includes 132kV transmission line from Jagran-IV HPP to Jagran-I Powerhouse having an approximate length of 4.0 Km.

Keeping in view the power system expansion in future under regional grid system and the power potential in the vicinity and upstream of the project and to avoid future line corridor difficulties, a Double Circuit Steel Lattice Tower is proposed.

The scope of work under transmission line includes the following:

- Construction of vertical formation self-supported Double Circuit Lattice Steel Towers with ACSR Lynx conductor, galvanized steel earth wire, Fog Type Porcelain Disc Insulators, with complete Hardware and Stockbridge Vibration Dampers for Conductor and Shield Wire for 132kV Single Circuit Transmission Line from Jagran-IV HPP switchyard to the 132kV Jagran-I Powerhouse.
- Construction of Standard Steel lattice Poles, foundation and stringing work of 11kV single circuit lines with Rabbit Conductor testing and commissioning complete with hardware, disc/pin insulator and Optic fibre Cable (communication) from switchyard to weir intake having an approximate length of 3.5 Km.

Table 15: System Data

1.	Nominal Voltage	kV	132
2.	Maximum system voltage	kV	145
3.	BIL (Impulse)	kV (Peak)	650
4.	Power frequency withstand voltage (Wet)	kV (rms)	275
5.	Minimum Corona extinction voltage at 50 Hz AC system under dry condition	kV (rms) phase to earth.	110(Min)

13.3 Lattice Steel Tower Structure

13.3.1 General Requirement of Steel Tower (132 kV)

The double circuit tower structure shall be of galvanized lattice steel, square base self-supporting type and shall have the capability to carry the loads and meet the loading conditions. It shall be of standard construction and shall be designed to reduce the number of different parts to a minimum, thus facilitating transport and erection.

The standard suspension and tension type 132 kV Double Circuit Towers shall be used for single circuit transmission line configuration. The towers shall be fabricated, supplied as per in accordance with WAPDA specification P-139, with step bolts, and anti-climbing device complete with barbed wire including fixture. Number, danger, and phase. The galvanization of towers shall be carried out in accordance with WAPDA specification P-82:

The following types of 132 kV double circuit towers shall be used for the project:

Table 16: Types of 132 kV Line Towers

Designation	Position	Angle of Deviation	Type of Insulators	Use
ZM - 1	Straight Line	0°-1°	Suspension	for line angle up to 1^{o}
ZM - 30	Angle	1°-30°	Tension	for line angle up to 30^{o}
ZM - 60	Angle	30°-60°	Tension	for line angle up to 60^{o} for dead end/Terminal Tower

Basic tower shall be as indicated in the above table. The tower shall also be designed so that their heights may be extended by 3 to 6m where required. An extended tower shall be denoted by the

addition of the height of extension to its basic designation, i.e., ZM 1+3M means a suspension tower extended by 3m.

13.3.2 Material

Material for the steel towers shall be of the type and grade most suitable for the application intended shall conform to the latest applicable standard, specifications, and recommended practices of the industry. High-strength structural steel shall be used for the fabrication of the towers.

13.3.3 Steel Properties

In fabricating structures, the contractor shall use structural steels having chemical composition and tensile properties as specified. The steel shall be made either by open hearth, basic oxygen, or electric furnace process.

13.3.4 Chemical Composition

The steels shall conform to the following chemical composition:

Table 17: Chemical Composition of Steels

Element	Composition Percentage	
	Mild Steel	High Tensile Steel
Carbon	0.26	0.20
Manganese	0.85	1.35
Phosphorus Maximum	0.04	0.04
Sulphur Maximum	0.05	0.05

13.3.5 Tensile Properties

The steel shall conform to the requirements as to tensile properties prescribed below:

Table 18: Tensile Properties of Steel

Description	Unit	Mild Steel	High Tensile Steel
Tensile strength			
Minimum	kg/mm^2	40	50
Maximum		56	80
Yield points			
Minimum	kg/mm^2	26	35

Description	Unit	Mild Steel	High Tensile Steel
Elongation in 200 mm gauge length percent, minimum	%		
Up to 8 mm thickness		16	15
Over 8 mm thickness		20	18

13.3.6 Bolt Size and its Spacing

Nut and bolts shall be in accordance with WAPDA Specification P-19. Only 16mm diameter bolts shall be used. The minimum edge distance shall be as follow:

Table 19: Minimum Edge Distances of Bolts

Minimum Bolt Dia	Minimum Edge Distance	
	Rolled Edge	Sheared Edge
16.0 mm	20.0 mm	30.0 mm

For gusset plates one and a half bolt diameter. The minimum Spacing of Bolts shall be:

Table 20: Minimum Spacing of Bolts

Bolt Diameter	Minimum Bolt Spacing
16.0 mm	40.0 mm

13.3.7 General Requirements of Steel Tower (11 kV Lattice Poles)

The 11 kV lattice poles shall be fabricated from structural steel complying with ASTM A-36. It shall have the following requirements as per WAPDA Specification P-34:68: Each of the 11 m lattice steel poles shall have an earthing hole (18 mm dia.) located at the center of the lower plate for earthing purposes. Every steel lattice pole shall be supplied with (11 Nos.) electrically galvanized, high stress, hexagonal –headed (M-16) fully threaded bolt (35 mm) length of screw with nut, plain washer & spring washer. Material properties are given below.

Tensile strength

- Minimum 40.0 kg/mm2
- Maximum 56. 0 kg/mm2
- Yield point (Minimum) 25.0 kg/mm2
- Elongation in 200 mm gauge length for:
- Angle of 5 mm (3/16") thickness min: 15 percent
- Angle of 3 mm (1/8) thickness min: 12.5 percent

The material shall be mild steel complying the ASTM-A36 and shall be hot dipped galvanized. The bolts shall comply with ASTM-394 and the lattice structure to be tested in accordance with WAPDA Standard P-34:68.

13.4 Survey and Right of Way

A preliminary line route has been marked on drawing which is indicative, however based on the indicative line route, the contractor shall carryout an investigation of the route and shall make necessary modifications and establish the terminal points, the line angles, locations, road crossings and during the survey, the Contractor will ascertain whether the route indicated to him is most suitable. If in his opinion change in route would be more desirable on technical ground or shall be more economical, the contractor shall report his findings to the Engineer who will then decide about the adoption of new route.

The final route to be made after taking into account all the local rules and regulations and other specified conditions about safe distance from airports, rail, road, telecommunication lines etc. Contractor shall be responsible for obtaining approvals from various agencies. The Contractor shall also obtain necessary rules and regulations.

13.5 Foundation Requirements

13.5.1 General

The contractor shall design and construct the various types of concrete foundations for all types of towers. The foundation shall be able to withstand the ultimate forces tension, compression, shear, and uplift for the worst possible combination of ultimate loads. However, for angle towers the ultimate loads shall be multiplied by an additional factor.

The foundation work for the steel towers shall include but not limited to the following

- The contractor shall perform all clearing and levelling works as required for the construction of footings and erect the steel towers.
- Performing all required excavation, dewatering, shuttering, compacting backfill for the concrete footings. Installing steel stub angles for towers in the concrete footings.
- Tower grounding before placement of concrete.
- All concrete work for the footings, includes the cost of furnishing all reinforcing bars, and all materials for concrete.

Each tower foundation shall have four footings and each footing shall consist of a steel stub angle embedded in plain/reinforced concrete. The footings for each tower in a tangent section of the line shall be placed so that the longitudinal exits of the tower cross arm will lie in a plane perpendicular to the traverses of the line. Unless otherwise directed by the Engineer, the footings for each angle tower shall be placed so that the tower crossarm will lie in a plane bisecting the interior angle formed by the intersection of the traverses of adjacent section of the line.

13.5.2 Structural Design of Foundation

The structure design of foundation shall be suitable for maximum bending moments due to side thrust in transverse and longitudinal directions combined with uplift (tension), down thrust (compression). The combined uplift and bending shall determine the requirement of longitudinal

reinforcement in the foundation. The stub angle shall be embedded in the chimney to its full depth and anchored to the bottom slab/ pyramid. The chimney shall be designed considering the passive resistance of soil leaving 500 mm from ground level.

13.5.3 Design Loads

The loads used to design the foundations shall be actual loads applied to the foundations by the towers.

The foundation may be subjected to three types of forces (ultimate loads):

- Compression or downward thrust
- Tension or uplift force
- Lateral force or side thrust in both transverse and longitudinal directions.

The magnitudes of each type of load depend on the type of tower and configuration of the transmission lines.

The foundations shall be designed in such a manner to meet the factors of safety for the above loads.

13.5.4 Types of Foundations to be used

The foundation classification shall depend upon the type of soil, subsoil water level and the presence of surface water. The types of foundations likely to be used for the project are classified as follows

a) Dry Foundation

Foundation to be used for locations where normal dry cohesive or non- cohesive soils intact and sub- soil water is met at 3.5 meters or more below the ground level.

b) Wet Foundation

Foundation to be used for locations where there is sub-soil or surface water, or the foundation is fully or partially submerged. This type of foundation is likely at the river crossing locations.

c) Wet and Dry Fissured Rock Foundation

This foundation shall be used locations where decomposed or fissured rock, hard gravel, limestone, etc. or any other soil of similar nature with possibility of subsoil water exists.

d) Hard Rock Foundation

The locations where chiselling, drilling, and blasting is required for excavation, hard rock type foundations are to be used. For these locations rock anchoring is to be provided to resist the uplift forces.

e) Special foundation

Special type foundations shall also be provided by the Contractor if required depending on the site conditions.

13.6 Tower Erection

Erection shall be done strictly in accordance with the manufacturer's drawings and material lists. No tower shall be erected until ten days after the last concrete was place in the foundation nor backfill has been completed where and when required.

The Tower steel shaft shall be handled so as to prevent deformation of the members and damage to the galvanizing. Materials shall not be dumped, dragged, barred, rolled or dropped but shall be carefully loaded/unloaded and stored. A mechanical means such as a hoist or crane shall be used when material cannot be properly bundled or placed by hand.

13.6.1 Equipment and Method

All assembly and erection shall be through method and equipment that will not cause damage to, or distort, any part of the tower. Extreme care shall be taken to establish and maintain the true geometric shape of the sections of tower assembled. Reaming shall be done only with the approval of the Engineer and will be permitted for the correction of undersized holes; for removing excessive galvanizing; and for holes off gauge line. No hole shall be reamed more than one-eight of its original diameter. Reaming to remove fitting difficulty due to improperly set footings; to correct improper tower assembly and Erection; that would distort holes or distort any member; or that would damage the galvanizing shall not be allowed.

13.6.2 Damage to Galvanizing

Small areas of galvanizing damaged by abrasion, in straightening bent pieces or by necessary clipping in the field, shall be repaired by carefully cleaning the affected area and painting. The Contractor shall furnish the paint.

Damaged area shall be wiped with clean rare saturated with Xylene or equivalent cleaning agent, followed by wire brushing then re-cleaned with solvent to remove residue, and painted with one coat of "Galvanox" or equivalent. Galvanizing damaged by drilling or punching shall be repaired by applying zinc rich coating material, to completely fill all voids between the bolt and the surfaces bared, or all exposed steel surfaces around the holes or on cuts on which such corrective work is permitted, shall be given coat of "Galvanox".

13.7 Stringing of Conductor and Earthwire

Maximum efforts shall be made to use the maximum conductor lengths to reduce the number of joints to the minimum. The number and location of conductor and overhead earth wire tension joints shall be subject to Engineer’s approval. The proposed conductor lengths shall be designed specifically for the final stringing length and appropriate drum schedule submitted for approval before production.

All stringing equipment shall be properly anchored and shall be positioned in such a way that structures, insulators, and fittings will not be overloaded. The conductor and earth wire drums shall be securely anchored during the stringing operation and drum jacks shall be of the self-braking type to prevent conductor over run.

The insulators strings shall be cleaned and inspected before assembly. Any defective insulator shall be removed from site forthwith. Insulators shall have the security clip, cotter pins and other locking devices fully in place and shall be erected in a manner avoiding damage to the sheds, fibre-glass rod or locking devices.

13.8 Tower Signs and Mark of Warning

Tower signs shall normally be installed on the tower so that they will be readily visible when viewed in the direction of increasing tower numbers. However, if signs installed in the normal position will not be readily visible from a permanent access road, they shall be installed on the tower faces best exposed to view from the access roads. The tower numbers shall be painted on No. signs and shall be supplied by the Contractor. Sample shall be submitted to the Engineer for approval. Bolt holes for normal mounting of tower No. Plates and marks of warning have been provided on relevant tower members.

13.9 Anti-Climbing Devices

The anti-climbing device shall consist of an arrangement of barbed wire stretched, over a steel frame to prevent un-authorized personnel from climbing the tower. It shall be made in accordance with WAPDA specification P-163:82. The outer most barbed wire shall be at least 600 mm from tower leg. Spacing shall not exceed 150 mm. The anti-climbing device shall be fixed at about 3 mm from ground level.

13.10 Grounding of Towers

Before placing foundation concrete, basic grounding earthing rods shall be installed to each of the foundation cleats. Each tower shall be grounded by installing one ground rod below the tower footings. Ground rods shall be driven at least 2.0 meters into undisturbed soil at the bottom of the footing excavation. The ground rod shall be connected to the stub angles by a ground wire, the connection of this wire to the ground rod and to the stub angle shall be made by a bolted clamp. Installation shall ensure that earthing can be isolated from the tower and concrete foundation to allow measurement of earth resistance. Measurement of footing resistances of all towers shall be carried out with an approved instrument before stringing of an overhead earth wire.

13.11 Conductors and Insulators for Transmission Lines

The technical provision specifies the requirements for ACSR Lynx Conductor, Galvanized shield wire, fog type insulators, hardware and accessories, stock bridge dampers for conductor for the transmission of power. Selection of the conductor is based on current carrying capacity and mechanical strength owing to the climatic condition of the area. Rabbit conductor has been selected for transmission of Power from powerhouse to weir Intake on standard lattice poles as per WAPDA specification.

The conductor used for 132kV transmission line shall be Aluminium Conductor Steel Reinforced (ACSR) Lynx", Conductor, ACSR Rabbit, Conductors shall be use for the 11kV line and shall comply with IEC-60889. The Aluminium shall be of the highest purity commercially obtainable and shall not be less than 99.5%. The Contractor shall submit certificates of analysis giving the percentage and nature of impurities in the metal of which the wires is made. There shall be no joints in the individual wire of the outer layers of aluminium wires. All steel core wires unless specified to the contrary shall be hot-dipped galvanized to comply with the requirements of IEC-60826 and ASTM-B232.

13.11.1 Technical Data

ACSR LYNX conductor shall be used for 132kV single circuit Line from Jagran-IV Powerhouse. ACSR conductor Rabbit will be used for 11kV line from Powerhouse to Weir Intake as per specifications given in below table:

Table 21: Conductor Specifications

ACSR Conductor Specufication		Conductor Code Name		
		Area	Rabbit (11kV)	Lynx (132kV)
Nominal aluminum area		mm²	52.88	175
Stranding structure No.	Aluminum.	No	6	30
	Steel.	No	1	7
Stranding structure Diameter	Aluminum Dia.	mm	3.35	2.79
	Steel Día	mm	3.35	2.79
Overall diameter		mm	10.05	19.53
Sectional area	Aluminum	mm²	52.88	183.4
	Steel	mm²	8.82	42.8
	Total	mm²	62	226.2
Weight of conductor	Aluminum	kg/km	145	507
	Steel	kg/km	69	335
	Total	kg/km	214	842
Ultimate Tensile Strength		Kg	1871	8192
Calculate D.C resistance at 20℃		Ω/km	0.5426	0.1576
Approx. current carrying capacity		A	240	527

13.11.2 Overhead Shield Wire

The galvanized steel wire strand is used for overhead ground lines or electrical power transmission lines in accordance with BS 183. The hardware for suspension and tension fitting and mid span joints of earth wire shall comply with the requirements of WAPDA specification-141:80

13.12 Insulators

13.12.1 Disc Type Insulators for 132 kV Line

The Insulator strings shall consist of Anti-Fog Type discs for a three phase, 50 Hz, effectively earthed 132 KV transmission system. The discs shall be cap and pin, ball, and socket type.

The insulators shall be made of good commercial grade wet process porcelain. The entire surface of the insulators shall be smoothly glazed. The standard colour of the glaze shall be as indicated in below Table 10-9. The entire surface shall be free from imperfections as indicated in WAPDA Specification P-8:96

The size of disc insulator, minimum creepage distance, the number to be used in different type of strings, their electromechanical strength and mechanical strength of insulator string along with hardware fittings shall be as follows:

Table 22: Technical Specification of Porcelain Disc Insulator Data

Disc Type Porcelain Insulator		
Description	**Unit**	**Values**
Type Designation	Disc type U80BLF	
DIMENSIONS		
Disc Diameter (D)	mm	255
Disc Spacing (P)	mm	146
Minimum Creepage Distance	mm	430
Standard Couple Pin Diameter	mm	16
MECHANICAL VALUES		
short time Electromechanical Breaking Load	KN	80
Mechanical Routine Test Load	KN	32
Mechanical Impact Strength	Nm	6.2
ELECTRICAL VALUES		
Power Frequency withstand voltage	kV	85
Wet Power Frequency withstand voltage	kV	50
Impulse withstand voltage	kV	110
Low frequency Puncture Voltage	kV	130
Galvanizing Coating (Cap, Pin& all Ferrous parts): Hot dipped	g/m^2	1050
RADIO NOISE		
Maximum Radio influence at 1000 kHZ	µV	50
Test Voltage to Ground	kV	10
Colour of Glaze	Brown	

13.12.2 Pin Type Insulator (11kV)

For 11 kV line from switchyard to intake weir shall be constructed on standard 11 kV lattice structure in accordance with WAPDA Specification, Disc and pin type insulator shall be used for 11 kV line.

Table 23: Technical Data of Pin Insulator

Nominal System Voltage	11 KV
Highest System Voltage	12 KV
Minimum Failing Load	5 KN
Dimensions (mm)	
Overall Height	130 mm
Diameter of Insulator	120 mm
Groove Diameter	
Top	98-104
Neck	73 (±) 3
Creepage Distance	230 mm
Dry Power Frequency 1 Min. Withstand Voltage	45 KV
Wet Power Frequency 1 Min. Withstand Voltage	35 KV
Dry Power Frequency Flashover Voltage	50 KV
Wet Power Frequency Flashover Voltage	40 KV
Power Frequency Puncture Withstand Voltage	105 KV
Impulse Flashover Voltage	95 KV
Impulse Withstands Voltage	75 KV
Visible Discharge Test Voltage	9 KV

13.13 Stringing of Conductor and Overhead Shield Wire

Adequate safety precautions shall be taken to protect the employees and others from the potential voltage build-up during construction. The following minimum safety and grounding procedures shall be followed by the Contractor during stringing operations in the Sections with parallel existing high voltage lines

- The voltage build-up may be comparatively small during normal operations but could be lethal during switching and ground fault conditions on the energized parallel line.
- Temporary electrical grounds shall be placed at both ends of the section requiring special safety precautions and at intervals along the line which is under construction. The grounding sets installed at both ends of the section of line shall remain in place until the completion of the work and shall be removed as the last phase of cleanup. Hot stick shall be used for installing and removing the grounding sets.
- All pulling and tensioning equipment shall be bonded and effectively grounded with approved-type driven grounds securely attached to the equipment. At least two driven grounds shall be used at both the pulling and tensioning set up. All conductive parts of the

tensioning set up and equipment shall be operated from grounded or insulated platform provided with barricades or insulated walkways.

13.13.1 Conductor Sagging

The conductors shall be sagged in accordance with sag charts. The exact value of sag for a given span length at a given temperature can be ascertained from the appropriate table or by linear interpolation of data. Conductor sagging temperature shall be measured by an accurate thermometer.

Temporary snubs shall be used between a section previously sagged and clipped in and the section being sagged dead ending or snubbing will not be permitted on any towers except dead end towers at the normal point of attachment.

Sag at sharp vertical angles and horizontal angles of 10 or more degrees shall be checked on both sides of the angle. The sag shall be determined by means of a transit or other approved methods. At least one person shall be provided to measure the correct sag for pulls up to five spans and in proportion for more spans.

Keeper piece shall be so rounded that the conductor strands are not damaged during installation.

13.13.2 Erection of Vibration Dampers

Before erection of dampers, the conductors should be wound with aluminium tape. The winding direction of the tape shall agree with the stranding direction of the external aluminium strands and the clamps should cover the broken points. One number of dampers is to be installed at each end of each conductor/earth wire within a span.

Dampers shall not be installed on the conductors and overhead ground wires at the incoming and outgoing lines on the section between the terminal tower and the grid station (or switchyard).

13.13.3 Splices and Dead Ends

All splices shall be made at least 15 meters away from structures and no splices shall be made in dead-end spans greater than 200 meters or spans crossings over the highways, rail, roads, major canals, rivers, or power lines of voltages greater than 35 kV unless approved by the Engineer. As a rule, not more than one joint or splice should be made in any one conductor in any one span. However, in exceptional cases as in the repair of damaged conductors, or when necessary, owing to stringing limitations two splices will be allowed.

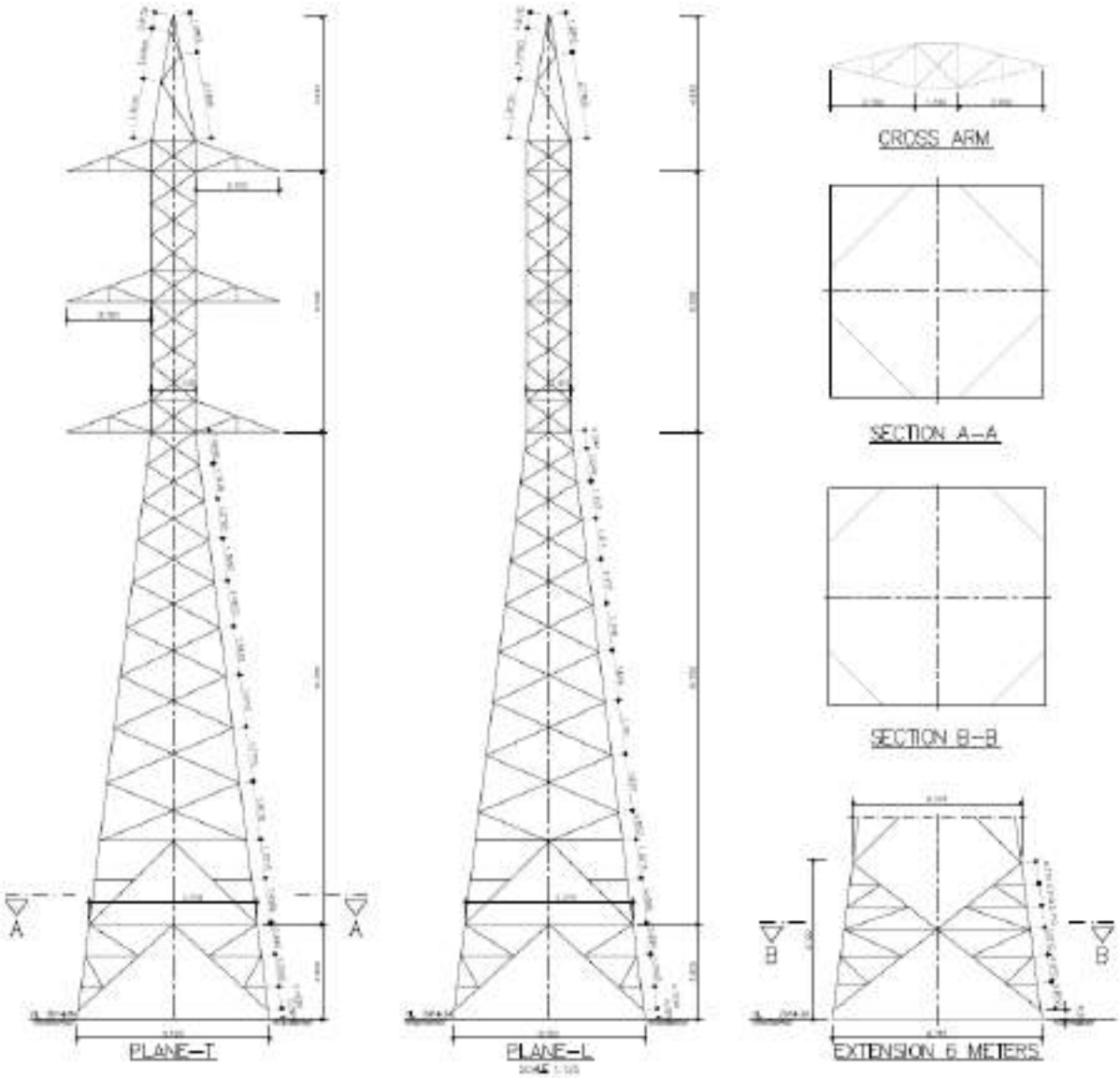


Figure 1: 132 kV Transmission Line-Tower Type- ZM-1

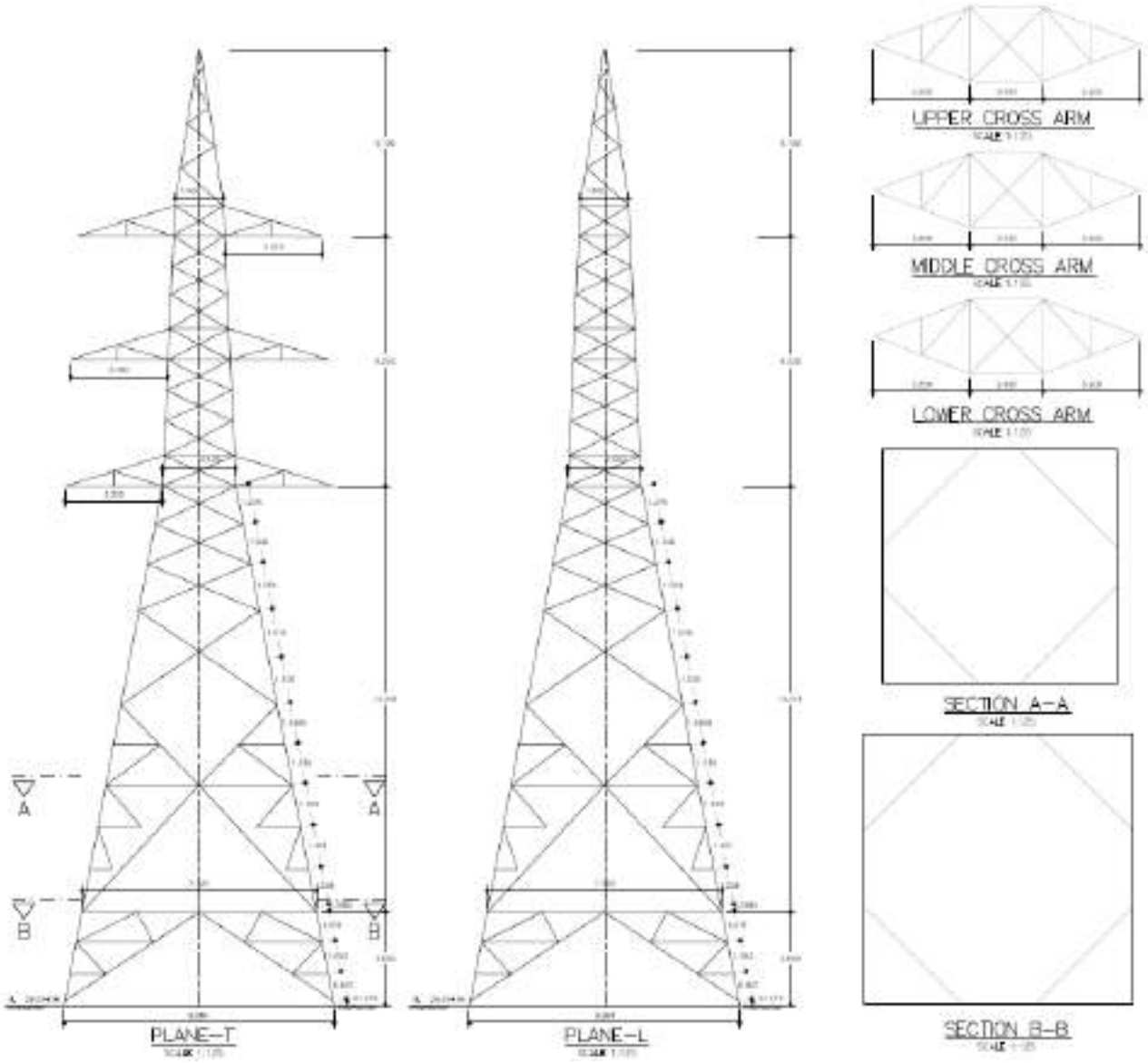


Figure 2: 132 kV Transmission Line-Tower Type-ZM-30

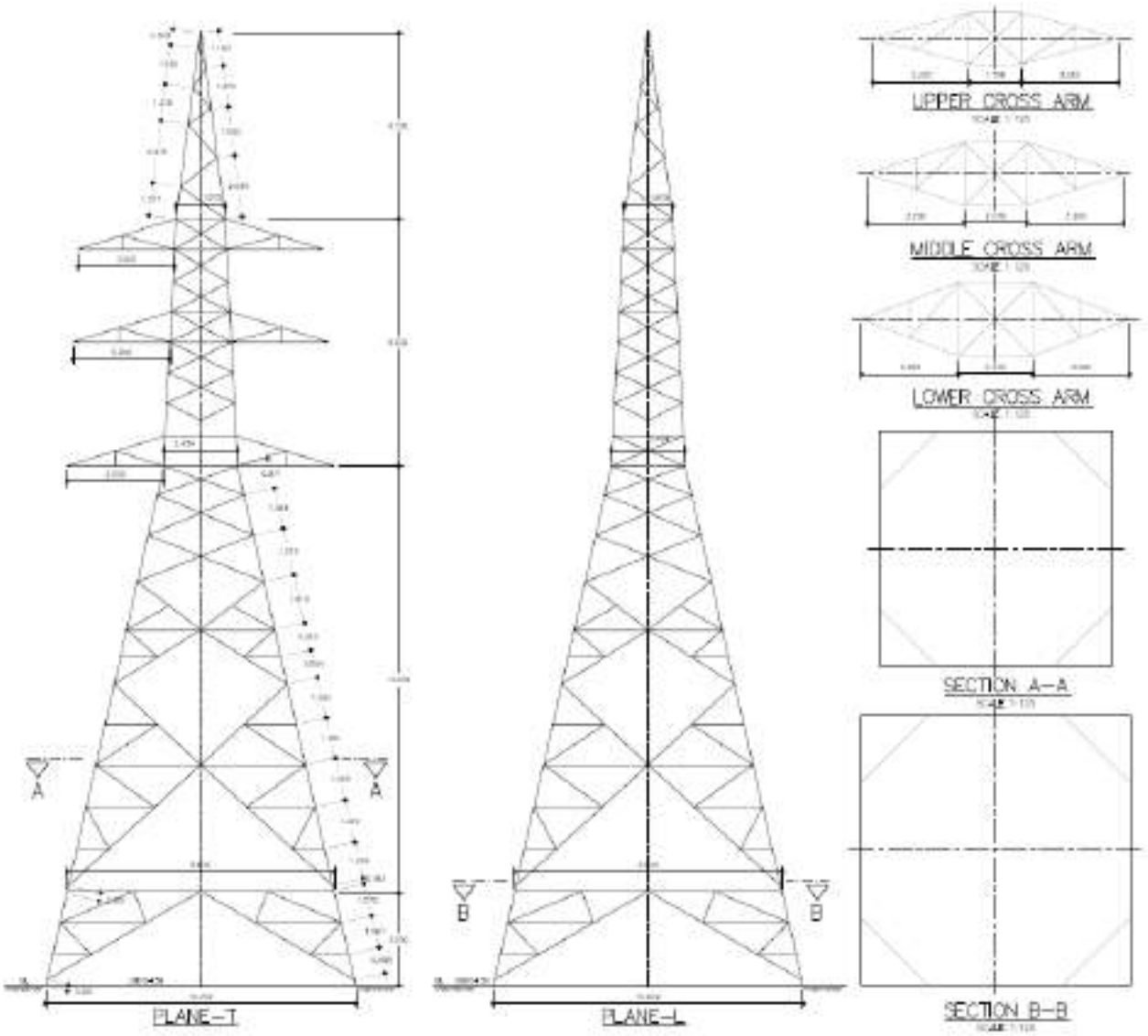


Figure 3: 132 kV Transmission Line-Tower Type-ZM-60

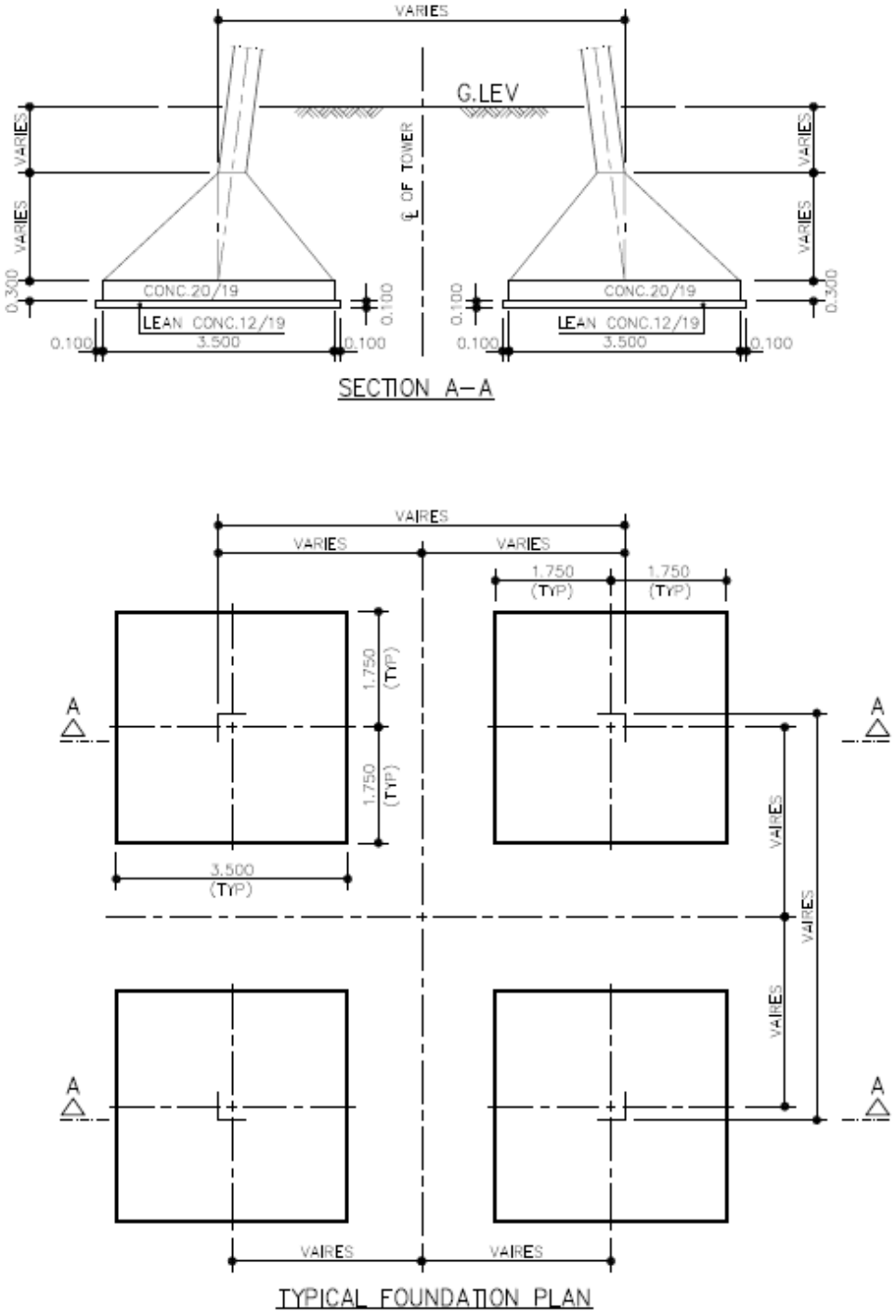


Figure 4: 132 kV Transmission Line-Typical Tower Foundation

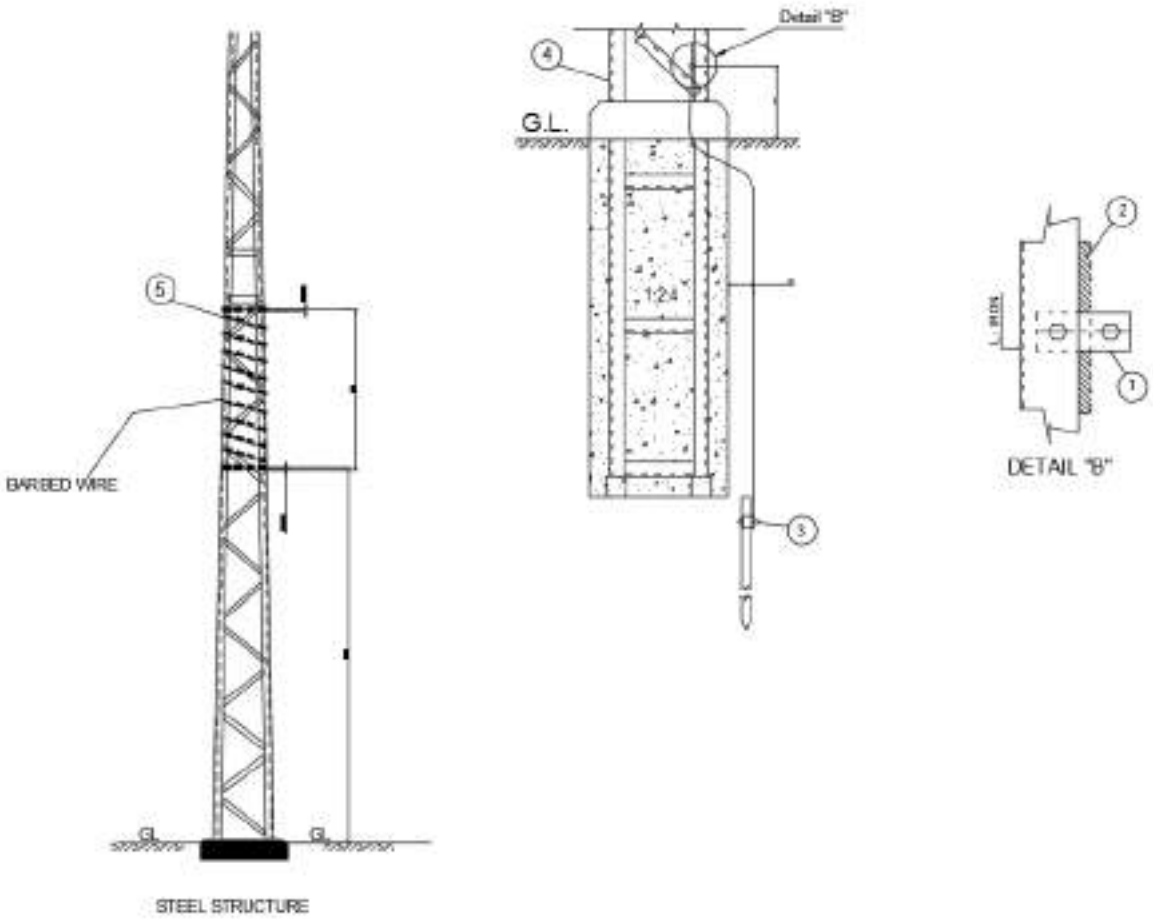


Figure 5: 11 kV Lattice Structure Earthing

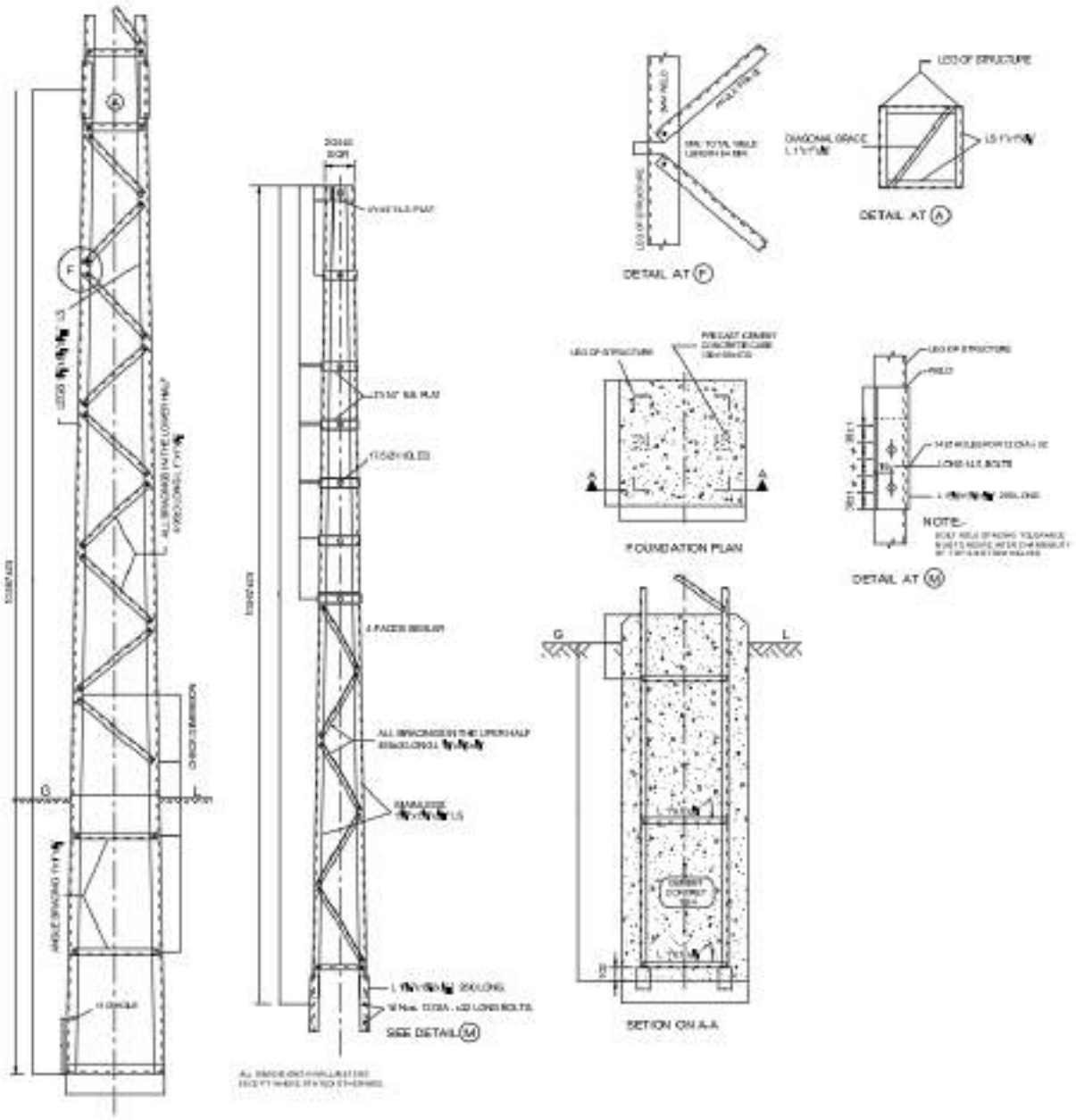


Figure 6: 11 kV Lattice Structure and Foundation

13.14 Tests

13.14.1 General

All the components shall be subject to type, sample and routine tests in accordance with the latest edition of the appropriate IEC, ASTM and WAPDA standards.

13.14.2 Manufacture's Tests

The Manufacturer shall select two samples from each heat to carry out the following tests to satisfy himself that the products comply with the WAPDA specification P-139:80.

a) For Sections and Plates
   - o Chemical Composition (Ladle Analysis)
   - o Tensile Tests
   - o Bend Tests

b) For Nuts and Bolts
   - o Proof Load test
   - o Ultimate tensile strength test
   - o Ultimate tensile strength test under eccentric load
   - o Cold bend test
   - o Hardness test
   - o Galvanizing test

The manufacturer shall maintain a record of tests carried out by them for examination by Inspector.

13.14.3 Acceptance Tests

The following acceptance tests shall be carried out.

a) For Sections and Plates

- o Visual examination
- o Verification of dimensions and weights
- o Prototype tests
- o Chemical composition (Check analysis)
- o Tensile tests
- o Bend Tests Galvanizing test
- o Galvanizing test

b) For Nuts and Bolts

- o Verifications of dimensions
- o Visual inspection
- o Proof load test
- o Ultimate tensile strength test
- o Galvanizing test

13.14.4 Acceptance and Rejection Test

a) Chemical Composition

To indicate adequately, the Chemical composition of a heat or a Lot, the minimum number of samples selected to represent the heat shall be as follow.

Table 24: Minimum Number of Samples for testing Chemical Composition

Quantity	No. of Sample
50 Tones or more	2
50 Ton or less	1

If the pieces fail to meet the requirement the lot shall be rejected.

b) Tensile Properties

Two tension and two bend tests shall be made from each heat and strength unless the finished material from a heat and strength gradation is less than 50 tons, where one tension and one bend test will be sufficient. However, when material from one heat and strength gradation differs 9 mm in thickness, one tension and one bend test shall be made from both the thickness and the thinnest material rolled in that strength gradation regardless of weight represented.

Two tension and two bend tests shall be made on every finished shape for every 10 tons. If a test piece fails to meet the requirement the lot shall be rejected.

c) Verification of Dimensions and Weight

The binding dimensions of the material shall be measured and weighed and shall be as shown on the relevant approved drawings.

13.14.5 Assembly Test

One structure of each type shall be assembled completely in the shop to verify the dimensions and suitability for field erection. Reaming or unfair holes shall not be permitted and only a reasonable amount of drifting will be allowed in assembling. Poorly matching holes shall be cause for rejection.

a) Steel Support Structure

The Contractor shall perform analyses and tests on all material furnished by him to demonstrate these Specifications requirements. If required by the Engineer, the Contractor shall furnish the Engineer certificates listing the heat numbers and the chemical and physical properties of the metals from which articles or materials furnished by him were made.

All structures shall be works assembled and all footing and equipment mounting dimensions checked.

13.14.6 Test Method

a) Chemical Composition Tests

I. Ladle Analyses

An analysis of each heat of steel shall be made by the manufacturer to determine percentages of the elements specified below. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall be reported to the Engineer.

II. Check Analyses

Analysis shall be made from finished material representing each heat or lot. The chemical composition thus determined shall not vary from the range or limits specified below, but the several determinations of any elements in a heat may not vary both above and below the specified range.

Table 25: Limits for Chemical Composition

Element	For Mild Steel		For High Tensile Steel	
	Under the Limit	Over the Limit	Under the Limit	Over the Limit
Carbon	0.03	0.04	0.03	0.04
Manganese	0.06	0.08	0.09	0.12
Phosphorus	—	0.01	—	0.01
Sulphur	—	0.01	—	0.01

b) Bend Test

The bend test specimens shall stand being bent cold through 180 deg. without cracking to an internal diameter of the specimen. The steels shall withstand the following Bend Test Requirements.

Table 26: Bend Test Requirements

Type of Material	Thickness of Material	Ratio of Bend Diameter to Thickness for Specimen
Mild steel	Up to 25 mm	1
High tensile steel	Up to 25 mm	2

c) Tensile Test

The test shall be performed in accordance with ISO-82.

Table 27: Tensile Test Requirements

Property of material	Unit	Mild Steel	High Tensile Steel
Tensile strength (minimum)	kg/mm2	40	50
Tensile strength (maximum)	kg/mm2	56	80
Yield Point minimum	kg/mm2	26	35
Elongation in 200 guage length minimum (up to 8 mm)	%	16	15
Elongation in 200 guage length minimum (Over 8 mm)	%	20	18

d) Galvanizing Test

This test shall be carried out on all ferrous parts complying with the following requirements.

- Weight of zinc coating
- Uniformity of zinc coating
- Adherence of zinc coating
- Embrittlement tests

Test samples for determination of compliance to the test specification be performed in accordance with WAPDA specification P; 82:81 and shall be taken from each lot. The lot shall consist of quantity as specified in the relevant specification.

AJK POWER DEVELOPMENT ORGANIZATION
GOVERNMENT OF AZAD JAMMU & KASHMIR

EPC/TURNKEY BIDDING DOCUMENT
FOR
ENGINEERING PROCUREMENT AND CONSTRUCTION
OF
22 MW JAGRAN-IV HYDROPOWER PROJECT

LOT-2: ELECTRICAL AND MECHANICAL WORKS

BIDDING DRAWINGS
(VOLUME - III)

July 2026

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

JAGRAN-IV HYDROPOWER PROJECT (22 MW) DISTRICT NEELUM , AZAD JAMMU KASHMIR
BIDDING DOCUMENTS LIST OF DRAWINGS

PART-A: SUBMITTED IN LOT-1 OF BIDDING DOCUMENTS GIVEN FOR PROJECT INFORMATION ONLY NOT PART OF THE SCOPE OF WORK

SR. NO.	DRAWING NO.	TITLE
1. GENERAL (PART-A)		
1.	JAG-01-GEN-001	PROJECT LOCATION MAP
2.	JAG-01-GEN-002	GENERAL NOTES
2. LAYOUT (PART-A)		
3.	JAG-02-LAY-001	PROPOSED LAYOUT PLAN
4.	JAG-02-LAY-002	LAYOUT PLAN & PROFILE (SHEET 1 OF 4)
5.	JAG-02-LAY-003	LAYOUT PLAN & PROFILE (SHEET 2 OF 4)
6.	JAG-02-LAY-004	LAYOUT PLAN & PROFILE (SHEET 3 OF 4)
7.	JAG-02-LAY-005	LAYOUT PLAN & PROFILE (SHEET 4 OF 4)
8.	JAG-02-LAY-006	LAYOUT PLAN ON SATELLITE IMAGERY (SHEET 1 OF 2)
9.	JAG-02-LAY-007	LAYOUT PLAN ON SATELLITE IMAGERY (SHEET 2 OF 2)
3. WEIR (PART-A)		
10.	JAG-03-WER-001	WEIR LAYOUT PLAN
11.	JAG-03-WER-002	WEIR PLAN
12.	JAG-03-WER-003	WEIR SECTIONS
13.	JAG-03-WER-004	WEIR SECTIONS
14.	JAG-03-WER-005	WEIR PLAN (STRUCTURE)
15.	JAG-03-WER-006	WEIR SECTIONS 1-1 & 2-2
16.	JAG-03-WER-007	WEIR SECTIONS 3-3, 6-6 & 7-7
17.	JAG-03-WER-008	REINF. DETAIL OF WEIR WALLS & RIGHT WALL ABUTMENT SECTIONS
18.	JAG-03-WER-009	REINF. DETAIL OF WEIR WALLS
4. INTAKE (PART-A)		
19.	JAG-04-INK-001	PROPOSED INTAKE LAYOUT
20.	JAG-04-INK-002	POWER INTAKE PLAN AND SECTION
5. CONNECTING CHANNEL (PART-A)		
21.	JAG-05-CON-001	CONNECTING CHANNEL PLAN & SECTION
6. SANDTRAP (PART-A)		
22.	JAG-06-STR-001	LAYOUT OF SANDTRAP
23.	JAG-06-STR-002	SANDTRAP PLAN & SECTION
24.	JAG-06-STR-003	STRUCTURAL PLAN OF SANDTRAP AND DETAIL-X
25.	JAG-06-STR-004	SANDTRAP SECTIONS 1-1, 2-2, 3-3 AND 4-4
26.	JAG-06-STR-005	SANDTRAP SECTIONS 5-5 AND 6-6

SR. NO.	DRAWING NO.	TITLE
7. HEADRACE PIPE (PART-A)		
27.	JAG-07-SRP-001	SECTIONS OF HEADRACE PIPE
28.	JAG-07-SRP-002	SECTIONS OF HEADRACE PIPE
8. RIVER DIVERSION (PART-A)		
29.	JAG-08-DIV-001	RIVER DIVERSION DURING CONSTRUCTION
30.	JAG-08-DIV-002	RIVER DIVERSION DURING CONST. (CONSTRUCTION STAGES)
9. POWERHOUSE & TAILRACE (PART-A)		
31.	JAG-09-PHS-001	LAYOUT PLAN OF POWERHOUSE
32.	JAG-09-PHS-002	SECTION 1-1 OF POWERHOUSE
33.	JAG-09-PHS-003	POWERHOUSE PLAN
34.	JAG-09-PHS-004	POWERHOUSE SECTION 1-1
10. HYDRAULIC STEEL WORKS (PART-A)		
35.	JAG-10-MEC-001	INTAKE GATE DETAILS
11. ARCHITECTURAL / RESIDENTIAL COLONY (PART-A)		
36.	JAG-11-BLD-001	ARCHITECTURAL LAYOUT PLAN
37.	JAG-11-BLD-002	EXECUTIVE QUARTER
38.	JAG-11-BLD-003	EXECUTIVE QUARTER
39.	JAG-11-BLD-004	STAFF QUARTER
12. MECHANICAL (PART-B)		
40.	JAG-10-MEC-002	LAYOUT PLAN OF POWER HOUSE
41.	JAG-10-MEC-003	SECTION 1-1 OF POWER HOUSE
42.	JAG-10-MEC-004	POWER HOUSE PLAN
43.	JAG-10-MEC-005	POWER HOUSE SECTIONS
44.	JAG-10-MEC-006	MACHINE HALL PLAN EL. 2072.05
45.	JAG-10-MEC-007	GENERATOR FLOOR PLAN EL. 2074.05
46.	JAG-10-MEC-008	LP COMPRESSED AIR SYSTEM
47.	JAG-10-MEC-009	SCHEMATIC DRAWING OF COOLING WATER SYSTEM
48.	JAG-10-MEC-010	SCHEMATIC DRAWING FOR DRAINAGE AND DEWATERING SYS.
13. ELECTRICAL (PART-C)		
49.	JAG-12-ELE-001	LEGEND
50.	JAG-12-ELE-002	SLD SINGLE LINE DIAGRAM
51.	JAG-12-ELE-003	SWITCHYARD LAYOUT PLAN

SR. NO.	DRAWING NO.	TITLE
52.	JAG-12-ELE-004	SECTION VIEW 132 kV SWITCHYARD
53.	JAG-12-ELE-005	STATION SERVICE SUPPLY SWICHYARD & POWERHOUSE
54.	JAG-12-ELE-006	400 V DISTRIBUTION SYSTEM POWER PLANT
55.	JAG-12-ELE-007	DC DISTRIBUTION SYSTEM POWER PLANT
56.	JAG-12-ELE-008	MV SWITCHGEAR ARRANGEMENT POWER PLANT
57.	JAG-12-ELE-009	11 kV LATTICE STRUCTURE EARTHING
58.	JAG-12-ELE-010	11 kV LATTICE STRUCTURE & FOUNDATION
59.	JAG-12-ELE-011	132 kV Transmission Line-Tower Type-ZM-1
60.	JAG-12-ELE-012	132 kV Transmission Line-Tower Type-ZM-30
61.	JAG-12-ELE-013	132 kV Transmission Line-Tower Type-ZM-60
62.	JAG-12-ELE-014	132 kV Transmission Line-Typical Tower Foundation

1-GENERAL

AZAD JAMMU & KASHMIR

LEGEND

- PROVINCE BOUNDARY
- DISTRICT BOUNDARY
- LINE OF CONTROL
- RIVER
- NALA
- BRIDGE
- SITE

POWER STATION

1. PROPOSED
2. UNDER CONSTRUCTION
3. STUDY PHASE
4. CONSTRUCTED

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

PROJECT LOCATION MAP

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-01-GEN-001	

G E N E R A L N O T E S

A. GENERAL

1. ALL DIMENSIONS AND ELEVATIONS ETC. ON DRAWINGS ARE IN METERS AND MILLIMETERS (UNLESS NOTED OTHERWISE.) UNO
2. THE GRIDS, CO-ORDINATES OF POINTS AND CONTOURS ARE IN METERS.
3. THE CONTRACTOR SHALL PREPARE AND SUBMIT HIS PLAN FOR EXCAVATION OF FOUNDATION AND LIFT DRAWINGS FOR CONCRETE STRUCTURES TO THE ENGINEER PRIOR TO POURING OF CONCRETE AT SITE.
4. ALL AREAS DISTURBED DUE TO THE CONSTRUCTION ACTIVITIES SHALL BE PROPERLY RESTORED TO ITS ORIGINAL FORM OR AS DIRECTED BY THE ENGINEER.
5. LOCATIONS OF VARIABLE FEATURES SUCH AS NATURAL STREAMS, DEPRESSIONS AND HOUSES ETC., SHOWN IN DRAWINGS ARE SUBJECT TO CHANGE.
6. TO RECORD THE EXISTING GROUND LEVELS FOR MEASUREMENT OF EXCAVATION AND FILL IN EMBANKMENTS, THE AREA SHALL BE JOINTLY SURVEYED BY THE CONTRACTOR AND THE ENGINEER BEFORE STARTING THE WORKS, AND SAME SHALL BE USED FOR QUANTITY CERTIFICATION.
7. ANY VARIATION BETWEEN DRAWINGS AND SITE CONDITIONS SHALL BE BROUGHT TO THE NOTICE OF THE ENGINEER FOR CLARIFICATION BEFORE EXECUTION OF THE WORK.
8. DRAWINGS SHALL BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT DRAWINGS.
9. LOCATION OF STRUCTURE IS TENTATIVE SUBJECT TO VERIFICATION BY THE ENGINEER AT SITE.
10. EXCAVATED MATERIAL SUITABLE FOR EMBANKMENT FILL SHALL BE USED FOR COMPACTED IN EMBANKMENT.
11. EARTH FILL IN EMBANKMENTS SHALL BE COMPACTED AS PER SPECIFICATIONS.
12. THE STRUCTURES SHOULD BE CONSTRUCTED ON FILL SHALL BE PLACED ON FILL COMPACTED TO 95% OF DRY DENSITY.
13. CONCRETE IN DECK SLAB SHALL BE PLACED IN FULL WIDTH. NO CONSTRUCTION JOINT SHALL BE PERMITTED.

B. EARTHWORK

1. EXCAVATION SHALL BE CARRIED TO THE LINES AND GRADES AS SHOWN ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER AND THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE STABILITY OF THE EXCAVATED AREA.
2. FILL, BACKFILL AND SELECT FILL MATERIAL WHERE REQUIRED, SHALL BE PLACED AND COMPACTED TO THE REQUIREMENTS AS PER TECHNICAL SPECIFICATIONS AND DRAWINGS.
3. THE EARTHEN RAMPS AROUND THE STRUCTURE SHALL HAVE SLOPE OF 1V:30H UNLESS OTHERWISE MENTIONED.
4. ANY LOOSE SOIL ENCOUNTERED DURING EXCAVATION OF CANAL OR STRUCTURE FOUNDATIONS, SHALL BE REPLACED WITH APPROVED FILL MATERIAL AS PER SPECIFICATIONS AND DRAWINGS.
5. THE CONTRACTOR SHOULD KEEP THE EXCAVATED AREA DRY DURING THE CONSTRUCTION ACTIVITY AND AT LEAST 12 HOURS AFTER CONCRETING IT OR AS DIRECTED BY THE ENGINEER.
6. DEVELOPMENT OF ANY EXCESSIVE PRESSURE BEHIND THE ABUTMENT AND RETAINING WALLS DUE TO OVER COMPACTION SHALL BE AVOIDED.
7. ALL BACKFILL MATERIAL FOR BRIDGE ABUTMENT WALLS SHALL BE COMPACTED TO 95% OF MAXIMUM MODIFIED DRY DENSITY (ASTM D1557).

C. CONCRETE

1. CONCRETE DESIGN AND CONSTRUCTION SHALL CONFORM TO THE PROVISIONS OF ACI CODE.
2. UNLESS OTHERWISE NOTED ON THE DRAWINGS, THE MINIMUM COMPRESSIVE CYLINDER STRENGTH fc° OF CONCRETE TO 28 DAYS SHALL BE AS FOLLOWS:
   - i) RCC COLUMNS, SHEAR WALLS, SECOND STAGE CONCRETE = 5000 PSI (35 MPA)
   - ii) RCC SLAB, BEAMS, RCC WATER TANKS, PLAIN CONCRETE, FIRST STAGE CONCRETE = 4000 PSI (28 MPA)
   - iii) CYCLOPEAN, PLUM CONCRETE = 2500 PSI (18 MPA)
   - iv) BLINDING CONCRETE = 2000 PSI (14 MPA)
3. ORDINARY PORTLAND CEMENT SHELL BE USED IN CONCRETE UNLESS OTHERWISE SPECIFIED ELSEWHERE.
4. CONCRETE FINISHES AND TOLERANCES SHALL BE AS PER TECHNICAL SPECIFICATIONS.
5. ALL EXPOSED CONCRETE EDGES SHALL BE CHAMFERED 25mmX25mm.
6. THE DESIGN OF FORM WORK AND FLUSH WORK AS WELL AS ITS CONSTRUCTION SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR. DESIGN OF FORM WORK AND FLUSH WORK SHALL CONFORM TO THE TECHNICAL SPECIFICATIONS.
7. ALL REINFORCED CONCRETE SHALL BE FAIR-FACED TO BE CAST IN PROPERLY DESIGNED STEEL FORM WORK AND PLATES.

D. REINCORCEMENT

1. CONCRETE DESIGN AND CONSTRUCTION SHALL CONFORM TO THE PROVISIONS OF ACI CODE. MEASUREMENT WILL BE MADE OF THE NUMBER OF KILOGRAMS OF REINFORCING STEEL ACCEPTABLE PLACED ON THE BASIS OF THE LENGTHS OF BARS INSTALLED IN ACCORDANCE WITH THE APPROVED DRAWINGS OR BAR SCHEDULE OR AS DIRECTED, CONVERTED TO WEIGHTS FOR THE SIZE OF BARS LISTED BY THE USE OF UNIT WEIGHTS PER LINEAR METER AS FOLLOWS: -

Sr. No	Dia. Inches	Dia. (mm)	# FPS	# SI	Weight Lbs./Foot	Weight Kg/Meter
1	0.375	9.5	# 3	# 10	0.376	0.560
2	0.500	12.7	# 4	# 13	0.668	0.994
3	0.625	15.9	# 5	# 16	1.043	1.552
4	0.750	19.1	# 6	# 19	1.502	2.235
5	0.875	22.2	# 7	# 22	2.044	3.042
6	1.000	25.4	# 8	# 25	2.670	3.973
7	1.128	28.7	# 9	# 29	3.400	5.060
8	1.270	32.3	# 10	# 32	4.300	6.404
9	1.410	35.8	# 11	# 36	5.310	7.907
10	1.693	43	# 14	# 43	7.650	11.38
11	2.257	57.3	# 18	# 57	13.600	20.24

2. UNLESS OTHERWISE NOTED ON THE DRAWINGS, THE MINIMUM COMPRESSIVE CYLINDER STRENGTH fc° OF CONCRETE TO 28 DAYS SHALL BE AS FOLLOWS:

CONCRETE CAST AGAINST AND PERMANENTLY EXPOSED TO EARTH	75mm
FOOTINGS	75mm
TOP SURFACE OF GLACIS AND STILLING BASIN	62.5mm
PILES	75mm
BEAMS, COLUMNS: TIES, STIRRUPS	37.5mm
RAILINGS, SPIRALS, PILE CAPS	25mm

(i) DEVELOPMENT LENGTH IN TENSION

TOP BARS*

fc' MPa(Psi) \ BAR SIZE	DEVELOPMENT LENGTH (in)								
	#3	#4	#5	#6	#7	#8	#9	#10	#11
4000	18	25	31	37	54	62	69	77	85
5000	17	22	28	33	48	55	62	69	76
6000	16	20	26	30	43	50	56	63	69

OTHER BARS

fc' MPa(Psi) \ BAR SIZE	DEVELOPMENT LENGTH (in)								
	#3	#4	#5	#6	#7	#8	#9	#10	#11
4000	15	19	24	28	42	47	53	59	65
5000	13	17	21	25	37	42	48	53	58
6000	12	16	19	23	33	39	45	48	52

(ii) DEVELOPMENT LENGTH IN COMPRESSION

fc' MPa(Psi) \ BAR SIZE	DEVELOPMENT LENGTH (in)								
	#3	#4	#5	#6	#7	#8	#9	#10	#11
4000	8	10	12	15	17	19	21	24	26
5000	8	9	11	14	16	18	20	23	25
6000	8	8	10	13	15	17	20	22	24

* HORIZONTAL REINFORCEMENT SO PLACED THAT MORE THAN 12in. OF FRESH CONCRETE IS CAST IN THE MEMBER BELOW

5. SPLICE/LAP LENGTH

a) WELDED WIRE FABRIC MESH SHOULD BE LAPPED OVER ADJACENT SHEET BY 300mm.

b) BARS SHALL BE SPLICED ONLY WHERE INDICATED, OR AT LOCATIONS SPECIFICALLY APPROVED BY THE ENGINEER.

c) EXCEPT AS OTHERWISE SHOWN ON THE DRAWINGS, WHENEVER REINFORCING BARS OF DIFFERENT SIZES ARE TO BE LAP SPLICED IN COMPRESSION, SPLICE LENGTH SHALL BE THE LARGER OF THE DEVELOPMENT LENGTH OF THE LARGER BAR, OR SPLICE LENGTH OF THE SMALLER BAR.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

GENERAL NOTES

SHEET 1 of 2

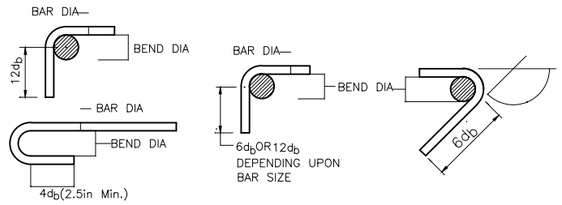
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-01-GEN-002	

G E N E R A L N O T E S

3. THE BEND DETAILS SHALL BE AS SHOWN IN THE TABLE AND FIGURES BELOW:

MINIMUM DIAMETER OF BEND

BAR SIZE	MINIMUM DIAMETER OF BEND
#3 THROUGH #8	6db
#9,#10 AND #11	8db



4. DEVELOPMENT LENGTH

STANDARD HOOKS FOR REINFORCEMENT OTHER THAN STIRRUPS, TIES AND HOOPS

STANDARD HOOKS FOR STIRRUPS, TIES AND HOOPS

UNLESS NOTED OTHERWISE ON THE DRAWINGS, MINIMUM BASIC DEVELOPMENT LENGTH FOR REINFORCEMENT STEEL OF GRADE-60 (60,000 Psi) SHALL BE AS FOLLOWS:

5. SPLICE/LAP LENGTH

d) THE LAPS SHOULD BE STAGGERED

e) UNLESS NOTED OTHERWISE ON THE DRAWINGS, MINIMUM LAP LENGTH FOR REINFORCEMENT STEEL OF GRADE-60 (60,000 Psi) SHALL BE AS FOLLOWS:

(i) LAP SPLICE LENGTH IN TENSION

TOP BARS*

fc' MPa(Psi) \ BAR SIZE	SPLICE LENGTH (in)								
	#3	#4	#5	#6	#7	#8	#9	#10	#11
4000	24	32	40	48	70	80	90	100	110
5000	22	29	36	43	63	72	81	90	99
6000	21	27	33	39	57	66	75	81	90

OTHER BARS

fc' MPa(Psi) \ BAR SIZE	SPLICE LENGTH (in)								
	#3	#4	#5	#6	#7	#8	#9	#10	#11
4000	18	25	31	37	54	62	69	77	85
5000	17	22	28	33	48	55	62	69	76
6000	16	20	26	30	43	50	56	63	68

(ii) LAP SPLICE LENGTH IN COMPRESSION

fc' MPa(Psi) \ BAR SIZE	SPLICE LENGTH (in)								
	#3	#4	#5	#6	#7	#8	#9	#10	#11
4000	11	15	19	23	26	30	34	38	41
5000	11	15	19	23	26	30	34	38	41
6000	11	15	19	23	26	30	34	38	41

6. EXCEPT AS OTHERWISE SHOWN ON THE DRAWINGS, WHENEVER REINFORCING BARS OF DIFFERENT SIZES ARE TO BE LAP SPLICED IN COMPRESSION, SPLICE LENGTH SHALL BE THE LARGER OF THE DEVELOPMENT LENGTH OF THE LARGER BAR, OR SPLICE LENGTH OF THE SMALLER BAR.
7. THE LAPS SHOULD BE STAGGERED.
8. THE CONTRACTOR SHALL PREPARE ALL BAR BENDING SCHEDULES AS PER CONSTRUCTION DRAWINGS AND SUBMIT TO THE ENGINEER WELL BEFORE EXECUTION FOR APPROVAL.
9. ALL REINFORCING STEEL SHALL BE ACCURATELY PLACED IN THE FORM WORK AND HELD FIRMLY BEFORE PLACING CONCRETE, BY MEANS OF 16 GAUGE BLACK ANNEALED WIRES AND ADEQUATELY DESIGNED SPACERS.

E. BORING, CASTING & TESTING OF PILES

1. IT IS RECOMMENDED THAT THE "OBSERVATIONAL APPROACH" BE ADOPTED FOR BORED PILE CONSTRUCTION. THE INFORMATION OBTAINED DURING SUB-SURFACE INVESTIGATIONS CAN GREATLY BE ENHANCED BY INPUT DURING CONSTRUCTION AS THE SOIL PROFILE CAN BE UPDATED AS PILING WORKS PROGRESS. IN ADDITION, DURING PILE CONSTRUCTION / INSTALLATION, ANY OTHER UNEXPECTED GEOLOGICAL FORMATIONS AND UNCERTAINTIES DETECTED AND SUBSEQUENT REFINEMENT TO DESIGN CAN THEN BE CONTINUOUSLY CARRIED OUT BY "THE ENGINEER" AS CONSTRUCTION PROGRESSES TO ENSURE SAFE AND COST-EFFECTIVE DESIGN.
2. GROUP EFFICIENCY FACTOR HAS BEEN CONSIDERED DURING DEVELOPMENT OF PILE LOAD CARRYING CAPACITY.
3. PILE CAPACITIES MUST BE CONFIRMED BY FULL SCALE PILE LOAD TEST.
4. A FULL-SCALE PILE LOAD TEST MUST BE CARRIED OUT BEFORE CONSTRUCTION OF WORKING PILES TO 3.0 TIMES THE DESIGN LOAD TO FINALIZE THE DESIGN AS DIRECTED BY THE ENGINEER.
5. THE TEST PILE, SHALL BE BORED & CAST NEAR THE SITE OF ACTUAL PILE. ITS SIZE, DEPTH, STRENGTH OF CONCRETE AND REINFORCEMENT SHALL BE SAME AS OF ACTUAL PILES.
6. A TEST PILE AT APPROVED LOCATIONS SHALL BE BORED, CAST & TESTED BEFORE THE COMMENCEMENT OF THE CONSTRUCTION OF THE ACTUAL PILE WORK AND THE RESULTS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL.
7. LOAD TEST WILL BE CARRIED OUT AS PER ASTM D1143 STANDARD OR CP 2004, AFTER LAPSE OF AT LEAST 28 DAYS OR WHEN 6"X12" CYLINDER MINIMUM COMPRESSIVE STRENGTH OF 4000 PSI IS ATTAINED.
8. APPROVED METHOD & PROCEDURE OF LOAD TESTING SHALL BE USED. THE PROGRAM SHALL BE NOTIFIED TO THE ENGINEER WELL IN ADVANCE.
9. A FULL-SCALE WORKING PILE LOAD TEST MUST BE CARRIED OUT TO 1.5 TIMES THE DESIGN LOAD TO ENSURE SAFE LOAD CARRYING CAPACITY OF PILES.
10. SONIC INTEGRITY TESTING (SIT) SHOULD BE PERFORMED ON ALL THE WORKING PILES.
11. PILES SHALL NOT BE OUT OF ALIGNMENT BY MORE THAN 1 IN 114.
12. THE PILE TIP LEVELS SHOWN ON THE DRAWING ARE TENTATIVE AND SHALL BE CONFIRMED AFTER THE PERFORMANCE OF PILE LOAD TEST.

E. STRUCTURAL STEEL

1. ALL STRUCTURAL STEEL SHALL CONFORM TO THE REQUIREMENT OF ASTM A36 UNLESS NOTED OTHERWISE ON DRAWINGS.
2. ALL WELDED CONSTRUCTION SHALL BE WITH CONTINUOUS FILLET WELD WITH ELECTRODES OF APPROVED QUALITY UNLESS OTHERWISE SHOWN ON THE DRAWINGS.
3. ALL STRUCTURAL STEEL SHALL BE GALVANIZED OR PAINTED AS DIRECTED BY THE ENGINEER.

F. MISCELLANEOUS

1. TWO COATS OF APPROVED QUALITY OF BITUMEN SHALL BE APPLIED ON THE EARTH FACE OF THE STRUCTURES FOR WATERPROOFING AS PER CONTRACT SPECIFICATIONS UNLESS OTHERWISE SHOWN ON THE DRAWINGS.
2. ALL WATERSTOPS SHALL BE 9" WIDE PVC WATERSTOPS WITH THREE BULBS AND OF THE SHAPE AND SIZE ONLY FOR CONSTRUCTION JOINTS.
3. THE CONSTRUCTION OF EXPANSION, CONTRACTION,DUMMY AND CONSTRUCTION JOINTS IN CONCRETE LINING OR STRUCTURE WHERE SHOWN ON THE DRAWINGS, SHALL BE CARRIED OUT AS PER THE REQUIREMENTS OF TECHNICAL SPECIFICATIONS AND THE DRAWINGS.
4. UNLESS OTHERWISE SHOWN ON THE DRAWINGS, CONSTRUCTION JOINTS SHALL BE PROVIDED, WITH THE APPROVAL OF THE ENGINEER AND SHALL BE PLANNED BEFORE EXECUTION OF WORK.
5. RAIN WATER OUTLET PIPE OF 9" DIA SHALL BE PROVIDED AS SHOWN ON DRAWINGS AND SHALL CONFORM TO RELEVANT TECHNICAL SPECIFICATIONS.
6. REFERENCE BENCH MARKS (BM) ESTABLISHED BY THE CONSULTANTS IN THE PROJECT AREA SHALL BE USED FOR CARRYING OUT ALL FURTHER SURVEY AND CONSTRUCTION WORKS.
7. CONCRETE REINFORCEMENT STRENGTH OF ALL PRECAST RC PIPES DIA. 6" & 9" SHALL CONFORM TO THE REQUIREMENTS OF BS 5911: 1981 (PART-1).
8. CONCRETE AND REINFORCEMENT STRENGTH OF ALL PRECAST RCC PIPES USED SHALL CONFORM TO THE REQUIREMENTS OF ASTM DESIGNATION C-76 FOR CLASS-III, WALL-A PIPE.

ABBREVIATIONS

ARB	ARTERIAL ROAD BRIDGE
BF	BAFFLE FALL
BL	BED LEVEL
BM	BENCH MARK
BR	BRIDGE
BW	BED WIDTH
CDS	CROSS DRAINAGE STRUCTURE
CG	CATTLE GHAT
CR	CROSS REGULATOR
C. JT.	CONSTRUCTION JOINT
CL	CENTRE LINE
CONC.	CONCRETE
CONT. JT.	CONTRACTION JOINT
CR	CROSS REGULATOR
DISTY.	DISTRIBUTARY
D/S	DOWNSTREAM
DRB	DISTRICT ROAD BRIDGE
EF	EACH FACE
E.I.	ENAMELED IRON
EL	ELEVATION
EXP. JT.	EXPANSION JOINT
FB	FREE BOARD
FCJ	FLOOD CARRIER JUNCTION
FSD	FULL SUPPLY DEPTH
FSL	FULL SUPPLY LEVEL
GFS	GLACIS FALL
GFSBR	GLACIS FALL CUM BRIDGE
HL	HEAD LOSS
HR	HEAD REGULATOR
MR	MINOR
NSL	NATURAL SURFACE LEVEL
NTS	NOT TO SCALE
PCC	PLAIN CEMENT CONCRETE
PI	POINT OF INTERSECTION
PC	POINT OF CURVATURE
PS	PRE-STRESSED CONCRETE
PT	POINT OF TANGENT
RC	REINFORCED CONCRETE
RD	REDUCED DISTANCE
RL	REDUCED LEVEL
ROW	RIGHT OF WAY
T&B	TOP AND BOTTOM
TYP.	TYPICAL
U/S	UPSTREAM
VFS	VERTICAL FALL
VFSBR	VERTICAL FALL CUM BRIDGE
VRB	VILLAGE ROAD BRIDGE
WCO	WATERCOURSE OUTLET
UNO	UNLESS NOTED OTHERWISE

SYMBOLS

BR
CDS
CR
HR
GFS
GFSBR
VFS
WCO
VFSBR
CG
FCJ
BF

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

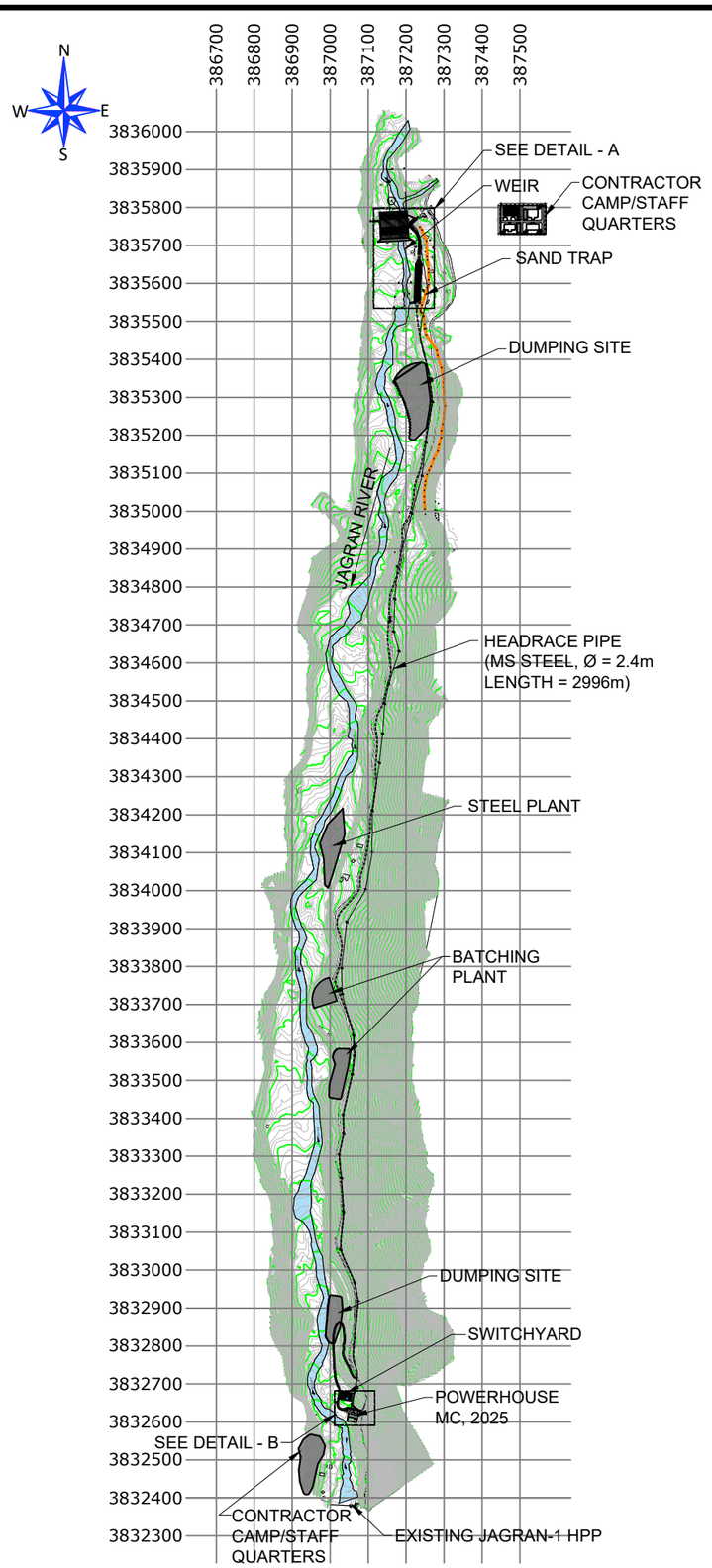
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

GENERAL NOTES

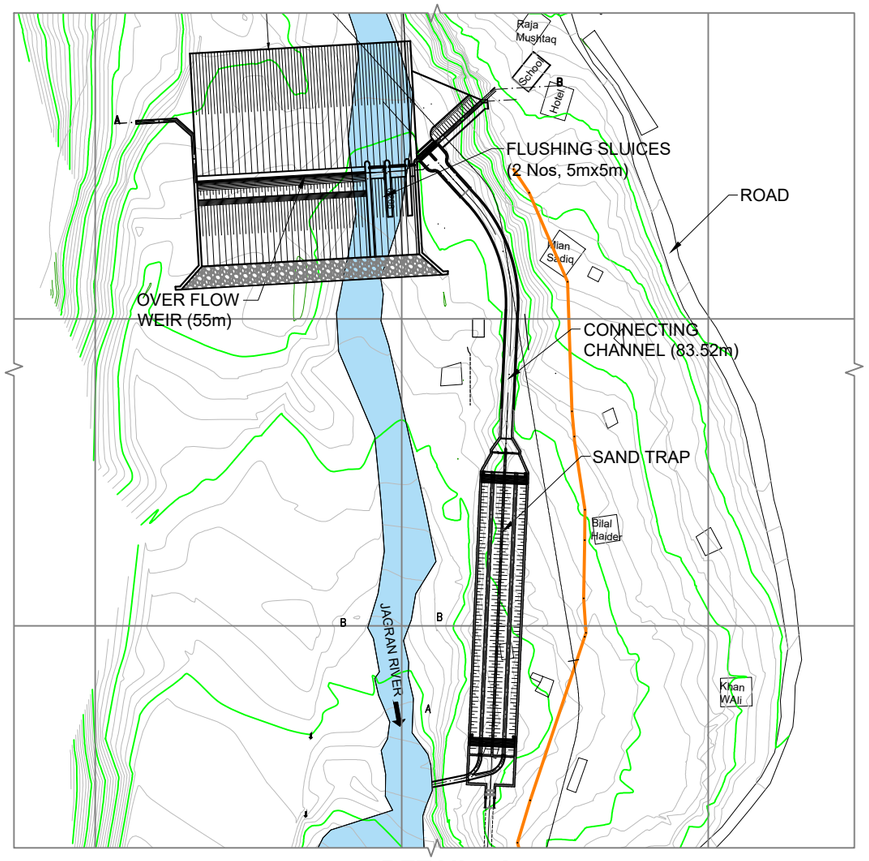
SHEET 2 of 2

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-01-GEN-002	

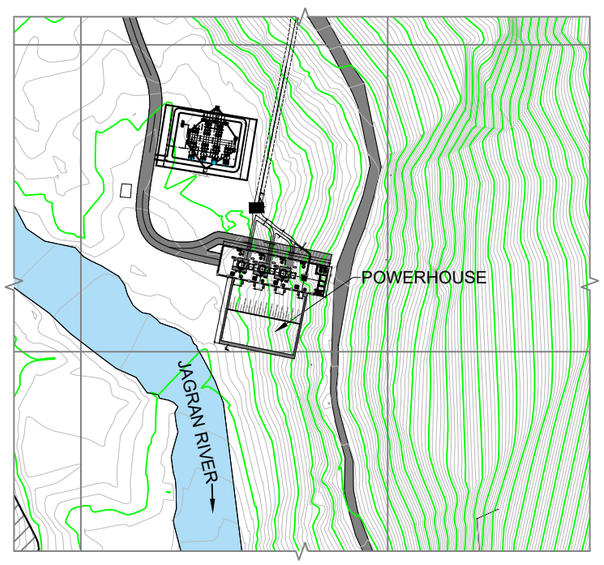
2-LAYOUT



LAYOUT PLAN
SCALE:-1



DETAIL - A
SCALE:-2



DETAIL - B
SCALE:-2

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-1

0 200 400 600 800m

SCALE:-2

0 25 50 75 100m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

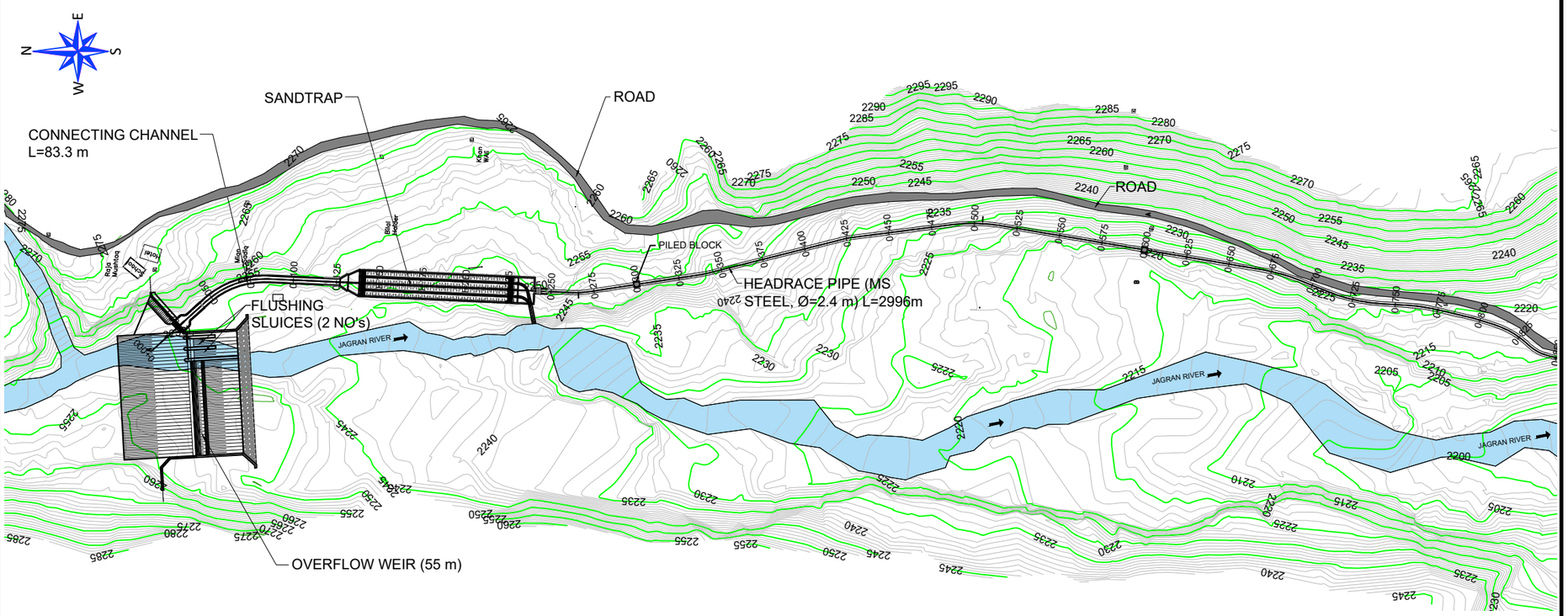
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

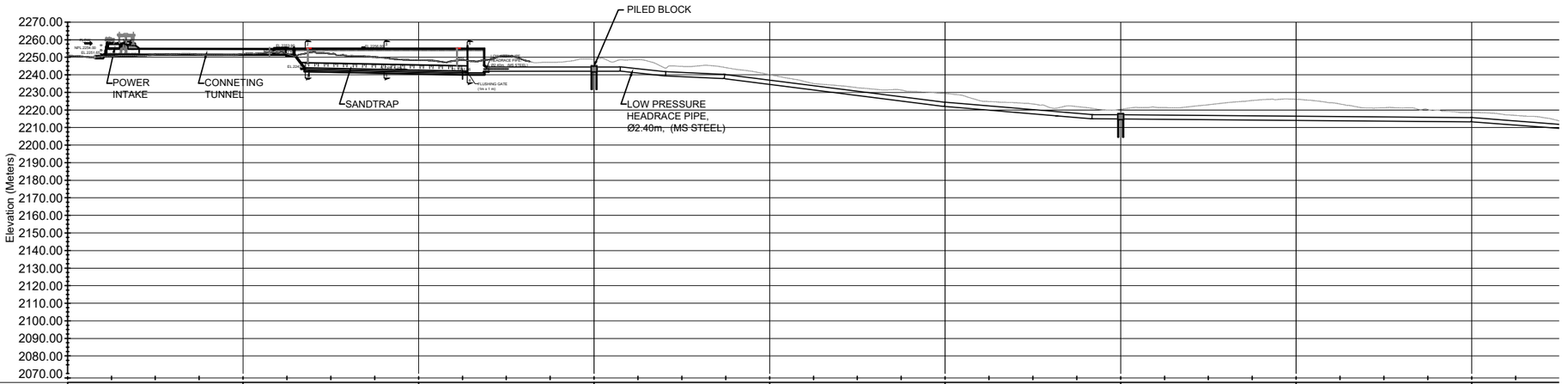
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

PROPOSED LAYOUT PLAN

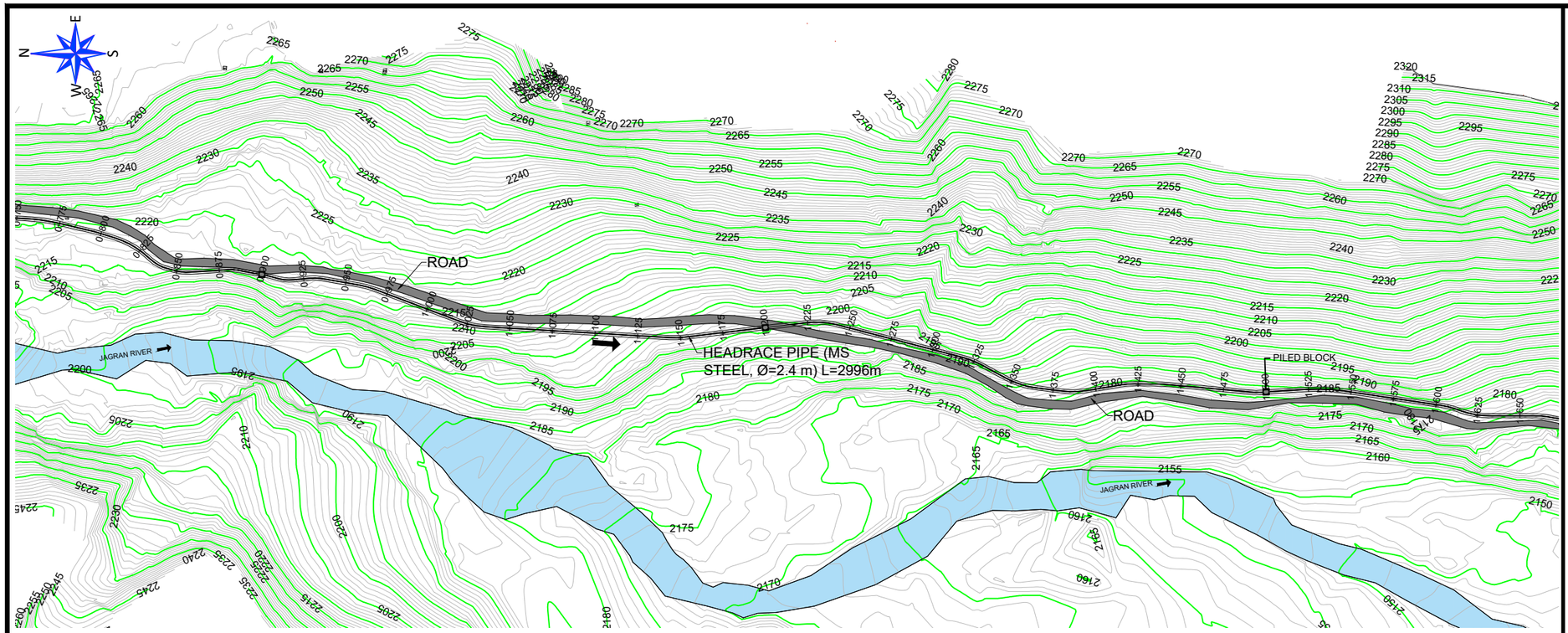
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-02-LAY-001	


N
E
S
W
SANDTRAP
ROAD
CONNECTING CHANNEL
L=83.3 m
ROAD
PILED BLOCK
HEADRACE PIPE (MS
STEEL, Ø=2.4 m) L=2996m
FLUSHING
SLUICES (2 NO's)
JAGRAN RIVER
OVERFLOW WEIR (55 m)

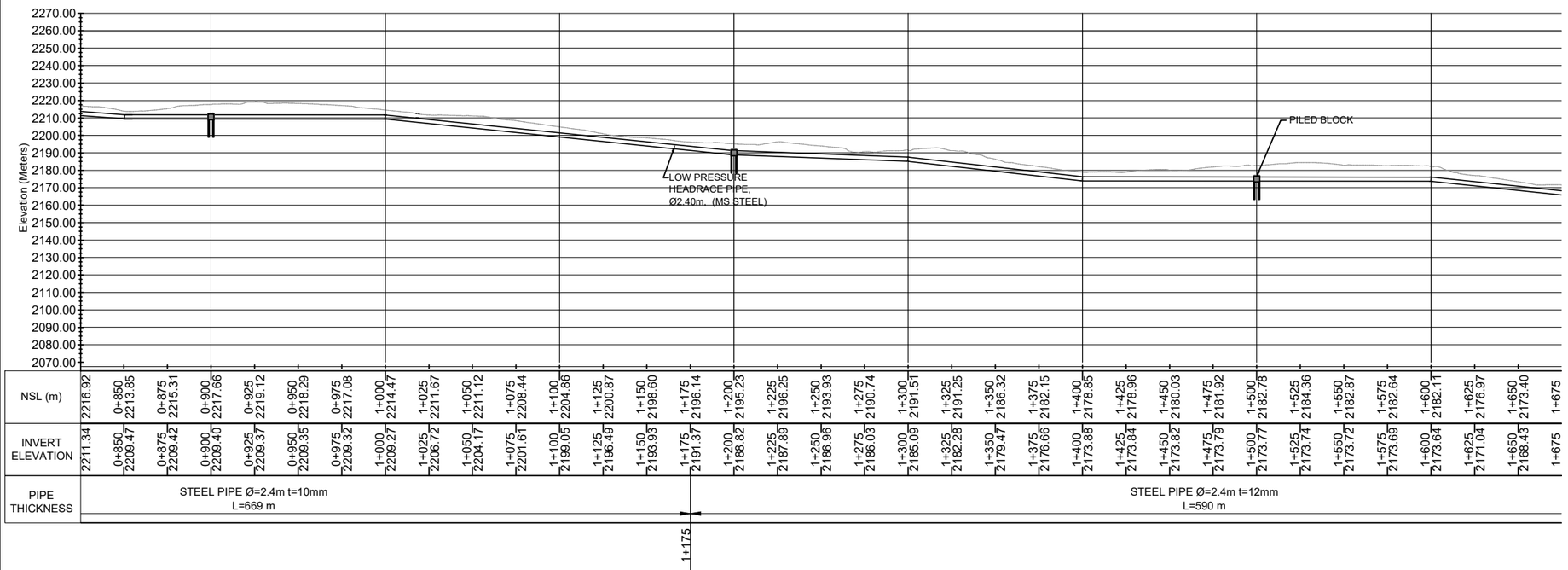
PLAN


PILED BLOCK
POWER
INTAKE
CONNETING
TUNNEL
SANDTRAP
LOW PRESSURE
HEADRACE PIPE,
Ø2.40m, (MS STEEL)
Elevation (Meters)

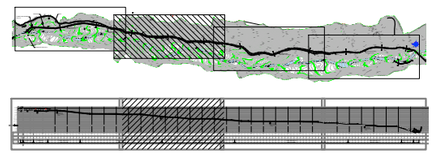
| | | |



PLAN



PROFILE



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 30 60 90 120 150m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

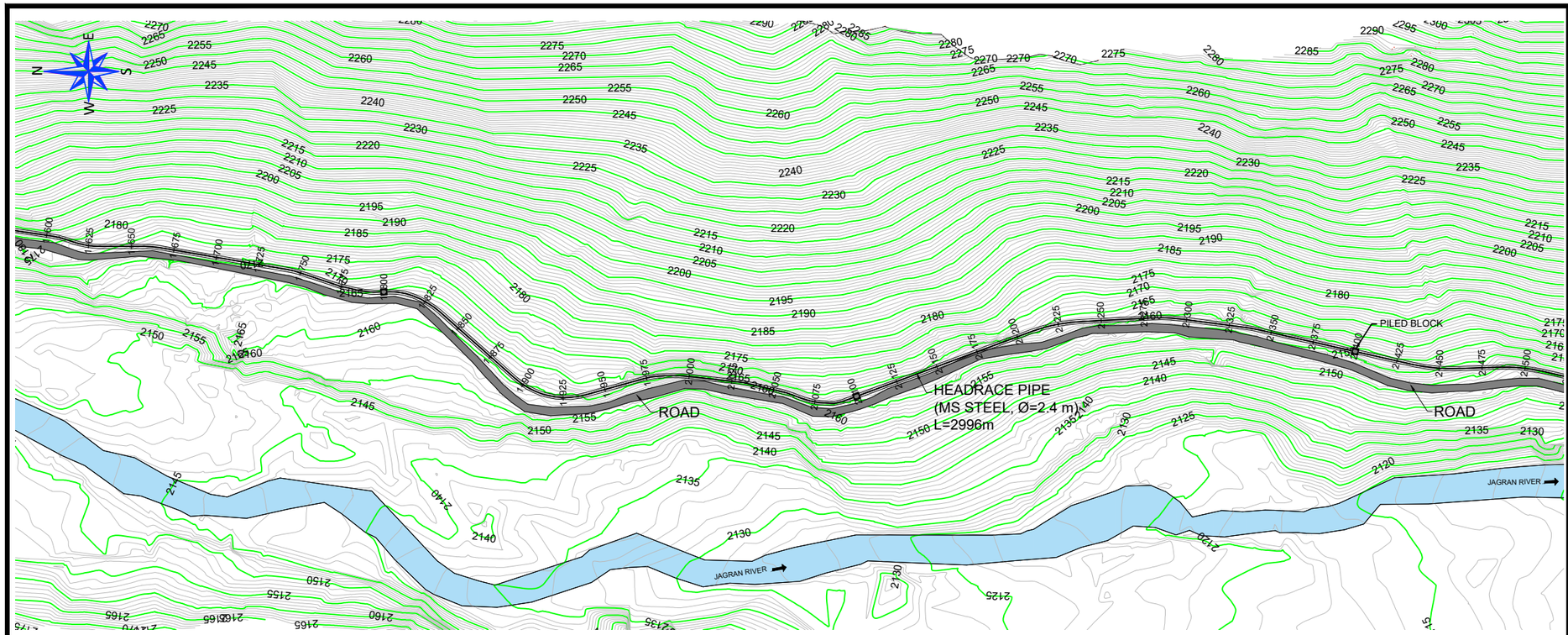
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

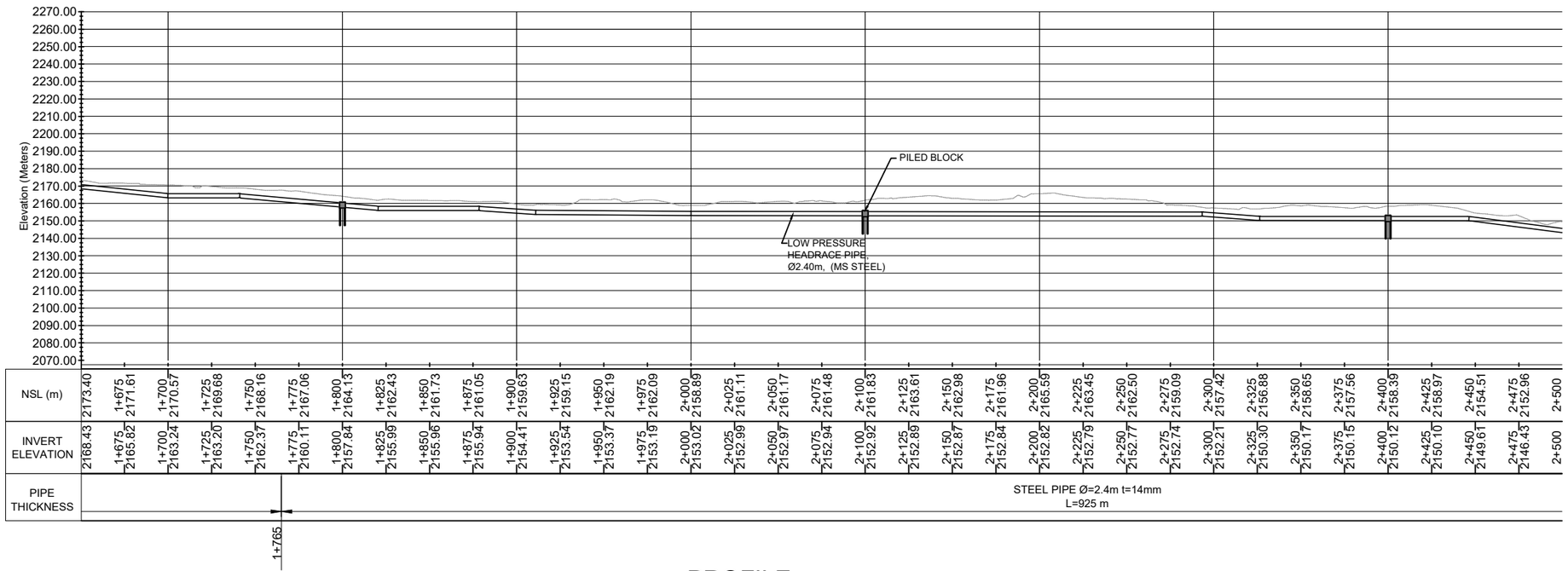
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN AND PROFILE (SHEET 2 OF 4)

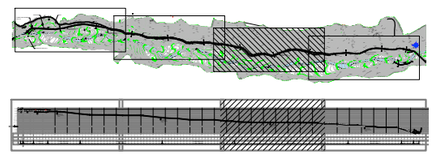
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-02-LAY-003	



PLAN



PROFILE



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 30 60 90 120 150m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

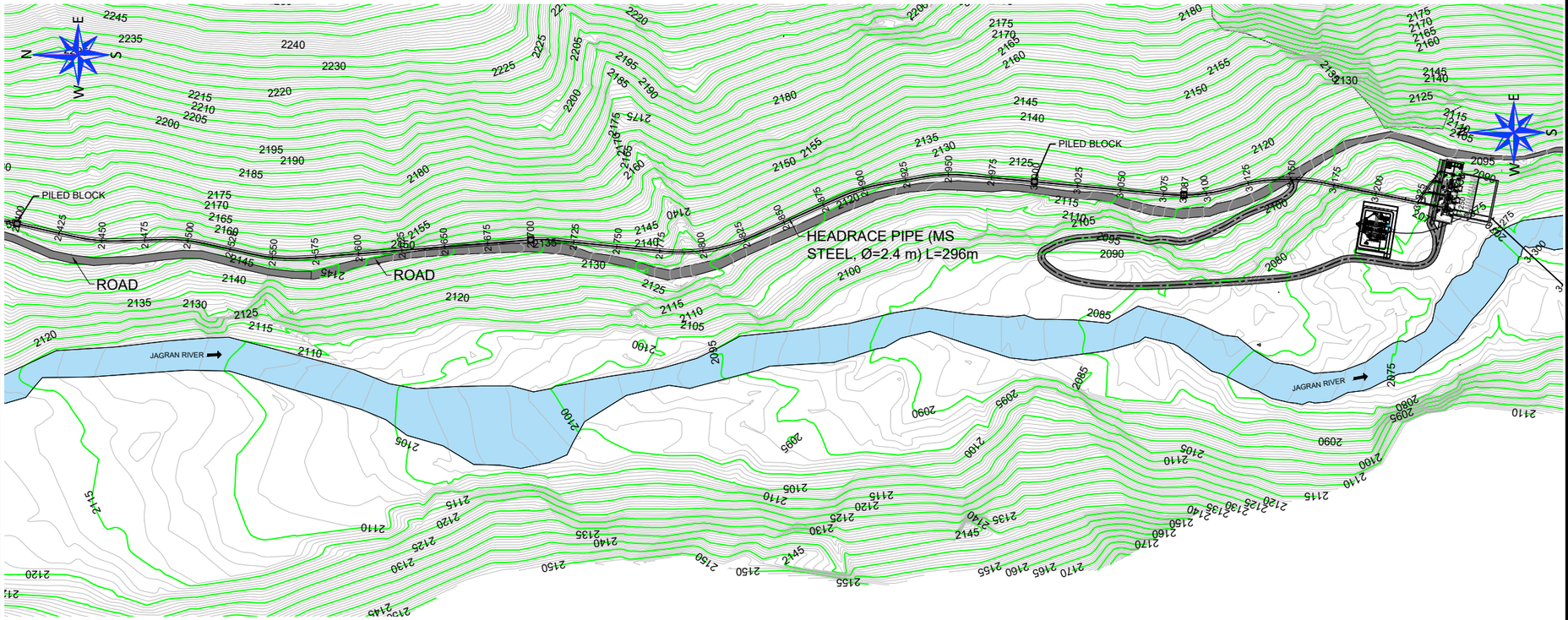
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

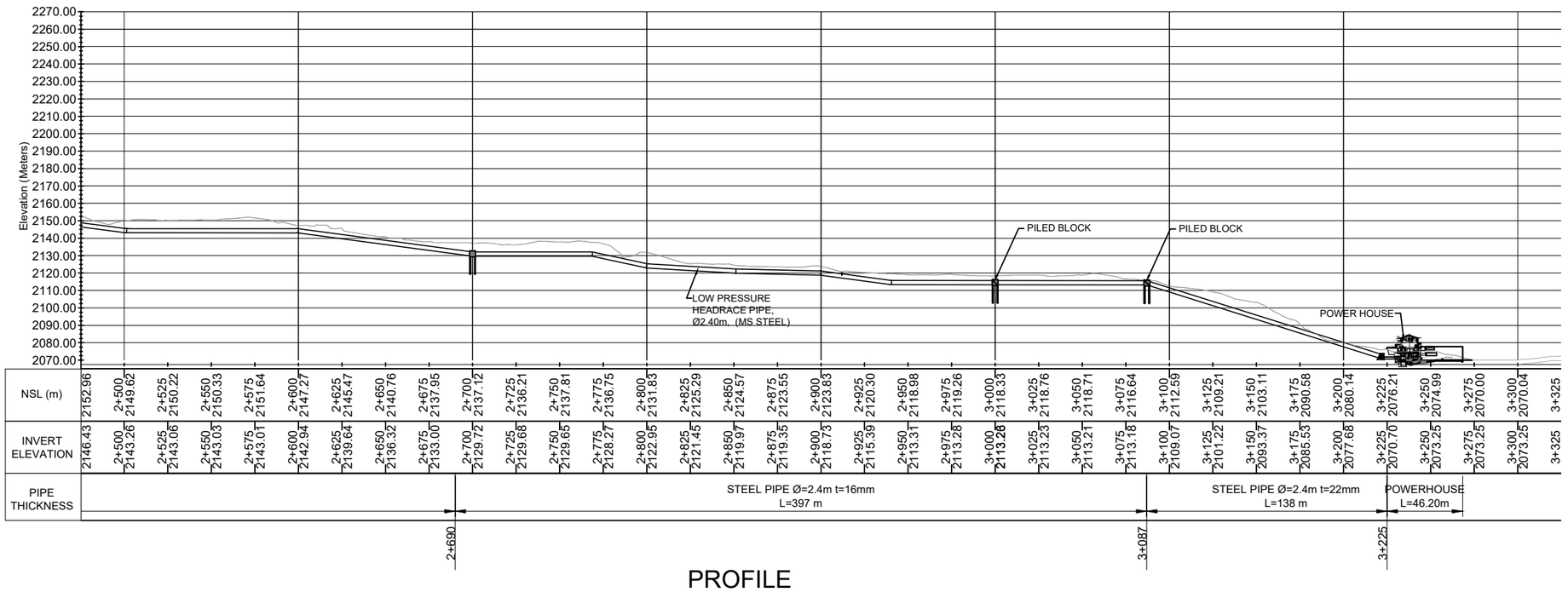
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN AND PROFILE (SHEET 3 OF 4)

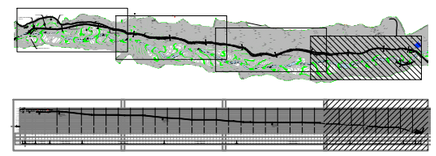
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-02-LAY-004	



PLAN



PROFILE



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 30 60 90 120 150m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

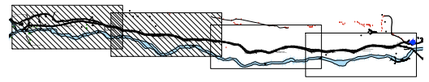
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN AND PROFILE (SHEET 4 OF 4)

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-02-LAY-005	

PLAN

PLAN



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 30 60 90 120 150m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

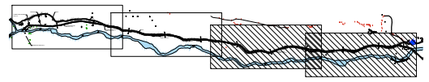
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN ON SATELLITE IMAGERY (SHEET 1 OF 2)

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	FEBRUARY-26	JAG-02-LAY-006	

PLAN

PLAN



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 30 60 90 120 150m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

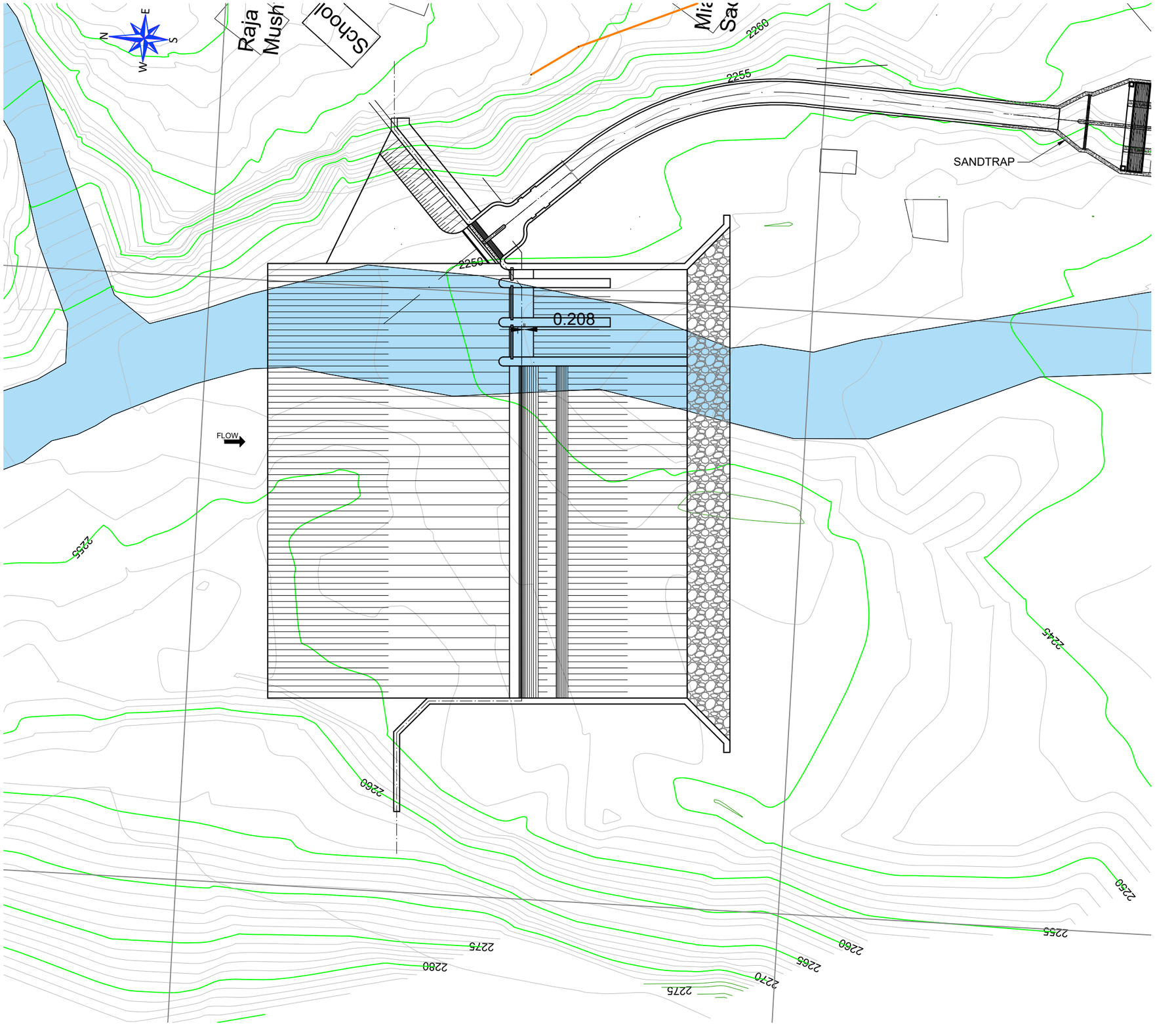
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN ON SATELLITE IMAGERY (SHEET 2 OF 2)

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	FEBRUARY-26	JAG-02-LAY-007	

3-WEIR



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 10 20 30m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

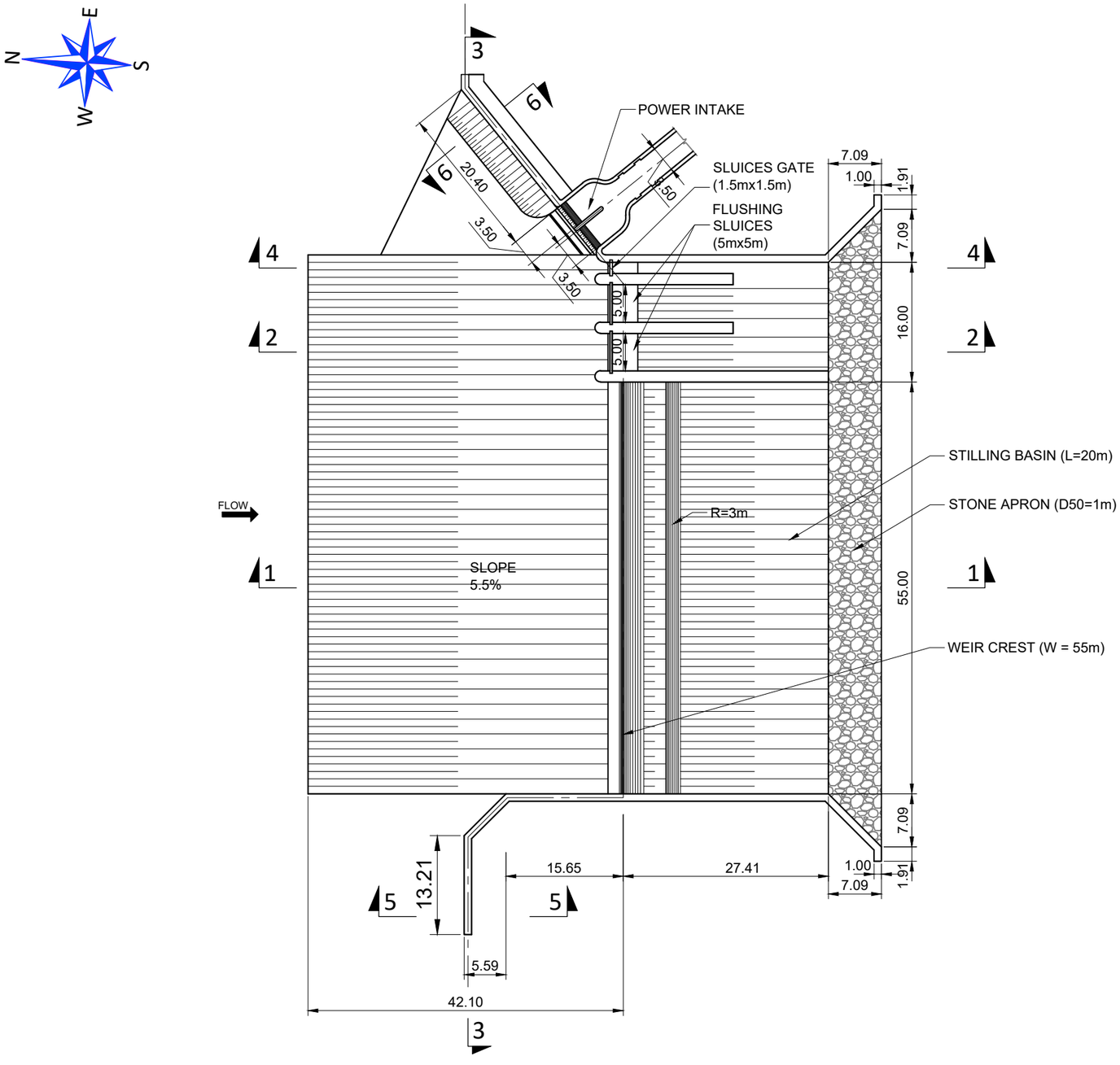
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

WEIR LAYOUT PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WR-001	



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 10 20 30m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

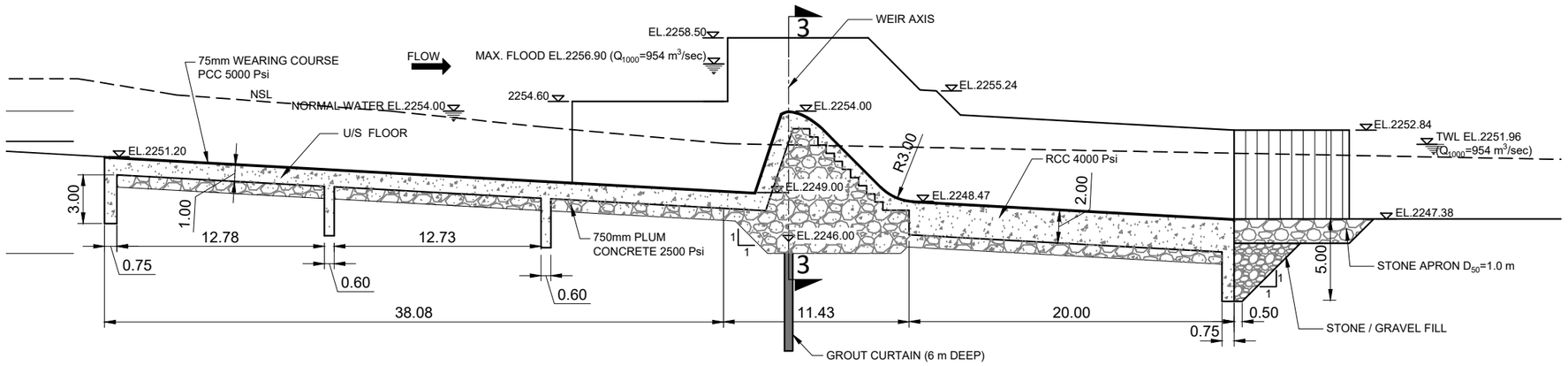
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

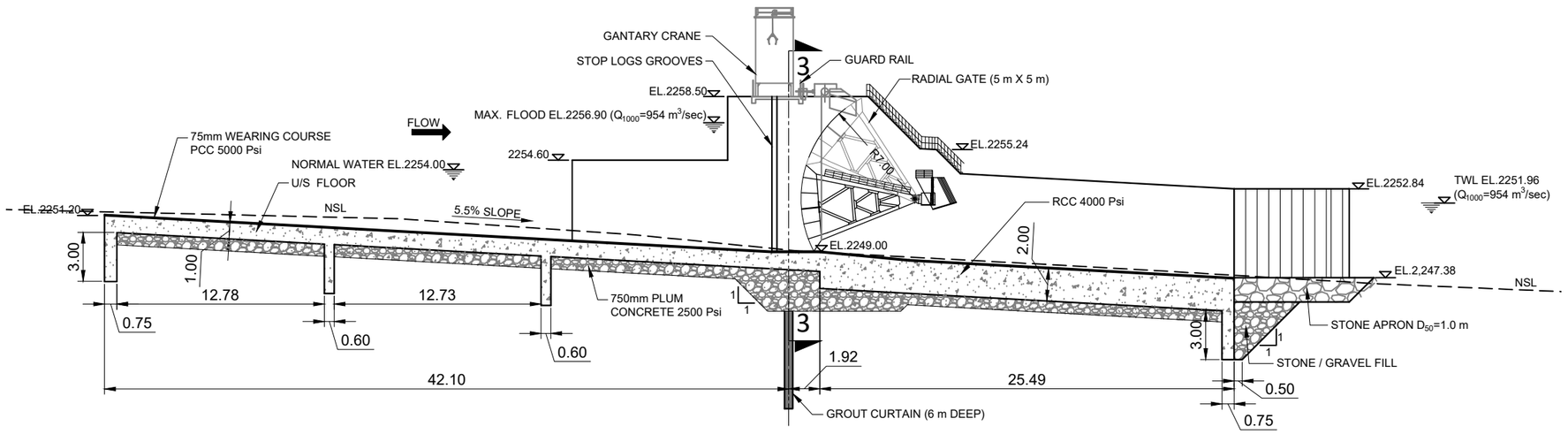
WEIR PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WR-002	



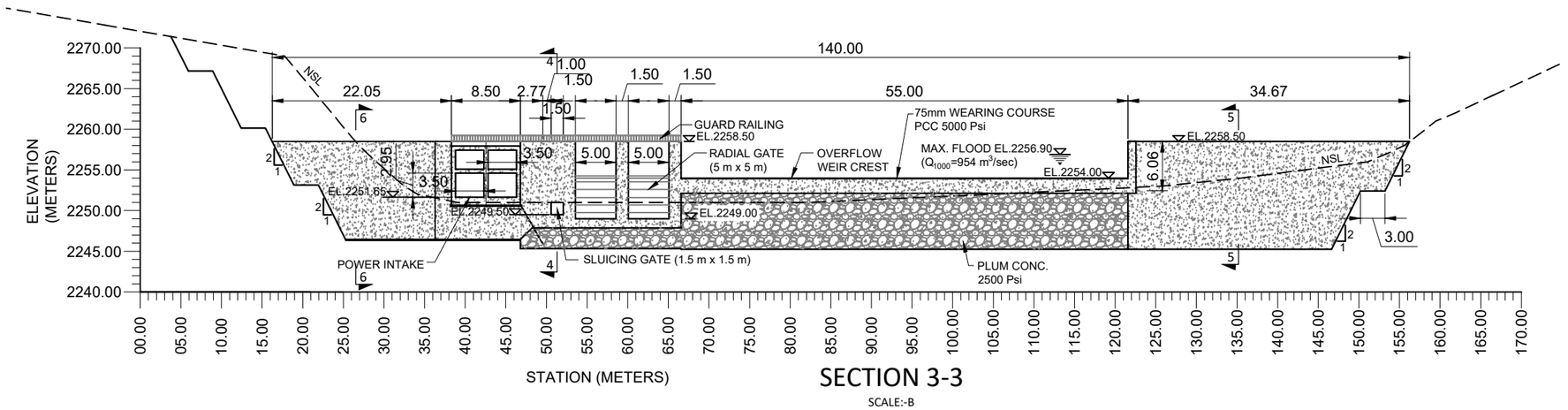
SECTION 1-1

(SCALE:-A)



SECTION 2-2

SCALE:-A



SECTION 3-3

SCALE:-B

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

LEGEND:

REINFORCED CONCRETE

CYCLOPEAN CONCRETE

SCALE:-A

0 5 10 15m

SCALE:-B

0 10 20 30m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

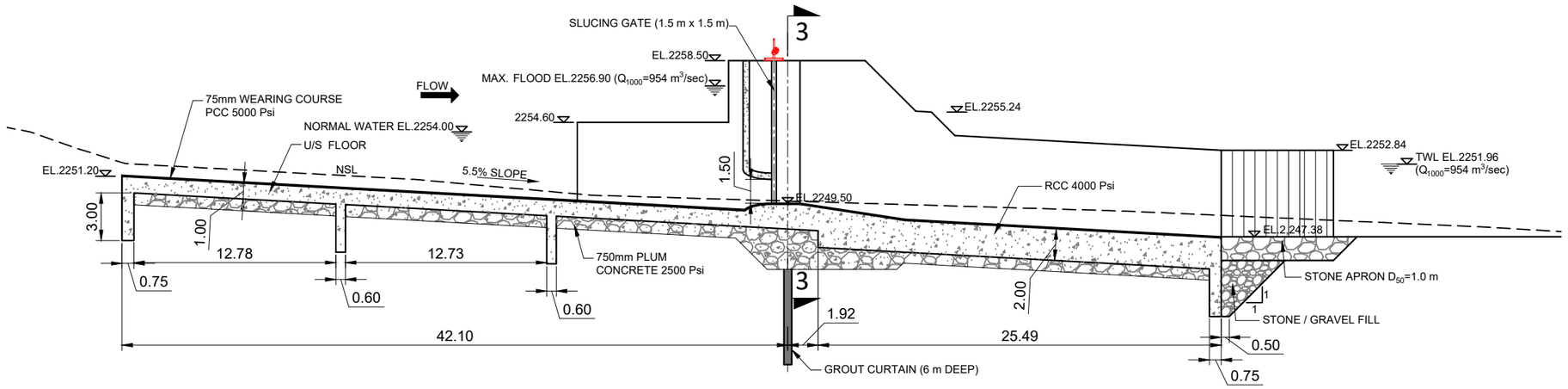
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

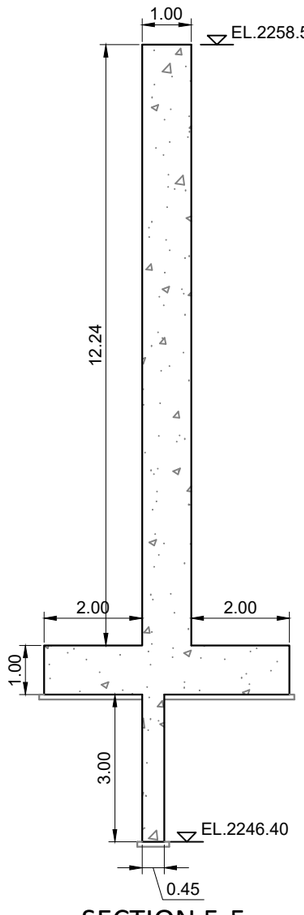
WEIR SECTIONS

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WR-003	



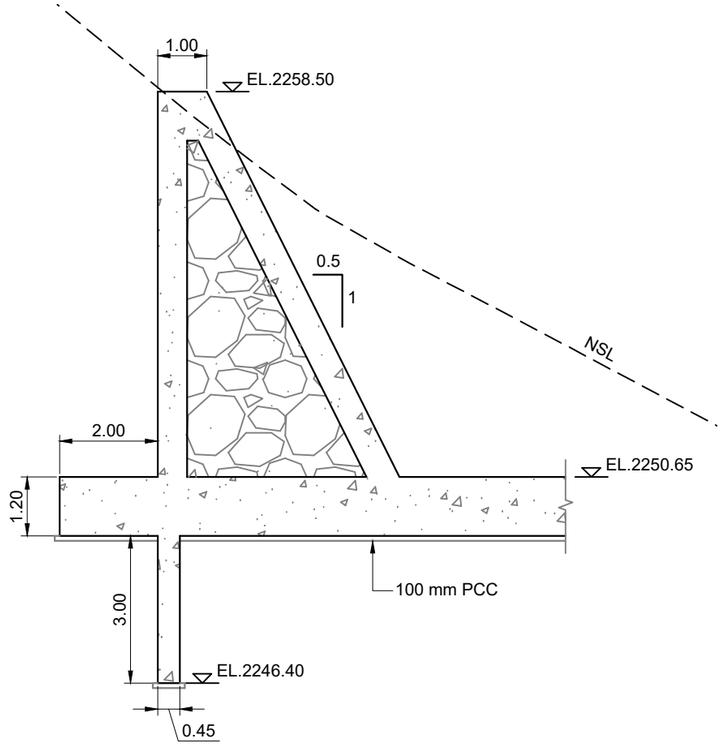
SECTION 4-4

SCALE:-A



SECTION 5-5

SCALE:-B



SECTION 6-6

SCALE:-B

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

LEGEND:

REINFORCED CONCRETE

CYCLOPEAN CONCRETE

SCALE:-A

0 10 20 30m

SCALE:-B

0 2 4 6m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

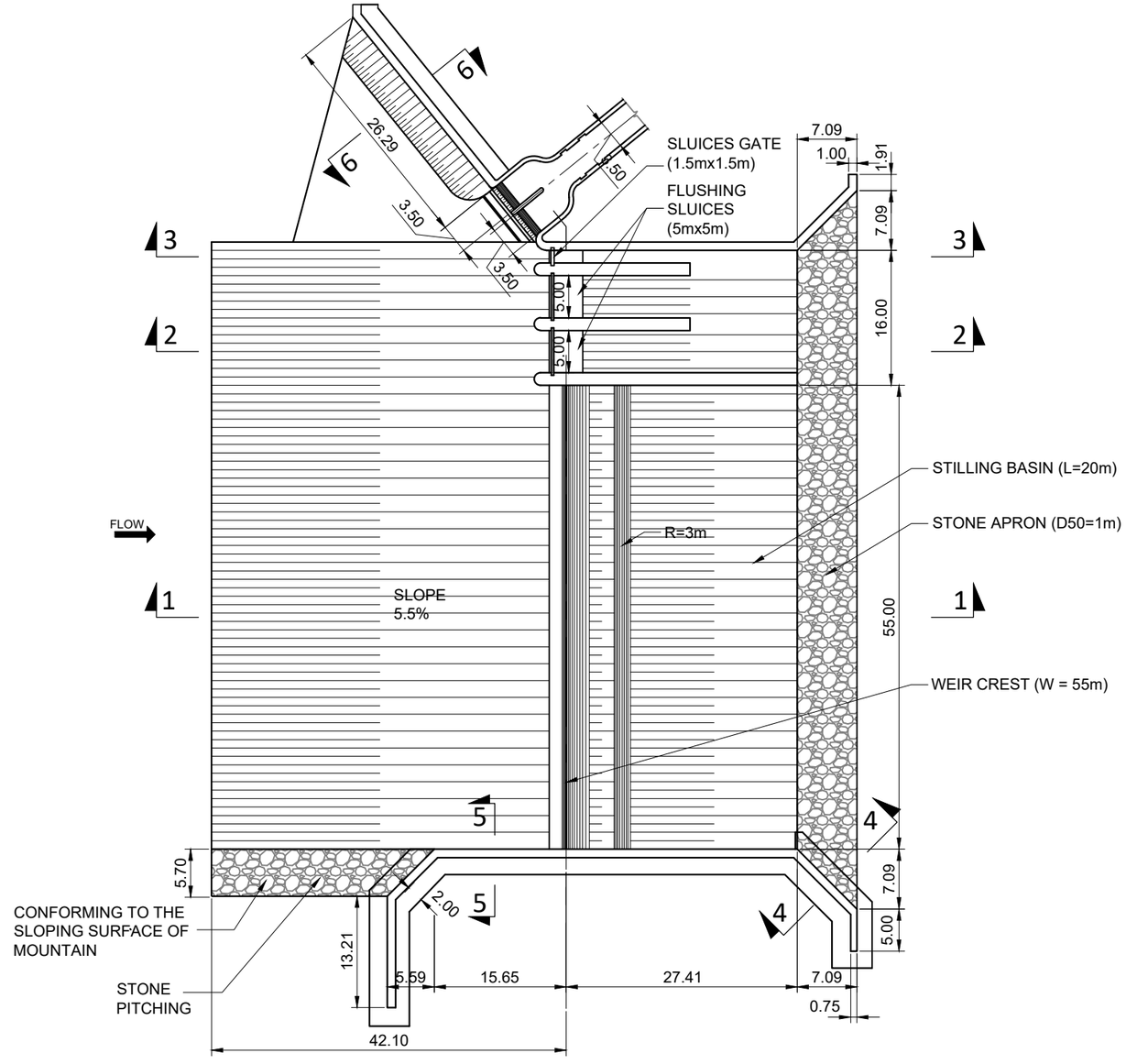
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

WEIR SECTIONS

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WR-004	



STRUCTURAL PLAN OF WEIR

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 10 20 30m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

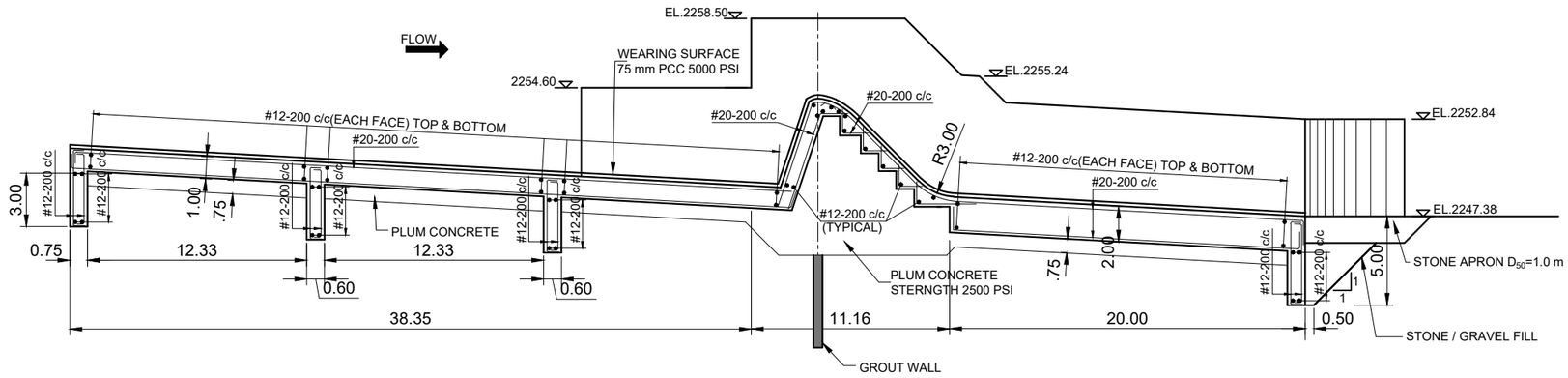
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

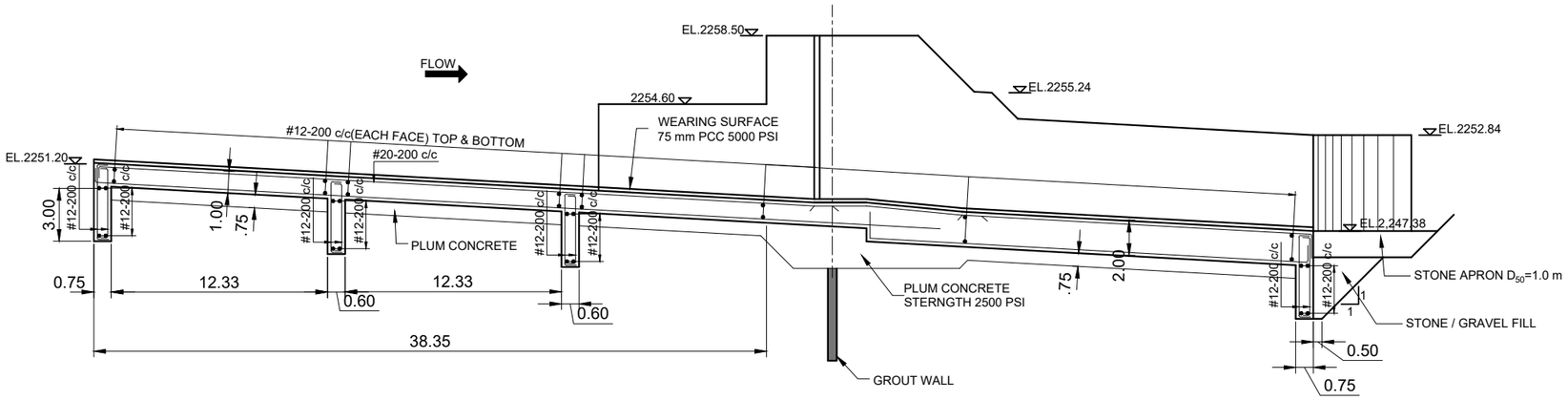
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

WEIR PLAN (STRUCTURAL)

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WER-005	



SECTION 1-1



SECTION 2-2

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 5 10 15m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

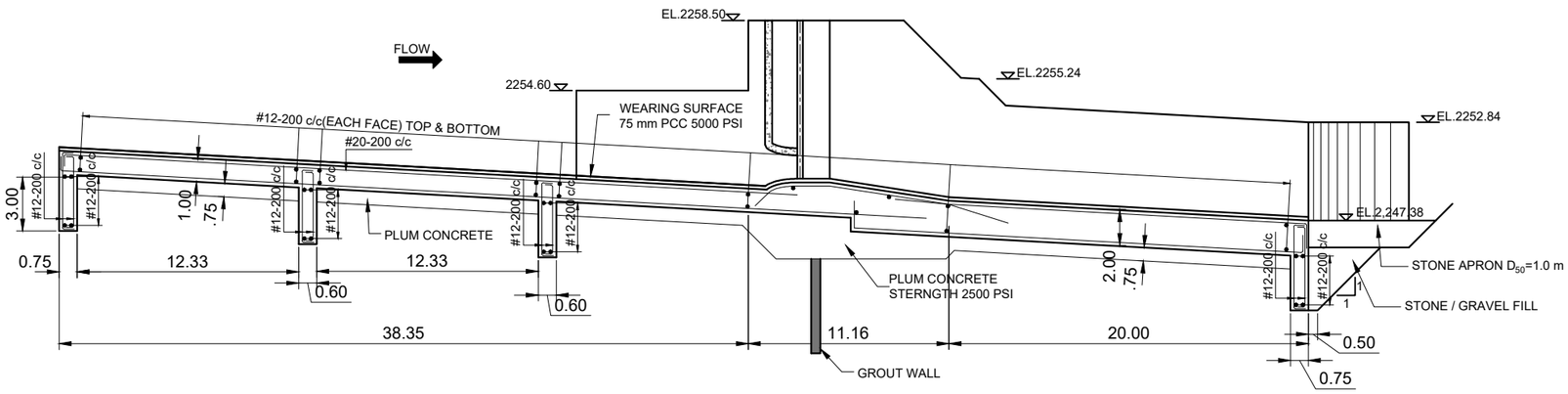
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

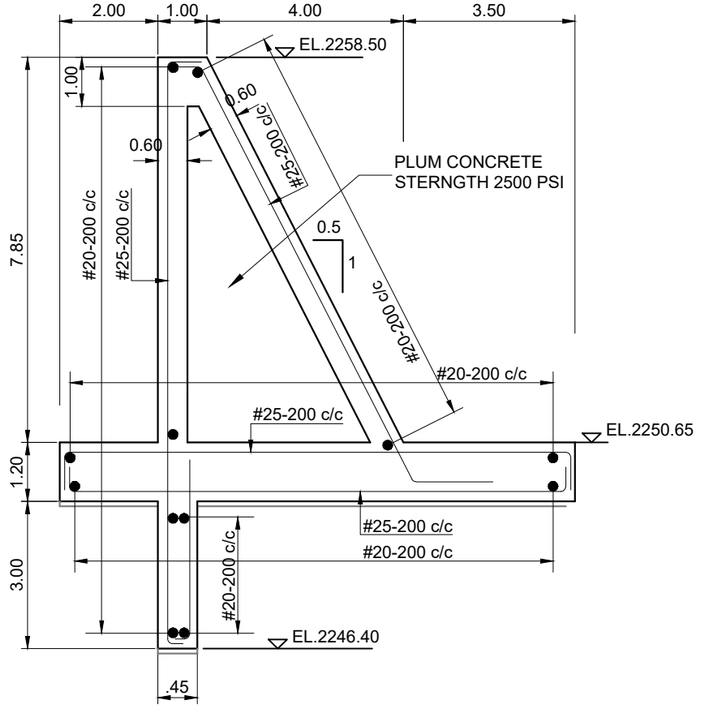
WEIR SECTIONS 1-1 & 2-2

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WER-006	



SECTION 3-3

SCALE:-A



SECTION 6-6

SCALE:-B

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 5 10 15m

SCALE:-B

0 2 4 6m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

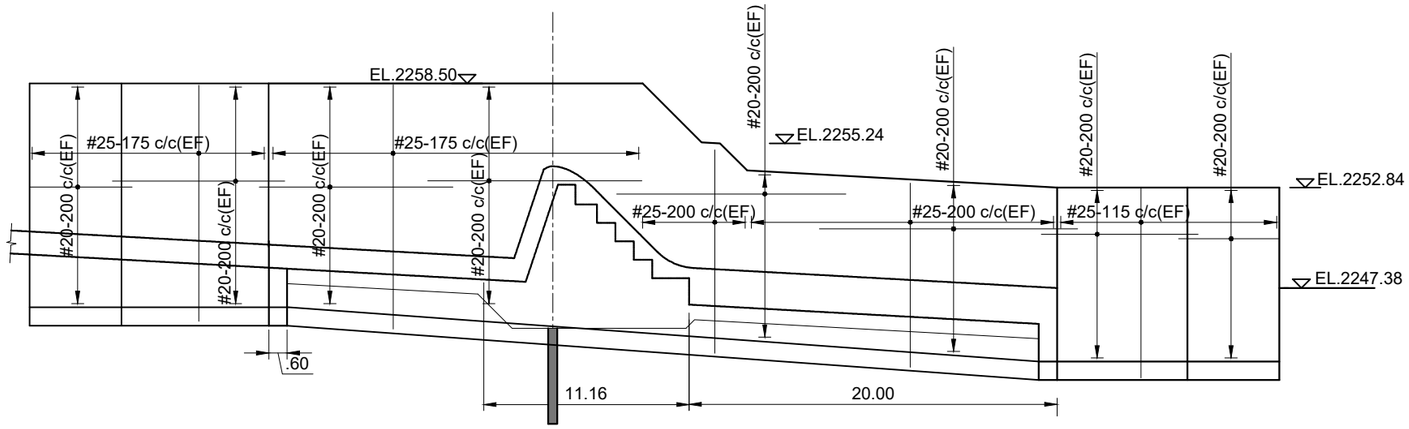
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

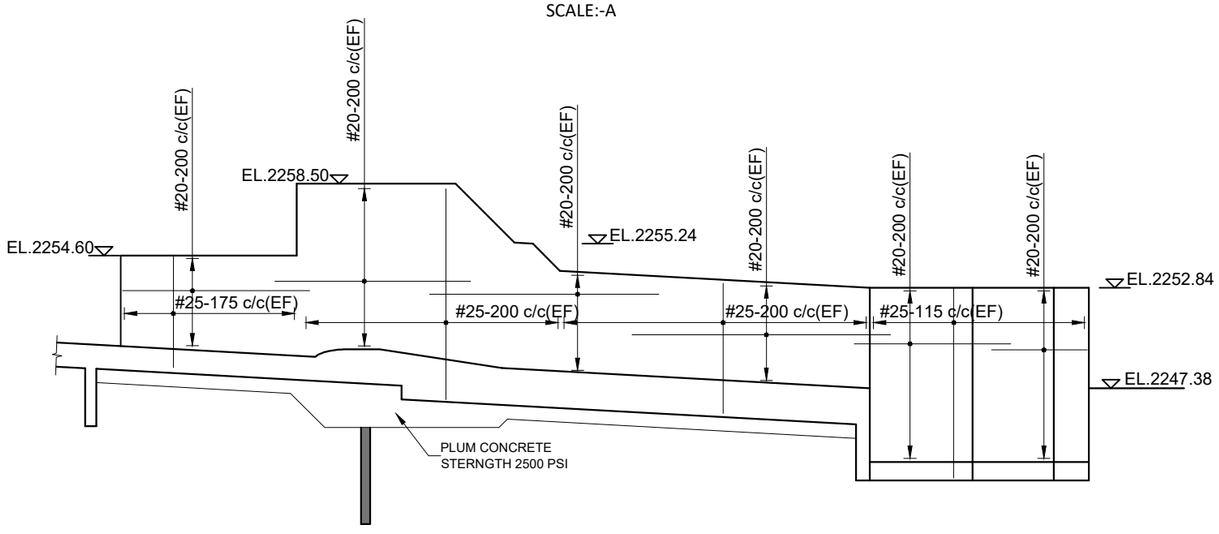
WEIR SECTIONS 3-3,6-6 & 7-7

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE		JAG-03-WER-007	



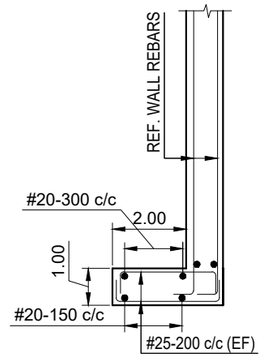
REINF. DETAIL OF RIGHT WALL ABUTMENT

SCALE:-A



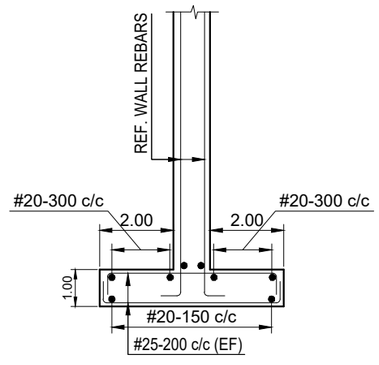
REINF. DETAIL OF LEFT WALL ABUTMENT

SCALE:-A



SECTION 5-5

(SCALE:-B)



SECTION 4-4

(SCALE:-B)

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 5 10 15m

SCALE:-B

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

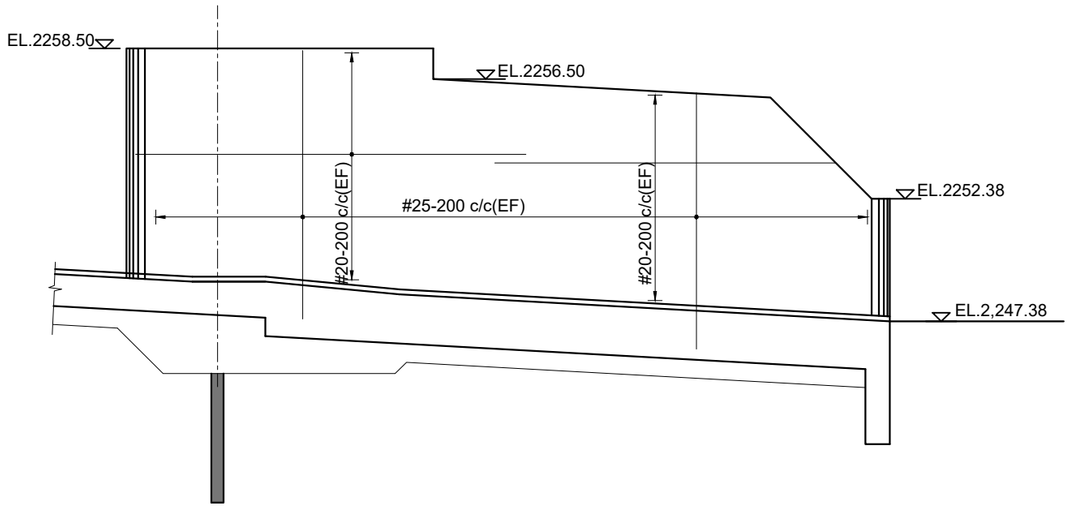
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

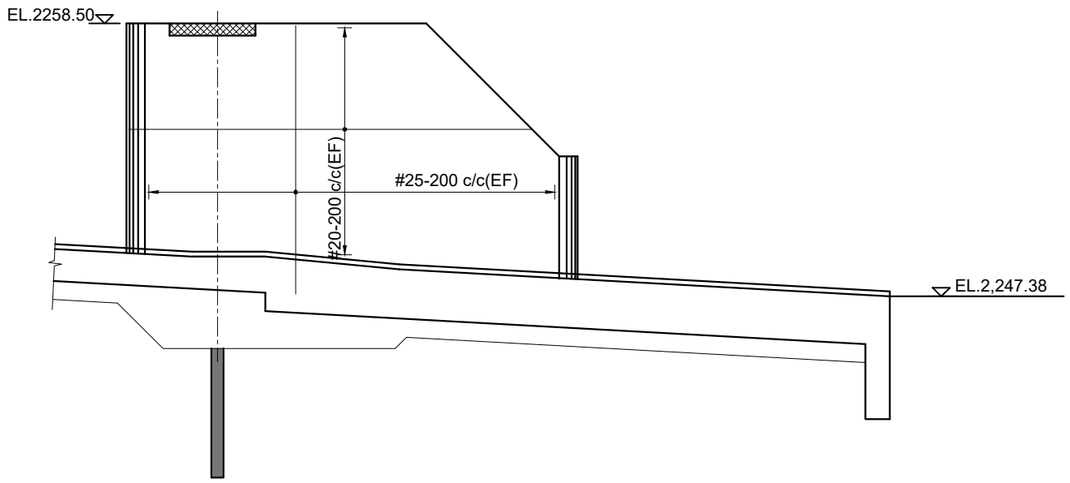
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

REINF. DETAIL OF LEFT AND RIGHT WALL ABUTMENT

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WER-008	



REINF. DETAIL OF WEIR AND ESCAPE PASSAGE



REINF. DETAIL OF ESCAPE RADIAL GATE

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 4 8 12m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

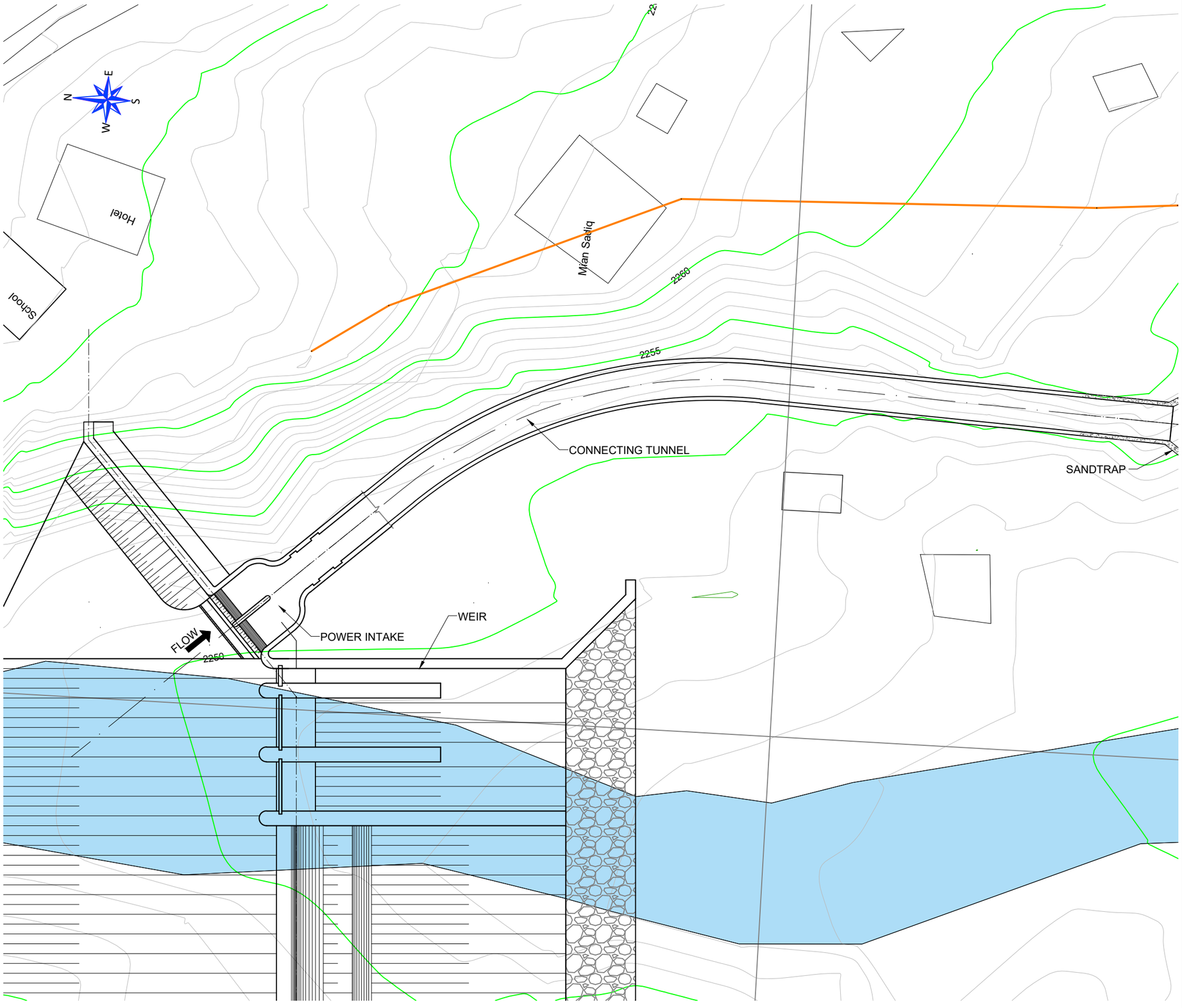
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

REINF. DETAIL OF WEIR WALL

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-03-WER-009	

4-INTAKE



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 5 10 15 20m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

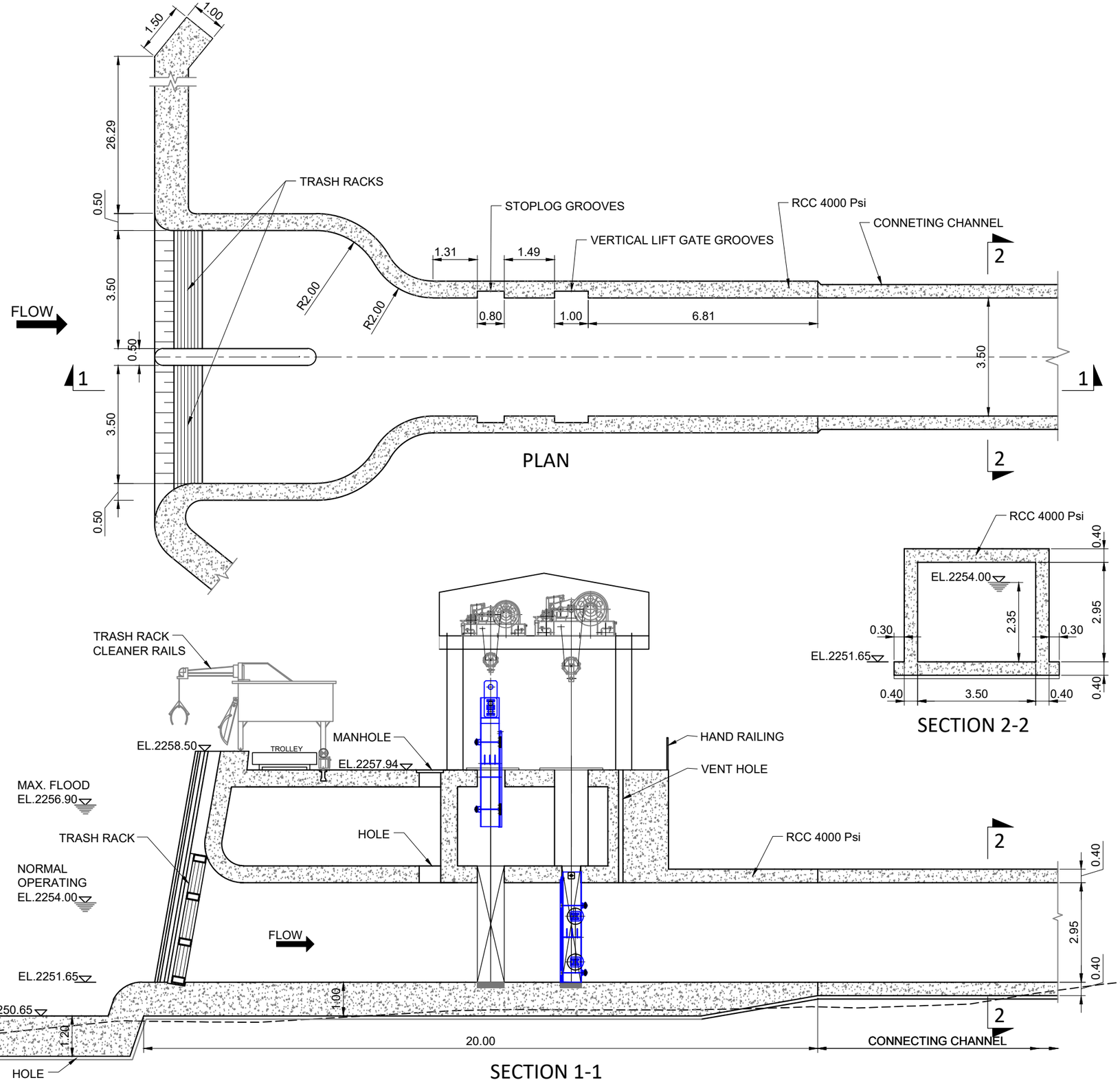
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

INTAKE LAYOUT PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-04-INT-001	



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

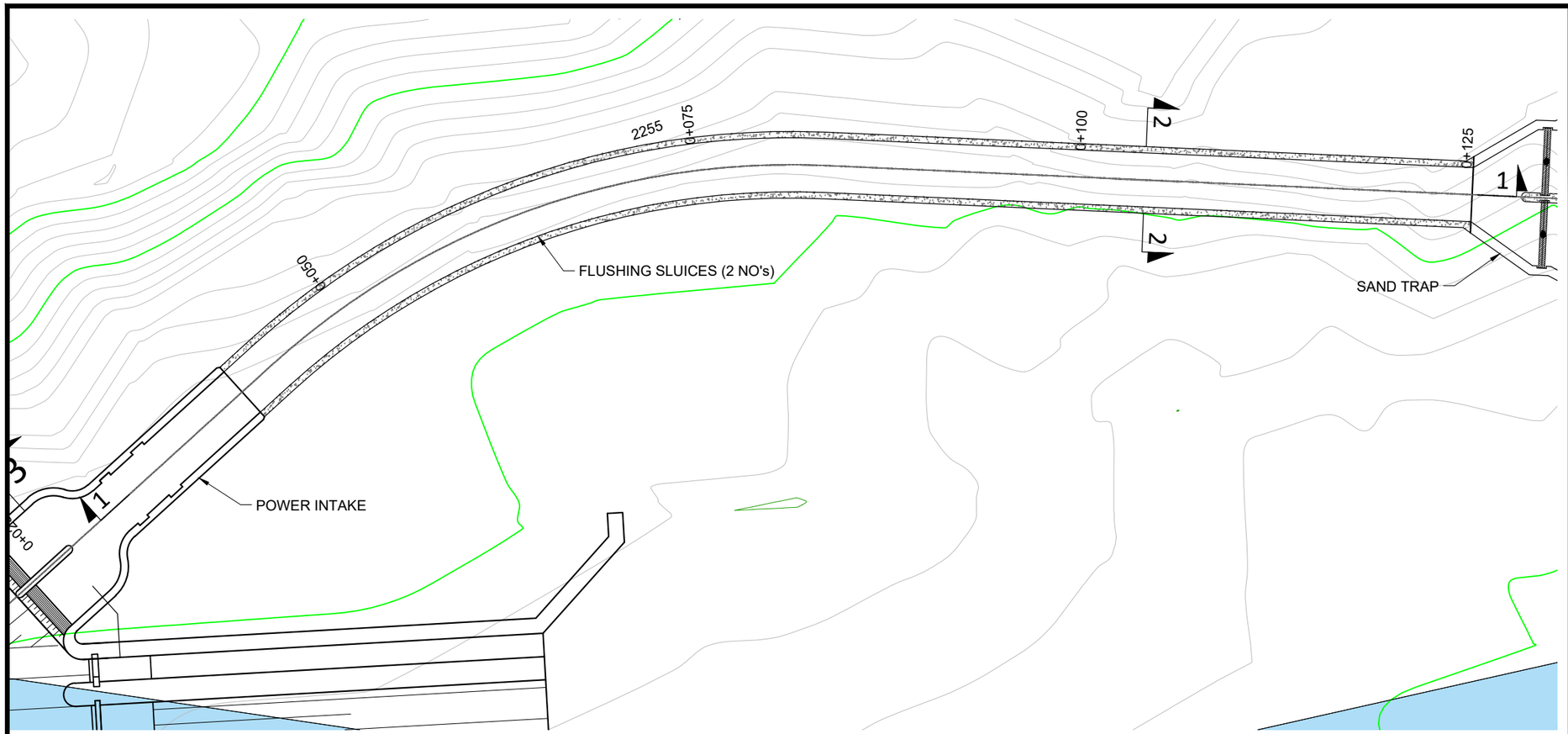
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

POWER INTAKE PLAN & SECTION

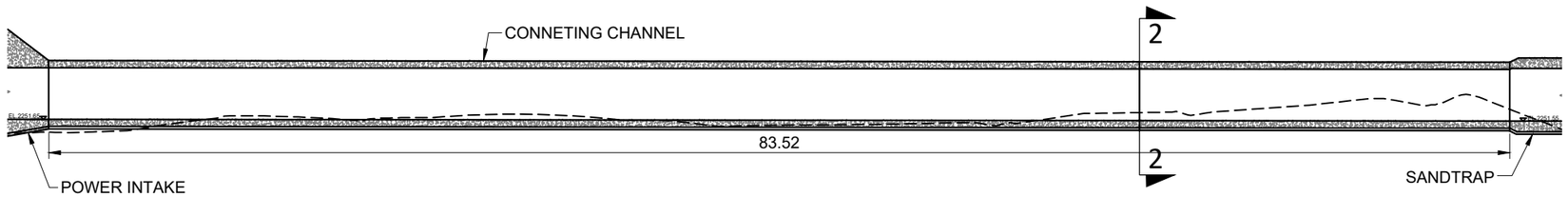
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-04-INT-002	

5-CONNECTING CHANNEL



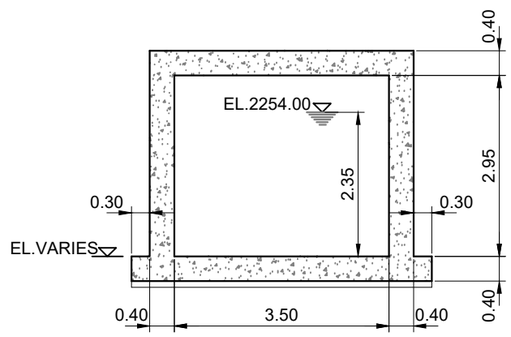
PLAN

SCALE:-1



SECTION 1-1

SCALE:-1



SECTION 2-2

SCALE:-2

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 5 10 15m

SCALE:-B

0 1.5 3 4.5m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

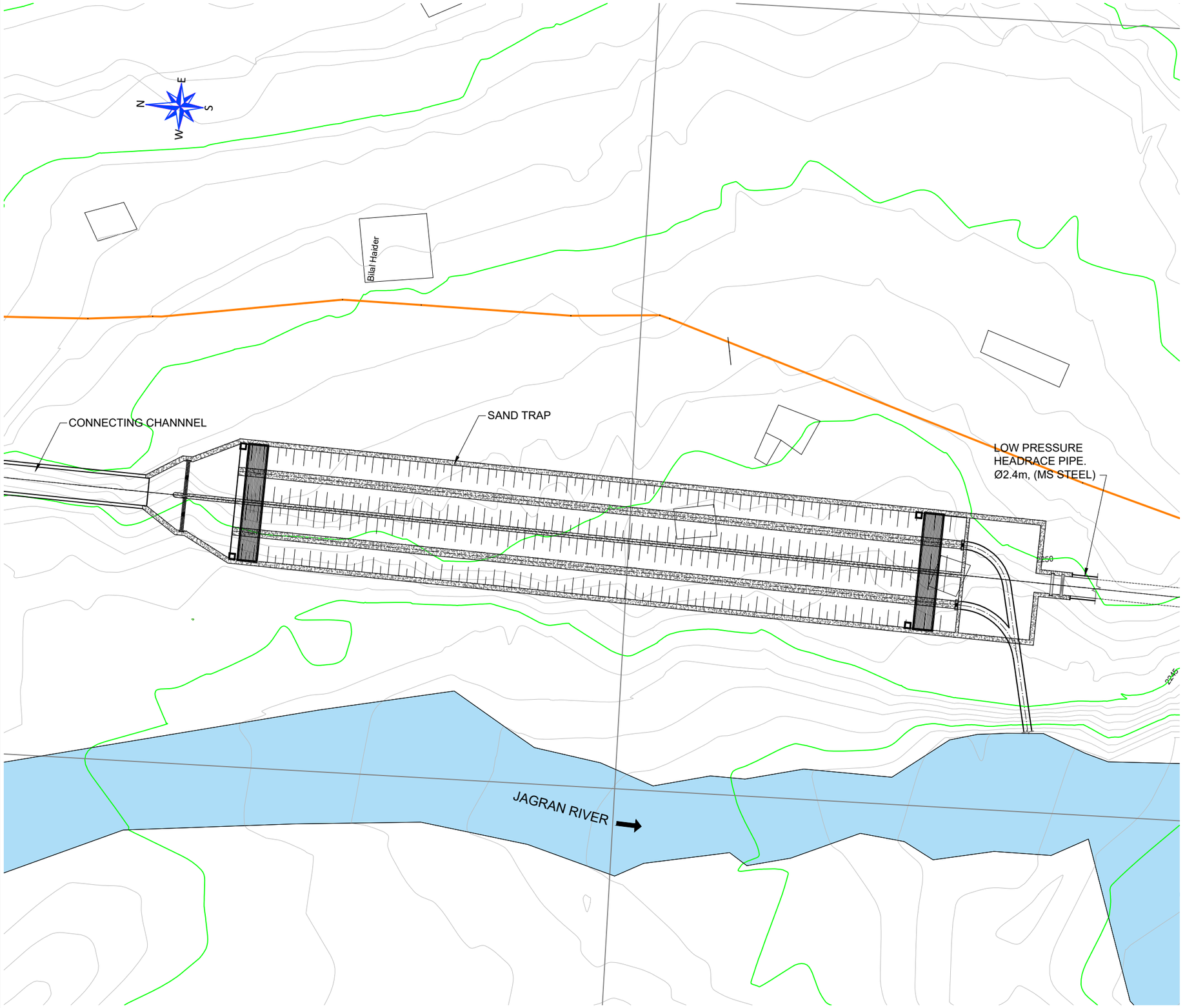
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

CONNECTING CHANNEL PLAN & SECTIONS

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-05-CON-001	

6-SANDTRAP



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

TOPOGRAPHY LEGEND

Major Contour (5M Interval)	
Minor Contour (1M Interval)	
Road	
Electric POle	E
Wooden Foot Bridge	
Nalla/River	
House/ Settelment	
Rock	

SCALE:-

0 5 10 15 20m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

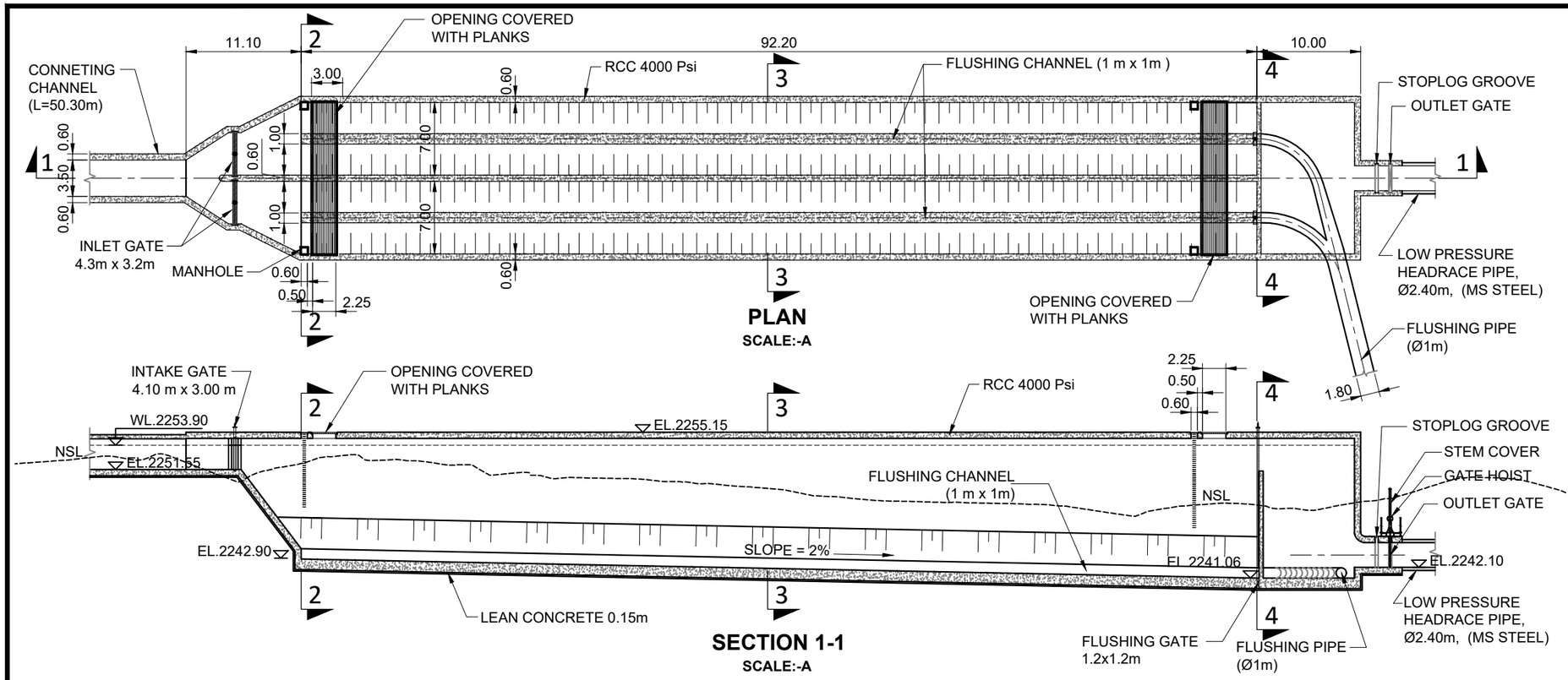
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

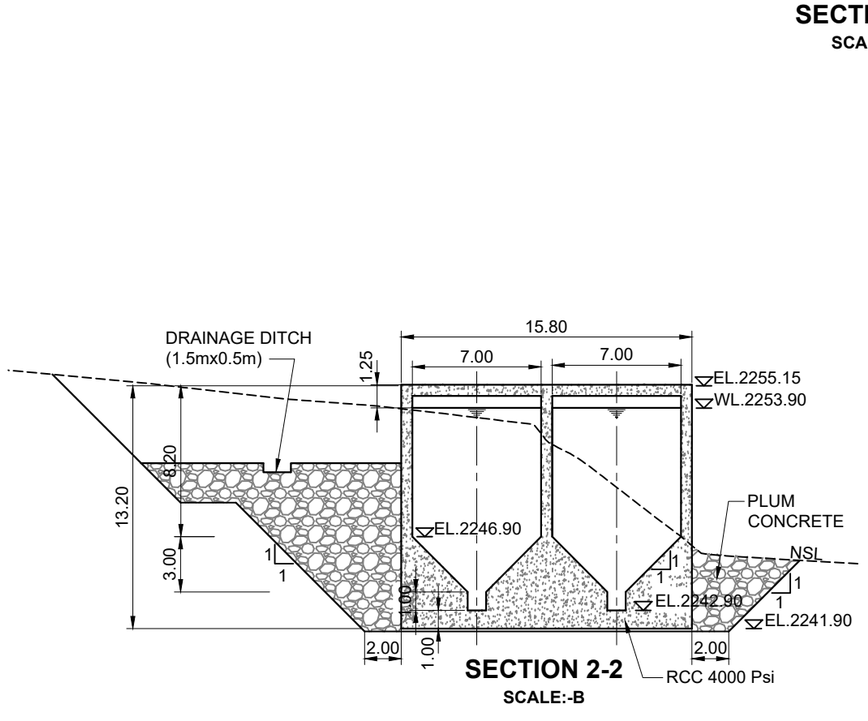
Saud Consult Saudi Consulting Services Company, KSA

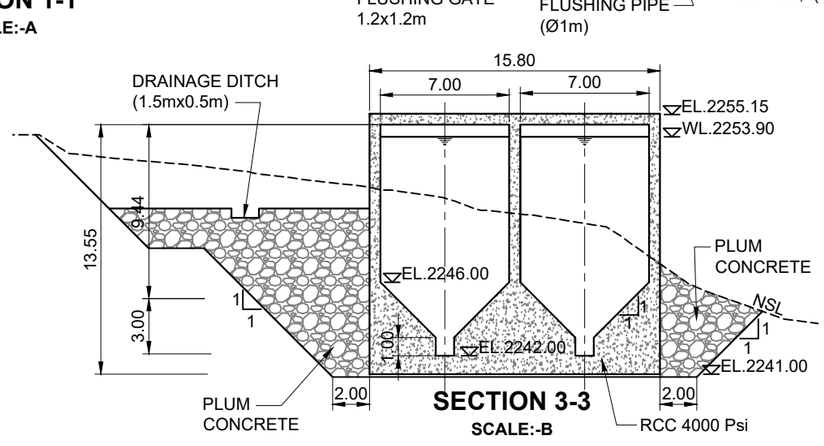
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

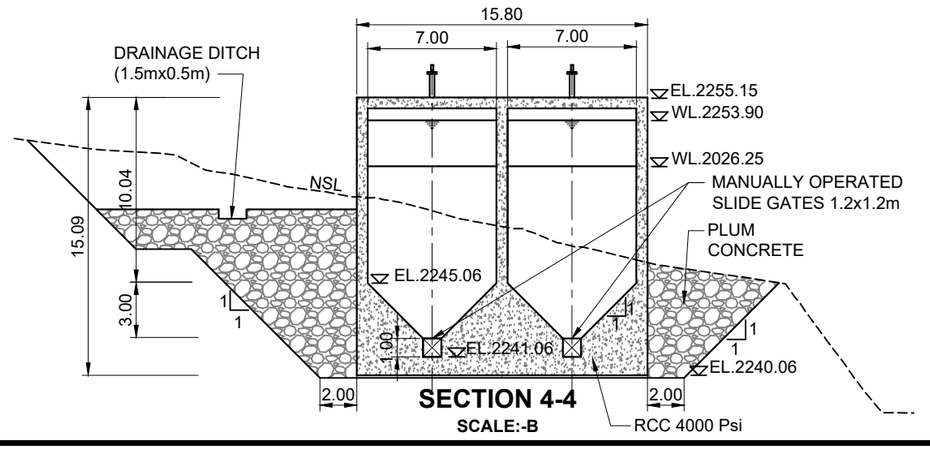
SANDTRAP LAYOUT PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-06-STR-001	









NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 2.5 5 7.5 10 12.5m

SCALE:-B

0 5 10 15 20 25m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

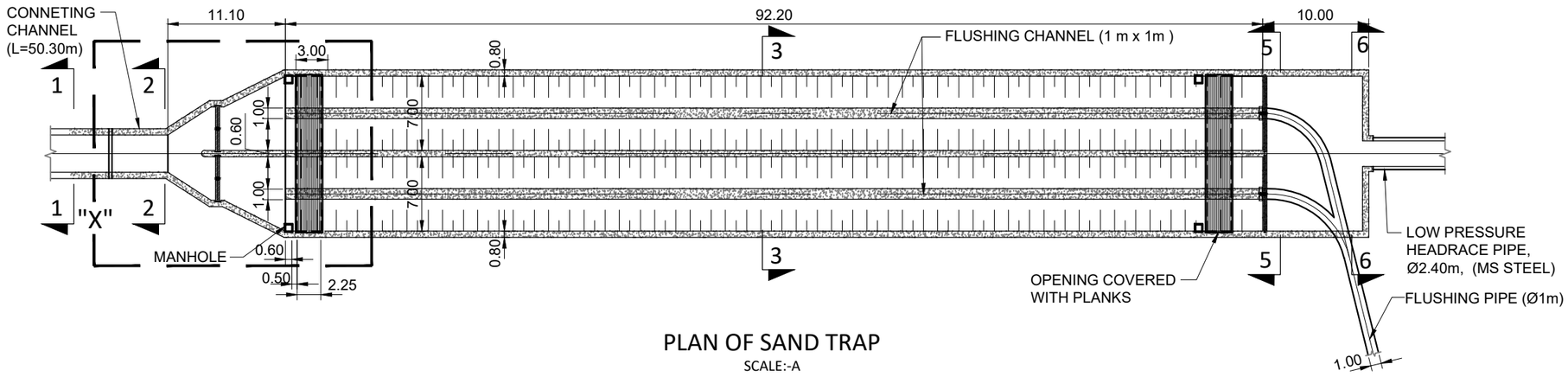
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

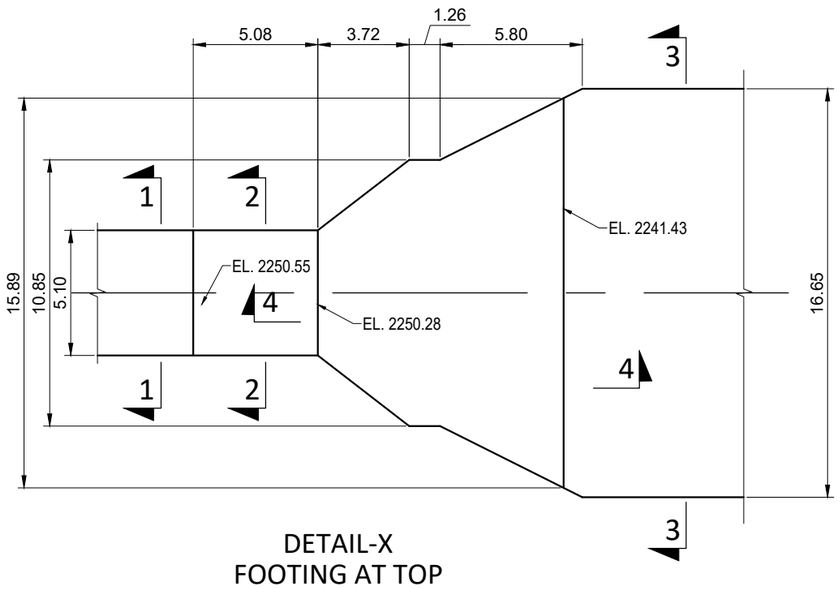
SAND TRAP PLAN AND SECTIONS

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	JAG-06-STR-002
DATE	February-26		



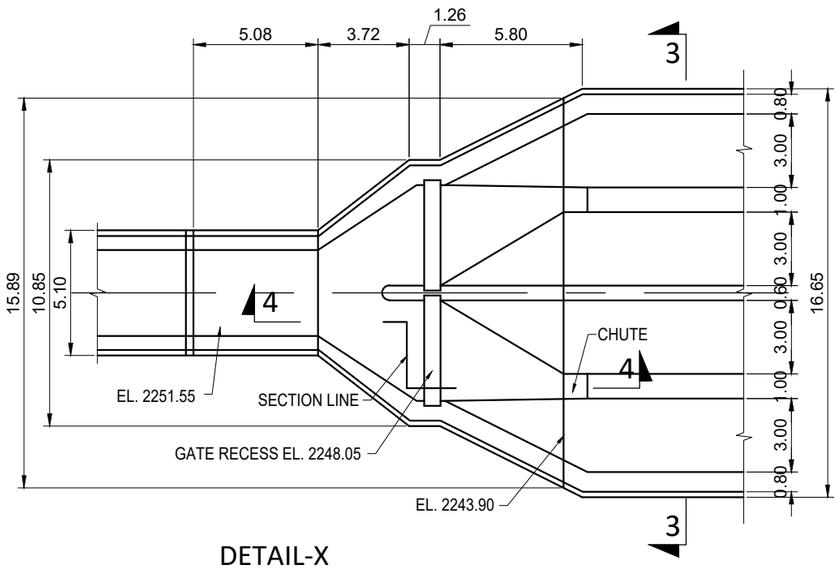
PLAN OF SAND TRAP

SCALE:-A



DETAIL-X
FOOTING AT TOP

SCALE:-B



DETAIL-X
FOOTING AT BOTTOM

SCALE:-B

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 5 10 15 20 25m

SCALE:-B

0 2.5 5 7.5 10 12.5m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

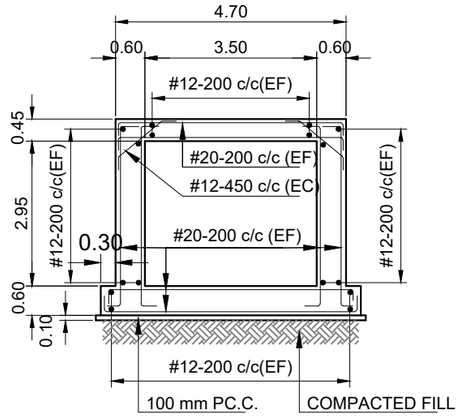
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

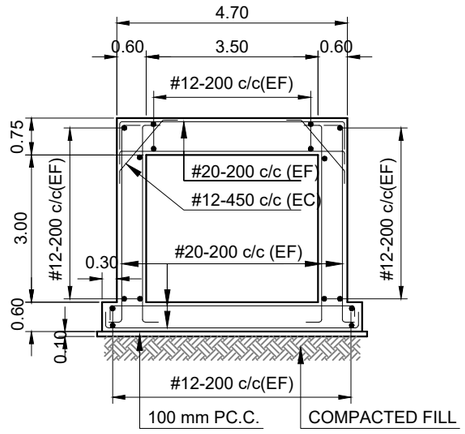
STRUCTURAL PLAN OF SAND TRAP AND DETAIL-X

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-06-STR-003	



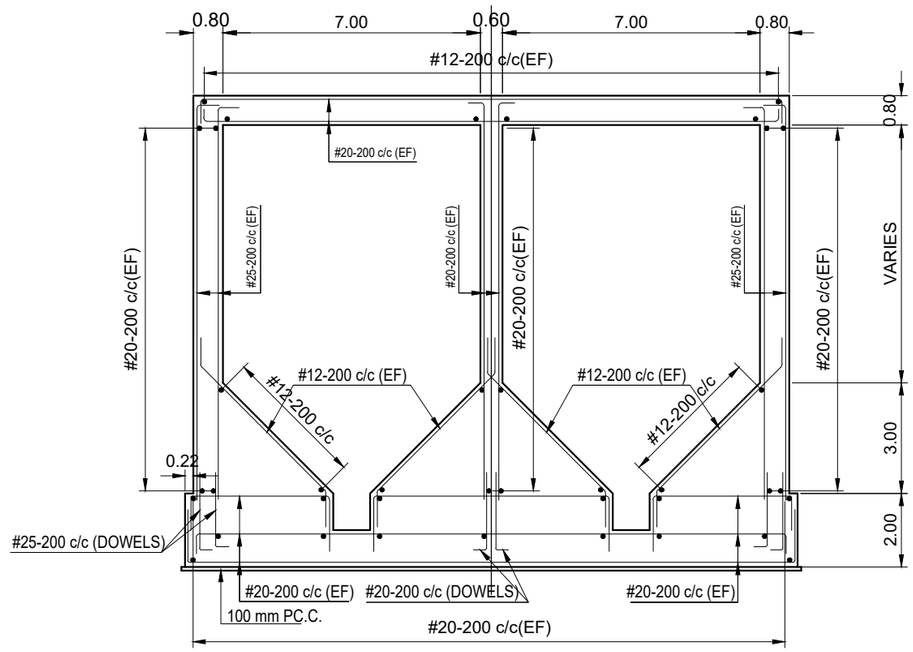
REINF. DETAIL OF CONNECTING CHANNEL
(SECTION 1-1)

(SCALE:-B)



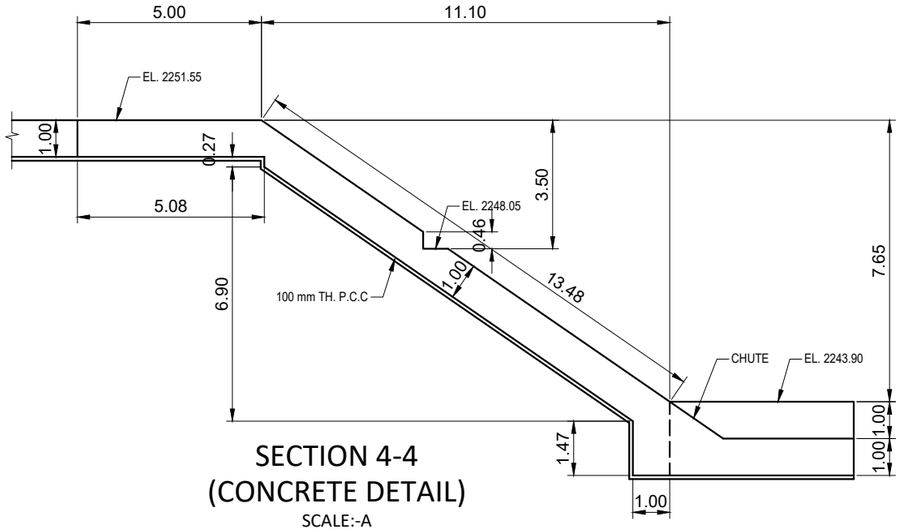
REINF. DETAIL OF CONNECTING CHANNEL
SECTION 2-2

SCALE:-B



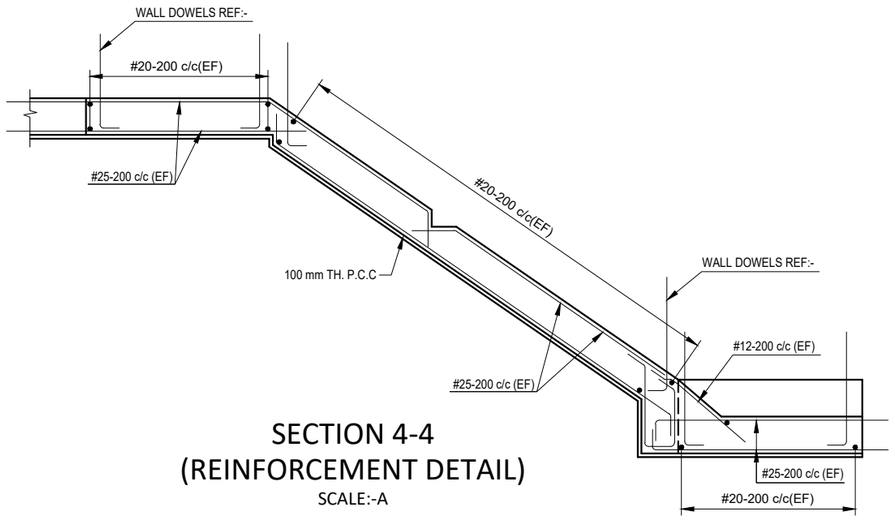
SECTION 3-3

SCALE:-A



SECTION 4-4
(CONCRETE DETAIL)

SCALE:-A



SECTION 4-4
(REINFORCEMENT DETAIL)

SCALE:-A

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

SCALE:-B

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

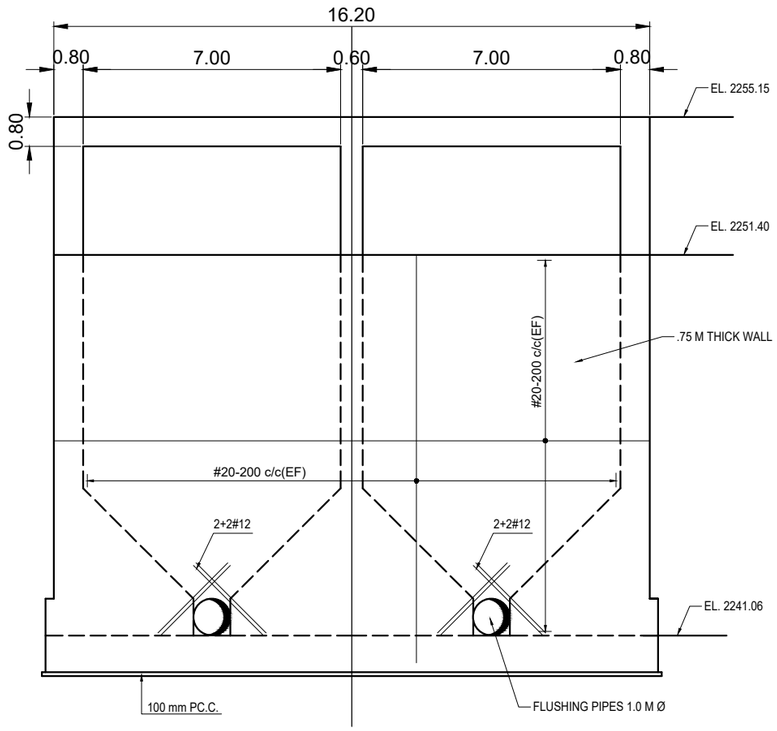
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

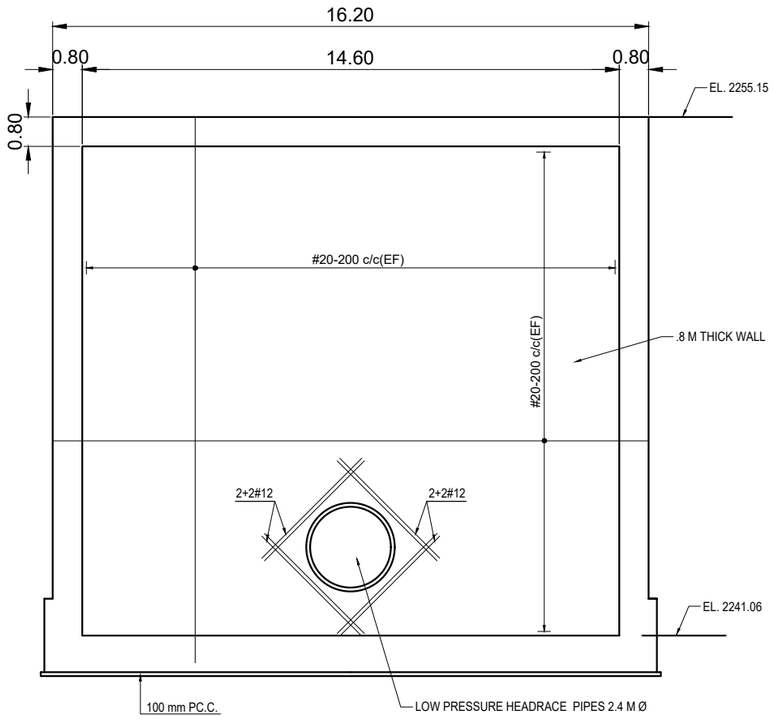
SAND TRAP
SECTIONS 1-1, 2-2, 3-3 & 4-4

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-06-STR-004	



SECTION 5-5

(SCALE:-B)



SECTION 6-6

(SCALE:-B)

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

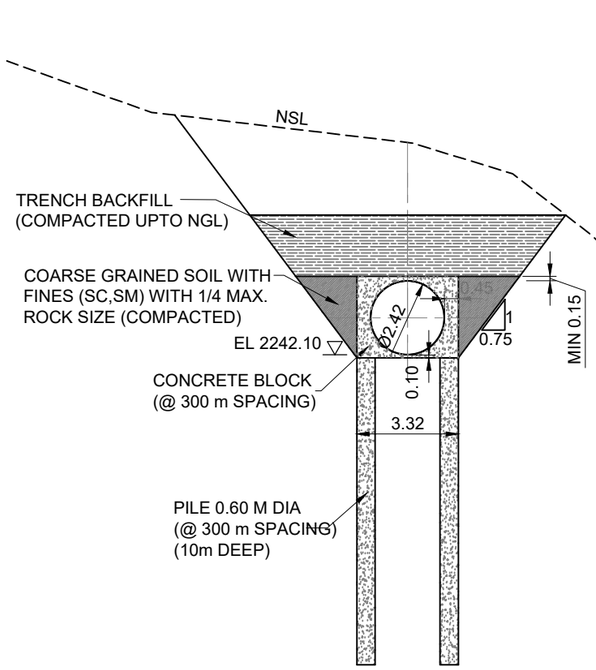
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

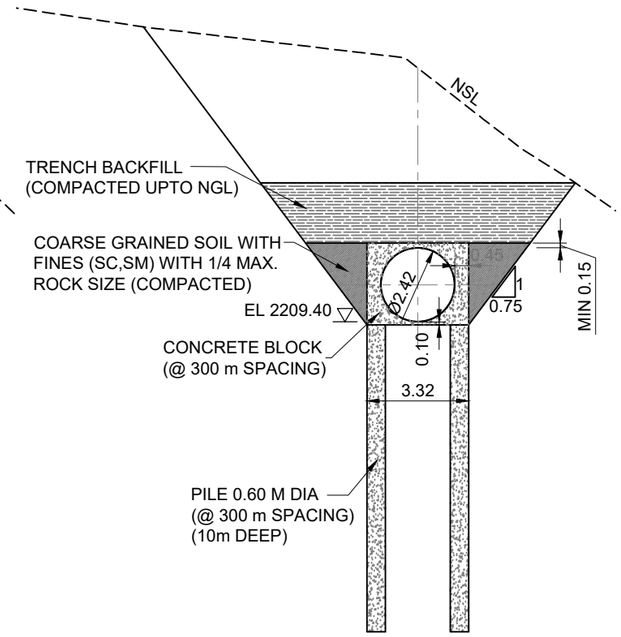
SAND TRAP
SECTIONS 5-5 & 6-6

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-06-STR-005	

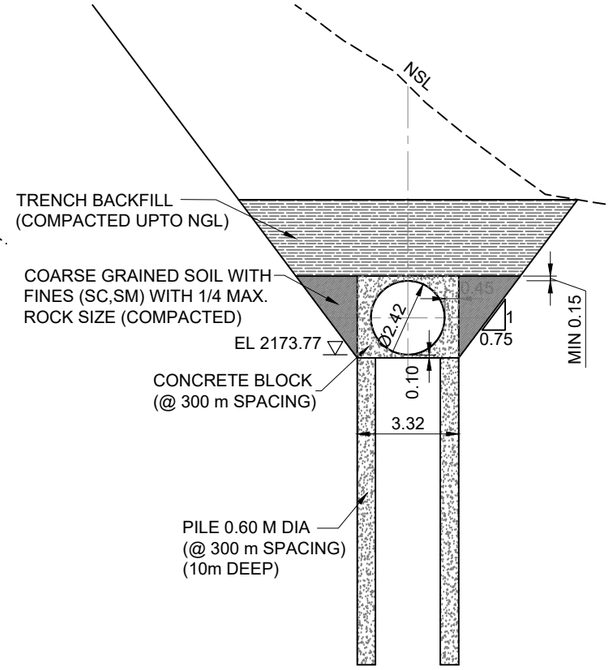
7-HEADRACE PIPE



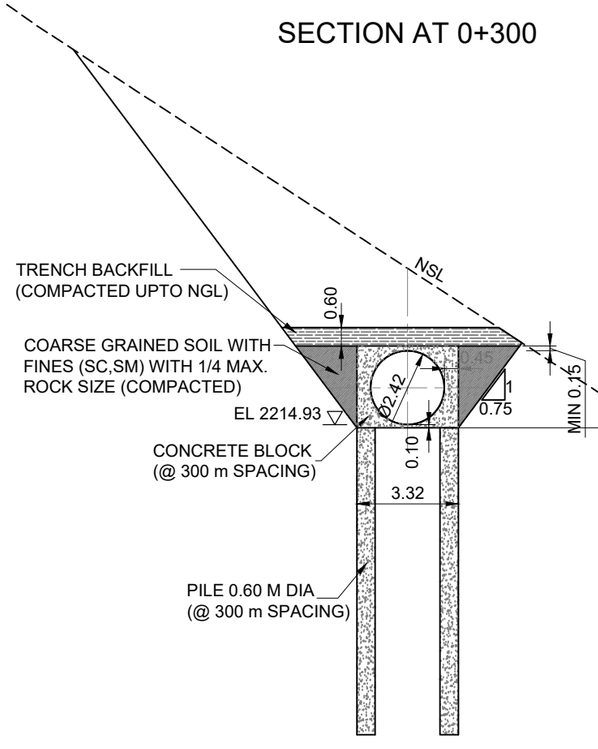
SECTION AT 0+300



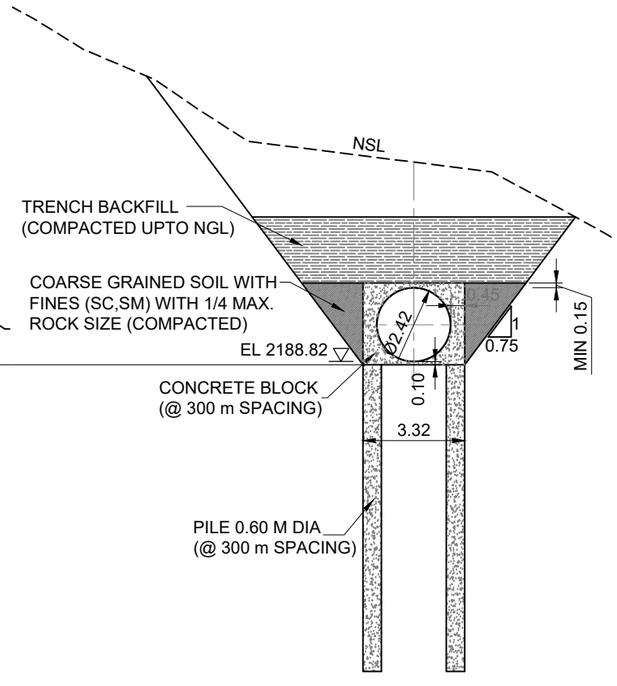
SECTION AT 0+900



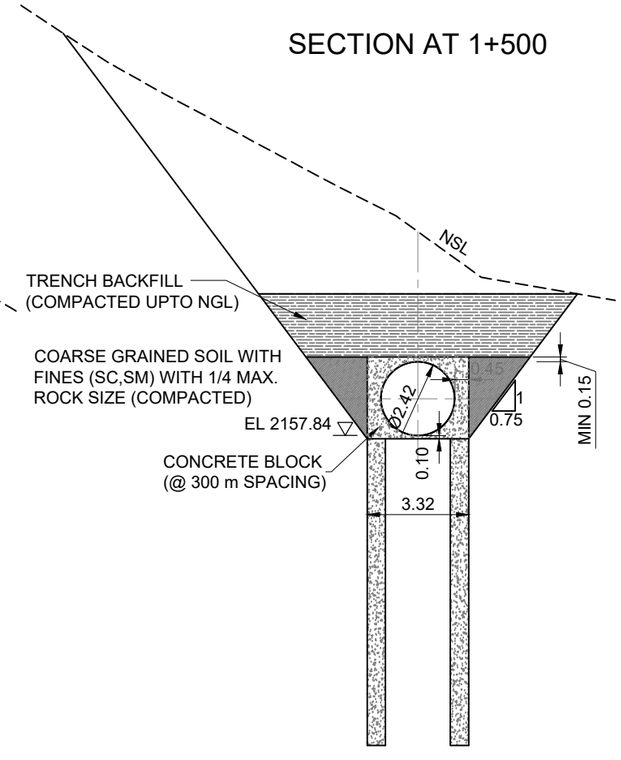
SECTION AT 1+500



SECTION AT 0+600



SECTION AT 1+200



SECTION AT 1+800

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6 8 10m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

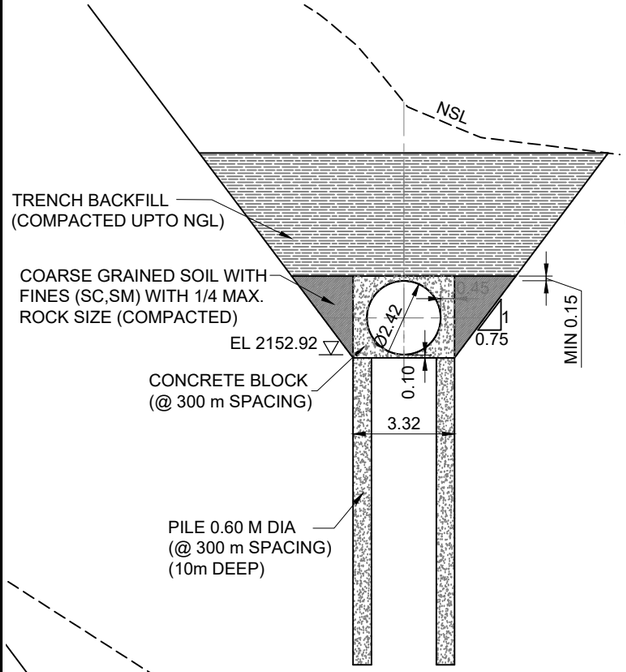
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

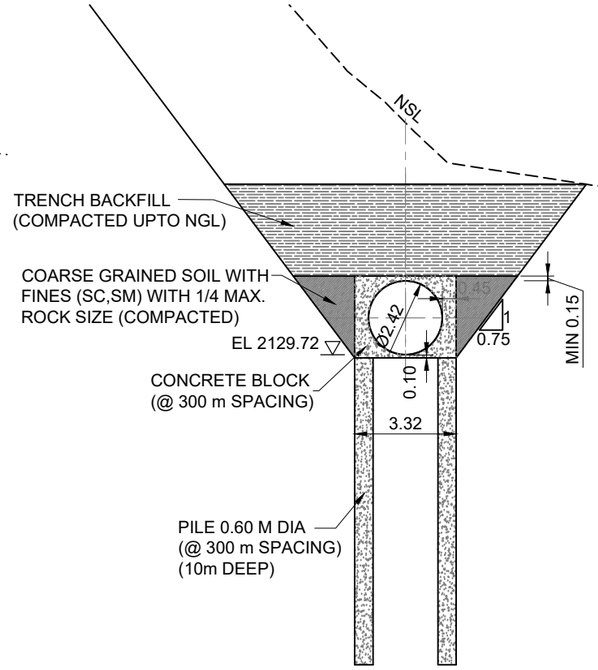
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SECTIONS OF HEADRACE PIPE

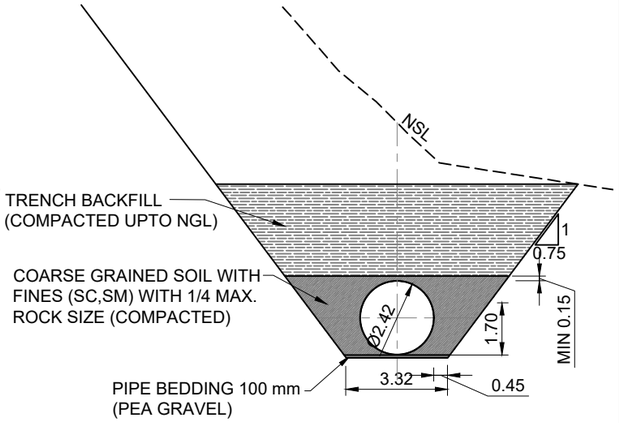
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-07-SRP-001	



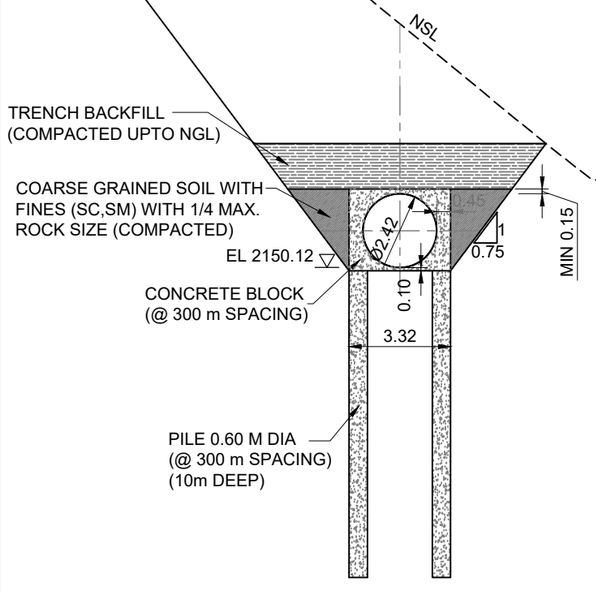
SECTION AT 2+100



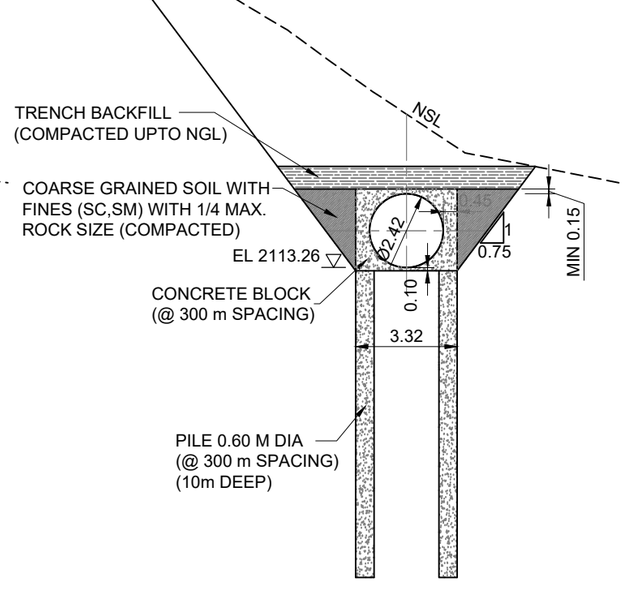
SECTION AT 2+700



TYP. SECTION WITHOUT PILED BLOCK



SECTION AT 2+400



SECTION AT 3+000

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6 8 10m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

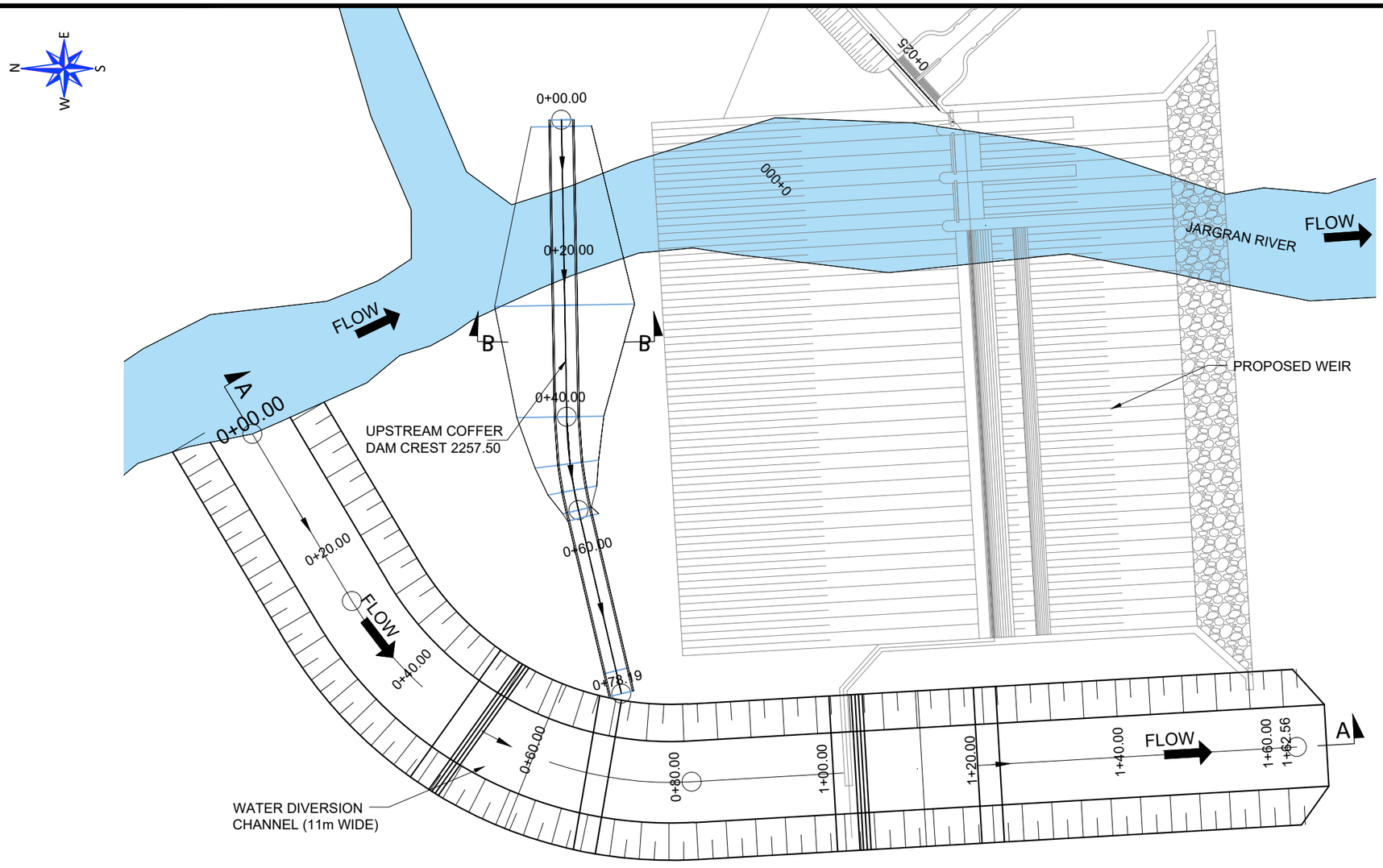
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SECTIONS OF HEADRACE PIPE

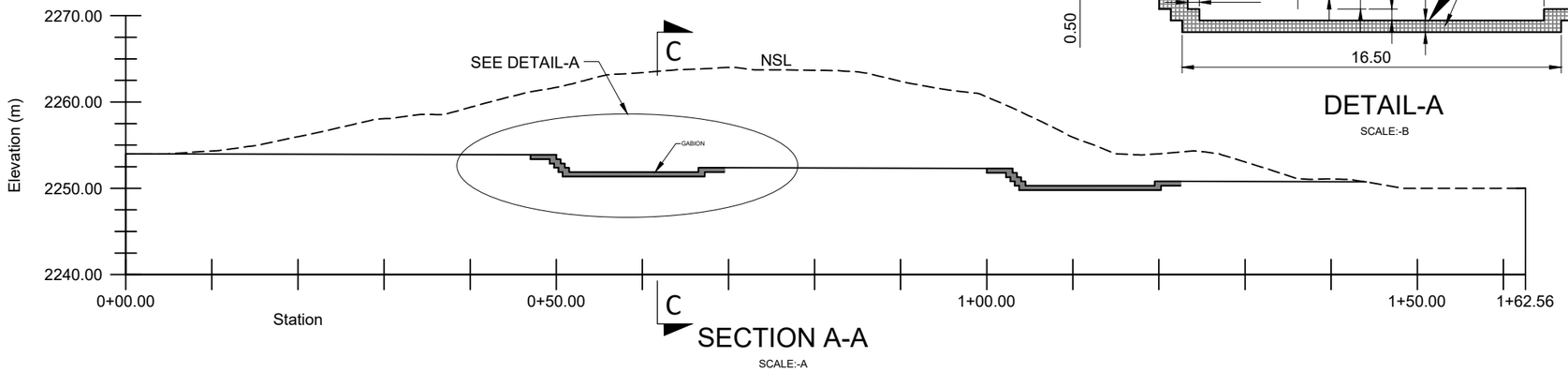
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-07-SRP-002	

8-RIVER DIVERSION



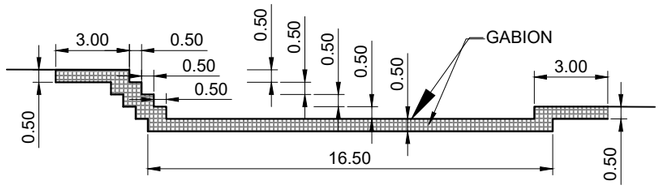
PLAN

SCALE:-A



SECTION A-A

SCALE:-A



DETAIL-A

SCALE:-B

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 5 10 15 20 25m

SCALE:-B

0 2 4 6 8 10m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

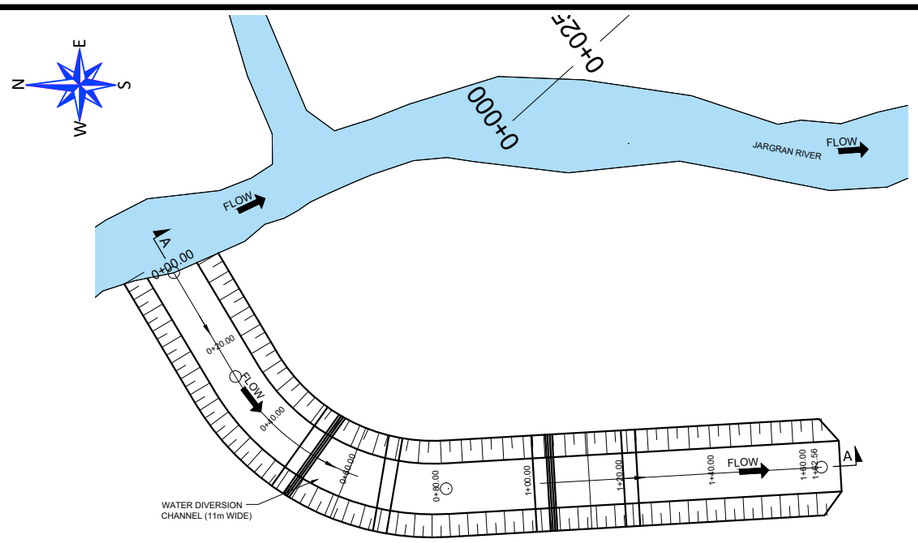
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

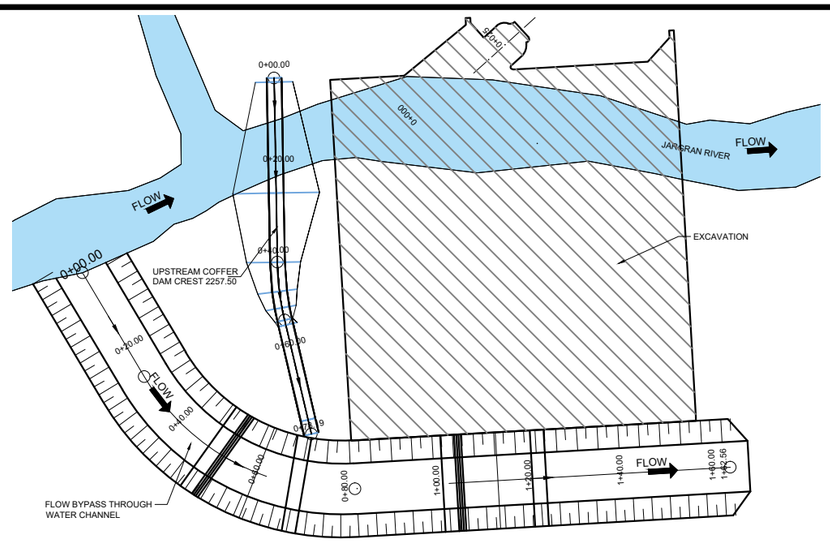
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

RIVER DIVERSION DURING CONSTRUCTION

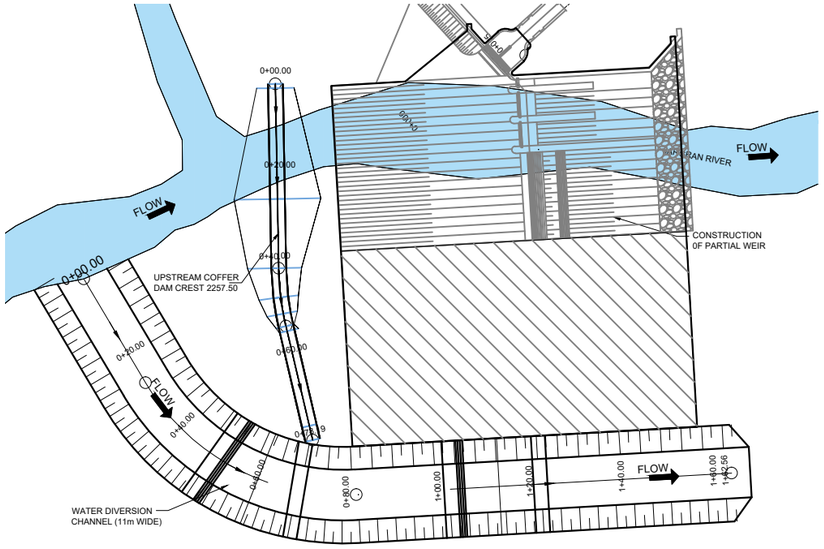
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-08-DIV-001	



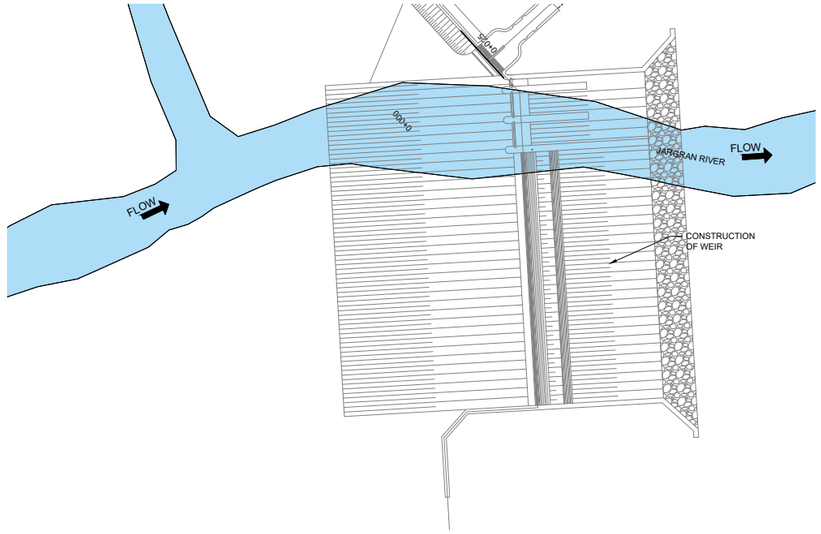
1st STAGE (WINTER SEASON-1)
CONSTRUCTION OF DIVERSION CHANNEL
SCALE:- A



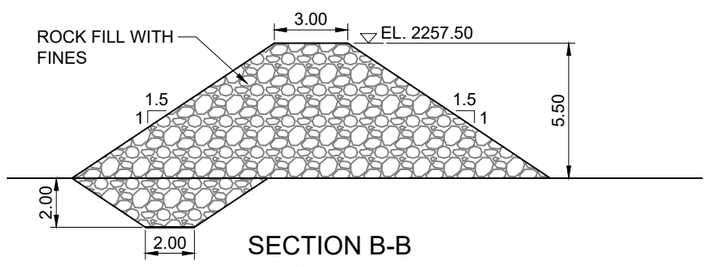
2nd STAGE (WINTER SEASON-1)
CONSTRUCTION OF COFFER DAM
AND EXCAVATION WORKS
SCALE:- A



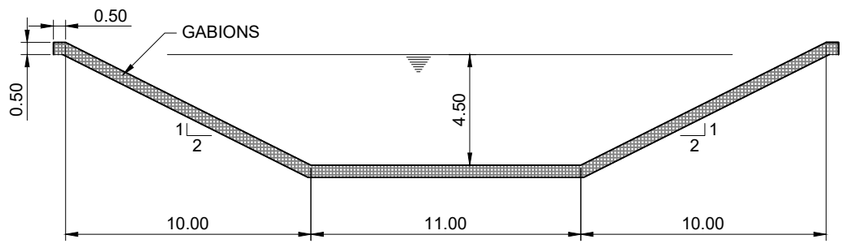
3rd STAGE (WINTER SEASON-2)
PARTIAL WEIR CONSTRUCTION
SCALE:- A



4th STAGE (WINTER SEASON-3)
CONSTRUCTION OF WEIR
SCALE:- A



SECTION B-B
SCALE:- B



SECTION C-C
SCALE:- B

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-A

0 10 20 30 40 50m

SCALE:-B

0 2.5 5 7.5 10m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

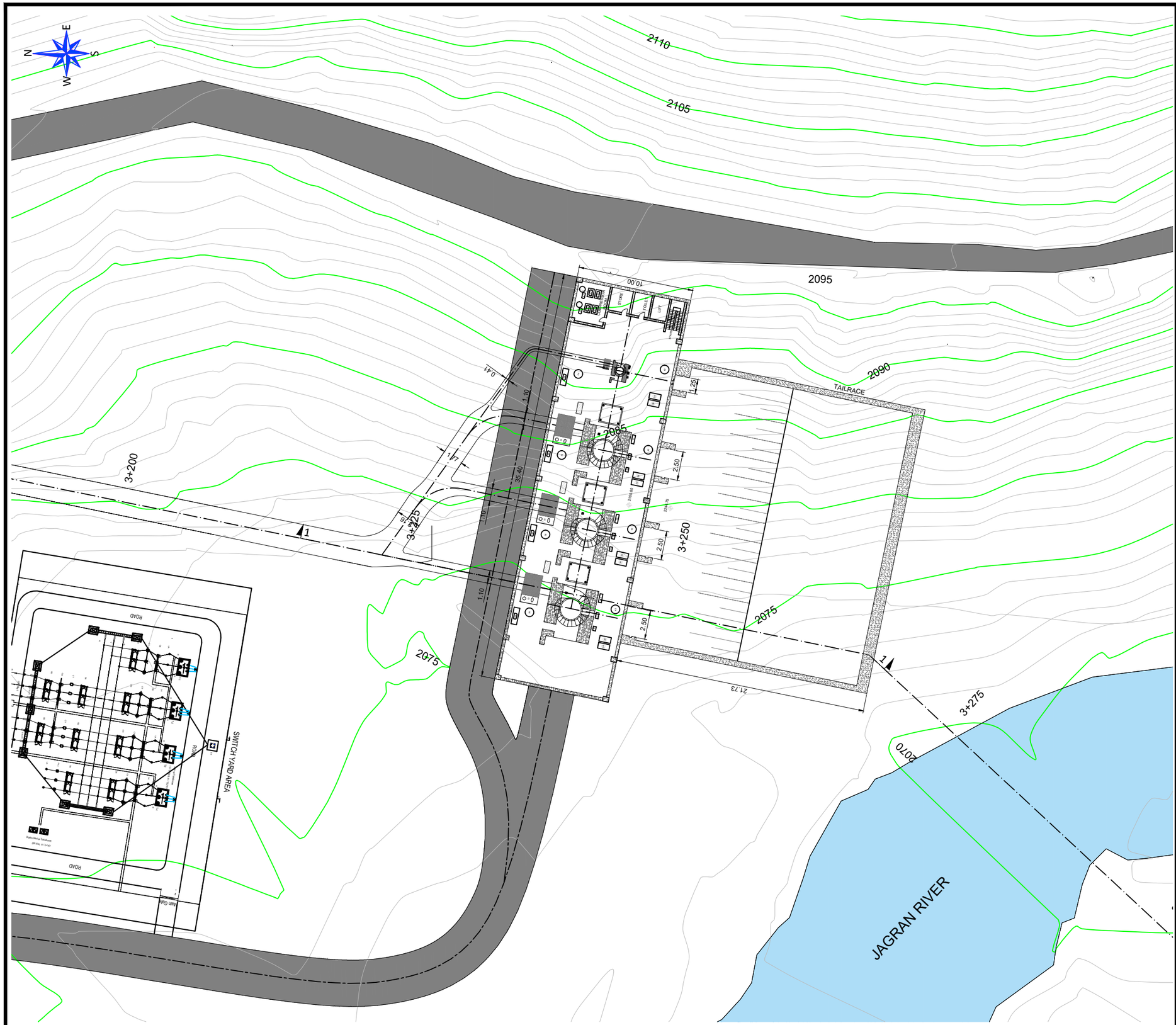
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

RIVER DIVERSION DURING CONSTRUCTION (CONSTRUCTION STAGES)

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-08-DIV-002	

9-POWER HOUSE AND TAILRACE



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 5 10 15m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

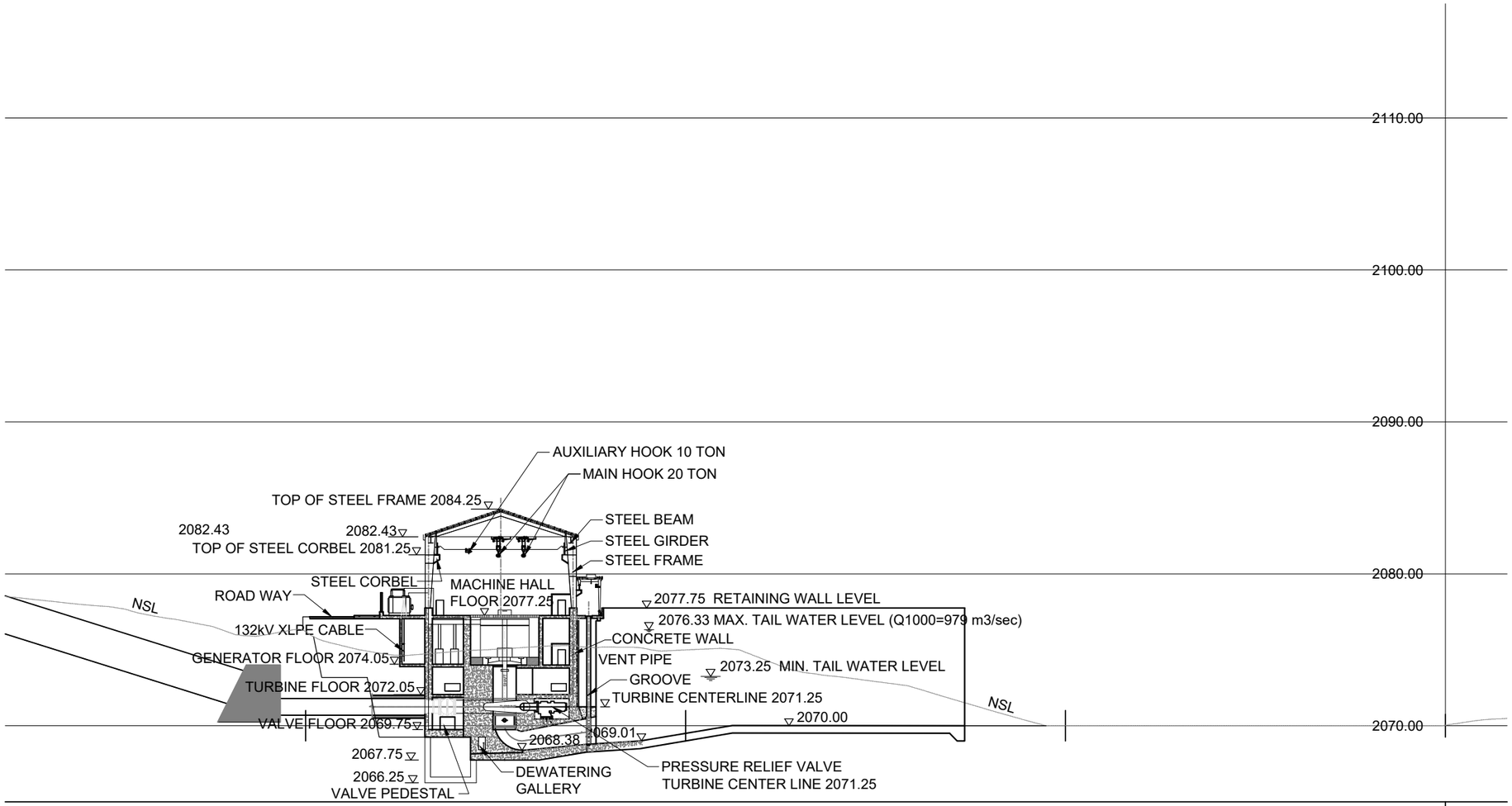
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN OF POWER HOUSE

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-09-PHS-001	



3+225	2076.21	3+250	2074.99	3+275	2070.00	3+300	2070.04
3+225	2070.71	3+250	2073.25	3+275	2073.25	3+300	2073.25

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 5 10 15m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

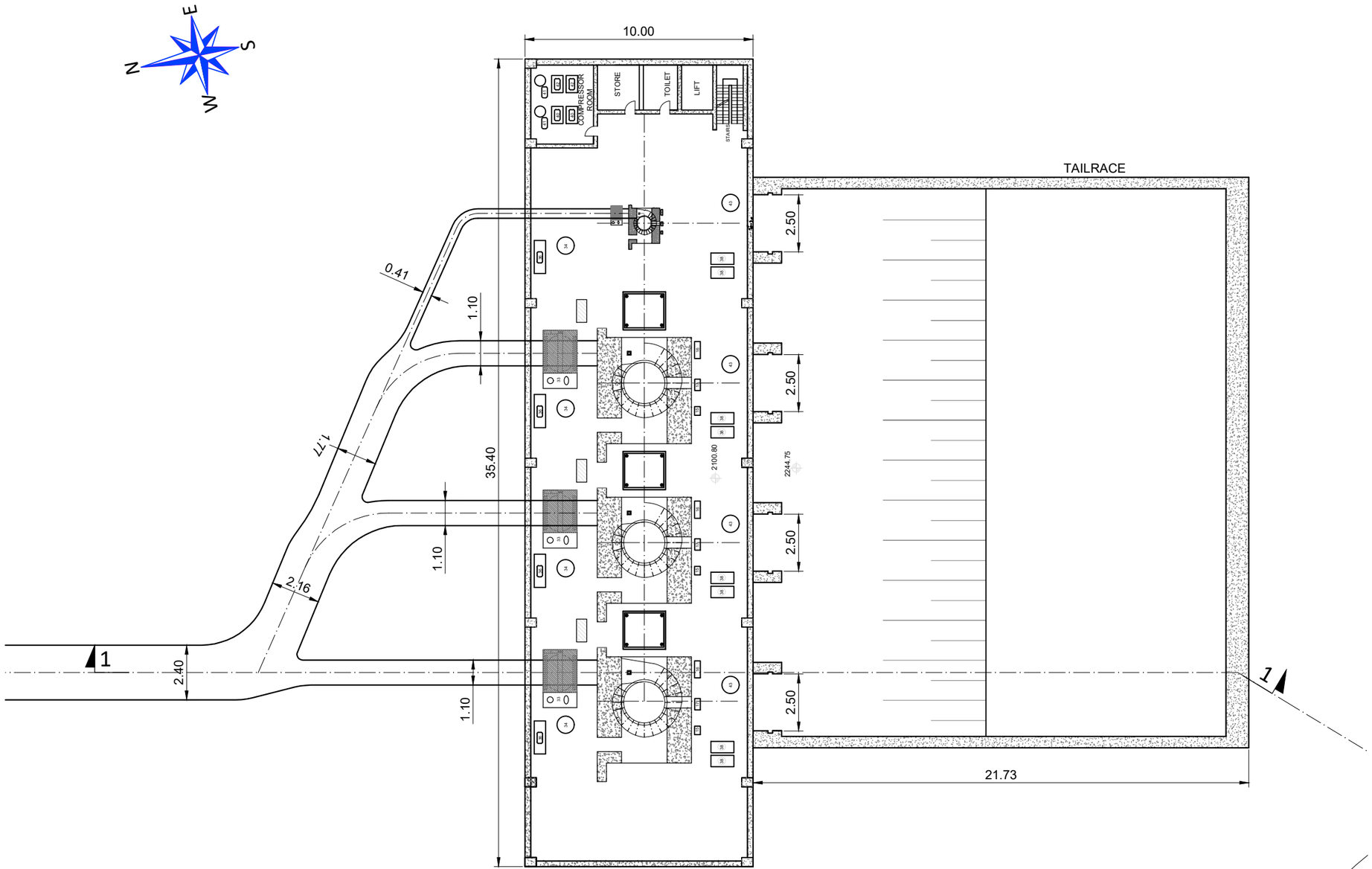
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SECTION 1-1 OF POWER HOUSE

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-09-PHS-002	



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6 8 10m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

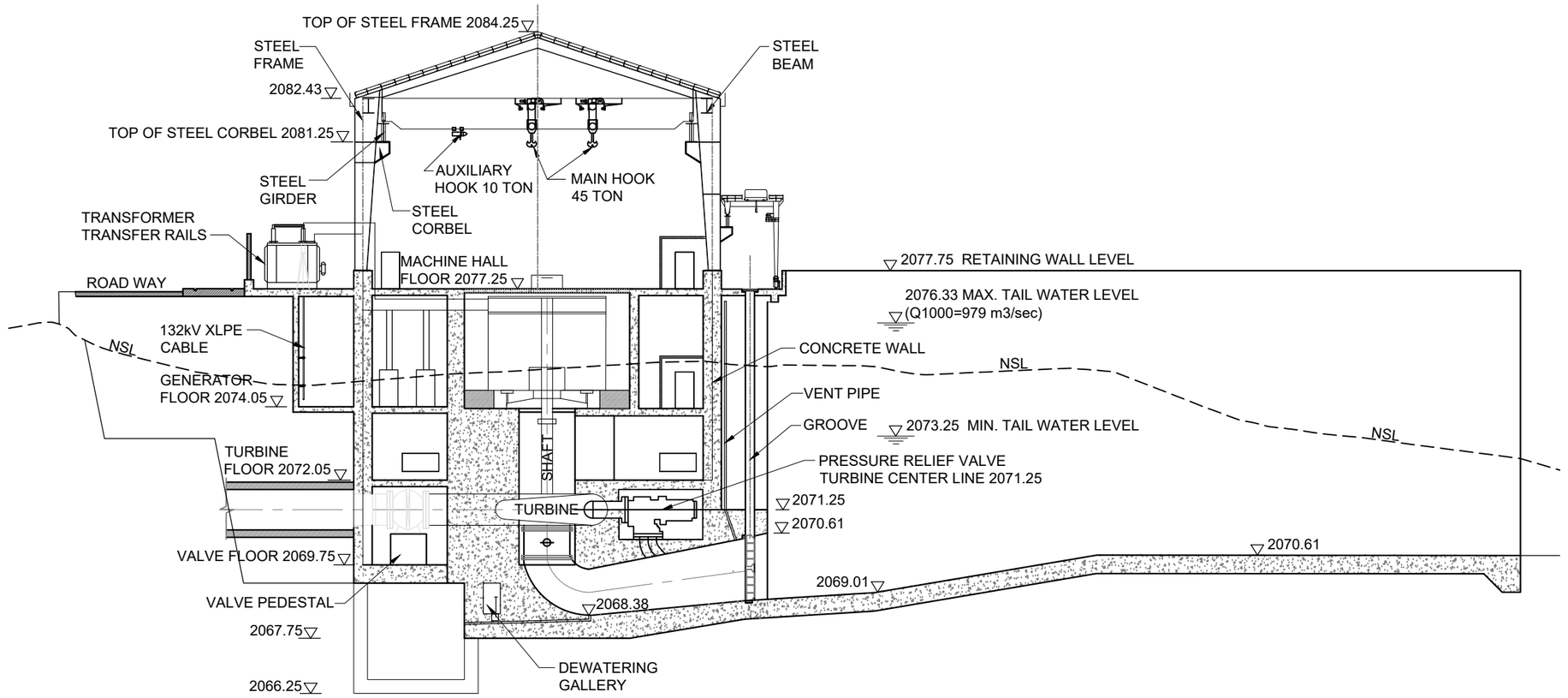
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

POWER HOUSE PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-09-PHS-003	



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

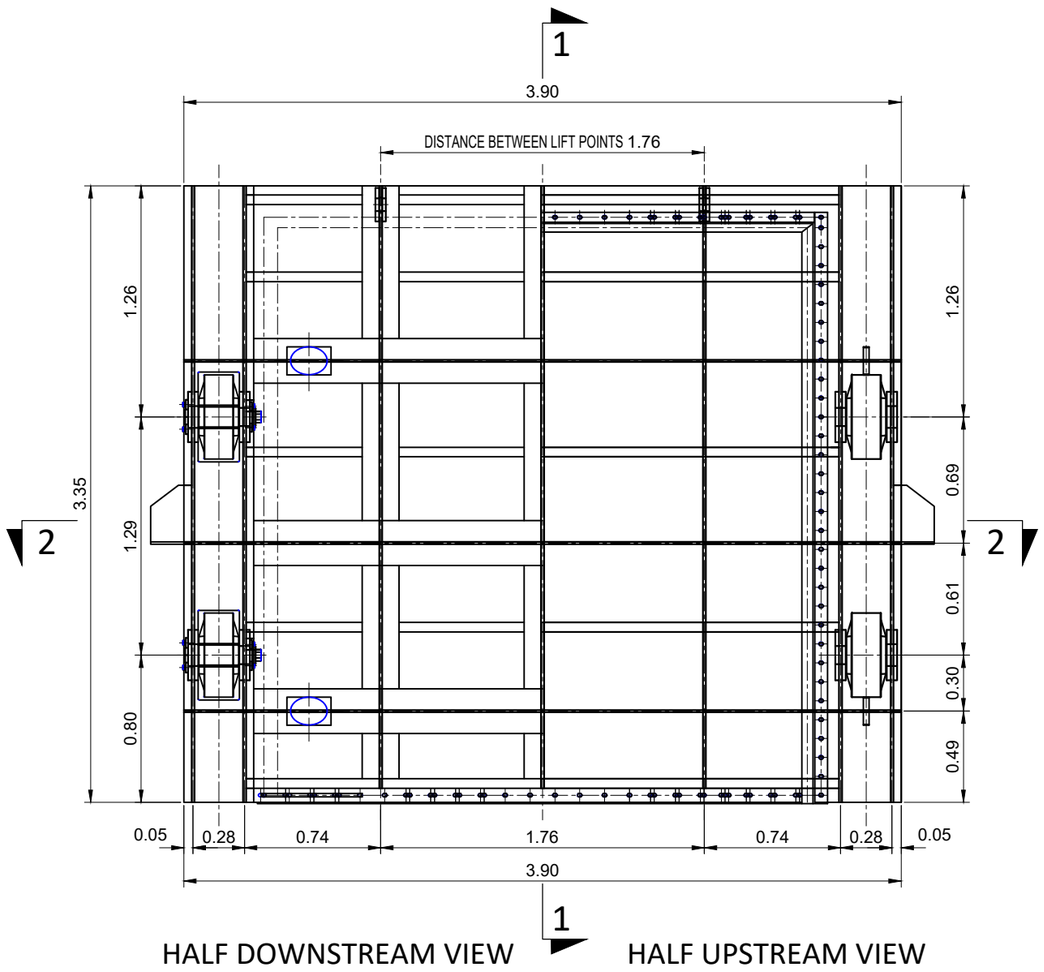
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

POWER HOUSE SECTION 1-1

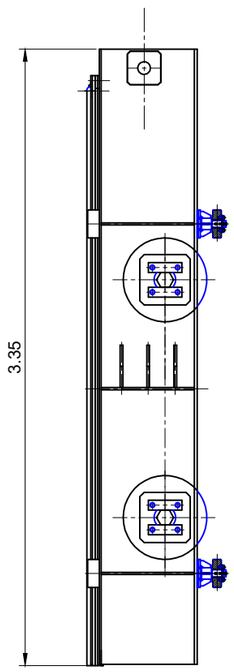
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-09-PHS-004	

10-HYDRAULIC STEEL WORKS

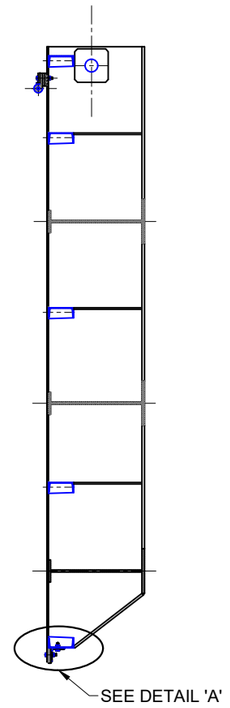


HALF DOWNSTREAM VIEW

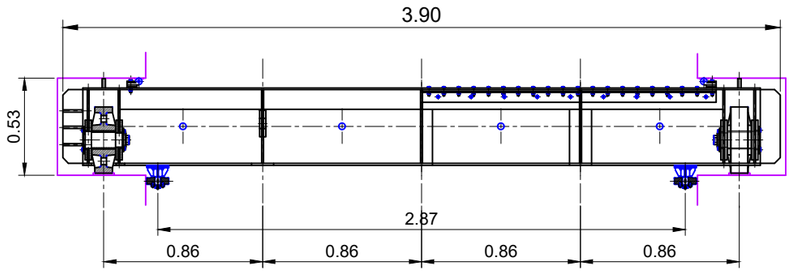
HALF UPSTREAM VIEW



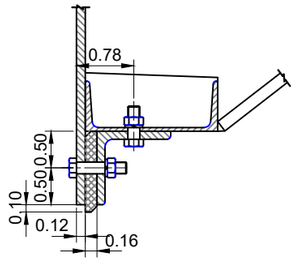
LATERAL VIEW



SECTION 1-1



SECTION 2-2



DETAIL 'A'

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 0.5 1.0 1.5m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

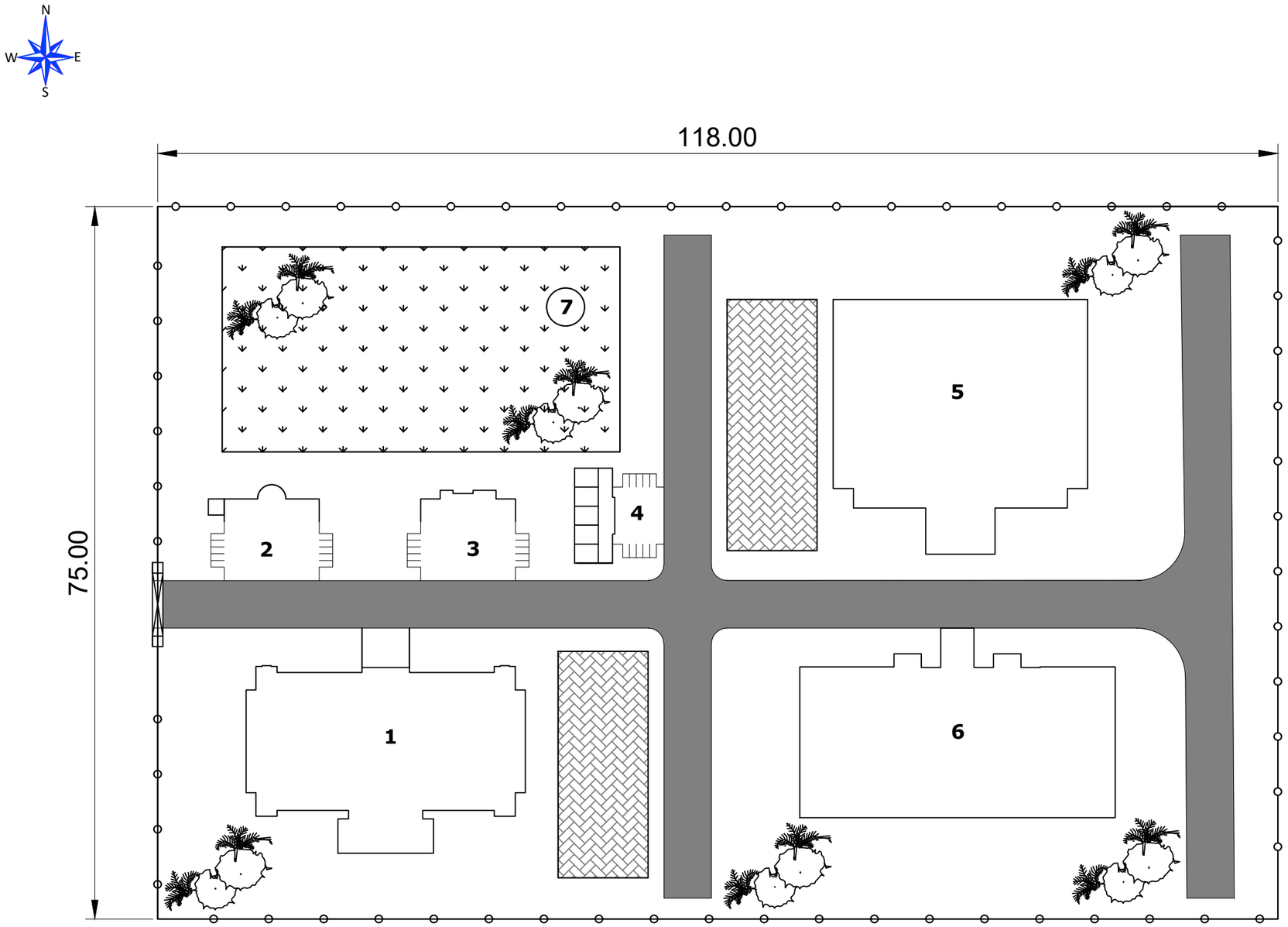
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

INTAKE GATE DETAILS

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-001	

11-OFFICE BUILDING & STAFF QUARTERS



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

LEGEND

Sr. No.	FACILITY
1	OFFICE
2	MOSQUE
3	DISPENSARY
4	MARKET
5	EXECUTIVE QUARTER
6	STAFF QUARTER
7	OVER HEAD WATER TANK

SCALE

0 10 20 30 40 50m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

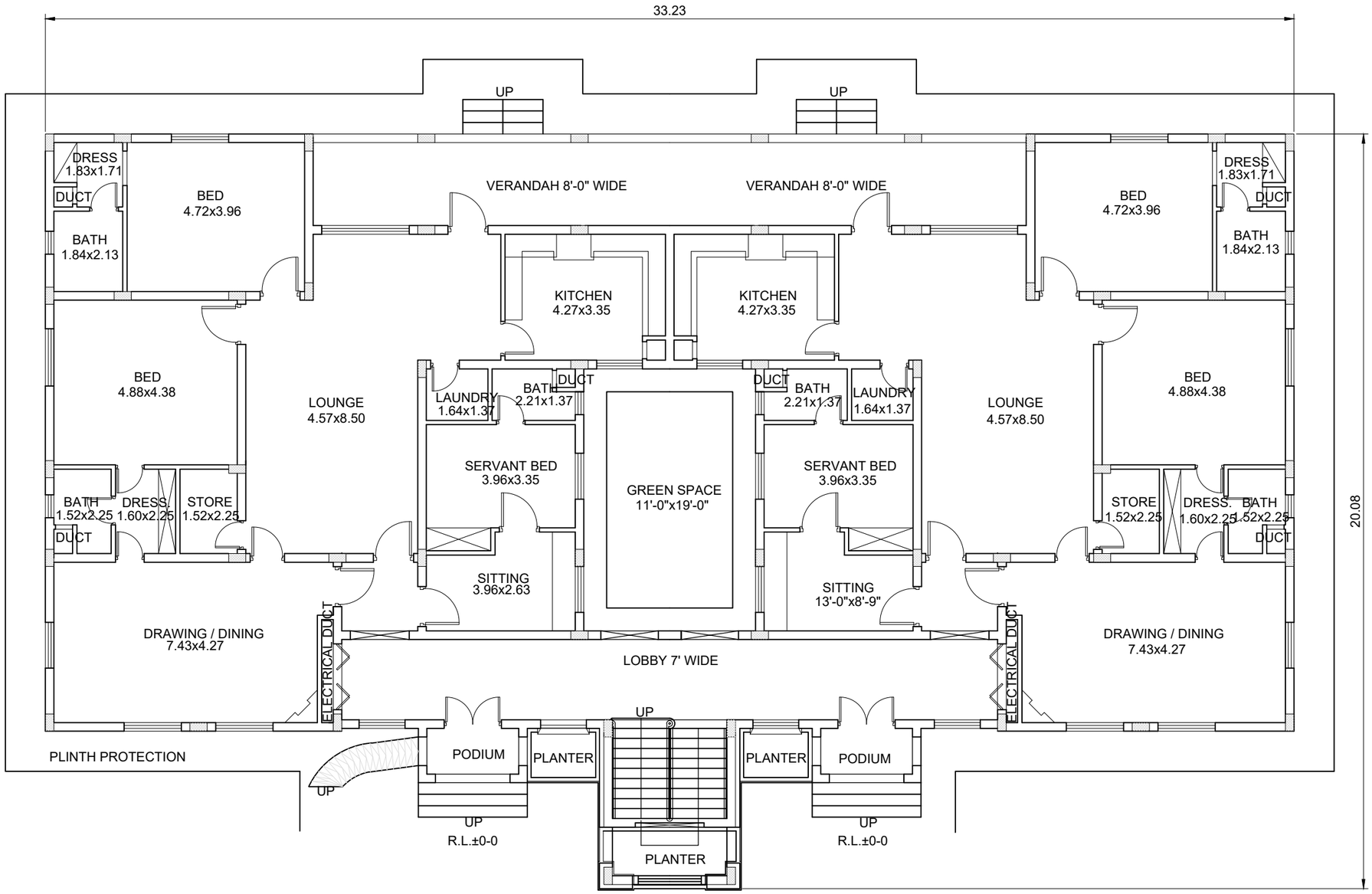
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

OFFICE BUILDING & STAFF QUARTERS ARCHITECTURAL LAYOUT PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	JAG-11-BLD-001
DATE	February-26		



GROUND FLOOR PLAN
COVERED AREA=518 sqm

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

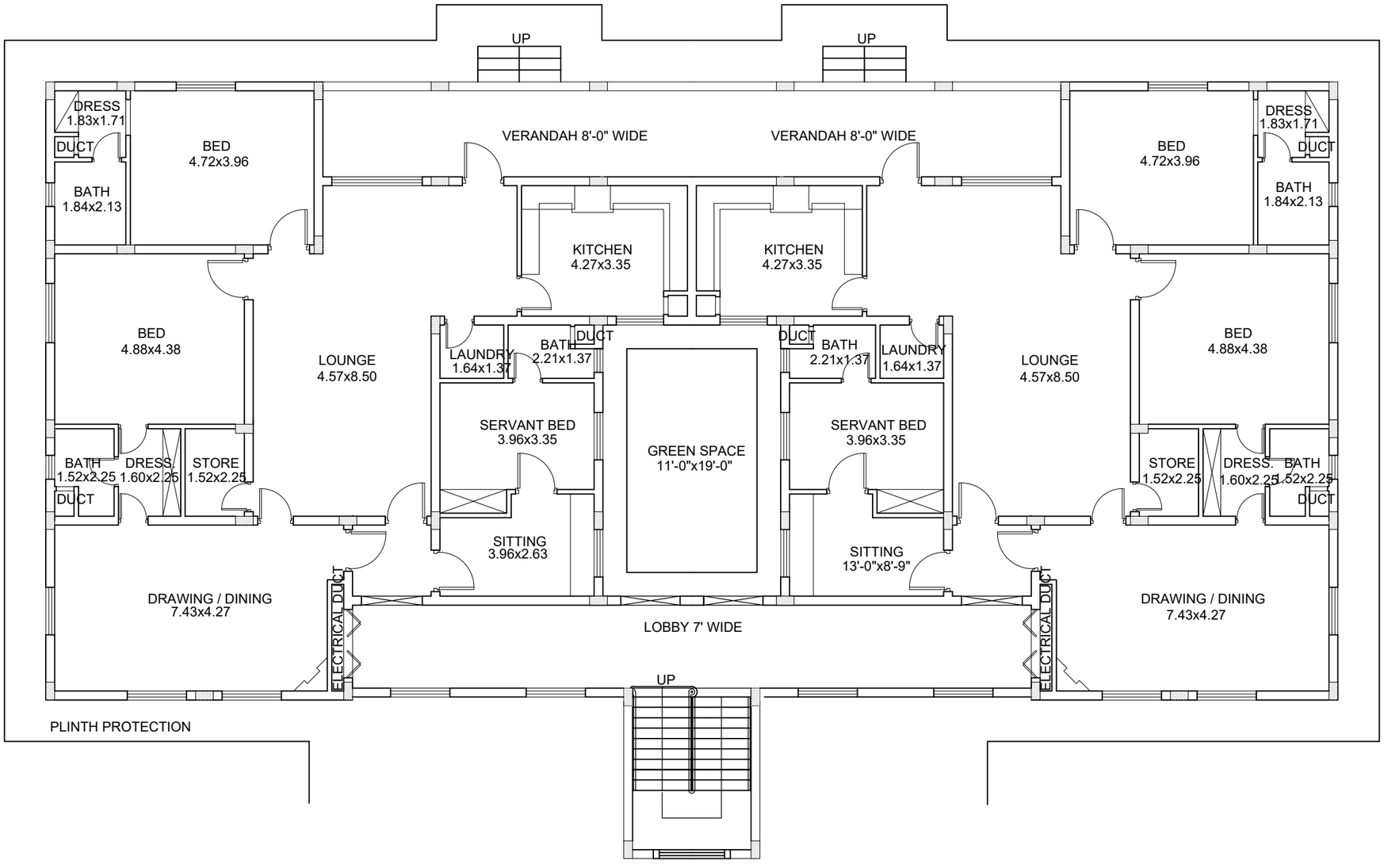
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

EXECUTIVE QUARTER

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	JAG-11-BLD-002
DATE	February-26		



FIRST FLOOR PLAN

COVERED AREA=510 sqm

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

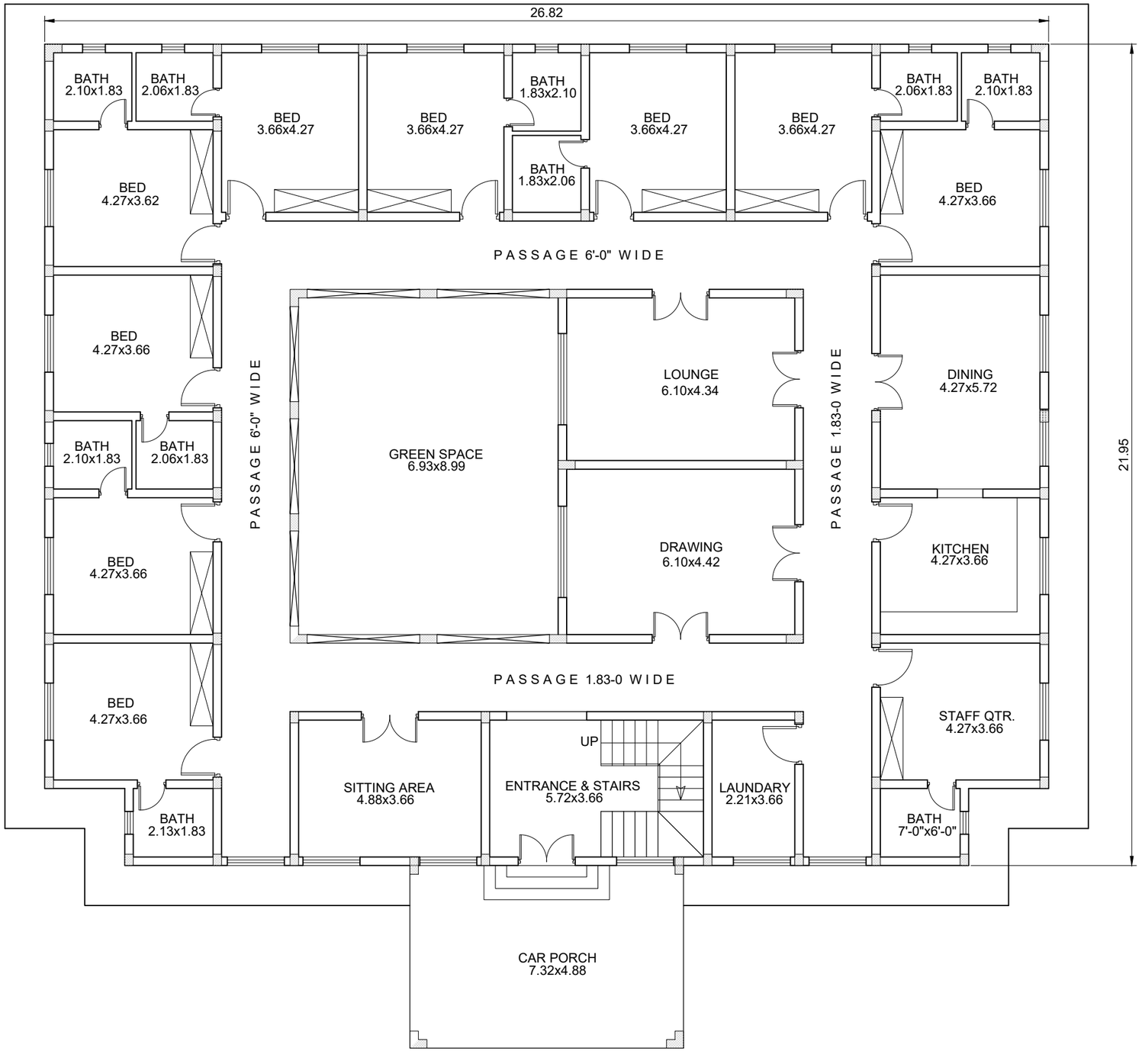
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

EXECUTIVE QUARTER

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	JAG-11-BLD-003
DATE	February-26		



GROUND FLOOR PLAN

COVERED AREA=552.65 sqm

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

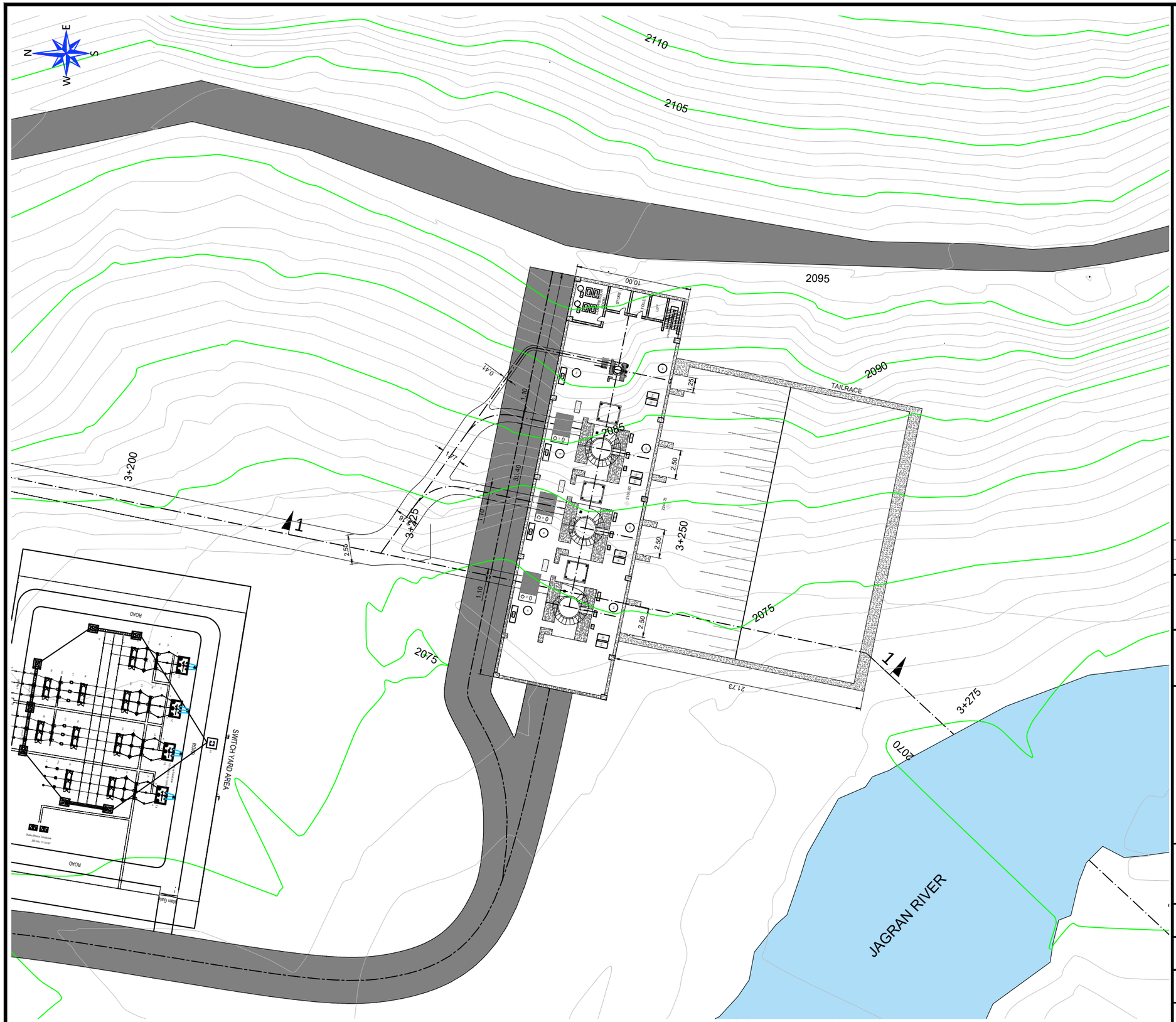
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

STAFF QUARTER

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	JAG-11-BLD-004
DATE	February-26		

12-MECHANICAL



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 5 10 15m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

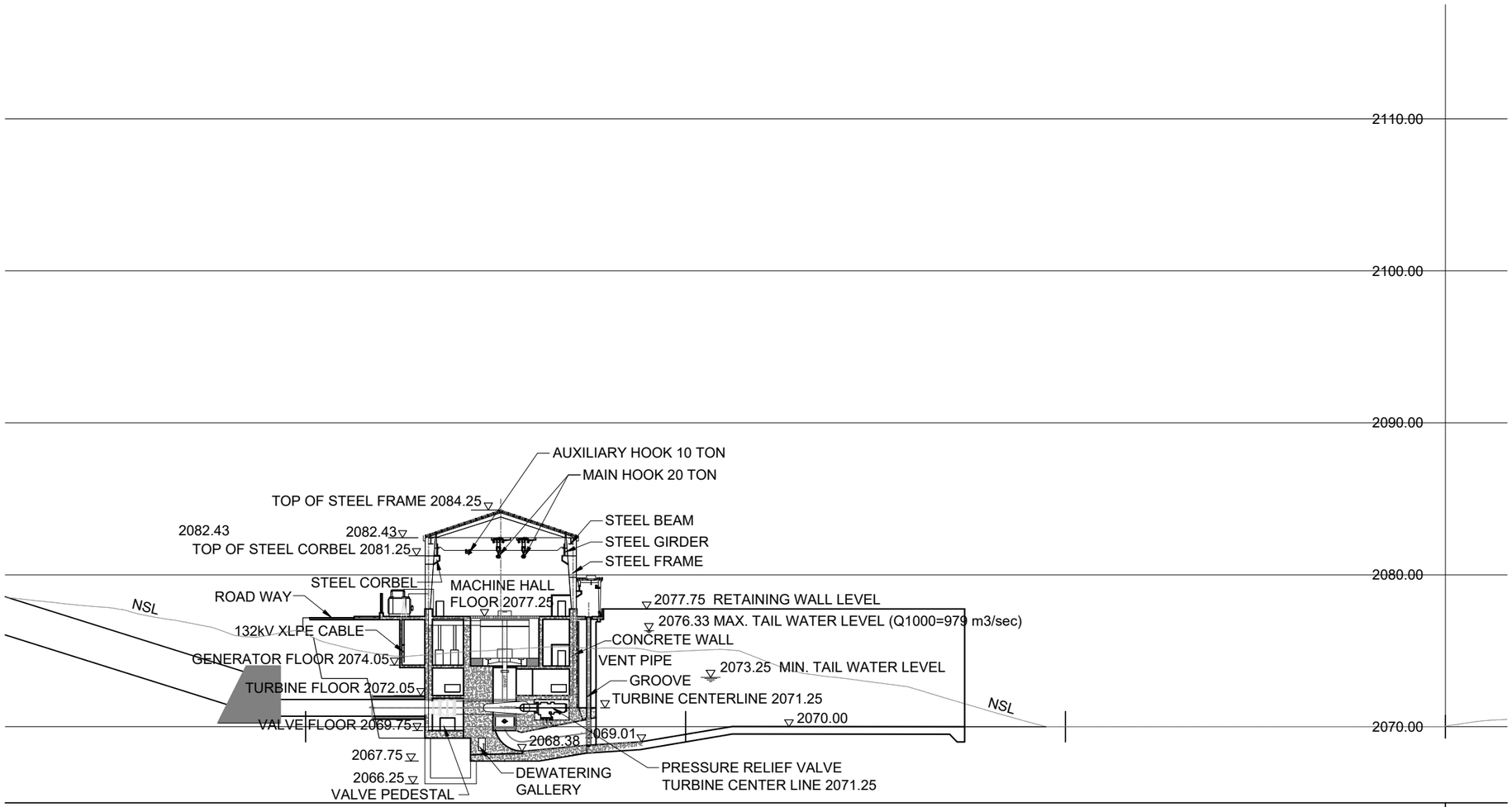
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LAYOUT PLAN OF POWER HOUSE

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-002	



3+225	2076.21	3+250	2074.99	3+275	2070.00	3+300	2070.04
3+225	2070.71	3+250	2073.25	3+275	2073.25	3+300	2073.25

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 5 10 15m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

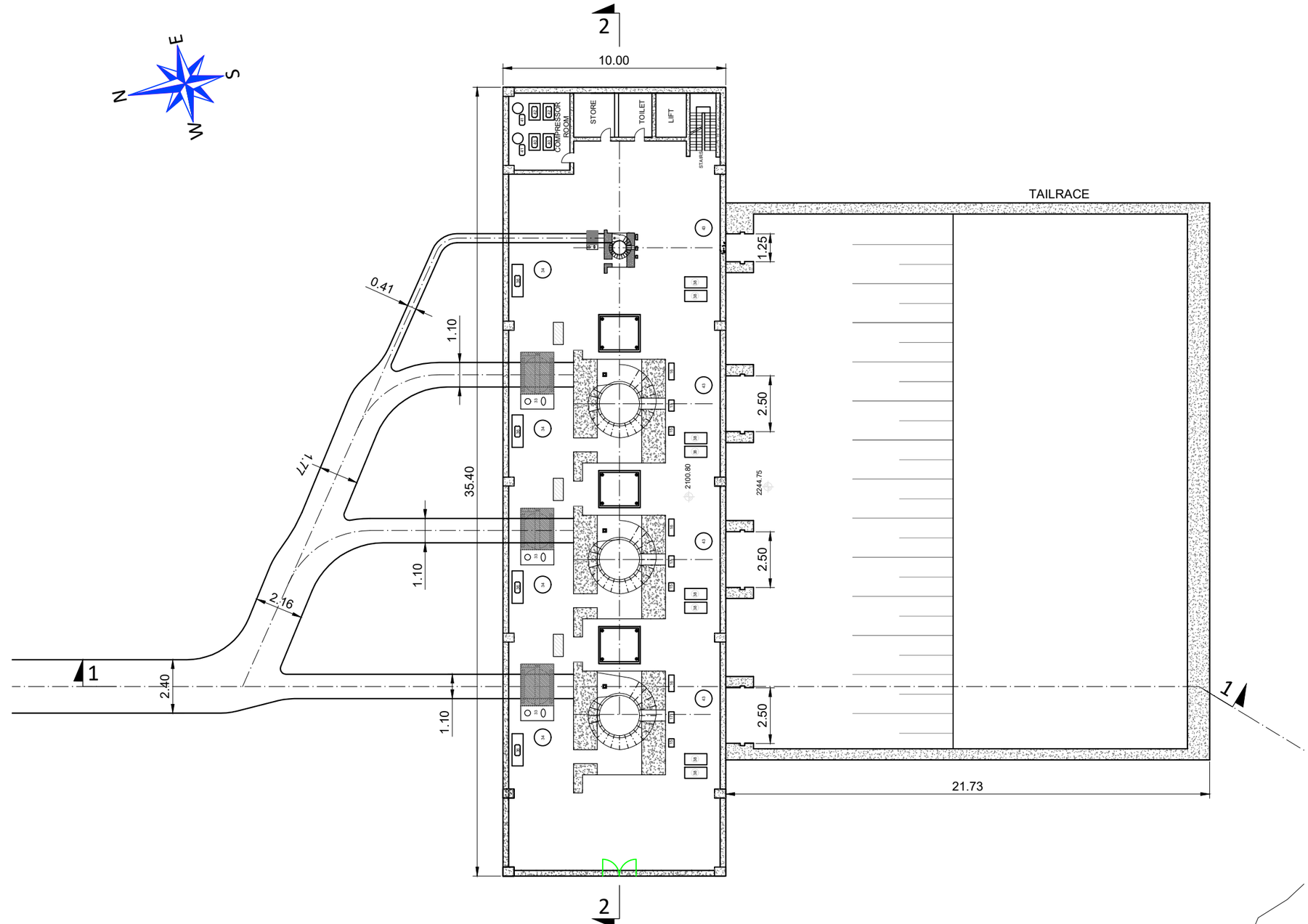
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SECTION 1-1 OF POWER HOUSE

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-003	



PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6 8 10m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

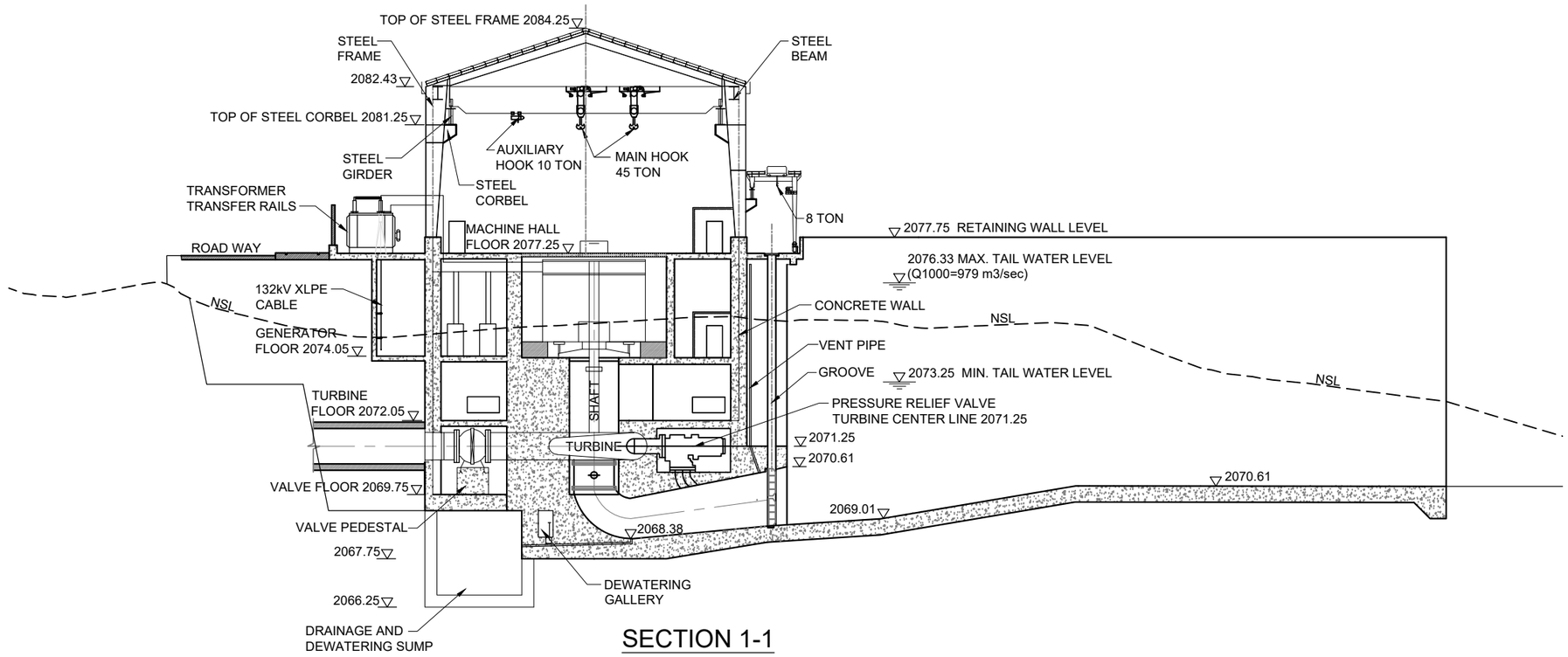
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

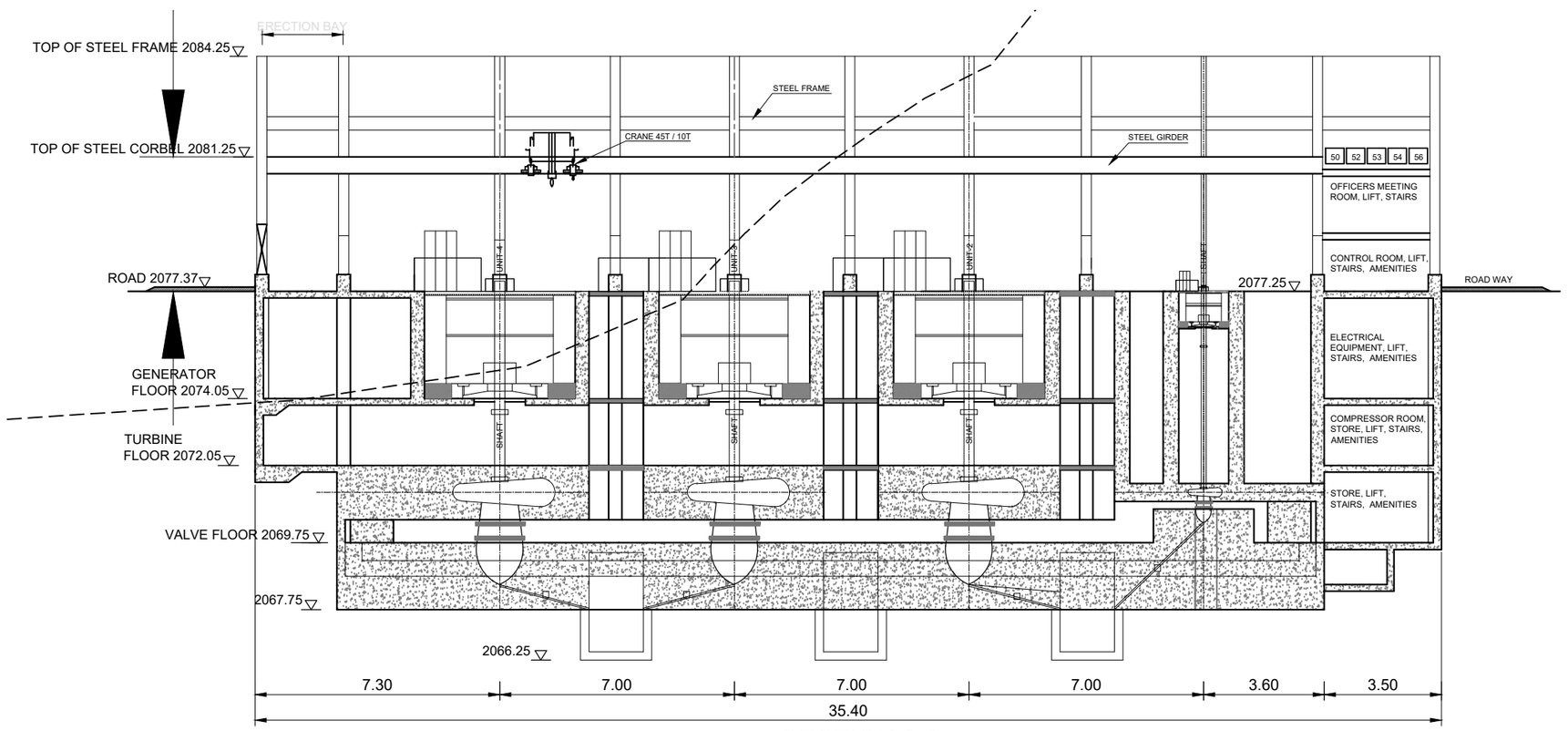
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

POWER HOUSE PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-004	



SECTION 1-1



SECTION 2-2

NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

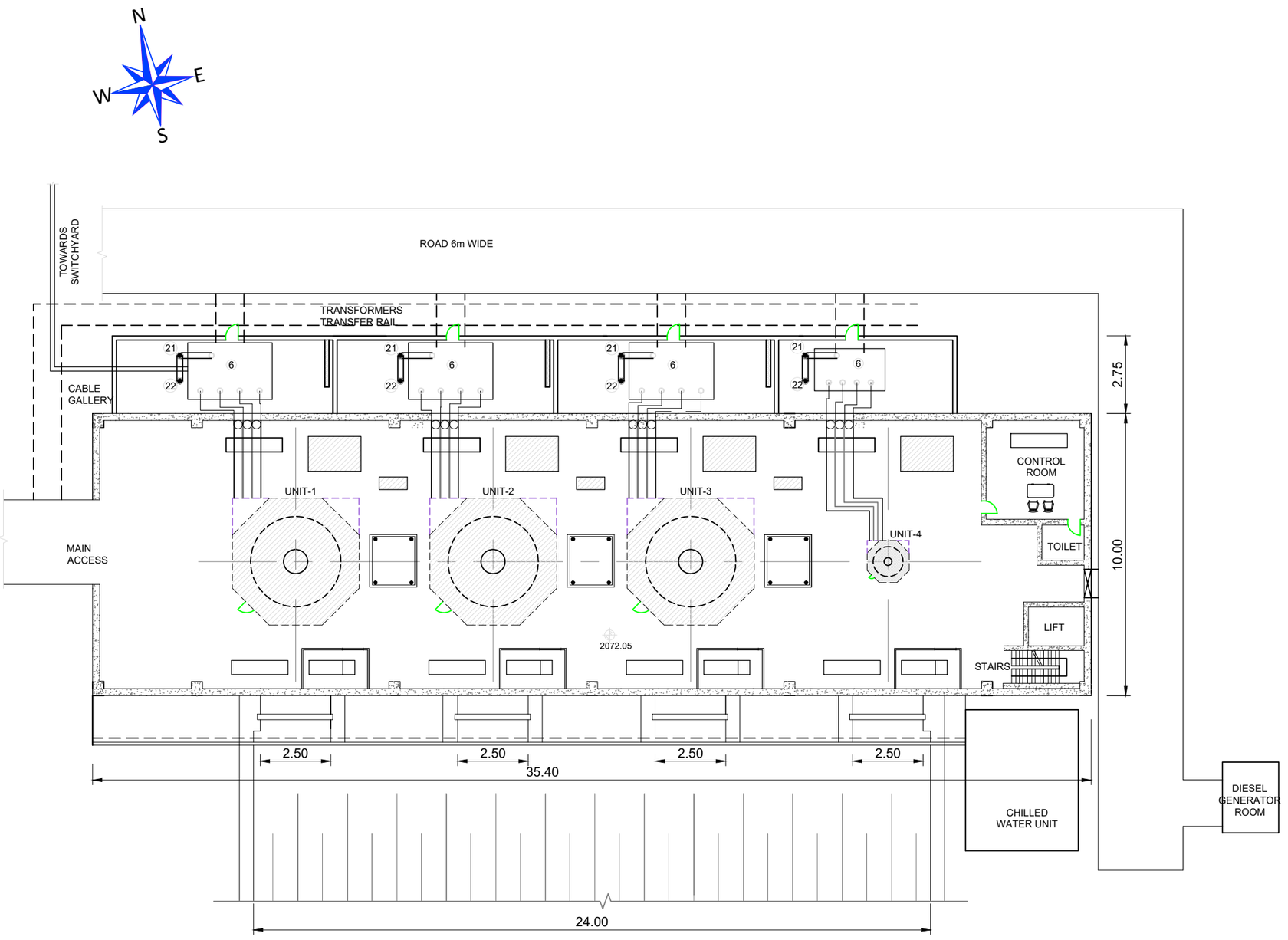
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

POWER HOUSE SECTIONS

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-005	



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).

SCALE:-

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

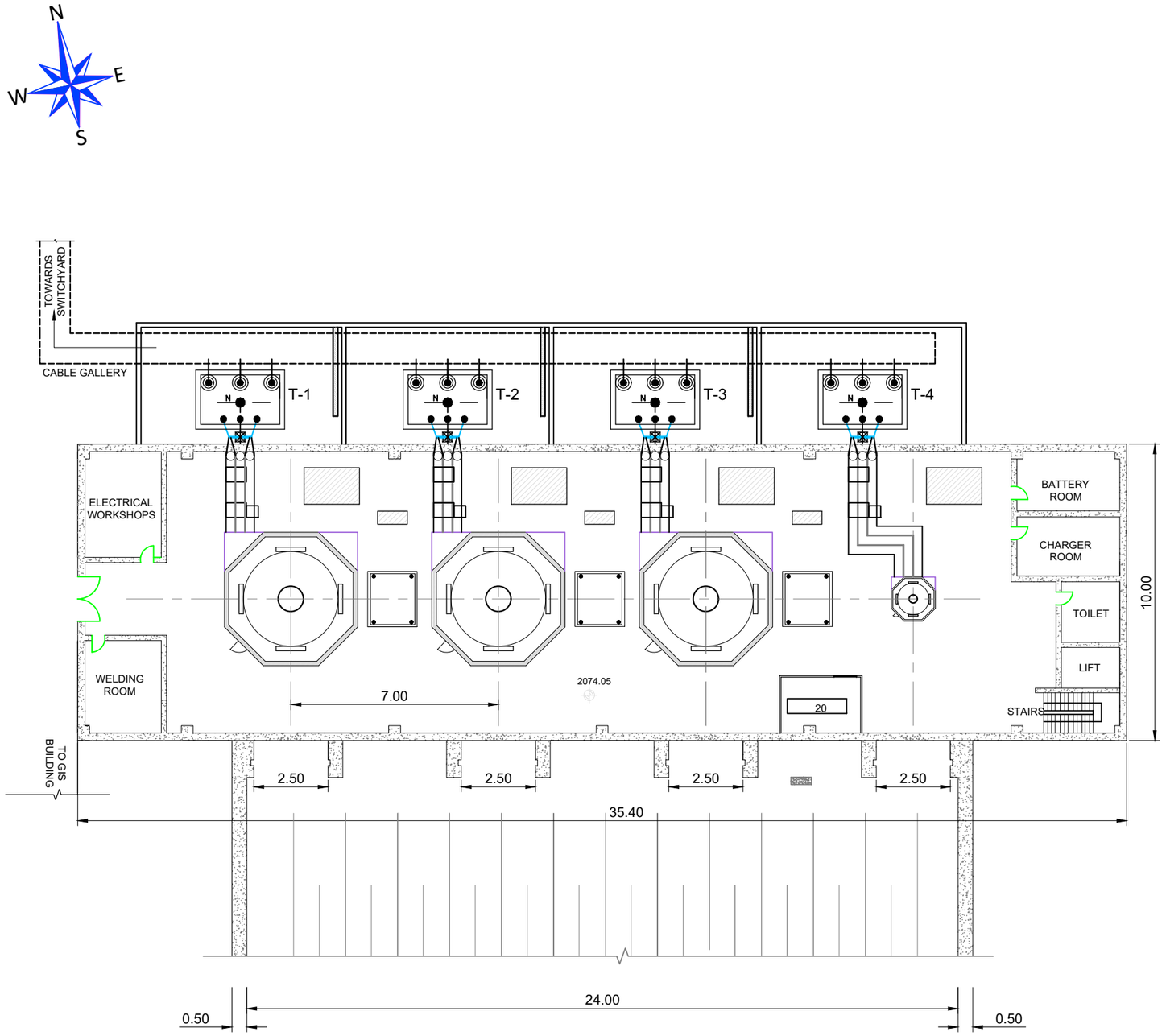
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

MACHINE HALL PLAN EL. 2072.05

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-006	



NOTES:

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. ALL ELEVATIONS ARE IN METERS ABOVE MEAN SEA LEVEL.
3. ALL COORDINATES ARE REFERENCED TO UTM ZONE (WGS-84 DATUM).
4. THE APPROXIMATE LENGTH OF UNDER GROUND TRENCH CONNECTING POWER HOUSE TO SWITCHYARD IS 40 METERS.

SCALE:-

0 2 4 6 8m

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

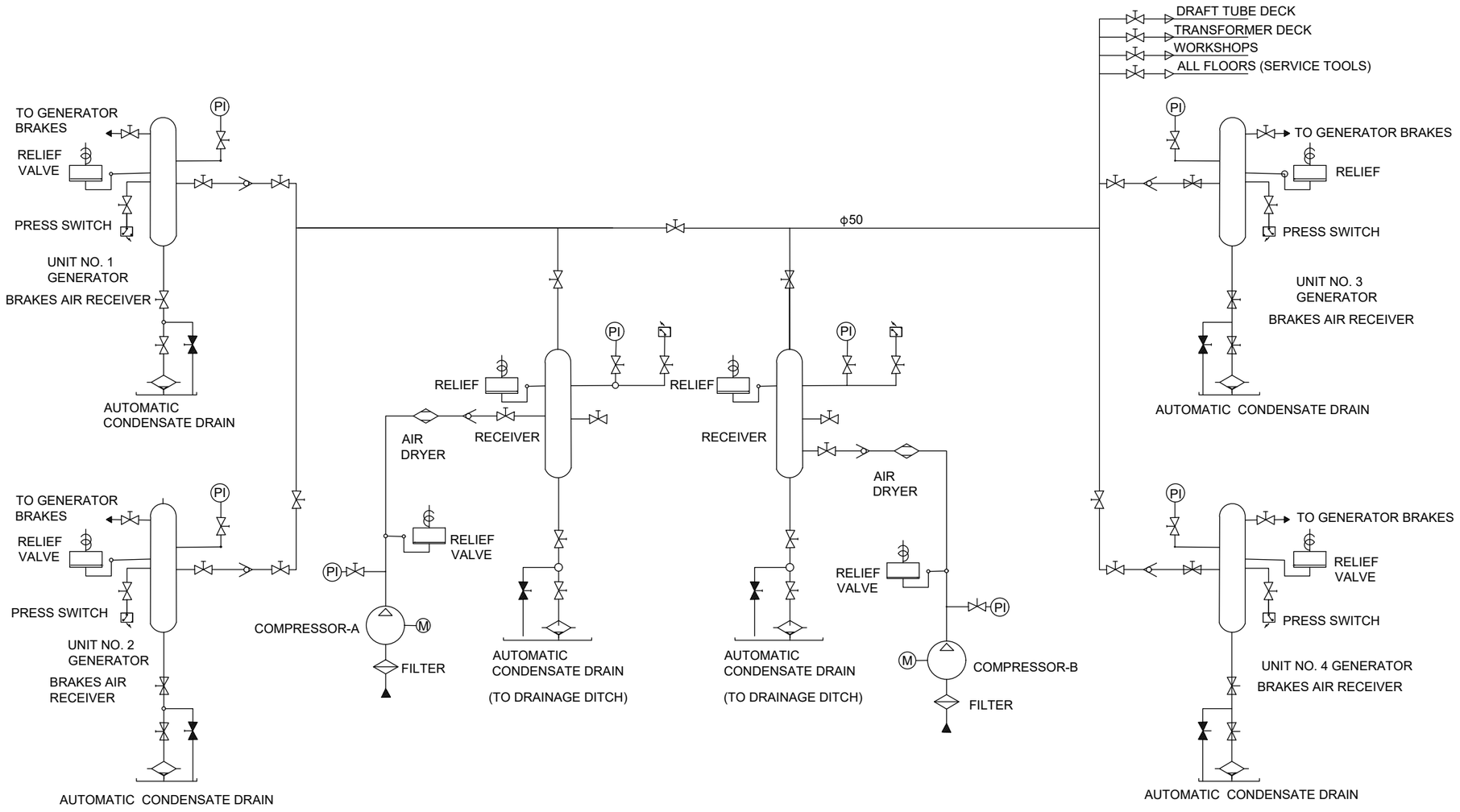
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

GENERATOR FLOOR PLAN EL. 2074.05

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-007	



NOTES:-

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHER WISE NOTED.
2. THE DETAILS SHOWN IN THIS DRAWING ARE INDICATIVE ONLY. FINAL STAGE DETAILS SHALL BE DEVELOPED BY THE EPC CONTRACTOR AT DESIGN.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

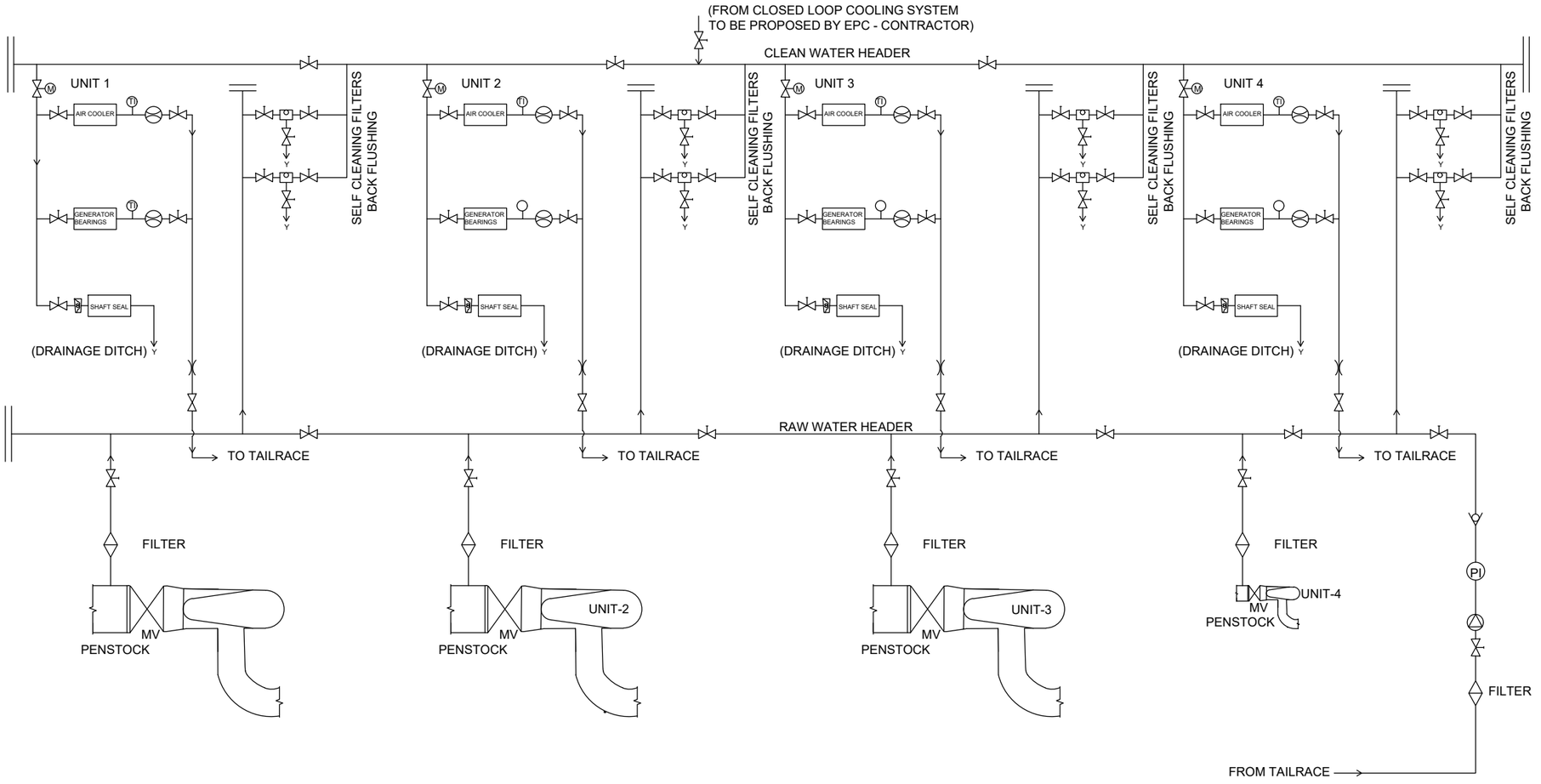
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LP COMPRESSED AIR SYSTEM

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-008	



NOTES:-

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHER WISE NOTED.
2. THE DETAILS SHOWN IN THIS DRAWING ARE INDICATIVE ONLY. FINAL STAGE DETAILS SHALL BE DEVELOPED BY THE EPC CONTRACTOR AT DESIGN.
3. CLOSED LOOP COOLING WATER SYSTEM WILL PROVIDE CLEAN COOLING WATER FOR ALL AIR COOLERS, GENERATOR BEARINGS AND SHAFT SEALS OF ALL 4 UNITS.
4. OPEN LOOP COOLING WATER SYSTEM WILL DRAW RAW COOLING WATER FROM U/S OF MIVs AND COOL DAWN THE CLOSED LOOP WATER THROUGH HEAT EXCHANGERS (TUBE & PLATE) & WILL BE DRAINED OUT TO TAIL RACE CHANNEL.
5. EPC CONTRACTOR WILL SUBMIT THE FINAL DESIGN OF COOLING WATER SYSTEM BASED ON MANUFACTURER'S DATA OF HEAT GENERATION AND REQUIRED DISSIPATION RATE.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)	PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

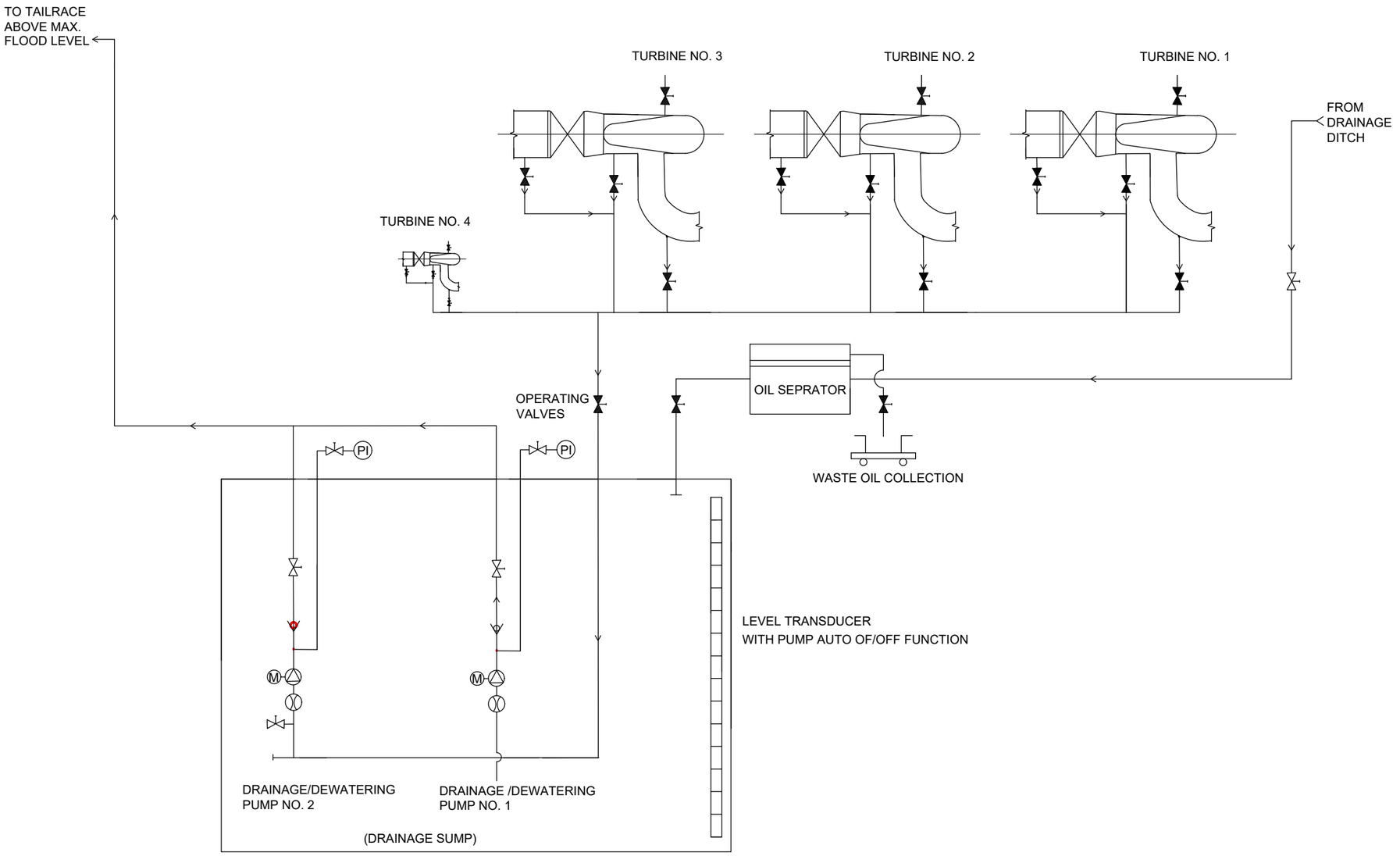
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SCHEMATIC DRAWING OF COOLING WATER SYSTEM

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-009	



NOTES:-

1. ALL DIMENSIONS ARE IN METERS UNLESS OTHER WISE NOTED.
2. THE DETAILS SHOWN IN THIS DRAWING ARE INDICATIVE ONLY. FINAL STAGE DETAILS SHALL BE DEVELOPED BY THE EPC CONTRACTOR AT DESIGN.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SCHEMATIC DRAWING FOR DRAINAGE AND DEWATERING SYSTEM

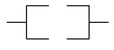
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	AS SHOWN	DRAWING No.	
DATE	February-26	JAG-10-MEC-010	

13-ELECTRICAL

LEGEND

SYMBOL	DESCRIPTION
	PUMP
	NORMALLY CLOSED VALVE
	MOTOR-OPERATED VALVE
	NO RETURN VALVE
	PUMP
	FLOW SWITCH
	STRAINER
	PRESSURE RELIEF VALVE
	PIPE CONNECTION
	HYDROCYCLONE
	PRESSURE INDICATOR
	TEMPERATURE INDICATOR
	PRESS SWITCH
	COMPRESSOR

LEGEND

SYMBOL	DESCRIPTION
	DIRTY OIL TANK 1O m3
	CONDENSATE DRAIN
	MANUALLY OPERATED VALVE
	AIR DRYER
	OIL FILTER/ SEPRATOR
	AIR SCOUR
	FILTER
	OIL SKIMMER
	ORIFICE
	FIRE HOSE CABINET
	LEVEL SWITCH
	COUPLER
	PORTABLE PUMPING SYSTEM

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

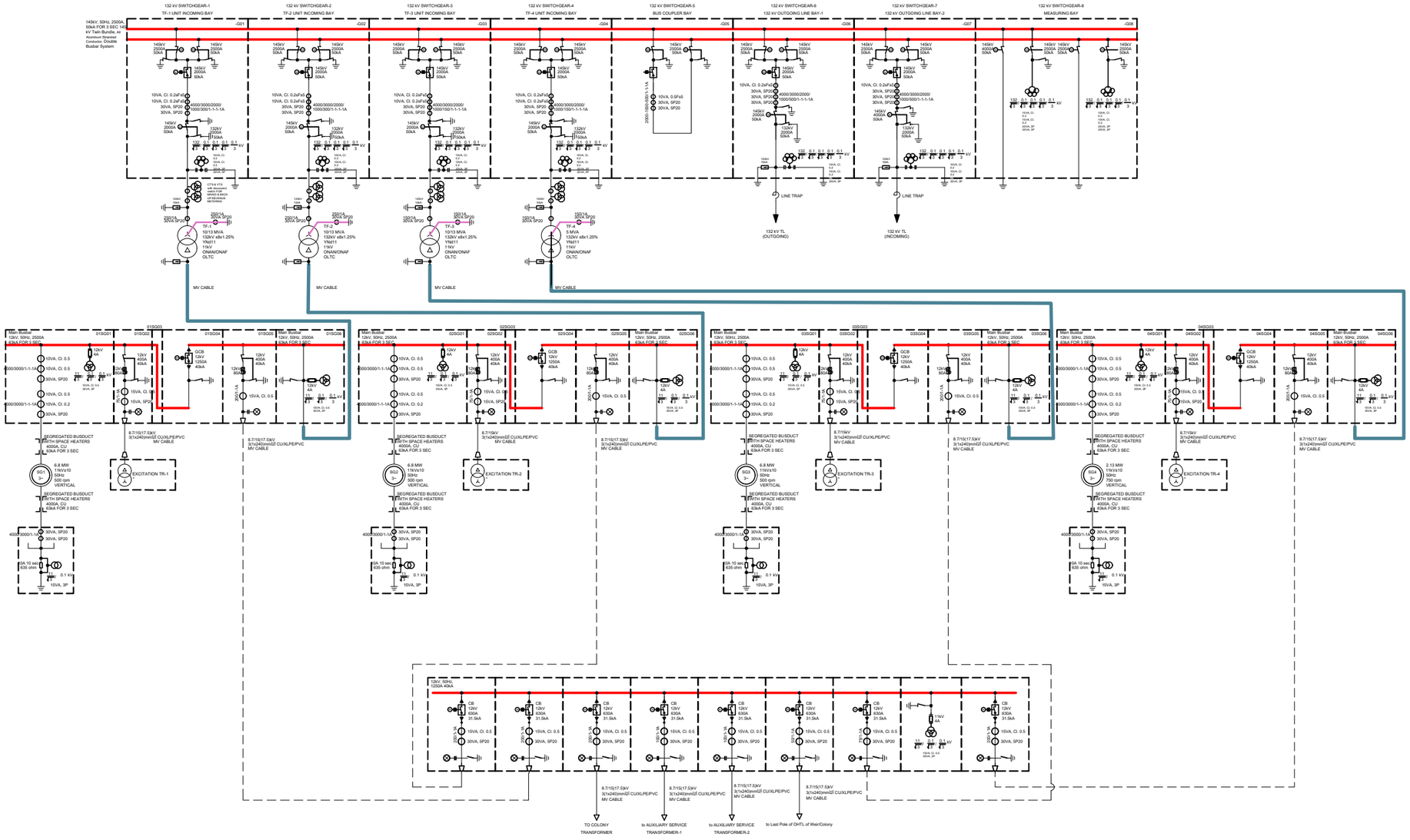
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

LEGEND

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-001	



* THE CAPACITY OF EXCITATION SYSTEM TRANSFORMER SHOULD BE CALCULATED BY THE CONTRACTOR ACCORDING TO THE MANUFACTURER DESIGN.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

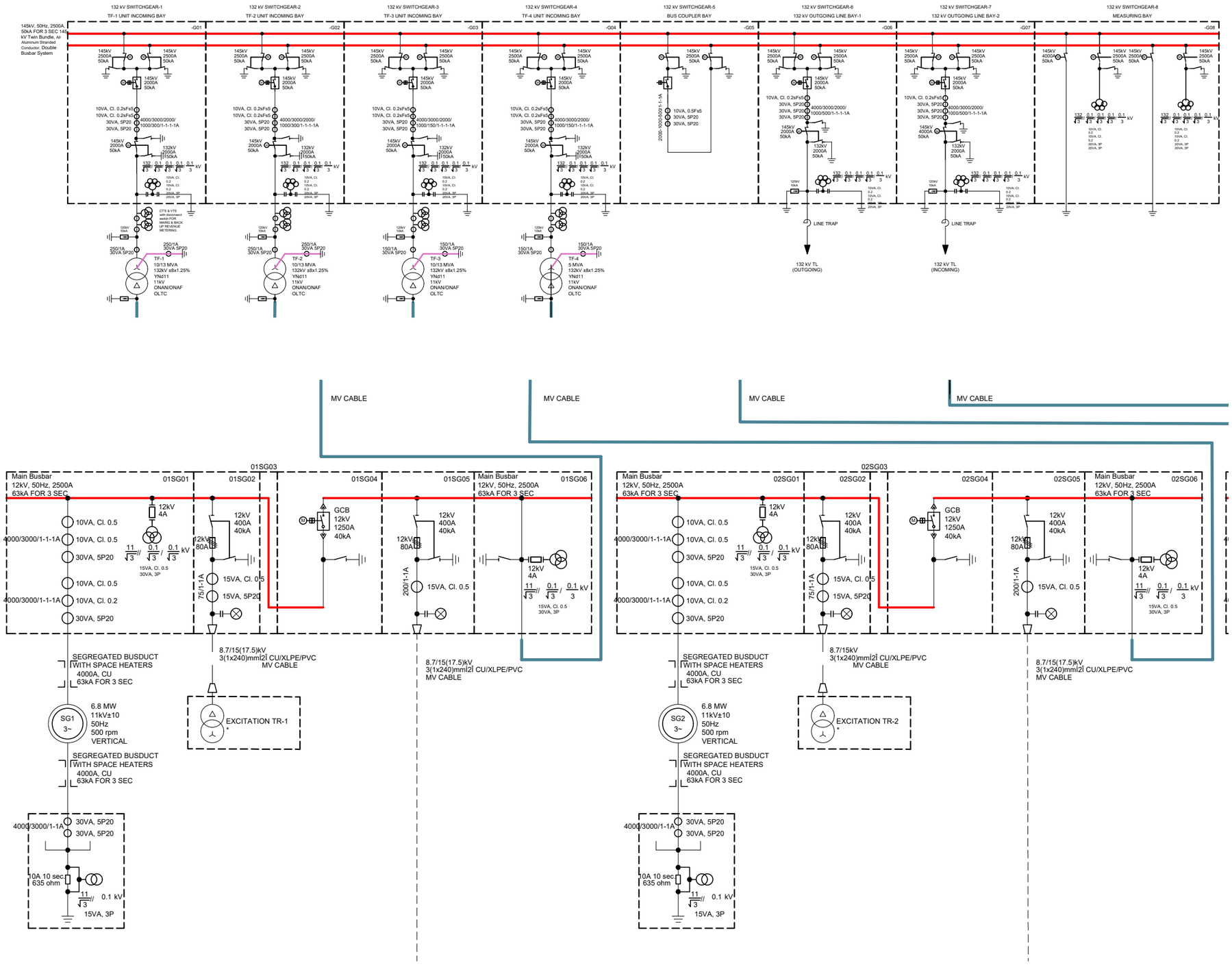
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SLD SINGLE LINE DIAGRAM

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-002	



REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

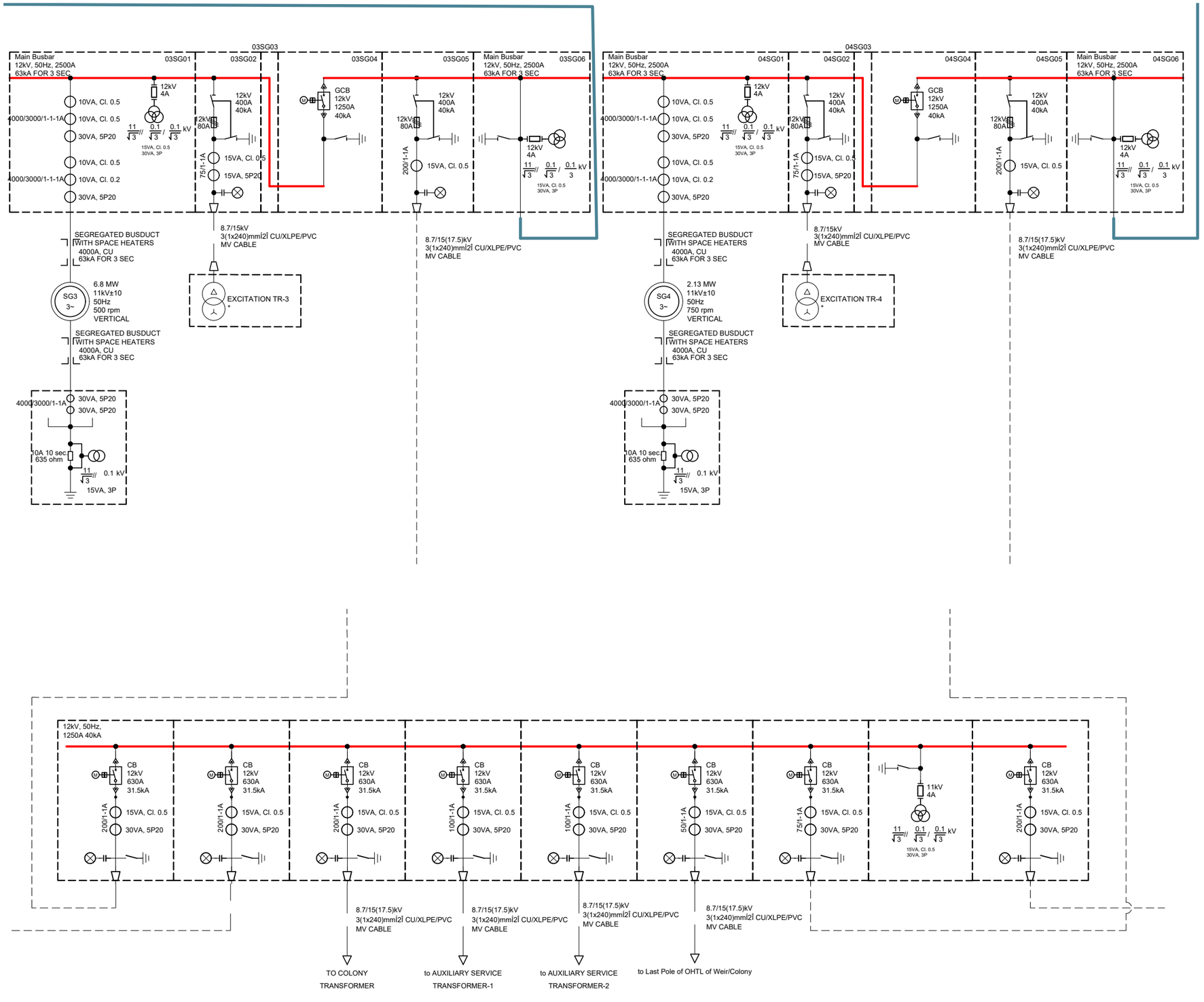
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SLD SINGLE LINE DIAGRAM ENLARGED PLAN

sheet 1 of 2

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	JAG-12-ELE-002
DATE	February-26		



REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

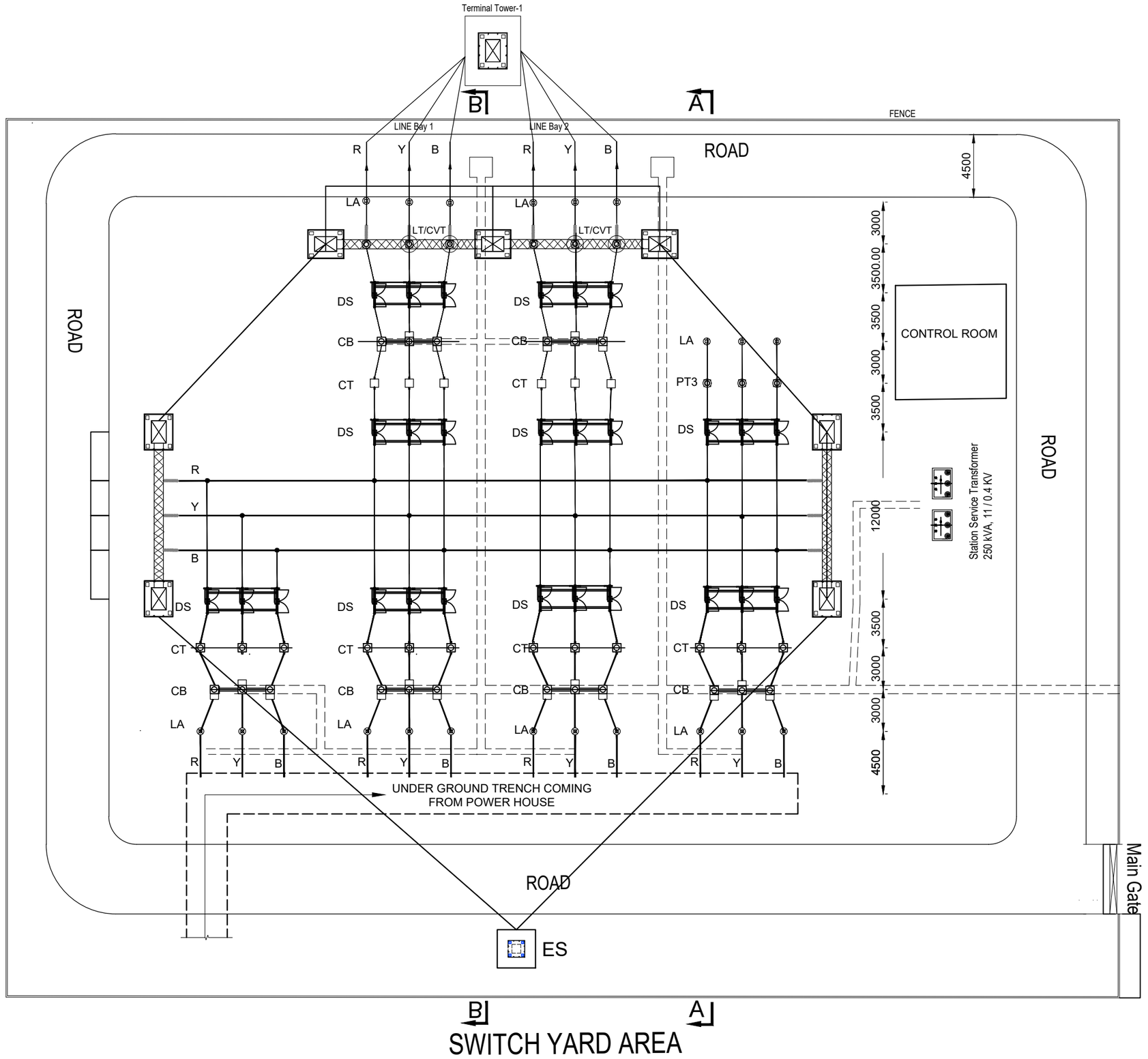
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SLD SINGLE LINE DIAGRAM ENLARGED PLAN

sheet 2 of 2

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	JAG-12-ELE-002
DATE	February-26		



NO.	NAME OF EQUIPMENT	LABEL
1	Lightning Arrester	LA
2	Potential Transformer	PT
3	Current Transformer	CT
4	Disconnecting Switch	DS
5	Circuit Breaker	CB
6	Wave/Line Trap	LT
7	Capacitive Voltage Transfomer	CVT
8	Earthing Mast	ES
9	Bus Bar Gantry	BG
10	Line Gantry	LG
12	Tension insulator string	Insu
13	Main Power Transformer	MTR
14	Station Service Transformer	SSTR
15	11 kV Cable Support Structure	CS
16	ACSR Conductor	Conductor
17	Earth Wire	EW
18	Boundry Fence	F
19	Transformer Way	T W
20	Local Supply Transformer	LTR

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

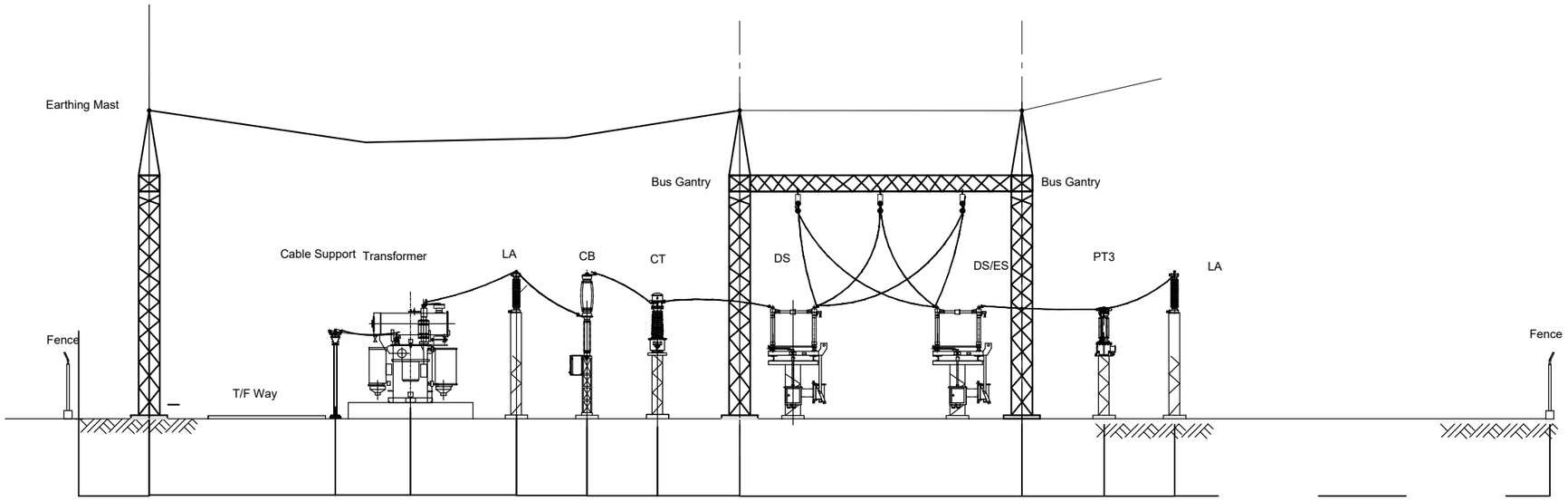
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

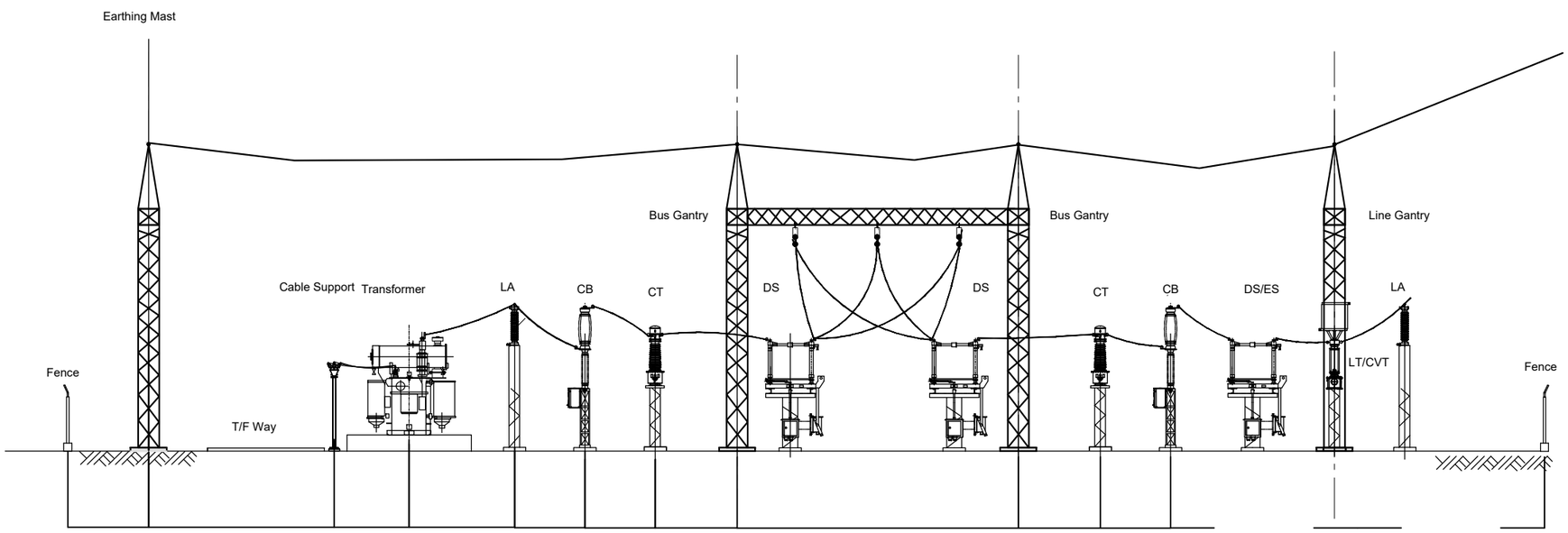
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SWITCHYARD LAYOUT PLAN

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-003	



SECTION A–A



SECTION B–B

NOTES:

1. THE TRANSFORMERS SHOWN IN THE SUBJECT DRAWING ARE IMAGINARY JUST FOR BETTER UNDERSTANDING, ORIGINALLY THE TRANSFORMERS ARE LOCATED IN THE POWER HOUSE AND CONNECTED WITH THE SWITCHYARD THROUGH UNDER GROUND CABLE TRENCH.

NO.	NAME OF EQUIPMENT	LABEL
1	Lightning Arrester	LA
2	Potential Transformer	PT
3	Current Transformer	CT
4	Disconnecting Switch	DS
5	Circuit Breaker	CB
6	Wave/Line Trap	LT
7	Capacitive Voltage Transfomer	CVT
8	Earthing Mast	ES
9	Bus Bar Gantry	BG
10	Line Gantry	LG
12	Tension insulator string	Insu
13	Main Power Transformer	MTR
14	Station Service Transformer	SSTR
15	11 kV Cable Support Structure	CS
16	ACSR Conductor	Cond.
17	Earth Wire	EW
18	Boundry Fence	F
19	Transformer Way	T W

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

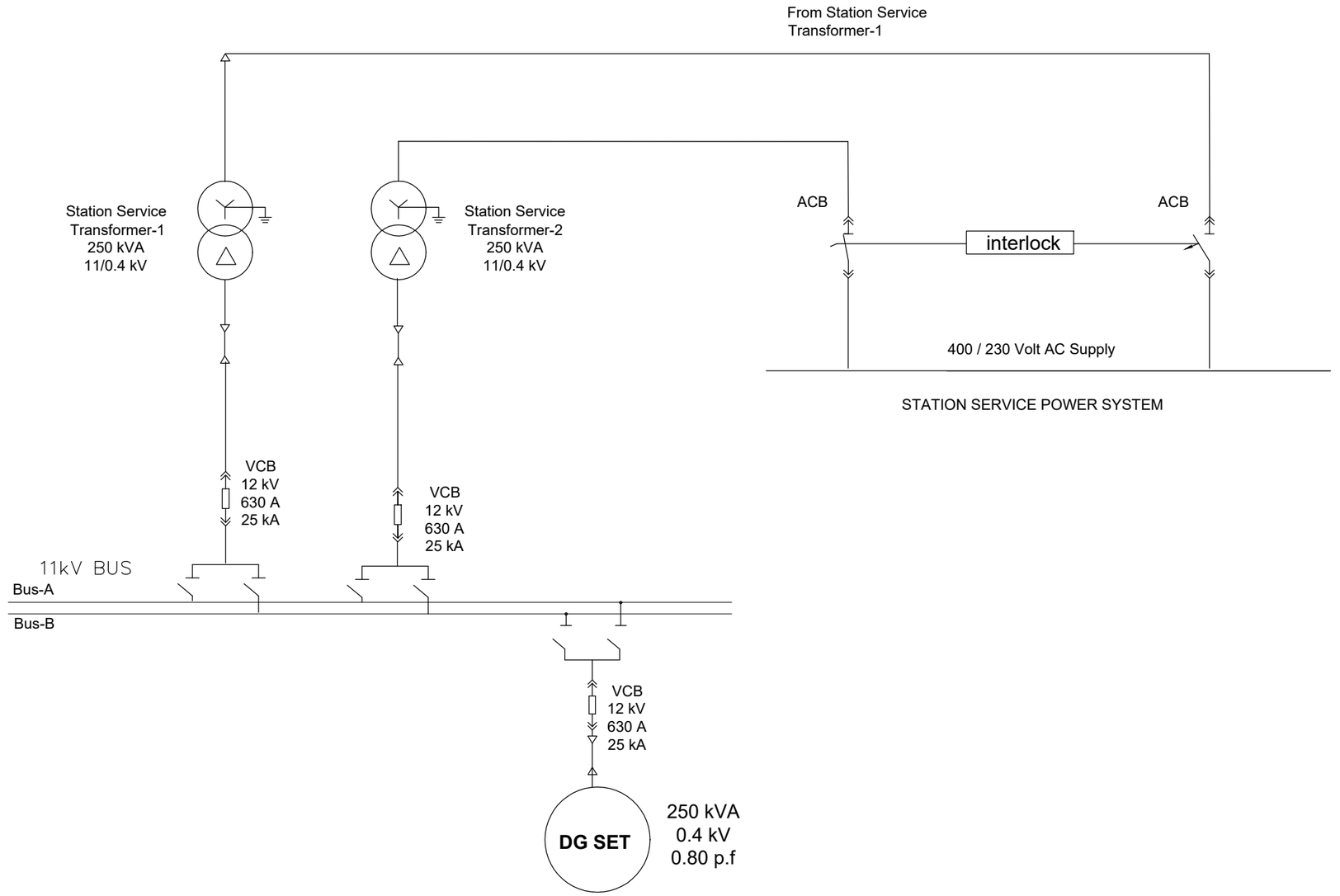
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

SECTION VIEW
132 kV SWITCHYARD

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-004	



STATION SERVICE POWER SYSTEM

Notes:-

1. This drawing indicates the basic concept of typical station supply system. The contractor shall develop the final scheme during detail design.

2. The contractor shall calculate the exact capacity of station service transformers and DG set based on the exact loads/ratings of connected equipment .

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

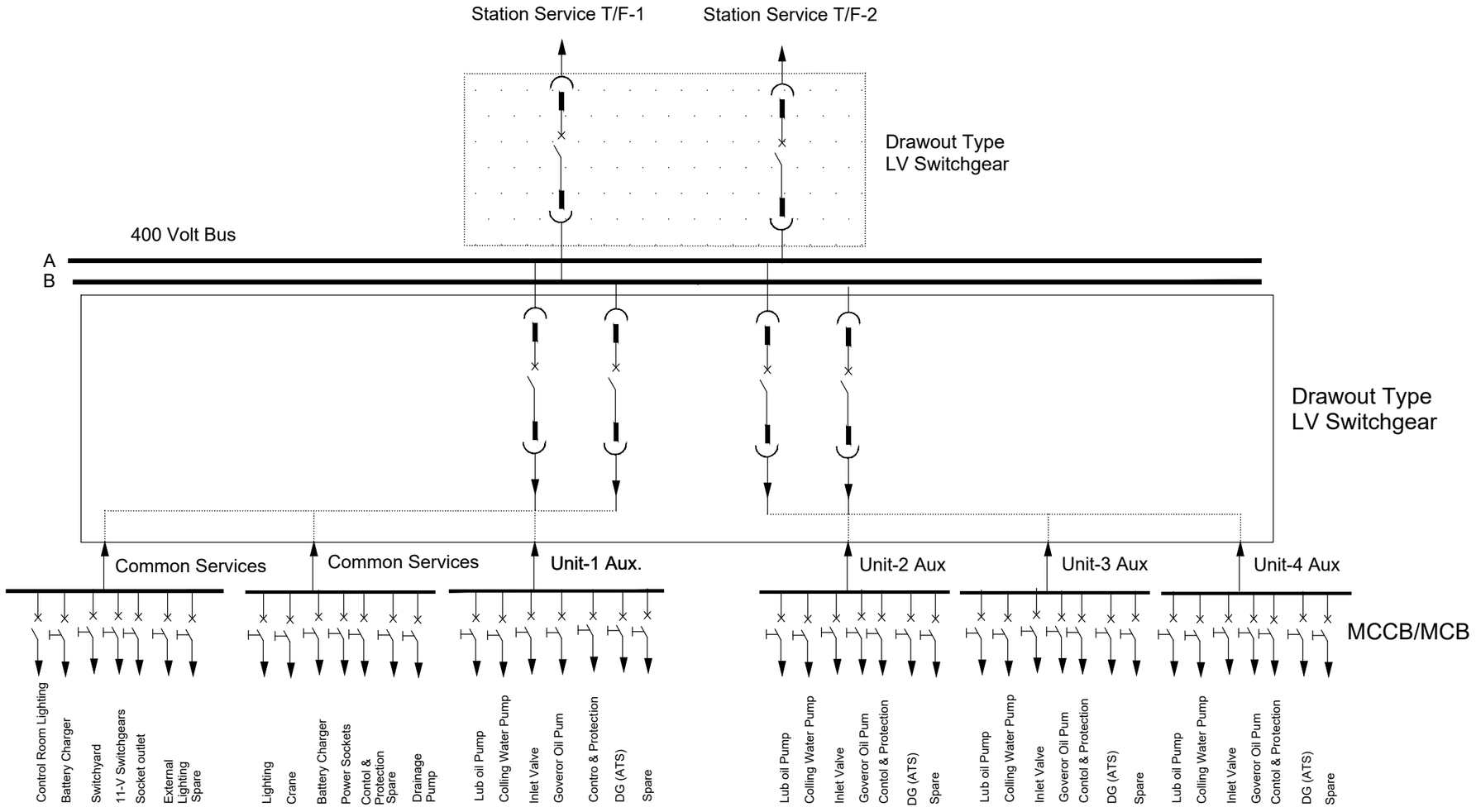
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

STATION SERVICE SUPPLY SWICHYARD & POWERHOUSE

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-005	



Notes:-

This drawing indicates general schematic arrangement of 400 Volts Distribution System for Jagran-IV Power House and Switchyard. The contractor shall design final comprehensive scheme in accordance with the requirement of the Substation.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

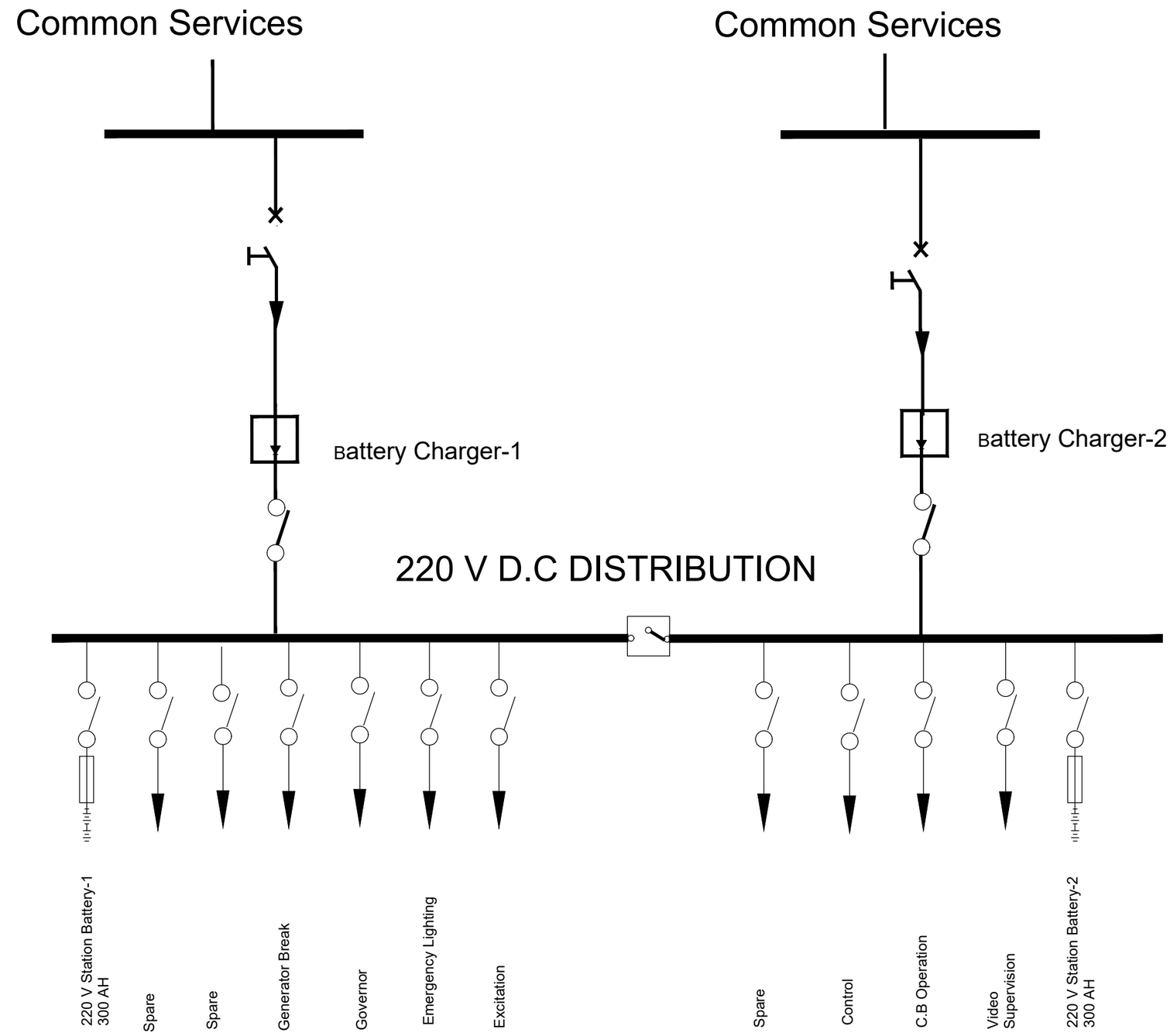
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

400 V DISTRIBUTION SYSTEM POWER PLANT

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-006	



Notes:-

This drawing indicates general schematic arrangement of DC Distribution System for Jagran-IV Powerhouse & Switchyard. The contractor shall design final comprehensive scheme in accordance with the requirement of the Substation.

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)	PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

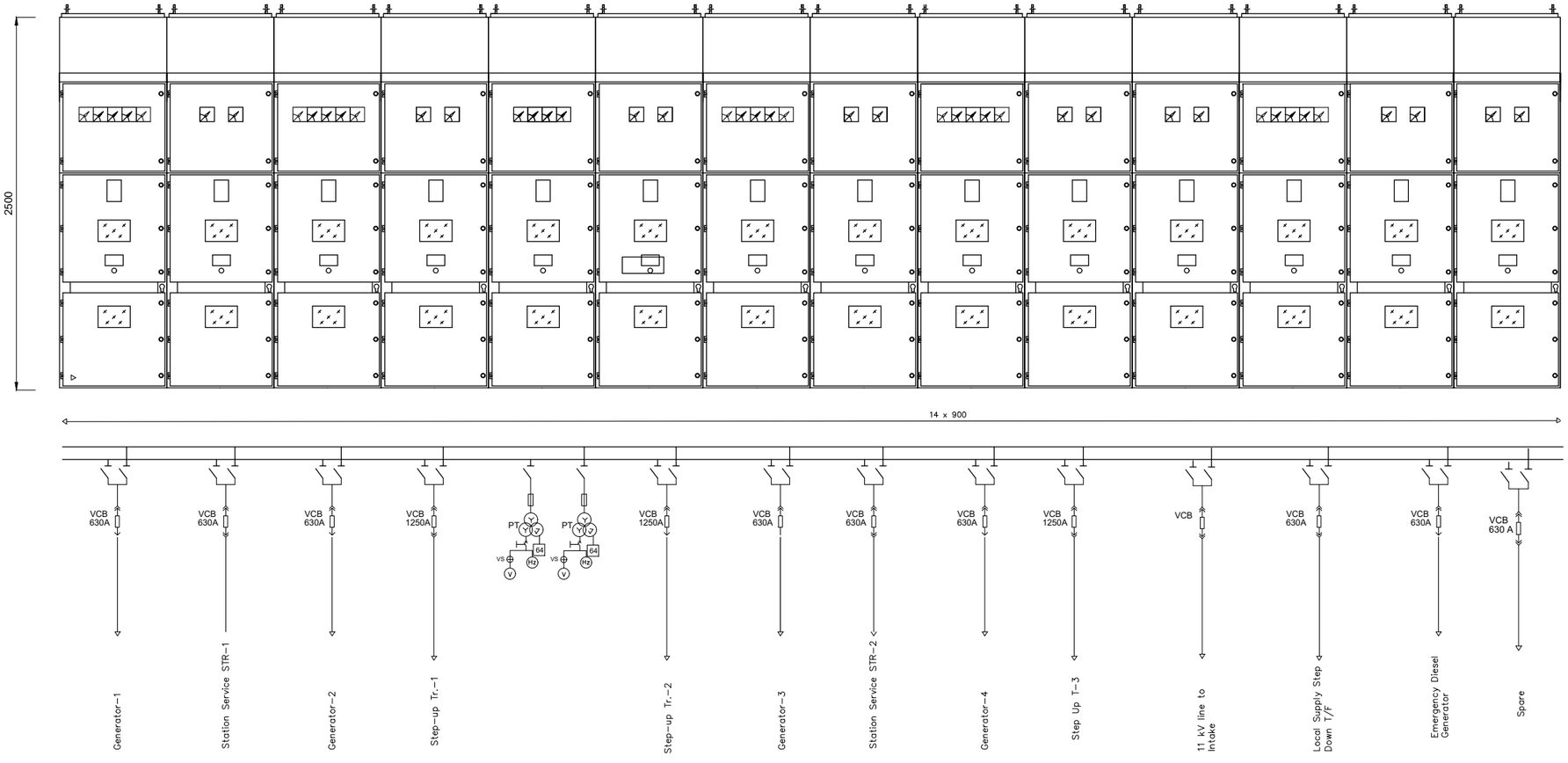
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

DC DISTRIBUTION SYSTEM
POWER PLANT

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-007	



REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

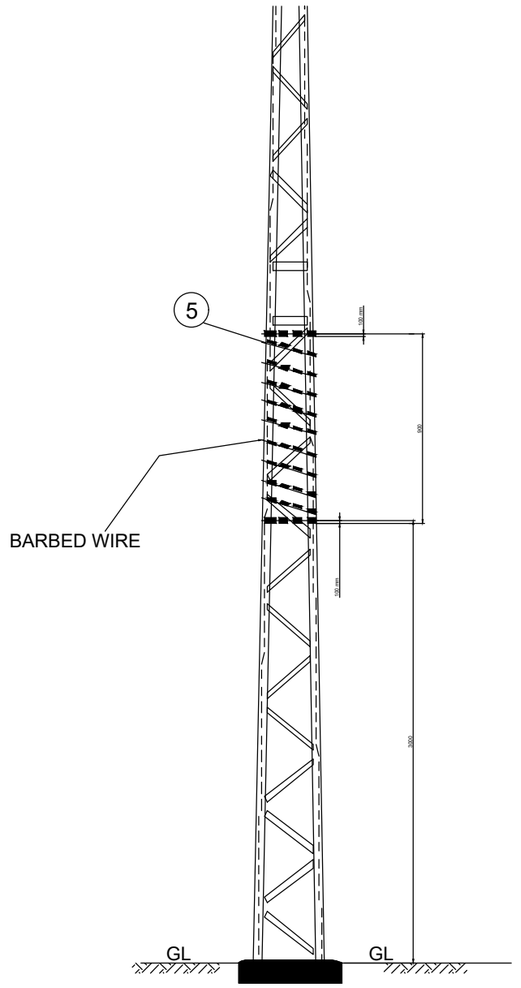
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

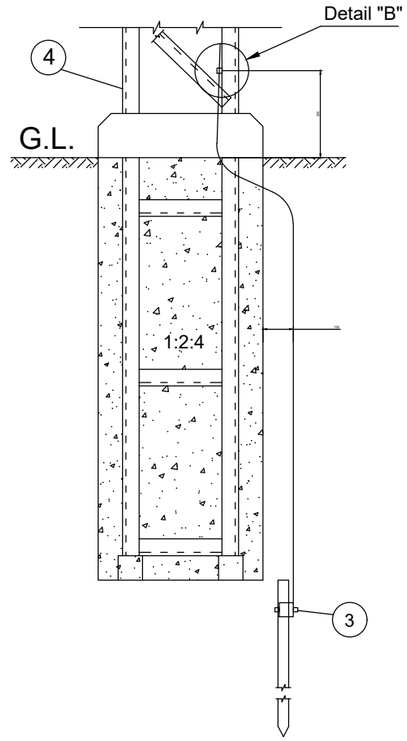
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

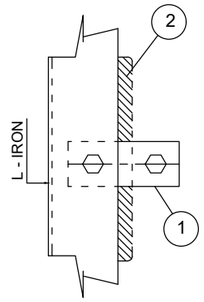
MV SWITCHGEAR ARRANGEMENT POWER PLANT

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	JAG-12-ELE-008
DATE	February-26		



STEEL STRUCTURE





DETAIL "B"

NOTE:

1. Grounding Conductor WAPDA Specification P-16:68
2. Galvanized steel wire (7/3.2mm-10 mm) strand WAPDA Specs P-12
3. Lattice steel Structure WAPDA Specs, P-34
4. Barded wire, according to WAPDA Specification P-162:81
5. Danger and Sign Plates according to WAPDA Specification P-104:76
6. Earthing Rod in accordance with WAPDA Specification P-116:81
7. All dimensions are in MM except where stated otherwise

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

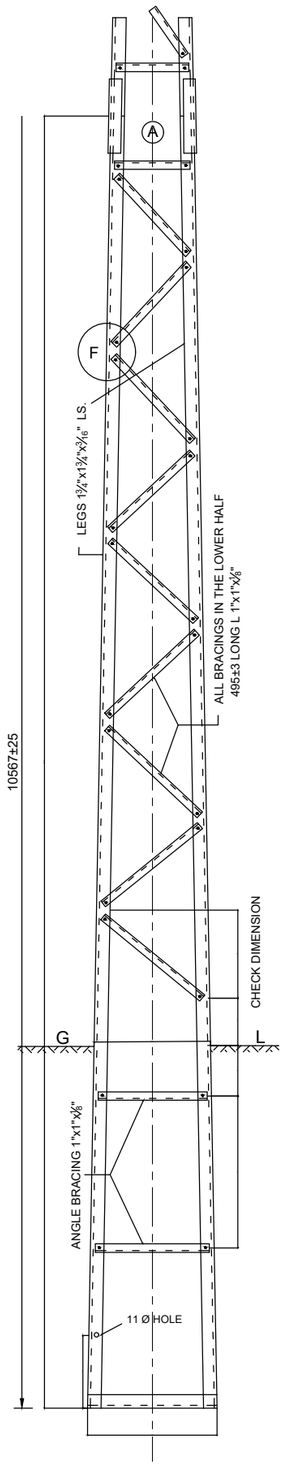
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

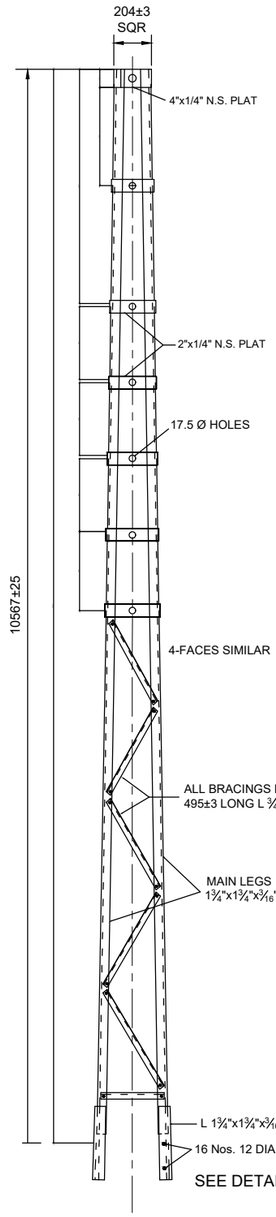
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

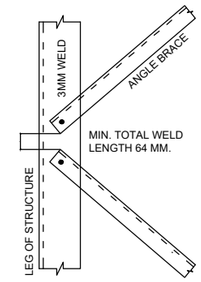
11 kV LATTICE STRUCTURE EARTHING

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-009	

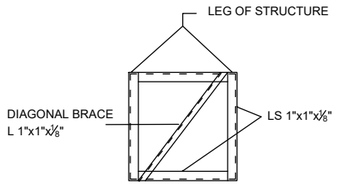




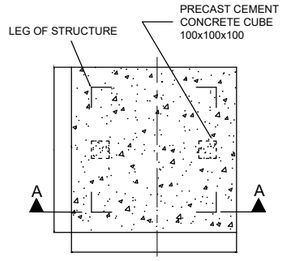
ALL DIMENSIONS IN MILLIMETERS
EXCEPT WHERE STATED OTHERWISE.



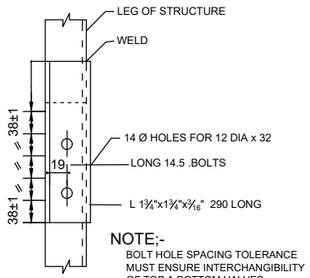
DETAIL AT F



DETAIL AT A

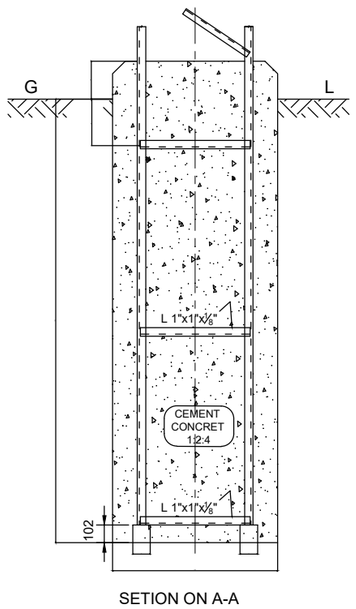


FOUNDATION PLAN



NOTE;-
BOLT HOLE SPACING TOLERANCE
MUST ENSURE INTERCHANGIBILITY
OF TOP A BOTTOM HALVES

DETAIL AT M



SETION ON A-A

NOTE:-

1. All Dimensions are in Millimeters
2. Material - Mild Steel in accordance with to ASTM A-36 or 8815
3. Finish - Hot dip Galvanized in accordance with WAPDA Specification P-82:81
4. Bolts in accordance with ASTM A-394
5. Structure to be manufactured and tested in accordance with WAPDA Specification P-34

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

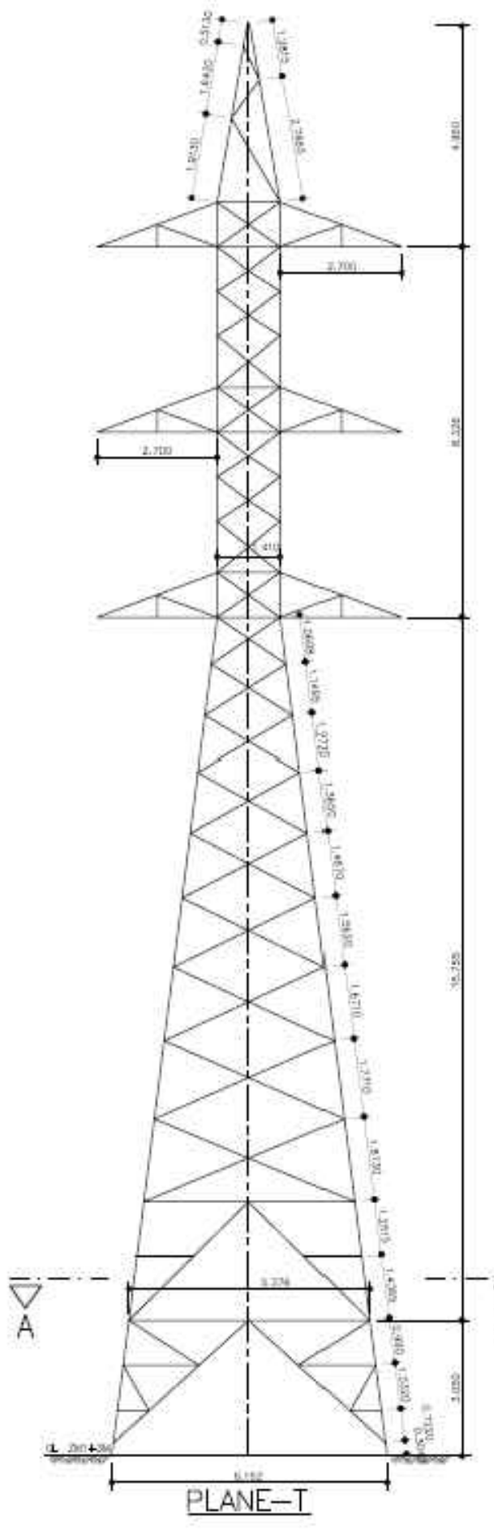
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

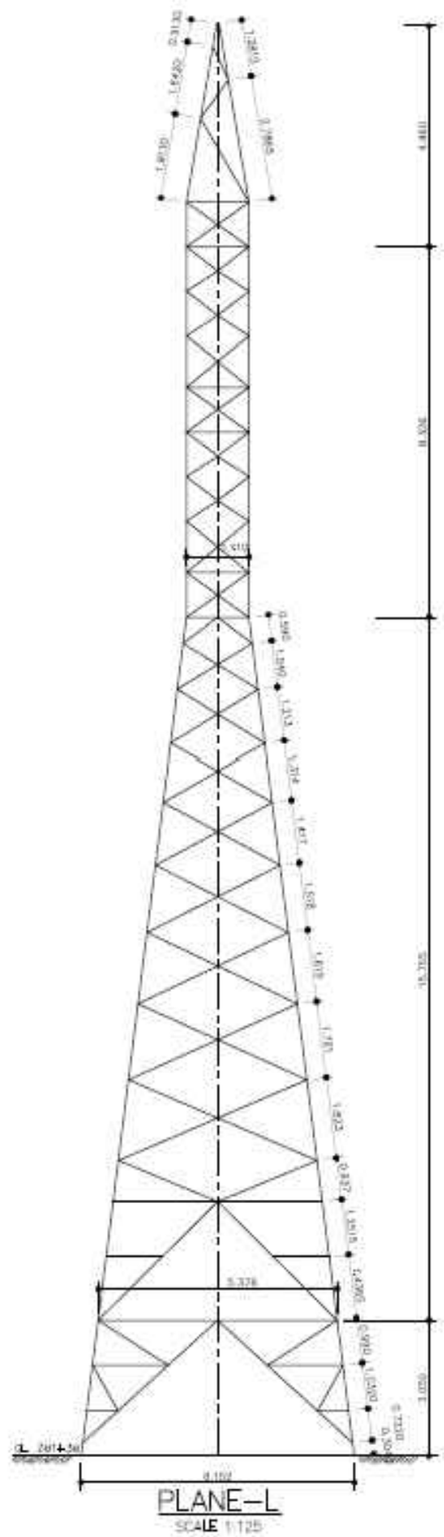
Saud Consult Saudi Consulting Services Company, KSA

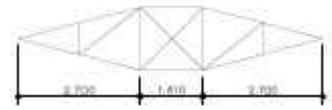
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

11 kV LATTICE STRUCTURE & FOUNDATION

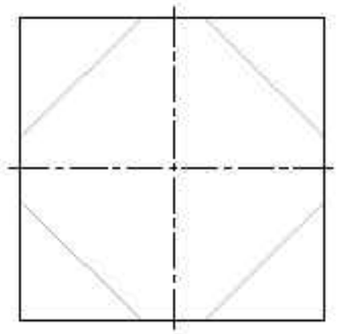
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	JAG-12-ELE-010
DATE	February-26		



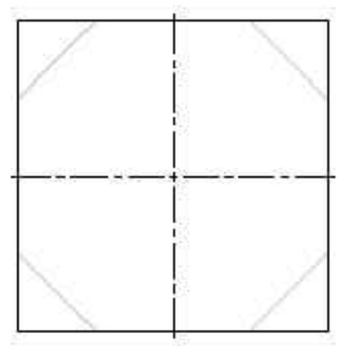




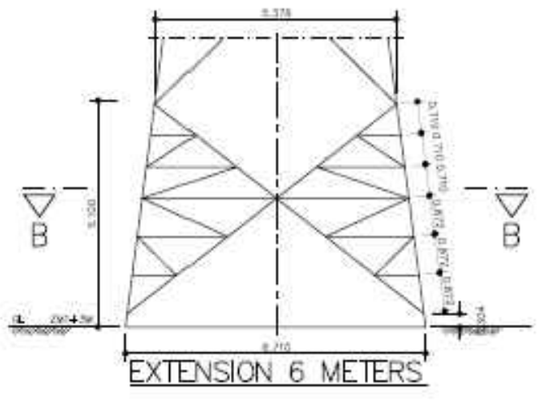
CROSS ARM



SECTION A–A



SECTION B–B



0		-
REV	DATE	DESCRIPTION

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)	PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

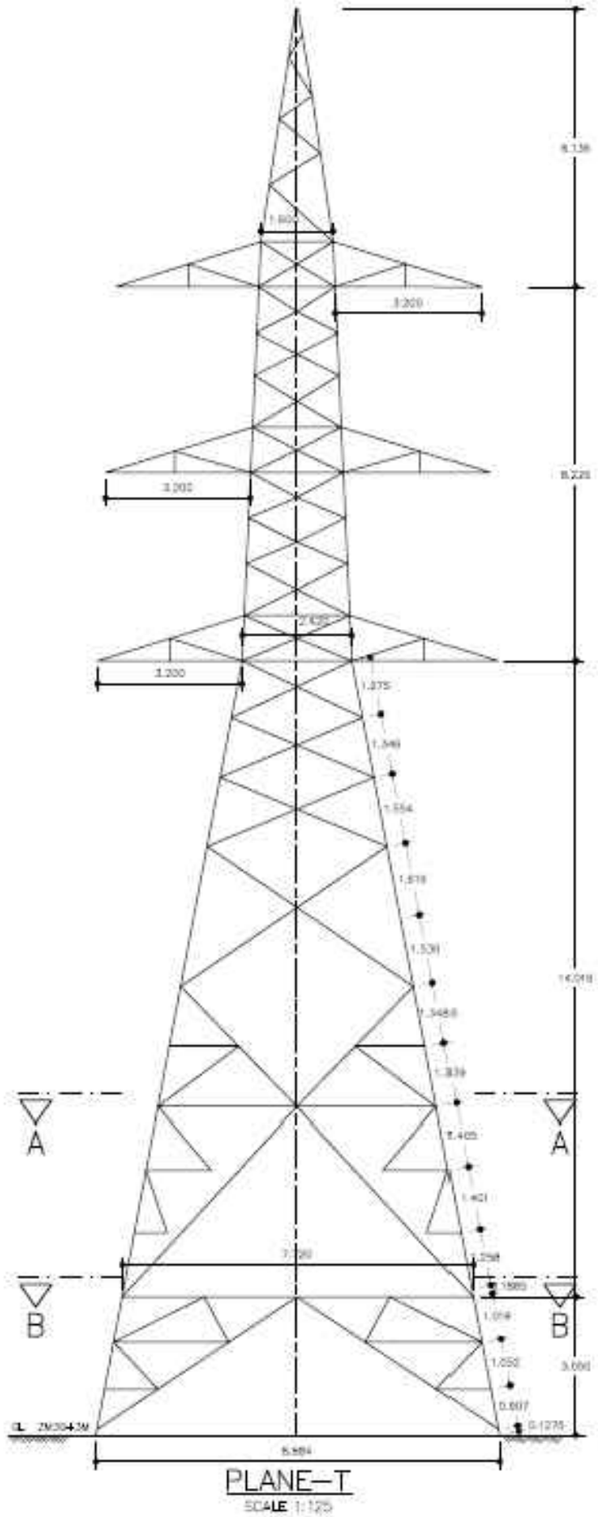
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

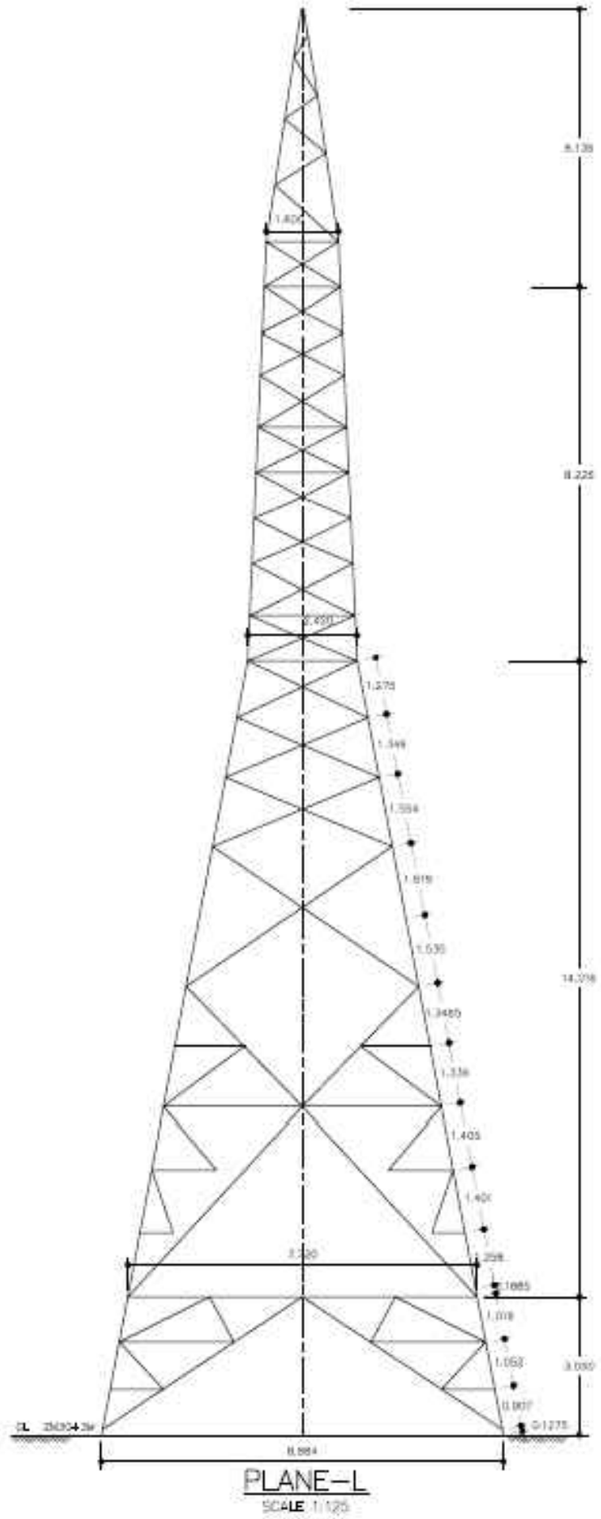
Saud Consult Saudi Consulting Services Company, KSA

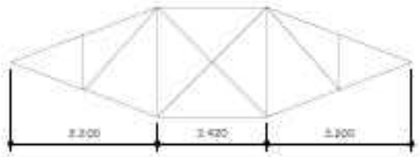
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

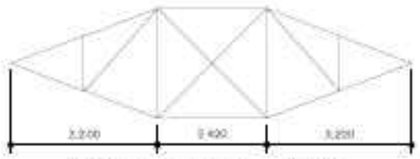
132 kV Transmission Line-Tower Type-ZM-1

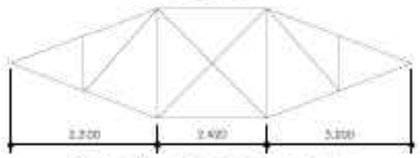
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-011	

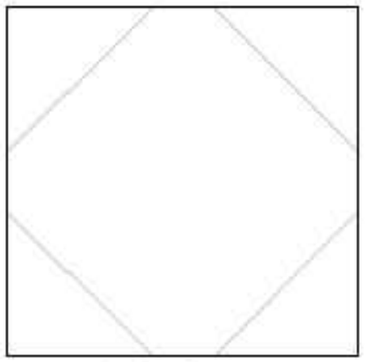


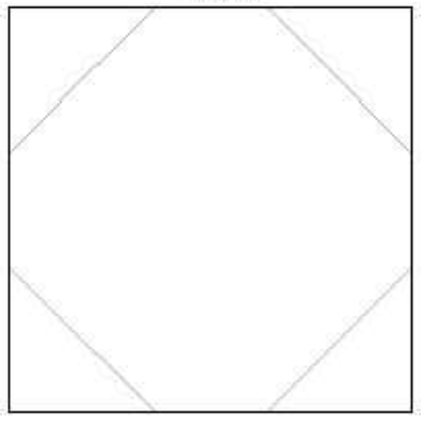












REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)	PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

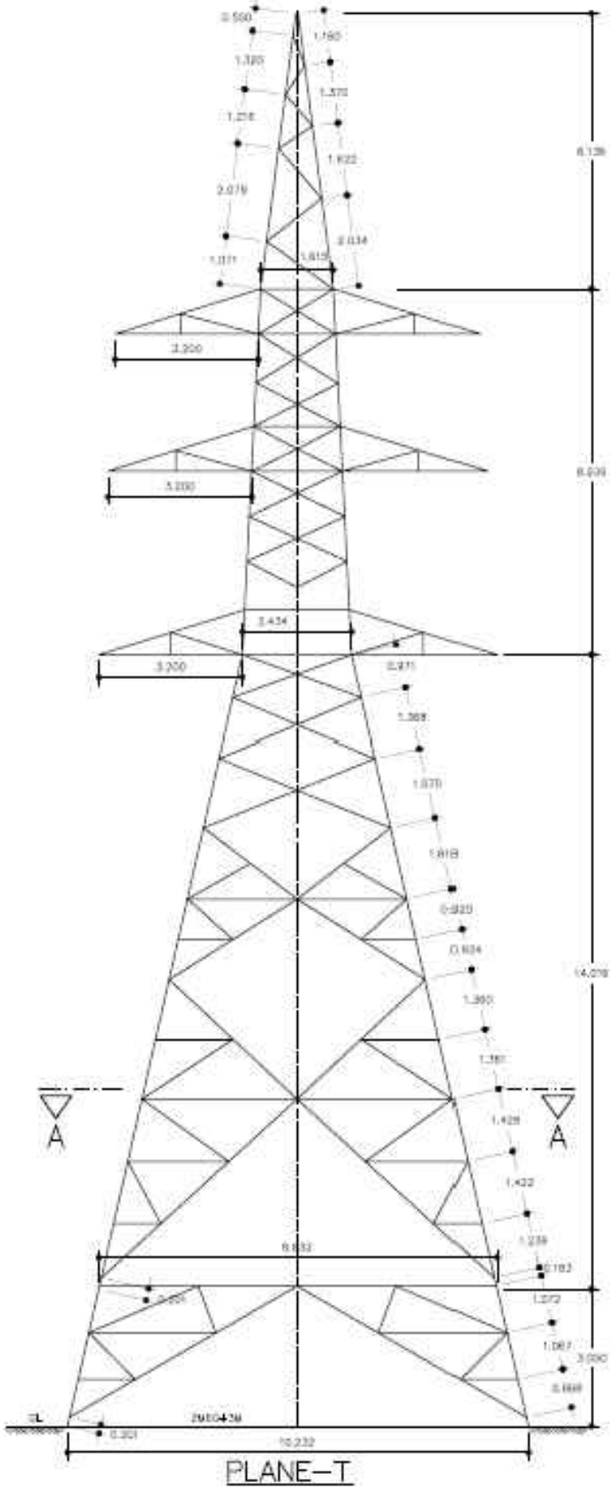
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

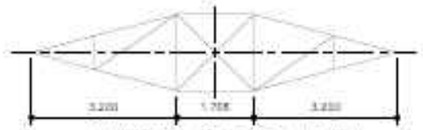
Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

132 kV Transmission Line-Tower Type-ZM-30

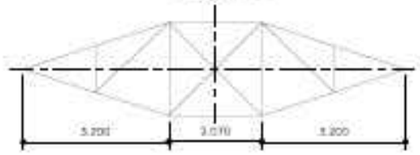
DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-012	





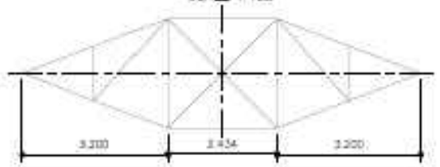
UPPER CROSS ARM

SCALE 1:125



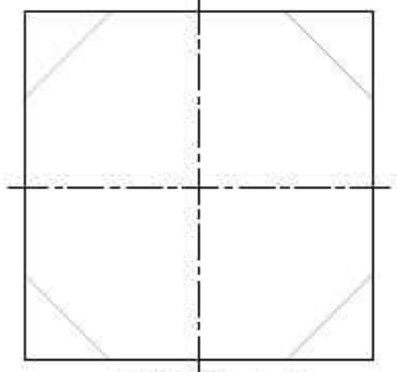
MIDDLE CROSS ARM

SCALE 1:125



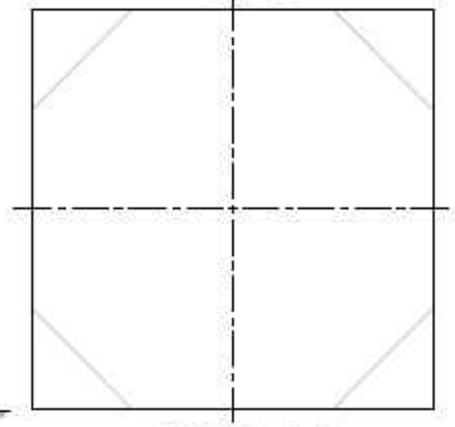
LOWER CROSS ARM

SCALE 1:125



SECTION A–A

SCALE 1:125



SECTION B–B

SCALE 1:125

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK

GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

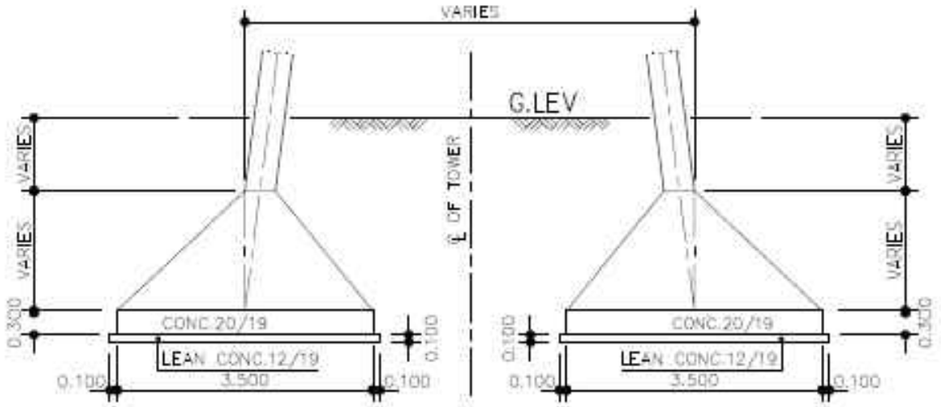
Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

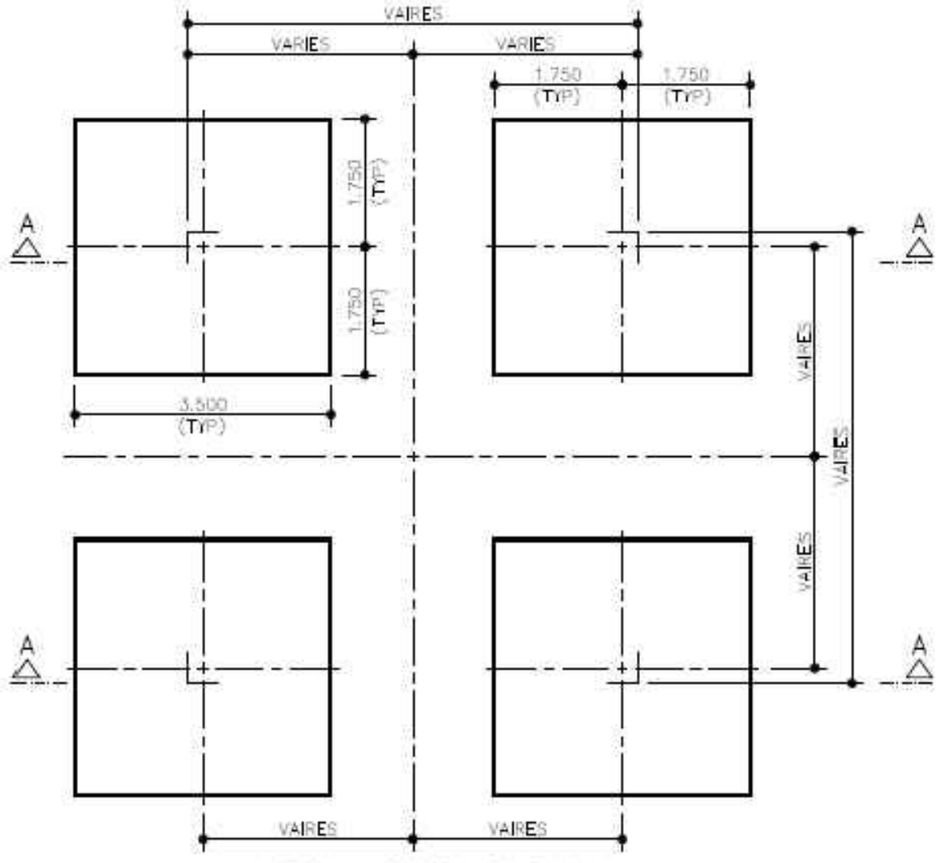
Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

132 kV Transmission Line-Tower Type-ZM-60

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-013	



SECTION A–A



TYPICAL FOUNDATION PLAN

REV	DATE	DESCRIPTION
0		-

POWER DEVELOPMENT ORGANIZATION, AJK
GOVERNMENT OF AZAD JAMMU KASHMIR

JAGRAN-IV HYDROPOWER PROJECT (22MW)

PHASE: TENDER DESIGN

MANAGEMENT CONSULTANTS
JOINT VENTURE OF:

Associated Consulting Engineers – ACE Limited
36-M Civic Center Model Town Extension, Lahore
Tel: +92 4235201206-07

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan.
Tel: +92 42 35229624 - 25

132 kV Transsmission Line-Typical Tower Foundation

DESIGNED	-	CHECKED	-
DRAWN	-	APPROVED	-
SCALE	NTS	DRAWING No.	
DATE	February-26	JAG-12-ELE-014	

Draft-1

AJK POWER DEVELOPMENT ORGANIZATION

JAGRAN-IV HYDROPOWER PROJECT (22 MW)
DISTRICT NEELUM, AZAD JAMMU & KASHMIR

Tender Design Report

Volume 1 - Main Report

February 2026

Associated Consulting Engineers - ACE Limited (Lead Firm)

1-C/2, M.M. Alam Road, Gulberg-III, Lahore – Pakistan. Tel: +92 42 35759417 - 19

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore

160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan. Tel: +92 42 35229624 - 25

JAGRAN-IV HYDROPOWER CONSULTANTS - (JHC)

Project Office: 36-M, Civic Centre, M-Block, Model Town Extension, Lahore-54700
Phone: 92-42-35219147-48 Email: mcjagranivhpp@gmail.com

Ref. No. DHS/31/19

Date: February 19, 2026

Project Director

22 MW Jagran-IV Hydropower Project
AJ&K Power Development Organization (AJ&K PDO),
PDO Complex, Upper Chatter,
Muzaffarabad, Azad Kashmir, Pakistan

Project: **CONSULTANCY SERVICES FOR DESIGN REVIEW, CONSTRUCTION SUPERVISION AND MANAGEMENT OF 22 MW JAGRAN-IV HYDROPOWER PROJECT**

Subject: **Submission of Tender Design Report (Draft)**

Dear Sir,

We are pleased to submit two copies of the subject Tender Design Report (Draft) for your review, comments and approval. The report has been arranged into two volumes as below:

- Volume I – Main Report
- Volume II – Tender Drawings

Based on the Final Tender Design Report, we will prepare the Bill of Quantities, Cost Estimate and Technical Specifications to be incorporated and made part of the Bidding Documents.

Thanking you and assuring you of our best professional services at all times, we remain.

Best Regards,

Project Manager
Jagran-IV Hydropower Project

Encl: As stated above

Copy for information:
1. Regional Head (North) ACE Regional Office (N), Lahore
2. ACE Account Section
3. JV Partners

Documents / Report Control Form:

Project Name	**Jagran-IV Hydropower Project**
Report Name	Tender Design Report Volume 1 - Main Report
Execution	Azad Jammu & Kashmir Power Development Organization (AJ&K PDO)
Report for	PD Jagran-IV Hydropower Project (AJ&K PDO)

Preparation, Review and Authorization:

Revision	Date	Prepared by	Reviewed by	Approved for Issue by
0-00	19th February 2026	Project Team	Farooq Bhutta	Muhammad Khan

Issue Register:

Distribution List	Date issued	Number of Copies
PD Jagran-IV Hydropower Project (AJ&K PDO)	19th February 2026	2

DISCLAIMER

This document is issued for the client and for specific purposes connected with the above-captioned project only. It should not be relied upon by any other party or used for any other purpose.

We accept no responsibility for the consequences of this document being relied upon by any other party, or being used for any other purpose, or containing any error or omission which is due to an error or omission in data supplied to us by other parties.

This document contains confidential information and proprietary intellectual property. It should not be shown to other parties without consent from us and from the client.

MANAGEMENT CONSULTANCY SERVICES FOR CONSTRUCTION OF

22 MW JAGRAN-IV HYDROPOWER PROJECT AT JAGRAN RIVER

TENDER DESIGN REPORT VOLUME 1 – MAIN REPORT

Table of Contents

EXECUTIVE SUMMARY 1
S-1 Background 1
S-2 Location 2
S-3 Hydrological and Sedimentation Studies 3
S-4 Geotechnical Analysis & Design 3
S-5 Hydraulic Design Studies 4
S-6 Structural Design Review 4
S-7 Civil Structures 4
S-8 Hydraulic Steel Structures 4
S-9 Electro-Mechanical Equipment 5
S-10 Power & Energy Calculations 5
S-11 Construction Schedule 6
S-12 MC Proposed Layout Plan for the Project 6
S-13 Salient Features of the MC Proposed Tender Design 6
1. INTRODUCTION 1
1.1 Background 1
1.2 Accessibility to the Jagran-IV Hydropower Project Site 1
1.3 Scope of Consultancy Services 3
1.4 Basis of the Tender Design 3
1.4.1 Recommendation for Tender Level Design Studies 3
1.4.2 Recommendation for Detailed Engineering Design by EPC Contractor 4
1.5 Structure of the Tender Design Report (This Report) 6
2. HYDROLOGY AND SEDIMENTATION STUDIES 89
2.1 General 89
2.2 Catchment Conditions 89
2.3 Hydro Meteorological Stations 91
2.4 Climatic Data 92
2.4.1 Precipitation Data 92
2.4.2 Temperature Data 93
2.5 River Flows 95
2.5.1 Flow Duration Curve 96

2.6 Design Floods 97
2.6.1 Collection of Flood Data 97
2.6.2 Historic Flood 2010 98
2.6.3 Review of Design Flood Studies of Jagran-II Hydropower Project 98
2.6.4 Estimated Design Floods for Jagran-IV Hydropower Project 99
2.7 Sediment Loads 100
2.8 Further Data Collection and Studies to be carried out by EPC Contractor 100
3. GEOTECHNICAL ANALYSIS AND DESIGN 101
3.1 General 101
3.2 General Design Guidelines and Criteria 102
3.3 Site Geology and the Geotechnical Strata 102
3.3.1 Lithological Units at Site 102
3.3.2 Geotechnical Data in Previous Studies (FSR 2010 and TPV 2021) 104
3.3.3 Subsurface Strata Characterization 104
3.3.4 Proposed Additional Investigations by MC 110
3.3.5 Electrical Resistivity Tomography (ERT) Survey - Present Study 110
3.3.6 Seismic Refraction Test (SRT) Survey - Present Study 116
3.4 Geotechnical Design Profiles and Parameters 119
3.5 Geotechnical Modelling and Simulations using PLAXIS 3D software 121
3.5.1 Modelling and Simulations of Intake/Diversion Weir 121
3.5.1.1 Seepage Analysis 124
3.5.1.2 Foundation and Slope Stability Modelling and Simulations 136
3.5.2 Powerhouse Analysis – Under Static Conditions 147
3.5.3 Powerhouse Analysis – Under Seismic Conditions 151
3.5.4 Headrace Pipe Analysis 152
3.5.5 Desander – Excavation Stability Analysis 154
3.6 Conclusions 154
3.7 Summary of Proposed Field Investigations 157
4. PROJECT LAYOUT AND HYDRAULIC DESIGN REVIEW 158
4.1 General 158
4.2 Design Philosophy 158
4.3 Design Features 162
4.4 River Bed Profile 162
4.5 River Water Surface Profile Analysis 163
4.5.1 HEC-RAS Analysis 163

4.6 Overflow Weir 165
4.6.1 Design Criteria 165
4.6.2 Hydraulic Calculations of Overflow Weir 167
4.6.3 Hydraulic Design of Undersluices 171
4.6.4 Discharge Capacity Evaluation of Weir using HEC-RAS 174
4.6.5 Energy Dissipation Structure 177
4.6.6 Weir Freeboard 183
4.7 Power Intake 184
4.7.1 General 184
4.7.2 Hydraulic Design & Methodology 184
4.8 Connecting Channel 187
4.8.1 Design Considerations 188
4.8.2 Alignment 189
4.8.3 Hydraulic Design Criteria 189
4.8.4 Hydraulic Design & Methodology 189
4.8.5 Cross Drainage 191
4.9 Hydraulic Design of Sand Trap 191
4.9.1 General 191
4.9.2 Layout and Structural Configuration 191
4.9.3 Gates and Flow Control 192
4.9.4 Design Criteria 193
4.9.5 Hydraulic Calculations for Sand Traps 195
4.10 Headrace Pipe 197
4.10.1 General 197
4.10.2 General Design Considerations 197
4.10.3 Hydraulic Design of Headrace Pipe 198
4.10.3.1 Penstock Thickness 201
4.11 Debris Barrier Upstream of Weir 202
4.12 Head Losses Through Water Ways 204
4.12.1 General 204
4.12.2 Design Criteria for Calculation of Head losses 204
4.12.3 Results of Head Loss Calculations 208
4.13 Power House 208
4.14 Conclusions 209
5. POWER AND ENERGY CALCULATIONS 210

5.1 General 210
5.2 Input Data 210
5.3 Operating Criteria 210
5.4 Results 210
6. STRUCTURAL DESIGN REVIEW 220
6.1 General 220
6.2 3D Pictorial Illustration of aforementioned Structures 220
6.3 Design Review Sources 221
6.3.1 Proponent Standards & Specifications 221
6.3.2 Industry Codes & Standards 222
6.4 Soil Parameters 223
6.4.1 Earlier Site 223
6.4.2 Newly Proposed Site for Intake and Powerhouse Areas: 223
6.5 Meteorological & Seismic Design Data 223
6.5.1 Wind 223
6.5.2 Earthquake Data 224
6.5.3 Selection of Seismic Design Parameters 224
6.5.4 Seismic Design Parameters 224
6.5.5 Ambient Air & Soil Temperatures, (°C): (Assumed Values) 224
6.5.6 Requirement of Concrete & Reinforcement for Pump Station: 225
6.6 Philosophy of Structural Analysis & Design: 225
6.6.1 Column Capacity 226
6.6.2 Strength Reduction Factor f 228
6.6.3 Section Flexural Capacity 230
6.6.4 Shear & Torsional Capacity of Section 237
6.6.5 Bearing Strength of Sections 239
6.6.6 Punching Shear (Two-Way Shear Strength 240
6.7 Design Loads: 241
6.7.1 Dead Loads [D] 241
6.7.2 Live Loads [L] 241
6.7.3 Wind Loads [W] 241
6.7.4 Seismic Loads [S] 243
6.7.5 Temperature Loads [T] 244
6.7.6 Fluid Loads [F] 245
6.7.7 Soil Pressure Loads [H] 245

6.7.8 Soil Water (GWT) Pressure Loads [HW] 245
6.8 Load Combinations and Load Factors 245
6.8.1 Service Design Load Combinations and Load Factors 245
6.8.2 Strength Design Load Combinations and Load Factors 246
6.9 References 247
6.10 Annexures 247
7. HYDRO MECHANICAL EQUIPMENT 248
7.1 General 248
7.2 Turbines 249
7.2.1 Design Standards 249
7.2.2 Type and Rating 250
7.2.3 Turbine Leading Design Parameters 250
7.2.4 Design Requirements for Speeds and Balance 251
7.2.5 Vibration 251
7.2.6 Resonance 251
7.2.7 Regulation 252
7.2.8 Speed Regulation 252
7.2.9 Requirements for Pressure Regulation 253
7.2.10 Air Admission System 253
7.2.11 Efficiency 253
7.2.12 Torque Fluctuations 254
7.2.13 Stresses and Materials 254
7.3 Design Requirements of Turbine Components 255
7.3.1 Runner 255
7.3.2 Turbine Shaft 256
7.3.3 Turbine Guide Bearing 256
7.3.4 Spiral Casing 257
7.3.5 Covers 257
7.3.6 Discharge Ring 257
7.3.7 Draft Tube 258
7.3.8 Guide Vanes, Wicket gates and Regulating Mechanism 258
7.3.9 Wicket gates 258
7.3.10 Guide Vane Leakage 258
7.3.11 Regulating Gear 259
7.3.12 Bearings for Guide Vanes and Regulating Gear 259

7.3.13 Guide Vane Position Indication 259
7.3.14 Guide Vane Servomotors 259
7.3.15 Turbine Noise 260
7.4 Digital Governor 260
7.4.1 Scope 260
7.4.2 Design Standards and Reference 260
7.4.3 General 260
7.4.4 Type and Description 261
7.4.5 Functional Requirements 261
7.4.6 Hydraulic Pressure Unit for Governor 261
7.4.7 Oil Pumping System 262
7.5 Main Inlet Valves 262
7.5.1 Scope 262
7.5.2 Type of Valves 262
7.5.3 Hydraulic Power Unit for MIV 262
7.6 Howell Bunger type Pressure Relief Valves 263
7.7 Main Lifting Equipment 264
7.7.1 Powerhouse Crane 264
7.8 Mechanical Auxiliaries 265
7.8.1 Scope 265
7.8.2 Applicable Codes and Standards 265
7.8.3 Compressed Air system 265
7.8.4 Functional Requirements of Service Air System 265
7.8.5 Design Considerations of Cooling Water System 266
7.8.6 Service Water System 267
7.8.7 Dewatering System 268
7.8.8 Station Drainage System 268
7.8.9 Potable Water System 269
7.8.10 Sewage System 269
7.8.11 Fire Detection and Firefighting System 269
7.8.12 Personnel Safety 271
7.8.13 Heating, Ventilation and Air Conditioning System 271
7.8.14 Lubricating Oil Treatment / Handling System 273
7.8.15 Workshop, Tools and Spare Parts 273
7.9 Hydraulic Steel Structures 275

7.9.1 General 275
7.9.2 Standards 275
7.9.3 Radial Gates for Under Sluicing of Weir 276
7.9.4 Stoplogs for Isolation of Weir Radial Gates 278
7.9.5 Fixed Wheel Gates for Intake 279
7.9.6 Stoplogs for Isolation of Fixed Wheel Gates at Intake 280
7.9.7 Intake Trash rack and Trash Cleaning Machine 281
7.9.8 Sand-trap Flushing Gates 282
7.9.9 Sand-trap Inlet and Outlet Gates 282
7.9.10 Draft Tube Gate Equipment 283
8. ELECTRICAL EQUIPMENT 286
8.1 Generator and Excitation System 286
8.1.1 Generator 286
8.1.2 Excitation System 289
8.2 Transformers 290
8.2.1 Technical Data of Power Transformers 291
8.2.2 Transformer Oil 291
8.2.3 Oil Conservator Tank 292
8.2.4 Gas Relay 292
8.2.5 Resistance Temperature Detectors 292
8.2.6 Cooling Systems 292
8.2.7 Joints and Gaskets 292
8.2.8 Tape Changers 293
8.2.9 Rating Plates 293
8.3 Switchgears 293
8.3.1 High Voltage (HV) Switchgear 293
8.3.2 Medium Voltage (MV) Switchgears 296
8.3.3 LV Switchgear 297
8.3.4 DC Power Supply System 298
8.4 Plant Control and Automation System 299
8.4.1 Plant Control Levels 299
8.4.2 System Architecture 300
8.5 Telecommunication and Security Systems 300
8.6 Protection System of Power Plant, Switchyard and Substation 301
8.6.1 Protection Devices 301

8.7 Main Earthing Lightning Protection System 302
8.7.1 Earthing System 302
8.7.2 Lightning Protection system 302
8.7.3 Earthing Points 303
8.8 Cables and Cable Trays 303
8.8.1 Cable Supports and other Steelwork 303
8.9 Emergency Diesel Generator Set 304
8.9.1 Diesel Engine 304
8.9.2 Generator 304
8.9.3 Parallel Operation 305
8.10 Electrification of Powerhouse, Switchyard and Intake 305
8.11 Civil Works of Switchyard 306
8.12 Power Dispersal and Transmission Lines 306
8.12.1 132 kV Transmission Line 306
8.12.2 11 kV Transmission Line 306
9. CONSTRUCTION PLANNING 309
9.1 General 309
9.2 Land Acquisition 309
9.3 Mobilization and Preparatory Works 310
9.4 Exploration for Borrow Areas and Construction Materials 310
9.5 Coffer Dams and Care of Water 310
9.6 Weir and Intake Structure Works 310
9.7 Connecting Channel from Intake to Sand trap 310
9.8 Sand Tap 310
9.9 Low Pressure Headrace Steel Pipe 311
9.10 Penstock and Manifolds 311
9.11 Powerhouse 311
9.12 Tailrace 311
9.13 Installation of E&M Equipment 311
9.14 Transmission Line 311
9.15 Testing and Commissioning 312

List of Tables

Table S-1: Salient Features Jagran-IV Hydropower Project....8
Table 1-1: Accessibility to the Project Area....2
Table 1-2: Salient Features of 22 MW Jagran Hydropower Project....5
Table 2-1: List of Hydro meteorological Station in the Region....91
Table 2-2: Long Term Climatic Stations in Jhelum River Basin....92
Table 2-3: MC Proposed Flow Duration Curve at Weir Site Jagran-IV HPP....96
Table 2-4: Annual Maximum Observed Floods at Muzaffarabad (1963-14) 97
Table 2-5: Adopted Floods at the Weir and Powerhouse sites of Jagran-II HPP....99
Table 2-6: MC Proposed Design Floods at Weir site of Jagran-IV HPP 99
Table 3-1: Geotechnical Analysis Requirements 101
Table 3-2: Summary of the Geotechnical Design Parameters 121
Table 3-3: Summary of Proposed Field Investigations....157
Table 4-1: Coordinates of Weir and Powerhouse locations....160
Table 4-2: Overflow Weir crest Profile data 168
Table 4-3: Over flow weir discharge capacity calculation....170
Table 4-4: Discharge Rating of Overflow Weir and undersluices calculate using HEC-Ras 175
Table 4-5: Result of Stone size calculations 183
Table 4-6: Approximation of Normal and Minimum Freeboard....184
Table 4-7: Discharge rating of Power intake 185
Table 4-8: Veilkanov's function (Ref. Mosonyi)....195
Table 4-9: Economical penstock diameter using various empirical formula 199
Table 4-10: Checking Submergence of Headrace Pipe at Inlet....201
Table 4-11: Summary Result of Segment wise Penstock thickness....202
Table 4-12: Calculation of Head losses through Power Waterways....208
Table 7-1: Applicable Requirements from Standards....249
Table 7-2: Jagran-IV HPP- Leading Parameters of Turbine....250
Table 7-3: Jagran-IV HPP- Turbine Salient Features....251
Table 7-4: Turbine Weighted Efficiency 254
Table 7-5: Allowable Material Stresses....254
Table 7-6: Design Standards for Governors 260
Table 7-7: Key Parameters for Main Inlet Valve....263
Table 7-8: Key Parameters for Pressure Relief Valves 264
Table 7-9: Key Parameters HVAC design....272
Table 7-10: Workshop Equipment 274

Table 7-11: Under Sluices - Radial Gates for Weir 277
Table 7-12: Stoplogs and Gantry Crane for Weir 278
Table 7-13: Fixed Wheel Gates for Intake 280
Table 7-14: Stoplogs and Gantry Crane for Intake 281
Table 7-15: Trash racks and Cleaning Machine 281
Table 7-16: Simple Slide Gates for Flushing the Sandtrap 282
Table 7-17: Simple Slide Gates for Inlet & Outlet of the Sand-trap 283
Table 7-18: Draft Tube Stoplogs 284
Table 8-1: The Technical Data of Generators 286
Table 8-2: Technical Data of Step-Up and Step Down Transformers 291
Table 8-3: Technical Data of Auxiliary Transformers 291
Table 8-4: Rated Impulse & Power Frequency Withstand Voltages 294
Table 8-5: Minimum Distances 294
Table 8-6: Technical Requirements of MV Switch Gears 297
Table 8-7: Gears Main Parameters of Storage Batteries 298

List of Figures

Figure S-1: Proposed Layout plan of 22 MW Jagran-IV Hydropower Project 7
Figure 2-1: Catchment Area of Jagran River (FS, 2010) 90
Figure 2-2: Location of Hydro Meteorological Stations (Jagran-II Project Report) 91
Figure 2-3: Total Annual Precipitations at Muzaffarabad Climate Station 93
Figure 2-4: Total Annual Precipitations at Naran Climate Station 93
Figure 2-5: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station 94
Figure 2-6: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station 94
Figure 2-7: Comparison of Observed & Extended Flows at Thunian Station (TPV, 2021) 95
Figure 2-8: Estimated Mean Annual Flows at Proposed Weir Site of Jagran-IV HPP 96
Figure 2-9: Suspended Sediment Rating Curve for Nausehri Station (FS, 2010) 100
Figure 3-1: Typical view of the large boulders along the riverbanks (FSR 2010) 105
Figure 3-2: Cored samples from boulders at greater depths (17.0-26.0 m) (2010 FSR) 106
Figure 3-3: Typical view of the glacial/moronic overburden deposits exposed in a test pit excavated at the site (FSR 2010) 106
Figure 3-4: Surface geological map of the proposed weir area, showing the extent of the overburden strata (yellow) and the granite rock outcrop (red) 107
Figure 3-5: Geological section of the proposed weir area (FSR 2010), showing the extent of the overburden strata and the granitic gneiss bedrock 107
Figure 3-6: Geological section along the proposed Headrace Steel Pipe (FSR 2010), showing the extent of the overburden strata and the granitic gneiss bedrock 108
Figure 3-7: Geological section along the proposed surge pipe (FSR 2010) 109
Figure 3-8: Proposed powerhouse location according to FSR 2010 and TPV 2021 110
Figure 3-9: Geological cross-section assessed at the proposed weir location 120
Figure 3-10: Geological cross-section assessed at the proposed powerhouse location 120
Figure 3-11: The cross-sectional details of the proposed Intake/Diversion Weir 122
Figure 3-12: A basic 3D numerical model of the Weir and its natural surroundings prepared in PLAXIS 3D software, showing weir components and subsurface strata 122
Figure 3-13: The basic 3D numerical model of the Weir and its components prepared in PLAXIS 3D software, showing 3 m deep cut-offs at the U/S floor 123
Figure 3-14: The basic 3D numerical model of the Weir and its components prepared in PLAXIS 3D software, showing 3 m deep cut-off walls at the U/S floor and the Weir's Heel 123
Figure 3-15: Different views of Basic 3D numerical model of Weir and its components prepared in PLAXIS 3D software, showing a 6 m deep cut-off at heel and a 3 m deep toe cut-off 123
Figure 3-16: Water flow model under Normal Water Elevation (NWE) conditions, showing the Normal and Tail Water Elevations 125
Figure 3-17: 3D view of steady-state seepage results under Normal Water Elevation (NWE) conditions, showing a 3D surface flow, with subsurface flow shown in Figure 3-13. 125

Figure 3-18: A 3D view of the subsurface steady-state seepage results under Normal Water Elevation (NWE) conditions, showing the subsurface flow. 126

Figure 3-19: A cross-section through the Weir showing the subsurface flow without the cutoff walls during NWE. 126

Figure 3-20: A cross-section through the Weir interface with the right abutment showing the subsurface flow without the cutoff walls. 127

Figure 3-21: A cross-section through the Weir showing the groundwater head due to the subsurface flow under NWE without the cutoff walls. 127

Figure 3-22: A cross-section through interface between Weir and right abutment showing groundwater head due to subsurface flow under NWE without cutoff walls. 128

Figure 3-23: A 3D view of about 45 mm upheaval of D/S floor due to residual/net water head of 6 m due to NWE. 128

Figure 3-24: A cross-sectional view showing an upheaval of about 45 mm of D/S floor due to residual/net water head of 6 m due to NWE 129

Figure 3-25: A cross-section through Weir showing subsurface flow with three 3 m cutoff walls during NWE. 129

Figure 3-26: A cross-section through the Weir showing the water head due to subsurface flow under NWE with three 3 m cutoff walls. Maximum water head under D/S floor is 5.0 m. 130

Figure 3-27: A cross-section through the Weir showing the subsurface flow during NEW with three 3m cutoffs below the U/S floor and one 6 m cutoff wall at the weir's heel. 130

Figure 3-28: A cross-section through Weir showing water head due to subsurface flow under NWE with three 3 m & one 6 m cut-off walls. Max. water head under D/S floor is 3.5 m. 131

Figure 3-29: Water flow model under Maximum Flood Water Elevation (FWE) conditions 132

Figure 3-30: Water flow model under Flood Water Elevation (FWE) conditions, showing 3D subsurface flow 133

Figure 3-31: Water flow model under Flood Water Elevation (FWE) conditions without any cutoff, showing seepage cross-section at the Weir 133

Figure 3-32: Water flow model under Flood Water Elevation (FWE) conditions without a cutoff wall, showing water head contours along the weir 134

Figure 3-33: Water flow model under Flood Water Elevation (FWE) conditions, showing uplift displacements (~60 mm) for a1.5 m thick D/S floor 134

Figure 3-34: Water flow model under Flood Water Elevation (FWE) conditions, showing uplift displacements (~60 mm) for a 1.5 m thick floor 135

Figure 3-35: Water flow model under Flood Water Elevation (FWE) conditions with three 3 m and one 6 m cutoff, showing the seepage cross-section at the Weir 135

Figure 3-36: Water flow model under Flood Water Elevation (FWE) conditions with three 3 m and one 6 m cutoff, showing the groundwater head cross-section at the Weir. 136

Figure 3-37: Water flow model under Flood Water Elevation (FWE) conditions, showing uplift displacements (~10 mm) for a 2.0 m D/S thick floor 136

Figure 3-38: Stress-strain model under Normal Water Elevation (NWE) conditions, showing vertical stresses in the concrete section and the pressure at the foundation level 137

Figure 3-39: Stress-strain model under Normal Water Elevation (NWE) conditions, showing horizontal stresses in the concrete section and the pressure at the foundation level 138

Figure 3-40: Lateral displacement anticipated under NWE condition. 138

Figure 3-41: Stress-strain model under Flood Water Elevation (FWE) conditions, showing vertical stresses in the concrete section and the pressure at the foundation level..... 139

Figure 3-42: Stress-strain model under Flood Water Elevation (FWE) conditions, showing horizontal stresses in the concrete section and the foundation. 139

Figure 3-43: Lateral displacement anticipated under Flood Water Elevation (FWE)..... 140

Figure 3-44: Water flow model under Flood Water Elevation (FWE) conditions, showing slope instability conditions..... 140

Figure 3-45: Seismic Analysis Horizontal Earthquake spectrum applied to weir section (kh=0.68g) 141

Figure 3-46: Seismic Analysis Vertical Earthquake spectrum applied to weir section (kh=0.15g) 142

Figure 3-47: Expected deformation of the weir and its natural environment WITHOUT heel cutoff under the peak earthquake acceleration of 0.68g 142

Figure 3-48: Expected deformation of the weir and its natural environment WITHOUT heel cutoff under the peak earthquake acceleration of 0.68g. 143

Figure 3-49: Expected deformation of the weir and its natural environment WITH heel cutoff under the peak earthquake acceleration of 0.68g. 143

Figure 3-50: Expected vertical stresses in the weir and its natural environment under the peak earthquake acceleration of 0.68g. The maximum vertical stress in the concrete body is 2000 kPa, and the maximum vertical stress on the soil is 500 kPa 144

Figure 3-51: Expected horizontal stresses in weir & its natural environment under peak earthquake acceleration of 0.68g. Maximum horizontal stress in concrete body is 8000 kPa . 145

Figure 3-52: Instability condition in the weir's abutment slopes under the peak earthquake acceleration of 0.68g 145

Figure 3-53: Displacements in the Weir and its Foundation under the peak earthquake acceleration of 0.68g 146

Figure 3-54: Horizontal Accelerations in the Weir and its Foundation under the peak earthquake acceleration of 0.68g. 146

Figure 3-55: Spectral Accelerations in the Weir and its Foundation under the peak earthquake acceleration of 0.68g. 147

Figure 3-56: Superposition of powerhouse (PH) and tailrace (TR) on geological section 148

Figure 3-57: Proposed cross-section of the powerhouse and the tailrace 148

Figure 3-58: 3D views of powerhouse and tailrace model with maximum flood level 149

Figure 3-59: A close-up 3D view of PH, tailrace, and associated raft & retaining wall piles 149

Figure 3-60: A 3D Deformation/displacement model of the powerhouse and the tailrace 150

Figure 3-61: A deformation/displacement section through the tailrace structure 150

Figure 3-62: A deformation/displacement section through the powerhouse structure 151

Figure 3-63: Pile capacity plots for 100 cm diameter piles proposed for Pipe anchor blocks/supports – Scour depth = 2.0 m.....151

Figure 3-64: Deformation Tendency Scenario of the Powerhouse and its natural environment under peak earthquake acceleration of 0.68g. The maximum displacement expected at powerhouse is negligible (around 2 mm). 152

Figure 3-65: Conceptual plan and sections of the piled-block, recommended to be provided at every 300 m section. 153

Figure 3-66: Pile capacity plots for 60 cm diameter piles proposed for Pipe anchor blocks/supports – Scour depth = 2.0 m.....153

Figure 3-67: Excavation plan for desander, requiring a slope of 1H:2V for temporary works. 154

Figure 3-68: The extents of the initially designed weir, marking the lack of a proper interface with the highly permeable overburden deposits 155

Figure 3-69: Recommended minimum width of the weir to abut the ends into the low-permeability rock strata 155

Figure 3-70: Conceptual section of the piled-raft foundation for the powerhouse and the piles for the retaining walls of the powerhouse and the tailrace.....156

Figure 4-1: Proposed Layout plan of 22 MW Jagran-IV Hydropower Project 161

Figure 4-2: River bed profile of Jagran River within study reach 163

Figure 4-3: HEC-RAS model showing marking of river cross sections.....163

Figure 4-4: River discharge rating at Stilling basin location.....164

Figure 4-5: River discharge rating at Power house location.....164

Figure 4-6: Overflow Weir Crest Profile 169

Figure 4-7: Sectional elevation of spillway, undersluices and intake 170

Figure 4-8: Discharge Rating curve of Ungated Overflow weir.....171

Figure 4-9: Longitudinal section along under sluice 172

Figure 4-10: Typical Sketch of Submerged Orifice.....173

Figure 4-11: HECRAS Model showing Inline Structure (Overflow weir and Undersluices) 174

Figure 4-12: Combined Discharge Rating Curve of Overflow weir and Undersluices 176

Figure 4-13: HECRAS Model showing Inline Structure (Overflow weir and Undersluices) 176

Figure 4-14: Parameters for computation of theoretical velocity at toe of glacis.....178

Figure 4-15: Length in terms of Conjugate depth, d_2 (Basin V, Case D).....179

Figure 4-16: Plan of Spillway and Undersluices.....180

Figure 4-17: Longitudinal section along overflow Spillway 181

Figure 4-18: Discharge Rating Curve of Power intake 186

Figure 4-19: Section along Power Intake.....186

Figure 4-20: Section along Power Intake.....187

Figure 4-21: Conveyance system showing conduit.....188

Figure 4-22: Typical Cross section of Connecting Channel....188
Figure 4-23: Discharge Rating Curve of Connecting channel 190
Figure 4-24: Plan and Longitudinal section of Sandtrap....192
Figure 4-25: Plan, Longitudinal section and Cross section of Sandtrap 193
Figure 4-26: Submergence of Power Intake....199
Figure 4-27: Proposed Debris Barrier Upstream of Weir....203
Figure 4-28: Proposed Typical Plan and Section of Debris Barrier 203
Figure 4-29: Proposed Typical Plan and Section of Debris Barrier 204
Figure 4-30: Resistance Coefficients for bends 207
Figure 4-31: Loss Coefficient for gradual contraction....207
Figure 6-1: Three-dimensional Pictorial View of Intake Area....221
Figure 6-2: Three-dimensional Pictorial View of Powerhouse Area....221
Figure 9-1: Construction Schedule Jagran IV Hydropower 313

EXECUTIVE SUMMARY

S-1 Background

The 22 MW Jagran-IV Hydropower Project is a run of river scheme, located on Jagran River, which is a right bank tributary of Neelum River situated in District Neelum, Azad Jammu & Kashmir (AJK). The Project Sponsoring Agency is Government of AJK. The Project is being executed through AJK Power Development Organization (AJK PDO). The Project loan financing is available through Saudi Government loan (Saudi Fund for Development SFD) up to extent of 85% of the total project cost whereas the remaining 15% cost shall be arranged through GoAJK ADP & PDO.

The Project was identified by Hydro Electric Power (HEP) Board as a run of river. The HEP was later re-organized to Azad Jammu & Kashmir Power Development Organization (AJK PDO) under the AJK PDO Act 2014. In the downstream of Jagran River, the Jagran-I (constructed) Jagran-II (under construction) and Jagran-III (at planning stage) Hydropower Projects are located.

In 2010, the Feasibility Study of the project was carried out by M/s Fida Hussain Chaudhry (FHC) Consulting Engineers in association with M/s Scott Wilson Limited of United Kingdom. The capacity of the proposed project was determined as 22 MW. The feasibility design is a weir, connecting channel, sand trap, 3.0 m dia penstock pipe, surge tank and powerhouse discharging directly to Jagran River. The power shall be transmitted vis 132 KV transmission line.

In April 2021, the AJK PDO hired a Third-Party Validation (TPV) Consultant consisting of M/s INTEGRATION e&e, PES and Integration Energy to review and validate the FS report, conduct the Topo Survey and supervise the Geotechnical investigation executed by sub-contractor; M/s Universal Drilling Engineers. Based on the new Topo Survey, and site visits of consultant's experts, the TPV Consultant reviewed the feasibility study project layout and designs and proposed some changes to the salient features of the project conceived in the Feasibility Studies.

The AJK PDO has awarded the Management Consultancy (MC) Services for construction of 22 MW Jagran-IV Hydro Power Project to the joint venture (JV) of ACE, Saud Consult and RHC Consultants. The Contract Agreement was signed on August 15, 2025 having the Commencement of Works on August 29, 2025. The date of completion of the project is June 29, 2029 with a duration of the consultancy services of 46-months, which includes 6-months for assisting the Procurement process and 40-months for Pre-Construction & EPC Construction Phase. The defect liability period is 12-months after the date of completion.

As per the ToRs, the MC are responsible for review and up gradation of the feasibility study reports & tender designs, prepare the EPC / turnkey tender documents for inviting National/ International Competitive Bidding (ICB), prepare replies to bidder's quarries, evaluation of bids, assist the PDO in negotiations with successful bidder and finalization of Contract Award and Agreement. The MC shall also review the EPC contractor's detailed engineering designs and perform the project management, supervision and contract administration activities.

After mobilization, the Client and the MC experts performed a joint site visit to the Project area during the period from 15 to 19th October 2025 and visually inspected the various layouts proposed in previous studies including weir, connecting channel, sand trap, low pressure pipe and powerhouse. The team also visited the weir & powerhouse cavern of the existing Jagran-I as well as the weir & powerhouse structures of the under construction Jagran-II Hydropower Project. A follow-up meeting was also held in AJK PDO Office, Muzaffarabad, wherein the visiting team briefed the Managing Director, PDO and Project Director about the sites visited and the key findings which are summarised below:

- Shifting of the weir site a bit further upstream from one suggested in the TPV study, 2021 was proposed because of an active landslide on the right abutment. The weir and upstream floor will be accommodated within the land already acquired.
- Shifting of the powerhouse site a bit further downstream from one suggest in the TPV study, was proposed to avoid the watershed path to protect against potential mud and debris flows.
- The additional geophysical investigation pertaining to the ERTs and SRTs surveys at the proposed weir and weir sites and along the low-pressure pipeline was proposed. Besides, the construction material testing was also proposed. The Client principally agreed with the further Geotechnical investigations; therefore, the Project Director required to send a written request to the Client in detail in this respect. Accordingly, the MC sent a request vide letter No. DHS / 31 / 168 Dated 20-10-2025.
- The visiting team also foreseen the requirement for updating the earlier design flood studies.

A site visit report covering the above aspects was also prepared and submitted to the Client vide letter No. DHS / 31 / 171 dated 24th October 2025.

Subsequently, after conducting the site visit, the MC completed review of the previous studies pertaining to the FS 2010 and TPV 2021. The MC also reviewed the design reports of the Jagran-I and Jagran-II Hydropower Projects. Based on above comprehensive reviews, the MC identified the gaps in the previous studies of Jagran-IV and proposed their recommendations in the Feasibility Study and Design Review Report which was submitted to the Client vide letter No. DHS / 31 / 185 dated 14th November, 2025. The above findings of the site visit were also included as key recommendations in the Feasibility Study and Design Review Report.

This Tender Design Report has been prepared as per the MC recommended layout of the project proposed in the Feasibility Study and Design Review Report. The Client approved the MC proposal regarding additional investigation vide letters No. 7676-77 dated 25th November 2025, therefore, a specialist qualified sub-contractor (M/s GEMS) was hired who completed the ERTs & SRTs surveys at the field and submitted the results in separate reports. Therefore, the results of above investigations have also been considered in this Tender Design Report.

While preparing this tender design report, the MC experts have performed state of the art analyses & calculations pertaining to the various hydraulic, geotechnical and electro-mechanical aspects, updated design floods & proposed sizing of the various structures including weir, power intake, connecting channel, low pressure pipeline and surface powerhouse with vertical turbine-generator set configurations, in view of the topographic survey conducted by TPV Consultants.

S-2 Location

The Jagran River join Neelum River at Kundal Shahi village located on Neelam Valley Road. The proposed project area is sited about 20 Km from Kundal Shahi. The distance of Jagran-IV Hydropower Project from Muzaffarabad is about 95 Km moving along the Neelum River main road. It requires approximately 4 hours to travel from Muzaffarabad to the project site located near Thunian village. The proposed powerhouse is located at about 270 m upstream of the existing intake of Jagran-I Hydropower Project. The coordinates of selected weir site and powerhouse site are given below:

Sites	Easting (m)	Northing (m)
Weir	387132.296	3835744.368
Powerhouse	387059.167	3832626.851

S-3 Hydrological and Sedimentation Studies

The description of catchment show that Jagran River originates from mountain peaks of Kala Pani at elevations of 5030.70 and 5021.00 m asl. The river along its length has a few tributaries joining the main stream from either bank. The flows of Jagran River are generated with snow fall and rainfall in the catchment. Several glaciers exist in its upper catchment above El. 4,000m. The catchment of Jagran River experience snowfall in winter months and rainfall in summer months. The intensive rainfall and snow results in high flows during summer months. The catchment areas at the weir and powerhouse sites are 205 km^2 and 216 km^2 respectively.

The total annual precipitations at nearby station Muzaffarabad vary from 747.3 mm in 1975 to 2154.4 mm in 2006. The mean annual precipitation is 1488.0 over a period from 1961 to 2010.

The annual mean maximum temperatures at nearby station Muzaffarabad vary with the minimum value of 25.3 °C in 1982 and maximum value of 29.5 °C in 2001. Similarly, the annual mean minimum temperatures at Muzaffarabad vary with the minimum value of 12.4 °C in 1991 and maximum value of 14.8 °C in 1976.

The estimated mean annual flow at proposed weir site varies from 4.9 to 17.7 m^3/s with average value of 12.30 m^3/s.

The estimated design floods at the weir and powerhouse sites corresponding to 1000-year return period are 954 m^3/s and 970 m^3/s respectively.

The estimated total annual sediment load at the proposed weir site is 0.5249 M ST per year. The average %age value (composition of suspended sediment) for sand, silt and clay is 13%, 64% and 23% respectively.

S-4 Geotechnical Analysis & Design

Based on information & data from boreholes, test pits and geological mapping, it is confirmed that rock is not exposed at any of the proposed project sites for the weir, connecting channel, sand trap, buried headrace steel pipeline and powerhouse. The geological rock units exposed in the project area include metamorphic units, with granitic gneisses, granite, and granodiorite intrusions present at certain locations. The rock in this area, according to ISRM standards, is very strong to extremely strong, thickly bedded, slightly to moderately weathered, closely jointed, & fractured.

The weir would most likely be founded on overburden, as the thickness in this area appears to exceed 40 meters. The permeability of the overburden material ranges from 2 to 10-2 cm/s. The highly permeable strata in the upper 10-15 m of the riverbed would result in high seepage losses across the weir foundation. The seepage water would create a high net water head on the downstream floor, which may cause uplift damage to the floor. Therefore, based on the optimized analysis, three cut-off walls, each of 3 m and one of 6 m have been proposed to reduce the water head to a desirable value. In addition, to counter the net water head during the flood water elevation, the downstream floor with minimum thickness of 2.0 m has been proposed.

The buried steel headrace pipeline will mainly be founded on rock and partially on the overburden. The slopes and terrain along the pipeline route would be vulnerable to global and local instabilities, including landslides, mudflows, debris flows, rock avalanches, and snow avalanches. Therefore, piled-block foundations with four 60 cm-diameter piles, each 10 m deep, at approximately 300 m intervals have been proposed to secure the pipeline.

The powerhouse appears to be founded on river alluvium deposits. This configuration may make the powerhouse foundation strata vulnerable to erosion and to high differential displacements caused by floodwater flow impact. Therefore, the powerhouse is proposed to be founded on a piled-raft foundation. There is a high probability that moving boulders will impact the tailrace retaining wall. Therefore, the retaining wall is also proposed to be founded on pile foundations.

S-5 Hydraulic Design Studies

The following hydraulic design studies have been carried:

- The HEC RAS analysis by using the cross-section data and the flood data to estimate the water surface profiles at weir and powerhouse location.
- Sizing of overflow spillway and undersluices based on selected design flood.
- The power intake sizing based on optimized design discharge.
- The hydraulic design of Conduit, Sandtrap, and buried steel headrace pipe dia.
- The thickness selection of buried steel headrace pipe due pressure rise due water hammer.
- The detailed calculation of Power waterways Head Losses.

S-6 Structural Design Review

The structural design review is carried with STAAD Pro analysis program and framed in the light of proponent standards, industry codes and standards by assuming the soil parameters, meteorological and seismic design data, wind loads, combination of loads, etc. The crux of the analysis & design philosophy is to ensure that the resisting capacity of structural elements against worst possible loading scenarios i.e. applied loads in axial, shear and torsion or combination thereof, be always greater or equal.

S-7 Civil Structures

The proposed civil structures for Jagran-IV Hydropower Project are listed below:

- Weir of 5 m height above the river bed level accommodating an un-controlled overflow weir and 2 No's of Undersluices with stilling basin as energy dissipation arrangement.
- Uncontrolled overflow weir, 55 m long having crest at an elevation of 2254.00 m. The Type-V stilling basin of 20 m length is proposed.
- 2 No's of Undersluices with radial gate with and invert level of 2249.00 m and size 5 m (W) and 5 m (H), which joins stilling basin of Type-V.
- Power Intake structure on left bank of river to pass total discharge of 19.2 m^3/s (including flushing discharge of 3.2 m^3/s) through connecting channel to sandtrap.
- Reinforced concrete connecting channel of 3.5 m x 2.95 m size to convey discharge from intake to sandtrap. The length of connecting channel is 83.50 m.
- Two sand trap chambers (92.2 m x 7 m) to remove sediment particles of 0.25 mm.
- Buried steel headrace pipe with internal dia of 2.40 m & length of 2,996 m, which branches into four penstock pipes each leading to main inlet valve of vertical axis turbine units.
- Surface powerhouse with four Francis turbines, each with separate pressure relief valve.
- Debris barrier upstream of weir

S-8 Hydraulic Steel Structures

- Two (02) hydraulically operated radial gates at Weir
- Two (02) Stoplogs for isolation of radial gates at Weir
- One (01) electrically operated Gantry Crane and lifting beam for Stoplogs of Weir

- One (01) electrically operated Gantry Crane and lifting beam for Stoplogs of Intake.
- Two (02) fixed wheel gates with fixed electromechanical hoist for Power channel intake
- Two (02) Stoplogs for isolation of Fixed Wheel Gates at Intake.
- Trash rack for Intake along with trash cleaning machine.
- Two (02) fixed wheel gates with manual hoisting for sand trap (sediment flushing gates).
- One (01) intake slide gate at Sand trap inlet, operated with manual hoisting machine.
- One (01) outlet slide gate at Sand trap outlet to provide water to the Power Chanel; operated with manual hoisting.
- Four (04) vertical slide gates for Turbine Draft tubes, operated by gantry crane.

S-9 Electro-Mechanical Equipment

Four Francis turbines have been proposed with the following features and parameters:

Parameters	Values				Units
	Turbine 1	Turbine 2	Turbine 3	Turbine 4	
Turbine Type	Francis	Francis	Francis	Francis	
Configuration	Vertical	Vertical	Vertical	Vertical	
Rotational Speed 'N'	500	500	500	750	RPM
Rated Head (H_n)	166.1	166.1	166.1	166.1	m
Rated Discharge (Q_r)	4.83	4.83	4.83	1.51	m^3/s
Acceleration (gravity)	9.81	9.81	9.81	9.81	m^2/s
Turbine Efficiency (η_t)	91.00%	91.00%	91.00%	91.00%	%
Generator Efficiency (η_g)	95.00%	95.00%	95.00%	95.00%	%
Transformer Efficiency (η_{tr})	99.00%	99.00%	99.00%	99.00%	%
Turbine Power (P_t)	7.16	7.16	7.16	2.24	MW
Net Power of all Units	23.72	-	-	-	MW
Generator Power (P_g)	6.80	6.80	6.80	2.13	MW
Power at Transformer (P_{tr})	6.74	6.74	6.74	2.11	MW
Net Power (Total)	22.33	-	-	-	MW
Internal losses and aux.	330	-	-	-	KW
Net Plant Capacity	**22**				**MW**

The powerhouse will be equipped with auxiliary mechanical equipment for the smooth operation as well as maintenance. Four generators, three of 8.5 MVA (6.8 MW) and one of 2.50 MVA (2.13 MW) have been proposed. Power factor would be 0.85 and generation will be at 11 kV. The generators will be synchronised at a common bus-bar feeding to four step-up transformers of 10/13 MVA capacity. The power would be transmitted through 132 kV lines to the substation.

S-10 Power & Energy Calculations

The power and energy have been calculated as per the MC proposed project layout by using the flow duration curve based on mean daily estimated flows at the weir site, design discharge of

16.0 m^3/s, compensation flows of 0.3 m^3/s, net head of 166.10 m, the installed capacity would be 22 MW and it would generate annual energy of 98.51 GWh with the plant factor of 50.40 %.

S-11 Construction Schedule

The construction activities would span over a period of 40 months. After notice to proceed, the Contractor shall establish the site camps and installations, mobilize the staff and equipment.

The EPC Contractor as its responsibility shall prepare the Detailed Engineering Design Level-1, final the plant size & layout and perform the additional geotechnical investigations. Meanwhile, the Employer shall get approval of revised PC-I if required & complete land acquisition for access roads and permanent structures, etc.

Upon review of Level-1 designs by the Engineer, the EPC Contractor shall furnish the Detailed Engineering Design of Level-2 including standards and technical specifications etc for review and approval to proceed further for implementation of works stage by stage.

The construction activities for civil structures may be undertaken individually and simultaneously. The deliveries of E&M equipment shall be materialized at site by 16^{th} month.

The winter season in the project area is quite severe with snow fall. Some of construction activities like concreting shall not be possible during winter season. The main working season is from March to October each year.

S-12 MC Proposed Layout Plan for the Project

Figure S-1 gives the MC proposed layout plan for 22 MW Jagran-IV Hydropower Project.

S-13 Salient Features of the MC Proposed Tender Design

Table S-1 gives the salient features of the MC proposed basic level tender design. For comparison, the salient features of FS 2010 and TPV 2021 have also been provided.

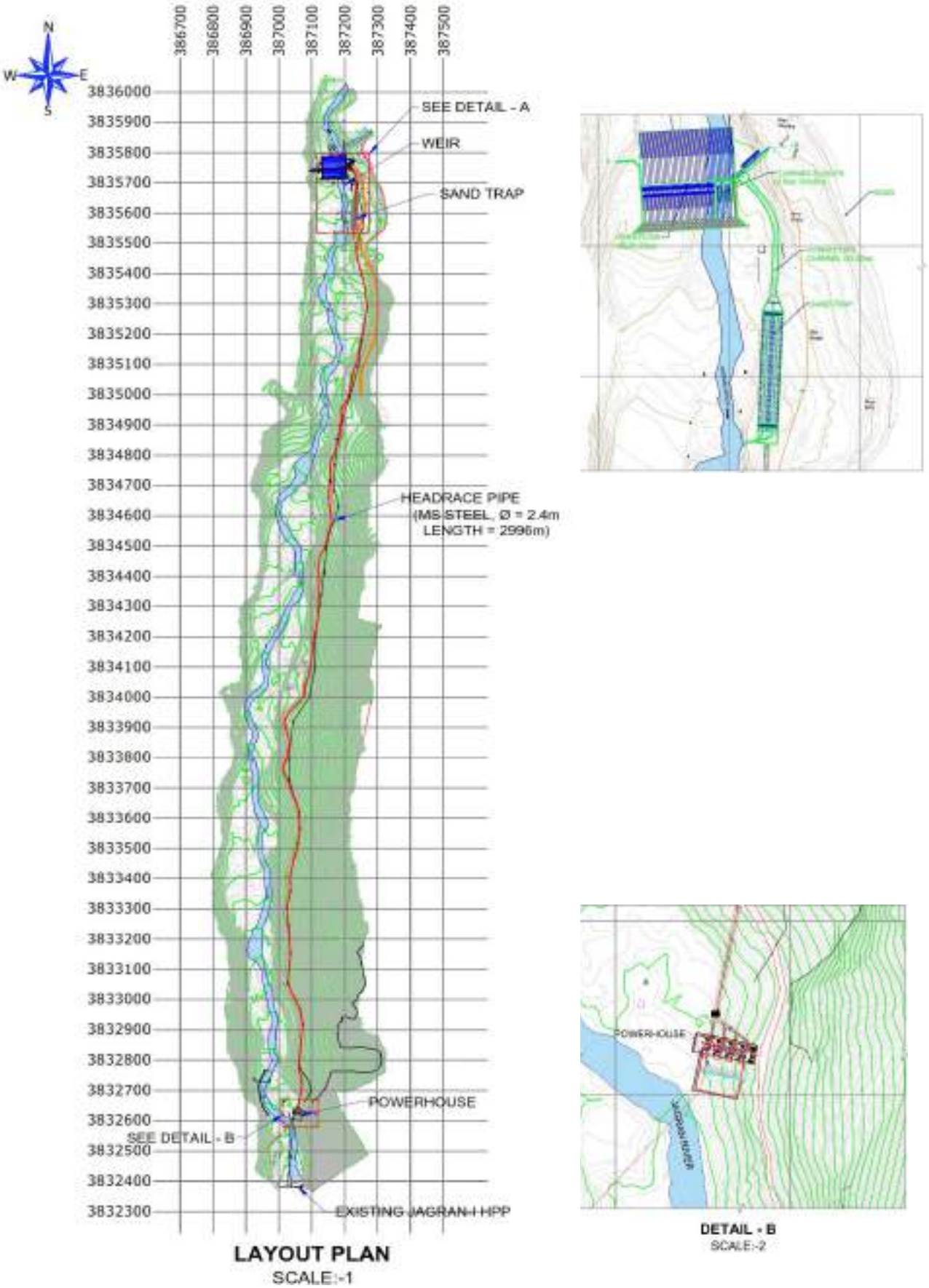


Figure S-1: Proposed Layout plan of 22 MW Jagran-IV Hydropower Project

Table S-1: Salient Features Jagran-IV Hydropower Project

Description	Project Features		
	Feasibility Study (FS), 2010	**Third Party Validation Study (TPV), 2021**	**Feasibility Study and Design Review Report (This Report)**
Catchment Area	Weir site = 214 Km^2 PH site = Not Available	Weir site = 205 Km^2 PH site = Not Available	Weir site = 205 Km^2 PH site = 216 Km^2
Gross Head	156 m	169 m	180.75 m
Net Head	144.2 m	158.44 m	166.10 m
Total Design Flow	18 m^3/s	16 m^3/s	16 m^3/s
Design Flow per Unit	4.9 m^3/s for three units & 3.27 m^3/s for one unit	4.83 m^3/s for three units & 1.45 m^3/s for one unit	4.83 m^3/s for three units & 1.51 m^3/s for one unit
Turbines	Francis-Vertical,	Francis Horizontal proposed as land is available at proposed site	Francis-Vertical,
Units	3x6MW & 1x4MW	3x6.67 MW & 1x2 MW	3x7.16 MW & 1x2.24 MW
Efficiency of Turbine	91 %	92.5%	91.0%
Efficiency of Generator	96 %	97 %	95%
Firm Power	2.3 MW	1.25 MW	0.92 MW
Total Energy Generation/annum	93.29 GWh	91.8 GWh	98.51 GWh
Plant Factor	51.25 %	50%	50.40%
Design Floods	• Design discharge of weir = 419 m^3/s • PH flood protection = Not proposed	• Design discharge of weir = Not proposed • PH flood protection = Not proposed	• Design discharge of weir = 954 m^3/s • PH flood protection = 979 m^3/s
Weir	H=6 m L=24 m	Weir axis is proposed 120 m downstream of previous location and with change in weir location, dimensions may change	Total Length = 140 m Overflow Section H=5 m & L=55 m Undersluices = 2 (5 x 5)
Connecting Channel	3.4x2.8 RCC and L=110 m	With change in weir location, dimensions may change	3.5 x 2.95 RCC and L=83.50 m
Sand Trap	2 (7 m x 56 m)	To be changed according to 16 m^3/s design flow	2 (7 m x 92.2 m). The sediment removal upto 0.25 mm dia is considered.

Description	Project Features		
	Feasibility Study (FS), 2010	**Third Party Validation Study (TPV), 2021**	**Feasibility Study and Design Review Report (This Report)**
Headrace Pipe	GRP headrace pipe L= 3,07 5m, Dia 2.5 m	Steel Penstock pipe L= 2,730 m, Dia 2.4 m	Steel Penstock pipe L= 2,996 m, Dia 2.4 m
Surge Pipe	L= 52 m, Dia = 5 m	Surge pipe is to be increased to 180 m or bypass surge relief valve to be installed with each turbine to ensure continuity of flow for the downstream power stations to avoid break down.	Surge pipe is deleted and pressure relief value are proposed to be installed with each turbine.
Penstock	L = 180 m, Dia = 2.5 m	This Pressure pipe penstock is not required.	This Pressure pipe penstock is not required.
Powerhouse	L=35.4 m W=10 m	Powerhouse site is proposed 40 m upstream of previous location with orientation favoring outflow into Jagran River.	L=35.4 m W=10 m
Tail Race	L=20 m	Will change according to new location	L=20 m
Generation Voltage	11 kV	11 kV	11 kV
Power Dispatch	132 kV	132 kV	132 kV
Project Cost	$US 43.249 million	$US 49.173 million	Being prepared as separate submission

1. INTRODUCTION

1.1 Background

Pakistan since long facing an affordable and sustainable Energy generation and distribution crises though Almighty Allah has blessed our country. Total hydropower potential in Pakistan is assessed to be more than 60,000 MW, of which more than 9,000 MW is available in the Pakistani-administrated territory of Azad Jammu & Kashmir (AJ&K).

To explore and develop hydropower potential, the government of AJ&K created Hydro Electric Power (HEP) Board in 1989 which was later re-organized to Azad Jammu & Kashmir Power Development Organization (AJK PDO) under the AJK PDO Act 2014.

The Government of Azad Jammu & Kashmir has decided to undertake the implementation of 22 MW Jagran-IV Hydropower Project through AJK PDO. The Project loan financing is available through Saudi Government loan (Saudi Fund for Development SFD) up to extent of 85% of the total project cost whereas the remaining 15% cost shall be arranged through GoAJK ADP & PDO. National objective of the project is to add a cheap and environment friendly, hydropower project into the system. This may help to reduce load shedding in the country up to some extent. In addition to national 'objective, Azad Jammu & Kashmir will be able to explore its valuable renewable resource and earn revenues from this project by selling power to the national grid.

District Neelum

The proposed Jagran-IV Hydropower Project is situated on the Jagran River in District Neelum, Azad Jammu and Kashmir. Neelum District is the northernmost and largest district by land area in the Pakistani-administered territory of Azad Kashmir, located in the disputed Kashmir region. It is famous for the Neelum Valley, a picturesque area along the Neelum River, known for its natural beauty and a destination for tourists. The district headquarters is in Athmuqam.

The Project

The proposed Jagran-IV Hydropower Project is identified on the intermediate stretch of Jagran River and forming the most upstream project in the Jagran river cascade hydropower projects. In the downstream, the **Jagran-I Hydropower Project** has already been constructed. In the further downstream, the **Jagran-II hydropower project** is currently under construction. At the most downstream, the **Jagran-III hydropower project** has been proposed, however, yet no construction activities have been started.

The official name of the project is

"Construction of 22 MW Jagran-IV Hydropower Project at Neelum River".

1.2 Accessibility to the Jagran-IV Hydropower Project Site

Access to the proposed Jagran-IV Hydropower Project site is generally good up to the vicinity of Kundal Shahi**.** It becomes more challenging within the Jagran Valley**,** where road conditions vary due to terrain and seasonal weather effects. The route from Islamabad to Jagran-IV primarily follows established highways and metaled roads, with the final approach requiring minor rehabilitation and the construction of a new bridge for full project access. A detailed summary of the access route is provided in **Table 1-1** below:

Table 1-1: Accessibility to the Project Area

Route Segment	Distance (km)	Road Condition	Accessibility	Key Notes / Estimated Travel Time
Islamabad to Murree	74	Wide, metaled, in excellent condition	Accessible year-round	The route forms part of the main Murree Expressway (E-75) and National Highway network. It is suitable for all vehicle types, including heavy trucks, buses, and light vehicles. The road is well-maintained, offering smooth connectivity from Islamabad to the hill region. Estimated travel time: 1– 1.5 hours.
Murree to Muzaffarabad (via Kohala)	80	Metalled road with frequent elevation changes and sharp bends	Accessible year-round	This section descends from the Murree hills toward Muzaffarabad through mountainous terrain. While the surface is generally good, the route includes steep gradients and sharp curves requiring cautious driving, particularly for heavy vehicles. Regular maintenance ensures all-season usability. Estimated travel time: 1.5 – 2.0 hours.
Muzaffarabad to Kundal Shahi (Neelum Road)	75	Good-quality metaled road running along the Neelum River	Accessible year-round	The Neelum Valley Road (N-15 extension) follows the Neelum River with occasional narrow or damaged stretches due to slope failures or monsoon runoff. It remains open for most of the year and serves as a vital corridor for the upper Neelum region. Estimated travel time: 2.0 – 2.5 hours.
Kundal Shahi to Kutton	5	Existing access road with some rough and narrow patches	Almost accessible year-round. However, limitation in flood season	This section sustained significant damage during the August 2025 cloudburst event. The bridge over the Jagran River was washed away, temporarily disrupting access to the project area. Connectivity is currently maintained via an alternative village route, increasing travel distance by approximately 4 km. Estimated travel time: 20 – 30 minutes under normal conditions; up to 45 minutes using the alternative route.
Kutton to Weir and Powerhouse Site (Jagran Road)	15	Existing access road with intermittent rough and narrow patches	Seasonal (limited access in winter)	The road enters the Jagran Valley and traverses' hilly terrain prone to localized landslides and surface deterioration from rain and snow. Heavy winter snowfall resulting avalanches may cause temporary closures, restricting movement of personnel and materials. Estimated travel time: 30 – 45 minutes in dry conditions; may extend to 1 hour or more after rainfall or during snow season.

Overall, while the main approach roads are reliable and operational year-round, targeted improvements within the Jagran Valley, including road strengthening, slope stabilization, and bridge construction, will be necessary to achieve safe and uninterrupted access to the project site during both construction and operation stages.

1.3 Scope of Consultancy Services

Consultants were invited through a Request of Proposal (RFP) for the Consultancy Services. A joint venture (JV) of Associated Consulting Engineers - ACE Limited, Saud Consultant and Rehman Habib Consultants (RHC) Lahore submitted their Technical and Financial Proposal.

After a nationwide competitive process by AJK Power Development Organization (AJK PDO) and Government of AJK, the Consultancy Services Agreement of Management Consultancy Services for 22 MW Hydro Power Project Jagran-IV, District Neelum (AJK) was awarded to joint venture (JV) of ACE, Saud Consult and RHC Consultants. The Contract Agreement was signed on August 15, 2025 having the Commencement of Works on August 29, 2025. The date of completion of the project is June 29, 2029 with a duration of the consultancy services of 46-months, which includes 6-months for assisting the Procurement process and 40-months for Pre-Construction & EPC Construction Phase. The defect liability period is 12-months after the date of completion.

As per the ToRs, the MC are responsible for review and up gradation of the feasibility study reports & tender designs, prepare the EPC / turnkey tender documents for inviting National/ International Competitive Bidding (ICB), prepare replies to bidder's quarries, evaluation of bids, assist the PDO in negotiations with successful bidder and finalization of Contract Award and Agreement. The MC shall also review the EPC contractor's detailed engineering designs and perform the project management, supervision and contract administration activities.

The Management Consultants (MC) has established their Head office in Lahore since the commencement and deployed the key experts and other staff who are providing their services on the intermittent basis under the supervision of full-time deputed Project Manager to meet the contractual obligation and reporting requirements**.**

1.4 Basis of the Tender Design

After mobilization, the Client & MC experts performed a joint site visit to the Project area during the period from 15 to 19th October 2025 and visually inspected various layouts proposed in previous studies including weir, connecting channel, sand trap, low pressure pipe & and powerhouse. The team also visited the weir & powerhouse cavern of existing Jagran-I as well as the weir & powerhouse structures of under construction Jagran-II Hydropower Project. A follow-up meeting was also held in PDO AJK Office, Muzaffarabad, wherein the visiting team briefed the Managing Director, AJK & Project Director about the sites visited & visit key findings.

Subsequently, the MC completed review of the previous studies pertaining to the FS 2010 and TPV 2021. The MC also reviewed the design reports of the Jagran-I and Jagran-II Hydropower Projects. Based on above comprehensive reviews, the MC identified the gaps in the previous studies and proposed their recommendations in the Feasibility Study and Design Review Report which was submitted to the Client vide letter No. DHS / 31 / 185 dated 14th November, 2025. The following recommendations were included in Feasibility Study and Design Review Report:

1.4.1 Recommendation for Tender Level Design Studies

1. The topographic survey work carried out by FS consultants is no more reliable due to frequent landslides observed on either side of the banks, which has resulted changes in river widening of the river. The flood of 2010 has also major impacts on topography. On the other, the survey map prepared of TPV consultants with 1 m contour covers all proposed structures of the project. Therefore, TPV consultant's topographic survey have been considered for the planning of project layouts and preparation of the tender level design and drawings.

2. The long term estimated river flows by FS consultants is found based on outdated river flow data upto 2010, it has also used 10-daily data which introduces errors in the calculation. On the other hand, the TPV consultants has used the latest daily flow data and achieved relatively high R2 = 84.21 as compared to the Feasibility value of R = 832, therefore, TPV consultants estimated long term daily flows at the weir site have been considered for selecting the design discharge of plant, performing the power and energy calculations and preparation of tender level design and drawings.
3. The flood studies carried out by FS consultants are found outdated as no flood data of 2010 has been considered. Keeping in view the devastating damages to existing Jagran-I project during the flood 2010 event and to ensure the safe operation of the proposed structures of the project, the enhanced revised design flood of 954 m^3/s for the design of weir and 979 m^3/s for the design of powerhouse flood protection are recommended.
4. The relocating of weir upstream from TPV, 2021 position to bypass an active right-abutment landslide is recommended. The site chosen by the MC has relatively stable abutments.
5. The relocation of the proposed powerhouse site is recommended to avoid the anticipated slope stability problems due to the necessary slope cutting for the powerhouse and penstock associated with FS consultants proposed location and move down from the mouth of a watershed valley to avoid the most likely potential hazard of mudflows or debris flows associated with the TPV proposed location.
6. The available geological and geotechnical data from previous reports do not seem to be sufficient to develop the tender level design for the Project. Several key inputs needed for the design of the foundations and other structural elements require additional and targeted investigations. Therefore, the MC recommended to the Client vide letter No. DHS / 31 / 168 Dated 20-10-2025 for additional investigation including ERT (Electrical Resistivity Tomography), SRT (Seismic Refraction Tomography) and Construction Material Testing to be performed on priority before weather conditions become unfavorable for further investigations. After Client approval the investigation were carried out as stated below.

1.4.2 Recommendation for Detailed Design to be furnished by EPC Contractor

1. It is recommended that the EPC contractor shall conduct the fresh topographic, bathymetric and LiDAR survey (along the route of the penstock pipe) by using the most updated available techniques at the detailed engineering design stage. This item will be included in the employer requirements of the EPC contractor.
2. It is recommended that the EPC contractor shall collect and purchase the latest available hydro meteorological data of climate, river flows and sediment of all relevant neighboring stations and update the hydrological data base and studies at the detailed engineering design stage. This item will be included in the employer requirements of the EPC contractor.
3. It is recommended that the EPC contractor shall establish an automatic weather and river flow measuring station with control room at the Jagran-IV power station at the preconstruction stage of the project. The proposed stations shall be equipment with all required sensors including the rainfall, temperature, humidity, etc as per requirement of the World Meteorological Organization (WMO) and Pakistan Meteorological Department (PMD). This item will be included in the employer requirements of the EPC contractor. The detailed specification shall be provided in the Bidding documents.

4. It is recommended that EPC contractor shall conduct detailed geological and geohazard mapping and drilling of bore holes. This item will be included in the employer requirements of the EPC contractor.

This Tender Design Report has been prepared as per the MC recommendations proposed in the Feasibility Study and Design Review Report. The Client approved the MC proposal regarding additional investigation vide letters No. 7676-77 dated 25th November 2025, therefore, a specialist qualified sub-contractor (M/s GEMS) was hired who completed the ERTs & SRTs surveys at the field and submitted the results in separate reports. Therefore, the results of above investigations have also been considered in this Tender Design Report.

While preparing this tender design report, the MC experts have performed state of the art analyses & calculations pertaining to the various hydraulic, geotechnical and electro-mechanical aspects and with due considering the TPV Consultants conducted topographic survey & updated design floods and proposed sizing of the various structures including weir, power intake, connecting channel, low pressure pipeline and surface powerhouse with vertical turbine-generator set configurations. **Table 1.2** gives the salient features of the 22 MW Jagran-IV Hydropower Project as per the above Tender Design prepared by the MC.

Table 1-2: Salient Features of 22 MW Jagran Hydropower Project

Location		Sand Trap	
95 km from Muzaffarabad and 20 km from confluence of Jagran River with Neelum River at Kundal Shahi		Length of main chamber	92.2 m (effective)
Organization		Design particle size	0.25 mm
Azad Jammu & Kashmir Power Development Organization (AJK PDO)		No and Size of Chambers, W x H	2 Nos each of 7.00 x 10.65 m
Hydrology		No and size of Inlet gates of Sandtrap, W x H	2 Nos each of 4.30 x 3.20 m
Catchment area (Weir Site)	205 km^2	No and size of Outlet gates of Sandtrap, W x H	2 Nos each of 7.20 x 3.70 m
Mean annual flow	4.9 to 17.7 (12.3 m^3/s average)	No and size of Flushing conduits, W x H	Gated 1.0 x 1.0 m
Weir: Design Flood, 1000-year return period	954 m^3/s	Length of flushing pipe	40 m
Powerhouse: Design Flood, 1000-year return period	979 m^3/s	Headrace Pipe	
Weir & Under sluices		Type	Steel pipe
Weir type	Ungated Ogee	Design Discharge	16 m^3/s
Design Capacity (cumecs) ungated overflow crest	602 m^3/s @ MFL=2256.90 m	Diameter	2.4 m
Width of overflow weir	55 m	Length	2996 m
Crest elevation of overflow weir	2254 m	Flow velocity	3.54 m/sec
Height of weir from river bed	5 m	Powerhouse and Tailrace	
Type of Undersluices	Radial Gated	Type	Surface
Design Capacity	302 m^3/s @ MFL=2256.90 m	Size (L x W x H)	35 x 10 x 18 m
No. of gates	2 No's	Tailrace length	20 m
Size of Undersluices (W x H)	5 x 5 m	Tailrace Width	24 m
Invert level of flushing outlets	2249 m	Type of turbine	Francis
Intake/ Connecting Channel		Plant rated flow	16 m^3/s
No. of intake gates	2 No's (vertical lift stoplog)	Unit orientation	Vertical axis
Design Discharge	16 (19.2 m^3/sec incl. Flushing)	No. of units	4 No's

Type and size of intake gates (W x H)	Vertical Lift 3.5 x 2.95 m	Installed capacity	3 Units of 7.16 MW each and one unit of 2.24 MW
Size of stoplog (W x H)	3.5 x 2.95	Power & Energy	
Intake invert level	2251.65 m	Gross Head	180.75 m
Length of Connecting Channel	83.5 m	Head Loss	14.65 m
Size W x H	3.50 x 2.95 m	Net Head	166.10 m
Flow Depth	2.35 m	Installed capacity	22 MW
Flow velocity	2.36 m/sec	Mean Annual Energy	98.51 GWh
Free Board	0.6 m	Plant Factor	50.40 %
Bed Slope	1 in 800		
Sand Trap			
Type	Free flow		
No. of chambers	2 No's		

1.5 Structure of the Tender Design Report (This Report)

The tender design report has been prepared and arranged in two volumes as below:

- Volume 1 - Main Report (this report), and
- Volume 2 - Tender Drawings.

The Volume 1 is further sub-divided as follows;

Chapter 1 - Introduction: This chapter describes the general background of the project, location, accessibility to project, scope of consultancy services & format for the current report.

Chapter 2 - Hydrology and Sedimentation Studies: This chapter outlines the Catchment, Rainfall, Temperature, River Flows, Flow Duration Curve, Design Floods & Sediment Loads. The further data collection & studies to be carried out by the EPC Contractor are also proposed.

Chapter 3 - Geotechnical Analysis & Design: This chapter reports available information on Geological, Geotechnical aspects from previous studies, observations on Ground Conditions at Structure Locations & details of Geophysical Investigations carried on site. The chapter also outlines Bearing Capacity, Subsurface Analysis, Seismic Hazard Evaluation & proposes foundation design for the weir, powerhouse & buried steel headrace pipeline. The recommendations for future investigation to be carried out by EPC Contractor are also provided.

Chapter 4 - Selected Layout Hydraulic Design Studies: This Chapter describes Layout of selected scheme. This includes river water surface profile analysis of Jagran river at weir and powerhouse location. Sizing of overflow spillway and Under sluices based on selected design flood. Power intake sizing based on optimized design discharge, hydraulic design of Conduit, Sandtrap, Headrace pipe dia and thickness selection, Powerhouse layout and detailed calculation of Power waterways Head Losses.

Chapter 5 - Power and Energy Simulation: This chapter describes detailed energy calculations by keeping in view the hydrology and selected dimensions of the power waterway.

Chapter 6 - Structural Design Studies: This chapter describes the structural design of Project features which includes Weir Structure, Power Intake, Connecting Channel, Sandtrap, Headrace pipeline, Powerhouse building, cross-drainage structures, retaining wall, etc.

Chapter 7 - Hydro-Mechanical Equipment Studies: This chapter describes the general arrangements of the Powerhouse. Hydromechanical design includes selection and sizing of Turbine and its setting, Governor System, sizing of Main Inlet Valve, system design of the aspects like, Cooling Water, Drainage and Dewatering, Fire Protection, Oil Handling, Sewerage Treatment, provision of the Elevator and Overhead Crane. This also includes the hydro mechanical design of power intake gates, under sluice Radial Gates, Flushing gate at sandtrap.

Chapter 8 - Electrical Equipment Studies: This chapter describes the general arrangements of Power Supply system and Electrical System. Further, in this chapter arrangement and parameters of Generators, Excitation System, Generator Phase & Neutral Cubicles, Switchgear, Transformers, SCADA, Communication & Security System, Metering System, Protection System, MV & LV System and other specifications of Lighting and Small Power are elaborated.

Chapter 9 - Construction Planning: This chapter details the Construction Planning including, Land Acquisition, Mobilization and Preparatory Works, Exploration for Borrow Areas and Construction Materials, Coffer Dams, Weir and Intake Structure Works, Conduit, Sand Tap, Buried Steel Headrace Pipe, Powerhouse, Installation of E&M Equipment, Transmission Line, Testing and Commissioning.

2. HYDROLOGY AND SEDIMENTATION STUDIES

2.1 General

This section describes the information on catchment area, climate, temperate, river flows, flow duration curve, design floods and sediment load which are considered while preparing the tender design studies for the Jagran-IV Hydropower Project.

2.2 Catchment Conditions

The Jagran River basin falls in the climatological region called as subtropical continental high lands. The climate in the region is arid and characterized by cold snowy winters with general winter and spring rains. At higher altitudes, mountains are perpetually clad with snow.

The description of catchment show that river descends from mountain peaks at elevations of 5030.70 and 5021.00 m asl. The river along its length has a few tributaries joining the main stream from either bank.

The flows of Jagran River are generated with snow fall and rainfall in the catchment. Several glaciers are in its upper catchment above El. 4,000m. The catchment of Jagran River experience snowfall in winter months and receive rainfall in summer months. The intensive rainfall and snow results in high flows during summer months.

The elevation at its confluence with Neelum River is 1330 m asl. The average gradient of Jagran River in the project area is about 4.4%. Generally, the ground slopes on either bank of river are very steep.

The MC Consultants has carried out catchment area analysis by using the SRTM data with 30 m by 30 m through conducting watershed analysis with GIS technique. Based on above analysis, the Catchment area of 205 km^2 at the weir site has been calculated. Similarly, the catchment area at the powerhouse is calculated as 216 km^2.

Figure – 2-1 gives the catchment area map of Jagran River as given in Feasibility Study, 2010:

.

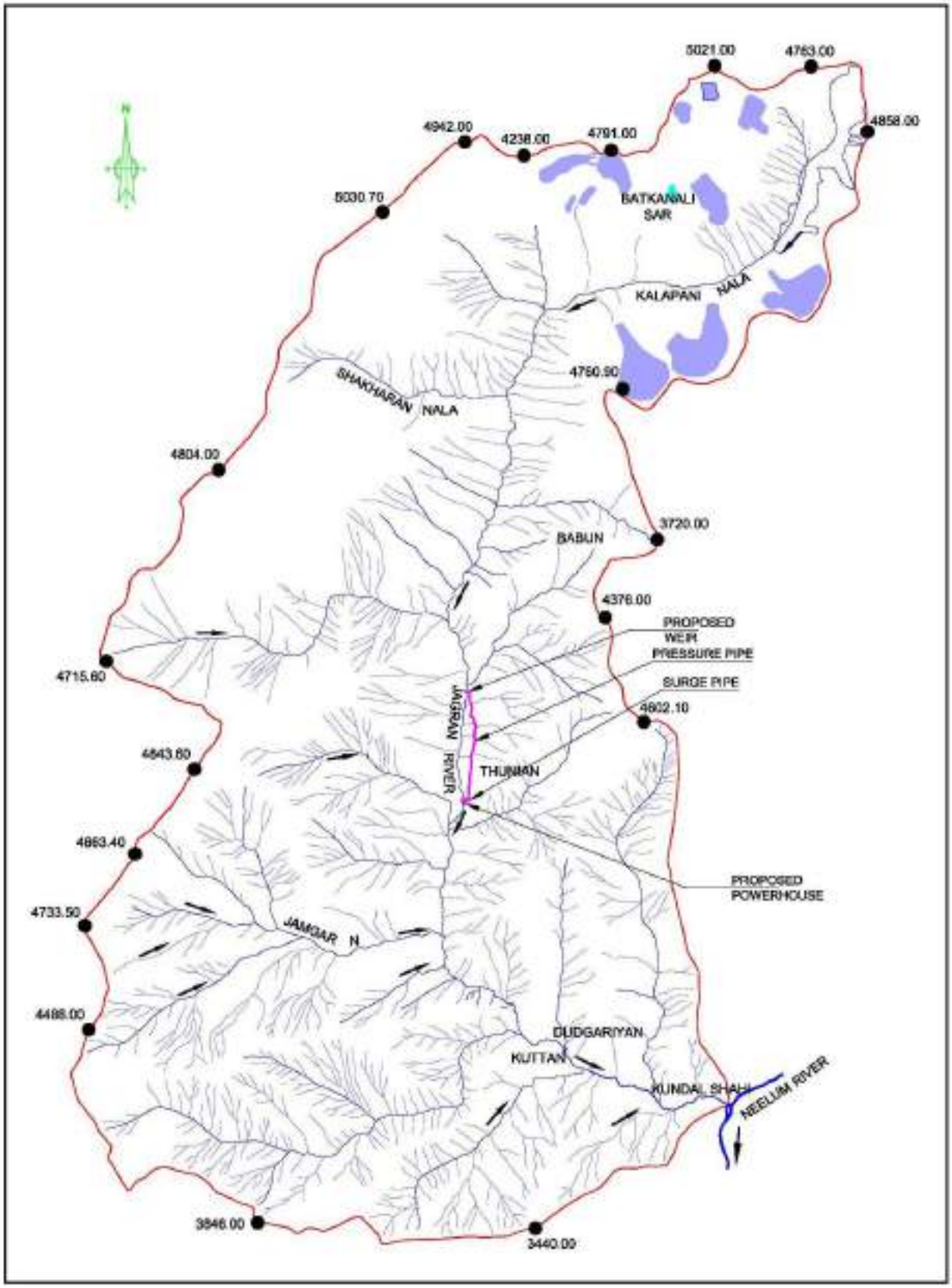


Figure 2-1: Catchment Area of Jagran River (FS, 2010)

2.3 Hydro Meteorological Stations

The climatic and river flow measurement data in Neelum valley is very scarce. One station in Neelum valley with limited climate record is at Dudhnial. The nearest stations to project area with long term record are located at Muzaffarabad and Naran. The Kundal Shahi and Thunian stations installed on Jagran River provide valuable records but for very limited time period, these stations are no more operative. The list of hydro meteorological stations in the region as reported in Feasibility study, 2010 is presented in **Table 2-1**. The locations of the stations are shown in **Figure 2-2**. The coordinates need to be confirmed.

Table 2-1: List of Hydro meteorological Station in the Region

Station / River	Location		El. (m asl)	Area (km²)	Period of Record	Mean Annual Flow (m³/s)	Specific Flows (l/s/km²)
	Latitude	Longitude					
Muzaffarabad	34°22’	73°28’	670	7278	1963-2006	337.6	46.2
Nausehri	34°23’	73°43’	1030	6809	1990-00	306.0	44.9
Dudhnial	34°42’	74° 7’	1823	4905	1980-92	259.2	52.8
Naran	35°27’	75°25’	2341	1036	1960-2000	48.0	46.3
Thunian	35°35’30”	75°18’50”	2150	219	Jul 94 - Jun 96	17.26	78.8
Kundal Shahi	35°27’22	75°18’40	1360	430	Jul 94 -Jun 96 & Sep 82-Aug 84	27.0	62.8
Taobut (Gagai)	35°35’30”	75°8’20”	2250	275	Jan 92 - Jun 95	19.35	70.4

Figure 2-2: Location of Hydro Meteorological Stations (Jagran-II Project Report)

2.4 Climatic Data

The climatic data in Neelum valley is very scarce. The nearest stations to project area with long term records are located at Muzaffarabad and Naran. The list of Climatological stations in the region is presented in **Table 2-2.**

Table 2-2: Long Term Climatic Stations in Jhelum River Basin

Station	Mean Annual Rainfall (mm)
Balakot	1718
Garhi Dopatta	1602
Dudhnial	1541
Muzaffarabad	1534
Bagh	1415
Sehr Kakota	1386
Rawalakot	1375
Kotli	1255
Palandri	1230
Mangla Dam	1221
Rehman Bridge	1132
Naran	1118
Kallar	945
Jhangi	921

Source: SWHP, WAPDA as reported in Feasibility Study, 2010

2.4.1 Precipitation Data

No precipitation data is available at the project site. The one meteorological station with long record of precipitation is located at Muzaffarabad, at a distance of about 95 km from the project area. **Figure 2-3** and **2-4** gives the total annual precipitations measured at the Muzaffarabad and Naran stations respectively.

In Figure 2-3, the total annual precipitations at Muzaffarabad vary from 747.3 mm in 1975 to 2154.4 mm in 2006. The mean annual precipitation is 1488.0 over a period from 1961 to 2010.

In Figure 2-4, the total annual precipitations at Naran vary from 755.4 mm in 1985 to 5138.1 mm in 1991. The mean annual precipitation is 1795.40 over a period from 1961 to 2014.

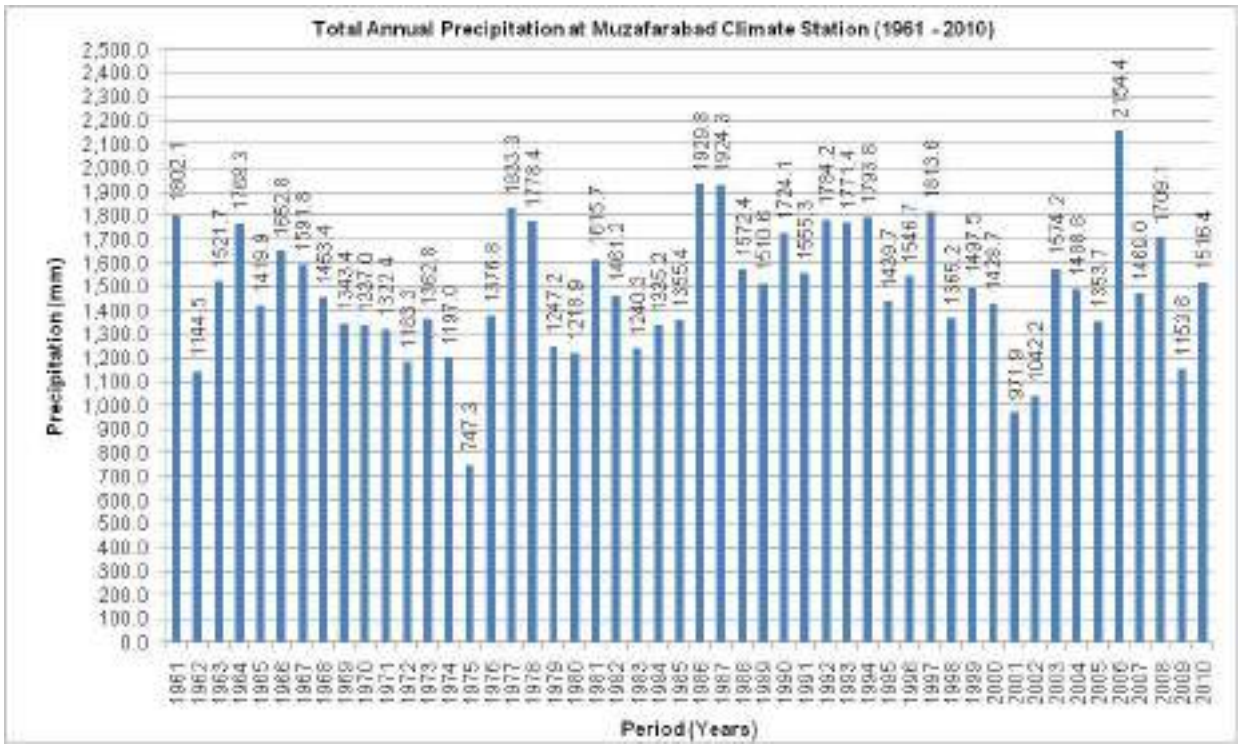


Figure 2-3: Total Annual Precipitations at Muzaffarabad Climate Station

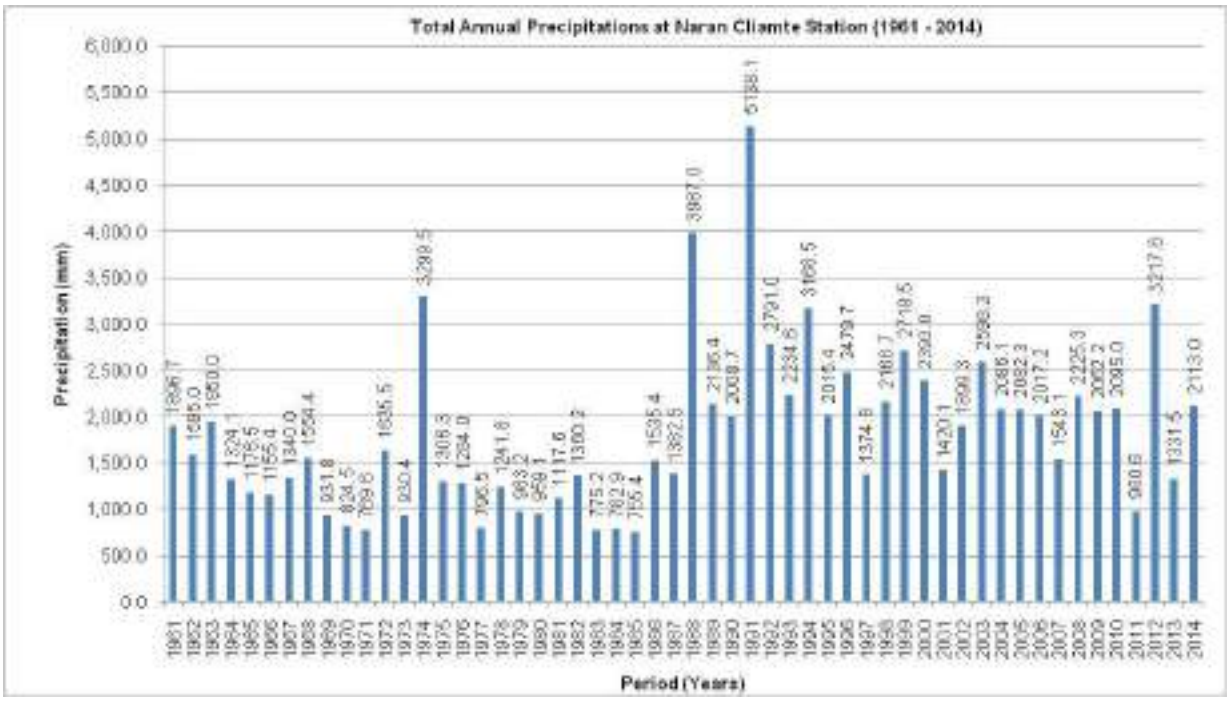


Figure 2-4: Total Annual Precipitations at Naran Climate Station

2.4.2 Temperature Data

No temperature data is available at the project site. The one meteorological station with long record of temperature is located at Muzaffarabad, at a distance of about 95 km from the project area. **Figure 2-5 and 2-6** gives the mean max minimum and maximum temperatures observed at the Muzaffarabad and Naran stations respectively.

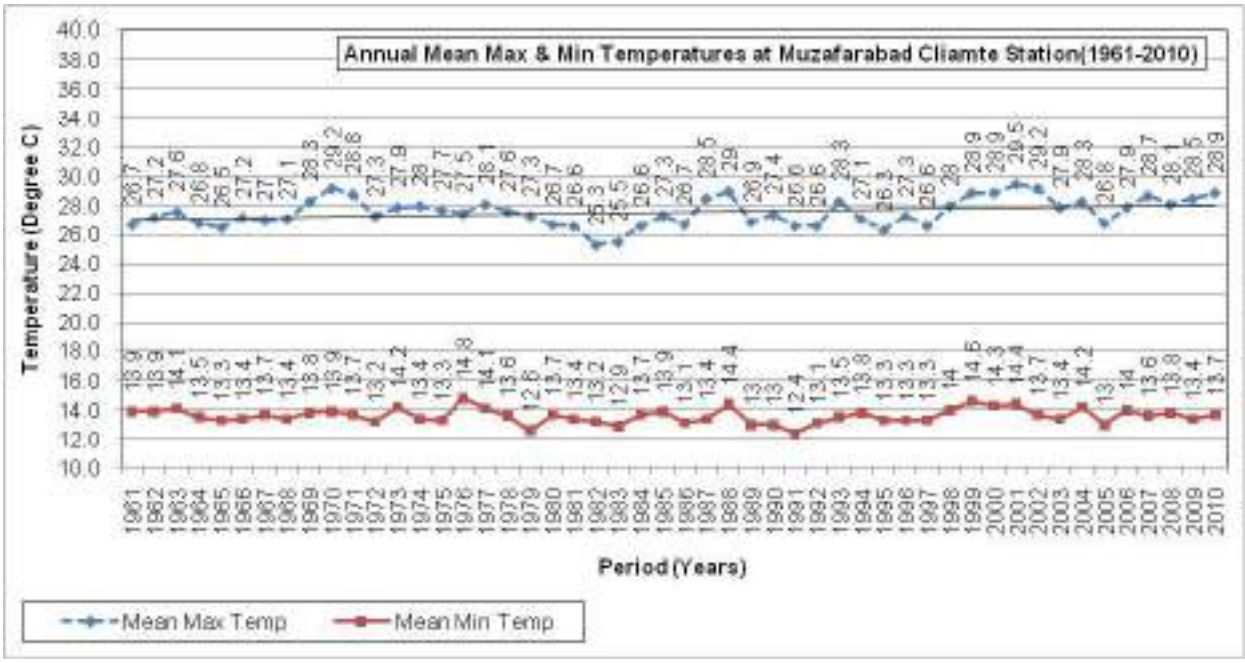


Figure 2-5: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station

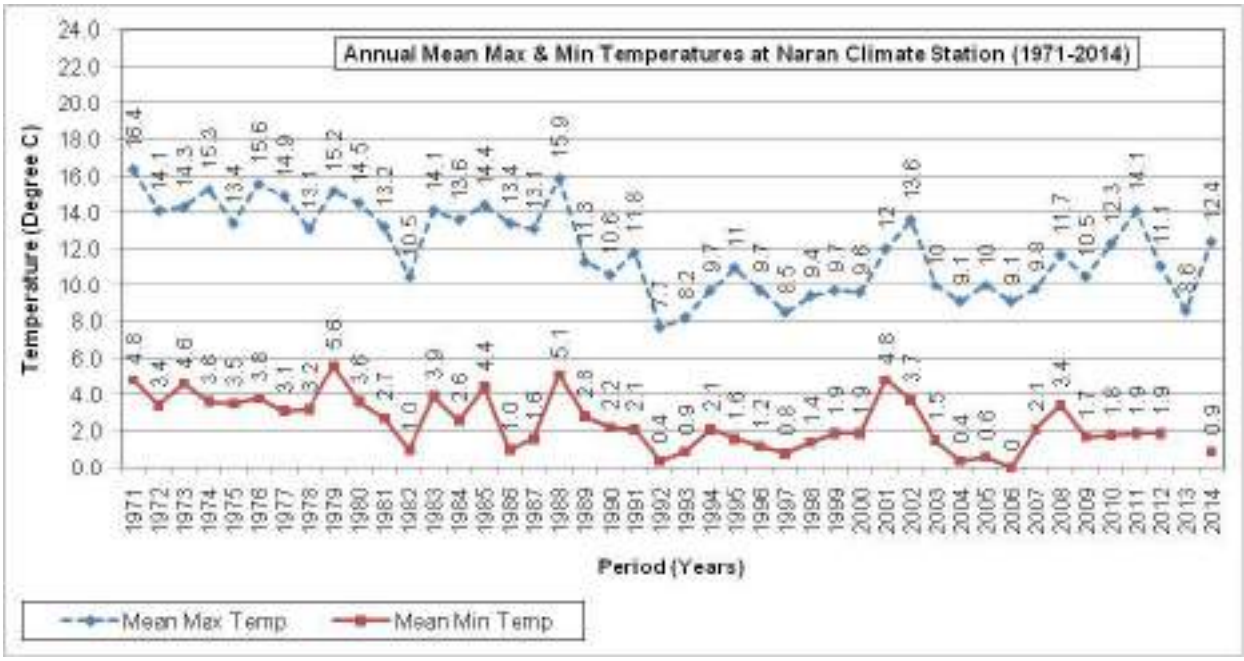


Figure 2-6: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station

In Figure 2-5, the annual mean maximum temperatures at Muzaffarabad vary with the minimum value of 25.3 °C in 1982 and maximum value of 29.5 °C in 2001. Similarly, the annual mean minimum temperatures at Muzaffarabad vary with the minimum value of 12.4 °C in 1991 and maximum value of 14.8 °C in 1976.

In Figure 2-6, the annual mean maximum temperatures at Naran vary with the minimum value of 7.7 °C in 1992 and maximum value of 16.4 °C in 1971. Similarly, the annual mean minimum temperatures at Naran vary with the minimum value of 0 °C in 2006 & 2013 and maximum value of 14.8 °C in 1976.

2.5 River Flows

A staff gauge was installed near the Thunian rest house on July 04, 1994 by the Jagran-I implementation Consultants. The data observation was carried out twice a day and once or twice a month and during floods, the observation was made every two hours. The observation upto May 06, 1996 i.e. covering almost two years were collected and processed.

The TPV Consultant collected the updated daily flow records of Naran station (Record: 1960-2008) on Kunhar River and Nausehri station (Record: 1991 to 2015) on Neelum River and has carried out the correlation analyses between the daily specific flows of Naran and Nausehri stations with the Thunian station.

Based on above analyses, the correlation between daily flows of Neelum River at Nausehri station and Jagran River at Thunian station was found more realistic and adopted for the estimation of daily flow record from 1991 to 2015 at the proposed weir site of Jagran-IV hydropower project.

Figure 2-7 gives the comparison of observed viz extended mean monthly flows at the proposed weir site of Jagran-IV hydropower project.

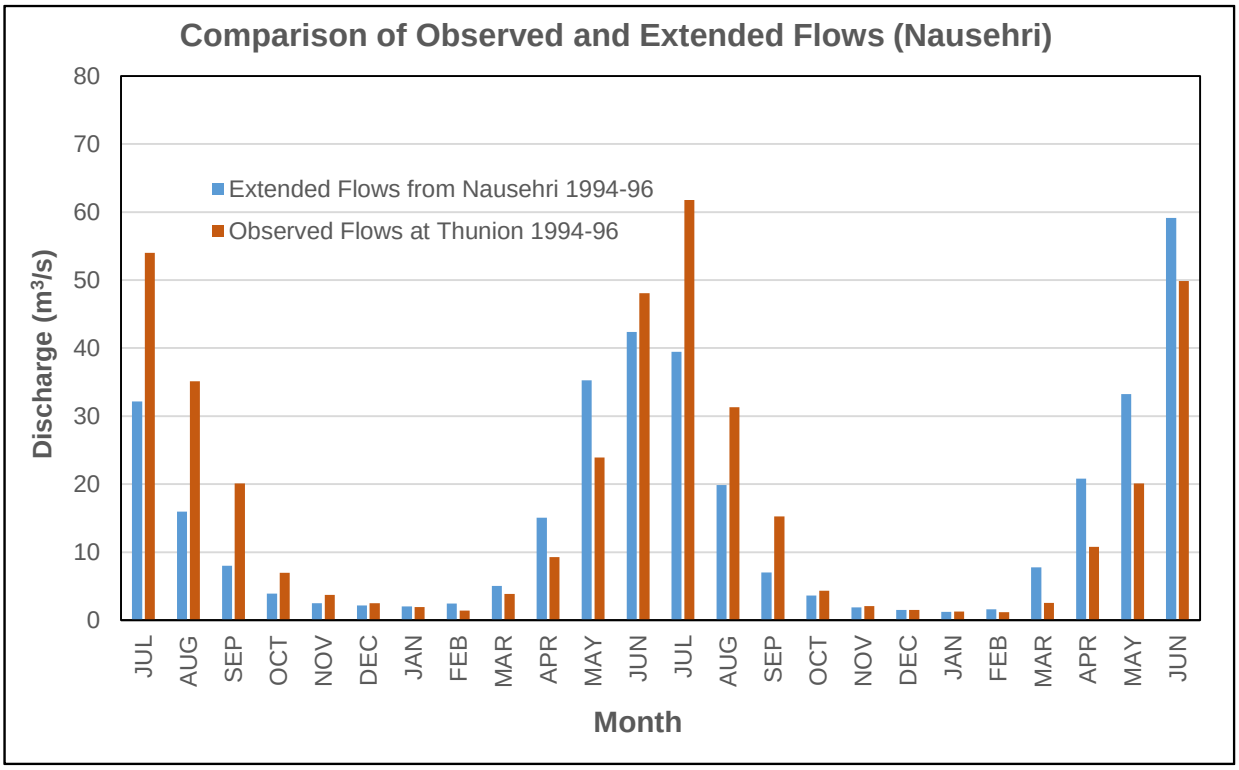


Figure 2-7: Comparison of Observed & Extended Flows at Thunian Station (TPV, 2021)

Figure 2-8 shows the variations in the mean annual flows of the extended flow series at the proposed weir site of Jagran-IV hydropower project. The figure shows that the estimated mean annual flow at proposed weir site of Jagran-IV hydropower project varies from 4.9 to 17.7 m^3/s with average value of 12.30 m^3/s.

Figure 2-8: Estimated Mean Annual Flows at Proposed Weir Site of Jagran-IV HPP

2.5.1 Flow Duration Curve

Table 2-3 gives the proposed flow duration curve which is developed in the TPV Consultant using the extended long term daily flow series at the weir site of Jagran-IV hydropower project.

Table 2-3: MC Proposed Flow Duration Curve at Weir Site Jagran-IV HPP

Time (%)	Flow (m^3/s)	Time (%)	Flow (m^3/s)
0	183.98	55	4.9
5	40.17	60	3.99
10	32.48	65	3.28
15	27.46	70	2.8
20	23.4	75	2.45
25	18.87	80	2.17
30	15.12	85	1.85
35	12.2	90	1.57
40	9.93	95	1.21
45	7.91	100	0.62
50	6.18	Mean	12.39

Source of Data: Third Party Validation Study, 2021

2.6 Design Floods

2.6.1 Collection of Flood Data

No instantaneous flood data is available for the Jagran River. The one meteorological station with long record of temperature is located at Muzaffarabad, at a distance of about 95 km from the project area. **Table 2-4** gives the annual maximum observed flood data from 1963-14 of Neelum River at Muzaffarabad.

Table 2-4: Annual Maximum Observed Floods at Muzaffarabad (1963-14)

Year	Date	Flood (m^3/s)	Year	Date	Flood (m^3/s)
1963	14-Jun	1375	1989	3-Jul	1347
1964	15-Jul	1538	1990	17-May	1345
1965	22-May	1767	1991	9-Jun	1560
1966	17-Jun	1721	1992	10-Sep	3766
1967	9-Jul	1675	1993	10-Jul	1431
1968	11-Jul	1310	1994	20-May	1127
1969	2-Jun	1661	1995	26-Jul	2351
1970	22-May	937	1996	21-Jun	2029
1971	9-Jun	812	1997	27-Aug	1294
1972	17-Jun	1534	1998	26-Apr	1053
1973	12-Jun	1307	1999	20-May	930
1974	19-Jun	846	2000	9-May	578
1975	16-May	1308	2001	11-May	453
1976	2-Aug	1565	2002	18-May	782
1977	12-Jun	1118	2003	6-Jun	1139
1978	25-May	1438	2004	20-May	784
1979	26-Jun	968	2005	28-Jun	1399
1980	21-Jun	1064	2006	16-May	1312
1981	6-May	1265	2007	30-Jun	815

Year	Date	Flood (m^3/s)	Year	Date	Flood (m^3/s)
1982	9-May	841	2008	30-May	1050
1983	2-Jul	1412	2009	21-May	1180
1984	3-Jul	1344	2010	10-Jul	3330
1985	7-Aug	990	2011	20-May	1136
1986	25-Jun	1531	2012	18-Sep	1003
1987	22-May	1542	2013	27-May	1133
1988	26-Jun	2237	2014	5-Sep	1563

2.6.2 Historic Flood 2010

The Jagran River has been subjected to several flooding in the past. During the flood 2010, the under-sluice gates installed at the weir of Jagran-I hydropower project were washed away. The flood 2010 also caused destruction to houses and switchyard of Jagran-I hydropower project was completely demolished. The rehabilitation of damaged infrastructure resulted in loss of money as well as shutdown of the power plant for about 1-year period. Therefore, estimation of reliable floods for the Jagran River is crucial which not only results in economy but also ensure the safe operation of the hydropower structures e.g. weir and powerhouse.

2.6.3 Review of Design Flood Studies of Jagran-II Hydropower Project

The updated Hydrology and Sedimentation Study Report, 2018 prepared by the EPC Contractor as part of the Stage-II detailed design studies for Jagran-II hydropower project was collected and reviewed. The EPC contractor has implied following approach to estimate various return period floods for Jagran-II Hydropower Project:

- The statistical approach has been adopted in estimation of floods.
- The annual maximum observed flood data from 1963-14 at Muzaffarabad is used.
- The catchment area of the Neelum River at Muzaffarabad station is taken as 7270 Km^2.
- The historic maximum flood is presented in 2010 with peak value of 850 m^3/s.
- A so called “factor of square root” of 0.19 is calculated from catchment area of Muzaffarabad station and Jagran-II Project weir.
- The above factor is applied to the annual maximum observed flood data at Muzaffarabad station & estimated annual maximum floods at Jagran-II project weir site.
- Flood frequency analysis with Log Pearson Type-III method is then carried out by using the above estimated annual maximum flood peaks and estimated various return period design floods at the weir and powerhouse sites and shown in **Table 2.5** below.

Table 2-5: Adopted Floods at the Weir and Powerhouse sites of Jagran-II HPP

Return Period (Years)	Weir Site	PH Site
	Catchment area = 262 Km^2	Catchment area = 354 Km^2
2	236	274
5	336	391
10	412	479
20	491	571
50	605	703
100	700	814
500	952	1107
1000	1078	1253

2.6.4 Estimated Design Floods for Jagran-IV Hydropower Project

The estimated design floods for Jagran-IV Hydropower Project are primarily based on design flood studies carried out by the EPC Contractor as part of the Stage-II detailed design studies for Jagran-II hydropower project by implying the following catchment ratio method:

- The factors of square root are calculated from catchment areas of weir and powerhouse sites of Jagran-VI hydropower project viz catchment area of weir site of Jagran-VI hydropower project.
- The factors are then multiplied with the estimated floods at weir site of Jagran-II hydropower project to get the estimated floods at the proposed weir and powerhouse sites of Jagran-IV hydropower project.

Table 2-6 gives the various return periods design floods which have been adopted for preparation of basic level tender design for Jagran-IV hydropower project.

Table 2-6: MC Proposed Design Floods at Weir site of Jagran-IV HPP

Return Period (Years)	Weir Site	Powerhouse
	Catchment area = 205 Km^2	Catchment area = 216 Km^2
2	209	214
5	297	305
10	364	374
20	434	446
50	535	549
100	619	636
500	842	864
1000	954	979

2.7 Sediment Loads

No sediment sampling measurements is available for the Jagran River; therefore, the sediments data available at Nausehri hydrological station has been used. **Figure 2-9** gives the rating curve drawn at the Nausehri station. The relation between discharge and sediment is shown below:

$$Y = 1.881X^{0.841} \ (R^2 = 0.432),$$

Whereas, Y represents sediment concentration (ppm) and X represent flow (m^3/s).

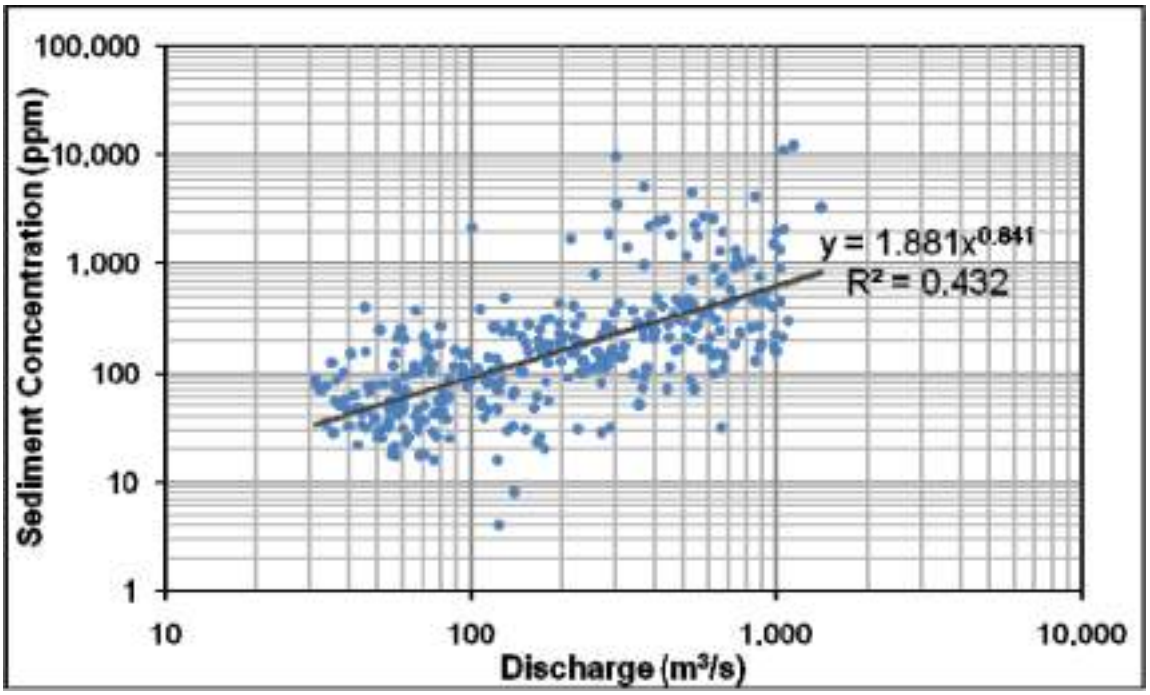


Figure 2-9: Suspended Sediment Rating Curve for Nausehri Station (FS, 2010)

By applying the above relationship, the sediment load at the weir site on Jagran River was calculated from the available sediment data and the detail is as under:

- Average flow (1991-2015) at Jagran-IV weir site = 12.3 m^3/s
- Suspended Sediment Load at Jagran-IV weir site (assumed) = 100 ppm
- 1-year total suspended sediment = 0.4374 M ST
- Add 20% suspended bed load, the total annual sediment load at weir site of Jagran-IV is calculated as 0.5249 M ST.
- The average %age value (composition of suspended sediment) for sand, silt and clay as 13%, 64% and 23% given in the Feasibility study may be proposed.

2.8 Further Data Collection and Studies to be carried out by EPC Contractor

The EPC contractor shall collect and purchase the latest available hydro meteorological data of climate, river flows and sediment of all relevant neighboring stations and update the hydrological data base and studies at the detailed engineering design stage. This item will be included in the employer requirements of the EPC contractor.

3. GEOTECHNICAL ANALYSIS AND DESIGN

3.1 General

The geotechnical design of the structures and facilities for the Jagran IV Hydropower Project includes analysis of subsurface seepage, foundations, and slope stability for these structures under static loading and seismic conditions. The structures involved in this hydropower project and the corresponding geotechnical analysis requirements are given in **Table 3-1** below.

Table 3-1: Geotechnical Analysis Requirements

Structure/Facility	Geotechnical Analysis	Design
Diversion Weir	Seepage	Seepage Cutoffs Sizing of U/S and D/S Floors
	Slope Stability (Static and Seismic)	Abutment and River Bank Slopes
	Bearing Capacity and Stability (Static and Seismic)	Weir Sizing/Dimensions
Desander	Excavation Slopes Stability	Excavation Slope angle/ Shoring works
Pieline/Penstock	Local Stability of the Thrust Blocks and/or Supports Foundations	Foundation Sizing
	Global Stability against the ground movements during Mudflows/Landslides/Avalanches	Ground Anchors/Piles
Powehouse and Tailrace	Long-term stability of the Powerhouse Foundation against Floodwater scouring, erosion, and seismic forces	Piled-Raft for the Powerhouse
	Long-term stability of the Powerhouse Retaining Walls against floodwater scouring, erosion, and seismic forces	Piles/deep foundations for the Retaining Wall
	Thrust due to the floodwater and the impact of moving boulders on the Tailrace Retaining Wall	Piles/deep foundations for the Tailrace Retaining Wall

This report provides the analysis and design details of the geotechnical aspects of the above-listed structures of the project. **Although the typical design details described in this chapter have been used for quantity estimation and economic evaluation, a precise design and the corresponding estimation should be reworked after the detailed Geological mapping and Geotechnical Investigations of the site by the EPC Contractor.**

3.2 General Design Guidelines and Criteria

The design criteria and principal guidelines for the geo engineering aspects of this hydropower facility are provided in this section.

- The abutment slopes of the diversion weir must remain stable under all conditions of construction and weir operations, including the maximum flood level and seismic forces;
- The resulting seepage or water head at the maximum flood water level must not be high enough to cause uplift and/or damage to the downstream floor;
- The weir foundation should not induce stresses exceeding the bearing capacity of the founding strata;
- The weir should be stable against lateral forces from static loading and seismic forces;
- Seepage through, around, and beneath the weir must be controlled to ensure that hydrostatic and seepage forces do not cause erosion at the interfaces;
- The headrace pipeline should be stable against all the local and global slope movements, like mudflows, debris flows, rock and snow avalanches, etc.
- The powerhouse and tailrace foundations should be able to resist all the possible erosion and undermining caused by the design flood conditions;
- The facility structure design should be such as to make optimum use of readily available materials, standard equipment, and normal construction controls.

3.3 Site Geology and the Geotechnical Strata

In the FSR 2010, most of the inferences and recommendations for the structures' geotechnical design were based on geological mapping data. This data includes a reconnaissance geological survey, identification of main geological features, and a surface geological map at a scale of 1:1000. The geological mapping results of this study indicate that the metamorphic crystalline rocks exposed in the valley form the cover and the basement. The surface geological mapping of the project area has been conducted on topographic sheets at a scale of 1:1,000 using a Total Station. Soil and rock units are shown on these maps. Some structural discontinuities, joints, and foliation trends are also marked. Based on these maps, the soil and rock units exposed at the site are described in the following sections. In most areas, the rock units are covered by sediments transported through glacial or alluvial processes.

3.3.1 Lithological Units at Site

3.3.1.1 Soil Units

The recent deposits are the most widespread soil units in the proposed project area, covering the bedrock and valley slopes and ranging from about 5 to 40 meters or more in thickness. Terrace deposits consist of mixtures of clay, silt, sand, gravel, and boulders in various proportions.

ABGM: Most slopes are covered with material composed of angular boulders, gravel with sand, and a significant amount of fines. These materials are primarily talus and glacial in origin, resulting from avalanches. The largest boulders in the area measure up to 8 x 7 x 6 meters.

RBGM: It consists of alluvial material with rounded to subrounded, loose to semi-consolidated boulders and gravel, sand, and a significant amount of fines. These deposits are found upstream of the proposed weir site in the form of terraces, as well as in the proposed powerhouse area and in the riverbed.

ABG: Overburden material consists mainly of large, angular/sub-angular boulders and gravel, with a minor amount of fines. These are found at the base of slopes.

RBG: Alluvial material deposited by streams is composed of rounded to sub-rounded boulders and gravel with a small amount of sand. These are loose and highly permeable, primarily found in the riverbed.

3.3.1.2 Rock Units

Primarily, the metamorphic rock unit, granitic gneiss, is exposed in the project area. Igneous intrusions of granite and granodiorite are also visible in some locations. The description of rock units exposed within the project area is provided in the following sections.

Gneiss: The gneiss found on the site appears dirty white to whitish gray on the weathered surface. Light-colored bands alternate with dark bands on the fresh surface. The flaky minerals indicate preferred orientation. The rock is medium to coarse-grained, hard, and sparsely jointed. Numerous granitic veins intrude into the surrounding rocks. Small pegmatitic dykes are also present within the gneissic granite. Mineralogically, it consists of a granular mixture of quartz, feldspar, muscovite, biotite, and accessory minerals such as tourmaline, garnet, magnetite, and apatite. Gneiss contains less mica, more quartz, and exhibits high strength.

Granite: It ranges from light gray to brownish in color. Fresh rock exposures display a whitish-gray hue. However, closer inspection reveals brownish-black biotite specks against a whitish-gray background. In some areas, black tourmaline is also present within the granite.

3.3.1.3 Rock Structure

Data on rock discontinuities and joint sets were gathered during surface geological mapping of the 2010 FSR. The most important aspect of a discontinuity is its orientation, indicated by strike and dip. Most of the observed discontinuities have medium-to-steep dip angles. Three major and two minor discontinuity sets were identified.

3.3.1.4 Rock Mass Assessment

In addition to the joint sets determination, the rock mass assessment has been carried out using the following rock mass classification systems for the various components.

- Rock Structure Rating (RSR).
- Geomechanics classification or Rock Mass Rating (RMR).

- Rock Tunneling Quality Index “Q” system.

The rock mass class is determined from the total rating (RMR = 67). An RMR value of 67 categorizes granitic gneiss as Class II, described as “Good Rock.” Similarly, the rock classification based on the Tunnelling Quality Index (Q) is determined using the listed factors, and it comes to 77. RSR for the rocks exposed close to the pipeline area is 64.

3.3.2 Geotechnical Data in Previous Studies (FSR 2010 and TPV 2021)

The geotechnical investigations were conducted during the FSR 2010 and TPV 2021. These investigations consisted of drilling boreholes and excavating test pits at the selected locations.

A geotechnical investigation involving nine boreholes with a total depth of 290 meters was conducted for the FSR 2010 & Design Report 2011.

An additional investigation was performed in 2021 as part of the Third-Party Validation Study. During this phase, five boreholes totalling 121 meters in depth were drilled. The boreholes were drilled at the left abutment of the proposed weir location, water conduit, sand trap, and powerhouse site. Samples obtained from the boreholes primarily consisted of cuttings from percussion drilling, core samples from the boulders, and additional sand samples. Standard Penetration tests (SPTs) and permeability tests were performed in the drilled boreholes.

To visually classify foundation soils at shallow depths and determine the depth of fill material, test pits were manually excavated at the project site. A total of ten (10) test pits were dug to a depth of 3.0 m. All the test pits were located along the proposed pipeline or channel route. Field density tests were also conducted in the excavated test pits. Bulk and disturbed soil samples were collected from each test pit at the site and analysed in the laboratory.

3.3.3 Subsurface Strata Characterization

Based on information and data from boreholes, test pits, and geological mapping, it is confirmed that rock is not exposed at any of the proposed project sites, and there is insufficient site-specific geotechnical data for a proper geotechnical assessment.

At the proposed weir site, the area on both the left and right banks of the river is covered with overburden containing large sub-rounded and sub-angular boulders (ABGM, RBGM, and ABG, RBG), along with rock debris and sand from fluvial and colluvial deposits. Both abutments are heavily vegetated and feature small cultivated terraces. The strata explored in the boreholes drilled at the abutment and nearby terrace deposits consisted of a thin, surficial layer approximately 1.5 to 3.0 meters thick, classified as greyish-brown to dark-brownish grey, silty SAND with trace gravels. SPT-N values suggest that the compactness of this layer is medium dense. Beneath this sandy layer lies the general soil or weathered rock overburden, composed of whitish to brownish-gray, sandy GRAVEL containing pebbles and cobbles that are subrounded to subangular, derived from various rocks, metasediments, phyllite, and granite.

There is no rock exposure at the proposed sites for the Intake Weir, Water Conduit Path, Sand Trap, and Powerhouse. However, the geological rock units exposed in the project area include metamorphic units, with granitic gneisses, granite, and granodiorite intrusions present at certain

locations, but at considerable elevations. The only accessible site for rock examination is on the road near the proposed powerhouse location. The rock in this area, according to ISRM (International Society for Rock Mechanics and Rock Engineering) standards, is very strong to extremely strong, thickly bedded, slightly to moderately weathered, closely jointed, and fractured. Although the rock exists on the left bank of the river, it was not encountered in the borehole drilled in the riverbed at the proposed powerhouse location to a depth of 34 meters.

The river surface is covered with large boulders, the largest of which measures up to 8 x 7 x 6 meters (**Figure 3-1**). The rocks that make up these boulders can be seen in the core samples (**Figure 3-2**). The nature of the overburden material of glacial origin is observable from the strata exposed during the excavation of a test pit (**Figure 3-3**). The permeability of the overburden strata, determined in the drilled boreholes, ranges from 2 to 10^{-2} cm/s. The extent of the overburden strata at the proposed weir location is shown in the geological map (**Figure 3-4**). The strata ascertained at each of the proposed structure sites are explained in the following sections.

Figure 3-1: Typical view of the large boulders along the riverbanks (FSR 2010)

3.3.3.1 Subsurface Conditions at the proposed Diversion Weir

The valley at the weir is in its mature stage according to geomorphological classification. The weir would most likely be founded on overburden, as the thickness in this area appears to exceed 40 meters. The riverbed comprises medium to large-sized boulders and gravel, with a small amount of sand (RBG), which is loose and highly permeable; the permeability of the overburden material ranges from 2 to 10-2 cm/s. The largest boulder here measures up to 8 x 7 x 6 meters. As identified in the FSR 2010 & TPV 2021, the proposed weir sites are marked on the surface geological map (**Figure 3-4**). A geological section along the weir axis (**Figure 3-5**) indicates that bedrock beneath the overburden is probably Granitic Gneiss; the depth of the bedrock still needs to be confirmed through drilling and/or seismic refraction surveys. Both abutment slopes are generally stable & form angles between 35° & 45° with the horizontal.

Figure 3-2: Cored samples from boulders at greater depths (17.0-26.0 m) (2010 FSR)

Figure 3-3: Typical view of the glacial/moronic overburden deposits exposed in a test pit excavated at the site (FSR 2010)

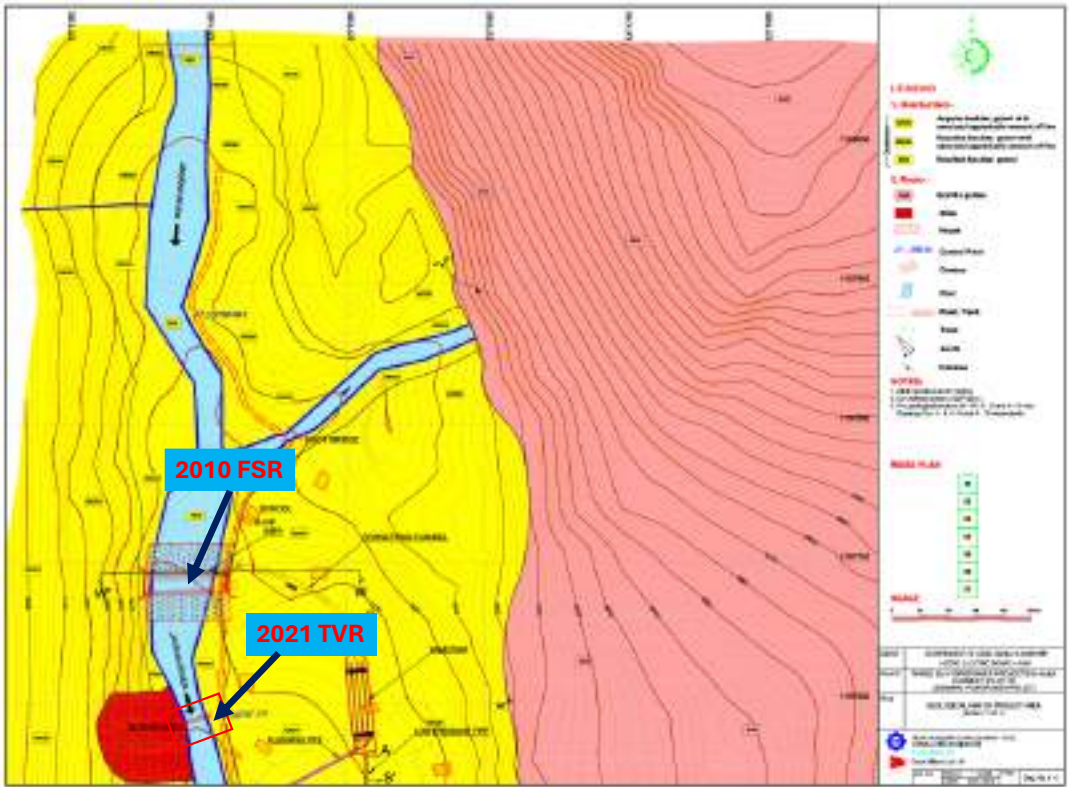


Figure 3-4: Surface geological map of the proposed weir area, showing the extent of the overburden strata (yellow) and the granite rock outcrop (red)

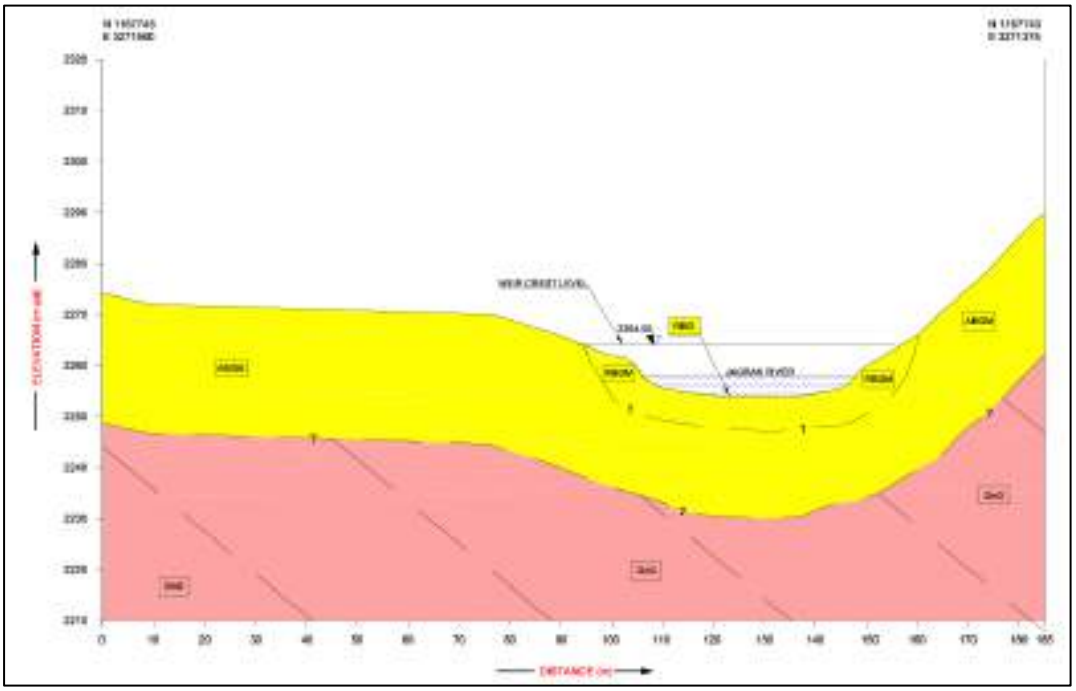


Figure 3-5: Geological section of the proposed weir area (FSR 2010), showing the extent of the overburden strata and the granitic gneiss bedrock.

3.3.3.2 Subsurface Conditions at the proposed Connecting Channel

The proposed connecting channel is located on the left bank of the Jagran River (**Figure 3-4**). Based on the geological mapping, it is anticipated that the channel will be excavated through overburden (ABGM) of moronic origin.

3.3.3.3 Subsurface Conditions at the proposed Sandtrap/Desander

The surface geological mapping of the sand trap was conducted at a 1:1,000 scale and is presented in a report at a 1:2,000 scale (**Figure 3-4**). The surface area of the proposed sand trap location is covered by the overburden material composed of angular boulders, gravel, sand, and a significant amount of fines (ABGM) overlying the granitic gneiss.

According to the TPV 2021, it might be possible to place the desander/sand trap on the Granitic Gneiss bedrock. However, the thickness of the overburden or the depth of the bedrock has yet to be determined through borehole drilling or geophysical surveys. Most of the excavation for the sand trap will be through the overburden (ABGM), which appears to be in a loose-to-semi-consolidated state.

3.3.3.4 Subsurface Conditions along the Headrace Steel Pipe

The buried headrace steel pipe, approximately 2,996 meters long, will primarily rest on overburden and partially on granite gneiss rock. According to **Figure 3-6**, the pipeline will traverse the rocky terrain from a chainage of about 2300 to 2,996 meters. In the FSR 2010, surface geological mapping of the pipe has been documented on maps created from satellite imagery with a superimposed Digital Elevation Model (DEM) at a scale of 1:1,000.

Generally, the slopes along the pipe's route are considered stable. However, heavy snowfalls and snow avalanches are common in this area. Therefore, the FSR 2010 recommended, and the TPV 2021 endorsed, that the entire length of the pressure pipe route be buried. Although the pipe will be buried, further study is needed to assess the overall global and local stability of the strata along the pipeline.

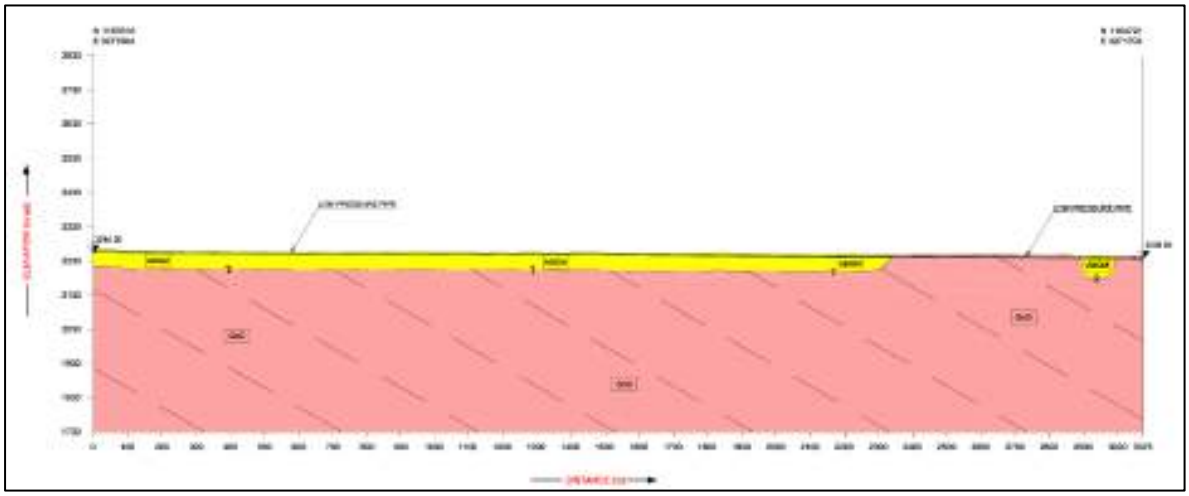


Figure 3-6: Geological section along the proposed Headrace Steel Pipe (FSR 2010), showing the extent of the overburden strata and the granitic gneiss bedrock

3.3.3.5 Subsurface Conditions at the Surge Pipe

Based on the geological mapping results in the FSR 2010 (**Figure 3-7**), the proposed surge pipe is expected to sit on the granitic gneiss rock. In contrast, the penstock will mainly be founded on rock and partially on the overburden.

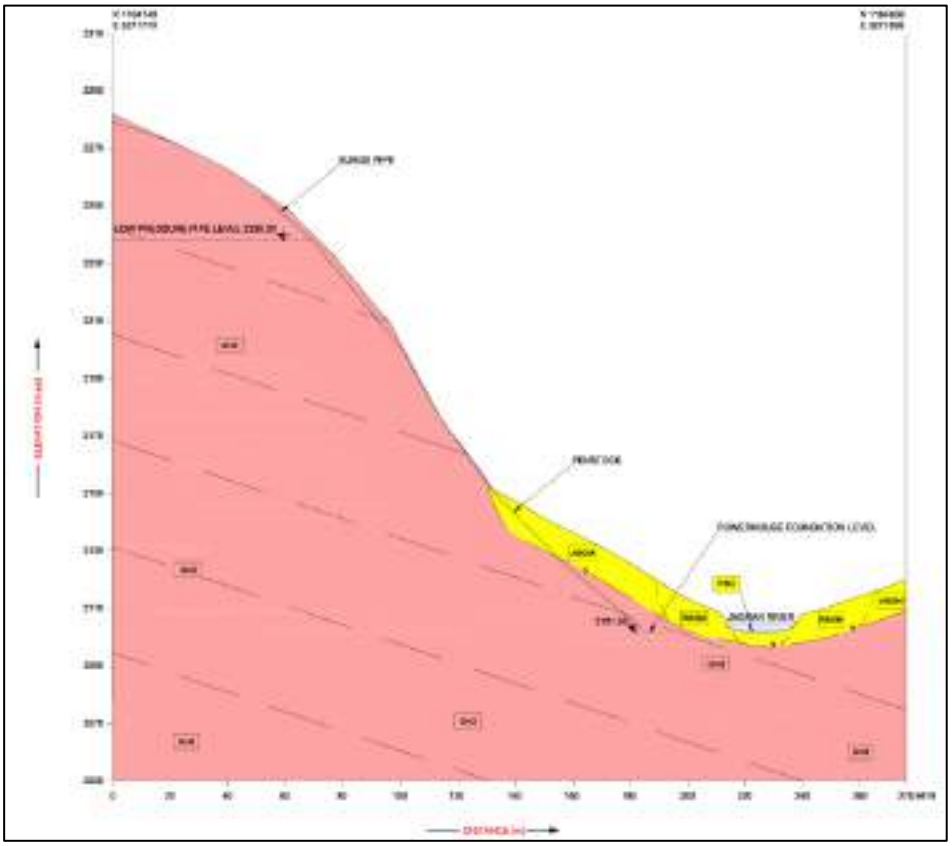


Figure 3-7: Geological section along the proposed surge pipe (FSR 2010)

3.3.3.6 Subsurface Conditions at the Proposed Surface Powerhouse

According to the FSR 2010, the powerhouse is planned to be located in the riverbed, about 300 meters from the Jagran-1 intake Weir (**Figure 3-8**). The riverbed area features large sub-rounded to sub-angular boulders (ABGM, RBGM, and ABG, RBG), along with rock debris and sand composed of fluvial and colluvial materials. At the left abutment, rock is exposed at road level; however, none is found exposed at the powerhouse site.

The surface area at the proposed powerhouse (FSR 2010) is covered by the overburden material composed of rounded boulders and gravel with a significant amount of fines (RBGM), probably overlying the granitic gneiss. Although the thickness of this overburden has not yet been determined through drilling, the powerhouse could likely be built on the granitic gneiss if the overburden is thin enough.

An alternative site for the powerhouse is suggested in the TPV 2021 study (**Figure 3-8**). This location is upstream of the spot recommended in the 2010 FSR. The TPV 2021 report stated that the site, located at the widest part of the riverbed at the end of the alluvial fan, not only reduces the risk of flood damage during peak season but may also mitigate the adverse effects of falling slide material.

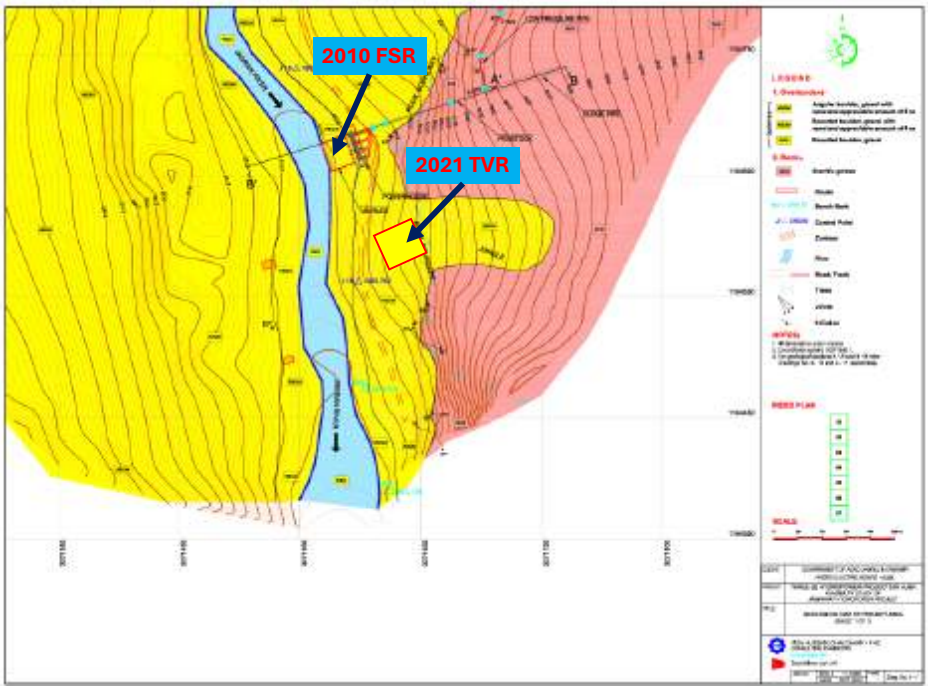


Figure 3-8: Proposed powerhouse location according to FSR 2010 and TPV 2021

3.3.3.7 Subsurface Conditions at the proposed Tailrace

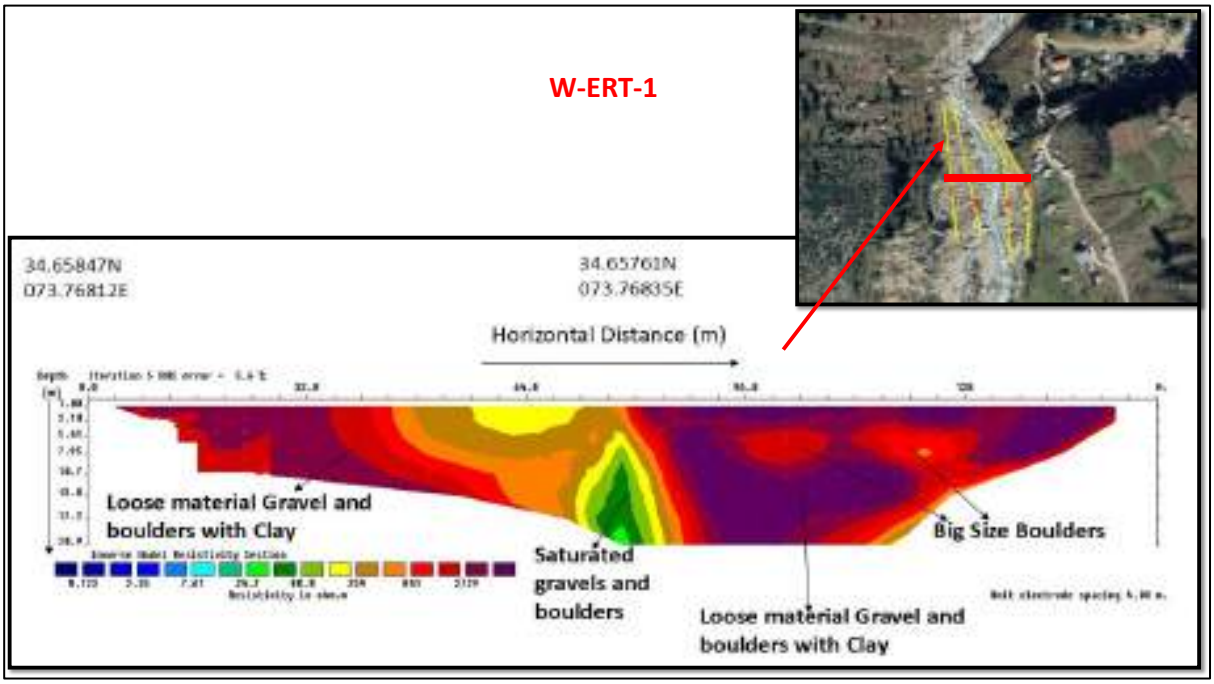
The tailrace for the Jagran-IV Hydropower Project will be excavated through overburden (RBGM). The outgoing water will be discharged into the left bank of the Jagran River.

3.3.4 Proposed Additional Investigations by MC

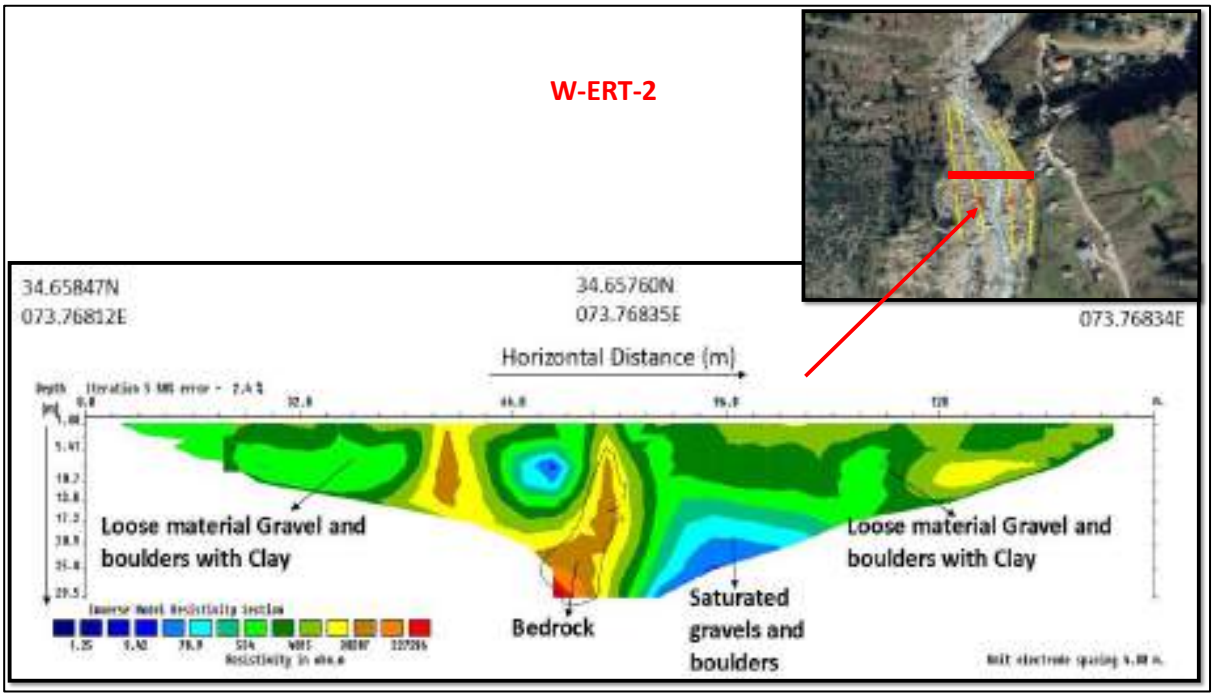
The available geological and geotechnical data from the FSR 2010 and TPV 2021 do not seem to be sufficient to develop the Basic Design Studies for the Project. Several key inputs needed for the design of the foundations and other structural elements require additional and targeted investigations. Given the type and characteristics of the strata and the specific information required for the project structures, these additional investigations should combine both geophysical and geotechnical methods. Additional detailed geological mapping may also be required along the penstock and underground powerhouse option. The detailed requirements for the further investigations are outlined in the following sections.

3.3.5 Electrical Resistivity Tomography (ERT) Survey - Present Study

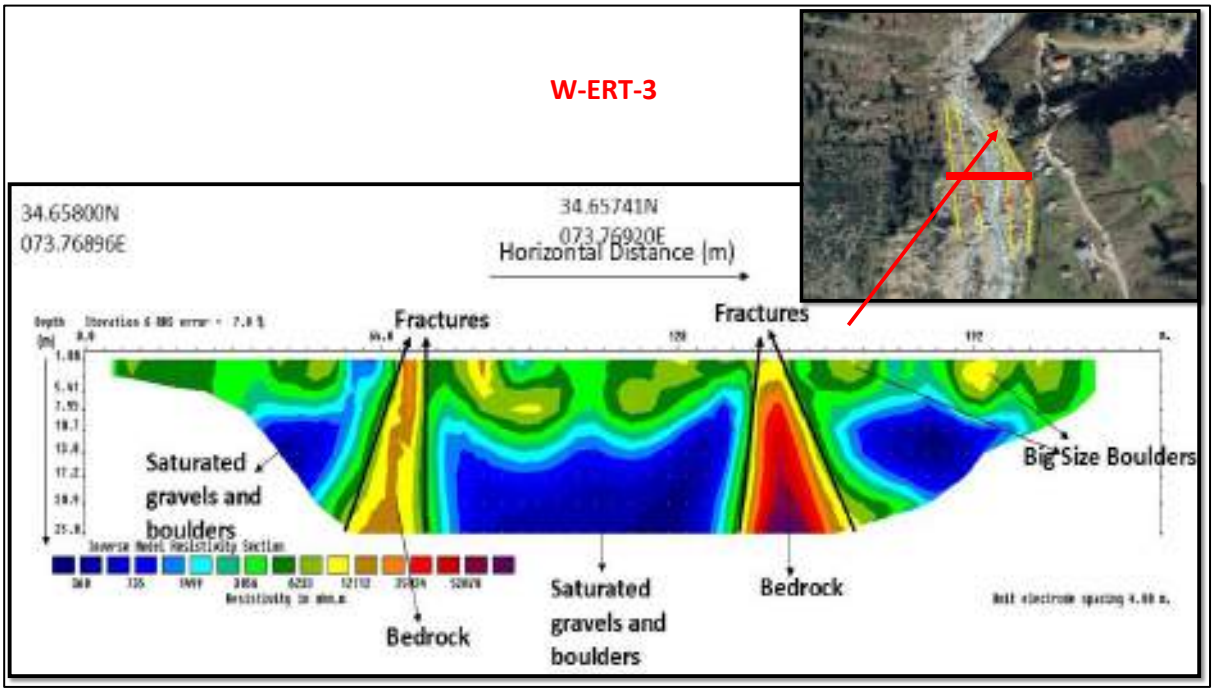
Given the availability of general geological and some geotechnical data for the project, a detailed subsurface investigation, consisting of additional boreholes and a geophysical survey, was required. However, due to limited time, a non-invasive investigation could be a quick and effective way to explore these sites. Electrical Resistivity Tomography (ERT) is one of the non-invasive techniques that can be performed quickly at these sites. Combined with existing geological and geotechnical information, the ERT survey could provide essential data for the design of these structures. The details of the ERT survey carried out for this study are provided in the ERT report attached as **Annexure "A"**, while the ERT results are presented below.



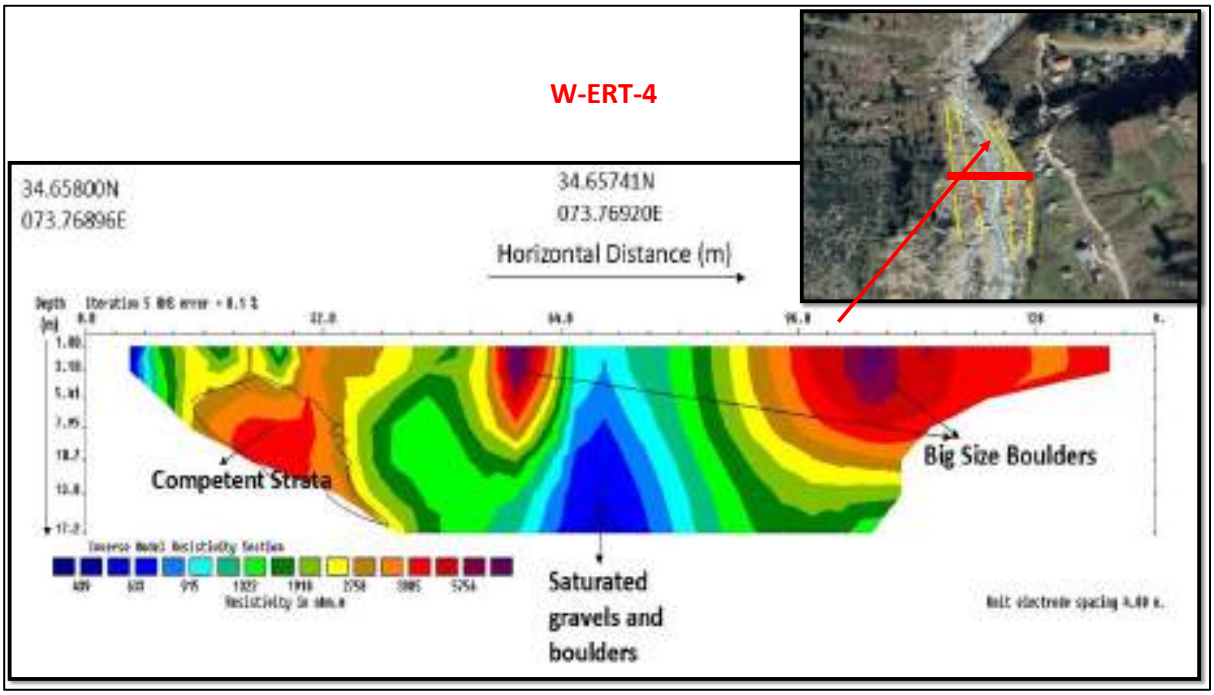
ERT-1 at the proposed Weir location



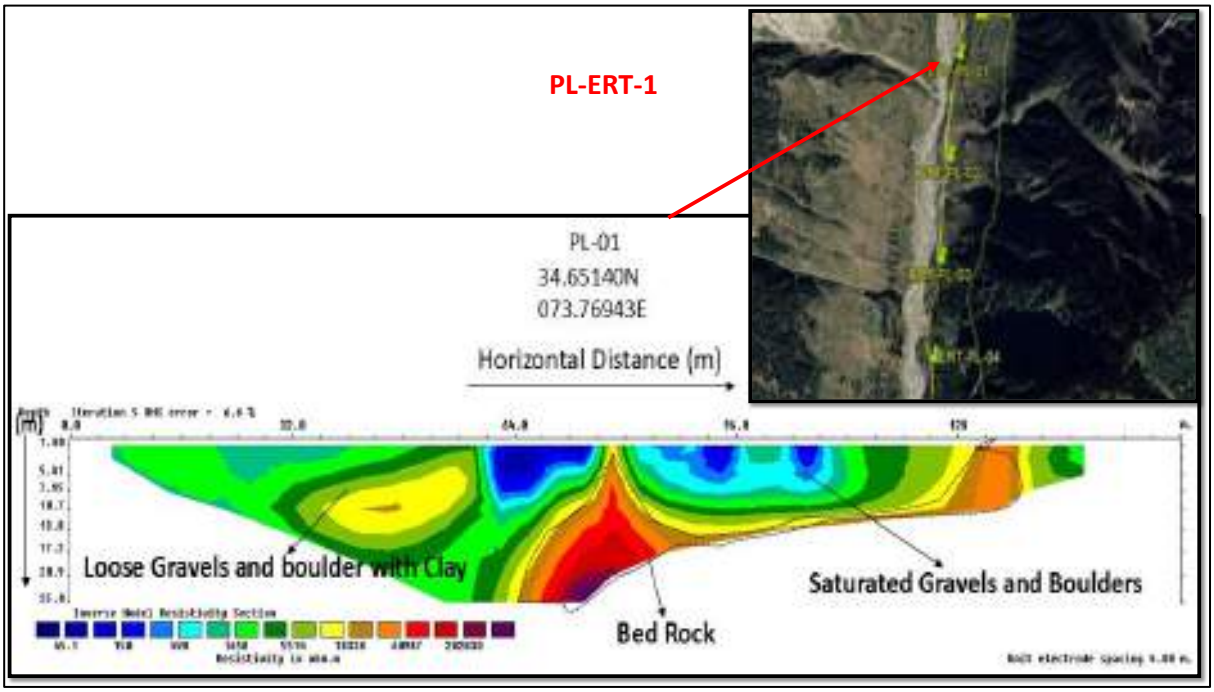
ERT-2 at the proposed Weir location



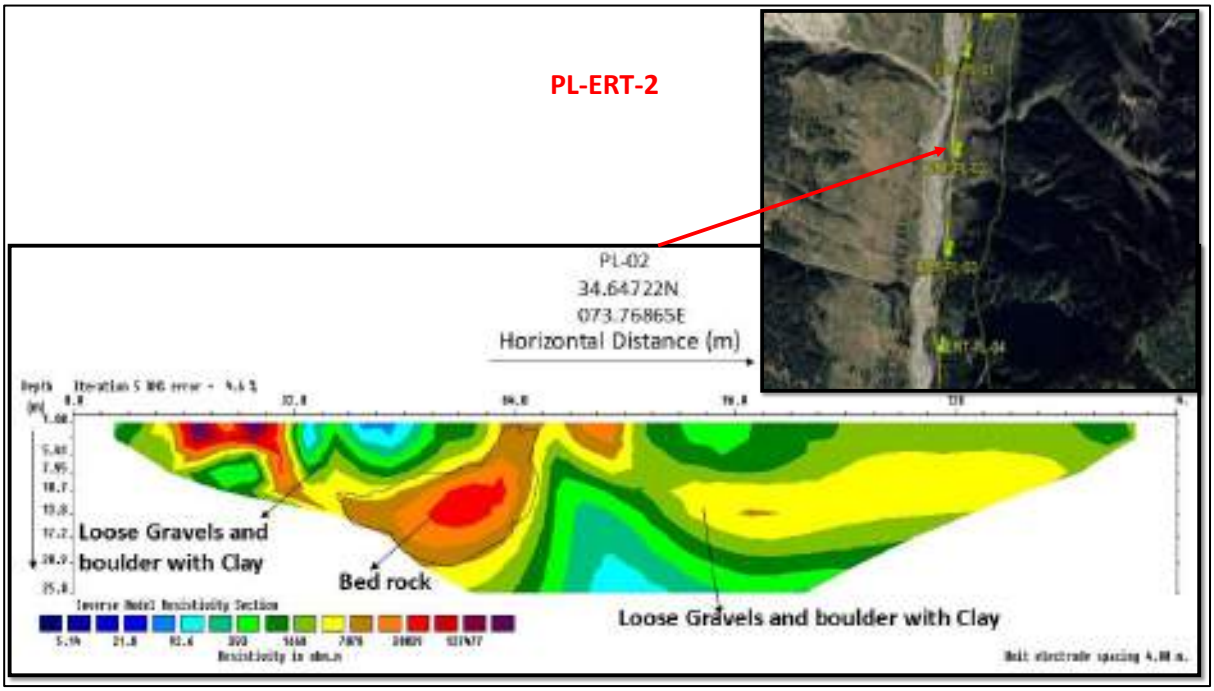
ERT-3 at the proposed Weir location



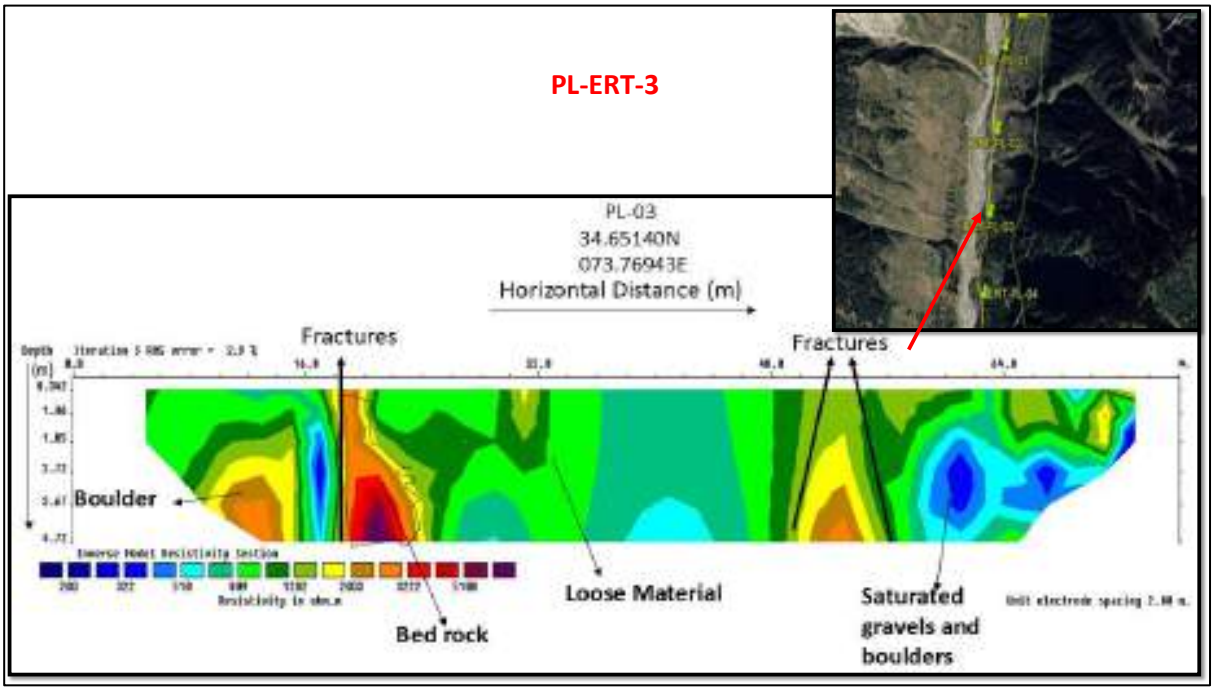
ERT-4 at the proposed Weir location



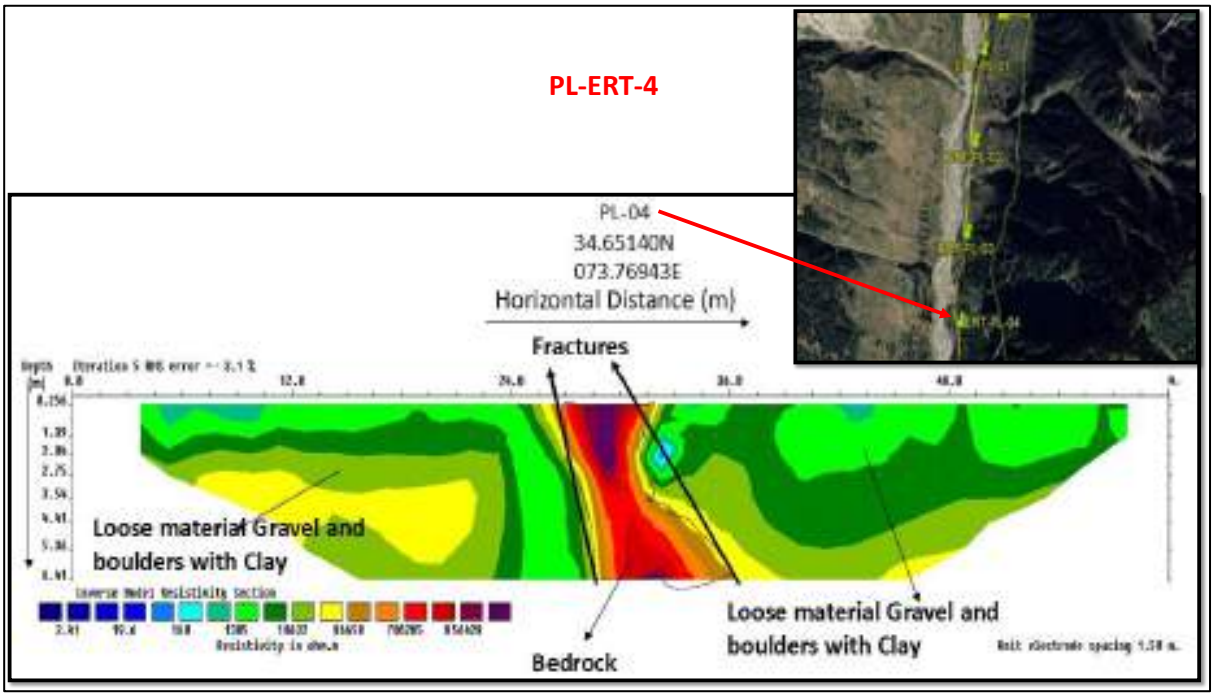
ERT-1 at the proposed Low-Pressure Headrace Pipe Location



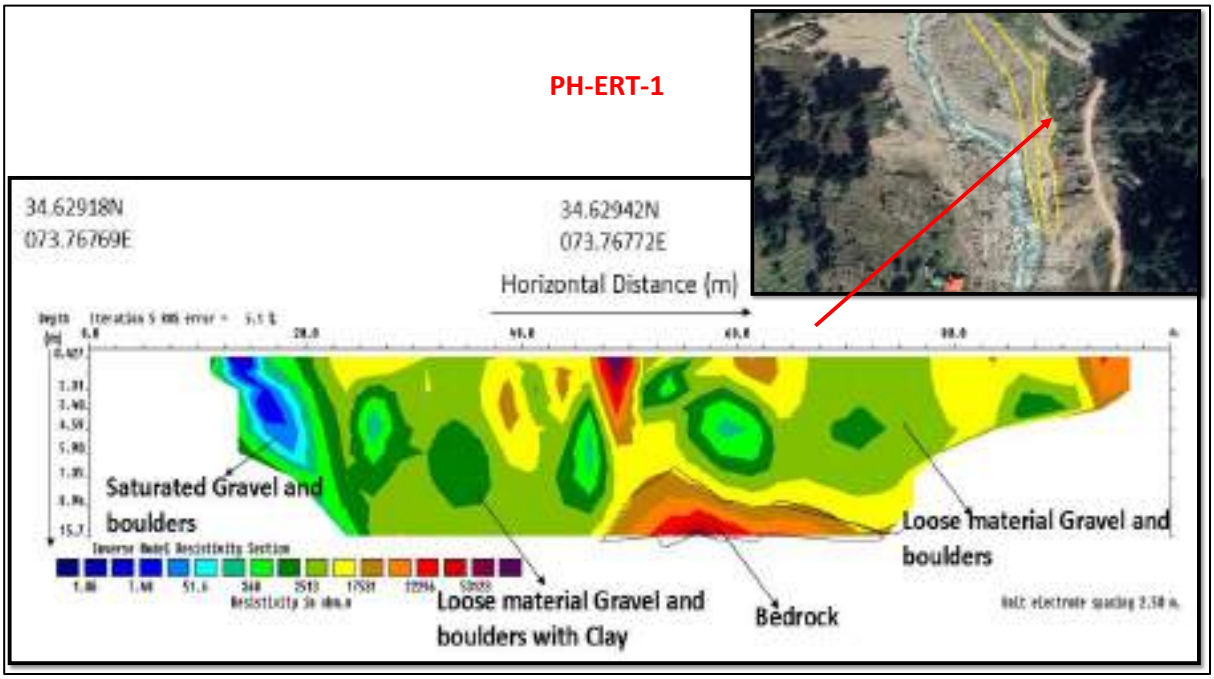
ERT-2 at the proposed Low-Pressure Headrace Pipe Location



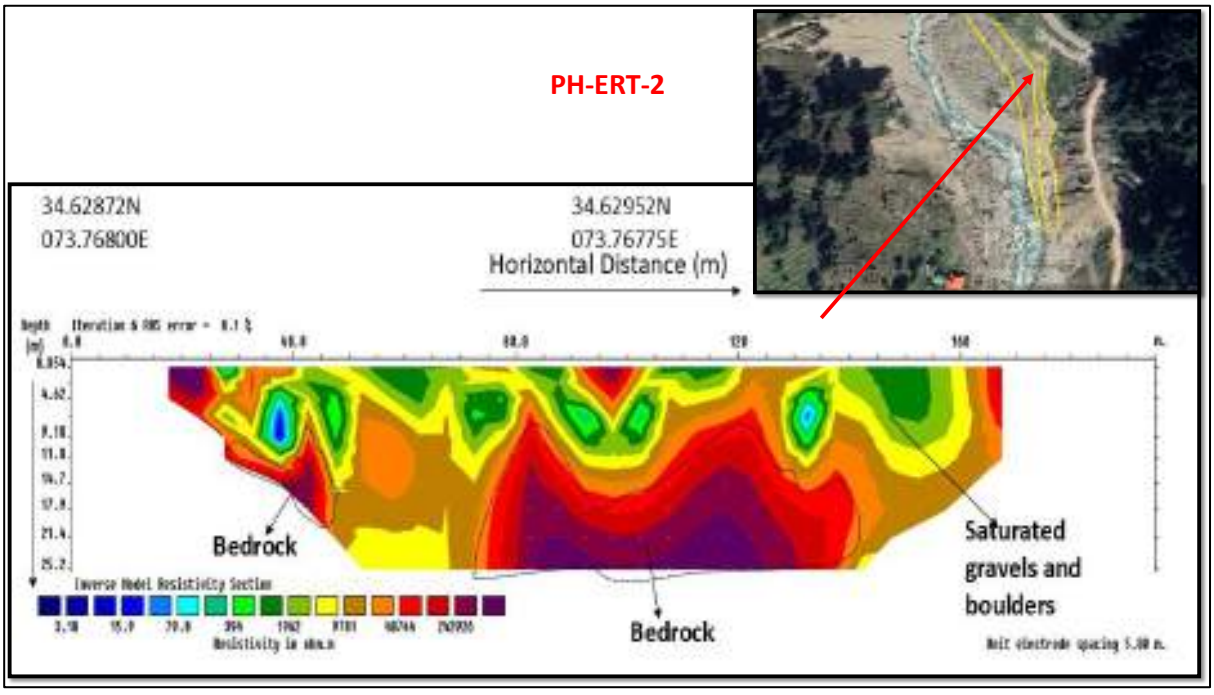
ERT-3 at the proposed Low-Pressure Headrace Pipe Location



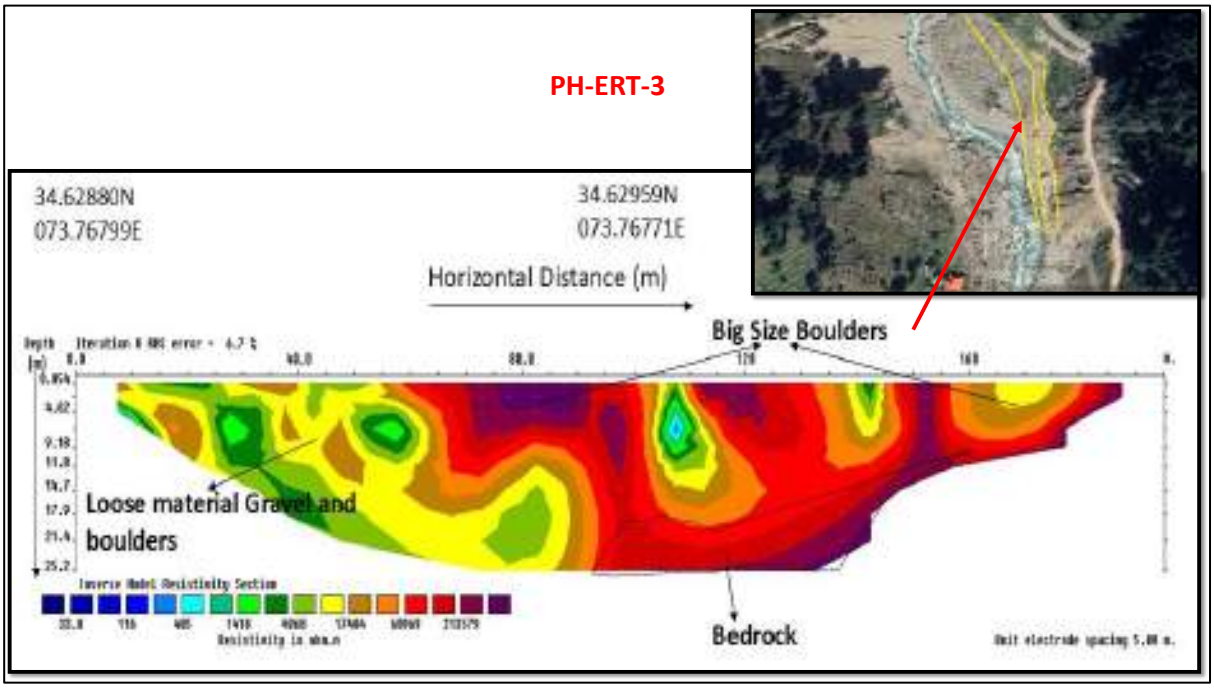
ERT-4 at the proposed Low-Pressure Headrace Pipe Location



ERT-1 at the proposed Powerhouse Location



ERT-2 at the proposed Powerhouse Location

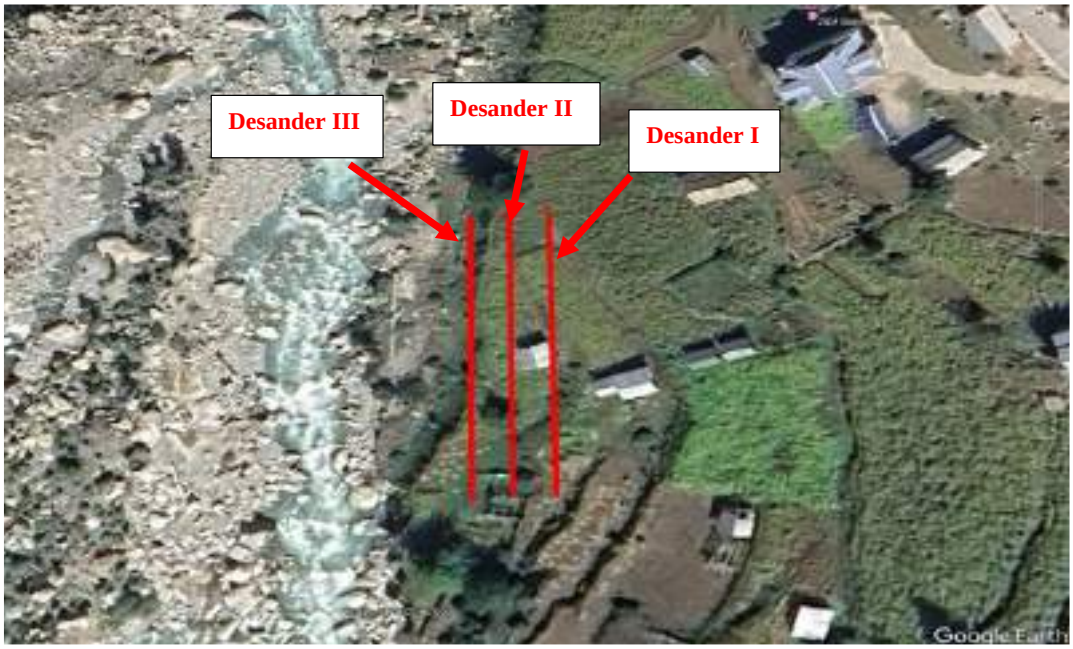


ERT-3 at the proposed Powerhouse Location

The ERT survey results indicate the general presence of overburden alluvium/terrace deposits/weathered rock to a maximum explored depth of about 25 m. However, at certain locations, rock has been found dipping from the adjacent hills. Rock strata have been assessed from ERTs conducted at the proposed weir and powerhouse locations. ERTs carried out along the proposed pipeline alignment do not reveal the rock strata within the proposed excavation plan for this facility.

3.3.6 Seismic Refraction Test (SRT) Survey - Present Study

Although rocky strata appear to be exposed only along the section of the pressure pipe (from chainage 2300 to 3075 m) and the penstock, it is considered essential to understand the rock's characteristics from multiple perspectives, including foundation type and excavatability. In this regard, the previous geotechnical reports from the FSR 2010 and TPV 2021 did not provide sufficient information about the rock's nature. Therefore, a Seismic Refraction Test (SRT) survey was conducted at the proposed desander, pipeline, and penstock locations. Details of the tests are provided in the attached SRT report (**Annexure "B"**), while the results are presented below.



SRTs at the proposed Desander Location

Velocity Time & Velocity Depth Graph Interpretation for Desander I

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 3m	400 to 600	Soil/ colluviums / surficial deposits/ Loose to semi-compact overburden
Layer II	3 to 10m	1200 to 2000	Highly Weathered and Fractured Rock
Layer III	> 10 to 22m	3000 to 3800	Competent Bedrock

Velocity Time & Velocity Depth Graph Interpretation for Desander II

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 3m	400 to 600	Soil/ colluvium/ surficial deposits/ Loose to semi-compact overburden
Layer II	3 to 9m	1200 to 2000	Highly Weathered and Fractured Rock
Layer III	> 9 to 20m	3000 to 3800	Competent Bedrock

Velocity Time & Velocity Depth Graph Interpretation for Desander III

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 3m	450 to 600	Soil/ colluvium/ surficial deposits/ Loose to semi-compact overburden
Layer II	3 to 10m	1200 to 2200	Highly Weathered and Fractured Rock
Layer III	> 10 to 20m	3000 to 3600	Competent Bedrock

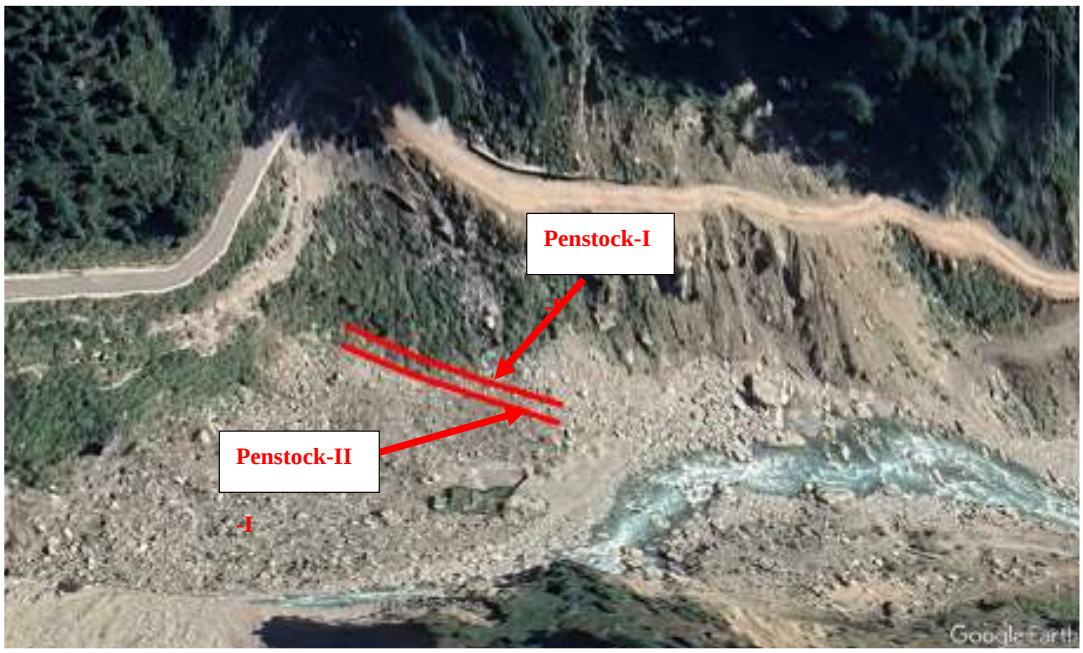
SRTs at the proposed Headrace Pipe Location

Velocity Time & Velocity Depth Graph Interpretation for PL-I

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 2m	350 to 550	Soil/ Colluvium/ Slope Debris
Layer II	2 to 7/8m	1000 to 2000	Weathered and Fractured Rock
Layer III	> 7/8 to 18m	2800 to 3600	Competent Bedrock

Velocity Time & Velocity Depth Graph Interpretation for PL-II

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 2m	400 to 600	Soil/ Colluvium/ Slope Debris
Layer II	2 to 8m	1000 to 2200	Weathered and Fractured Rock
Layer III	> 8 to 18m	2800 to 3450	Competent Bedrock



SRTs at the proposed Penstock Location

Velocity Time & Velocity Depth Graph Interpretation for Penstock I

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 2m	400 to 600	Soil/Colluvium/Slope Debris
Layer II	2 to 8/10 m	1000 to 2200	Weathered and Fractured Rock
Layer III	> 8/10 to 20m	2800 to 3450	Competent Bedrock

Velocity Time & Velocity Depth Graph Interpretation for Penstock II

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	1.5 to 2.5m	400 to 600	Loose Soil/Colluvium
Layer II	3.5 to 5.0m	700 to 1100	Dense Gravel/Weathered Rock
Layer III	Up to 6.0m	Greater than 1800	Competent Bedrock

In all SRT-interpreted results, the overburden and weathered rock are at least about 10 m thick. These results indicate that the pipeline and penstock would be placed or founded in overburden soil-like deposits. The desander excavation may encounter hard rock in the final few meters; otherwise, it should be excavatable with standard excavation equipment.

3.4 Geotechnical Design Profiles and Parameters

Due to the lack of detailed and relevant geotechnical investigations at the proposed facility sites, the geotechnical design parameters were largely inferred and assigned to the rock/soil subsurface layers based on data from previous studies and ERT and SRT surveys conducted during the current study. Based on all this data, geological cross-sections assessed at the proposed weir and the powerhouse locations are shown in **Figures 3-9 and 3-10**.

The assessed geotechnical design parameters for the analysis and design of the facility structures are tabulated in **Table 3-2**.

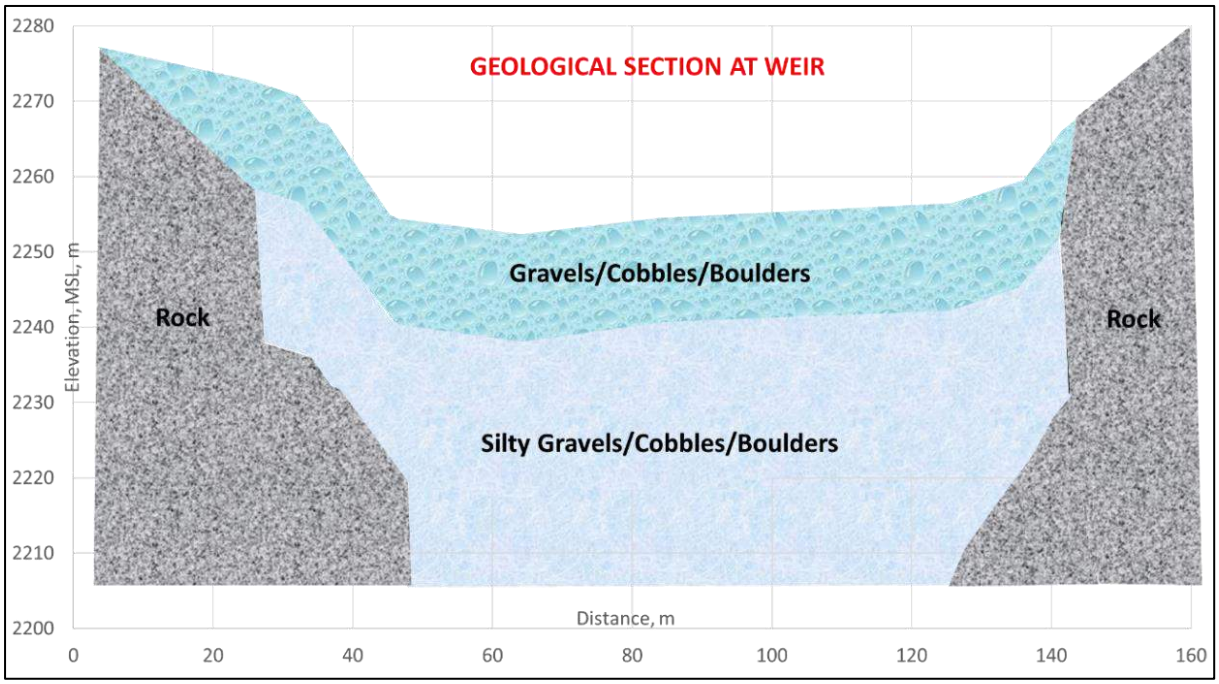


Figure 3-9: Geological cross-section assessed at the proposed weir location

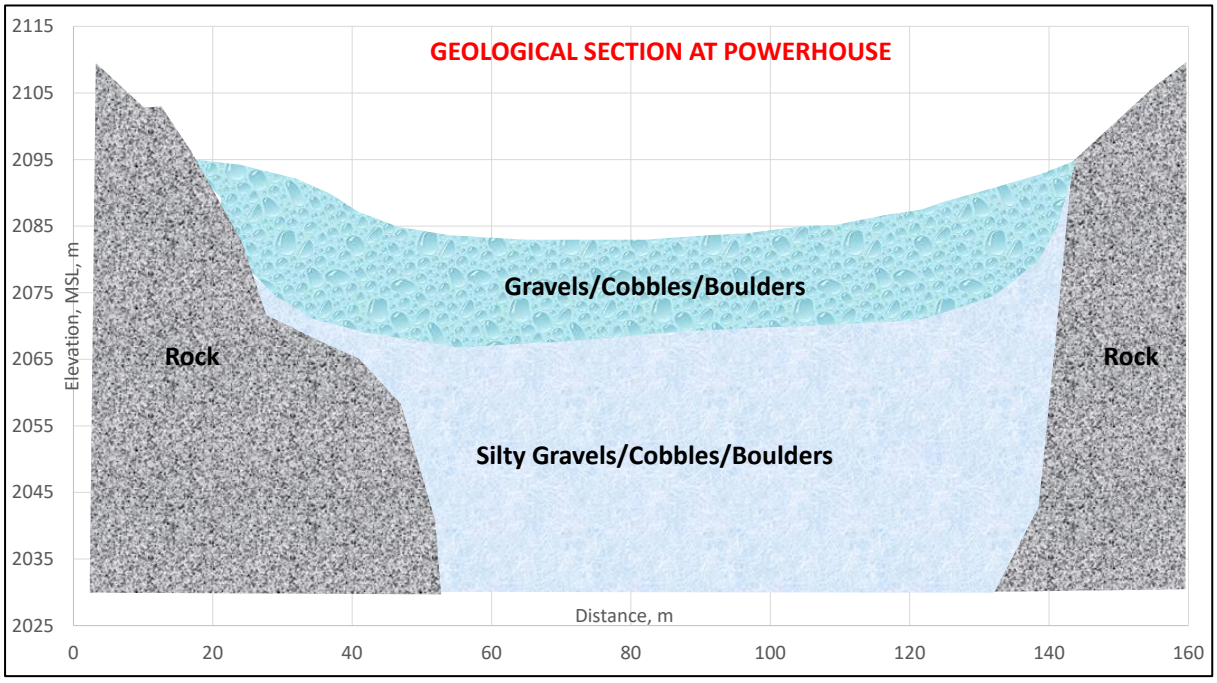


Figure 3-10: Geological cross-section assessed at the proposed powerhouse location

Table 3-2: Summary of the Geotechnical Design Parameters

Layer no.	Description	Unit weight (kN/m³)	Undrained cohesion, c_u (kPa)	Effective cohesion, c′ (kPa)	Angle of Internal friction, ϕ (°)	Deformation Modulus (MPa)	Permeability (cm/sec)
1	Riverbed Alluvium-1	18	250	-	38	75	10^{-2}
2	Riverbed Alluvium-2	19	500	-	40	100	10^{-5}
3	Terrace deposits	19	500	-	39	75	10^{-4}
4	Gneiss*	21	-	1000	42	400	10^{-9}
5	Granitic Gneiss**	22	-	500	40	450	10^{-9}

* Left abutment rocks
** Right abutment rocks

3.5 Geotechnical Modelling and Simulations using PLAXIS 3D software

Given the subsurface strata and hydrological and hydraulic design requirements, preliminary design sections were prepared for various project components. Geotechnical models of the diversion weir, desander, pipeline, and powerhouse were developed, and several stability and seepage scenarios were simulated. Stability was evaluated under static/steady-state seepage and seismic conditions.

PLAXIS 3D software has broad applications for diverse geo-engineering problems. It has rigorous analytical capabilities, encompasses a wide range of Constitutive Models, and is based on the Finite Element Modelling (FEM) simulations. The software can analyse and design the following tasks in parallel as 3D models.

- Seepage Analysis
- Foundation/Slope Stability Analysis
- Stress-Strain/Settlement/Displacement Analysis
- Earthquake/Seismic Analysis

3.5.1 Modelling and Simulations of Intake/Diversion Weir

The weir design section, proposed after hydrological and hydraulic considerations, is shown in **Figure 3-11**. This design section was modelled and analysed using the PLAXIS 3D simulation modules. The resulting PLAXIS model and its components are shown in **Figures 3-12 to 3-15**.

Based on limited subsurface information from the few boreholes drilled during previous studies, along with ERT and SRT surveys in the present study, the model was prepared assuming a 10 m-thick layer of alluvial deposits at the river surface, underlain by more compacted, relatively less permeable alluvial layers. The abutments, consisting essentially of rock strata and partially overlain by alluvial and terrace deposits, were modelled using geological models (**Figures 3-9**

and 3-10) prepared from mapping results from previous studies and ERT and SRT surveys conducted during the current study. The models shown in **Figures 3-12 to 3-15** differ primarily in the provision of cut-off walls of varying depths at the weir's heel.

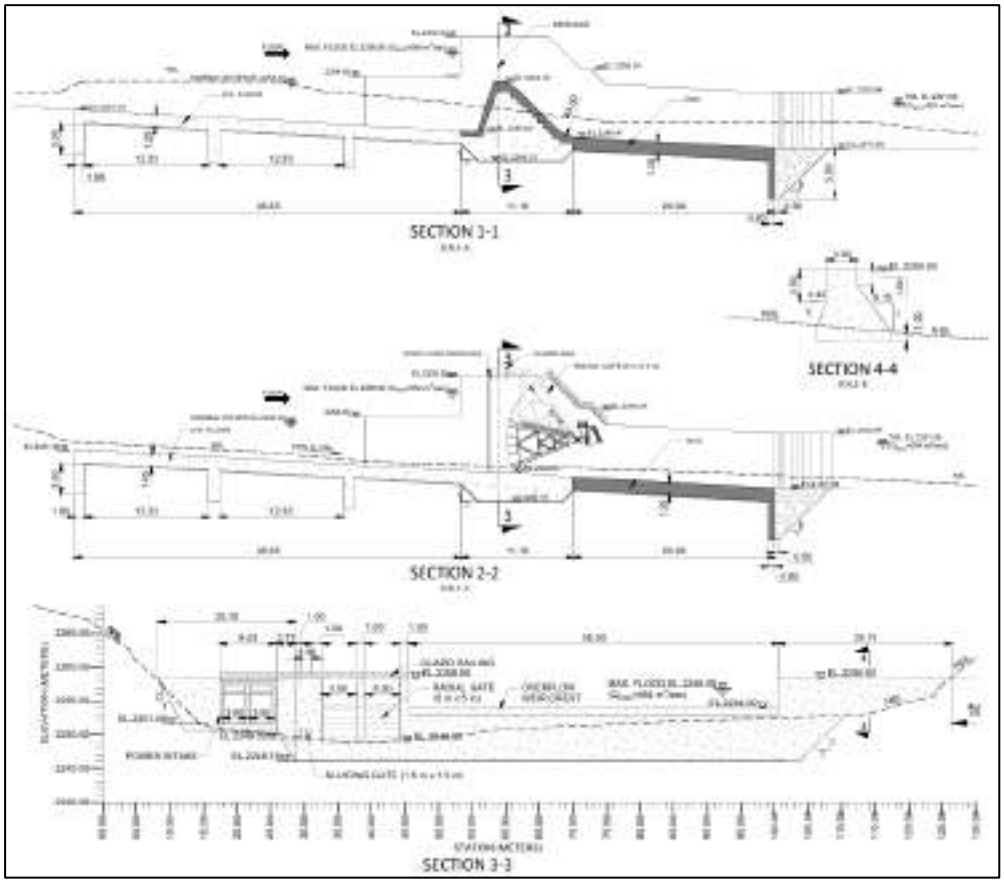


Figure 3-11: The cross-sectional details of the proposed Intake/Diversion Weir

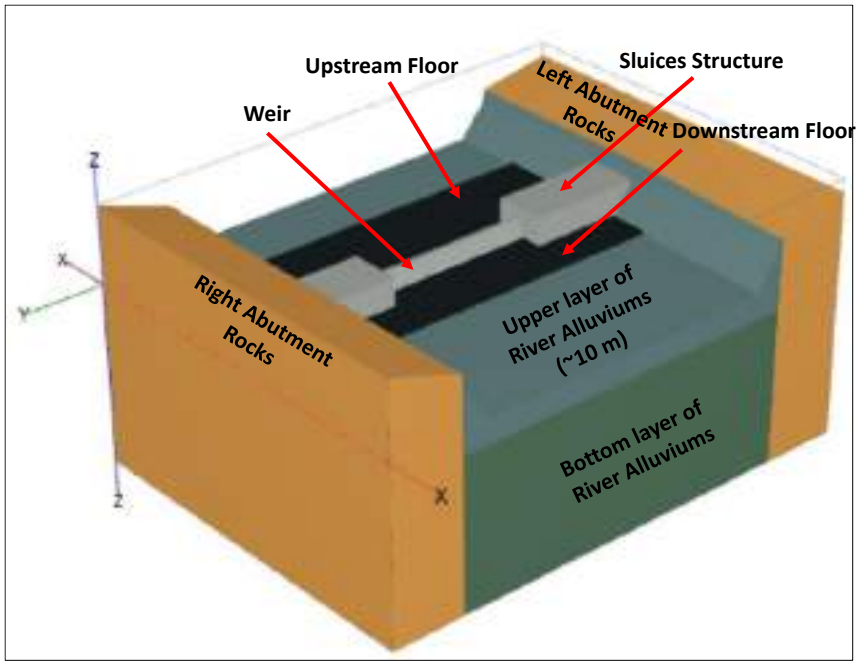


Figure 3-12: A basic 3D numerical model of the Weir and its natural surroundings prepared in PLAXIS 3D software, showing weir components and subsurface strata

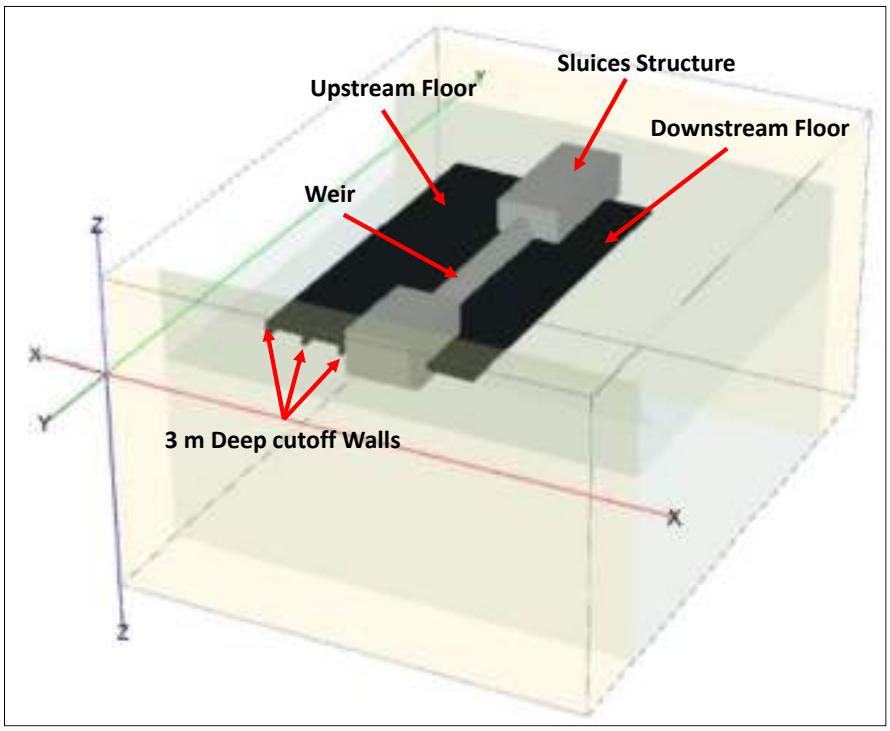


Figure 3-13: The basic 3D numerical model of the Weir and its components prepared in PLAXIS 3D software, showing 3 m deep cut-offs at the U/S floor

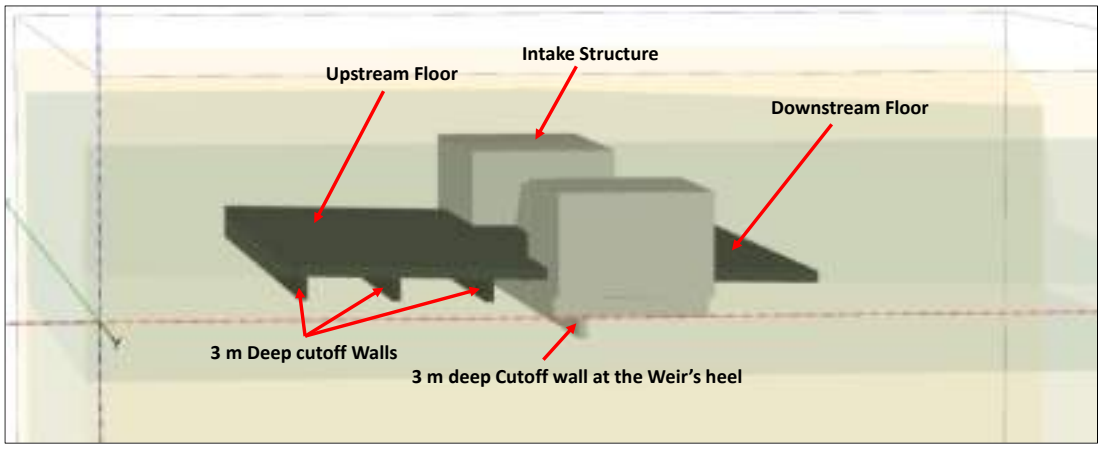


Figure 3-14: The basic 3D numerical model of the Weir and its components prepared in PLAXIS 3D software, showing 3 m deep cut-off walls at the U/S floor and the Weir's Heel

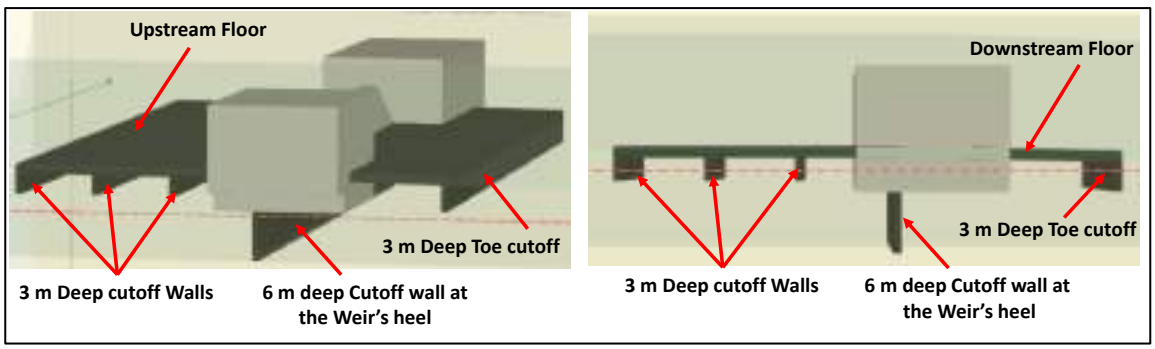


Figure 3-15: Different views of Basic 3D numerical model of Weir and its components prepared in PLAXIS 3D software, showing a 6 m deep cut-off at heel and a 3 m deep toe cut-off

3.5.1.1 Seepage Analysis

The steady-state seepage scenario under normal and flood water levels was initially modelled using the Flow module of the software. The Flow module was then supplemented with the Stress-Strain module to assess the ground surface displacements and slope failure scenarios. The Flow module requires two major inputs for each soil/rock layer specified in the model. One input is the variation of volumetric water content with soil suction (negative pore pressures). The second input is the variation in permeability with strata suction. Both inputs are required for all soil/rock layers that would be subjected to saturated and partially saturated conditions during the service life. However, for strata that would remain essentially saturated during the service life, only a saturated permeability value is required as an input. The saturated permeability values and their variation with suction were inferred from experience with similar soils/rocks.

Normal Water Elevation (NWE) Simulations

The seepage analysis model for steady-state flow at the Normal Water Elevation (NWE) is shown in **Figure 3-16**. To assess the extent of seepage and the resulting groundwater head on the D/S floor, different configurations of subsurface seepage cut-offs (**Figures 3-17 and 3-18**) were modelled in this study. The results shown in **Figures 3-19 to 3-22** pertain to the model without any subsurface seepage cut-off walls. These figures show significant seepage not only through the weir's foundation (**Figure 3-19**) but also through the interface between the weir and the surrounding strata (**Figure 3-20**). Moreover, a high resultant groundwater head acts on the facility's downstream floor (**Figures 3-21 and 3-22**). A residual water head of 6 m on the D/S floor may cause an upheaval of the floor with a thickness of 1.5 m. This has also been demonstrated through stress-strain simulation of the model at NWE (**Figures 3-23 and 3-24**). A downstream floor upheaval of about 45 mm is expected under these circumstances.

In the next simulation, four 3 m deep cutoffs, as shown in **Figure 3-14**, were added to the U/S floor. The seepage scenario and the resulting groundwater heads are shown in **Figures 3-25 and 3-26**, respectively. For this case, the resulting groundwater head is reduced to 5.0 m. As the final simulation case, the weir was modelled with three 3 m cut-off walls under the U/S floor and one 6 m deep cutoff wall at the heel of the weir, as shown in **Figure 3-15**. The corresponding seepage scenario & groundwater head sections are shown in **Figures 3-27 and 3-28**, respectively. This last case, consisting of three 3 m cutoffs under the U/S floor and one 6 m cutoff under the heel of the weir, brings the net waterhead under the D/S floor to 3.5 m. In this case, the uplift pressure due to the net groundwater head just balances the weight of the 1.5 m-thick floor.

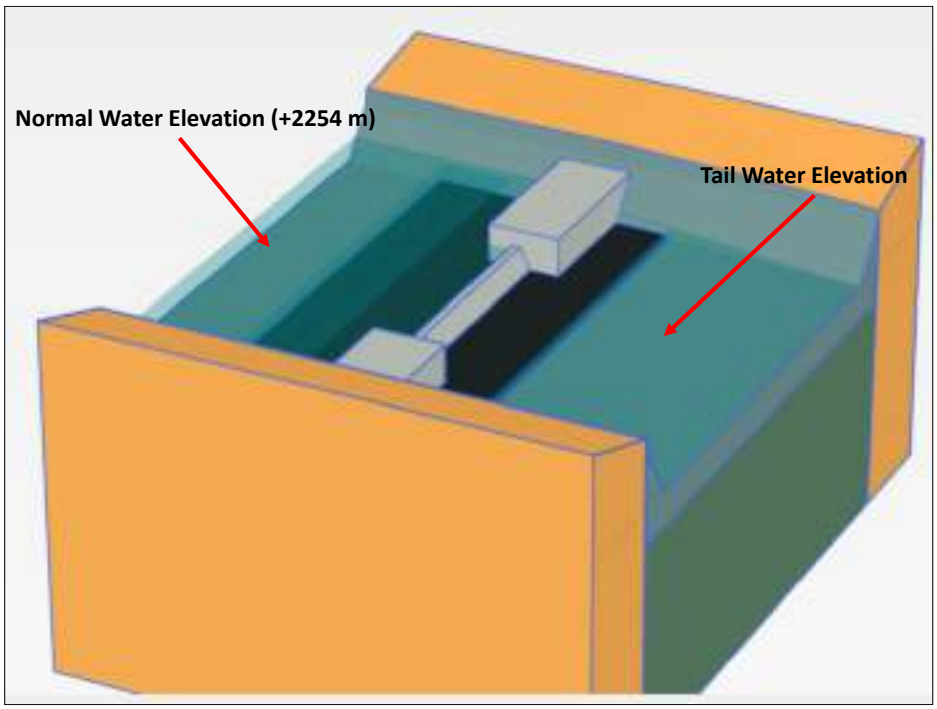


Figure 3-16: Water flow model under Normal Water Elevation (NWE) conditions, showing the Normal and Tail Water Elevations

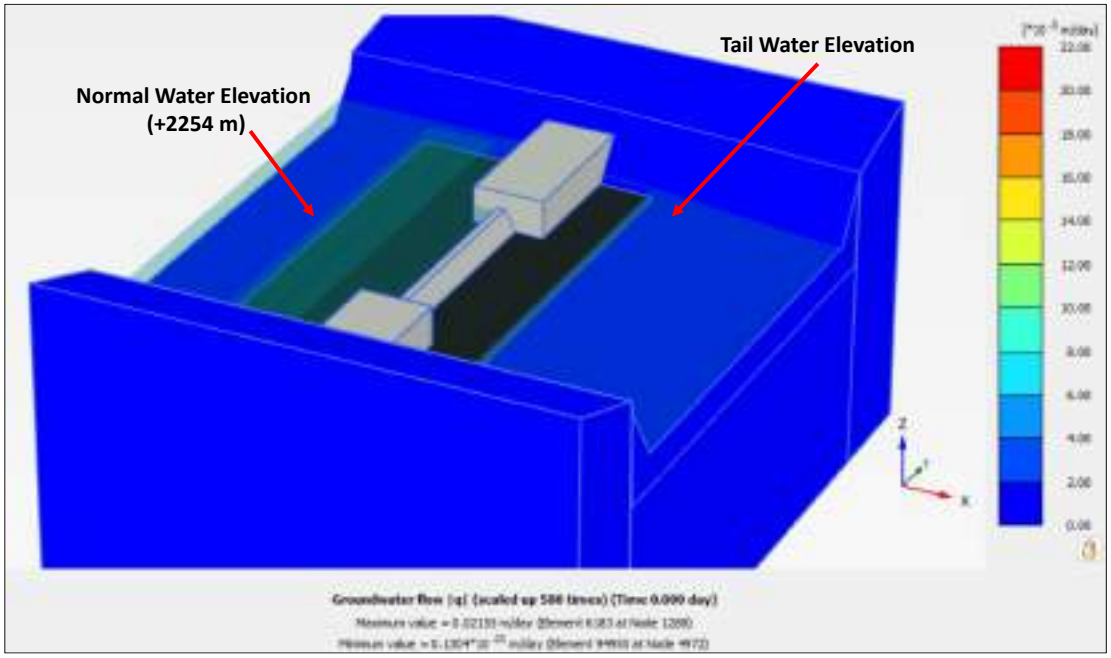


Figure 3-17: 3D view of steady-state seepage results under Normal Water Elevation (NWE) conditions, showing a 3D surface flow, with subsurface flow shown in Figure 3-13.

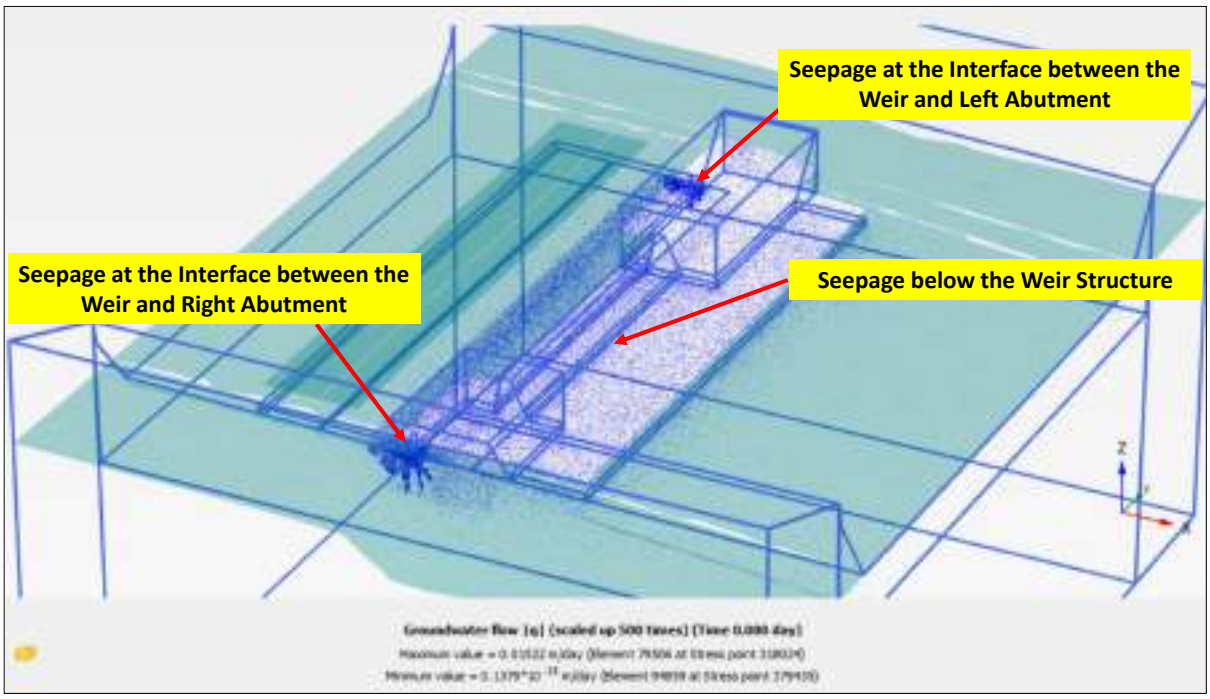


Figure 3-18: A 3D view of the subsurface steady-state seepage results under Normal Water Elevation (NWE) conditions, showing the subsurface flow.

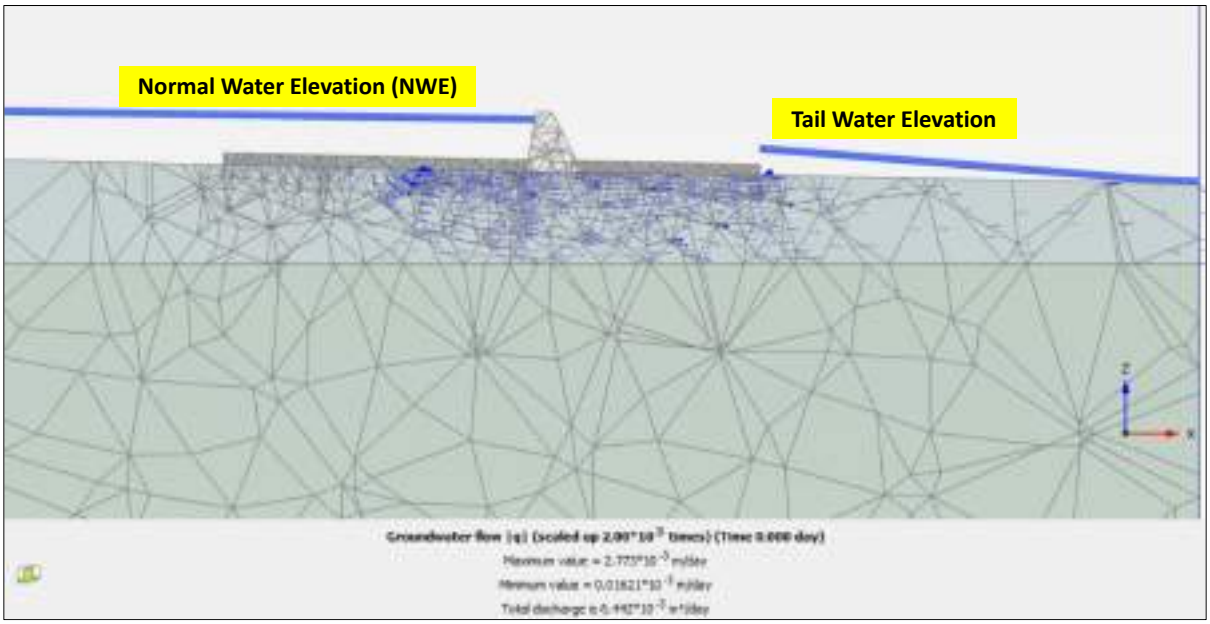


Figure 3-19: A cross-section through the Weir showing the subsurface flow without the cutoff walls during NWE.

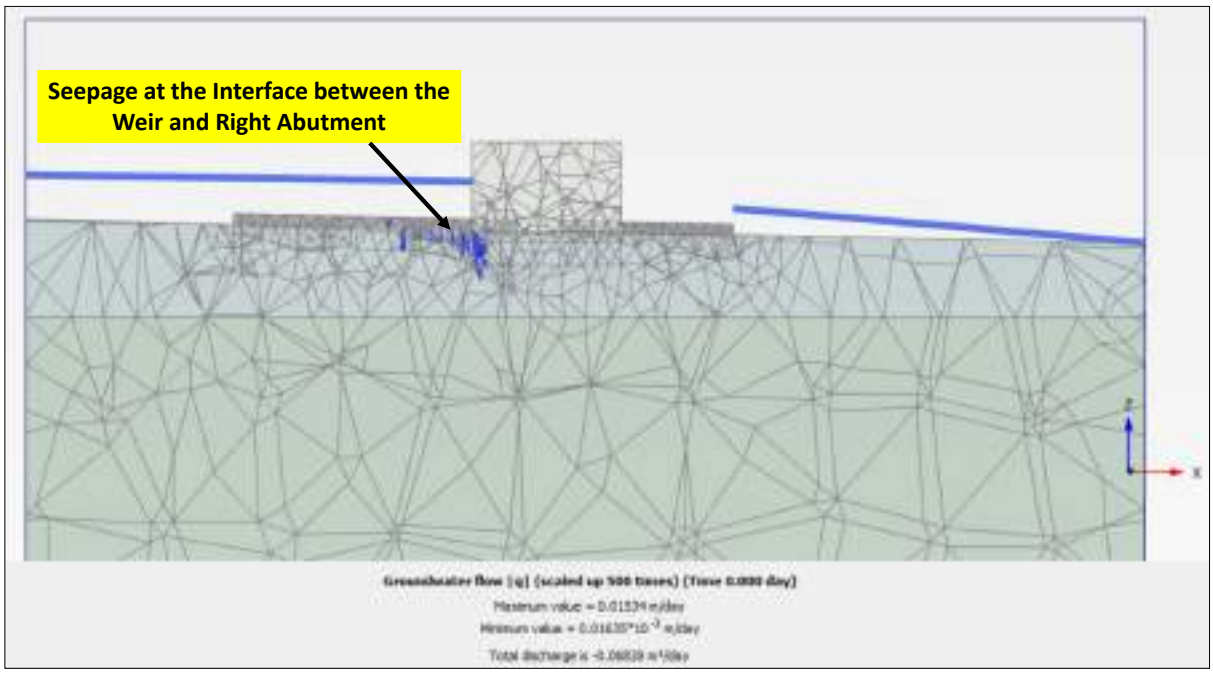


Figure 3-20: A cross-section through the Weir interface with the right abutment showing the subsurface flow without the cutoff walls.

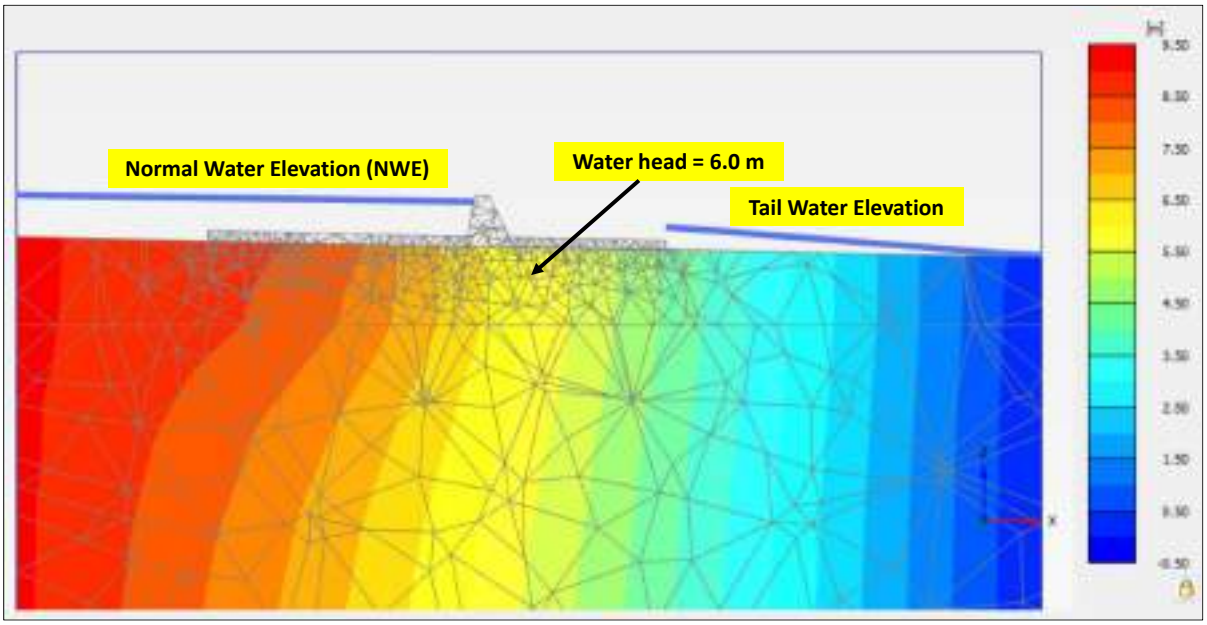


Figure 3-21: A cross-section through the Weir showing the groundwater head due to the subsurface flow under NWE without the cutoff walls.

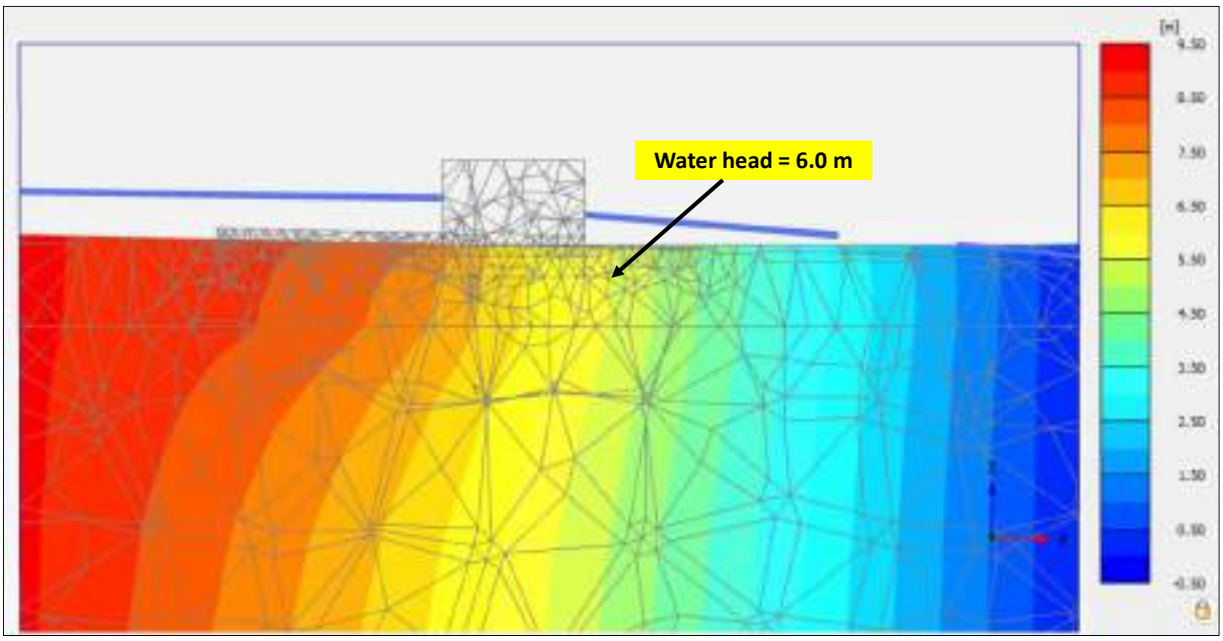


Figure 3-22: A cross-section through interface between Weir and right abutment showing groundwater head due to subsurface flow under NWE without cutoff walls.

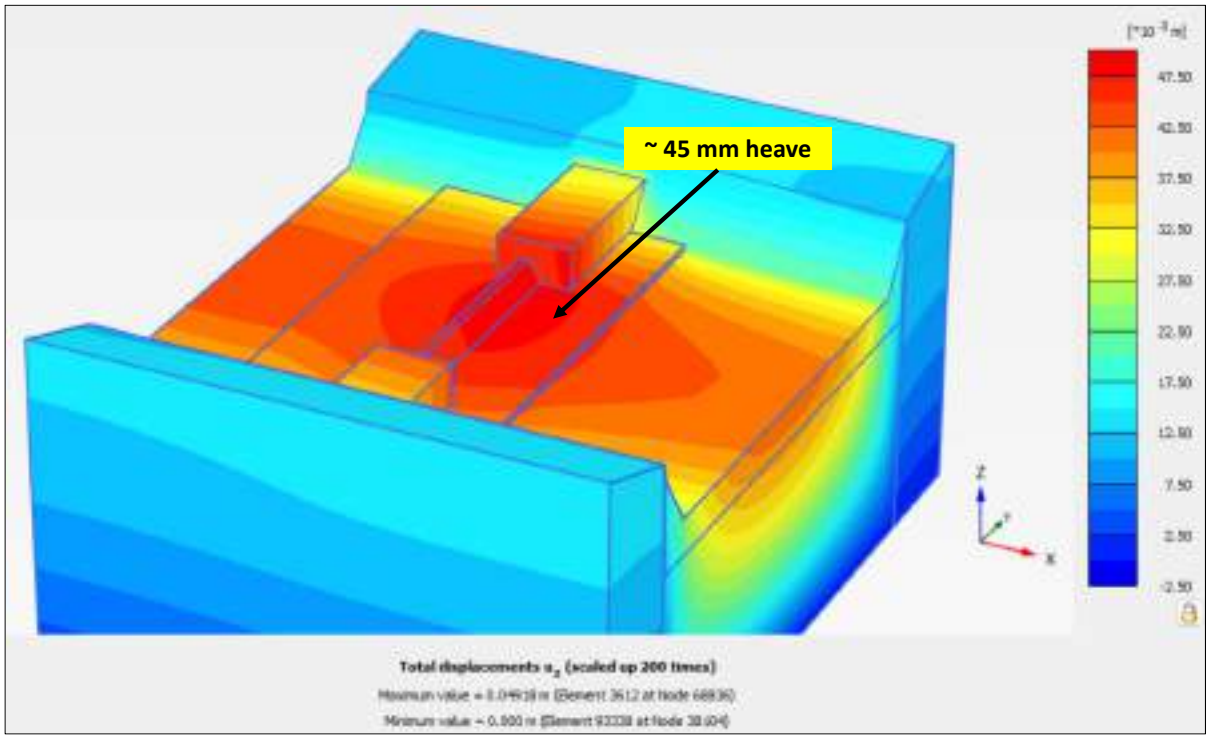


Figure 3-23: A 3D view of about 45 mm upheaval of D/S floor due to residual/net water head of 6 m due to NWE.

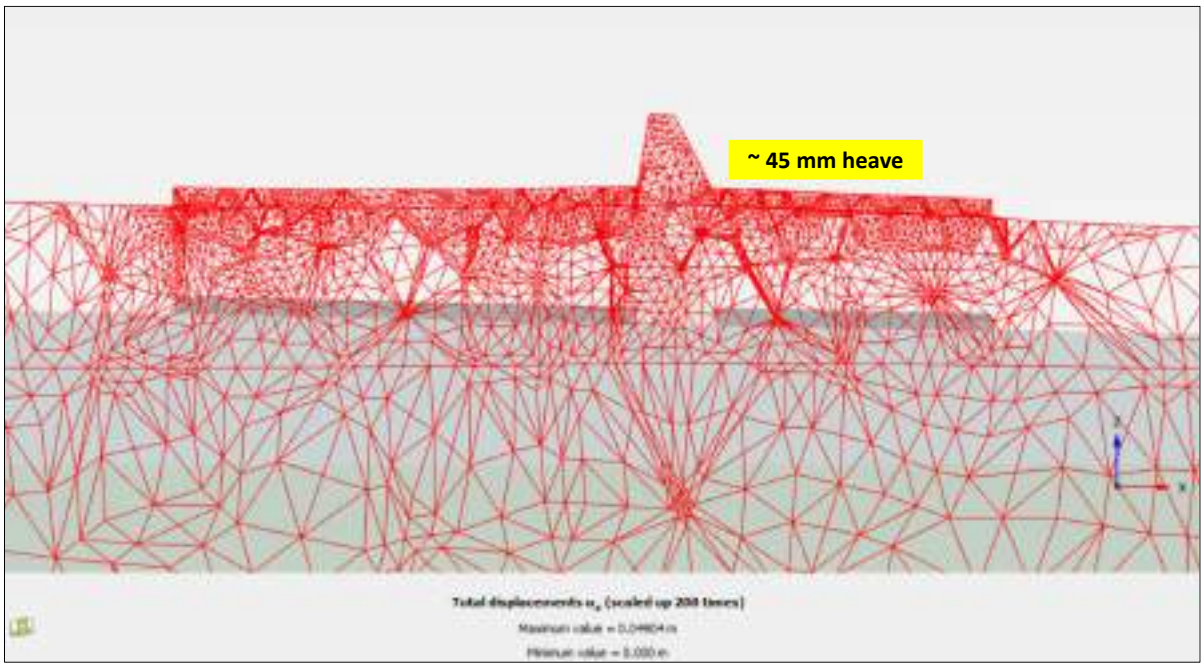


Figure 3-24: A cross-sectional view showing an upheaval of about 45 mm of D/S floor due to residual/net water head of 6 m due to NWE.

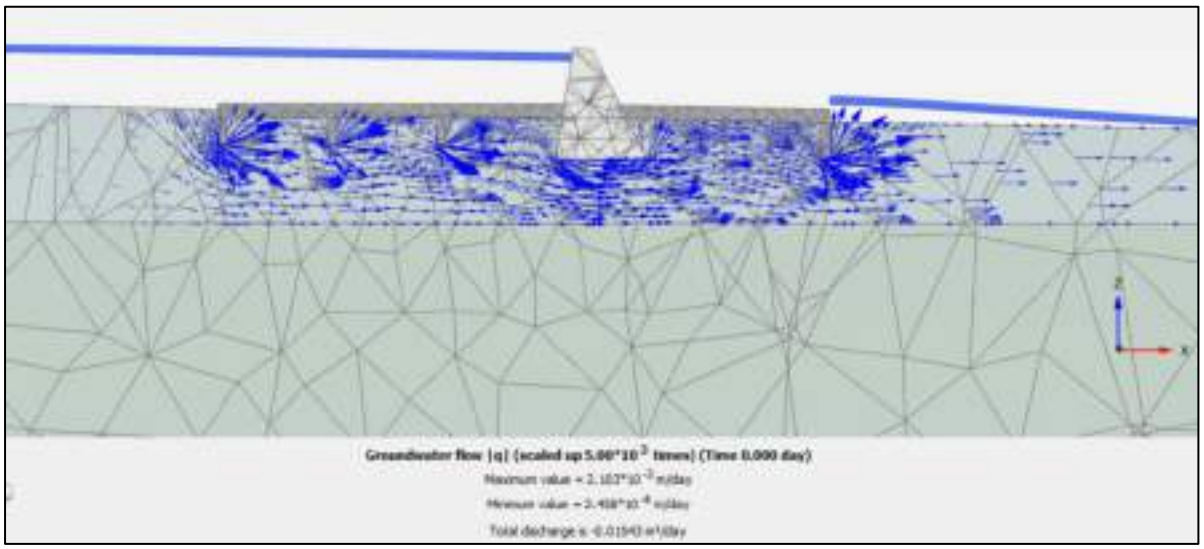


Figure 3-25: A cross-section through Weir showing subsurface flow with three 3 m cutoff walls during NWE.

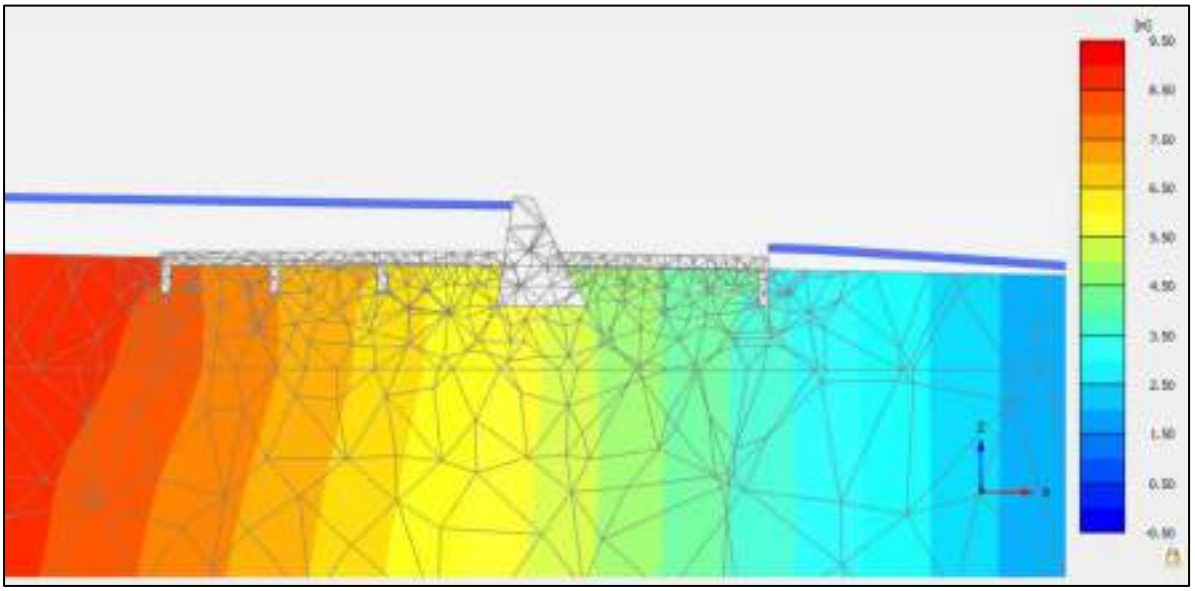


Figure 3-26: A cross-section through the Weir showing the water head due to subsurface flow under NWE with three 3 m cutoff walls. Maximum water head under D/S floor is 5.0 m.

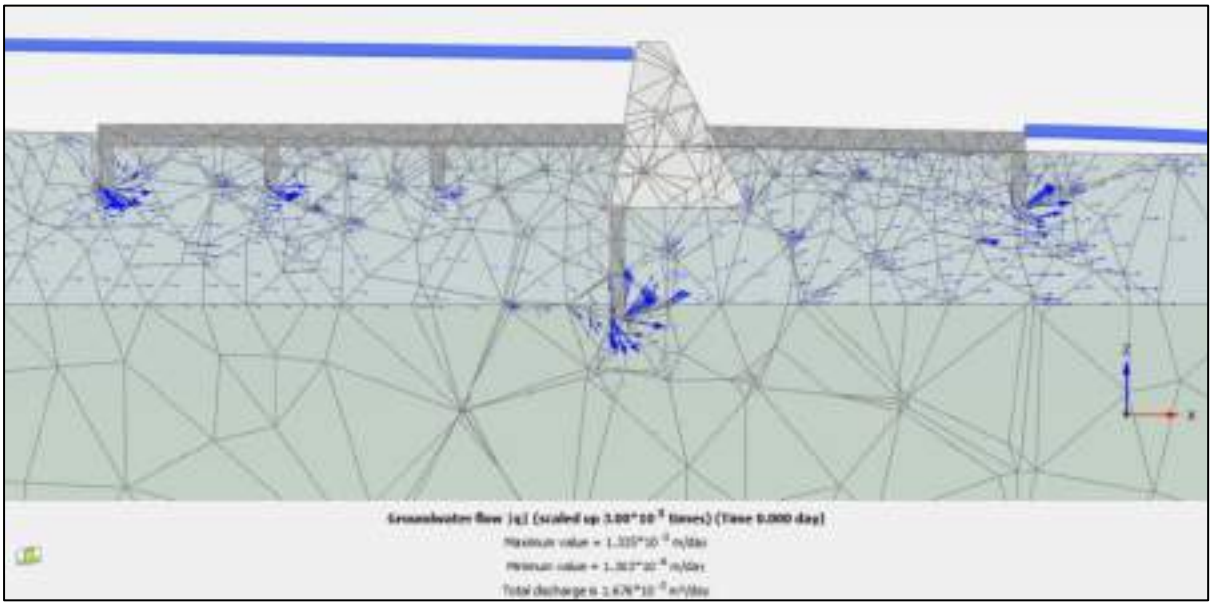


Figure 3-27: A cross-section through the Weir showing the subsurface flow during NEW with three 3m cutoffs below the U/S floor and one 6 m cutoff wall at the weir's heel.

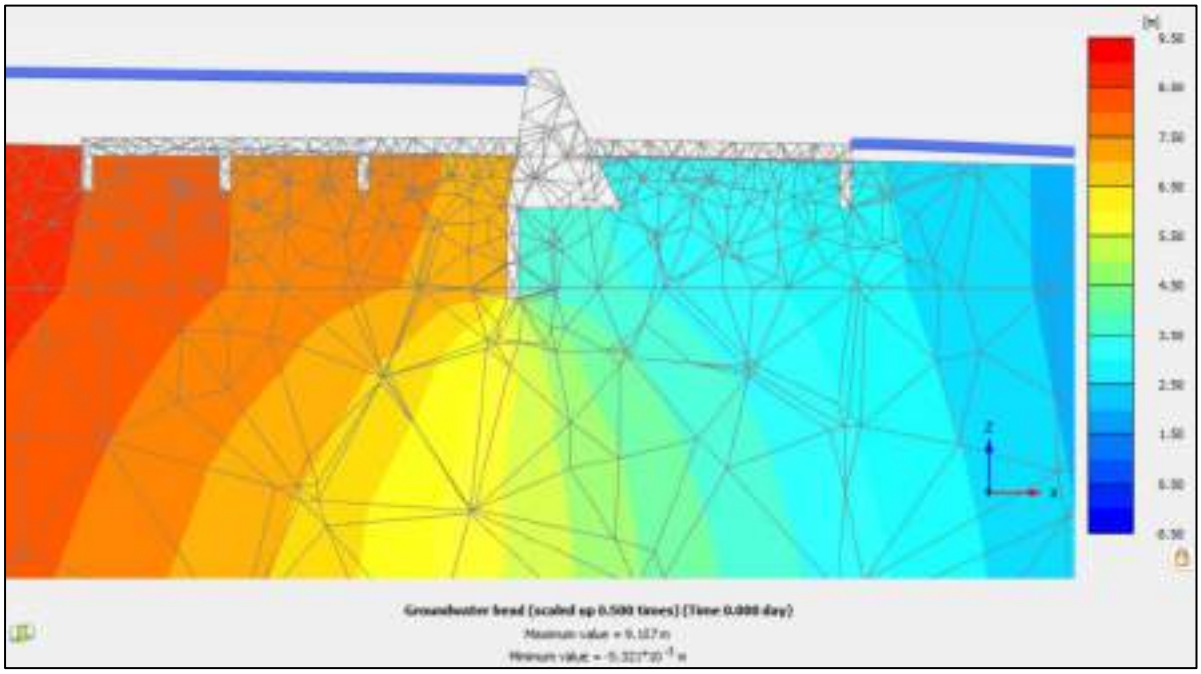


Figure 3-28: A cross-section through Weir showing water head due to subsurface flow under NWE with three 3 m & one 6 m cut-off walls. Max. water head under D/S floor is 3.5 m.

Flood Water Elevation (FWE) Simulations

The same model (**Figure 3-16**) was prepared for the Flood Water Elevation (FWE) and is shown in **Figure 3-29**. A 3D view of the seepage scenario without any cutoff walls is shown in **Figure 3-30**. The corresponding cross-sections showing the seepage paths and the groundwater head are shown in **Figures 3-31 and 3-32**, respectively. In this case, the maximum net groundwater head on the D/S floor is approximately 7.0 m. The expected system heave is shown in **Figures 3-33 and 3-34**. The same model was then augmented with three 3 m and one 6 m cutoffs, and the corresponding seepage scenario and water heads are shown in **Figures 3.35 and 3.36**, respectively. This case reduced the net waterhead on the D/S floor to about 5.5-6.0 m. To reduce the probable heave of the D/S floor during FWE, the same case was finally modeled with a 2.0 m-thick D/S floor; the maximum heave, shown in **Figure 3-37**, was now limited to about 10 mm.

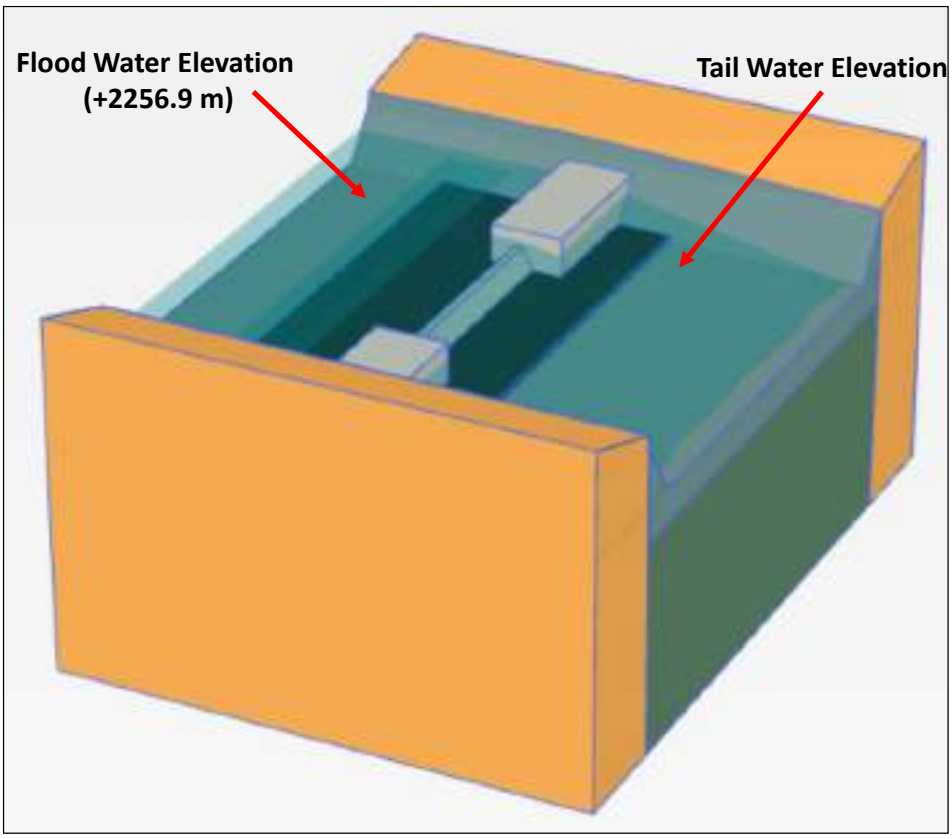


Figure 3-29: Water flow model under Maximum Flood Water Elevation (FWE) conditions

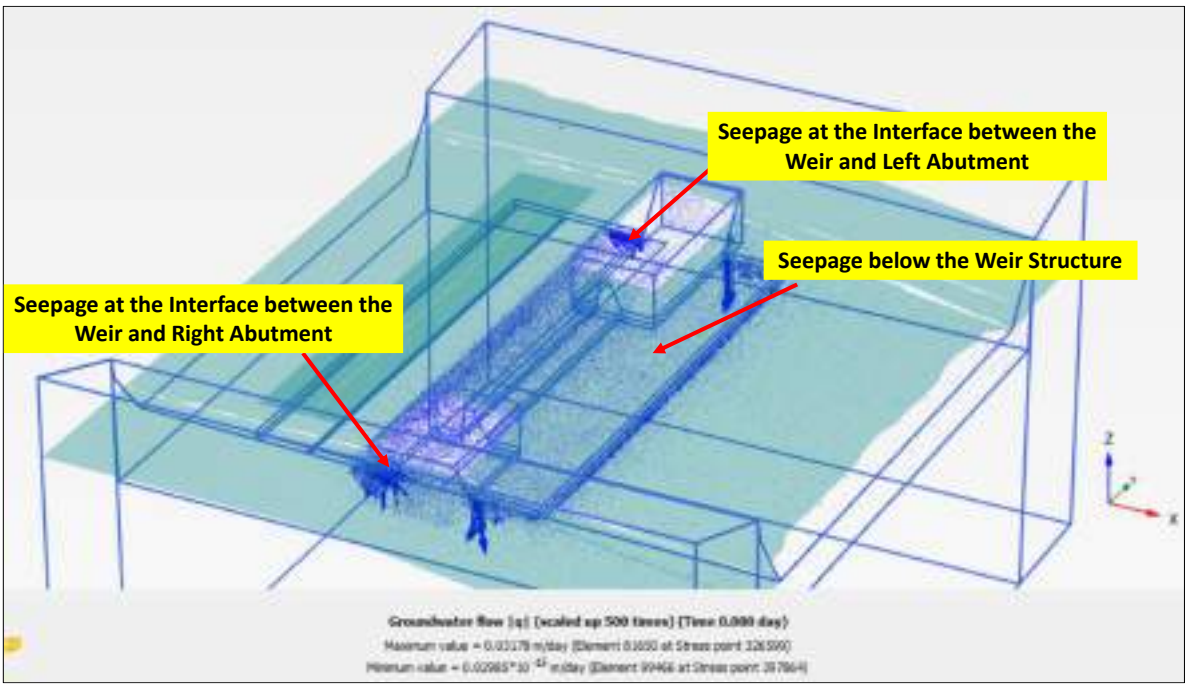


Figure 3-30: Water flow model under Flood Water Elevation (FWE) conditions, showing 3D subsurface flow

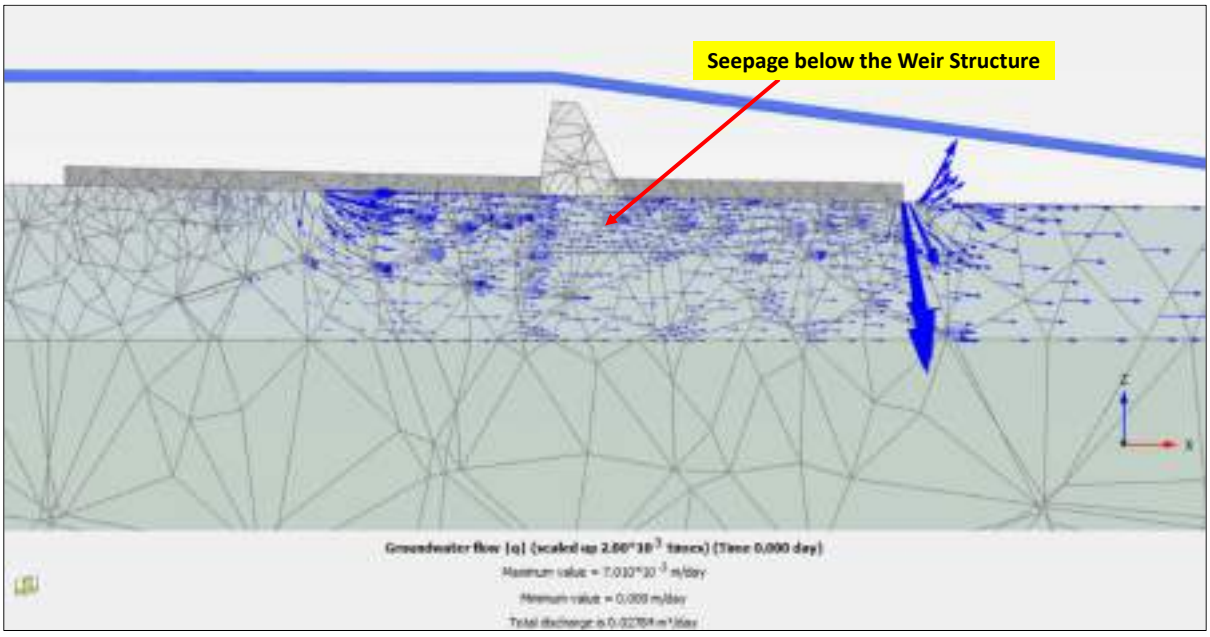


Figure 3-31: Water flow model under Flood Water Elevation (FWE) conditions without any cutoff, showing seepage cross-section at the Weir

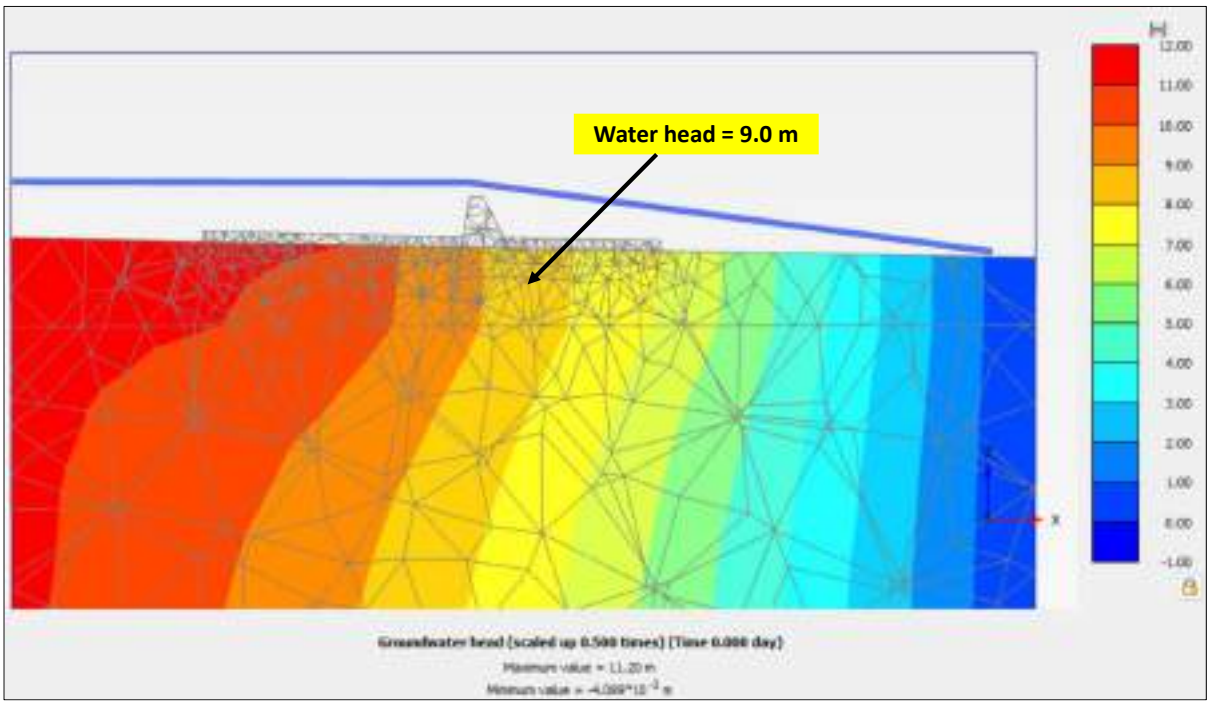


Figure 3-32: Water flow model under Flood Water Elevation (FWE) conditions without a cutoff wall, showing water head contours along the weir

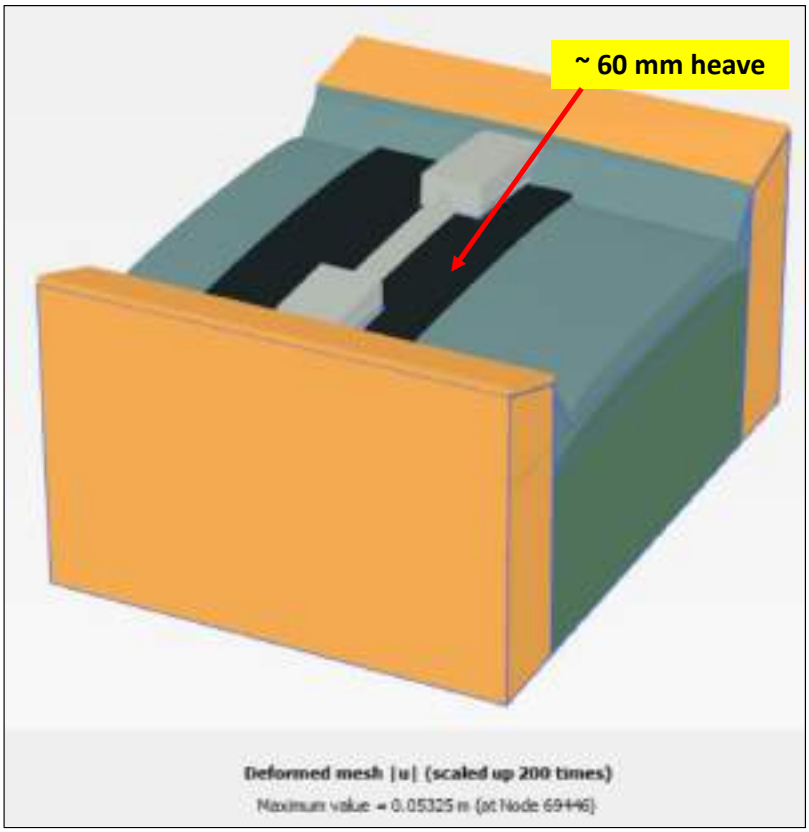


Figure 3-33: Water flow model under Flood Water Elevation (FWE) conditions, showing uplift displacements (~60 mm) for a1.5 m thick D/S floor

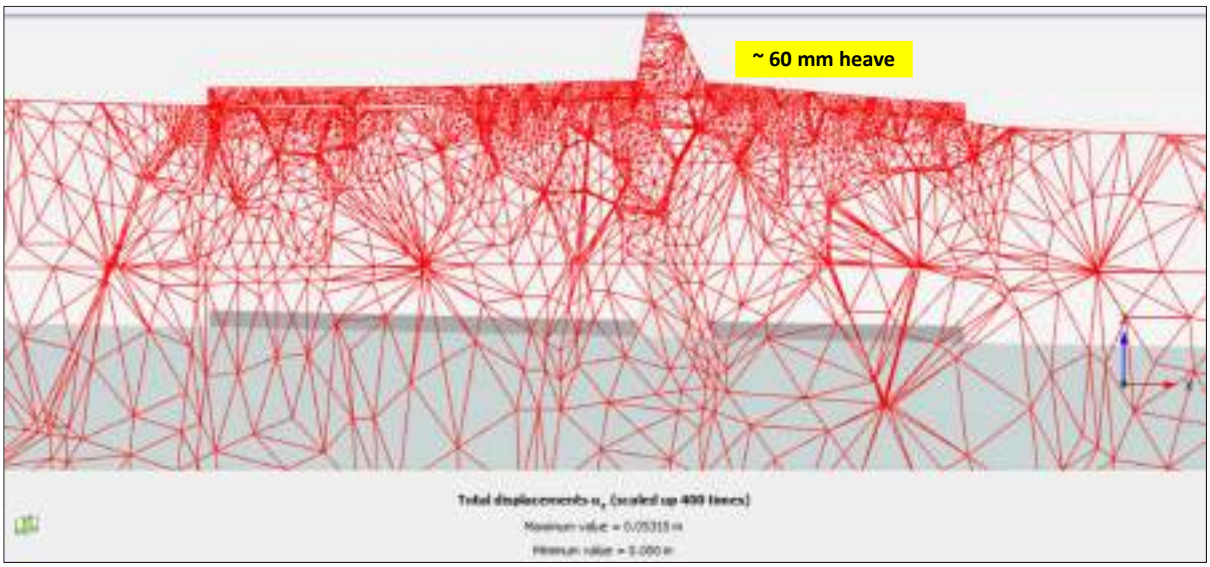


Figure 3-34: Water flow model under Flood Water Elevation (FWE) conditions, showing uplift displacements (~60 mm) for a 1.5 m thick floor

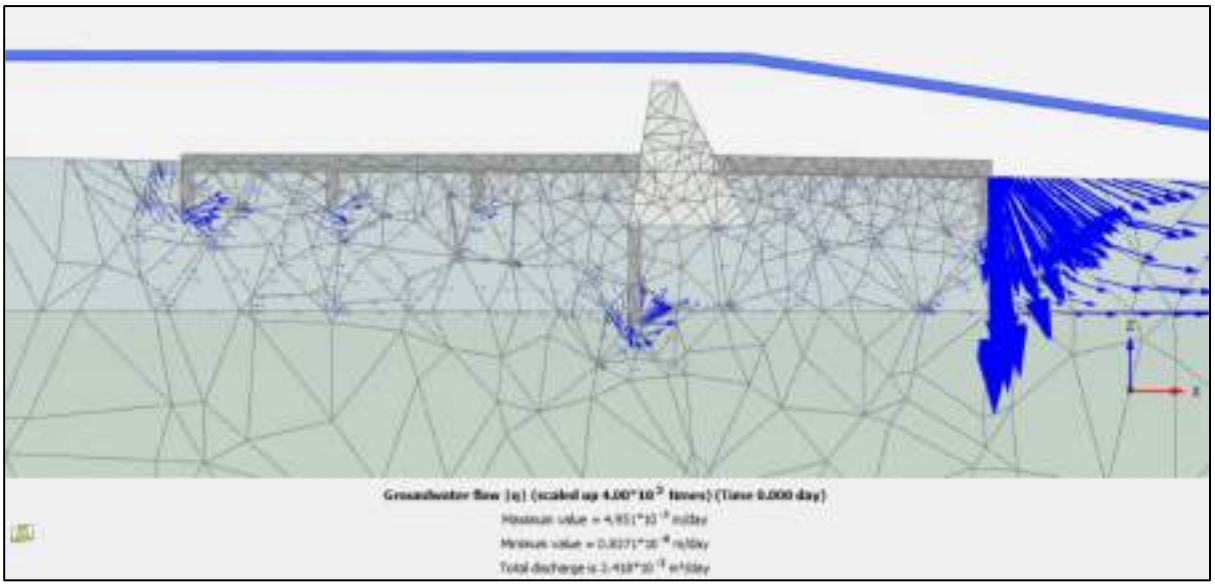


Figure 3-35: Water flow model under Flood Water Elevation (FWE) conditions with three 3 m and one 6 m cutoff, showing the seepage cross-section at the Weir

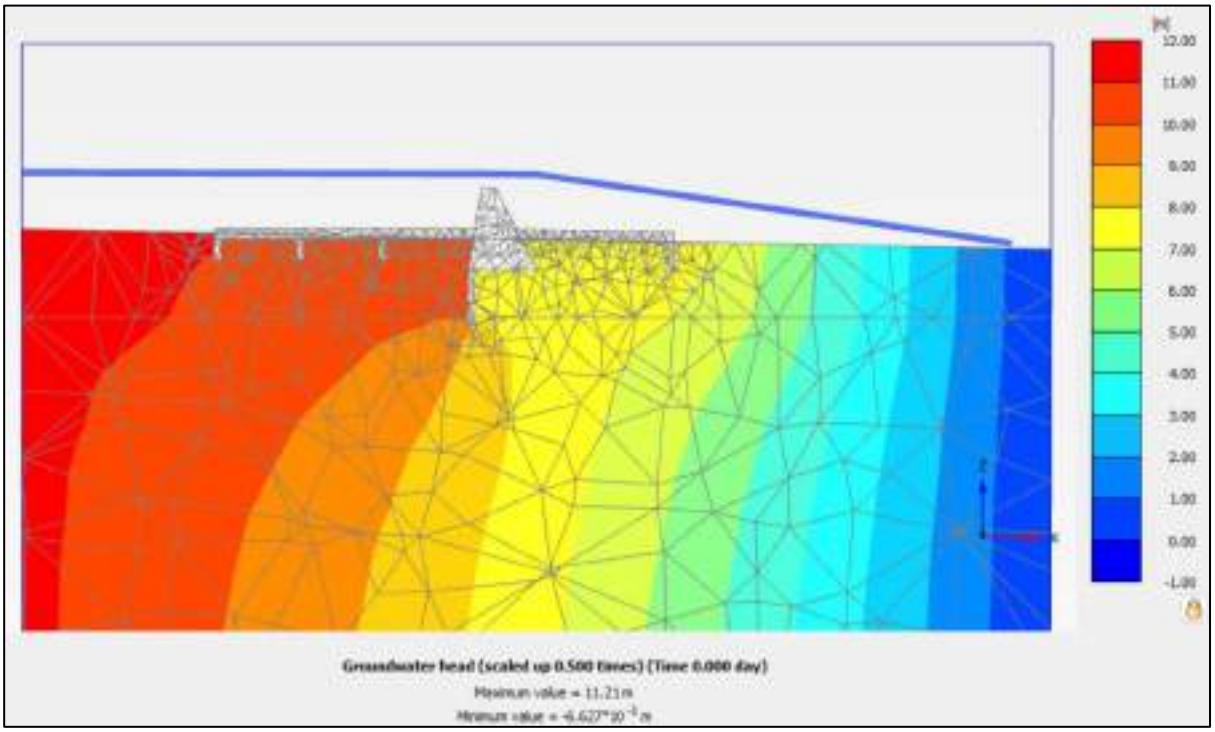


Figure 3-36: Water flow model under Flood Water Elevation (FWE) conditions with three 3 m and one 6 m cutoff, showing the groundwater head cross-section at the Weir.

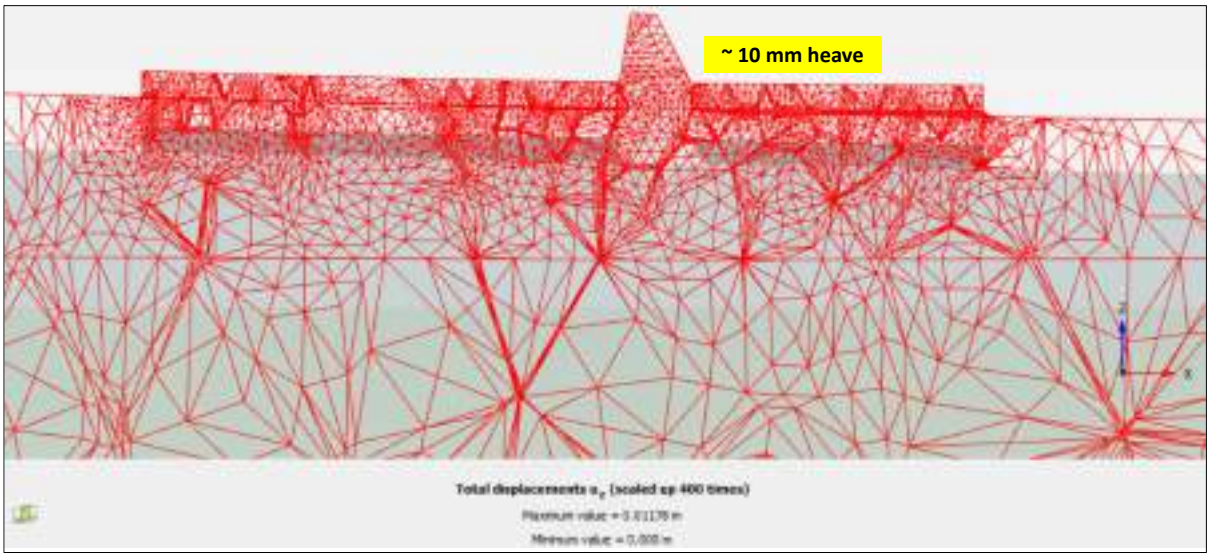


Figure 3-37: Water flow model under Flood Water Elevation (FWE) conditions, showing uplift displacements (~10 mm) for a 2.0 m D/S thick floor

3.5.1.2 Foundation and Slope Stability Modelling and Simulations

This analysis evaluates the stress-strain behaviour and displacements of the foundations and slopes associated with the Weir, Pipeline, Desander, and Powerhouse. The stability analysis was conducted under both static and seismic conditions.

3.10 Diversion Weir Analysis – *Under Static Conditions*

The stability analysis of the diversion weir considers the maximum stresses transmitted by the weir body to the foundation strata at normal and flood water levels. It also assesses the maximum stresses generated within the weir body under these conditions. The analysis further evaluates the stability of the soil and rock slopes that serve as the weir's abutments. The slope stability of the abutments and the slopes associated with other facilities must be ensured under both static and seismic conditions. The basic model of the Weir (**Figure 3-12**) was analysed for stress-strain behaviour, foundation pressures, and slope stability. The foundation pressures and the concrete stresses at normal and flood water levels are shown in **Figures 3-38 and 3-39**, respectively. As shown in **Figure 3-38**, the maximum vertical stress in the concrete is about 350 kPa, while the maximum pressure at the weir foundation is 120 kPa. The maximum pressure of 120 kPa is well below the maximum allowable bearing pressure of 650 kPa. The maximum horizontal stress at the weir and floor interfaces (**Figure 3-39**) is around 1200 kPa. As shown in **Figure 3-40**, the maximum displacement of the weir under normal water level conditions is negligible and only a couple of millimetres.

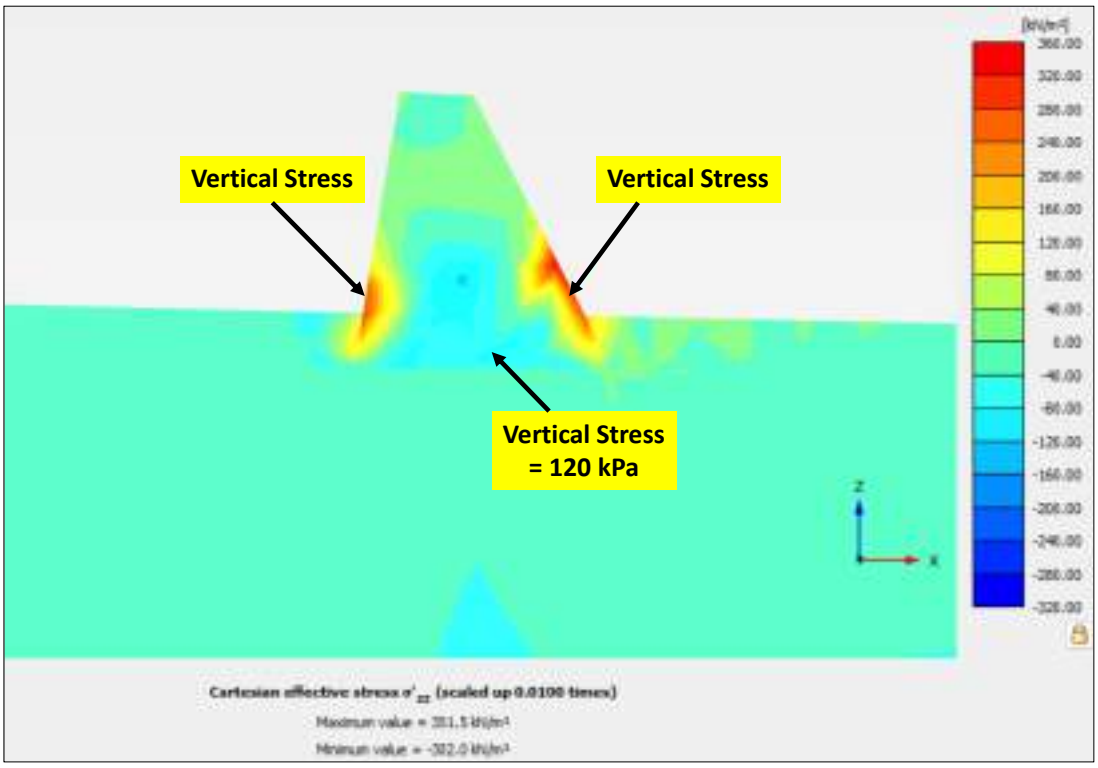


Figure 3-38: Stress-strain model under Normal Water Elevation (NWE) conditions, showing vertical stresses in the concrete section and the pressure at the foundation level

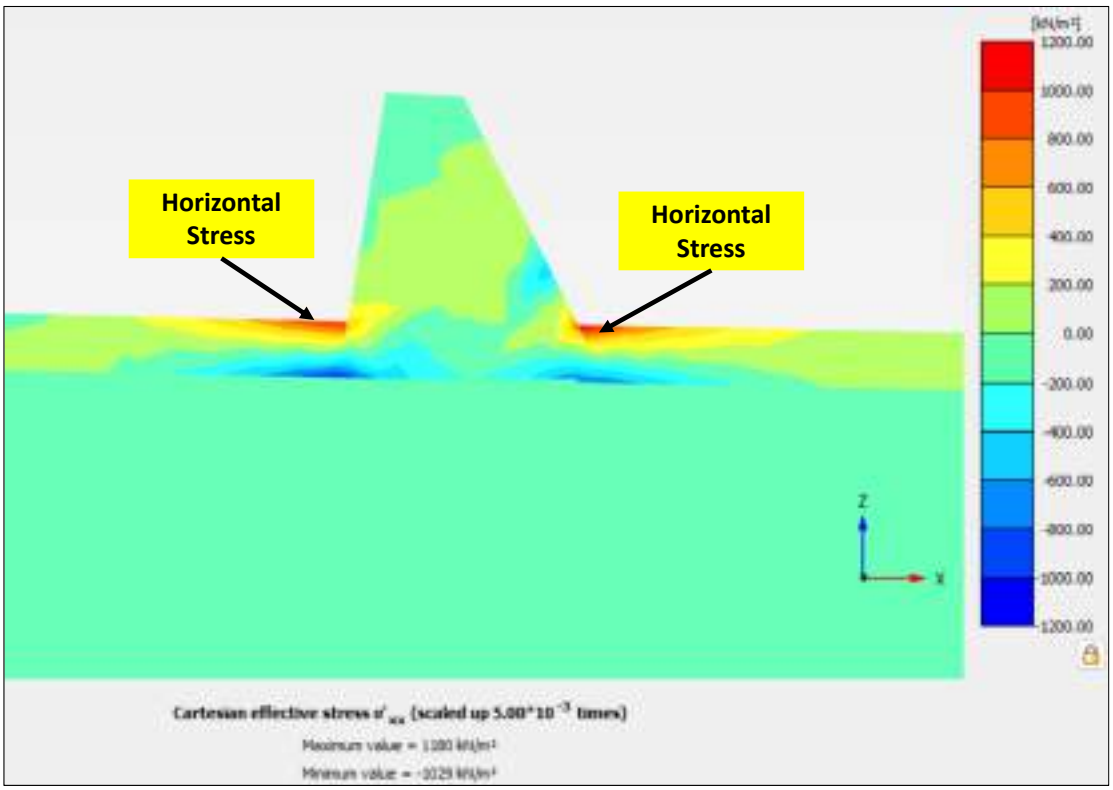


Figure 3-39: Stress-strain model under Normal Water Elevation (NWE) conditions, showing horizontal stresses in the concrete section and the pressure at the foundation level

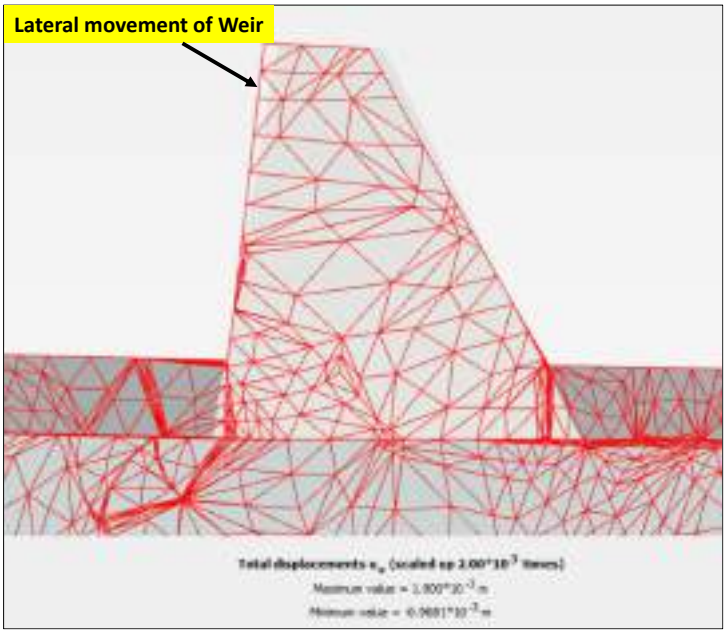


Figure 3-40: Lateral displacement anticipated under NWE condition.

Vertical stress and foundation pressures increase at maximum flood water level (**Figure 3-41**). The maximum vertical stress in the concrete reaches 450 kPa during the FWE. Although the maximum foundation pressure increases to 240 kPa at the maximum flood water level, it remains below the maximum allowable bearing capacity. The horizontal stress section is shown in **Figure 3-42**. The maximum displacement of the weir at the maximum flood water level is also negligible (**Figure 3-43**).

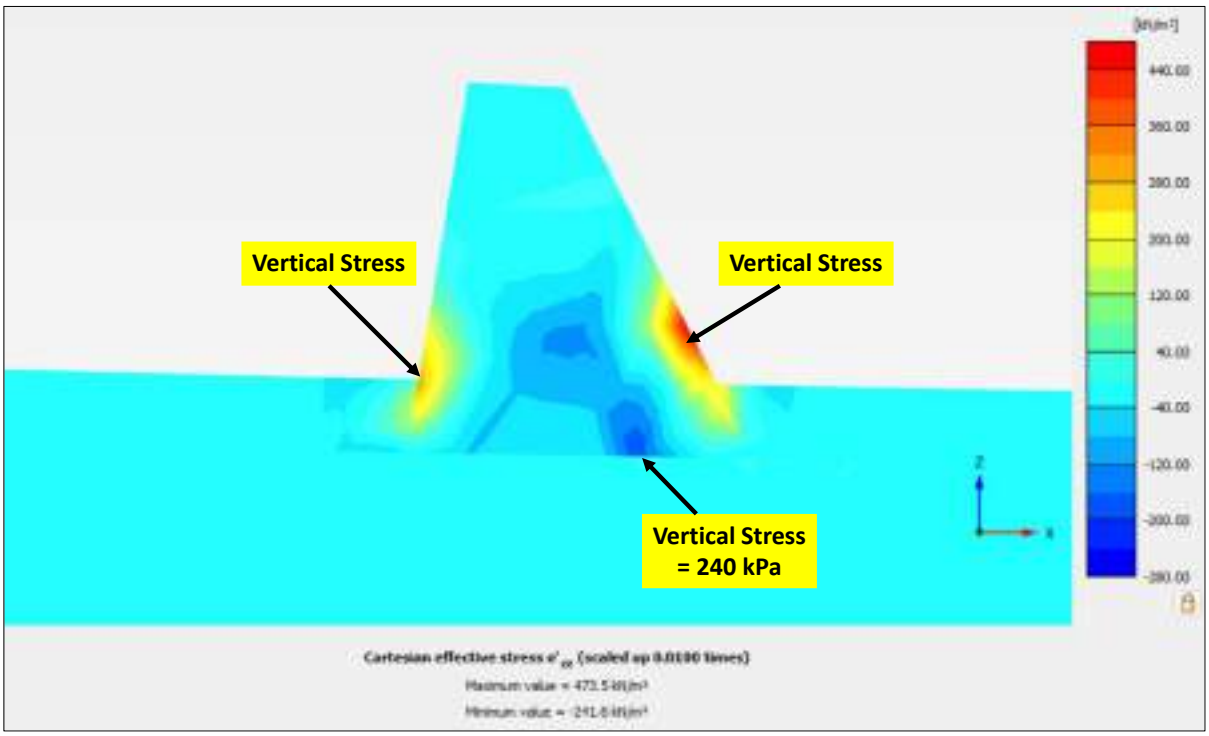


Figure 3-41: Stress-strain model under Flood Water Elevation (FWE) conditions, showing vertical stresses in the concrete section and the pressure at the foundation level

However, the slope stability analysis of the abutments at the flood water level indicates that soil slopes steeper than 1:1 may become unstable due to high saturation of the strata. The slope instability scenario for the river banks/abutments is shown in **Figure 3-44**.

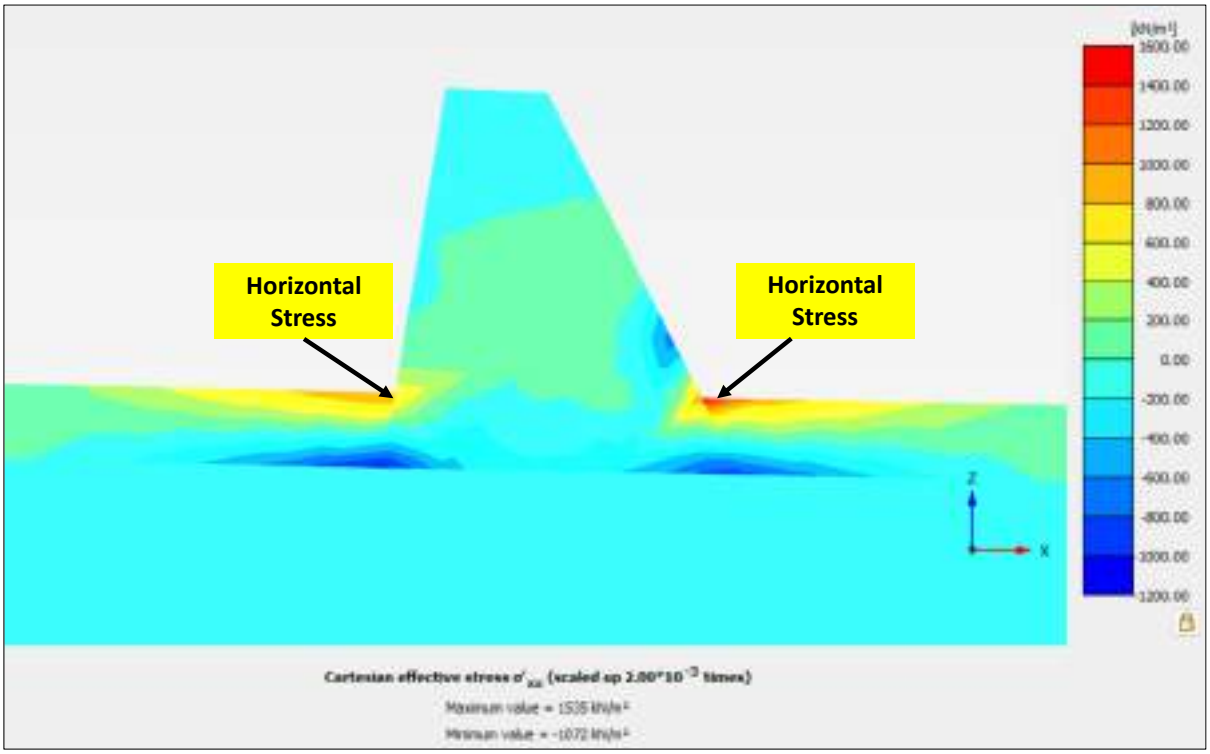


Figure 3-42: Stress-strain model under Flood Water Elevation (FWE) conditions, showing horizontal stresses in the concrete section and the foundation.

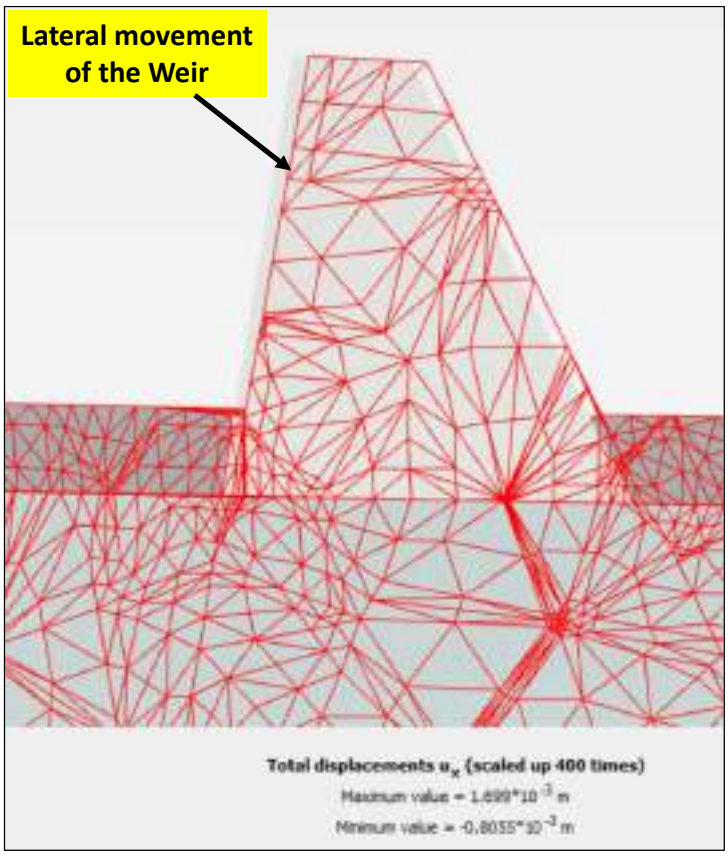


Figure 3-43: Lateral displacement anticipated under Flood Water Elevation (FWE).

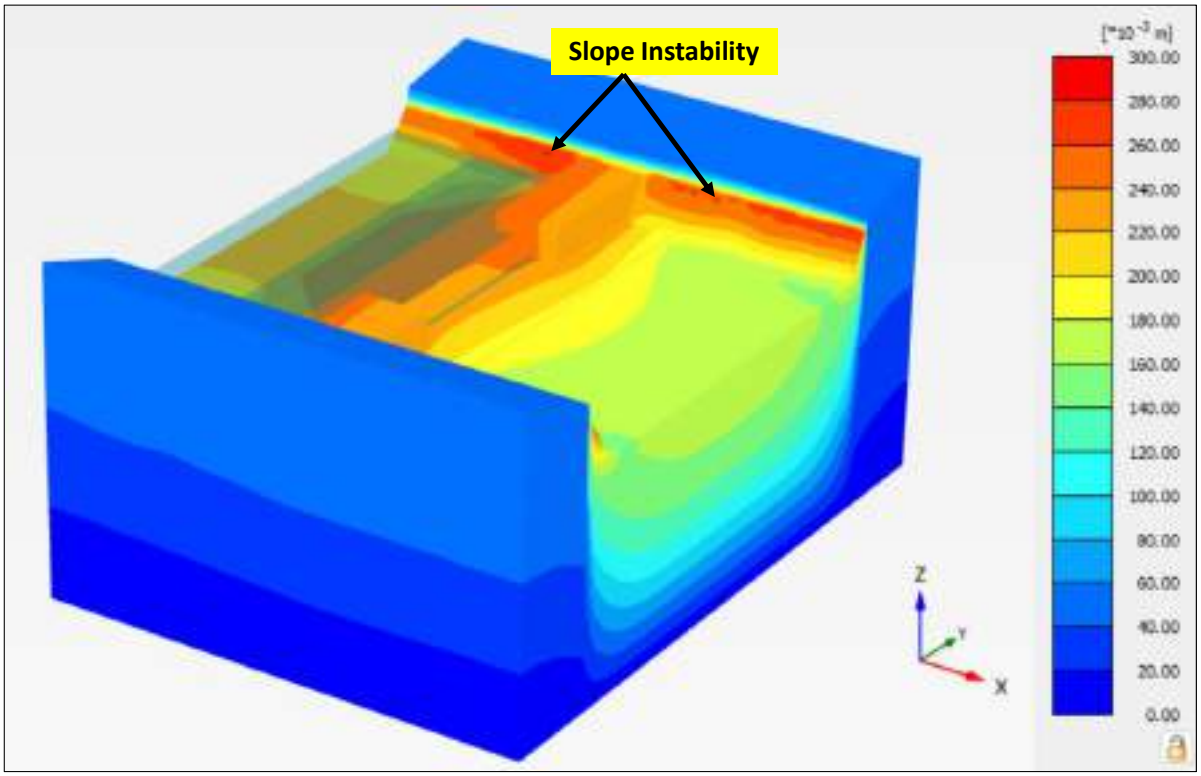


Figure 3-44: Water flow model under Flood Water Elevation (FWE) conditions, showing slope instability conditions.

Diversion Weir Analysis – *Under Seismic Conditions*

The basic weir model (**Figure 3-12**) was used to analyse the displacement and stress-strain response to seismic-induced ground acceleration at the base of the structure. Based on the Maximum Credible Earthquake (MCE) of 0.68g, the seismic analysis was simulated in the software's seismic module using a synthetic earthquake with peak horizontal and vertical accelerations of 0.68g and 0.15g, respectively (**Figures 3-45 and 3-46**). In PLAXIS 3D, each soil/rock layer requires the maximum shear modulus and the damping ratio as the primary input parameters. The model simulating steady-state seepage conditions at the normal water elevation (NWE) was used for the seismic simulations.

The formulated earthquake was applied at the base of the model, and the corresponding displacement scenario was recorded as the earthquake completed its acceleration spectrum for both cases. The resulting displacement of the weir body during the steady-state seepage stage under the anticipated earthquake at NWE is shown in **Figures 3-47 and 3-48**. The results indicate that the maximum anticipated displacement at the top of the weir is in the range of 250-300 mm. To reduce these displacements of the weir under probable seismic activity, the model was restimulated with a 6 m deep cutoff wall at the heel of the weir. The results of the simulations reveal that adding a 6.0 m-deep cutoff wall at heel of weir provides restraint against seismic shaking, deformations are restricted to maximum of about 50-100 mm (**Figure 3-49**).

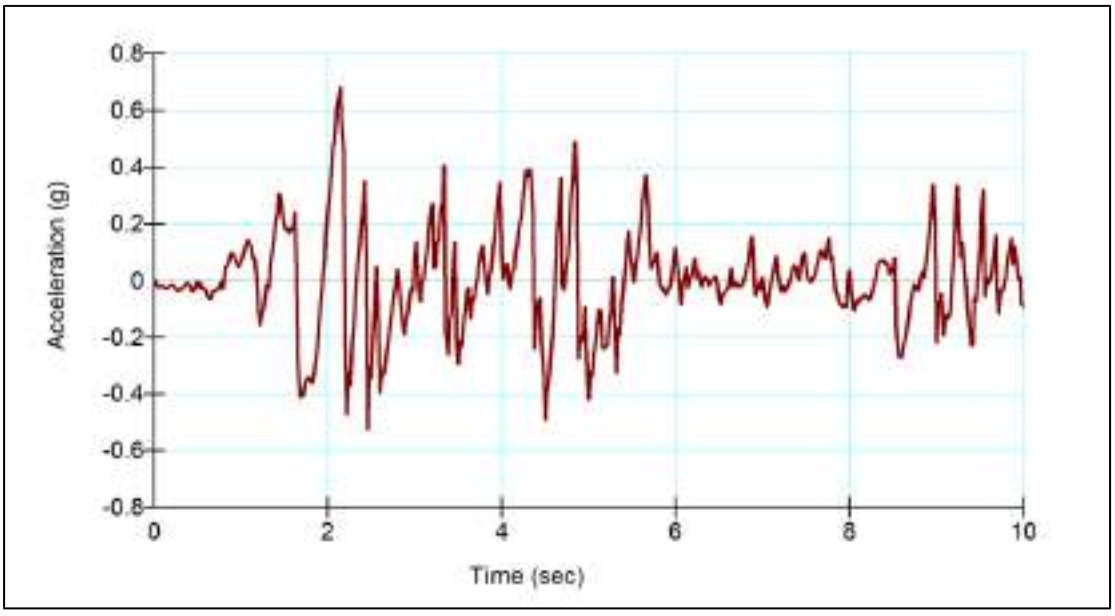


Figure 3-45: Seismic Analysis Horizontal Earthquake spectrum applied to weir section (kh=0.68g)

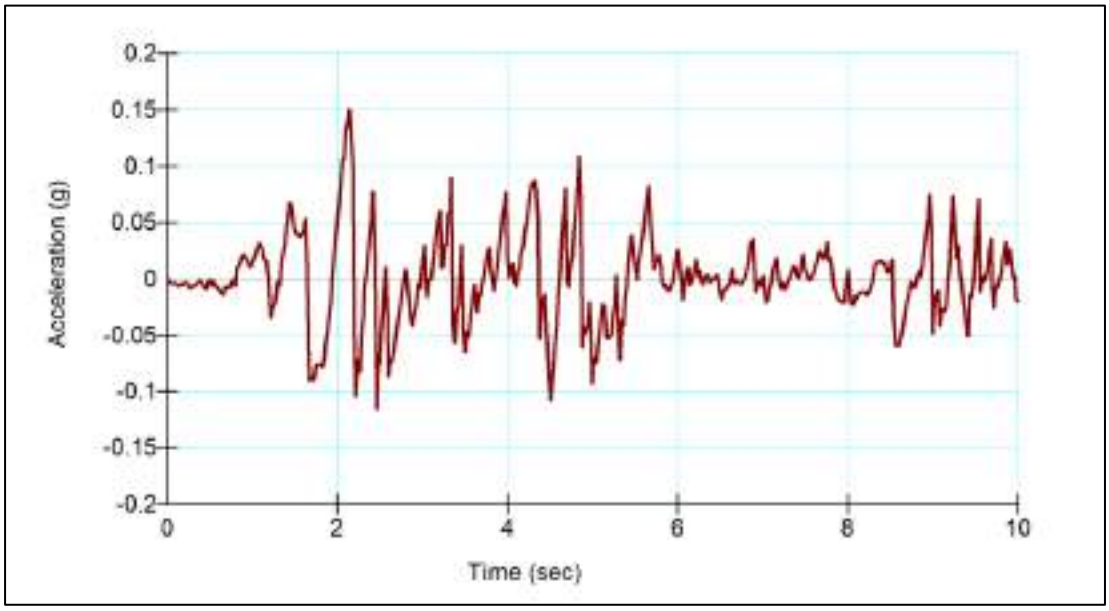


Figure 3-46: Seismic Analysis Vertical Earthquake spectrum applied to weir section (kh=0.15g)

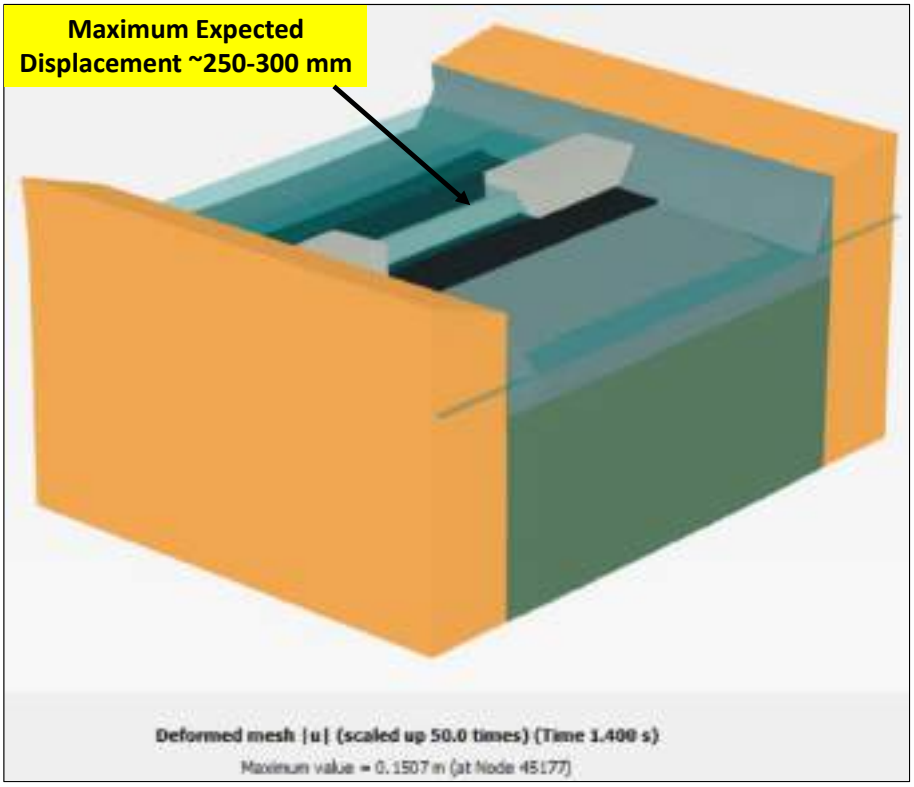


Figure 3-47: Expected deformation of the weir and its natural environment WITHOUT heel cutoff under the peak earthquake acceleration of 0.68g

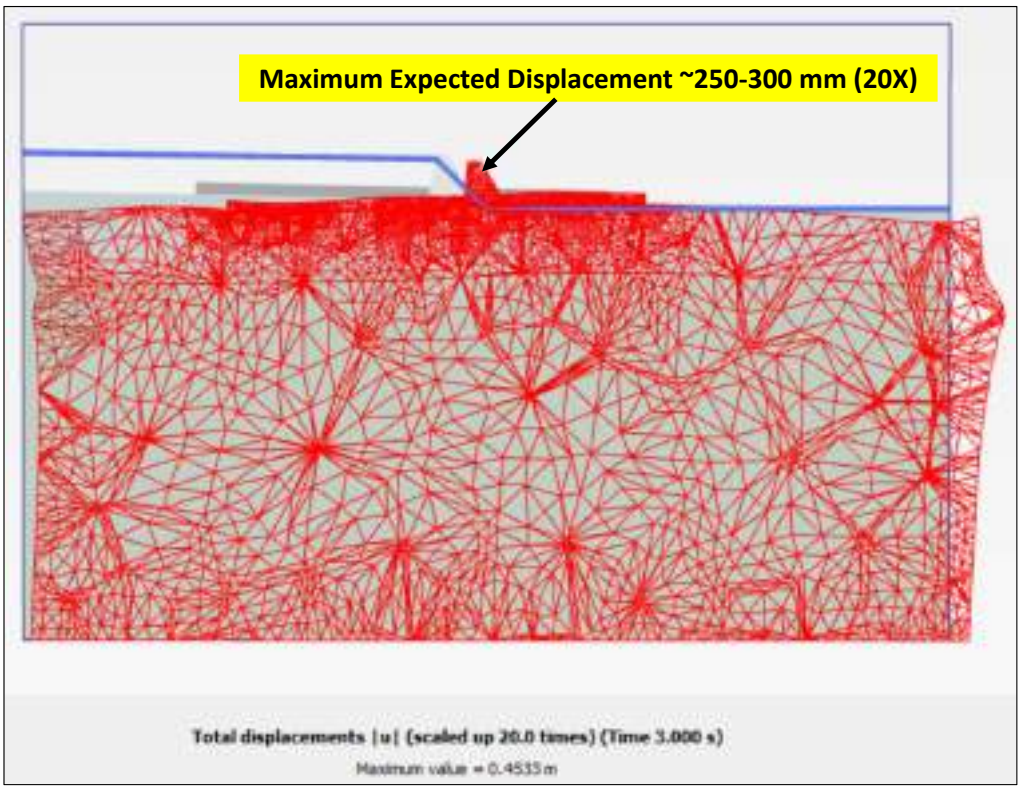


Figure 3-48: Expected deformation of the weir and its natural environment WITHOUT heel cutoff under the peak earthquake acceleration of 0.68g.

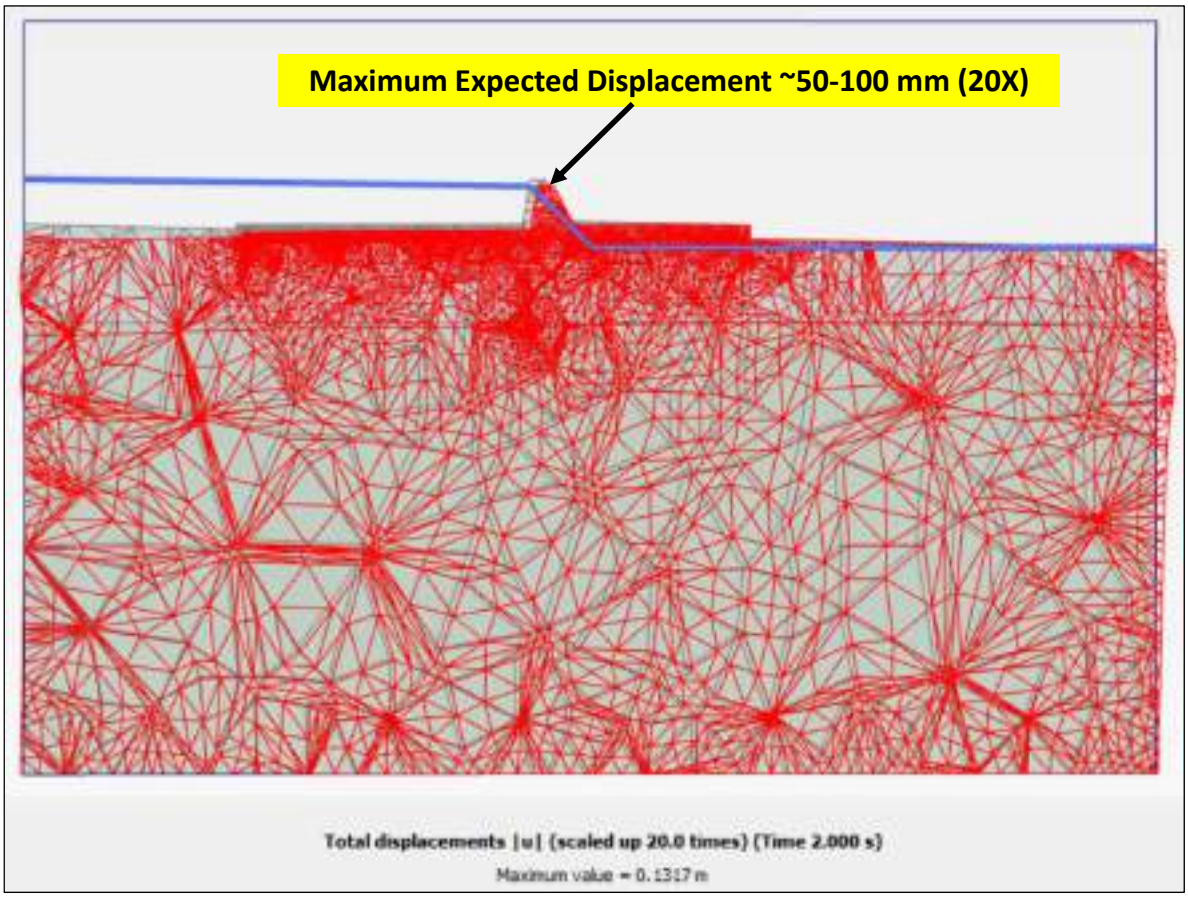


Figure 3-49: Expected deformation of the weir and its natural environment WITH heel cutoff under the peak earthquake acceleration of 0.68g.

The maximum vertical and horizontal stresses generated in the weir's concrete body during the earthquake are shown in **Figures 3-50 and 3-51**. **Figure 3-50** shows that the maximum vertical stress anticipated in the concrete section is about 2000 kPa. Moreover, the maximum pressure on the foundation strata is about 500 kPa, which is even lower than the maximum permissible bearing capacity. Similarly, **Figure 3-51** shows that the maximum horizontal stress anticipated in the concrete section of the weir is about 8000 kPa. During the seismic shaking, the expected instability in the abutment slopes is shown in **Figure 3-52** which reveals that the side slopes, composed of soil material, are prone to slope failure during probable seismic activity.

The seismic simulations of the basic weir model have also provided the parameters generally required for the facility's structural design. The required parameters, such as displacements, accelerations, and spectral accelerations, are presented in **Figures 3-53 to 3-55**. These parameters have been evaluated at the weir top, weir foundation, and right and left abutments.

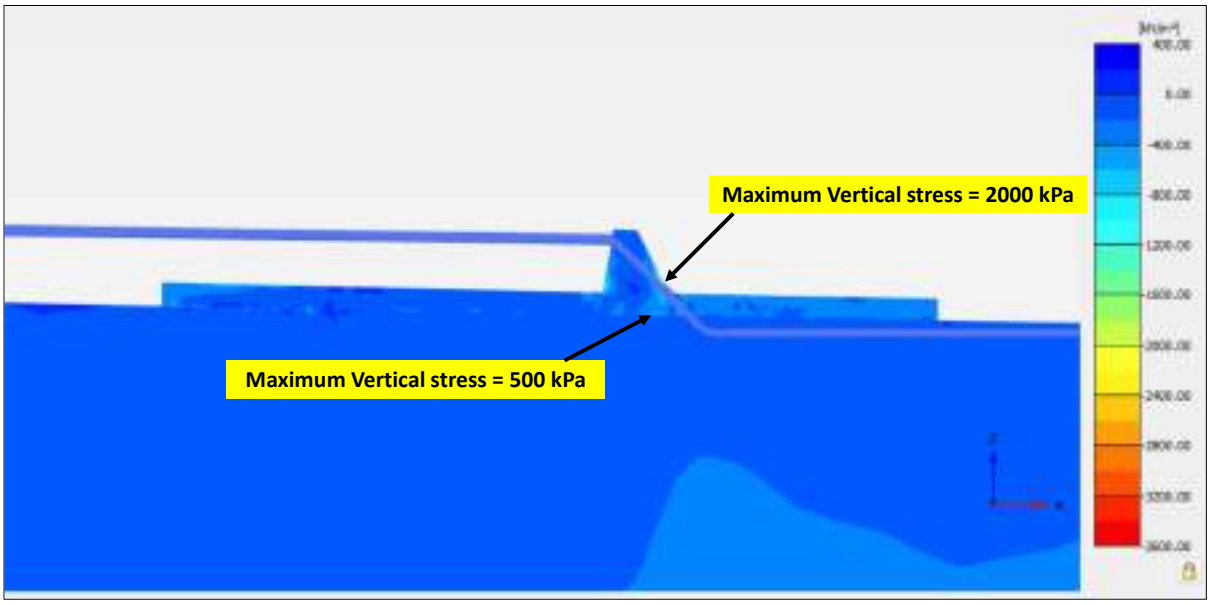


Figure 3-50: Expected vertical stresses in the weir and its natural environment under the peak earthquake acceleration of 0.68g. The maximum vertical stress in the concrete body is 2000 kPa, and the maximum vertical stress on the soil is 500 kPa

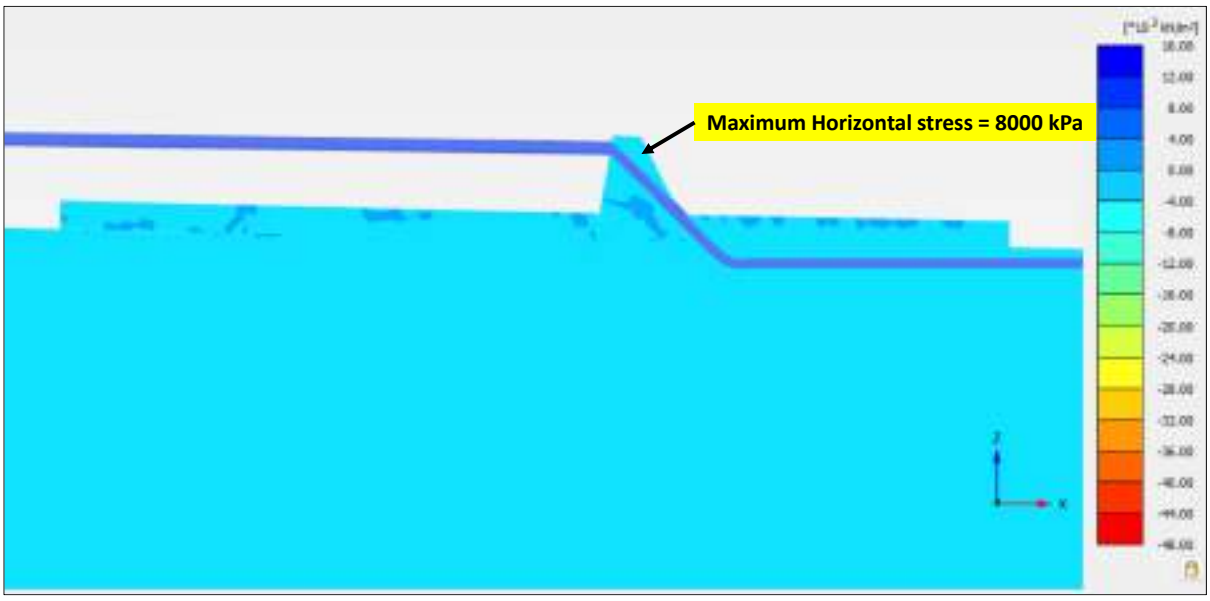


Figure 3-51: Expected horizontal stresses in weir & its natural environment under peak earthquake acceleration of 0.68g. Maximum horizontal stress in concrete body is 8000 kPa

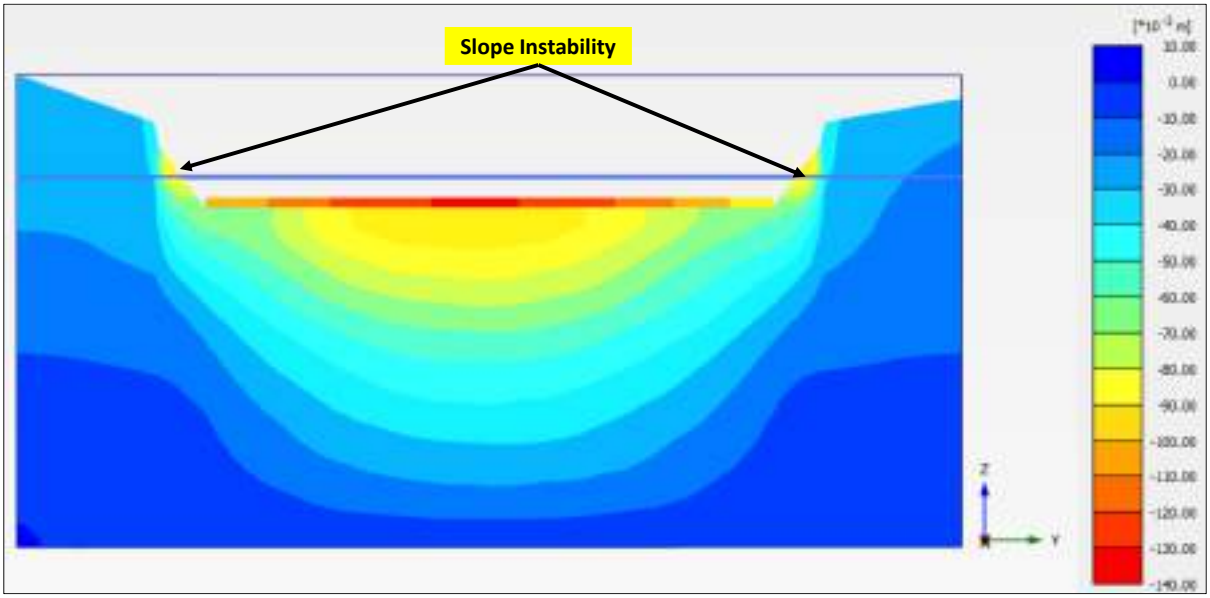


Figure 3-52: Instability condition in the weir's abutment slopes under the peak earthquake acceleration of 0.68g

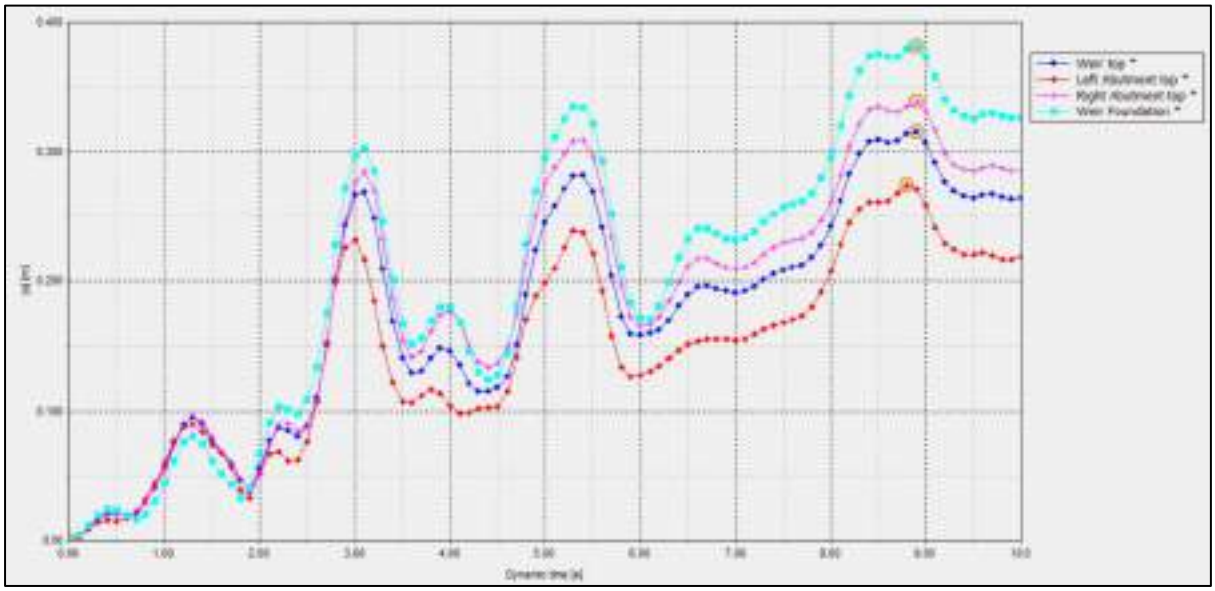


Figure 3-53: Displacements in the Weir and its Foundation under the peak earthquake acceleration of 0.68g

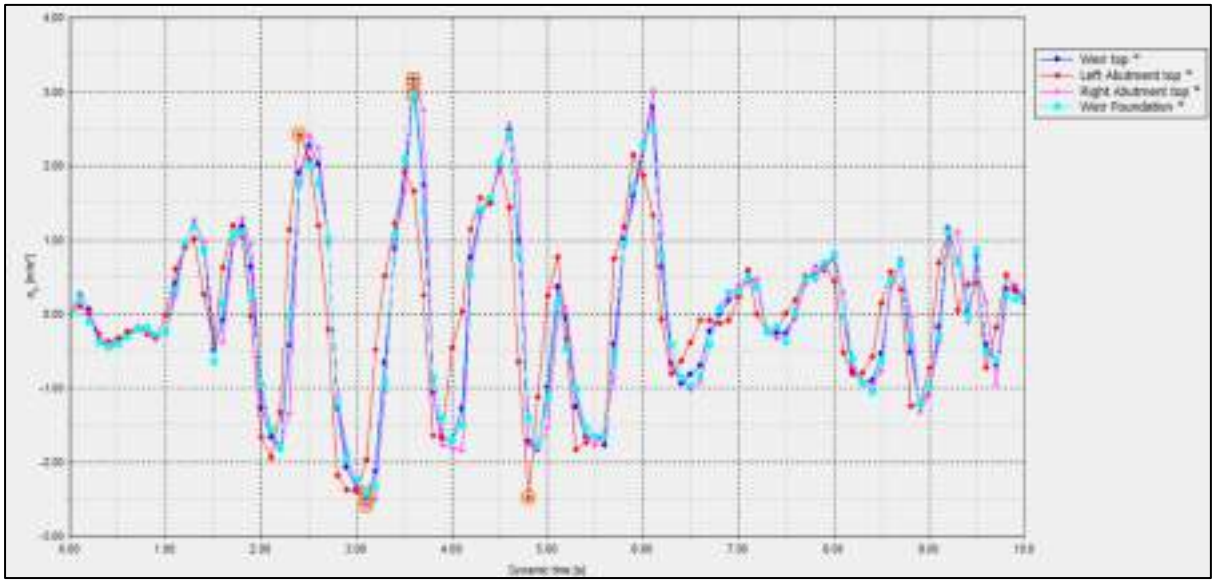


Figure 3-54: Horizontal Accelerations in the Weir and its Foundation under the peak earthquake acceleration of 0.68g.

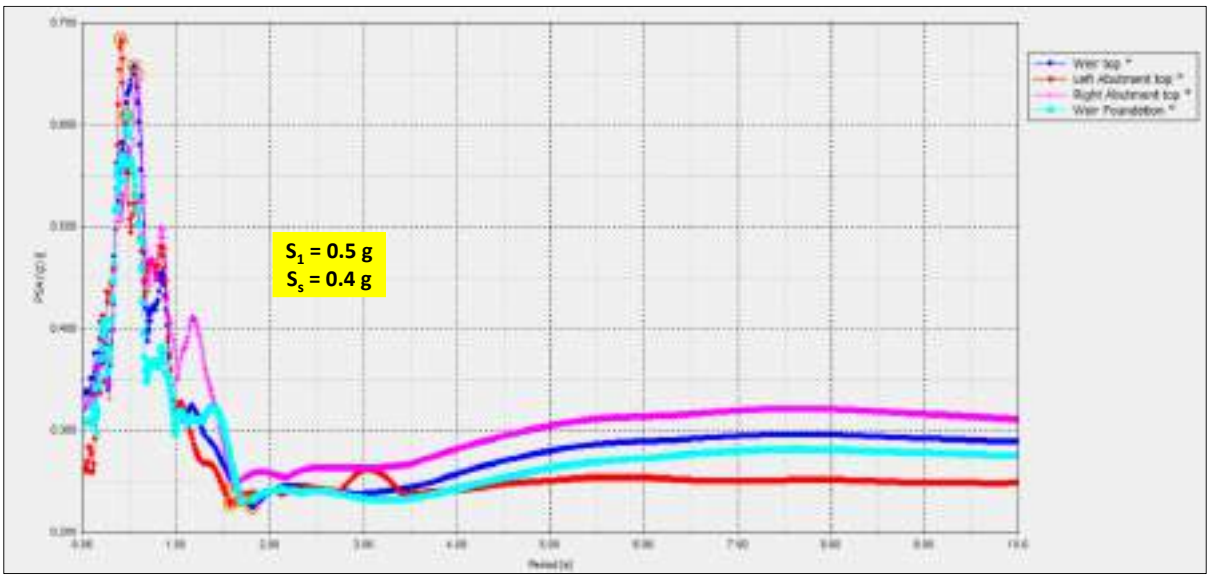


Figure 3-55: Spectral Accelerations in the Weir and its Foundation under the peak earthquake acceleration of 0.68g.

3.5.2 Powerhouse Analysis – Under Static Conditions

The basic powerhouse and tailrace model was embedded in the geological cross-section of **Figure 3-10** and is shown in **Figure 3-56**. As there is a likelihood of erosion of the subsurface strata during high flood levels, the foundations of the powerhouse and the associated retaining walls are proposed to be supported by piles. The proposed powerhouse model, based on hydrological and hydraulic considerations (**Figure 3-57**), was converted into a PLAXIS 3D model (**Figures 3-58 and 3-59**). In this model, the powerhouse is supported by the piled raft, while the associated retaining walls are also founded on piles. In this model, the tailrace retaining wall is also supported by pile foundations. Pile foundations are proposed to be of 1.0 m diameter, while depth will be either 15 m into the river bed alluvium or 3 m into the sound rock. Pile spacing is suggested to be provided in a grid of 2.5 x 5.0 m under the raft foundation. Considering the weight of the electromechanical equipment and the superstructure, a uniformly distributed load of 150 kPa is applied to the raft foundation.

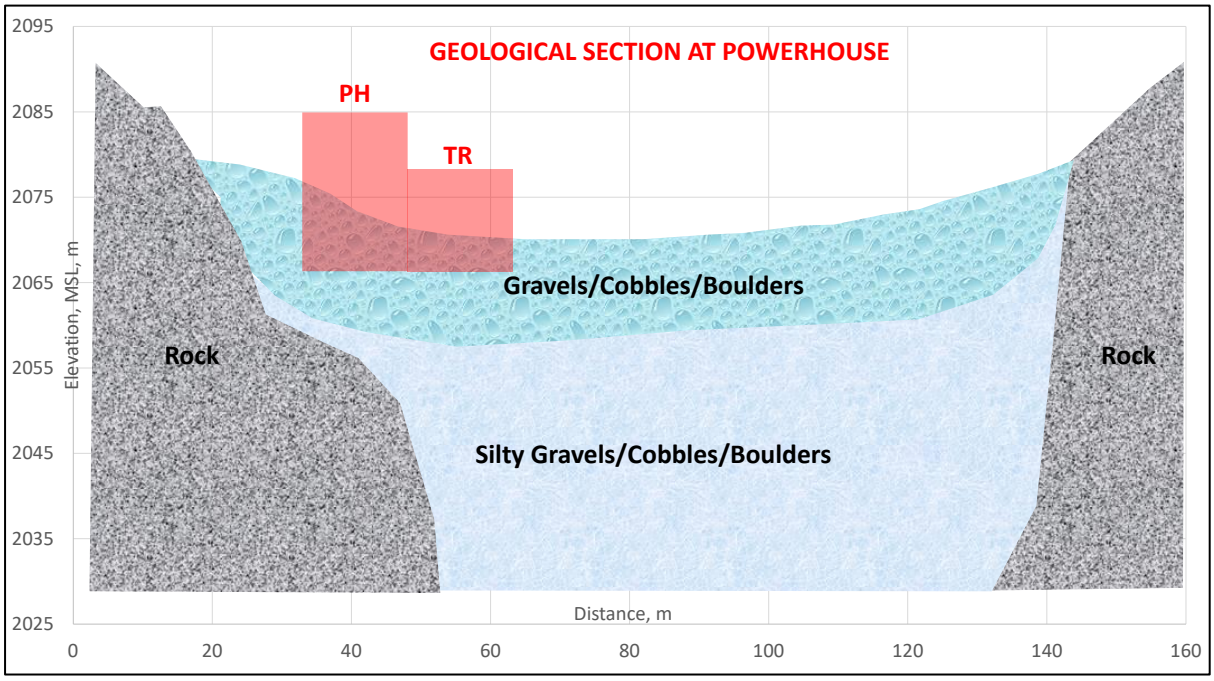


Figure 3-56: Superposition of powerhouse (PH) and tailrace (TR) on geological section

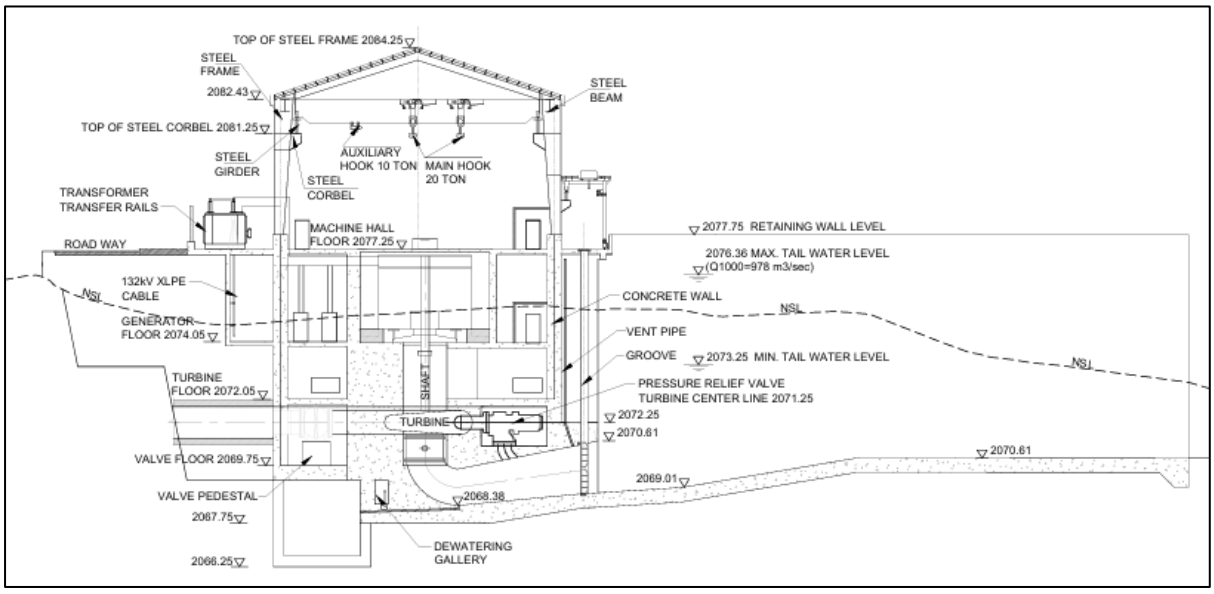


Figure 3-57: Proposed cross-section of the powerhouse and the tailrace

The settlement and slope stability analysis results for the powerhouse and tailrace foundations are shown in **Figure 3-60**. Two sections have been cut through the tailrace and powerhouse, and the results are shown in **Figures 3-61 and 3-62**, respectively. The results indicate that the maximum settlements of the piled raft are in the range of 50-60 mm. Moreover, the slopes appear vulnerable to collapse under maximum flood conditions. However, based on the simulation results discussed earlier, these slopes would remain stable if cut at 1H:1V or flatter. To facilitate the structural design of the foundations for loading other than that considered in this report, pile capacity plots for 1 m diameter piles are provided in **Figure 3-63**.

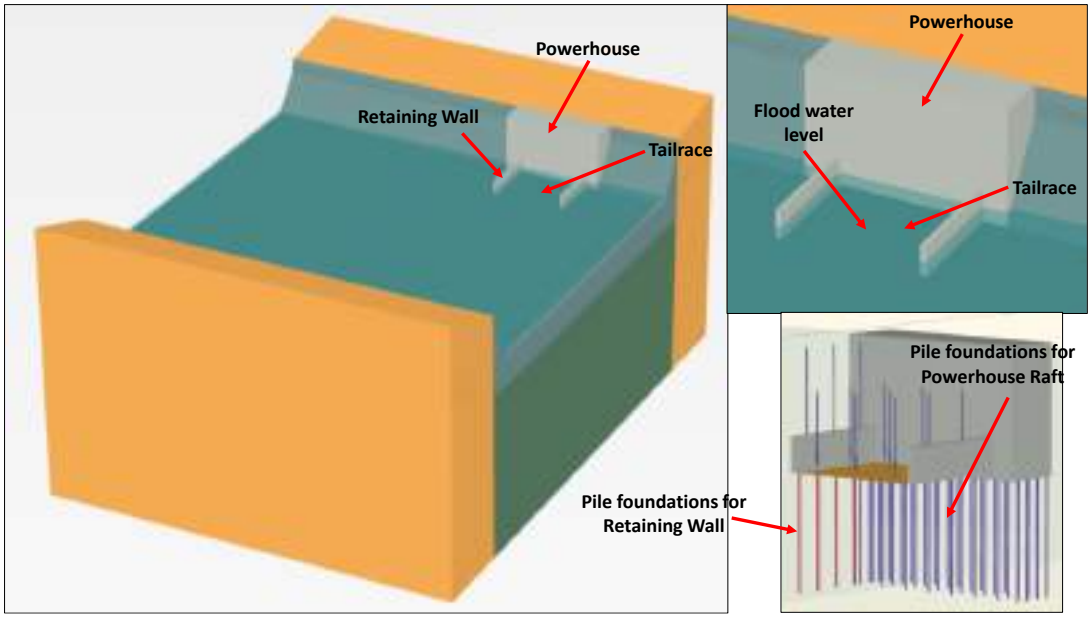


Figure 3-58: 3D views of powerhouse and tailrace model with maximum flood level

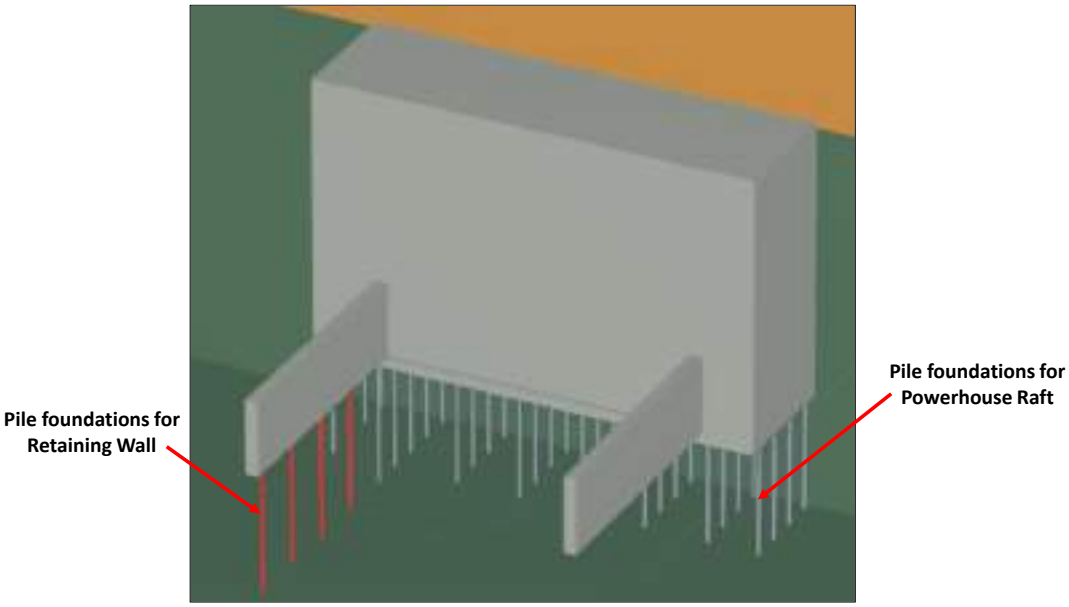


Figure 3-59: A close-up 3D view of PH, tailrace, and associated raft & retaining wall piles

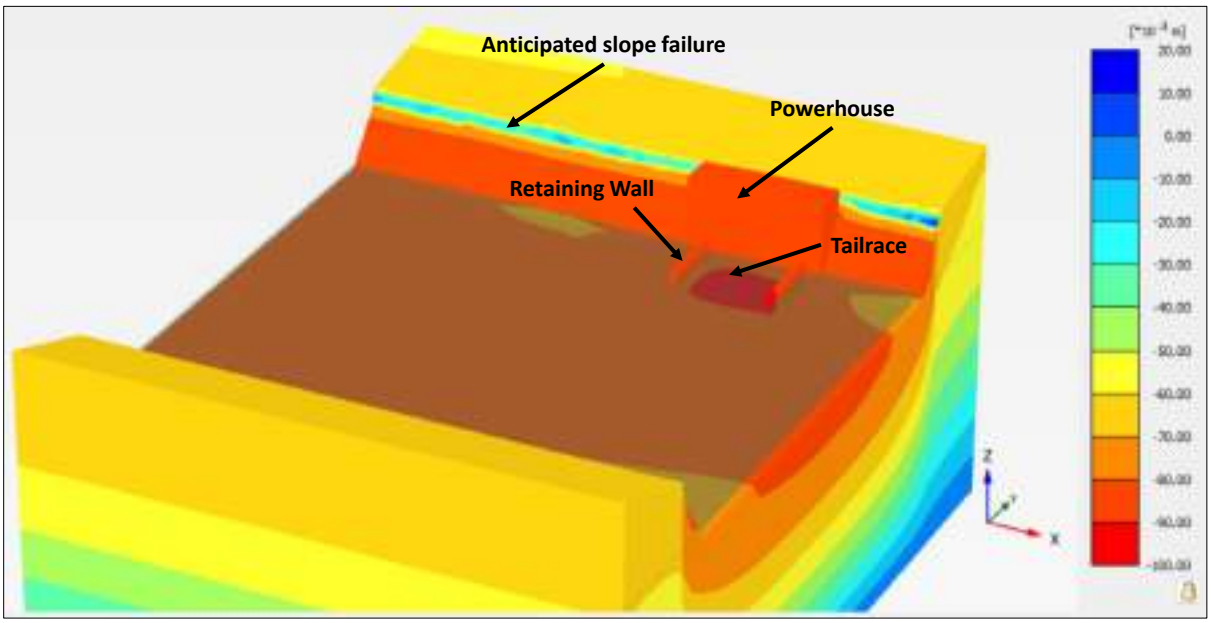


Figure 3-60: A 3D Deformation/displacement model of the powerhouse and the tailrace

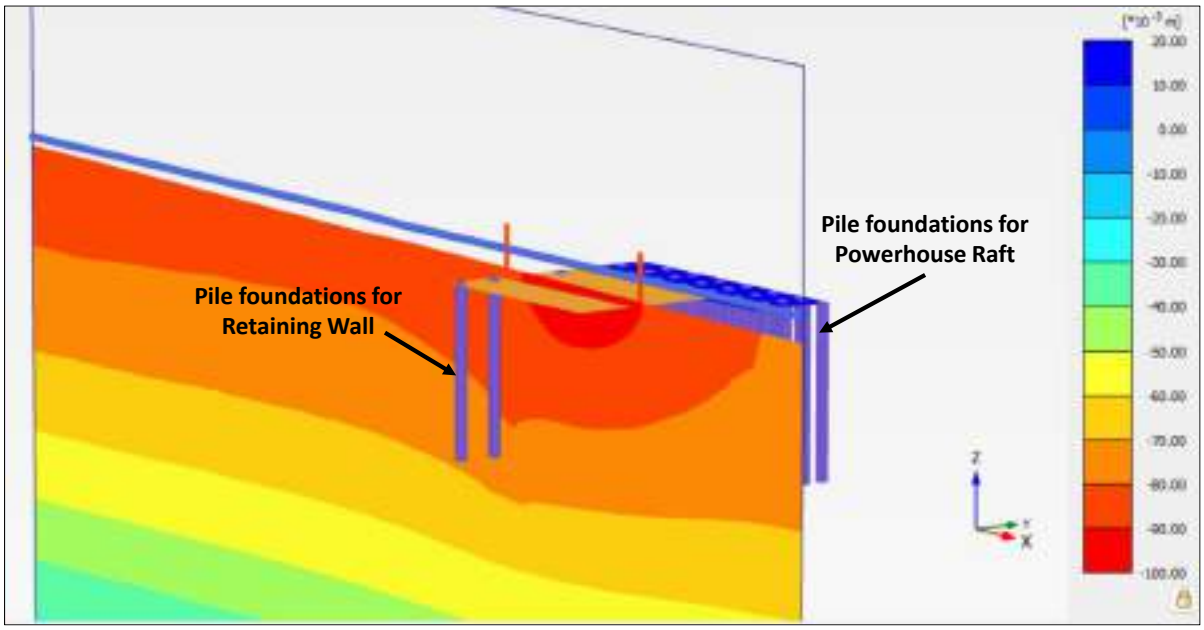


Figure 3-61: A deformation/displacement section through the tailrace structure

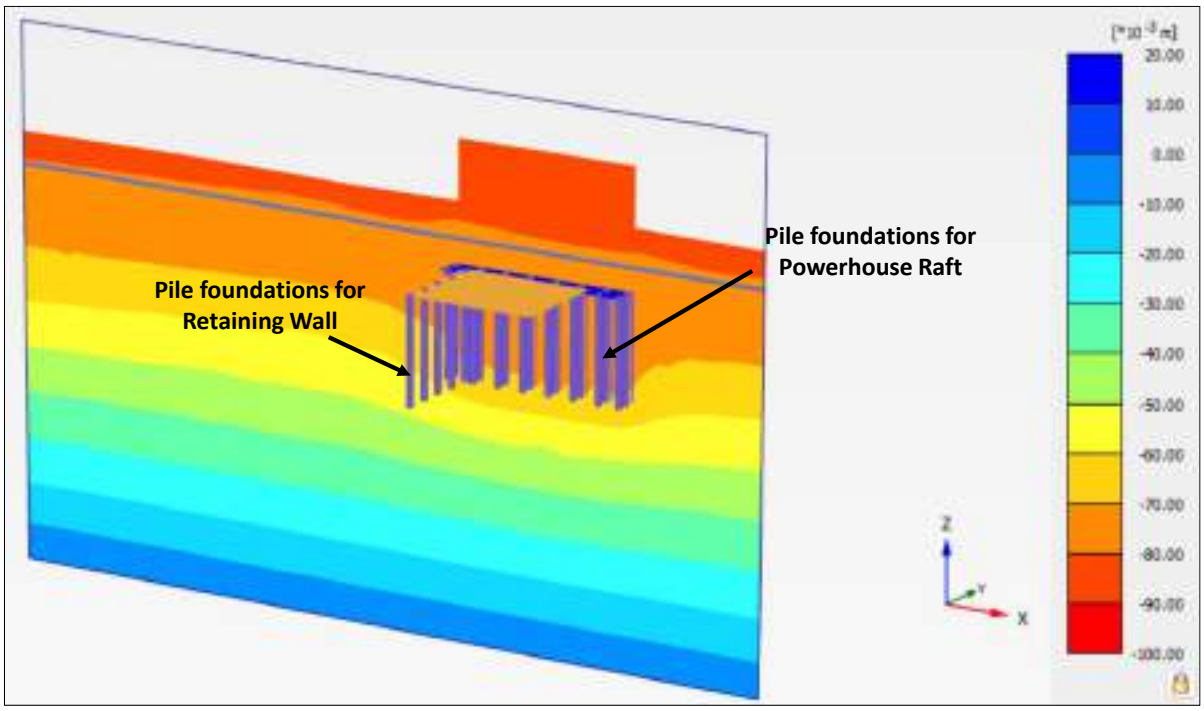


Figure 3-62: A deformation/displacement section through the powerhouse structure

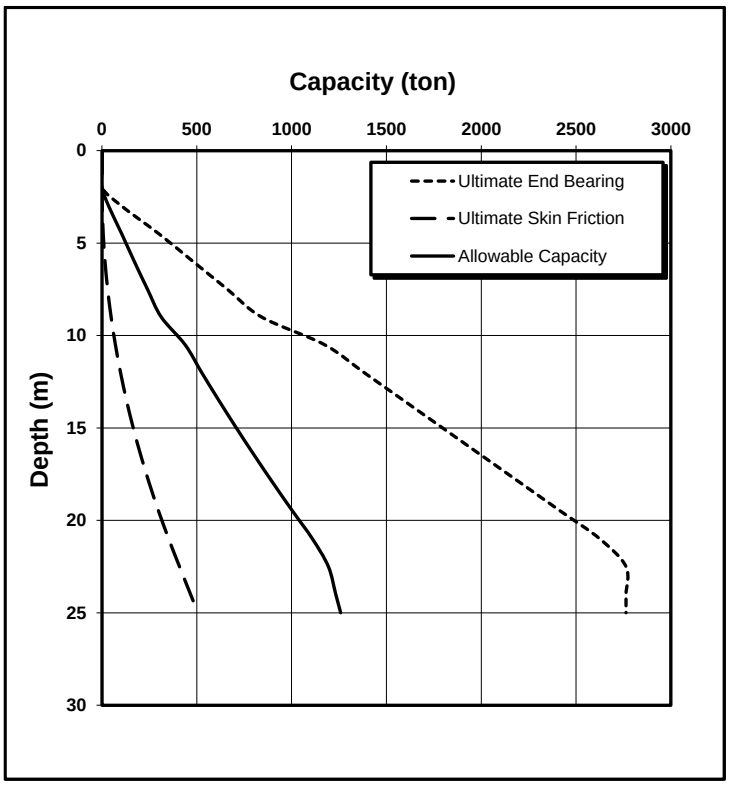


Figure 3-63: Pile capacity plots for 100 cm diameter piles proposed for Pipe anchor blocks/supports – Scour depth = 2.0 m

3.5.3 Powerhouse Analysis – Under Seismic Conditions

The basic powerhouse and tailrace model (**Figures 3-58 and 3-59**) was converted into a dynamic model by assigning constitutive models and then subjected to a synthetic earthquake with a peak acceleration of 0.68g. The results, shown in **Figure 3-64**, indicate that the powerhouse's piled-

raft foundation would experience negligible displacement and remain stable under these conditions.

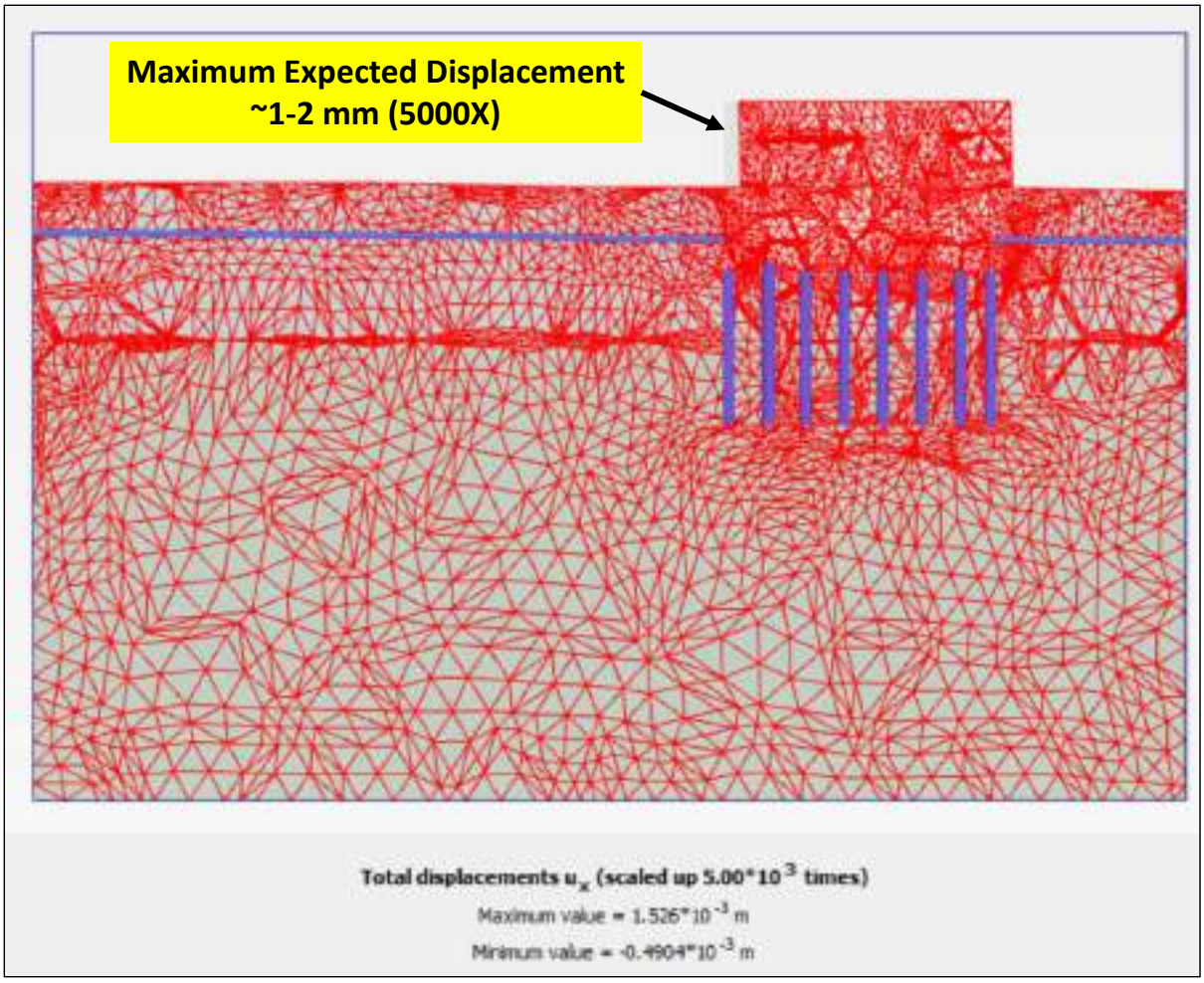


Figure 3-64: Deformation Tendency Scenario of the Powerhouse and its natural environment under peak earthquake acceleration of 0.68g. The maximum displacement expected at powerhouse is negligible (around 2 mm).

3.5.4 Headrace Pipe Analysis

The headrace pipeline passes through the foot of high-slope mountains. Although it is considered buried a couple of meters underground, highly probable global ground instability in the area, such as mudflows, mud avalanches, debris flows, and snow avalanches, would likely affect its stability. Therefore, it is suggested to anchor the pipeline in the subsurface by providing a block foundation supported by piles. The concept is shown in **Figure 3-65**. Pile foundations with a 60 cm diameter and a depth of 10 m below the pipeline block are suggested for anchorage. Piled blocks are recommended to be provided at every 300 m spacing along the pipeline. For structural design purposes, the capacity plots for 60 cm-diameter bored piles are shown in **Figure 3-66**.

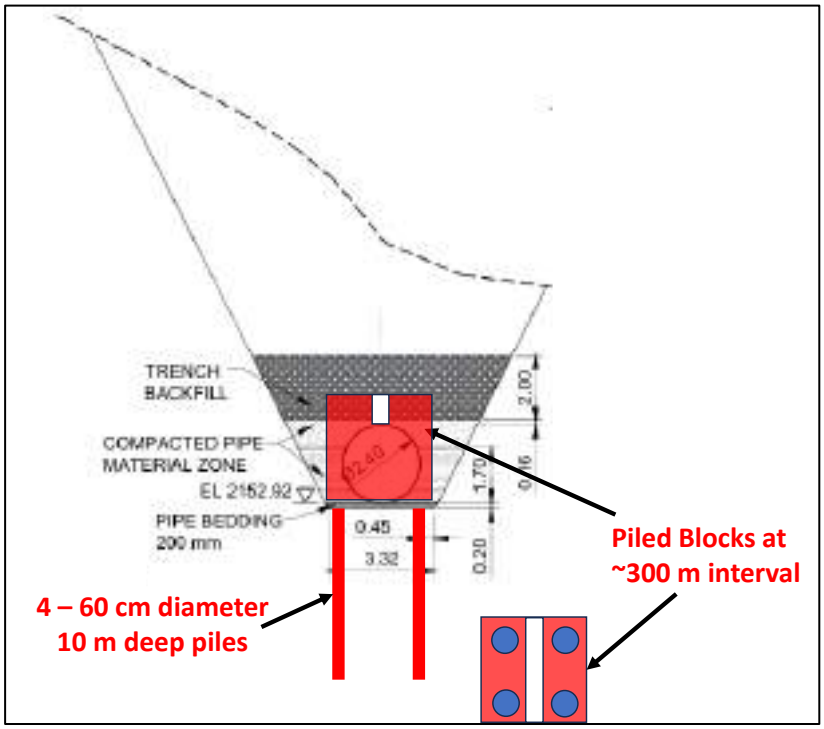


Figure 3-65: Conceptual plan and sections of the piled-block, recommended to be provided at every 300 m section.

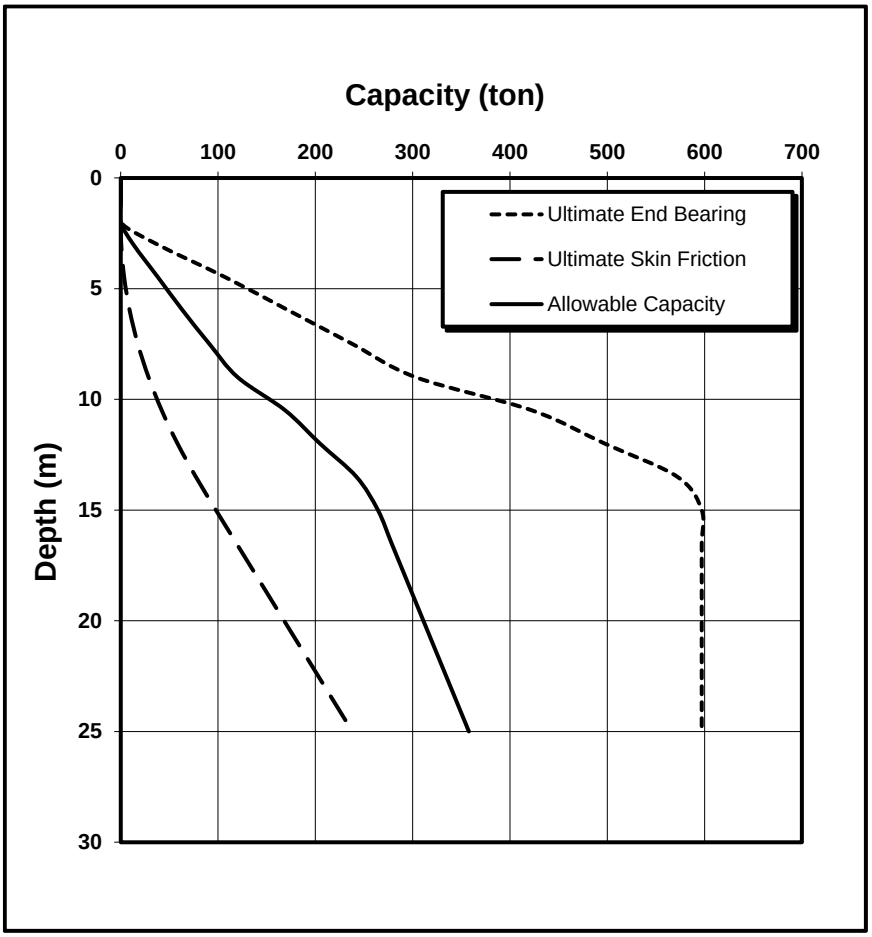


Figure 3-66: Pile capacity plots for 60 cm diameter piles proposed for Pipe anchor blocks/supports – Scour depth = 2.0 m

3.5.5 Desander – Excavation Stability Analysis

The primary geotechnical consideration for the desander is the excavation support requirements. Based on subsurface strata information from geological mapping in previous studies and the SRT survey in the current study, the excavation would primarily be carried out in terrace deposits and completely weathered rock. Based on the general characterization of the strata to be excavated, it appears that an open-cut excavation with a 1H:2V slope can be carried out without any short-term instability (**Figure 3-67**). To keep the excavation open for longer durations, it is advisable to use 1H:1V slopes.

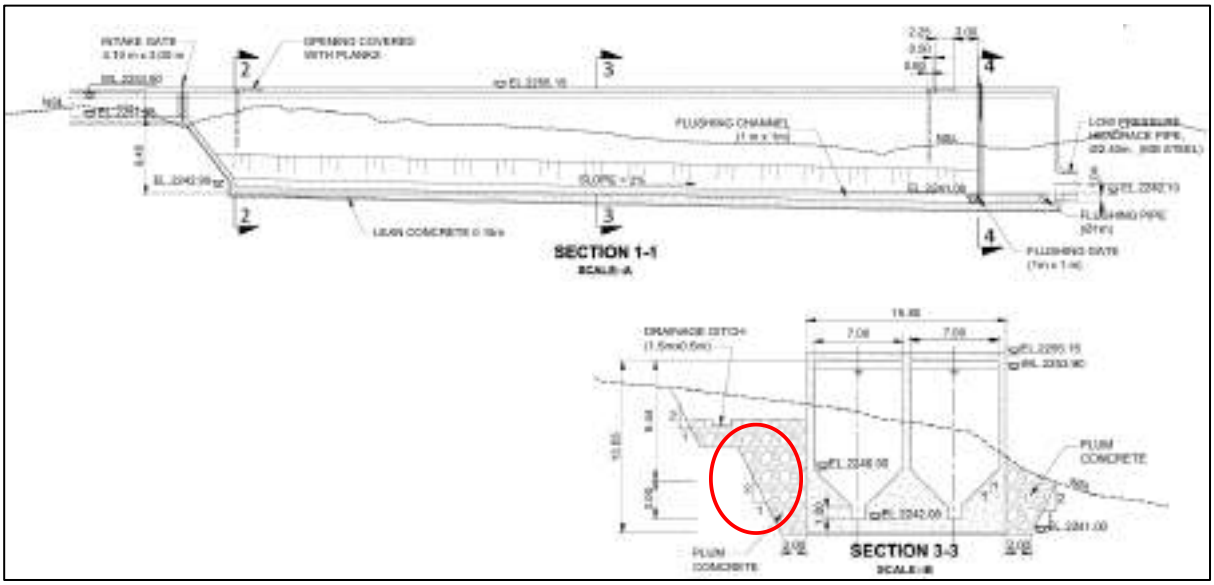


Figure 3-67: Excavation plan for desander, requiring a slope of 1H:2V for temporary works.

3.6 Conclusions

Based on the detailed geotechnical analysis of Jagran IV hydropower project's facilities, the following conclusions are reached.

- Considering the hydrological and hydraulic requirements, the total length of the intake/diversion weir is initially estimated at 110 m. However, based on the geological strata, the weir's edges fall within highly permeable overburden deposits (**Figure 3-68**). This would result in high seepage losses and erosion of strata at interfaces, both under steady-state seepage at normal water levels and during the highest floodwater levels. To ensure proper embedment of the weir's edges in the low-permeability, stable rock strata, it is recommended to increase the weir width to 140 m (**Figure 3-69**).

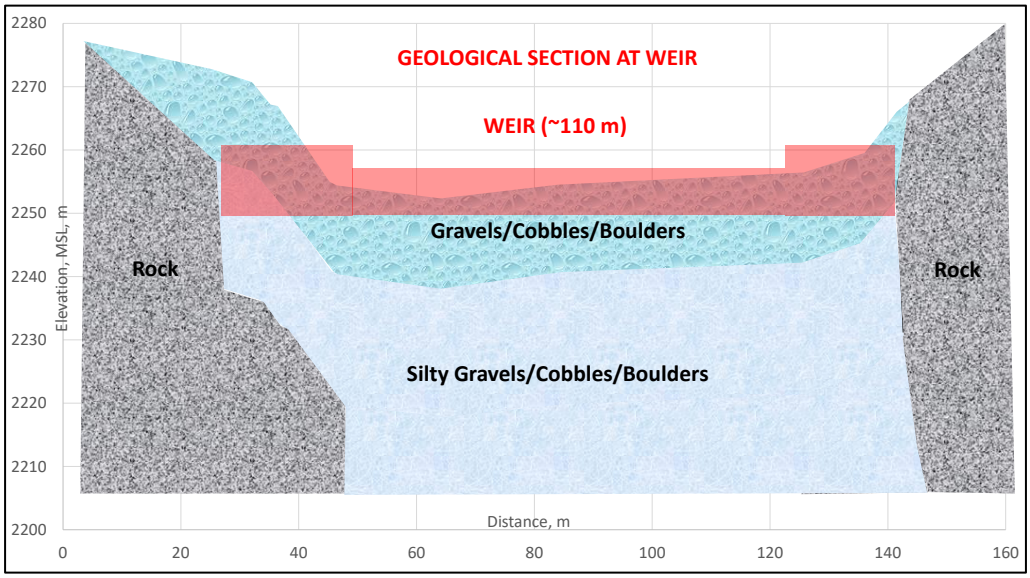


Figure 3-68: The extents of the initially designed weir, marking the lack of a proper interface with the highly permeable overburden deposits

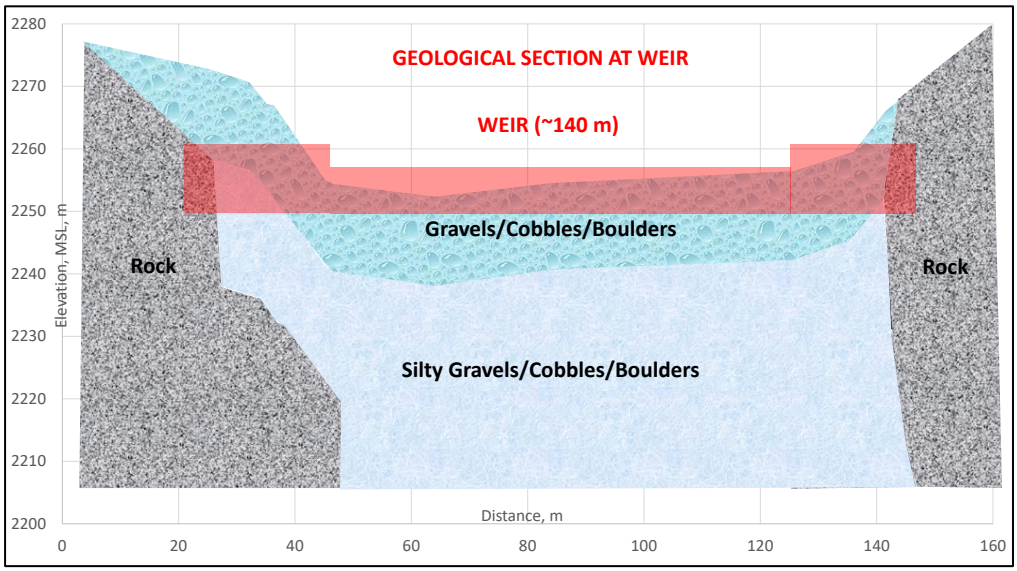


Figure 3-69: Recommended minimum width of the weir to abut the ends into the low-permeability rock strata

- Highly permeable strata in the upper 10-15 m of the riverbed would result in high seepage losses across the weir foundation. In addition, the seepage water would create a high net water head on the downstream floor, which may cause uplift damage to the floor. Therefore, it is recommended to provide seepage cutoff walls across the upstream floor and at the heel of the weir. Based on the optimized analysis, three 3-m and one 6-m cutoff walls would be required to reduce the water head to a desirable value. In addition, to counter the net water head during the flood water elevation, the downstream floor should have a minimum thickness of 2.0 m.

- The proposed MCE seismic accelerations of 0.68g could cause a permanent displacement of about 30 cm in the weir structures. However, the analysis results reveal that a six-meter-deep cutoff wall at the weir's heel would reduce the displacements to within acceptable limits.

- The slopes and terrain along the pipeline route would be vulnerable to global and local instabilities, including landslides, mudflows, debris flows, rock avalanches, and snow avalanches. These phenomena have become even more pronounced due to recent climatic changes. The northern areas of Pakistan, in general, and the Jargran Valley, in particular, have suffered significantly from these phenomena. Therefore, it is recommended to secure the pipeline by anchoring it into the ground at regular intervals. The analysis indicates that, to achieve this objective, piled-block foundations with four 60 cm-diameter piles, each 10 m deep, should be provided at approximately 300 m intervals along the pipeline.

- Based on subsurface information from the previous and current investigations, the powerhouse appears to be founded on river alluvium deposits. This configuration may make the powerhouse foundation strata vulnerable to erosion and to high differential displacements caused by floodwater flow and impact. Therefore, it is recommended that the powerhouse be founded on a piled-raft foundation (**Figure 3-70**). Moreover, there is a high probability that moving boulders will impact the tailrace retaining wall. Therefore, it is recommended that the retaining wall also be founded on pile foundations.

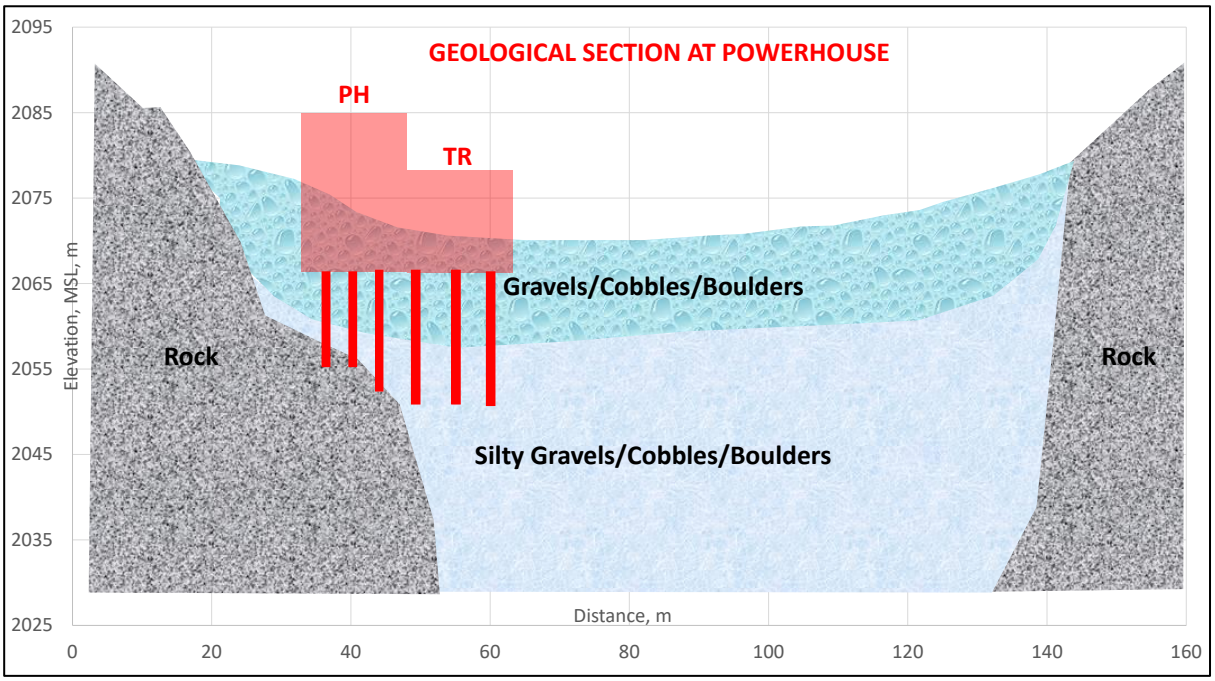


Figure 3-70: Conceptual section of the piled-raft foundation for the powerhouse and the piles for the retaining walls of the powerhouse and the tailrace

- Based on the slope stability analysis of various types and natures of the strata, the recommended long-term slopes in the overburden/alluvium/terrace deposits should be at most 1H:1V, while slopes cut in the rocky strata could be 1H:2V.

- Although geophysical investigations have been carried out during the current design stage, a detailed geotechnical investigation would still be required to confirm the subsurface strata. Therefore, the following geotechnical investigations are recommended to be performed by the EPC Contractor.

3.7 Summary of Proposed Field Investigations

The **Table 3-3** gives the summary of field investigation pertaining to drilling boreholes, test pits / trenches, permeability testing, geological / goehazard mapping and scanline survey lines proposed at various structures to be carried out by the EPC contractor.

Table 3-3: Summary of Proposed Field Investigations

Type of Structure	Boreholes	Test Pits/Trenches (2x2x3 m)	Lugeon /Permeability Tests	Geologic /Geohazard mapping (m^2)	Scanline Survey Lines
Weir	2BH x 25 m 1BH x 50 m	-	Yes	150 x 150 m	4
Open Conduit	-	2	-	50 m corridor	-
Desander	1BH x 20 m	-	Yes	100 x 100 m	2
Pressure Pipe	3BH x 10 m	4	-	100 m corridor	10
Surge Pipe	1BH x 25 m	-	Yes	100 x 100 m	2
Penstock	1BH x 25 m	-	-	100 m corridor	4
Powerhouse	2BH x 30 m	-	Yes	200 x 200 m	5
TOTAL	**11 BH x 205 m**	**6**	**40**	**417,500**	**27**

Notes:

- Lugeon/Permeability Tests: @ 1, 3, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 m depth intervals
- Boreholes at the weir location should extend at least 5 m into the competent rock (if encountered)
- One borehole (50 m) at the weir location and two boreholes (30 m each) at the powerhouse location are required to be drilled in the river bed.

The details of the proposed Laboratory Tests are as under,

- Soil classification tests (Grain Size Analysis, Atterberg Limits) - 30 Nos
- Natural Moisture Content - 20 Nos
- Unconfined Compression tests (Soil and Rock samples) - 20 Nos
- Direct Shear Test (Soil samples) - 15 Nos
- Hoek Triaxial Compression tests (Rock samples) - 5 Nos
- Point load index test (Rock samples) - 15 Nos
- Slake Durability Tests - 10 Nos
- Petrographic Analysis - 5 Nos
- Chemical Tests on Soil and Water samples - 12 Nos

ANNEXURE - A

ELECTRICAL RESISTIVITY TOMOGRAPHY (SRT) REPORT

JAGRN-IV HYDROPOWER PROJECT

ERT SURVEY AT PROPOSED SITE OF JAGRAN-IV HYDROPOWER PROJECT NEELUM VALLEY AZAD JAMMU & KASHMIR

Geophysical Investigation Report

Submitted By

Geological & Environmental Management Services (GEMS)

Submitted To

Associated Engineering Consultants

TABLE OF CONTENTS

1. Introduction 3
2. Material and Methods..... 7
3. Results and Discussion..... 8
3.1 Weir site ERT sections Results 8
3.2 Interpretation of ERT Section 01 at Weir Site 9
3.3 Interpretation of ERT Section 02 at Weir Site 10
3.4 Interpretation of ERT Section 03 at Weir Site 12
3.5 Interpretation of ERT Section 04 at Weir Site 14
3.6 Fence Diagram of Weir Site 16
3.7 Interpretation of Pipeline ERT Section – PL01 18
3.8 Interpretation of Pipeline ERT Section – PL02 18
3.9 Interpretation of Pipeline ERT Section – PL03 19
3.10 Interpretation of Pipeline ERT Section – PL04 20
3.11 Interpretation of Powerhouse ERT Sections 21
3.12 Interpretation of Powerhouse ERT-01 22
3.13 Interpretation of Powerhouse ERT-02 23
3.14 Interpretation of Powerhouse ERT-03 25
4. Conclusions 29
5. References 31

LIST OF FIGURES

Figure 1. Location Map of Project Area 4
Figure 2. Geological Map of the Study Area 6
Figure. 3: Terrameter and its accessories for ERT survey……...7
Figure. 4: ERT Survey procedure and current flow pattern……7
Figure 5. Base Map Showing ERT Profile Locations 9
Figure 6. ERT Section 01 – Weir Site (Right Bank) 10
Figure 7. ERT Section 02 – Weir Site (Right Bank) 12
Figure 8. ERT Section 03 – Weir Site (Left Bank) 14
Figure 9. ERT Section 04 – Weir Site (Left Bank) 16
Figure10. Fence Diagram of Weir Site 17
Figure 11. Base map of ERT sections at Pipeline…… 18
Figure 12 ERT Section – Pipeline PL01 19
Figure 13. ERT Section – Pipeline PL02 20
Figure 14. ERT Section – Pipeline PL03 21
Figure 15. ERT Section – Pipeline PL04 22
Figure 16. Base map of ERT sections at Powerhouse……..23
Figure 17. ERT Section – Powerhouse PHS-01 24
Figure 18. ERT Section – Powerhouse PHS-02 26
Figure 19. ERT Section – Powerhouse PHS-03 27

LIST OF TABLES

Table 1: Nominal Resistivity (Ohm-m) of some common rocks…… 05

1. INTRODUCTION

The present study was conducted in response to a client's request to investigate the subsurface geological conditions at the proposed site of Jagran Hydropower Project Phase IV in District Neelum Azad Jammu & Kashmir (Figure 1). Geophysical methods were employed to identify weak zones, fractures, and areas of water saturation. Understanding these subsurface features is crucial for construction process. For this study, the geophysical techniques Electrical Resistivity Tomography (ERT) have been carried out to delineate the subsurface geology, thickness of overburden, water seepages and other associated geological anomalies. These geophysical techniques have proven to be very useful for determining the geology, size of cavities, voids, conductive zones, mineralization zones, water channels and weak zones below the surface (Mathews et al., 2000; Beres et al., 2001; McGrath et al., 2002; Thierry et al., 2005; Rybakov et al., 2001, 2005). During the geophysical survey, a total of 11 geoelectrical profiles were conducted across the project area using Dipole-dipole configuration (Figure 2). Four ERT profiles were acquired at the weir site, four along the proposed pipeline alignment, and three at the powerhouse location. The exact positions of these profiles are illustrated in the respective base maps.

Resistivity Survey is one of the most popular techniques for shallow subsurface investigation and is applied for metal exploration, hydrogeological, engineering, and environmental questions (Telford et al., 1990). It has been used to image structures from the millimeter scale to kilometers (Linderholm et al., 2008; Storz et al., 2000). Instruments have been rapidly developing in the past decades. In most cases, fully automated instruments with multiple receiver channels are used, but in large-scale applications, independent dipoles for current injection and potential difference registration are used. The geoelectrical method provides relatively low cost, non-invasive and rapid means of generating spatial models of physical properties of the subsurface. It is especially beneficial for conductive zone identification, contaminated land, soil creeps and soil sinking related engineering, cavities and environmental issues (Hemeda, 2013).

Figure. 1: Map showing the ERT locations of Jagran IV site.

A Geoelectrical method that calculates the subsurface distribution of electrical resistivity from many resistance measurements made from electrodes placed in an arbitrary geometric pattern for in-situ applications, ERT uses electrodes on the ground surface using Ohms's law as expressed in equation 1.

$$V = IR \qquad (1)$$

Where V is the voltage and I is the induced current and R designates resistance.

The resistivity is often first encountered in physics when discussing the resistance of an ideal cylinder of length L and cross-sectional area A of uniform composition. The resistivity appears as the material-specific constant of proportionality in the expression for the total resistance of the cylinder,

$$R = \rho(L/A) \qquad (2)$$

The total resistance R may be obtained experimentally through Ohm's law,

$$\rho = (V/I)(A/L) = R_{app} .K \qquad (3)$$

where ρ is the resistivity and V is the potential difference between the ends of the cylinder and I is the total current flowing through the cylinder.

In Eq. 3, the resistivity is given by the product of the ‘‘apparent resistance’’ R app = (V/I) and a ‘‘geometric factor’’ K. = (A/L) that carries information about the geometry of the cylinder. This type of product of an apparent resistance and a geometric factor will appear again when the resistivity of the ground is to be determined.

Tomography means using any kind of penetrating wave for sectional imaging of a structure or object, while the image produced is a tomogram. The method of using electrical resistivity to partition the earth based on varying resistive properties of the earth materials to produce a tomogram is called electrical resistivity tomography. ERT has proven to be an effective geotechnical and environmental engineering tool (Zhou and Dahlin, 2003; Niaz et al., 2016; 2017; 2018; 2019). Electrical current flow in the subsurface is primarily electrolytic. Electrolytic conduction involves the passage of charged particles by means of groundwater. Charged particles move through liquids that infill the interconnected pores of permeable materials. When an electrical resistivity tomography survey is conducted in terrain, current flow is generally assumed to be electrolytic rather than electronic. Variations in the resistivity of subsurface materials are mostly a function of lithology. Information about resistivity variations within the subsurface can be associated with different materials. The nominal standard resistivity of different rocks that have been used as a reference for subsurface interpretation are given in table 1.

Table 1: Nominal Resistivity (Ohm-m) of some common rocks (Todd and Mays, 2005).

Material	Nominal resistivity (~m)
Quartz	3 x 102 – 106
Granite	3 x 102 – 106
Granite (weathered)	30 – 500
Consolidated shale	20 – 2 x 103
Sandstones	200 – 5000
Sandstone(weathered)	50-200
Clays	1 – 102
Boulder clay	15 – 35
Clay (very dry)	50 – 150
Gravel (dry)	1400
Gravel (saturated)	100
Lateritic soil	120 – 750
Dry sandy soil	80 – 1050
Sandy clay/clayey sand	30 – 215
Sand and gravel(saturated)	30 – 225
Mudstone	20-120
Siltstone	20-150

Figure 2 (a,b): Exposed surface geology of the study area.

2. MATERIALS AND METHODS

2.1.Electrical Resistivity Tomography (ERT)

The geoelectrical method was used to determine the subsurface geology, weak zone water saturation and fractures in the study area. The Dipole-dipole configuration has been widely used in the investigation of near surface variations in the sub-surface geology. Keeping in view, the 11 profiles have been examined by means of Dipole-dipole configuration using the instrument ABEM Terrameter (Sweden) and embellishments (Figure. 3) to stimulate the localities for resistivity with depth in response to the electric field induced in the ground. The (current and potential) electrodes were immersed in the ground (Figure. 4). The current will be introduced in current electrodes by means of cables and the resulting potential difference was measured with the assistance of potential electrodes (Figure. 4).

The acquired geo-electrical information was submitted to the iteration software RES2D in order to get 2D geo-electric sections. The resistivity section delineated the horizontal as well as a vertical extension of the geoelectrical layers in the sub-surface.

Figure. 3: Terrameter and its accessories for ERT survey

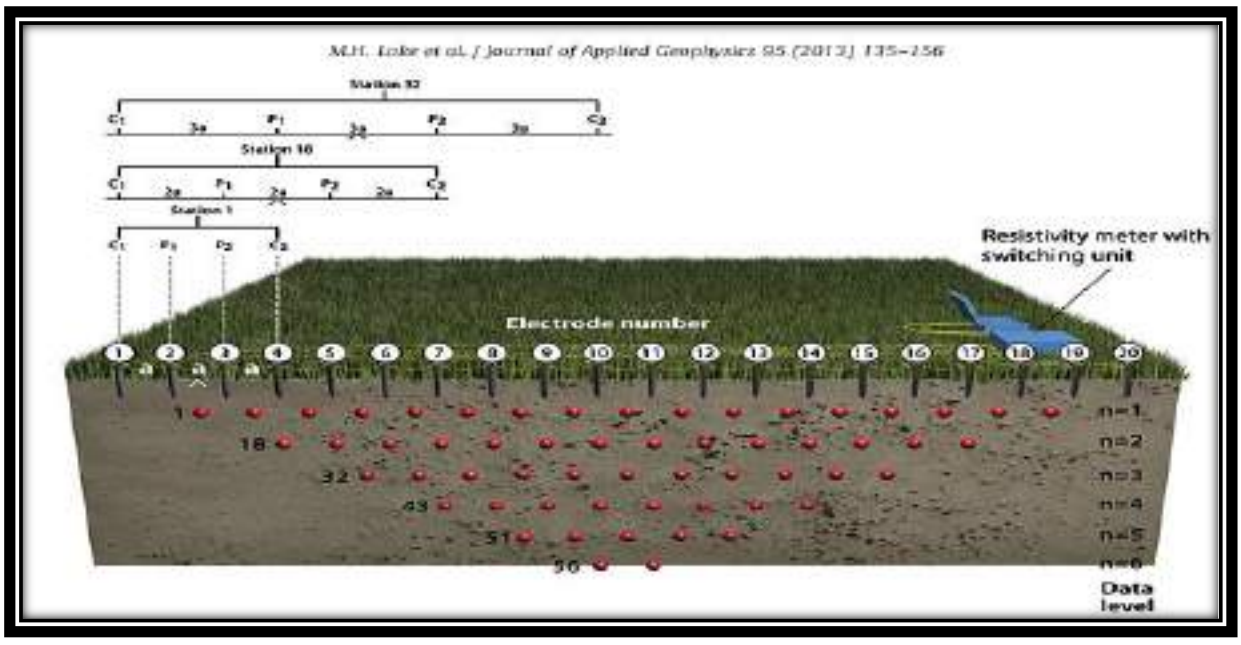


Figure. 4: ERT Survey procedure and current flow pattern.

3. RESULTS AND DISCUSSION

3.1 Weir site ERT sections result

An Electrical Resistivity Tomography (ERT) survey was conducted to investigate the subsurface geological conditions for construction of Jagran phase IV site. A total of 11 ERT profiles were acquired, out of which 4 ERT profiles were established at Weir site (Figure 5). The Length of profile was kept at 160 m with electrode spacing 4 m. The Dipole-Dipole configuration was employed for this survey, as it is well-suited for detecting near surface variations in subsurface geology, water seepages, and fracture zones. The survey successfully captured subsurface resistivity variations with depth providing critical insights for geological and hydrogeological assessments.

Figure 5. Base map showing Location of Weir site ERT profiles.

3.2.Interpretation of ERT Section 01 at Weir site

This ERT profile was acquired along the right bank of the Nala, as indicated on the base map. The total survey length is 160 meters, with an electrode spacing of 4 meters (Figure 6). The inversion results provide subsurface information down to a depth of approximately 21 meters at this location. The Electrical Resistivity Tomography (ERT) profile provides a detailed view of the subsurface lithology along the surveyed transect. The resistivity scale at the bottom of the section ranges from very low values (<5 Ω·m) to high resistivity zones (>2700 Ω·m), allowing clear differentiation of materials. Depth (m) values are shown on the left, while horizontal distance (m) is marked along the top.

The upper part of the profile is generally characterized by moderate to high resistivity zones, representing loose to semi-compacted gravels and boulders mixed with clayey material. These deposits appear discontinuous along the section and reflect heterogeneous alluvial channel sediments. Towards the central part of the section, a prominent low-resistivity anomaly (green to blue colours) extends downward, representing saturated gravels and boulders, likely indicating a high groundwater potential zone. This saturated zone suggests active subsurface water flow or accumulation, corresponding to coarser alluvial material with significant porosity.

On both the left and right sides of the profile, loose gravel-and-clay mixtures continue at shallow depths, while the right side shows distinct very high resistivity patches (red to purple colours) interpreted as large boulders or compact coarse material, indicative of a more consolidated and less permeable unit.

Overall, the ERT section reveals a complex alluvial subsurface, dominated by alternating layers of gravels, boulders, and clay lenses. The most significant feature is the central saturated gravel–boulder zone.

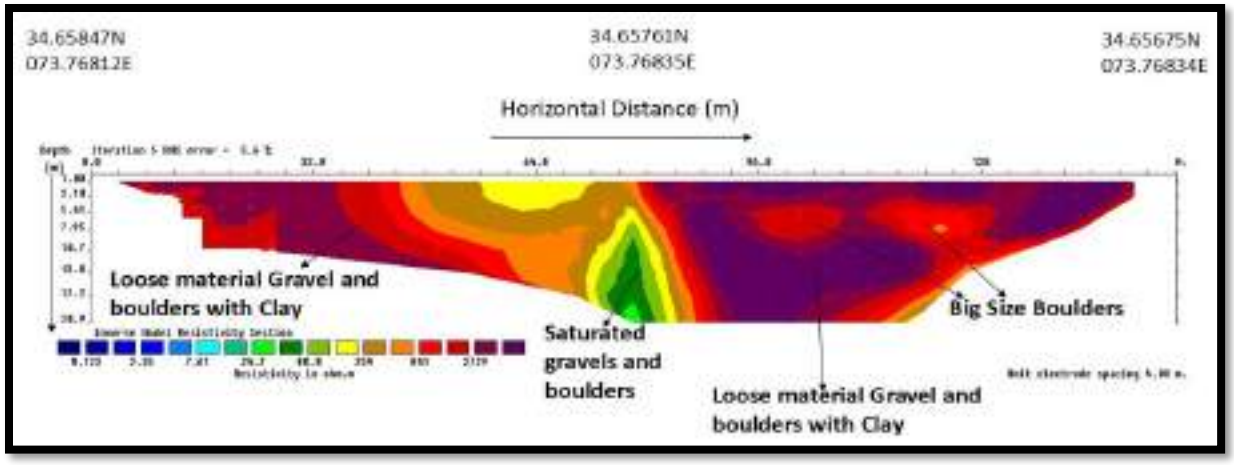


Figure 6: ERT Section 01 at Weir site right bank of Nala .

3.3.Interpretation of ERT Section 02 at Weir site

This ERT profile was acquired along the right bank of the Nala, as indicated on the base map. The total survey length is 160 meters, with an electrode spacing of 4 meters (Figure 7). The inversion results provide subsurface information down to a depth of approximately 29 meters at this location. The Electrical Resistivity Tomography (ERT) profile illustrates a well-defined subsurface stratigraphy along the surveyed alignment, with resistivity values ranging from very low (<10 Ω·m) to very high (>30000 Ω·m). Depth is calibrated along the left axis, while horizontal distance extends across the top of the section, enabling a clear visualization of lateral and vertical variations in lithology.

The near-surface zone throughout the profile is dominated by moderate resistivity values (light green to yellow colours)**,** representing loose alluvial deposits composed of gravel, boulders, and clay-rich material**.** These heterogeneous sediments are typical of an active or reworked fluvial environment and indicate variable compaction and grain-size distribution.

A key feature of the central part of the section is the presence of a very low-resistivity zone (blue to bluish green colours) dipping downward from the surface. This anomaly corresponds to saturated gravels and boulders**,** reflecting a high-permeability unit likely storing or transmitting groundwater. This saturated body forms a potential groundwater pocket or flow conduit and is important for assessing subsurface seepage conditions related to the weir structure.

Beneath this saturated zone, a **distinct high-resistivity core (orange to red colours)** is observed, which is interpreted as **bedrock or a highly compacted boulder layer**. Its sharp resistivity contrast and upward geometry suggest shallow bedrock exposure or a buried ridge controlling local groundwater flow. This feature also plays a critical role in determining foundation stability and seepage dynamics.

Towards both ends of the profile, the subsurface continues to show **loose gravel–boulder deposits with clay lenses**, consistent with channel-margin alluvium. Localized high-resistivity patches on the right side indicate **massive boulders or compact coarse material**, reflecting more consolidated and less water-bearing zones.

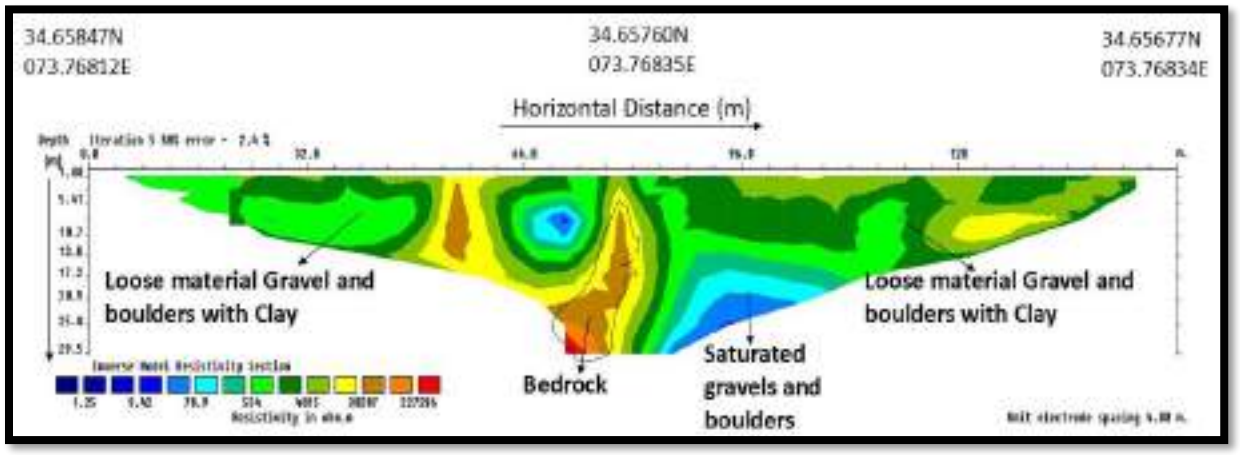


Figure 7: **ERT section 02 at Weir site on the right bank of Nala.**

3.4.Interpretation of ERT Section 03 at Weir site

This ERT profile was acquired along the left bank of the Nala, as indicated on the base map. The total survey length is 200 meters, with an electrode spacing of 4 meters (Figure 8). The inversion results provide subsurface information down to a depth of approximately 25 meters at this location. The Electrical Resistivity Tomography (ERT) section for Weir 3 illustrates subsurface resistivity variations along the profile extending between **34.65800°N, 73.76896°E** and **34.65720°N, 73.76935°E**. The horizontal axis represents distance in meters, while the vertical axis denotes depth to approximately 25 m. Resistivity values range from low (≈350

Ω·m) to very high (>50,000 Ω·m), enabling differentiation of saturated sediments, coarse bouldery deposits, fractures, and underlying bedrock.

1. Near-Surface Deposits (0–5 m Depth)

The uppermost layer consists of **green to yellow resistivities**, indicating:

- Unsaturated to semi-saturated alluvium
- Sand–gravel mixtures with scattered cobbles
- Weathered, loose surficial material

This layer is laterally continuous but varies in thickness due to changes in surface topography and underlying geology.

2. Low-Resistivity Zones – Saturated Gravels and Boulders

Throughout the central and left portions of the profile, deeper regions (5–18+ m) show low resistivity values (blue to light blue; 350–1500 Ω·m). These zones correspond to:

- Saturated gravels and cobble–boulder assemblages
- Highly permeable sedimentary material
- Probable zones of active groundwater flow

Two major saturated zones are evident:

- **Left segment (≈0–60 m):** Thick saturated bouldery gravels extending down to ~18 m.
- **Central segment (≈70–150 m):** Even more extensive saturation, forming a broad continuous low-resistivity body.

These indicate a strong groundwater connection and significant subsurface permeability.

3. Bedrock Structures – High Resistivity

High resistivity values (orange to purple; 12,000–50,000+ Ω·m) define the **bedrock signature**. Bedrock appears prominently in two locations:

- First bedrock high at ≈60–80 m
- Second bedrock high at ≈140–140 m

Both areas show steeply ascending resistive bodies, indicative of:

- Competent, massive bedrock
- Minimal saturation
- Sharp lithological contrast with overburden

These bedrock exposures produce local uplifts and funnel groundwater around them.

4. Fracture Zones – Vertical Conductive Pathways

At around **64 m and 128 m**, distinct vertical low-resistivity anomalies (<1500 Ω·m) cut through high-resistivity zones. These represent:

- **Fracture or fault-related conduits within bedrock**
- **Zones of increased porosity and moisture**
- **Potential preferential pathways for groundwater movement**

These fractures likely connect the saturated gravel units with deeper bedrock structures, influencing hydraulic behavior at the weir site.

5. Large Boulder Zones

Toward the **right side of the profile (≈160–200 m)**, moderate resistivity highs (green–yellow to light red) correspond to:

- Large, partially dry boulders
- Coarse, blocky material embedded within the overburden
- Heterogeneous shallow subsurface

These boulders cause strong resistivity contrasts and produce localized highs without indicating bedrock.

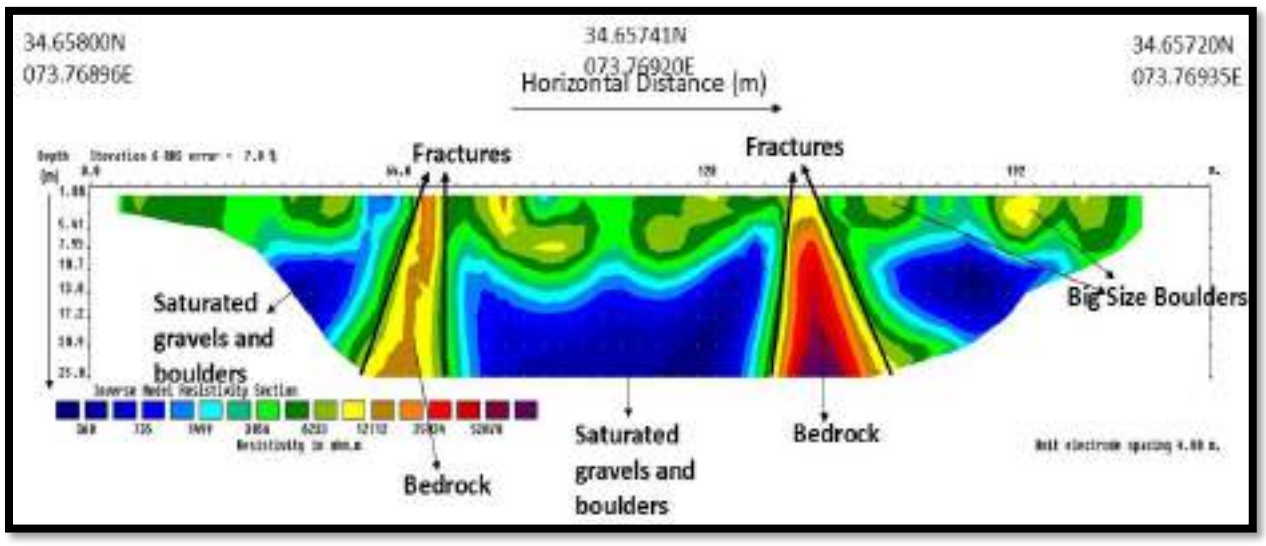


Figure 8. ERT Section -03 at Weir site Left bank of Nala.

3.5.Interpretation of ERT Section 04 at Weir site

This ERT profile was acquired along the left bank of the Nala, as indicated on the base map. The total survey length is 160 meters, with an electrode spacing of 4 meters (Figure 9). The inversion results provide subsurface information down to a depth of approximately 17.2 meters at this location. The Electrical Resistivity Tomography (ERT) section for Weir 4 illustrates subsurface resistivity variations along the profile between **34.65800°N, 73.76896°E** and **34.65720°N, 73.76935°E**. The horizontal axis represents distance in meters, while the vertical axis shows depth down to approximately 17–18 m. The resistivity range spans from low values (~400 Ω·m) to high values (>5,700 Ω·m), enabling clear differentiation between saturated sediments, competent strata, and coarse bouldery material.

1. Near-Surface Layer (0–4 m Depth)

The upper portion of the profile is dominated by **green to yellow resistivities**, indicating:

- Unsaturated or slightly moist soil cover
- Alluvial and colluvial material
- Mixed sand–gravel layers

This near-surface layer is relatively uniform but thins slightly toward the left where more competent material approaches the surface.

2. Competent Strata (High Resistivity – Left Side of Profile)

A well-defined high-resistivity body (orange to red; 2,700–5,700+ Ω·m) is observed on the **left side (approximately 10–25 m)**. This corresponds to:

- Competent subsurface strata or shallow bedrock
- Dense, compacted lithology with minimal saturation
- Structurally strong material suitable for supporting loads

This zone is relatively uniform and dips gently toward the center, transitioning into less resistive sediments.

3. Low-Resistivity Zone – Saturated Gravels and Boulders (Central Portion)

The central portion of the section (roughly 40–90 m) shows low resistivity values (blue to cyan; 400–1300 Ω·m), which indicate:

- Saturated gravels, cobbles, and boulder-rich sediments
- High-permeability materials capable of storing and transmitting groundwater
- Potentially loose subsurface conditions

This saturated unit extends to depths of 14–16 m, forming the thickest low-resistivity zone in the section. It likely represents an active groundwater-bearing layer.

4. High-Resistivity Zones – Large Boulder Accumulations (Right Side)

The right side of the profile (approximately 100–140+ m) shows **moderate to high resistivities (yellow–red)**, interpreted as:

- Large, partially dry boulders
- Coarse, blocky material with variable moisture
- Glacial or fluvial deposits with significant heterogeneity

This zone does not exhibit the continuity or uniformity of bedrock but instead corresponds to a boulder-dominated overburden.

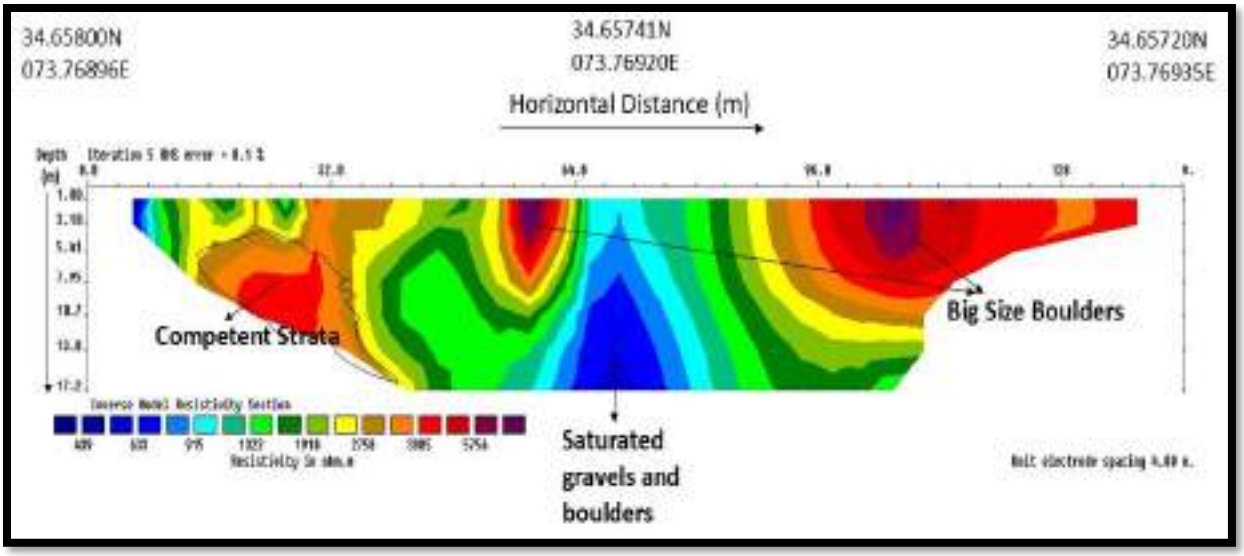


Figure 9. ERT section -04 at weir site left bank of Nala.

3.6.Fence diagram of Weir Site

The integrated interpretation of all four ERT sections at the Weir site reveals a consistent subsurface pattern dominated by heterogeneous alluvial deposits underlain by competent bedrock. Across both the left and right banks of the Nala, the near-surface zone is characterized by moderate to high resistivities representing loose to semi-compacted gravels, sand–gravel mixtures, and boulder-rich alluvium. A prominent and recurring feature in all profiles is the presence of **low-resistivity saturated gravel–boulder zones**, typically extending from mid to deeper depths (10–20+ m), indicating high-permeability materials and active groundwater flow pathways beneath the channel. Beneath or adjacent to these saturated units, all sections display **high-resistivity bodies interpreted as shallow to moderately deep bedrock or compacted coarse material**, with local bedrock highs and ridges exerting control on groundwater movement. Localized vertical conductive zones observed in multiple sections suggest fracture-controlled pathways within the subsurface. The repeated occurrence of massive boulders on both margins of the profiles further highlights the fluvial nature of the site. Overall, the fence diagram demonstrates a complex alluvial architecture with alternating coarse and saturated layers overlying undulating bedrock, providing essential insight for assessing foundation stability and seepage behavior at the proposed Weir location.

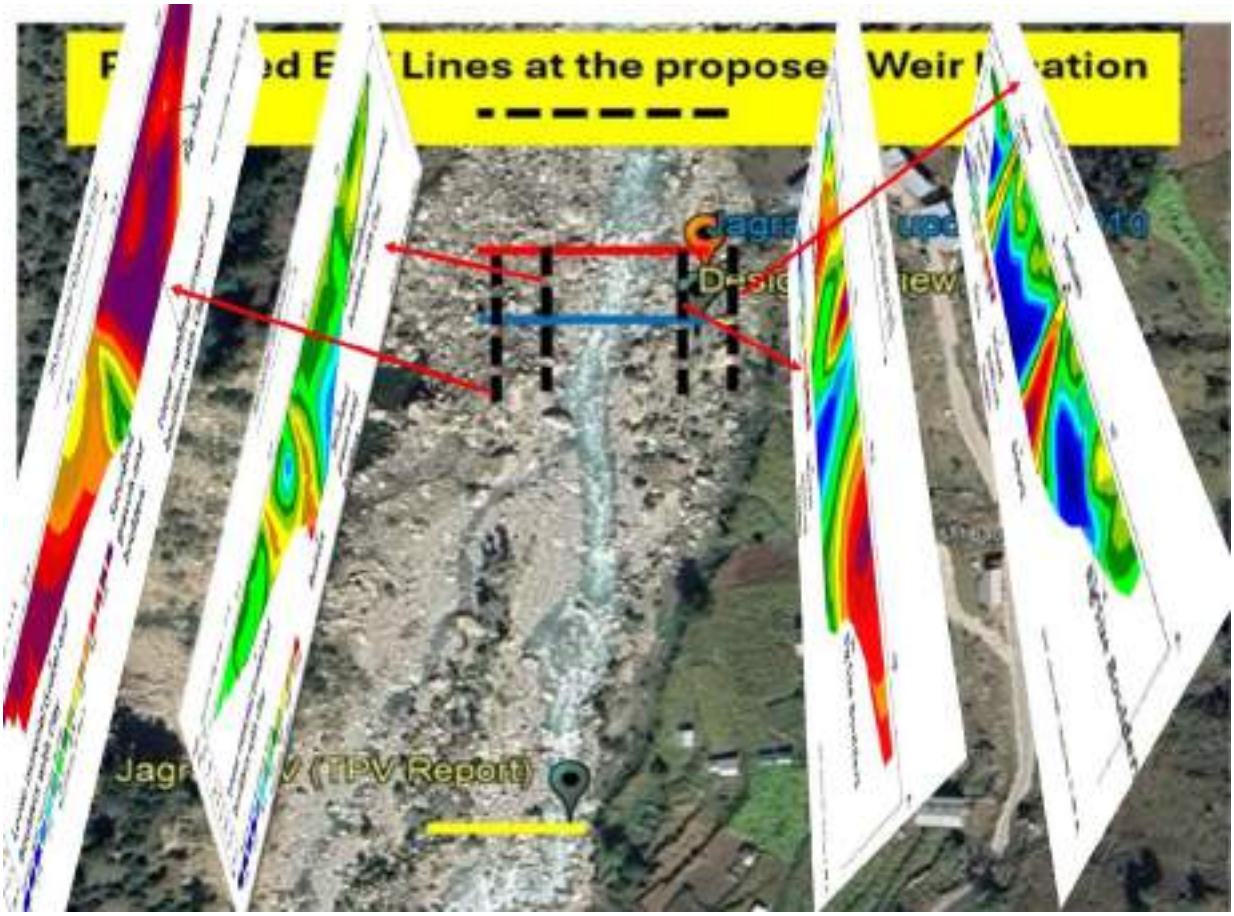


Figure 10. Computed view of Weir site ERT profiles.

3.7.Pipe Line ERT sections

A total of four ERT sections were acquired along the designated pipeline alignment, as shown in the base map (Figure 11). These profiles were conducted to characterize the subsurface geological conditions and provide reliable information for the proper design and placement of pipe anchor piles.

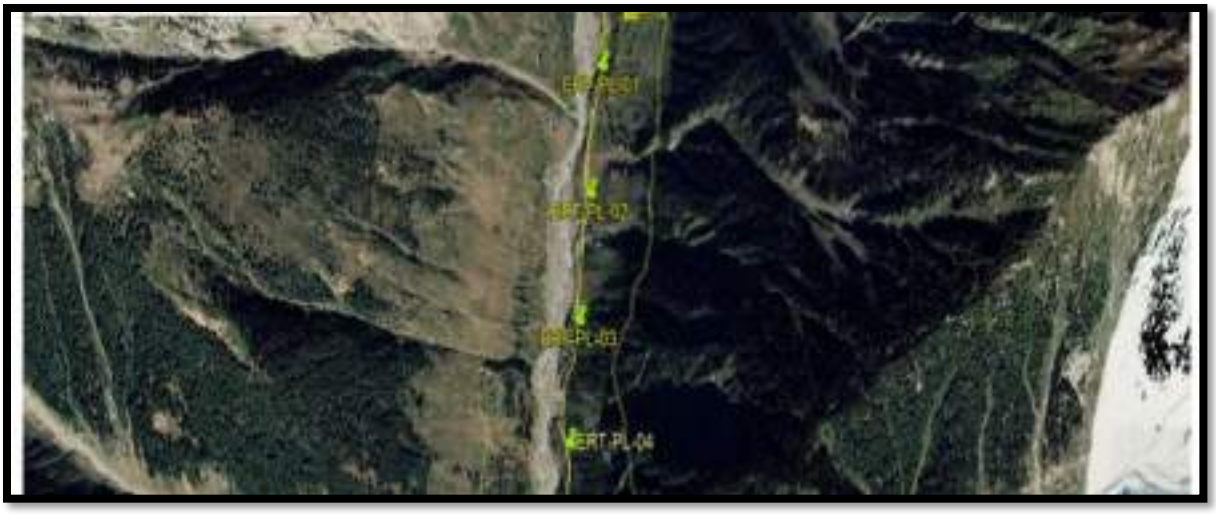


Figure 11. Base map of ERT section acquired along Pipeline locations.

3.8.PL-01

The ERT Profile PL-01, acquired with 4 m electrode spacing over a 128 m transect to a depth of ~25 m, reveals a heterogeneous subsurface comprising alluvium overlying a prominent bedrock high. Near-surface layers (0–5 m) exhibit low-to-moderate resistivity (100–1000 Ωm), representing loose gravel, sand, and boulders with clay interbeds. The central part of the profile (50–80 m) contains a steeply dipping, very high-resistivity body (>20,000 Ωm), indicating competent crystalline bedrock forming a subsurface ridge. To the west (0–50 m), moderate resistivity zones suggest heterogeneous alluvial/colluvial deposits with variable saturation, while the eastern section (90–128 m) shows a distinct low-resistivity lens (50–500 Ωm) corresponding to saturated gravels, indicating a potential groundwater-bearing zone. Overall, the bedrock geometry forms an uplifted ridge, with thicker sediments on both sides and groundwater preferentially accumulating along the eastern flank.

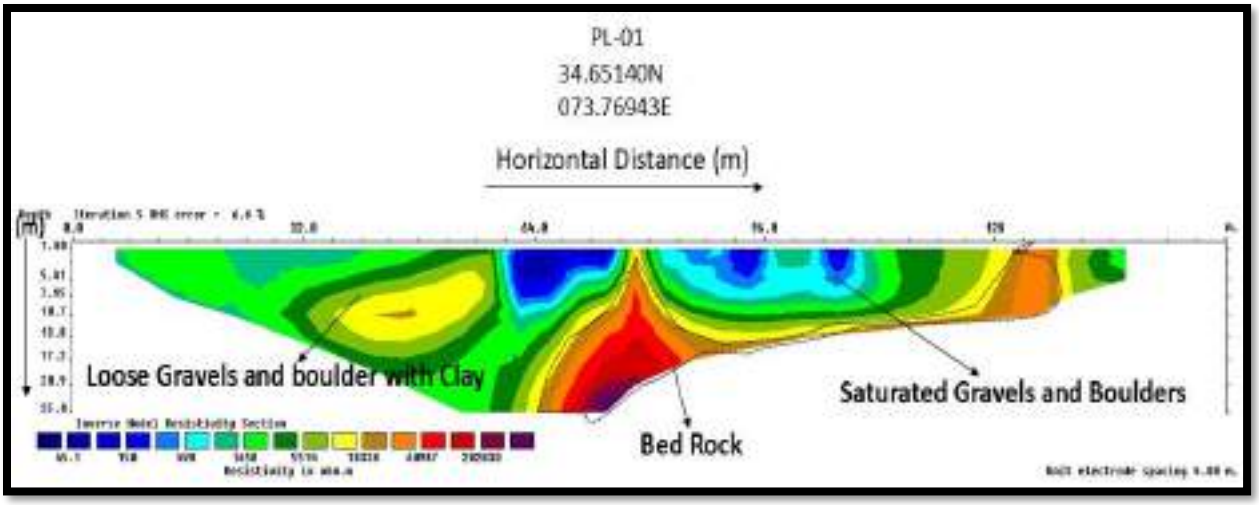


Figure 12. ERT section PL-01

3.9.PL-02

The ERT profile PL-02 reveals a subsurface dominated by unconsolidated alluvial deposits overlying an irregular bedrock surface. The near-surface zone across the entire line (0–5 m depth) consists mainly of low to moderate resistivity values, indicating loose gravels, sands, and boulders with clay lenses—consistent with fluvial or colluvial materials. Toward the central part of the profile (around 45–75 m horizontally), a prominent high-resistivity body appears between roughly 8 m and 20 m depth. This zone, characterized by resistivity exceeding 30,000 Ωm, represents a hard, competent bedrock unit that rises toward the surface and forms a distinct buried ridge. On both sides of this bedrock high, the resistivity transitions back into moderate values, reflecting thick sequences of mixed coarse gravels and clay-rich sediments. The western section (0–40 m) shows more variability, suggesting interlayered gravels and clay-rich pockets, while the eastern section (80–128 m) exhibits more uniform moderate resistivity, indicating extensive loose gravel and boulder deposits with clay. Overall, the profile indicates that a central bedrock uplift divides two broad alluvial zones, with significant thickness of unconsolidated sediments on both flanks. This geometry reflects a buried bedrock topography typical of valley-fill environments, with the alluvial deposits likely representing reworked materials from episodic high-energy flows.

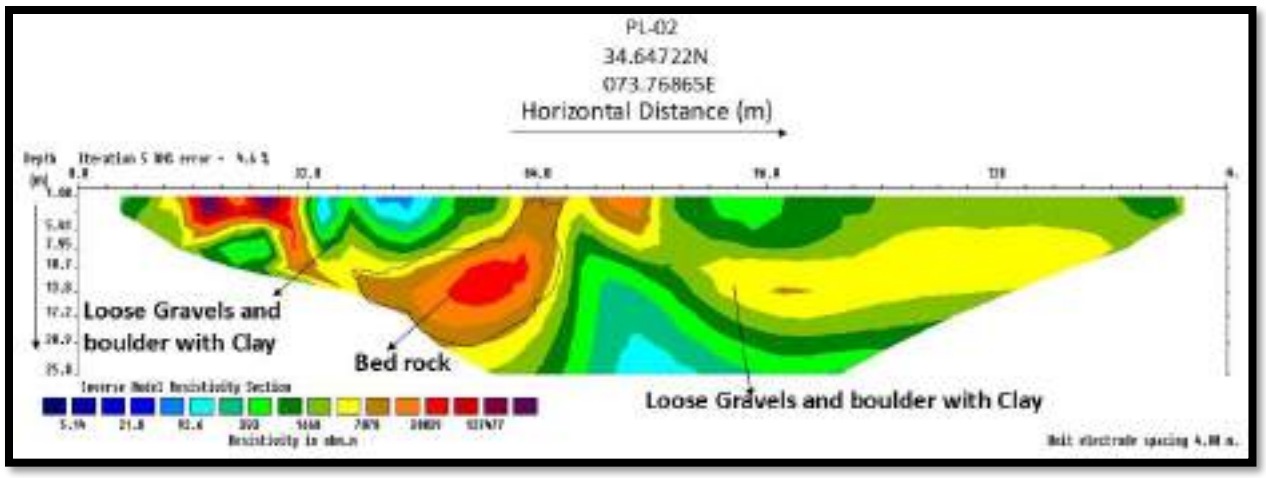


Figure 13. ERT section PL-02.

3.10. PL-03

The length of this ERT profile was acquired 80 m using Dipole-dipole configuration with electrode spacing of 2 m. The ERT profile PL-03 illustrates a shallow subsurface characterized by a mixture of coarse boulders, loose alluvial material, fractured zones, and localized saturated gravel layers. On the left side of the section, moderate to high resistivity values indicate the presence of large boulders embedded within the shallow subsurface, underlain by a small but distinct high-resistivity feature corresponding to competent bedrock. Adjacent to this bedrock high, a narrow vertical zone of contrasting resistivity is visible, representing a fracture or fault-like feature that likely facilitates limited water movement. The central portion of the profile (approximately 16–48 m) displays predominantly low to moderate resistivity values, identifying it as a broad zone of loose, unconsolidated sediments such as silty sand, gravel, and fine material with relatively low saturation. Moving toward the right side, a second set of vertical resistivity contrasts marks another fractured zone, which transitions into a region of low resistivity caused by saturated gravels and boulders, indicating a water-bearing zone or near-surface aquifer. Overall, the section reveals a heterogeneous environment where shallow bedrock and fracture systems interact with loose alluvial deposits, influencing both groundwater flow and subsurface stability.

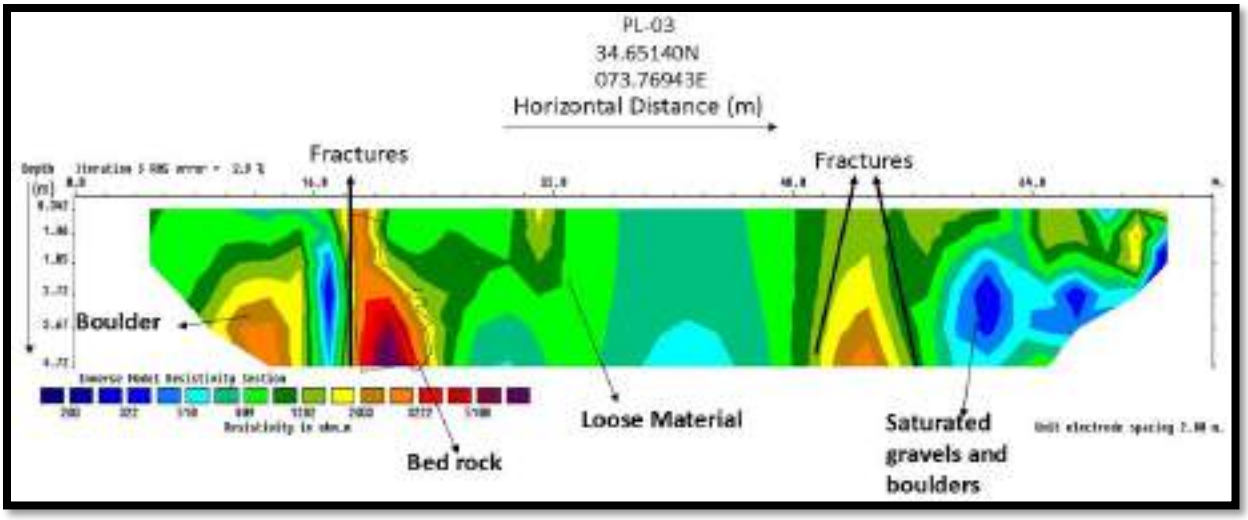


Figure 14. ERT section PL-03

3.11. PL-04

The inverse model resistivity section from location PL-04 (coordinates 34.65140N, 073.76943E) presents a detailed subsurface profile derived from Electrical Resistivity Tomography (ERT) with a unit electrode spacing of 1.50 meters to the total length of 60 m. The horizontal axis spans the survey line, while the vertical axis extends to a depth of 6.41 meters. The resistivity values, ranging from 2.41 ohm·m to 856,428 ohm·m, are color-coded to delineate various geological materials. The upper layers, predominantly green to yellow, indicate loose sediments composed of gravel and boulders mixed with clay, suggesting unconsolidated and potentially water-bearing zones. Central variations in resistivity, marked by abrupt transitions and localized anomalies, point to the presence of fractures, which may influence groundwater flow or structural stability. The deeper zones, represented in red to dark red, exhibit high resistivity values characteristic of competent bedrock, indicating a consolidated and less permeable formation. This geophysical interpretation is crucial for applications in geotechnical engineering, groundwater assessment, and site characterization for infrastructure development.

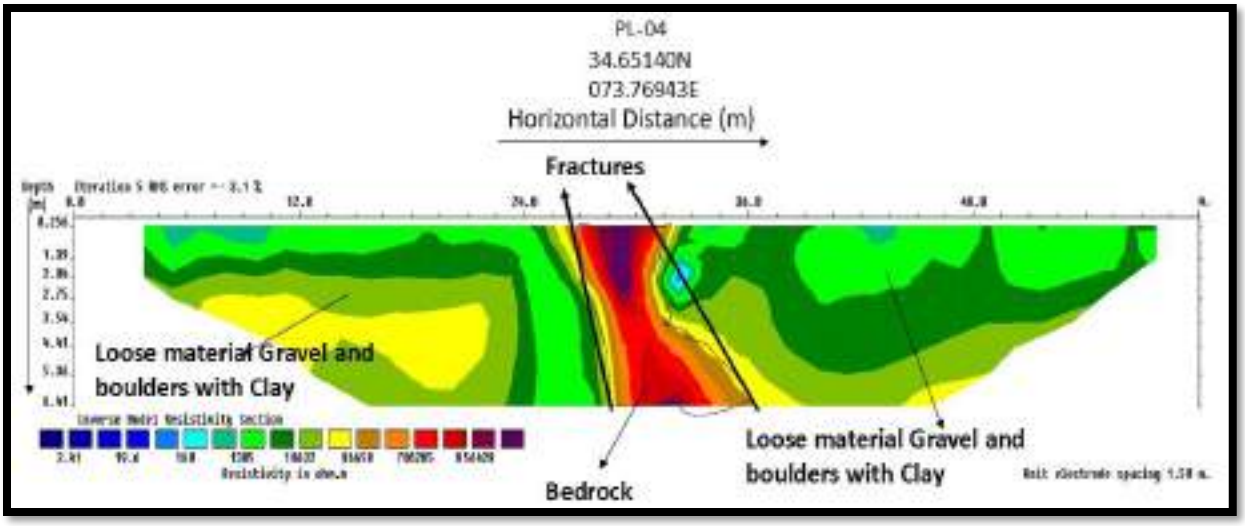


Figure 15. ERT section PL-04

3.12. Powerhouse ERT Sections

Three ERT sections were acquired at the proposed powerhouse site to delineate the subsurface geological conditions. The profile lengths varied between 150 and 200 meters, depending on the available space and the required orientation of each survey line.

Figure 16. Powerhouse ERT -01

3.13. Interpretation of the ERT Section – Powerhouse Site

The Electrical Resistivity Tomography (ERT) profile presents a detailed subsurface characterization along the investigated transect near the powerhouse location. The resistivity scale ranges from very low values (<10 Ω·m) to extremely high resistivity zones (>50,000 Ω·m), providing clear differentiation of geological materials. Depth is shown along the left axis (0–15 m), while horizontal distance extends from left to right between the coordinate range 34.62918N, 73.76769E and 34.62934N, 73.76781E.

1. Saturated Gravel and Boulders (Low Resistivity Zone – Blue/Light Blue; <50 Ω·m)
   The left portion of the section shows a prominent low-resistivity anomaly extending to ~8–10 m depth. This zone represents water-saturated gravels and boulders, indicating high groundwater potential in this part of the profile. The continuity of the low-resistivity region suggests significant water content and permeable material.

2. Loose Material, Gravel, and Boulders with Clay (Moderate Resistivity Zone – Green/Yellow;50–500Ω·m). The central part of the section is dominated by moderate resistivity values corresponding to mixed alluvial deposits, including loose gravel, cobbles, and clayey material. These heterogeneous sediments indicate variable compaction and moderate permeability. Localized clay pockets may be responsible for some of the isolated lower-resistivity patches observed.
3. Bedrock (High Resistivity Zone Red/Orange/Purple; >20,000 Ω·m)
   A distinct high-resistivity feature is visible at deeper levels (around 10–12 m depth) in the central to right portion of the profile. This zone represents bedrock or highly compacted consolidated material. The rise of this high-resistivity unit toward the surface suggests a shallow bedrock topography beneath the powerhouse site.
4. Loose Gravel and Boulder Deposits (Moderate Resistivity Zone – Green/Yellow)
   Toward the right side of the section, moderately resistive materials reappear, indicating loose, unsaturated gravel and boulder deposits. These materials are relatively dry compared to the left side and may allow limited infiltration.

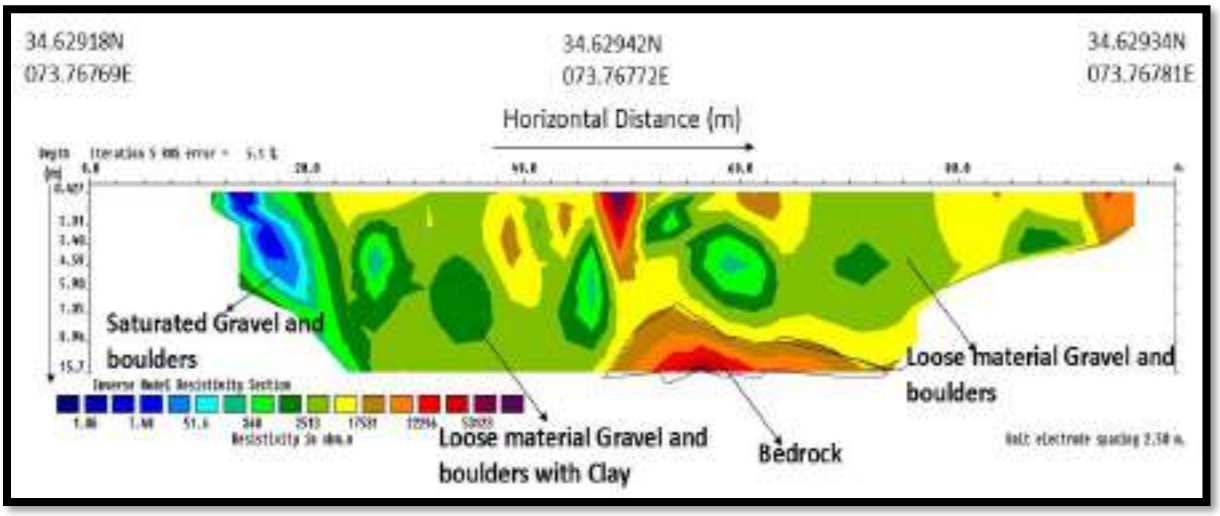


Figure 17. ERT section 02 of Powerhouse.

3.14. Powerhouse ERT-02

The presented Electrical Resistivity Tomography (ERT) section illustrates the subsurface resistivity distribution along the horizontal profile, where the horizontal axis represents distance in meters, and the left vertical axis represents depth below ground level. The resistivity scale at the bottom ranges from very low values (3–16 Ω·m) to extremely high values (>240,000 Ω·m), allowing clear differentiation of subsurface materials.

Overall, the section reveals distinct resistivity zones corresponding to varying lithologies and structural features:

1. Near-Surface Layer
   The shallow depth (0–5 m) displays mixed resistivity values ranging from moderate (green–yellow) to high (orange), indicating unsaturated sediments, likely comprising sandy gravels, overburden, and colluvial deposits.
2. Moderate Resistivity Zones (Potential Aquifer Units)
   Intermediate resistivity ranges (approximately 80–500 Ω·m) observed between ~5–15 m depth at several locations represent saturated sediments, particularly gravelly–sandy units. These zones correspond to areas where groundwater presence is expected.
   The labeled area toward the right side shows saturated gravels and boulders, characterized by low to moderate resistivity (blue–green). This suggests high permeability and good groundwater potential.
3. High Resistivity Zones and Bedrock
   Extensive regions of very high resistivity (red to purple; >10,000 Ω·m) are clearly visible at multiple depths. These zones correspond to competent bedrock, as also labeled on the section.
   - A shallow bedrock high appears toward the left side, where the resistive body approaches the surface at about 10–15 m depth.
   - A more extensive and deeper bedrock zone occupies the central portion, extending from approximately 50 m to 140 m along the profile and reaching depths of 15–25 m.

These features indicate structural undulations in bedrock topography, which can influence groundwater flow pathways.

4. Localized Low-Resistivity Anomalies. Small patches of low resistivity (blue tones) in the left and right segments may represent localized saturated pockets, clay-rich zones, or moisture accumulation areas.

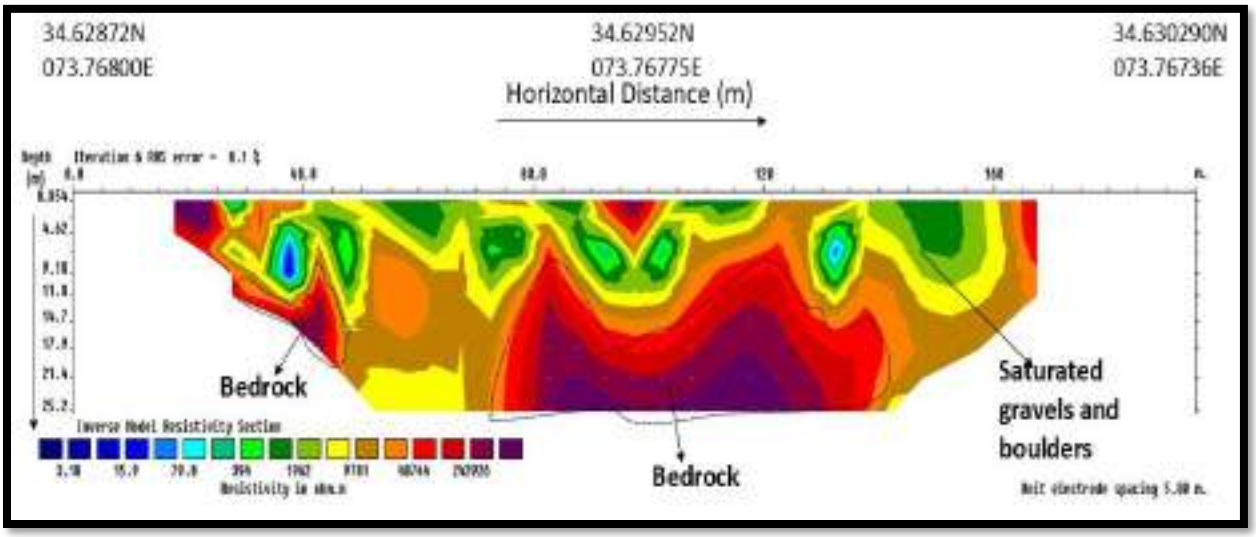


Figure 18. ERT section 02 of Powerhouse.

3.15. Powerhouse ERT-03

The presented Electrical Resistivity Tomography (ERT) profile illustrates the subsurface resistivity distribution along the surveyed transect between coordinates **34.62880°N, 73.76799°E** and **34.63017°N, 73.76740°E**. The horizontal axis represents distance in meters, while the vertical axis indicates depth below ground level. The resistivity scale spans from very low values (33 Ω·m) to extremely high values (>200,000 Ω·m), allowing differentiation of unconsolidated sediments, bouldery material, and underlying bedrock.

The ERT section reveals a heterogeneous subsurface beginning with a near-surface layer (0–5 m) of low to intermediate resistivity, representing loose gravelly alluvium, weathered sediments, and embedded boulders typical of recent fluvial or colluvial deposits with variable

moisture content. Below this, particularly on the left side, a moderate-resistivity zone (5–15 m) reflects saturated to semi-saturated gravels and mixed coarse sediments forming a permeable alluvial layer above the bedrock. Toward the central portion of the profile (110–130 m), resistivity increases sharply, indicating the presence of large, highly resistive boulders or clusters of coarse dry blocks embedded within the overburden. At greater depth (15–25 m), a continuous very high-resistivity zone marks the competent bedrock, showing structural undulations with a gently rising surface to the left and deeper bedrock (22–25 m) toward 120–160 m distance, suggesting tectonic or erosional influence. Scattered low-resistivity pockets (<100 Ω·m), mainly near the left and marginal zones, correspond to moist or saturated sediments, clay-rich patches, or localized groundwater-bearing zones within the loose overburden.

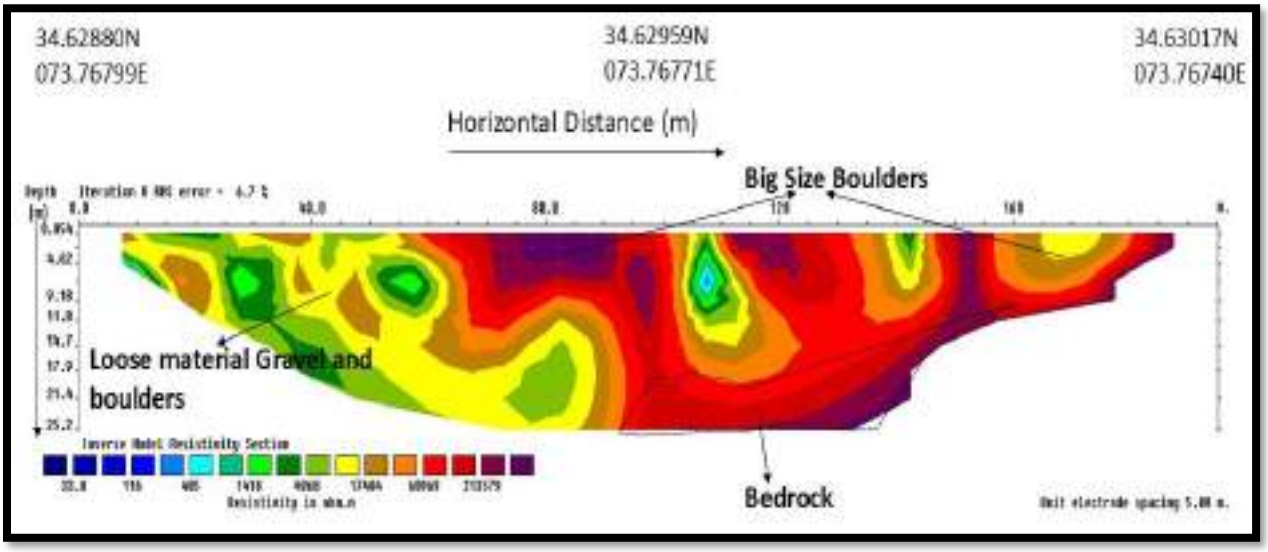


Figure 19. ERT section-03 of Powerhouse.

3.16. Consolidated Overview of Powerhouse ERT Survey Results

The cascade view of the Electrical Resistivity Tomography (ERT) sections across the powerhouse site reveals consistent subsurface features that collectively characterize the geological framework of the area. All three profiles exhibit a stratified resistivity distribution, delineating distinct lithological zones. Near-surface layers (0–5 m depth) consistently show moderate resistivity values (green to yellow), indicative of unconsolidated surficial deposits such as gravelly alluvium, loose sediments, and embedded boulders with variable moisture content.

Beneath these, intermediate resistivity zones (ranging from 50 to 1500 Ω·m) dominate the central portions of the profiles, representing saturated to semi-saturated gravels and boulders—suggesting potential aquifer units with good permeability. High resistivity zones (>20,000 Ω·m), often appearing in red to purple tones, are interpreted as competent bedrock or massive boulder clusters, with structural undulations evident across the transects. These bedrock features rise toward the surface in some sections and dip in others, indicating tectonic or erosional influences on subsurface geometry. Additionally, localized low-resistivity anomalies

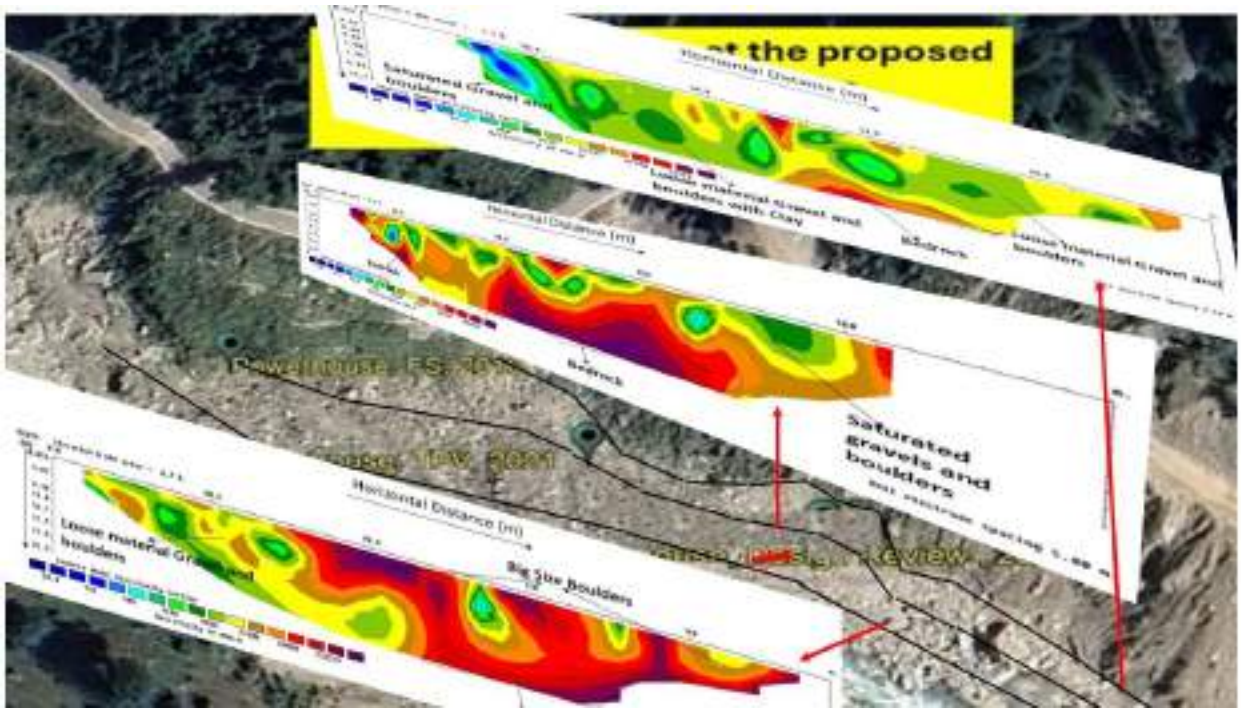


Figure 20. Computed View of Powerhouse ERT sections.

4. CONCLUSION

The Electrical Resistivity Tomography (ERT) survey successfully delineated the subsurface geological conditions across the Weir site, pipeline alignment, and powerhouse location of the Jagran Hydropower Project Phase IV. The integrated interpretation of 11 ERT profiles reveals a complex alluvial system consisting of gravel, cobble–boulder deposits, clay lenses, saturated zones, and variable bedrock topography. The results provide essential information regarding foundation stability, groundwater behaviour, potential seepage pathways, and the suitability of different locations for engineering structures. The presence of high-permeability saturated zones, undulating bedrock highs, and localized fracture-controlled conductive pathways are critical considerations for the design and safe construction of hydraulic structures and pipeline supports.

The ERT survey conducted across the Weir site, pipeline alignment, and powerhouse location provides a comprehensive understanding of the subsurface geological conditions of the Jagran Hydropower Project Phase IV. All profiles consistently reveal a heterogeneous alluvial sequence dominated by gravels, sand–gravel mixtures, and large boulders underlain by undulating bedrock. Saturated zones of low resistivity occur frequently across the valley floor, indicating active groundwater pathways that influence seepage behaviour and foundation stability. Bedrock appears as a high-resistivity unit, though its depth varies significantly across the surveyed area.

At the Weir site, the subsurface is characterized by alternating coarse alluvium, saturated gravel–boulder layers, and shallow to moderately deep bedrock ridges. These features highlight potential seepage zones, fracture-controlled pathways, and variable foundation conditions requiring careful geotechnical consideration. The pipeline alignment sections reveal similar variability, where thin overburden zones provide favourable conditions for anchoring structures, while deeper saturated pockets and steep bedrock undulations may require drainage measures, optimized support design, or minor route adjustments.

The powerhouse site exhibits relatively stable subsurface conditions, with coarse alluvial material overlying shallow bedrock that provides strong structural support. However, localized

saturation and boulder-rich layers demand attention during excavation and foundation preparation. Overall, the integrated ERT interpretation confirms a geologically complex but manageable site, where engineering solutions such as grouting, drainage control, and targeted foundation design will ensure stability and long-term performance of all project components.

REFERENCES

Hemeda S (2013) Electrical Resistance Tomography (ERT) Subsurface Imaging for Non-Destructive Testing and Survey in Historical Buildings Preservation. Australian Journal of Basic and Applied Sciences 7(1):344–357.

Linderholm P, Marescot L, Loke MH, Renaud P (2008) Cell culture imaging using micro impedance tomography. IEEE Transactions on Biomedical Engineering 55: 138–146.

McGrath R.J, Styles P, Thomas E, Neale S (2002) Integrated high-resolution geophysical investigations as potential tools for water resource investigations in karst terrain. Environ Geol 42:552–557.

M.R. Khan., Niaz, A., F. Hameed., 2018. Investigation of Water Seepage problem at the Neelum Jhelum Hydropower Project dam site using Electrical Resistivity Tomography (ERT) and Microgravity survey. Submitted to WAPDA.

Nasar M, and Abbas, Q 2021. Geological and Geophysical investigation of Iron ore Thatha lease area sindh.

Niaz, A., Sarfraz S., Niaz, J., 2019. Investigation of subsurface geology at Jagran Phase-II hydropower project dam site using electrical resistivity tomography survey. Submitted to FWO.

Niaz, A., Khan, M. R., Ijaz, U., Yasin, M. & Hameed, F. (2018). Determination of groundwater potential by using geoelectrical method and petrographic analysis in Rawalakot and adjacent areas of Azad Kashmir, sub-Himalayas, Pakistan. Arabian Journal of Geoscience, 11, 468. https://doi.org/10.1007/s12517-018-3811-0.

Niaz, A., Khan, M. R., Asghar, A., Mustafa, S., Hameed, F., Umair, B. N., Khan, S., Mughal, M. S., Farooq, M. & Rizwan., M. (2017). The study of aquifers potential and contamination based on geoelectric technique and chemical analysis in Mirpur Azad Jammu and Kashmir, Pakistan. Journal of Himalayan Earth Sciences, 50 (2), 60-73.

Niaz, A., Khan, M.R., Mustafa, S., Hameed, F. (2016). Determination of aquifer properties and vulnerability mapping by using geoelectrical investigation of parts of Sub-

Himalayas, Bhimber, Azad Jammu and Kashmir, Pakistan. Quaternary Journal of Engineering Geology and Hydrogeology. Vol. 49. pp 36-46.

Storz H, Storz W, Jacobs F (2000) Electrical resistivity tomography to investigate geological structures of the earth's upper crust. Geophysical Prospecting 48:455–471.

S.M. Ibrahim (2009). Stratigraphy of Pakistan.

Telford WM, Geldart LP, Sheriff RE (1990) Applied Geophysics. 2nd Edition. Cambridge University Press.

Thierry P, Debeblia N, Bitri A (2005) Geophysical and geological characterization of karst hazards in urban environments: application to Orleans (France). Bull Eng Geol Environ 64:139–150.

Todd DK, Mays LW (2005). *Groundwater Hydrology, third edition*. John Willey & Sons, NJ.

Zhou B, Dahlin T (2003) Properties and effects of measurement errors on 2D resistivity imaging surveying. Near Surface Geophysics 1(3):105–117.

ANNEXURE - B

SEISMIC REFRACTION TOMOGRAPHY (SRT) REPORT

JAGRN-IV HYDROPOWER PROJECT

SEISMIC REFRACTION TOMOGRAPHY (SRT) OF SUBSURFACE AT PROPOSED SITES OF JAGRAN-IV 22 MW HYDROPOWER PROJECT DISTRICT NEELUM AZAD JAMMU & KASHMIR

Geophysical Investigation Report

Submitted by:

Geological & Engineering Management Services (GEMS)

Submitted to:

Associated Consulting Engineers (ACE)

CONTENTS

Topics Page No.

Introduction----------3

Executive Summary----------4

Seismic Refraction Tomography (SRT) Methodology----------6

Instruments----------11

Acquisition Survey Design----------11

Results & Discussion----------13

SRT Profile Results at Desander Site----------13

Interpretation of 1st SRT Profile at Desander site----------15

Interpretation of 2nd SRT Profile at Desander site----------17

Interpretation of 3rd SRT Profile at Desander site----------21

Profile-wise Summary of Desander I, II, II----------24

SRT Profile Results on Pipeline Route----------25

Interpretation of SRT Pl-I----------27

Interpretation of SRT PL-II----------30

SRT Profile Results at Penstock Area----------33

Interpretation of 1st SRT Profile at Penstock Area----------35

Interpretation of 2nd SRT Profile at Penstock Area----------38

Conclusion----------41

References----------43

1. INTRODUCTION

Jagran Nala is a seasonal mountain stream located in the scenic and rugged Neelum Valley of Azad Jammu & Kashmir, Pakistan. It lies in the northern part of the valley**,** within the administrative boundaries of Neelum District, a region known for its dramatic Himalayan landscapes, clear rivers, and lush valleys that stretch northeast from Muzaffarabad Azad Kashmir.

The Jagran-IV Hydropower Project is a planned run-of-river hydropower scheme located in Jagran area of Neelum District, in Azad Jammu & Kashmir (AJK), Pakistan. It forms part of the regional government's broader hydropower development strategy aimed at harnessing the significant renewable energy potential of the mountainous rivers and streams that flow through the valley. The project is being designed and executed by the ***Power Development Organization (PDO)*** of the AJK Government, the principal agency responsible for energy projects in the region. Jagran-IV is planned to have an installed capacity of approximately 22 megawatts (MW) of electricity generation.

The primary objective of the Jagran-IV project is to tap indigenous hydropower resources of AJK, contributing to reliable electricity generation for local consumption and grid supply. Once commissioned, the project is expected to:

- Increase clean energy production, helping reduce reliance on fossil fuels and imported energy.
- Improve local electricity availability, especially for communities in the Neelum Valley and surrounding areas.
- Reduce load-shedding and energy shortages that have historically affected the region.
- Generate socio-economic benefits, including job creation during construction and long-term revenue through energy sales and grid integration.
- Support regional infrastructure expansion, including transmission lines connecting the project to the broader Muzaffarabad grid.

2. EXECUTIVE SUMMARY:

A Geophysical investigation by using Seismic Refraction Tomography (SRT) survey was simulated on the clients request for the proposed sites of the 22 MW Jagran-IV Hydropower Project located in Jagran Valley of District Neelum Azad Kashmir (Fig. 1).

The objective to use Seismic Refraction Tomography (SRT) is because it provides a detailed and reliable image of the subsurface by reconstructing the spatial variation of seismic wave velocities from first-arrival travel time data, allowing geophysicists to better understand complex geological conditions. Unlike conventional seismic refraction methods, which assume simple horizontal layering and laterally uniform velocities, SRT can handle strong lateral heterogeneity, irregular bedrock topography, and gradual velocity changes that are common in real near-surface environments.

By applying tomographic inversion techniques, SRT produces continuous 2-D velocity models that more accurately represent subsurface conditions, such as weathered layers, fractured zones, faults, buried channels, and variations in material stiffness.

This makes SRT particularly valuable for engineering and geotechnical investigations, where accurate determination of depth to bedrock, thickness of weathered zones, and identification of weak or low-velocity materials are critical for safe and economical design of foundations, tunnels, roads, and dams.

Additionally, SRT is widely used in hydrogeological and environmental studies to delineate aquifers, detect saturated or unconsolidated zones, and support groundwater or contamination assessments. Because it is non-invasive, relatively cost-effective, and capable of covering large areas with good resolution, Seismic Refraction Tomography has become a preferred method for near-surface subsurface characterization in complex geological settings.

By applying this geophysical investigation total of 07 SRT profiles were carried out on the proposed project sites (Fig. 2). Three (03) SRT profiles were conducted on desander area, two (02) SRT profiles carried out along the proposed pipeline segment and two (02) SRT profiles were produced at penstock thrust anchor location. The accurate location of conducted SRT profiles are shown in the base map.

Fig. 1: Location of Jagran Project Area from District Muzaffarabad Azad Kashmir

Fig. 2: Location of Jagran Project Area in the North of Jagran Village, District Neelum, AJK

3. SEISMIC REFRACTION TOMOGRAPHY (SRT) METHODOLOGY:

Seismic refraction method measures the travel times of seismic waves refracted at the interfaces between subsurface layers of different velocities. The development of powerful computer technology used for earthquake location and in the determination of seismic body waves travel times from near surface to deep earth's interior led to the modern field of seismic tomography, a powerful technique for determination of depths and velocities of overburden constituents and the refractors within the Earth's subsurface (**Telford et al., 1990; Kearey et al., 2002; Quigley, 2006**).

Seismic refraction tomography also known as "velocity gradient or diving-wave tomography" is an imaging technique that produces a cross-sectional picture (tomogram/ inverted velocity model) of the subsurface through response to non-destructive probing energy from external source such as hammer blow, little amount of dynamite of less energy, weight drop, etc (**Zhu and Mc-Mechan, 1989; Stefani, 1995; Tien-When and Philip, 1994**). The conventional seismic refraction data processing is deficient of showing the true strength of subsurface earth materials because it uses over generalized geometry for breaking model into continuous layers of constant velocity, whereas SRT does not require that the model has to be broken into constant velocity continuous layers, but has to be made up of a high number of small constant velocity grid cells or nodes (**Zhang and Toksoz, 1998**). The model is inverted by performing ray tracing, through an initial model and comparing the modelled travel times to the field data, and adjusting the model grid-by-grid in order to match the calculated travel times to the field data, so as to generate the resulting subsurface velocity model also known as tomogram/inverted velocity model after the number of program predefined iterations has been completed (**Gregory, 2002; Sheehan et al., 2005a**).

SRT technique is mainly used for mapping of weathered layer, depth to water table, basement structures for engineering purposes, and applying correction to reflection data (**Osemeikhian and Asokhia, 1994**). The information derived from SRT may be used to predict spatial variations in lithology, pore fluids, or rock fracturing. It can also be applied on a variety of spatial scales, from ranges of hundreds of metres, down to engineering or archaeological investigations of single columns in ancient buildings, as well as resolving velocity gradients, lateral velocity changes within the subsurface with greater ability and for modelling localized velocity anomalies (**Cardarelli and de Nardis, 2001**). In addition, SRT may be applied in geologic settings

where conventional refraction method fails, such as areas of compaction, karst, and zone faults, as well as in areas with extreme topography or complex near-surface structures where the user has little or no prior knowledge of subsurface structures (**Dutta, 1984; Zhang and Toksoz, 1998; Azwin et al., 2013**), and in areas with serious limitations in spread length.

a. Seismic Refraction Tomography Field Data Acquisition:

In the field procedure, SRT makes use of the same data acquisition equipment but requires more shot points and receivers than the conventional seismic refraction. The data acquisition equipment consists some of the following units:

i. Energy Source:

This could be hammer blow and metallic plate, weight drop or explosive charge (in small quantity) for generating and transmitting seismic waves into the subsurface.

ii. Geophones (Receiver):

Geophones are electrochemical transducers that convert ground motion into an electrical analog signal. A channel of geophones is used to detect arrival times (compression or P-wave) emanating from subsurface features. The geophones are rightly positioned using GPS and meter rule.

iii. Geophone Cables:

Geophone cables to transmit analog electrical impulses from geophones to seismograph.

iv. Seismograph:

Seismograph is housed in the measuring unit for recording the information detected by geophones on channel dynamic signal analyzer.

v. Laptop:

Laptop to dump field data for data analysis and processing.

SRT data acquisition employs sufficient shot points at different survey lines at the Earth's surface to obtain high quality seismic data. Figure 3a shows a typical SRT data acquisition layout consisting channel of geophones, geophones' cables connected to a seismograph, and a location of shot points for every survey line (SL). The survey line can be one or more depending on the traverse length, geometry of target point, and depth of investigation. Along the offsets, more

clusters of shot points are required due to the distance between every shot and geophone for high signal-to-noise ratio and deeper depth resolution, unlike shot points that are taken where the geophones are laid. The particular depth of interest can be probed by increasing the energy source at shot points. When the refractor is suspected to have a dip, the velocities of the beds and the dip of the interface can be obtained by shooting a second complementary profile in the opposite direction (**Kearey et al., 2002**). Figure 3b shows the instrumentation and progression of generated seismic P-waves through the subsurface and how they are refracted at boundary surfaces where changes in acoustic impedance occur during SRT data acquisition. However, some of the generated seismic waves are reflected at boundary surfaces while others do not travel through the subsurface but travel directly to the geophones as direct waves. The inversion software is therefore used for picking the first arrival times (compression or P-wave) through visual inspection from collected time record.

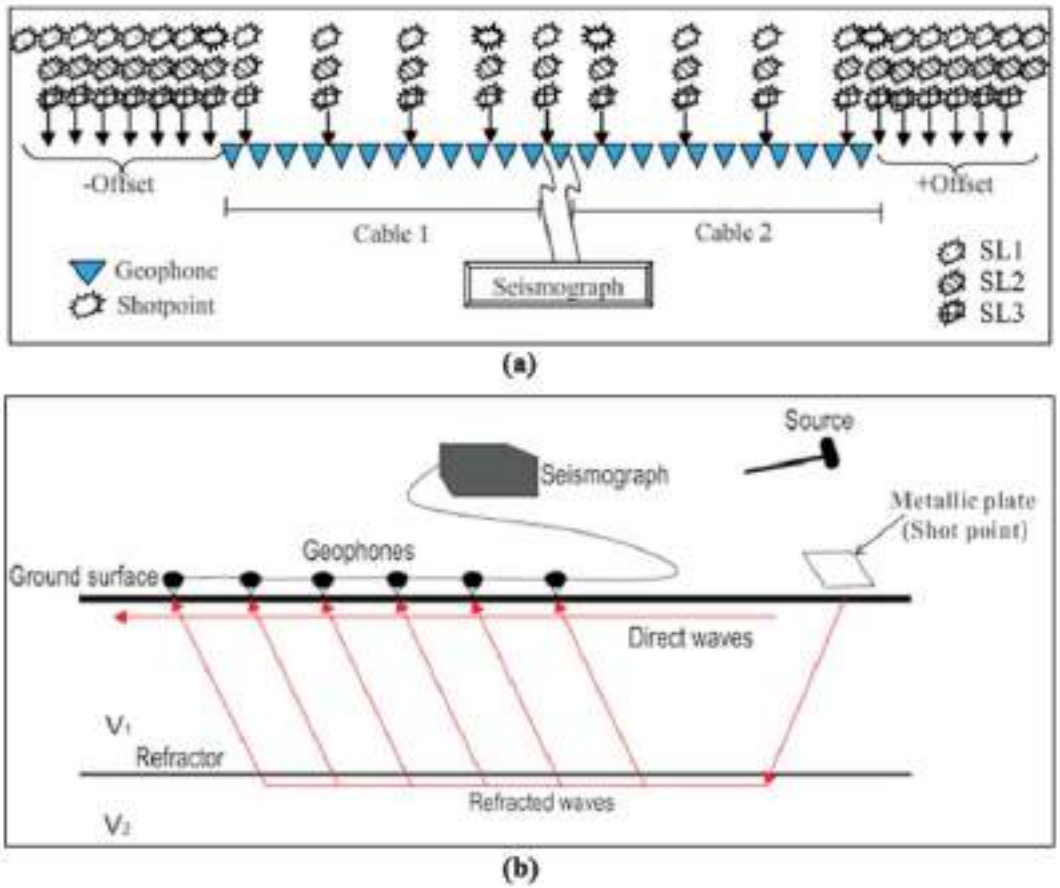


Fig. 3: (a) A typical SRT data acquisition layout showing channel of geophones, geophones' cables connected to seismograph, and location of shot points for every survey line (SL) (modified after **Azwin et al., 2013**). **(b)** Instrumentation and progression of seismic waves (compression or P-waves) generated at the surface and refracted at boundary surfaces during SRT data acquisition).

b. Seismic Refraction Tomography Data Processing & Interpretation:

The SRT data after acquisition will be processed on different software available and the sometimes one software is used to pick first wave arrivals and some other software is used to process and inversion of field data into different models.

The stages involved in SRT inversion processes are given below and the flow chart is shown in Figure 4.

i. The field data format is renamed/converted to readable file format of the software to be used for the data analysis and processing.
ii. Gain control is applied to the data to accentuate weak arrival times and other wavelets to improve the quality of the wavelet traces when to be picked.
iii. First arrival times (compression or P-wave) are manually picked through visual inspection from collected time record on software program and saved for subsequent analysis. All picked first arrival times are summed and averaged. Values below the average time are classified to be from the first layer, while those that are higher than the average time are considered to have been refracted from the second layer.
iv. A travel time curve is generated through the layer assignment technique in interpretation module.
v. The model is divided into a large number of smaller constant velocity grid cells or nodes. The model is then inverted by performing ray tracing with the grid cells adjusted in an attempt to match the calculated travel times to produce a 2D initial model.
vi. This is repeated until the number of pre-defined iterations within the program has been completed, with the resulting final subsurface velocity model/tomogram, being produced upon completion.

After processing a final velocity section will be prepared and then the interpretation of the velocity sections will be concluded to determine the depth of overburden material, alluvium, weathered rock, hard rock or bed rock on the basis of P-Wave velocity.

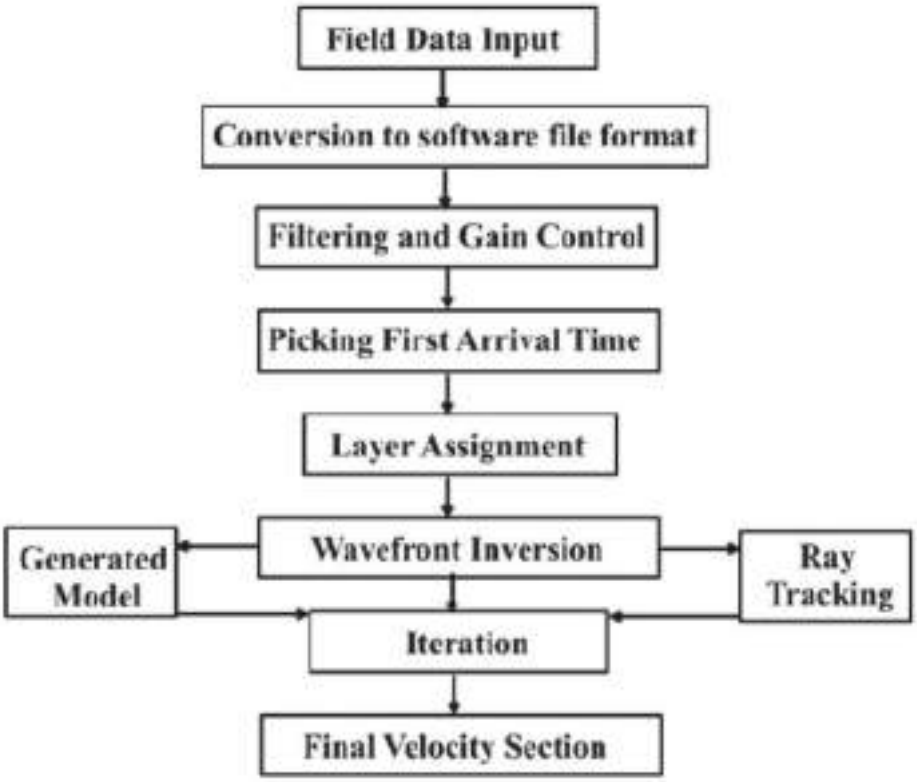


Fig. 4: Seismic refraction tomography data processing flow chart.

c. P-Wave Velocities of Materials:

All materials on earth have different capability of interacting with P-wave. P-wave passes with different velocity through different materials. The table.1 shows values of p-wave velocity interacting with various materials.

Sr. No.	Materials	P-Wave Velocity (m/s)
1	Air	331.5
2	Water	1400-1600
3	Sandstone and Shale	2000-4500
4	Limestone	2000-6000
5	Sand and Gravel	500-1500
6	Shale	2000-4500
7	Conglomerate	10-800
8	Alluvium	500-2000
9	Sand (dry)	200-1000
10	Sand (saturated)	1500-2000
11	Clay	1000-2500

Table. 1: P-Wave velocities of various Earth Materials (Viengthong, Xayavong, et al, 2020)

4. INSTRUMENTS:

- **Equipment:** 24-Channel PASI Seismograph.
- **Source:** Sensor attached Hammer (10 kg) with striker plate.
- **Geophones:** 24 geophones.
- **Connection:** Two wire rolls of connecting 12 geophones each.
- **Source Connection:** Wire roll with sensor attached to source for trigger.
- **Laptop:** for data acquisition storage

5. ACQUISITION SURVEY DESIGN:

SRT is proposed on different sites of Jagran-IV, 22MW Hydropower project with different specifications according to the requirement of client.

1. 03 SRT profiles were conducted at Desander area to acquire data up to 20meter depth.
2. 02 SRT profiles were carried out on Pipe line route to acquire data up to 10meter depth.
3. 02 SRT profiles were produced on Penstock area to acquire data up to 15meter depth.

Field Images During Data Acquisition

Field Images During Data Acquisition

Field Images During Data Acquisition

6. RESULTS AND DISCUSSION:

SRT Profile Results at Desander Site:

Seismic refraction testing was conducted using a PASI GEA-24 digital seismograph. The survey employed a 24-channel geophone array with a geophone spacing of 3.0 m, resulting in a total spread length of 69 m**.**

A 10 kg hammer striking a metal base plate was used as the seismic energy source. A total of 14 shot points were recorded along the profile at 6 m intervals, including an offset shot located 3 m before the first geophone and a final shot at 72 m from the start of the profile. All shot records were successfully acquired and stored in digital format for subsequent interpretation.

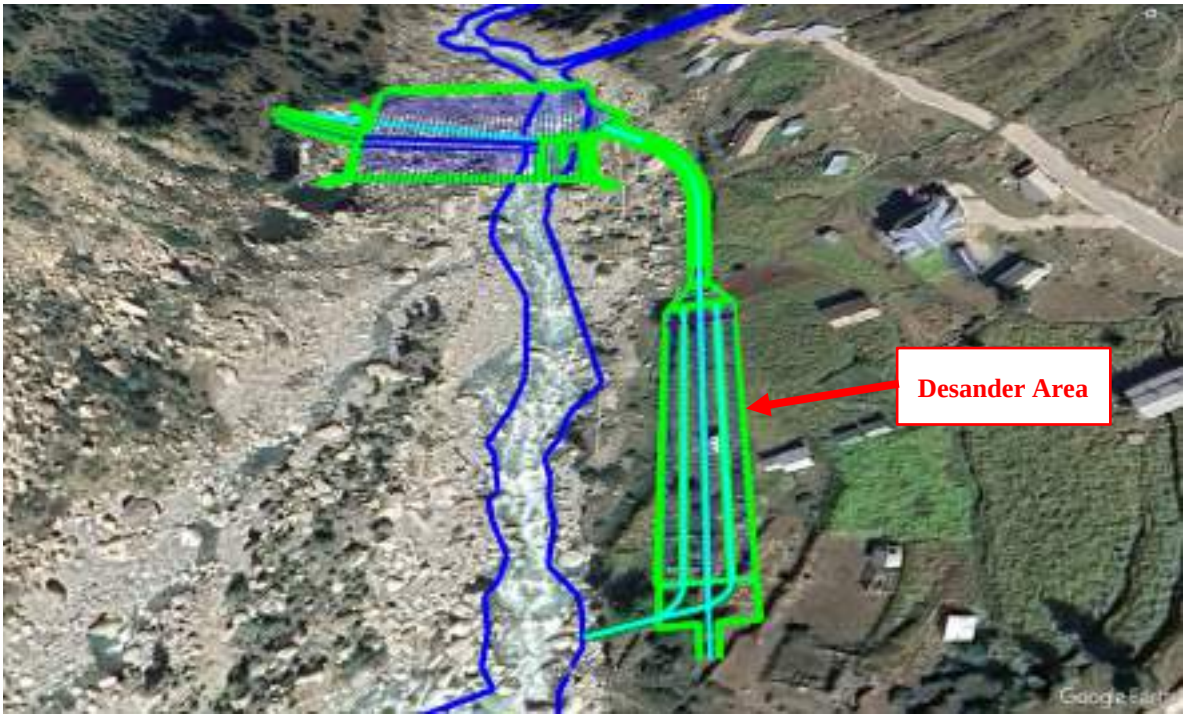


Fig. 5: Location of site for Proposed Desander of Jagran-IV Hydropower Project

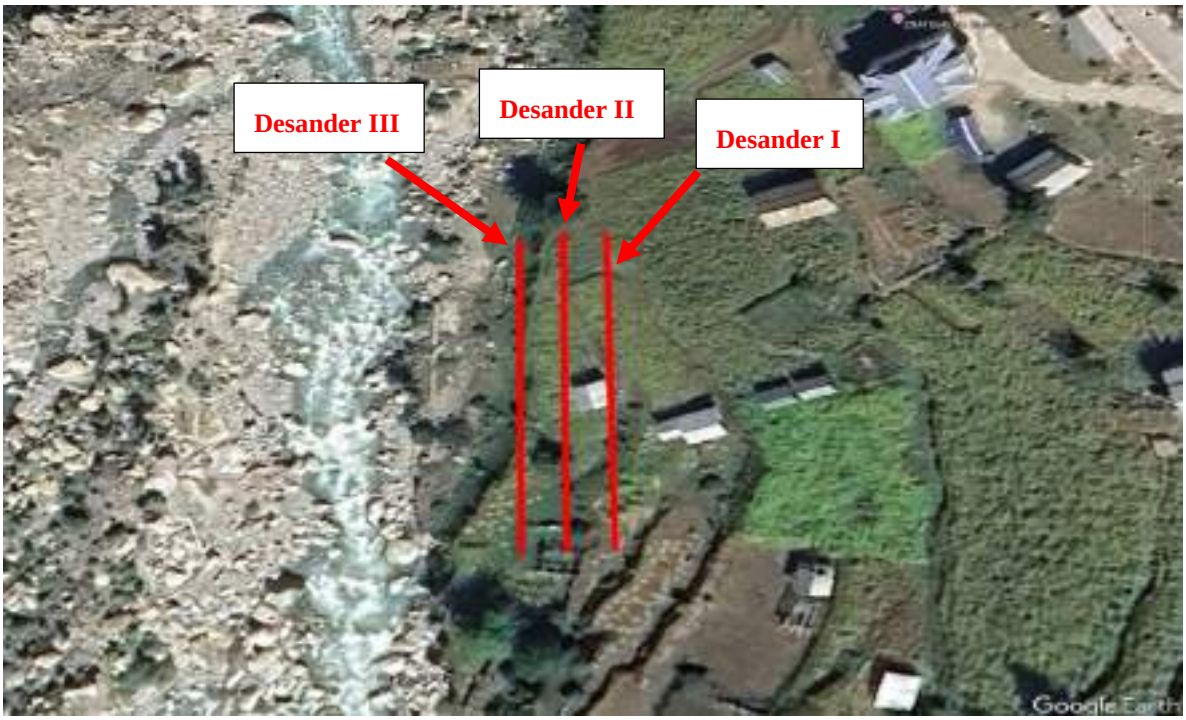


Fig. 6: SRT Profiles at site of Proposed Desander of Jagran-IV Hydropower Project

a. Interpretation of 1st SRT profile at Desander site:

The 1st profile of seismic refraction survey was conducted along a 72-meter long linear profile at the proposed Jagran-IV Hydropower Project, located in District Neelum, Azad Jammu & Kashmir. The survey line was oriented along accessible ground near the proposed project infrastructure to provide representative subsurface information for foundation and excavation assessment.

Profile Location (UTM):

The Desander-I seismic refraction profile is approximately 72 meters long**,** trending between UTM Coordinates:

- **Start:** 387237 E, 3835637 N
- **End:** 387235 E, 3835565 N

1. Velocity vs Time Graph (Desander I)

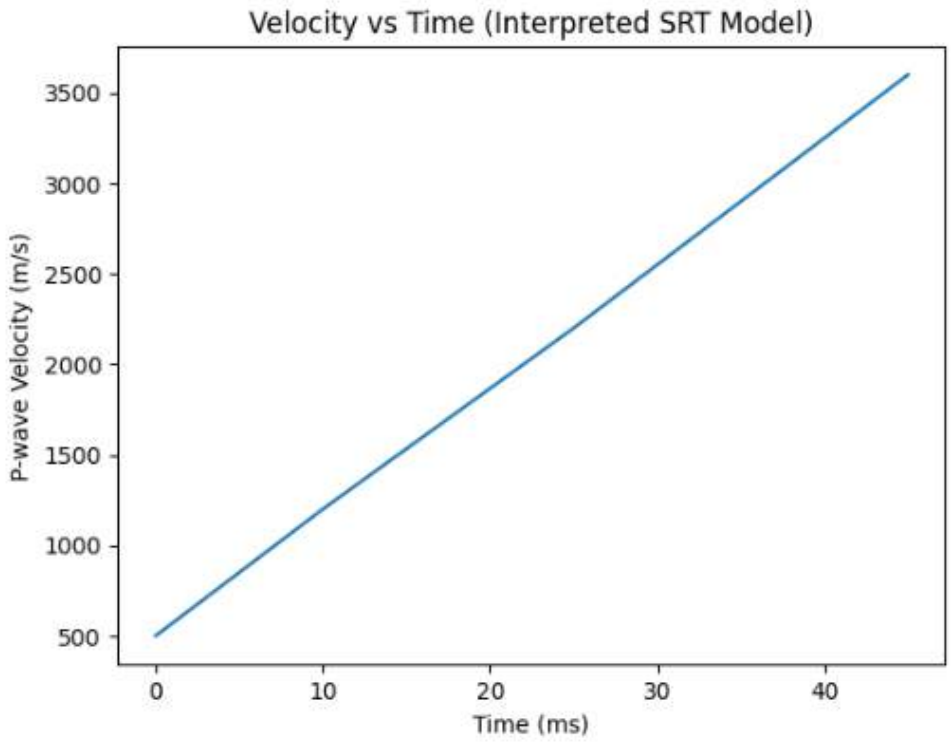


Fig. 7: Graph showing velocity vs time data of Desander I

This graph represents the increase of P-wave velocity with travel time and reflects transition from low velocity near surface material to higher velocity deeper strata.

For Geotechnical analysis it will be describe as:

- Early times → loose soil / colluvium
- Intermediate times → weathered & fractured rock
- Later times → competent bedrock

2. Velocity vs Depth Graph (Desander I)

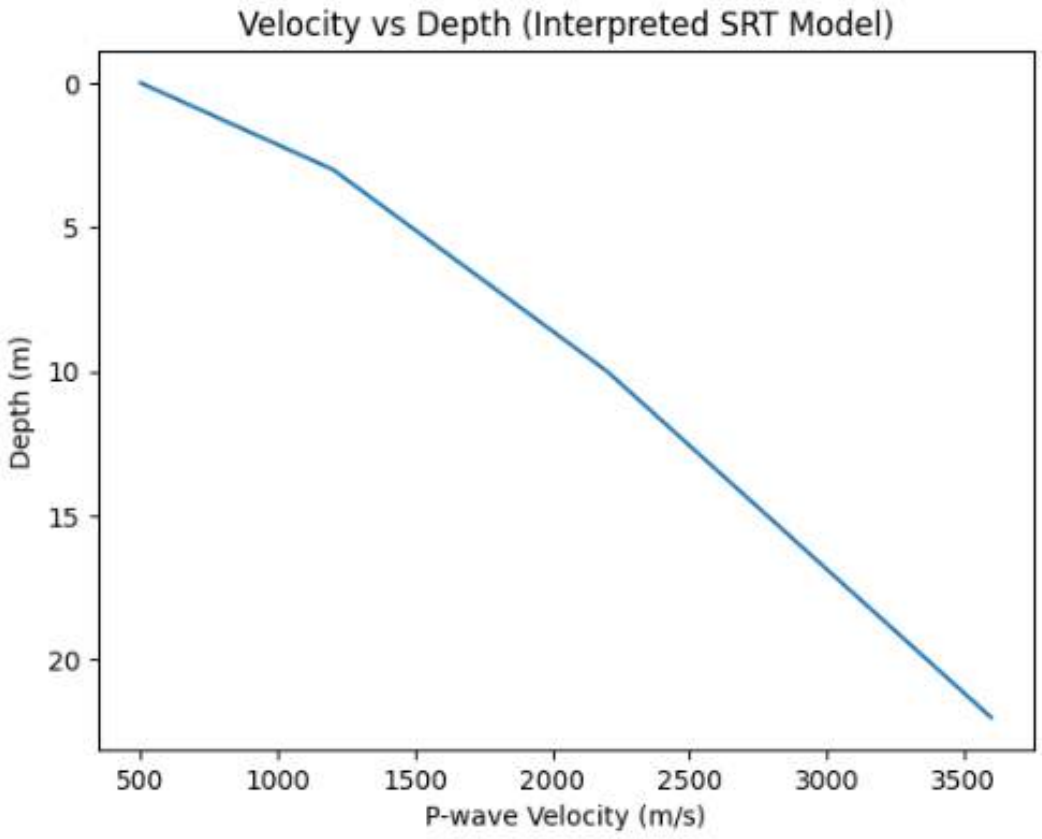


Fig. 8: Graph showing velocity vs Depth data of Desander I

This graph interpreted seismic refraction velocity–depth model indicates a three-layer subsurface sequence beneath the 72 m long profile. P-wave velocity increases systematically with depth, reflecting improving material competence.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 3m	400 to 600	Soil/colluvium/surficial deposits/ Loose to semi-compact overburden
Layer II	3 to 10m	1200 to 2000	Highly Weathered and Fractured Rock
Layer III	Greater than 10 to 22m	3000 to 3800	Competent Bedrock

The velocity–depth curve shows a sharp velocity contrast at approximately 10–12 m depth, marking the top of competent bedrock. Below this depth, velocities remain consistently high, indicating relatively intact rock mass conditions.

Seismic refraction interpretation indicates competent bedrock at approximately 10–12 m depth, overlain by weathered and fractured rock and a thin surficial overburden.

3. Interpretation:

The uppermost layer, with P-wave velocities ranging from approximately 400 to 600 m/s, represents loose surficial material consisting of soil, colluvium, and slope wash deposits. The thickness of this layer varies between 2 and 4 m.

Underlying this is a weathered and fractured rock layer, exhibiting velocities in the range of 1200 to 2000 m/s and extending to depths of approximately 8 to 10 m. The reduced velocities suggest a zone of significant weathering, jointing, and possible groundwater influence.

A marked increase in seismic velocity to values exceeding 3000 m/s is observed below approximately 10–12 m depth, indicating the presence of competent bedrock. Velocities within this layer range from 3000 to 3800 m/s, consistent with moderately jointed to fresh metamorphic or igneous rock typical of the Neelum Valley geology.

b. Interpretation of 2nd SRT profile at Desander site:

The 2nd profile of seismic refraction survey was conducted along a 72-meter long linear profile at the proposed Jagran-IV Hydropower Project, located in District Neelum, Azad Jammu & Kashmir. The survey line was oriented along accessible ground near the proposed project

infrastructure to provide representative subsurface information for foundation and excavation assessment.

Profile Location (UTM):

The Desander-II seismic refraction profile is approximately 72 meters long**,** trending between UTM Coordinates:

- **Start:** 387230 E, 3835636 N
- **End:** 387229 E, 3835565 N

The profile location is considered representative of site conditions within the project area and suitable for correlation with geological mapping and future geotechnical investigations.

1. Velocity vs Time Graph (Desander II)

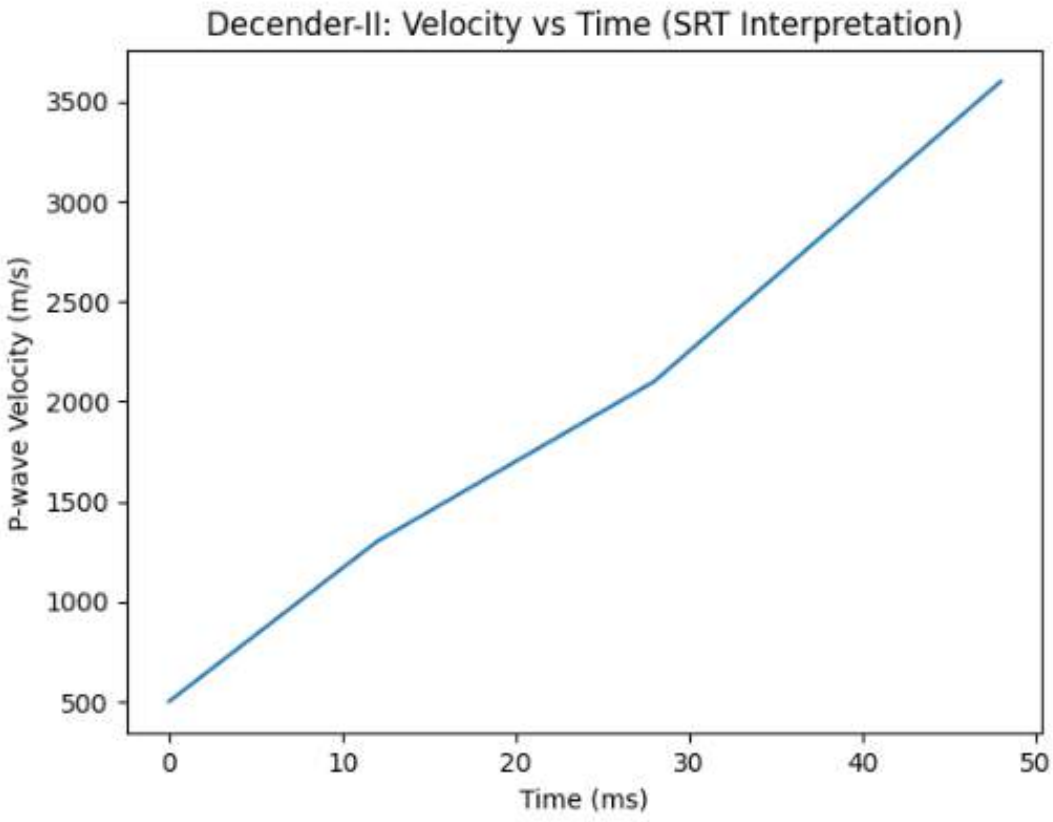


Fig. 9: Graph showing velocity vs time data of Desander II

The velocity–time plot shows a progressive increase in P-wave velocity with increasing first-arrival time. Low velocities at early times represent loose near-surface materials, while higher velocities at later times indicate the transition into weathered rock and finally competent bedrock.

For Geotechnical analysis it will be describe as:

- Early arrivals → soil/colluvium
- Intermediate arrivals → weathered & fractured rock
- Later arrivals → competent bedrock

2. Velocity vs Depth Graph (Desander II)

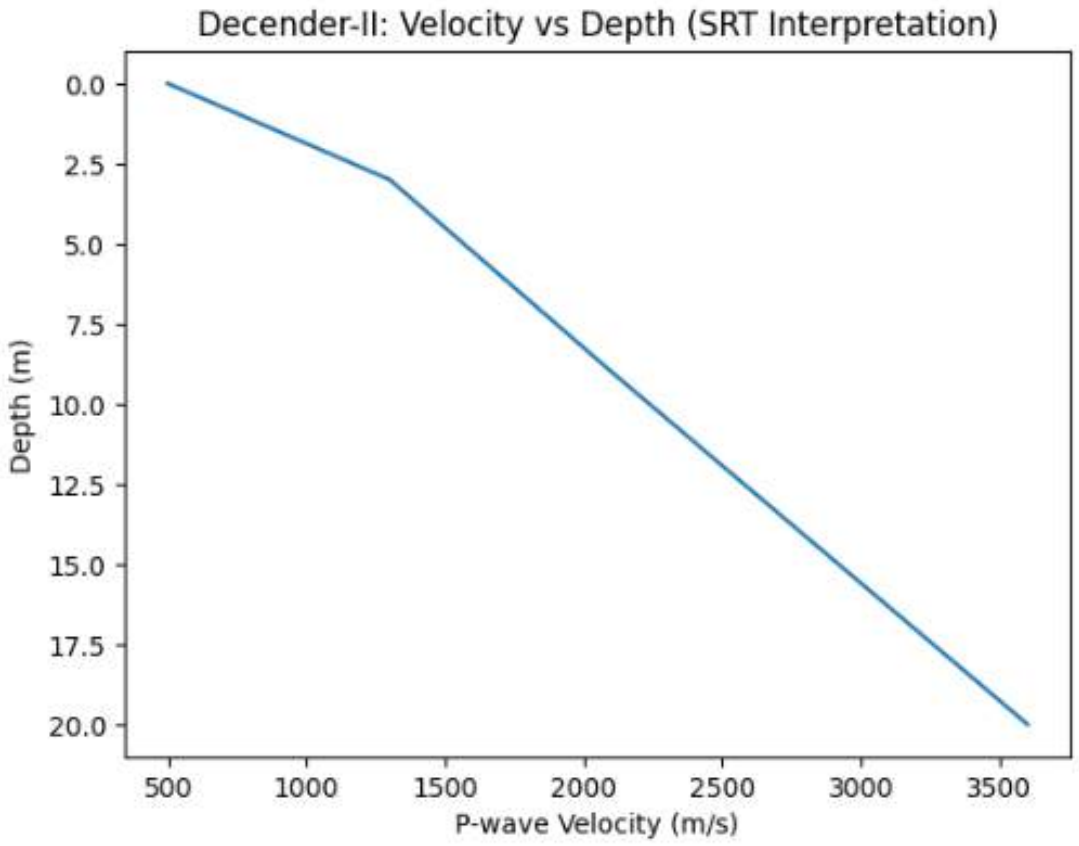


Fig. 10: Graph showing velocity vs depth data of Desander II

The velocity–depth model indicates a clear increase in seismic velocity with depth. A distinct velocity contrast is observed at approximately 9–11 m depth, marking the top of competent bedrock. Below this depth, velocities remain consistently high, suggesting relatively intact rock mass conditions. Interpretation of seismic refraction data recorded along the Desander-II profile indicates a layered subsurface velocity structure, characterized by increasing P-wave velocity with depth. The velocity–depth model suggests the presence of three distinct subsurface layers, representative of near-surface deposits, weathered rock, and competent bedrock.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 3m	400 to 600	Soil/colluvium/surficial deposits/ Loose to semi-compact overburden
Layer II	3 to 9m	1200 to 2000	Highly Weathered and Fractured Rock
Layer III	Greater than 9 to 20m	3000 to 3800	Competent Bedrock

Interpretation:

Interpretation of first arrival travel times from the seismic refraction data indicates a three-layer subsurface condition beneath the Desander-II profile.

The uppermost layer, extending to depths of approximately 2–3 m, exhibits low seismic velocities in the range of 400–600 m/s. This layer is interpreted as loose surficial material comprising soil, colluvium, and slope wash deposits.

The underlying layer shows P-wave velocities ranging from 1200 to 2000 m/s and extends to depths of approximately 8–10 m. These velocities are characteristic of weathered and fractured rock, likely affected by surface weathering, jointing, and possible groundwater presence.

A significant increase in velocity to values exceeding 3000 m/s is observed below approximately 9–11 m depth, indicating the presence of competent bedrock. Velocities within this

layer range from 3000 to 3800 m/s, suggesting moderately jointed to relatively fresh rock mass conditions consistent with the regional geology of the Neelum Valley.

c. Interpretation of 3rd SRT profile at Desander site:

The 3rd profile of seismic refraction survey was conducted along a 72-meter long linear profile at the proposed Jagran-IV Hydropower Project, located in District Neelum, Azad Jammu & Kashmir. The survey line was oriented along accessible ground near the proposed project infrastructure to provide representative subsurface information for foundation and excavation assessment.

Profile Location (UTM):

The Desander-II seismic refraction profile is approximately 72 meters long**,** trending between UTM Coordinates:

- **Start:** 387223 E, 3835637 N
- **End:** 387222 E, 3835565 N

The profile location is considered representative of site conditions within the project area and suitable for correlation with geological mapping and future geotechnical investigations.

1. Velocity vs Time Graph (Desander III)

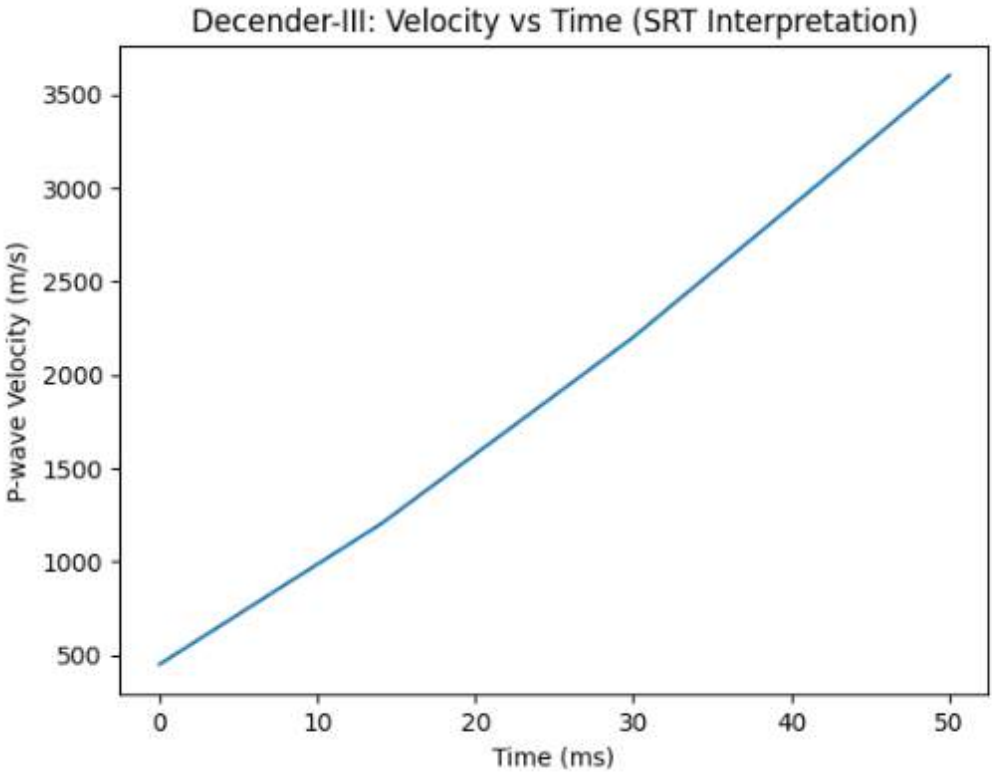


Fig. 11: Graph showing velocity vs time data of Desander III

The velocity–time plot for the Desander-III profile shows a progressive increase in P-wave velocity with increasing first-arrival time. Low velocities at early times correspond to loose surficial deposits, while higher velocities at later times indicate transition into weathered rock and subsequently competent bedrock.

For Geotechnical analysis it will be describe as:

- Early arrivals → soil / colluvial cover
- Intermediate arrivals → weathered & fractured rock mass
- Late arrivals → competent bedrock

This trend confirms improving material competence with depth along the profile.

2. Velocity vs Depth Graph (SRT Desander III)

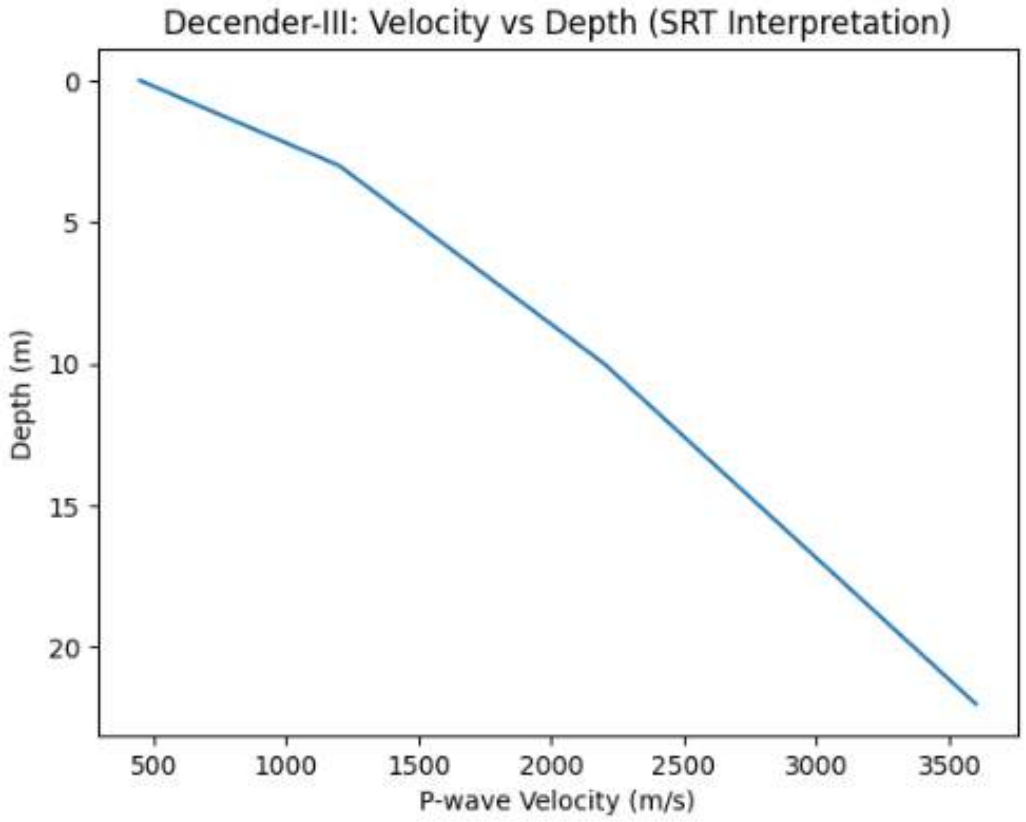


Fig. 12: Graph showing velocity vs depth data of Desander III

The interpreted velocity–depth model indicates a clear three-layer subsurface condition beneath the Desander-III profile. A distinct velocity contrast occurs at approximately 10–12 m depth, interpreted as the top of competent bedrock. Below this depth, seismic velocities remain high and relatively uniform.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 3m	450 to 600	Soil/colluvium/surficial deposits/ Loose to semi-compact overburden
Layer II	3 to 10m	1200 to 2200	Highly Weathered and Fractured Rock
Layer III	Greater than 10 to 20m	3000 to 3600	Competent Bedrock

3. Interpretation:

Seismic refraction data for the Desander-III profile were acquired using a PASI GEA-24 seismograph with 24 geophones at 3.0 m spacing, providing a total spread length of 69 m. A 10 kg hammer source striking a metal plate was used, with 14 shot points recorded at 6 m intervals, including an offset shot at –3 m and a final shot at 72 m.

Interpretation of first-arrival travel times indicates a three-layer subsurface model beneath the profile. The uppermost layer, extending to depths of approximately 2–3 m, exhibits low seismic velocities and is interpreted as loose soil and colluvial deposits. This layer is underlain by a weathered and fractured rock zone extending to depths of approximately 9–10 m, characterized by moderate seismic velocities.

A marked increase in P-wave velocity to values exceeding 3000 m/s is observed below approximately 10–12 m depth, indicating the presence of competent bedrock. These velocities are consistent with moderately jointed to relatively fresh rock, typical of the Neelum Valley

Profile-Wise Summary of Desander I, II, II

Seismic refraction surveys were carried out along three profiles (Desander-I, Desander-II, and Desander-III) at the proposed Jagran-IV Hydropower Project site to assess subsurface lithological conditions and estimate depth to competent bedrock. The surveys were designed to provide representative subsurface information for preliminary foundation assessment and excavation planning. A distinct increase in seismic velocity is observed at depths of approximately 9–12 m, marking the transition from weathered rock to competent bedrock across all profiles.

Summary of Desander I, II, II

Sr.No.	Profile	Depth to Bedrock (m)	Bedrock Velocity (m/s)	Remarks
1	Desander-I	10-12	3000-3800	Slightly thicker weathered zone
2	Desander-II	9-11	3000-3600	Consistent velocity contrast
3	Desander-III	10-12	3000-3600	Uniform bedrock response

Minor lateral variations in depth to bedrock are interpreted to be due to surface weathering, fracturing, and local geomorphological effects typical of the Himalayan terrain. The low-velocity upper layer corresponds to loose surficial material consisting of soil, colluvium, and slope wash deposits. This layer is thin but laterally continuous across the survey area. The intermediate-velocity layer represents weathered and fractured rock, likely affected by jointing and near-surface weathering. This layer exhibits moderate thickness and may locally contain groundwater, resulting in reduced seismic velocities.

The underlying high-velocity layer is interpreted as competent bedrock, characterized by velocities exceeding 3000 m/s. This layer is considered moderately jointed to relatively fresh rock mass, consistent with the regional geology of the Neelum Valley.

SRT Profile Results on Pipeline Route:

Seismic refraction tomography was conducted along the Pipeline route alignment to assess subsurface conditions relevant to pipeline excavation and support requirements. Two (02) SRT profiles SRT-PL-I & PL-II was acquired along the designated pipeline alignment, as shown in the map (Figure 13 & 14).

Profile Design:

- **Instrumentation:** PASI GEA-24 digital seismograph
- **Number of geophones:** 24
- **Geophone spacing:** 2.0 m
- **Total spread length:** 46 m
- **Hammer source:** 10 kg hammer striking metal plate
- **Shot geometry:**
    - First shot at **–3 m** from first geophone
    - Subsequent shots at **3.5 m intervals**
    - Last shot at **49 m**
- **Total shots:** 14
- **Profile length investigated:** 51 m

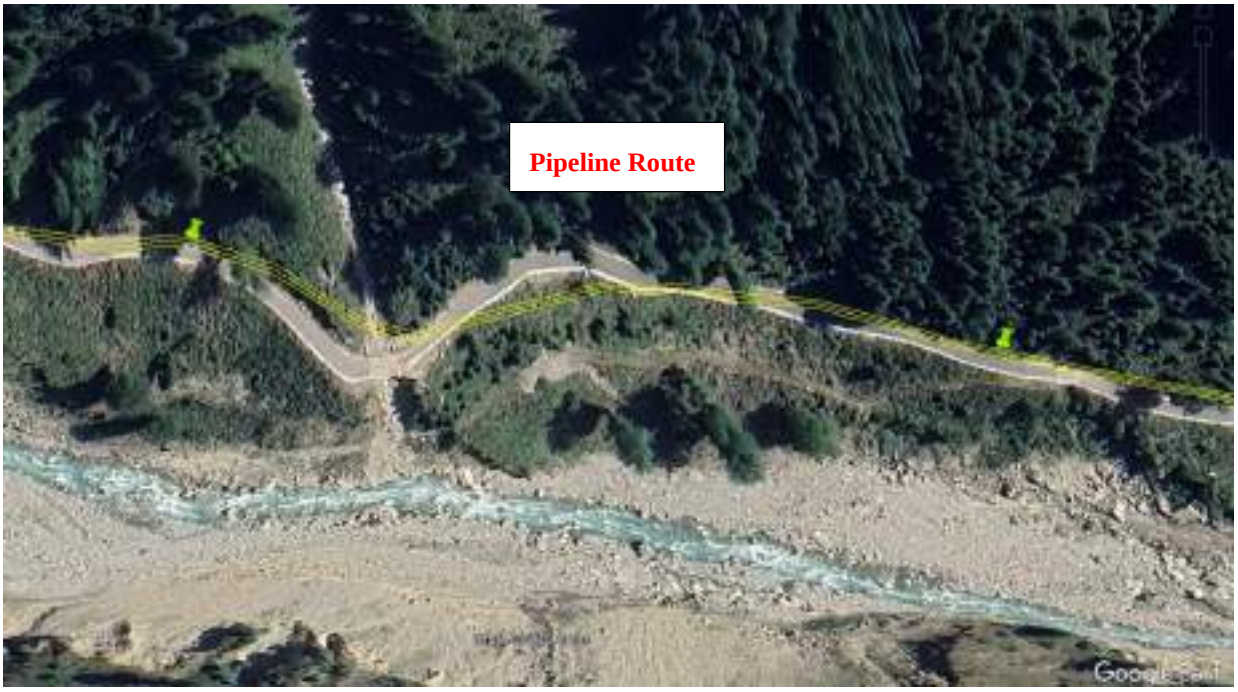


Fig. 13: Locations of Proposed Pipeline Route of Jagran-IV Hydropower Project

Fig. 14: SRT Profiles at the site of Proposed Pipeline Route of Jagran-IV Hydropower Project

a. Interpretation of SRT PL-I:

Profile Location (UTM):

The location of SRT PL-I along the pipeline route is given in UTM coordinates as below:

Easting: 387034 m

Northing: 3833142 m

The profile location is representative of subsurface conditions along the proposed pipeline corridor.

1. Velocity vs Time Graph (SRT PL-I)

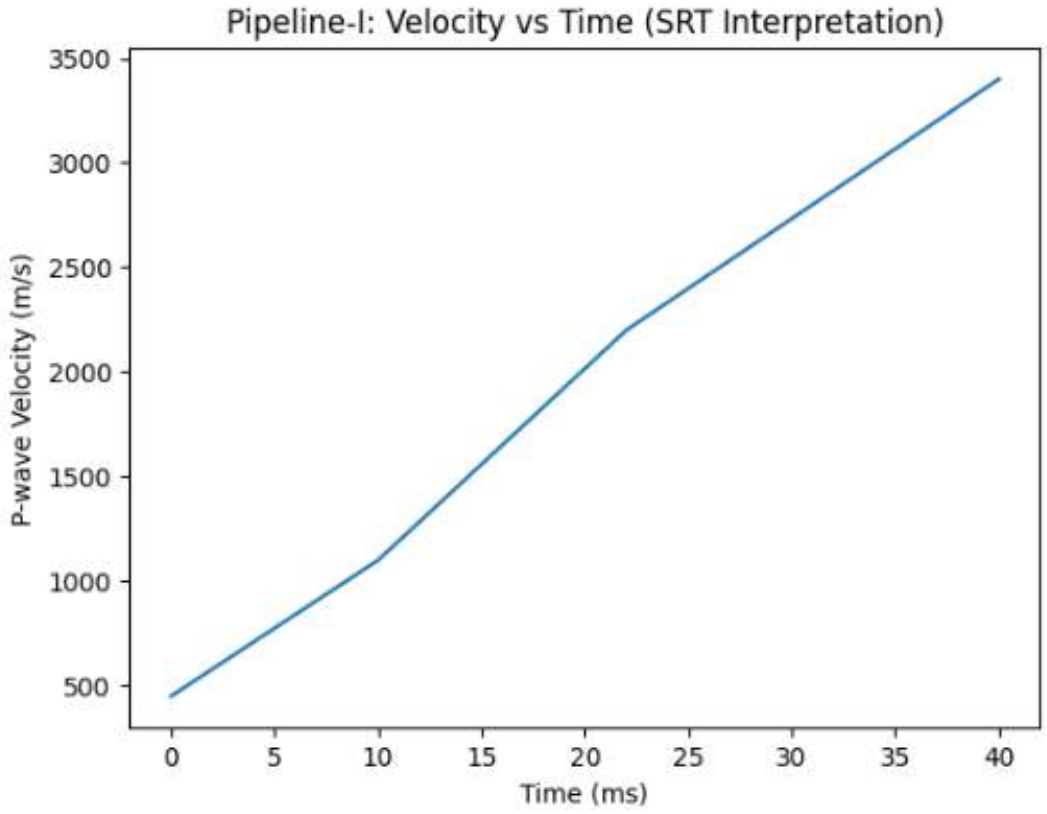


Fig. 15: Graph showing velocity vs time data of Pipeline-I

The velocity–time curve shows a systematic increase in P-wave velocity with increasing travel time, indicating progressively more competent subsurface materials with depth.

For Geotechnical analysis it will be describe as:

- Initial low velocities (~450 m/s) correspond to near-surface loose material.
- A sharp increase to ~1100–2200 m/s reflects weathered and fractured rock**.**
- Velocities exceeding 3000 m/s indicate arrival from competent bedrock.

This pattern confirms a layered subsurface with increasing stiffness and competence downward, which is typical of Himalayan slope environments.

2. Velocity vs Depth Graph (SRT PL-I)

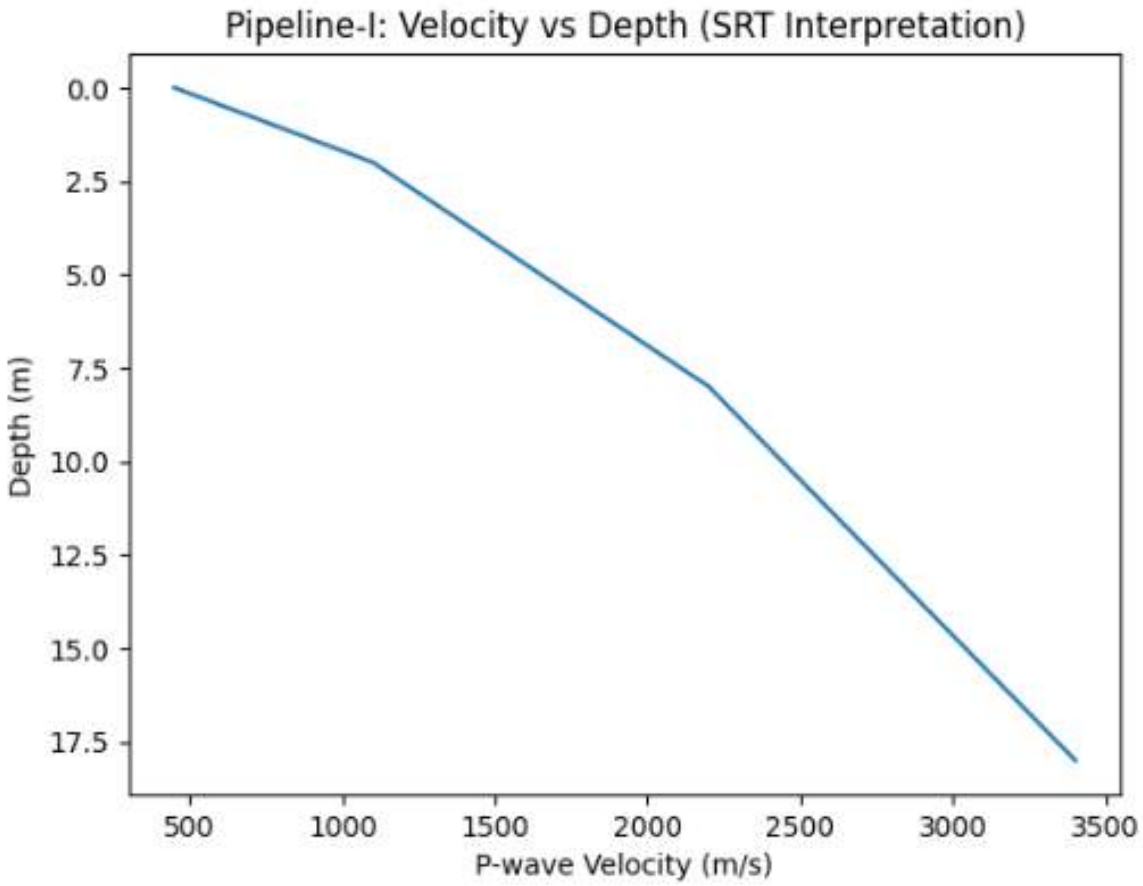


Fig. 16: Graph showing velocity vs depth data of Pipeline-I

The velocity–depth plot defines a three-layer subsurface model beneath the Pipeline-I alignment. Interpretation of first-arrival travel times indicates a three-layer seismic velocity model beneath the Pipeline-I profile.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	**Depth Range (m)**	**P-wave Velocity (m/s)**	**Interpretation**
Layer I	0 to 2m	350 to 550	Soil/Colluvium/Slope Debris
Layer II	2 to 7/8m	1000 to 2000	Weathered and Fractured Rock
Layer III	Greater than 7/8 to 18m	2800 to 3600	Competent Bedrock

A distinct velocity increase is observed at approximately 7–9 m depth, interpreted as the top of competent bedrock**.**

3. Interpretation:

The uppermost low-velocity layer represents loose surficial material, including soil, colluvium, and slope wash deposits. This layer is thin but laterally continuous along the profile. The intermediate velocity layer corresponds to weathered and fractured rock, characterized by reduced seismic velocities due to jointing, weathering, and possible groundwater presence. This layer is of moderate thickness and is expected to exhibit variable excavation behavior. The high-velocity layer, with P-wave velocities exceeding 2800–3000 m/s, is interpreted as competent bedrock**.** This layer likely consists of moderately jointed to relatively fresh rock consistent with the regional Neelum Valley lithology.

i. The upper soil layer is unsuitable for direct pipe support and should be removed during excavation.
ii. The weathered rock zone may require:
    a. Controlled excavation
    b. Local stabilization measures
    c. Possible temporary support in steep sections

iii. Competent bedrock at shallow depth provides favorable conditions for:

a. Anchor blocks
b. Thrust blocks
c. Pipeline stability on steep slopes

Overall, subsurface conditions along Pipeline-I are considered geotechnically favorable for construction, subject to standard excavation and stabilization practices.

b. Interpretation of SRT PL-II:

Profile Location (UTM):

The location of SRT PL-II along the pipeline route is given in UTM coordinates as below:

Easting: 387068 m
Northing: 3832854 m

The profile location is representative of subsurface conditions along the proposed pipeline corridor.

1. Velocity vs Time Graph (SRT PL-II)

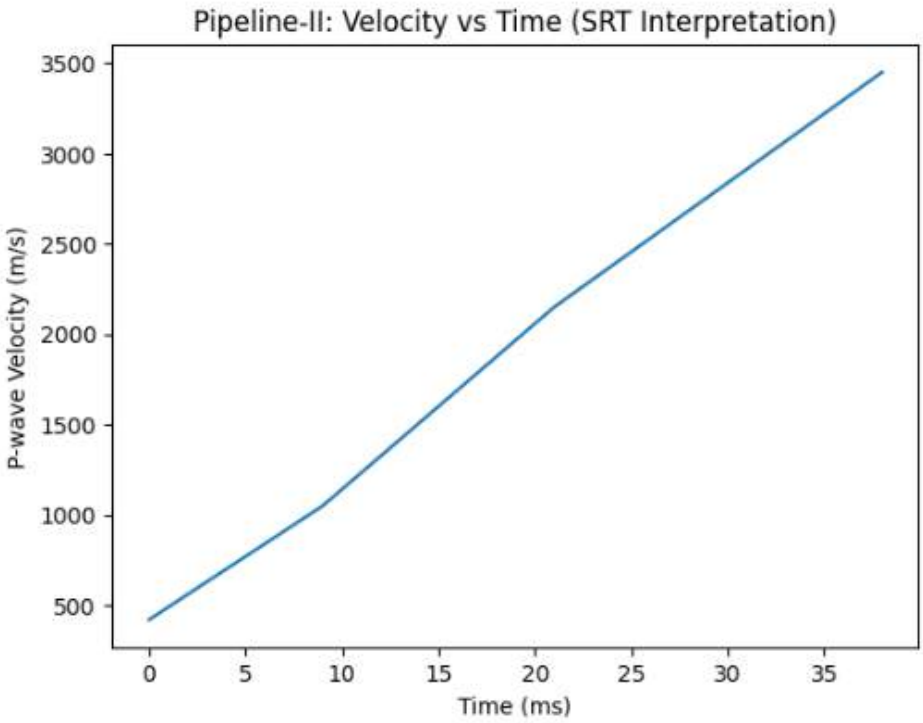


Fig. 17: Graph showing velocity vs time data of Pipeline-II

The velocity–time curve shows a systematic increase in P-wave velocity with increasing first-arrival time. This trend indicates progressively denser and more competent subsurface materials with depth.

For Geotechnical analysis it will be describe as:

- 0–10 ms: Low velocities (420–1050 m/s) representing loose surficial deposits
- 10–22 ms: Moderate velocities (1050–2150 m/s) indicating weathered and fractured rock
- >22 ms: High velocities (>3000 m/s) corresponding to competent bedrock

The clear breaks in slope reflect distinct subsurface layering.

2. Velocity vs Depth Graph (SRT PL-II)

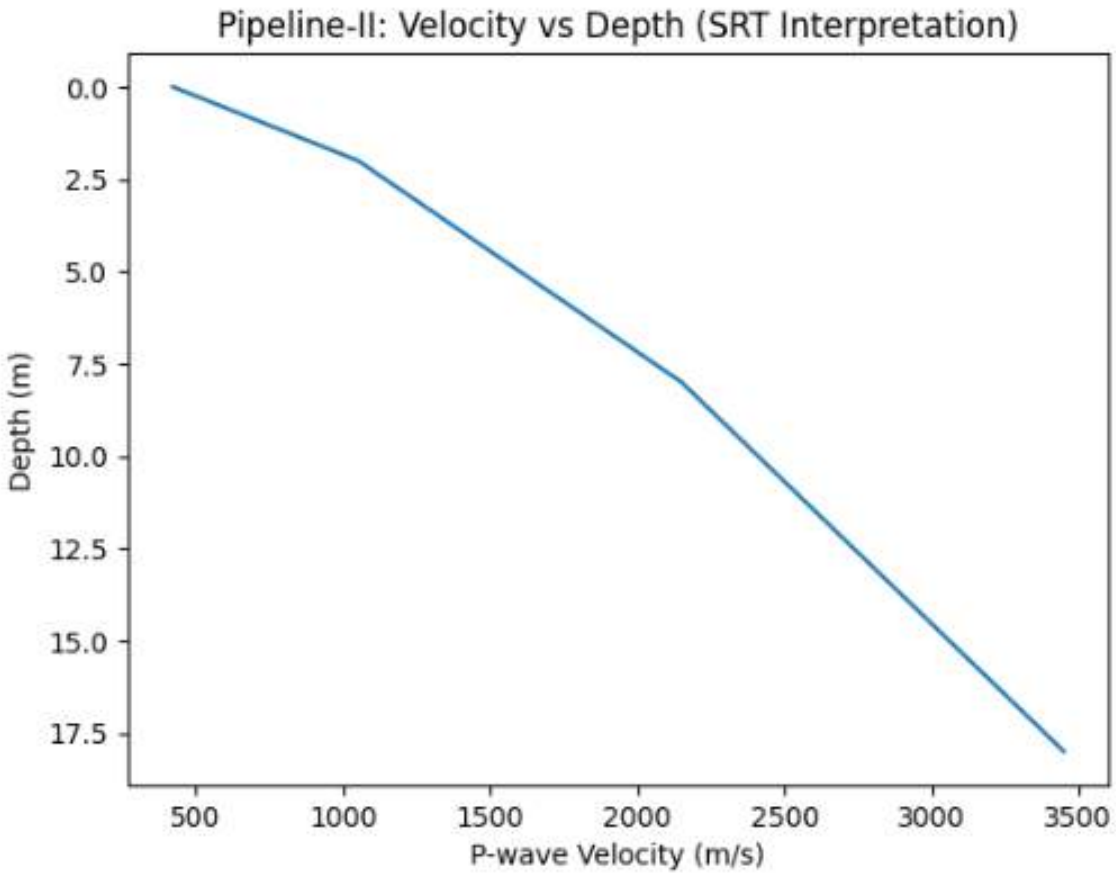


Fig. 18: Graph showing velocity vs depth data of Pipeline-II

The velocity–depth model defines a three-layer subsurface structure beneath the Pipeline-II alignment, with a pronounced velocity contrast marking the top of competent bedrock.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	**Depth Range (m)**	**P-wave Velocity (m/s)**	**Interpretation**
Layer I	0 to 2m	400 to 600	Soil/Colluvium/Slope Debris
Layer II	2 to 8m	1000 to 2200	Weathered and Fractured Rock
Layer III	Greater than 8 to 18m	2800 to 3450	Competent Bedrock

Depth to bedrock: approximately **7–9 m.**

3. Interpretation:

The near-surface layer consists of loose soil and colluvial material derived from slope processes. This is underlain by a moderately thick zone of weathered and fractured rock, characterized by reduced seismic velocities due to jointing and weathering. Beneath this zone, a high-velocity layer represents competent bedrock, consistent with the regional lithology of the Neelum Valley.

Surficial soil should be removed during trench excavation. The weathered rock zone may require controlled excavation and localized stabilization. Competent bedrock at shallow to moderate depth provides favorable conditions for:

- Pipeline foundations
- Anchor and thrust blocks
- Long-term pipeline stability

SRT Profile Results at Penstock Area:

Seismic Refraction Testing (SRT) was carried out along the Penstock-I alignment to evaluate subsurface conditions for penstock excavation, support, and stability. Two (02) SRT profiles SRT Penstock-I & Penstock-II was acquired along the designated Penstock area, as shown in the map (Figure 19 & 20).

- **Instrumentation:** PASI GEA-24 digital seismograph
- **Number of geophones:** 24
- **Geophone spacing:** 2.0 m
- **Total spread length:** 46 m
- **Energy source:** 10 kg hammer striking metal plate
- **Shot geometry:**
  - First shot at **–3 m** from first geophone
  - Subsequent shots at **3.0 m intervals**
  - Last shot at **51 m**
- **Total shot points:** 17
- **Profile length investigated:** ~51 m

Fig. 19: Location of site for Proposed Penstock Area & Power house of Jagran-IV Hydropower Project

Fig. 20: SRT Profiles at site of Proposed Penstock Area & Power house of Jagran-IV Hydropower Project

a. Interpretation of 1st SRT profile at Penstock area:

The profile traverses the proposed Penstock-I corridor and is representative of subsurface conditions along the alignment.

Profile Location (UTM):

The Penstock-I seismic refraction profile is approximately 51 meters long**,** trending between UTM Coordinates:

- **Start:** 387065 E, 3832684 N
- **End:** 387056 E, 3832627 N

1. Velocity vs Time Graph (SRT Penstock-I)

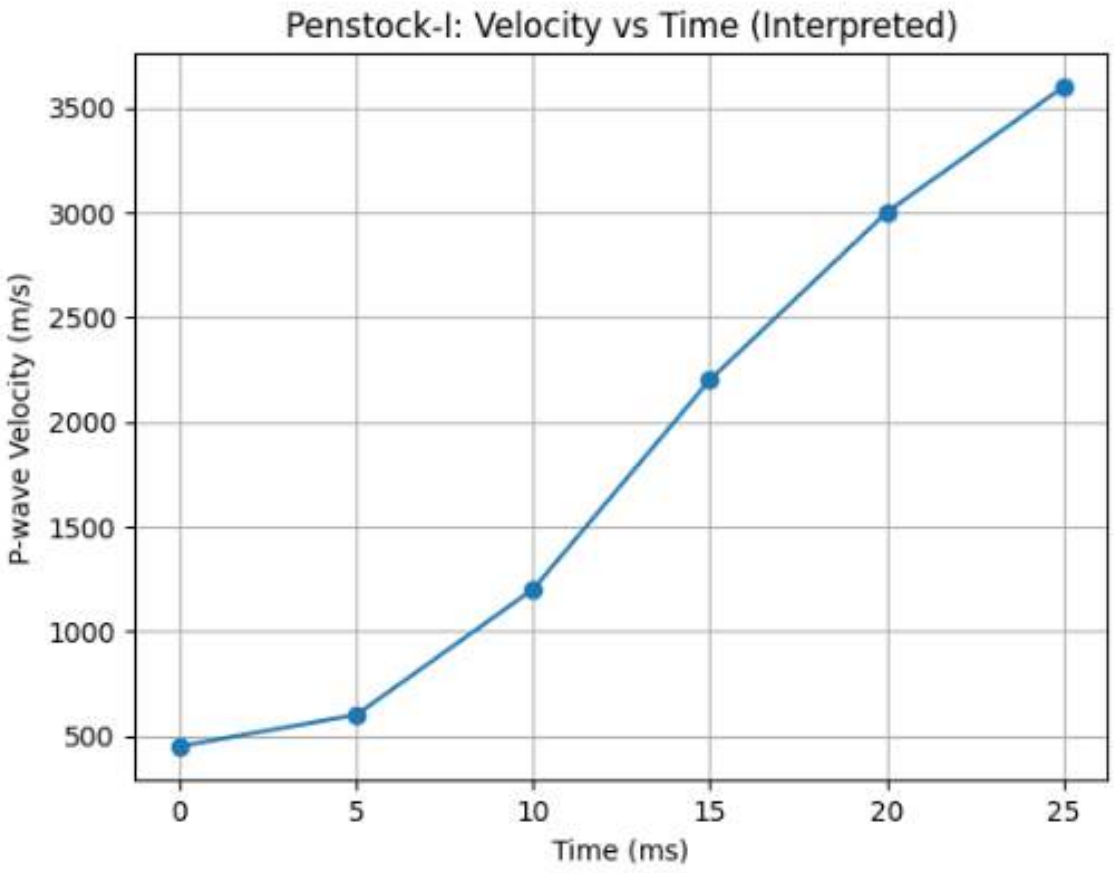


Fig. 21: Graph showing velocity vs time data of Penstock-I

The velocity–time relationship derived from first-arrival picks shows a progressive increase in P-wave velocity with travel time, indicating increasing material competence with depth.

For Geotechnical analysis it will be describe as:

- Low velocities (400–600 m/s) at early arrival times correspond to loose surficial deposits.
- Moderate velocities (1000–2200 m/s) indicate a zone of weathered and fractured rock.
- High velocities (>2800 m/s) represent arrivals from competent bedrock.

Distinct breaks in slope confirm a **three-layer subsurface model**.

2. Velocity vs Depth (SRT Interpretation)

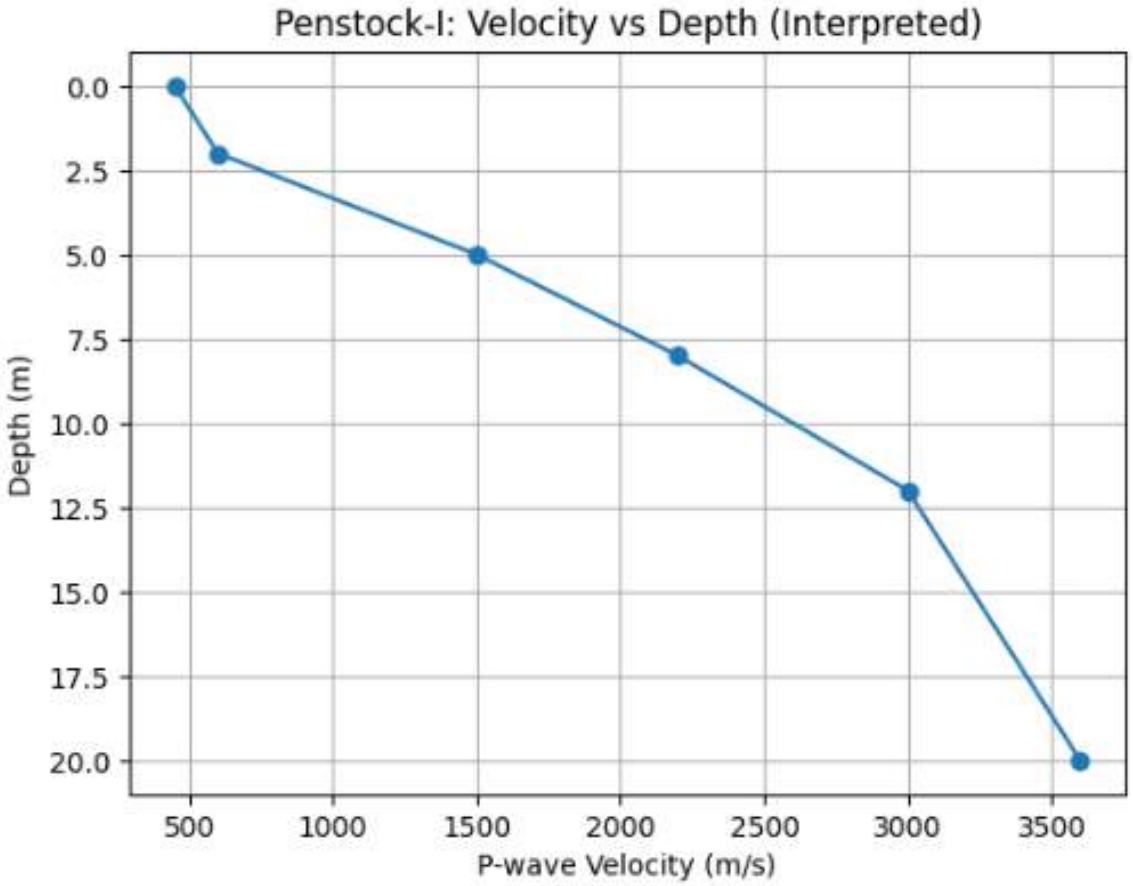


Fig. 22: Graph showing velocity vs depth data of Penstock-I

Interpretation of first-arrival travel times from all 17 shot records indicates a three-layer seismic velocity model**,** consistent with results from Desander and Pipeline profiles.

The velocity–depth model defines the depth and thickness of subsurface layers beneath the Penstock-I alignment.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	Depth Range (m)	P-wave Velocity (m/s)	Interpretation
Layer I	0 to 2m	400 to 600	Soil/Colluvium/Slope Debris
Layer II	2 to 8/10m	1000 to 2200	Weathered and Fractured Rock
Layer III	Greater than 8/10 to 20m	2800 to 3450	Competent Bedrock

A clear velocity contrast marks the top of competent bedrock at approximately 8–10 m depth**.**

3. Interpretation:

The near-surface layer consists of loose soil and colluvial material derived from slope processes. This is underlain by a moderately thick zone of weathered and fractured rock, characterized by reduced seismic velocities due to jointing and weathering. Beneath this zone, a high-velocity layer represents competent bedrock, consistent with regional lithology of the Neelum Valley.

The uppermost low-velocity layer represents loose surficial deposits, including soil and colluvial material derived from slope processes.

The intermediate velocity layer corresponds to weathered and fractured bedrock, affected by jointing and near-surface weathering, resulting in moderate seismic velocities.

The high-velocity layer, with velocities exceeding 2800 m/s, is interpreted as competent bedrock, consistent with the regional geology of the Neelum Valley Surficial soil layer should be removed during excavation.

Overall subsurface conditions along Penstock-I are geotechnically suitable for penstock construction, subject to standard design and stabilization measures.

b. Interpretation of 2nd SRT Profile at Penstock Area:

The profile is aligned along the proposed penstock route and is representative of subsurface conditions expected beneath the pipeline foundation corridor.

- **Profile Location (UTM)**

The Penstock-II seismic refraction profile is approximately **51 meters long**, trending between UTM Coordinates:

- **Start:** 387058 E, 3832686 N
- **End:** 387049 E, 3832631 N

1. Velocity vs Time Graph (SRT Penstock-II)

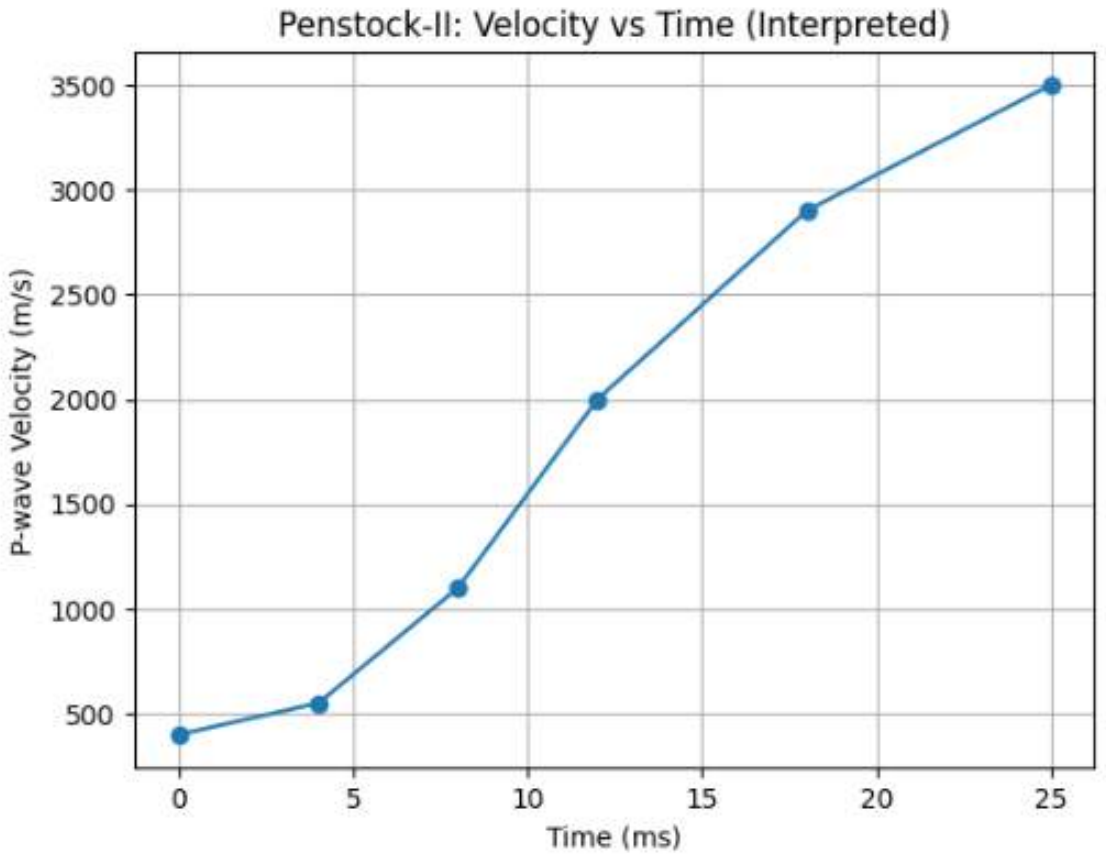


Fig. 23: Graph showing velocity vs time data of Penstock-II

The first-arrival travel-time curves derived from 17 hammer shots along the 51-m Penstock-II profile show:

- A steep initial slope at near offsets, indicating a low-velocity surficial layer
- A distinct break in slope at intermediate offsets, corresponding to a higher-velocity compact layer
- A second linear segment with reduced slope, interpreted as seismic energy refracted from competent bedrock

This multi-segment behavior confirms a three-layer subsurface velocity structure beneath the Penstock-II alignment.

2. Velocity vs Depth Graph (SRT Penstock-II)

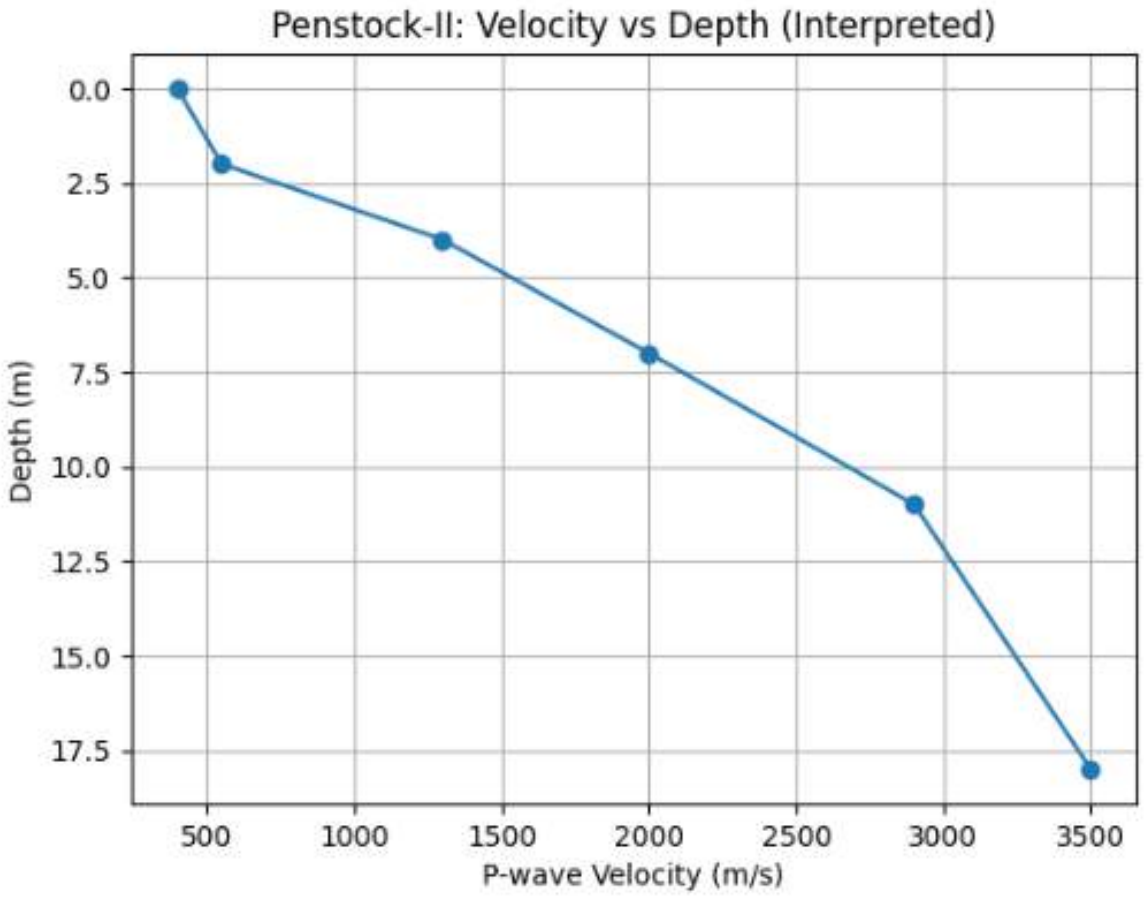


Fig. 24: Graph showing velocity vs depth data of Penstock-II

The velocity–depth relationship indicates:

- Rapid velocity increase within the upper few meters
- Gradual transition to a higher-velocity zone
- A pronounced velocity contrast marking the top of engineering bedrock

The velocity gradient suggests progressively increasing material competence with depth, typical of weathered rock overlying fresh bedrock.

Velocity Time & Velocity Depth Graph Interpretation:

Layers	**Depth Range (m)**	**P-wave Velocity (m/s)**	**Interpretation**
Layer I	1.5 to 2.5m	400 to 600	Loose Soil/Colluvium
Layer II	3.5 to 5.0m	700 to 1100	Dense Gravel/Weathered Rock
Layer III	Up to 6.0m	Greater than 1800	Competent Bedrock

Depth to seismic bedrock approximately 5.5 – 6.5 meters below ground level. Minor lateral variation in bedrock depth is expected along the profile due to natural weathering and topographic influence.

3. Interpretation:

Based on the interpretation of seismic refraction data acquired along the Penstock-II alignment using a PASI Gea-24 seismograph, the subsurface is interpreted to comprise three distinct layers. The uppermost layer consists of loose to moderately compact soil material with low seismic velocities, representing recent surficial deposits. This layer is underlain by a second layer of higher seismic velocity, interpreted as dense gravelly material or weathered rock, exhibiting improved mechanical competence. The third layer is characterized by significantly higher seismic velocities and is interpreted as competent bedrock. The depth to bedrock along the profile varies between approximately 5.5 and 6.5 meters. From an engineering perspective, the shallow soil cover and relatively uniform bedrock depth indicate **favorable foundation conditions** for penstock installation. However, localized over-excavation may be required where loose surficial materials are encountered. No major weak zones or anomalously low-velocity pockets were detected along the investigated alignment.

7. CONCLUSION

Desander I, II & III

- The surficial layer is unsuitable for direct foundation support and would require removal or treatment.
- The weathered rock zone may present require controlled excavation and local stabilization measures.
- Competent bedrock at approximately **10–12 m depth** is considered suitable for supporting hydropower structures, subject to confirmation by borehole investigations & geotechnical investigations.
- The seismic results provide a reliable preliminary estimate of bedrock depth for feasibility-level planning.
- The consistency of results across all three profiles increases confidence in the interpreted subsurface model.

Pipeline I & II

- The surficial soil layer is unsuitable for direct pipeline support and should be removed during trench excavation.
- The weathered rock zone may require controlled excavation and local stabilization, particularly on slopes.
- Competent bedrock is encountered at approximately **7–9 m depth**, providing suitable support for pipeline foundations and anchor blocks where required.
- The relatively shallow depth to bedrock is favorable for pipeline stability but may necessitate controlled blasting during construction.

Penstock I & II

- Suitable for **penstock foundation after removal of loose overburden**
- Bedrock encountered at **shallow to moderate depth**
- Minimal geotechnical risk anticipated
- The surficial soil layer is unsuitable for direct penstock support and should be removed during excavation.

- The weathered rock zone may require:
    - Controlled excavation
    - Local stabilization and anchoring
    - Careful slope management in steep sections
- Competent bedrock encountered at **8–10 m depth** provides:
    - Favorable foundation conditions for penstock supports
    - Suitable horizons for anchor blocks and thrust restraints

8. REFERENCES

- Viengthong, X., Vu, D.M., Nguyen, A.D. and Vu, M.T., 2020. Seismic Refraction Exploration for Groundwater Potential Evaluations: A Case Study of Vientiane Province, Laos. *VNU Journal of Science: Earth and Environmental Sciences*, *36*(4).
- Telford, William Murray, Lloyd P. Geldart, and Robert E. Sheriff. *Applied geophysics*. Cambridge university press, 1990.
- Kearey, Philip, Michael Brooks, and Ian Hill. *An introduction to geophysical exploration*. Vol. 4. John Wiley & Sons, 2002.
- Zhu, Xianhuai, and George A. McMechan. "2-D tomographic imaging of velocities in the Wichita uplift-Anadarko basin region of southwestern Oklahoma." *Bulletin of the Seismological Society of America* 79, no. 3 (1989): 873-887.
- Stefani, Joseph P. "Turning-ray tomography." *Geophysics* 60, no. 6 (1995): 1917-1929.
- Lo, Tien-when, and Philip L. Inderwiesen. *Fundamentals of seismic tomography*. Society of Exploration Geophysicists, 1994.
- Zhang, Jie, and M. Nafi Toksoz. "Nonlinear refraction traveltime tomography." *Geophysics* 63, no. 5 (1998): 1726-1737.
- Osemeikhian, J. E., and M. B. Asokhia. "Applied geophysics for engineers and geologists." *Saintos service Ltd Lagos* (1994).
- Cardarelli, Ettore, and Rita De Nardis. "Seismic refraction, isotropic anisotropic seismic tomography on an ancient monument (Antonino and Faustina temple AD 141)." *Geophysical Prospecting* 49, no. 2 (2001): 228-240.
- Azwin, I. N., Rosli Saad, and M. Nordiana. "Applying the seismic refraction tomography for site characterization." *APCBEE procedia* 5 (2013): 227-231.
- Viengthong, Xayavong, Duc Minh Vu, Anh Duong Nguyen, and Minh Tuan Vu. "Seismic Refraction Exploration for Groundwater Potential Evaluations: A Case Study of Vientiane Province, Laos." *VNU Journal of Science: Earth and Environmental Sciences* 36, no. 4 (2020).
- Akingboye, Adedibu Sunny, and Abimbola Chris Ogunyele. "Insight into seismic refraction and electrical resistivity tomography techniques in subsurface investigations." *Rudarsko-geološko-naftni Zbornik* 34, no. 1 (2019).

4. PROJECT LAYOUT AND HYDRAULIC DESIGN REVIEW

4.1 General

This chapter presents the hydraulic design of various structures for the layout selected during the site visit dated 15 to 19th October 2025 of Jagran IV Hydropower Project. The study comprises hydraulic design of Overflow weir, under sluices, energy dissipation arrangements, power intake, connecting channel, headrace pipe, power house layout and debris barrier.

4.2 Design Philosophy

The proposed project layout is planned on the left bank of Jagran River with diversion weir, lateral intake, sandtrap, headrace pressure pipe, surface powerhouse & tailrace discharging back into Jagran River. The access road to weir & powerhouse sites would be improved.

In order to develop small reservoir and to divert river water towards power waterways a 5 m high diversion weir has been proposed. Based on topographic & geological site features an ungated concrete weir is selected as an appropriate diversion structure for the project.

Keeping in view hydrological analysis, socio-environmental setting of the project area, and power demand the crest level of the overflow weir is determined at an elevation of 2254.00 m. The river bed level at the dam site is 2249.00 m which implies that weir height is 5 m above the river bed level.

The weir headworks structure has been designed to safely pass a 1000-year return period flood (954 m^3/s) and for this purpose an uncontrolled overflow weir of 55 m with 2 No's of Undersluices each having width and height of 5 m are proposed.

In order to ensure effective flushing of the small reservoir and to keep power intake area free from sediment deposition, undersluices are oriented on left side of the river near the power intake. Overflow weir is sized to pass 67% of design flood at maximum flood level of 2256.90 m while the remaining discharge of 33 % shall pass through the undersluices section. For sizing of overflow weir & Undersluices, the latest updated guidelines of US Army Corps of Engineers (USACE), US Bureau of Reclamation (USBR), and state of the art design literature is utilized.

For the purpose to divert river water towards power waterways, power intake is proposed on the left bank of the Jagran river. The intake is designed to allow design discharge of 16 m^3/sec for hydropower and discharge of 3.2 m^3/sec for flushing of Sandtrap. The total design discharge of intake is19.2 m^3/sec. Invert level of the power intake is selected 2.65 m above the lowest river bed elevation at the weir axis i.e., 2249.00 m. The Power intake is 7.5 m wide with 0.5 m pier in between and opening height is 3.90 m. At the upstream face, trash racks are provided across the intake opening to prevent the entry of floating debris and logs. The trash racks are inclined at an angle of 80° to horizontal to reduce head losses and to facilitate cleaning with a trash rack machine installed at an elevation of 2257.94 m. Immediately downstream of the trash rack, the intake structure widens and smoothly transitions into the conveyance section control section of size 3.5 m x 2.95 m. Stoplogs and Vertical lift gate are provided in series with the control section. The stoplogs are primarily intended for dewatering and maintenance of the intake and

downstream channel, whereas the vertical lift gate serves as the main control and emergency closure device. For Hydraulic design of power intake, guideline of American Society of Civil Engineers (ASCE) has been adopted.

Power intake is connected to rectangular connecting channel through 83.50 m cut and cover conduit of size 3.5 m x 2.95 m which is of reinforced concrete type.

The connecting channel is designed for gravity flow; the bed slope of the connecting channel is 1 in 800 and flow velocity is 2.36 m/sec for the design discharge of 19.2 m^3/sec. The bed level at the inlet of connecting channel is 2251.65m and at the end is 2251.55 m.

At the downstream end of the connecting channel, the flow is transitioned through a gradual horizontal expansion of 33° on either side, resulting in an overall width of 8.80 m. At the inlet of the sand trap, two vertical lift gates, each having size of 4.3 m × 3.2 m, are provided to regulate the discharge into the individual sand trap chambers. After the gated section, the structure further widens 27º on each side expanding to total internal width of 14.60m of Sandtrap. The total length of the inlet transition of sandtrap is 11.10 m.

Two sand trap chambers have been proposed, each having a clear width of 7.0 m and separated by an internal dividing wall of 0.60 m thickness. The sand trap has been sized to remove sediment particles of 0.25 mm, which has been adopted as the critical particle size for the project. The effective length of the sand trap chamber is 92.2 m, which provides adequate detention time for the settlement of the design sediment size. At the inlet section, the internal vertical height of the chamber, measured from the soffit to the top of the hopper, is 7.65 m. Each chamber is provided with a hopper of 3.0 m depth, with side slopes of 1V:1H to facilitate effective sediment collection and smooth flow towards the flushing system. A flushing channel of rectangular cross-section, 1.0 m × 1.0 m, is provided at bottom of each hopper to evacuate settled sediments. The flushing channel is laid with a longitudinal slope of 2% to ensure self-cleansing conditions during flushing operations. Two sand flushing gates will be required having width of 1 m & with a height of 1 m at the end of flushing channel. The sand flushing pipes from each chamber are combined to form a single flushing pipe of 1 m dia which carries the flushed sediment from each chamber towards the river. The length of flushing pipe is 40 m.

At the downstream end of the sand trap, a water collection chamber has been proposed with a length of 10 m and a width of 14.60 m. Two outlet gates are provided at the end of the chamber, each having a clear width of 7.2 m and a height of 3.7 m, to regulate the flow toward the conveyance system.

At the bottom of the downstream water collection chamber, a headrace pipe of 2.40 m diameter is provided at an invert elevation of 2242.10 m. The entrance to the pressure pipe is well-rounded and designed with adequate submergence to prevent air entrainment and the formation of vortices, ensuring smooth and efficient flow into the headrace steel pipe.

A buried steel headrace pipeline of 2.4 m diameter runs along the left bank of the Jagran River, generally following the existing road alignment. The total length of the headrace pipe is approximately 2,996 m. The pipe wall thickness varies along the alignment from 10 mm to 22 mm and is based on static head and head due to water hammer. To minimize hydraulic head losses

and ensure smooth flow conditions, the pipeline has been provided with smooth radius bends along both vertical and horizontal alignments.

At RD 3+100 downstream of the intake, the headrace pipe runs along the ground surface at an inclination of 17° towards the powerhouse, which is located on the left bank of the Jagran River. Downstream of this point, the inclined headrace pipe bifurcates into four separate penstocks, each conveying water to the main inlet valve of a vertical-shaft Francis turbine installed in a surface powerhouse. The project has a gross head of 180.75 m, while the total waterway head losses amount to 14.65 m, resulting in a rated net head of 166.10 m. The installed capacity of the project is 22 MW. **Table 4-1** gives the coordinates of selected weir and powerhouse sites whereas, **Figure 4-1** shows the proposed layout plan of the project.

Table 4-1: Coordinates of Weir and Powerhouse locations

Sites	Easting (m)	Northing (m)
Weir	387132.296	3835744.368
Powerhouse	387059.167	3832626.851

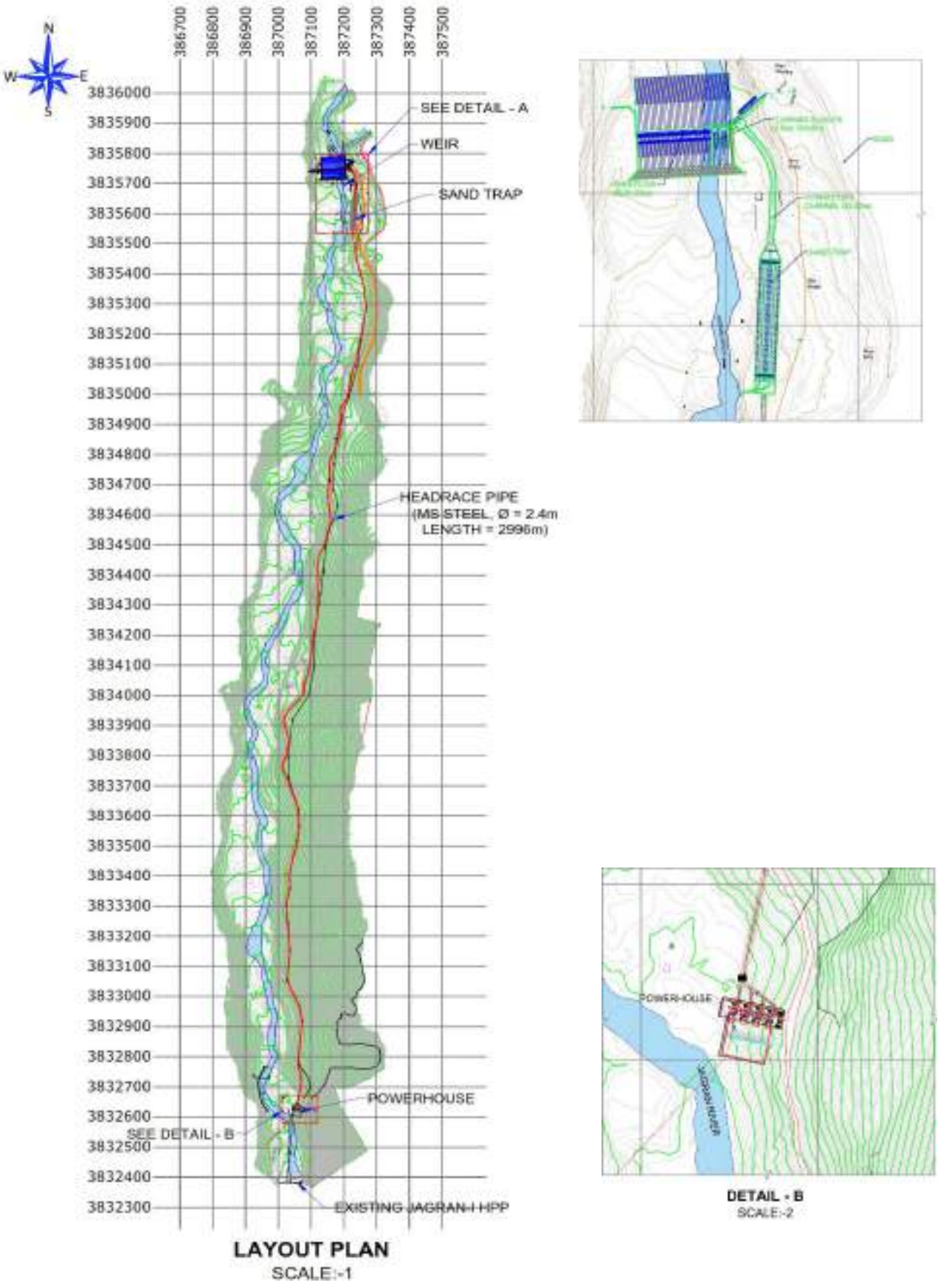


Figure 4-1: Proposed Layout plan of 22 MW Jagran-IV Hydropower Project

4.3 Design Features

The project is planned to utilize the reach of Jagran River upstream of Jagran-I Hydropower project to generate 22 MW power by constructing the following structures:

- Weir of 5 m height above the river bed level accommodating an un-controlled overflow weir and 2 No's of Undersluices with stilling basin as energy dissipation arrangement.
- Uncontrolled overflow weir, 55 m long having crest at an elevation of 2254.00 m. The Type-V stilling basin of 20 m length is proposed.
- 2 No's of Undersluices with radial gate with and invert level of 2249.00 m and size 5 m (W) and 5 m (H), which joins stilling basin of Type-V.
- Power Intake structure on left bank of river to pass total discharge of 19.2 m^3/s (including flushing discharge) through connecting channel to sandtrap.
- Reinforced concrete connecting channel of 3.5 m x 2.95 m size to convey discharge from intake to Sandtrap. The length of connecting channel is 83.50 m.
- Two sand trap chambers (92.2 m x 7 m) to remove sediment particles of 0.25 mm.
- Buried Headrace pipe (steel pipe) with internal diameter of 2.40 m and length of 2,996 m, which branches into four penstock pipes each leading to main inlet valve of vertical axis turbine units.
- Branch pipe of 1.2 m dia and 10 m length.
- Surface power house with four vertical shaft Francis turbines, each with separate Pressure relief valve.
- Debris barrier upstream of weir.

4.4 River Bed Profile

The average riverbed slope of the Jagran River within the reach developed for the Jagran-IV Hydropower Project as shown in **Figure 4-2** is approximately 5.3%, indicating a steep gradient characteristic of mountainous river systems.

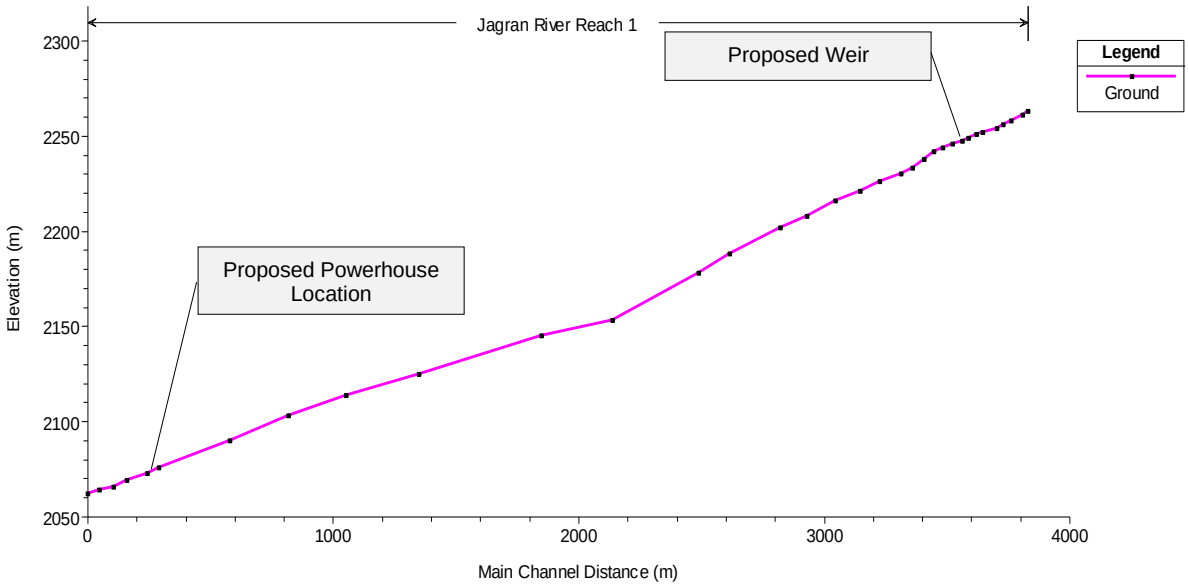


Figure 4-2: River bed profile of Jagran River within study reach

4.5 River Water Surface Profile Analysis

For developing the rating curves at various locations in the study area, latest updated version of HEC-RAS (6.6) developed by USACE has been utilized. Survey cross sections at various locations were prepared from the topographic survey. **Figure 4-3** shows the satellite image of the Jagran river with cross sections marked on it. The purpose of the analysis was to develop rating curve at the location downstream of the weir for designing the energy dissipation arrangements, for design for fixing various levels of Turbine and Powerhouse Building. The method used and assumptions made in development of river rating curve at various locations are described in the following sections.

Figure 4-3: HEC-RAS model showing marking of river cross sections

4.5.1 HEC-RAS Analysis

For the study reach 34 No's of cross section were modelled in HEC-RAS. The selected manning's roughness coefficient of the river channel is 0.045 and based on guidelines provided in open channel Hydraulics by VEN TE CHOW for mountainous streams. The model covers

approximately 3.8 km reach of River. River rating at Stilling basin and Powerhouse site is shown in **Figure 4-4** and **Figure 4-5** given below.

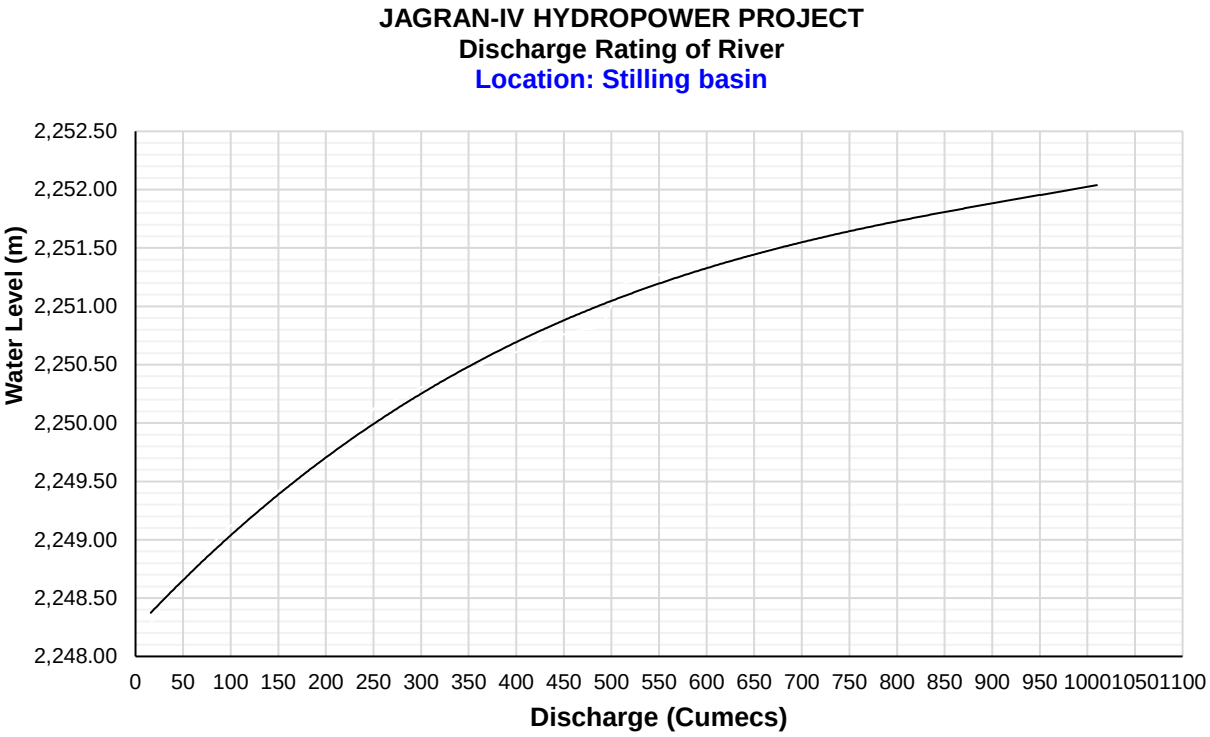


Figure 4-4: River discharge rating at Stilling basin location

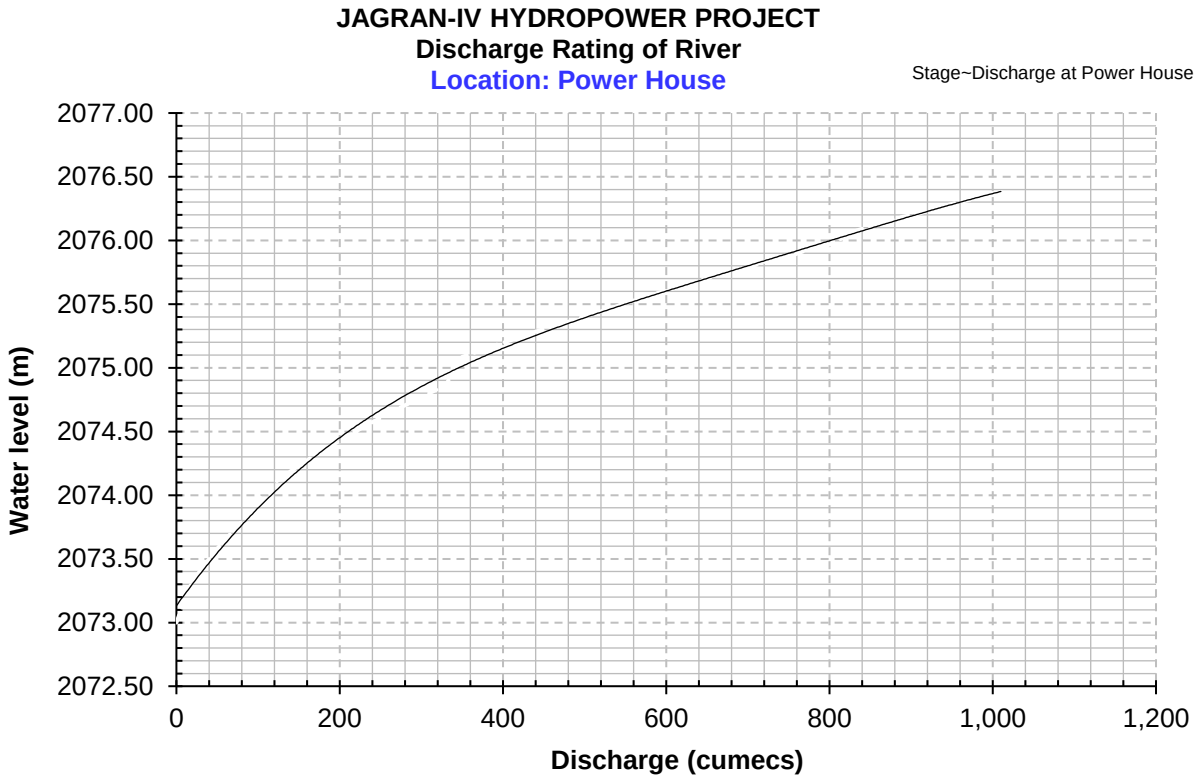


Figure 4-5: River discharge rating at Power house location

4.6 Overflow Weir

An uncontrolled overflow weir with undersluices has been selected for passing the flood discharges and to fulfil the flushing requirements. The weir is structurally safe and hydraulically adequate to pass the flood in excess of the under-sluices capacity or being non-operational. A stilling basin has been provided to dissipate the energy of water and release it downstream without any damages to the weir and allied structures.

Ogee-crested weir is designed to pass discharge that create not more than 2.90 m of surcharge above normal operating level of 2254.00 m. The surcharge of 2.90 m is selected as maximum limit to avoid serious social and environmental problems. For the selected dimension of the weir, its discharge capacity is 602 m^3/sec at maximum flood level of 2256.90 m. It implies that overflow spillway will pass 67% i.e., 602 m^3/sec of the design flood of 954 m^3/sec. So, remaining 33% discharge of 352 m^3/sec will be passed through undersluices. The basic design parameters are;

Overflow weir Crest Elevation	=	2254.00 m
Uncontrolled weir width	=	55.00 m.
River Bed Level	=	2249.00 m
No. of bays	=	01 No.
Upstream slope of spillway profile	=	Vertical
Downstream of spillway profile	=	1:1 (V: H)

All hydraulics and structural analyses followed well used and accepted standards such as those produced over the years by the US Bureau of Reclamation (USBR) and contained in manuals such as the Design of Small Dams (USBR, 1987), Engineering Monograph No. 25 (Peterka, 1984) and USACE etc.

4.6.1 Design Criteria

4.6.1.1 Selection of Design Flood

Selection of design floods for weir and powerhouse locations have been discussed in detail in Section-2. The selected design flood for weir and powerhouse sites are 954 m^3/sec and 979 m^3/sec respectively.

4.6.1.2 Hydraulic Conditions

Weir Crest Structure

For design assessment of the spillway crest structure and calculation of discharge capacity, the USACE EM-1110-2-1603 suggests considering the following effects;

- Effects of head on overfall coefficient and hydraulic effective width
- Effect of abutment and pier shape on hydraulic effective width.

Weir Chute Roughness

For spillway design assessment, Manning's roughness and value of n = 0.013 is adopted as suggested in "Open Channel Hydraulics" by V.T. Chow (1959).

Discharge Capacity of Overflow crest

The weir crest has been designed as an uncontrolled ogee. The discharge over a weir crest is determined by using Eq. 4-1 as given below:

$$Q = CL_e He^{3/2} \quad \textbf{Eq. 4-1}$$

Where,

Q = rate of discharge in, cubic meters per second (m^3/sec)

C = Coefficient of discharge

L_e = Effective length of spillway crest (m)

H_e = Effective head on spillway crest (m)

For design of spillway following relationship is true:

$$\frac{H_e}{H_d} > 1 \quad \text{Eq. 4-2}$$

Where H_d is the crest design head, in meters.

Effective Length of Crest

The piers and abutments are integral part of gated ogee spillway, which has been provided to

- Provide access bridge across the spillway
- Improve the approach conditions

The extent of the reduction in crest length depends on the shape of the upstream nose of the pier and abutments. The more streamlined the shape the less is the reduction in the crest length.

The effect of piers and abutments on the hydraulically effective crest width and thus on the spillway discharge capacity is estimated using Eq. below;

$$L = L' - 2(N \times k_p + k_a) \times H_e \quad \text{Eq. 4-3}$$

Where;

L= Effective length of crest, m

L'= Net length of crest, m

N= Number of piers

K_p= Pier contraction coefficient

K_a= Abutment contraction coefficient

H_e= Effective head on crest (m)

Contraction Coefficient

The piers and abutments cause side contraction of the overflow waterway, thus, reducing the effective width of the spillway bay, this also depends on the head over the crest. The contraction coefficients K_p and K_a are affected by the shape of the pier nose and abutment shape respectively. Values of these coefficients are available in publication of Design of Small Dams by U.S.B.R.

Discharge Coefficient

The effect of ogee upstream slope is taken from Design of Small Dams (Figure 9.25). It shows that for vertical upstream slope dams with P/H_o greater than 3.5 the effect on discharge coefficient is negligible. Since the value of P/H_o is 2.30 the value of basic discharge coefficient C_o is 3.94. The effect of head other than design head is taken from Design of Small Dams (Figure 9.24).

Crest Profile

The ogee profile is divided into two parts i.e., quadrant upstream of the crest axis which consists of two circular arcs and the quadrant downstream of the crest axis which consists of a parabolic curve. The downstream quadrant is given by Eq. 4-4;

$$\frac{y}{H_d} = -K\left(\frac{x}{H_d}\right)^n \qquad \text{Eq. 4-4}$$

Where;

X = Distance along x-axis (m)

Y = Distance along y-axis (m)

K, n = Constants

H_d = Design head (m)

The weir section has upstream face slope of 1V:0.33 H and downstream slope of 1V:1H. It is desirable to provide vertical upstream face for weir in order to achieve highest possible value of the discharge coefficient.

The values of constants “n” and “K” for high dams depend on the upstream inclination of the spillway section and the approach velocity. In case of high overflow dams that create big reservoirs, the velocity of approach is very small and the velocity head is usually neglected. The values of the constants have been taken from Figure No. 9.21, Design of Small Dams, Page No.366.

4.6.2 Hydraulic Calculations of Overflow Weir

4.6.2.1 Crest Profile

For determination of shape of upstream quadrant using the values of h_a/H_o the values of constants n, K, X_c/H_o, Y_c/H_o, R_1/H_o& R_2/H_o for vertical upstream slope is taken from above referenced figure and are given below.

K = 0.510

X_c/H_o = 0.226

Y_c/H_o = 0.082

R_1/H_o = 0.557

R_2/H_o = 0.180

n = 1.826

First Circular Curve

Radius: R_1 = 1.212 m

Offset from Crest Axis X_C = -0.492 m, Y_c = -0.178 m

Second Circular Curve

Radius: R_2 = 0.391m

Shape of nappe downstream of the origin is given by Eq. given below;

$$Y=-0.269X^{1.826} \qquad \text{Eq. 4-5}$$

The crest profile of the ogee spillway is connected to the terminal structure by a straight sloping chute. The chute has been given the same slope as the slope of the downstream face of the dam. The coordinates of the tangent point are calculated by taking first derivative of the above equation and equating it to the slope of the chute. The coordinates of the tangent point with reference to the origin (crest axis) are:

X_t = 2.368 m Y_t = -1.297m

Table 4-2 gives the profile data of the downstream curve of the ogee from crest level to the tangent point while **Figure 4-6** shows upstream and downstream profile of weir crest.

Table 4-2: Overflow Weir crest Profile data

X	Y	Elevation	Description
(m)	(m)	(m)	
-0.49	-0.18	2253.82	
-0.33	-0.08	2253.92	
-0.16	-0.02	2253.98	
0.00	0.00	2254.00	**Crest axis**

0.24	-0.02	2253.98	
0.47	-0.07	2253.93	
0.71	-0.14	2253.86	
0.95	-0.24	2253.76	
1.18	-0.37	2253.63	
1.42	-0.51	2253.49	
1.66	-0.68	2253.32	
1.89	-0.86	2253.14	
2.13	-1.07	2252.93	
2.37	-1.30	2252.70	**Tangent Point or start of chute slope**

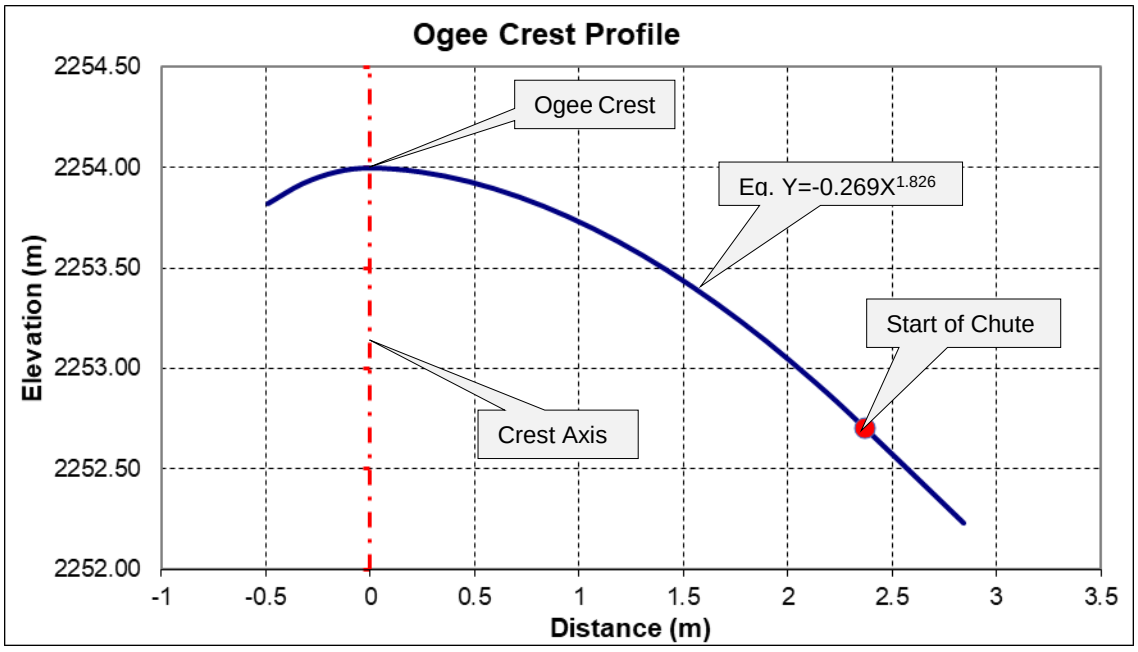


Figure 4-6: Overflow Weir Crest Profile

4.6.2.2 Overflow Weir Discharge Capacity

Overflow spillway has been designed to pass 67 % of design flood while the remaining 33 % will be passed through undersluices. Weir elevation is shown in **Figure 4-7**. Discharge calculations of the uncontrolled weir is presented in **Table 4-3**. Rating curve is presented in **Figure 4-8**.

Normal Reservoir Level = 2254.00 m

Maximum Flood Level = 2256.90 m

River bed level = 2249.00 m

Crest level = 2254.00 m

Total width, B = 55 m

Effective width = 53.84 m

Abutment contraction coefficient (k_a) = 0.20

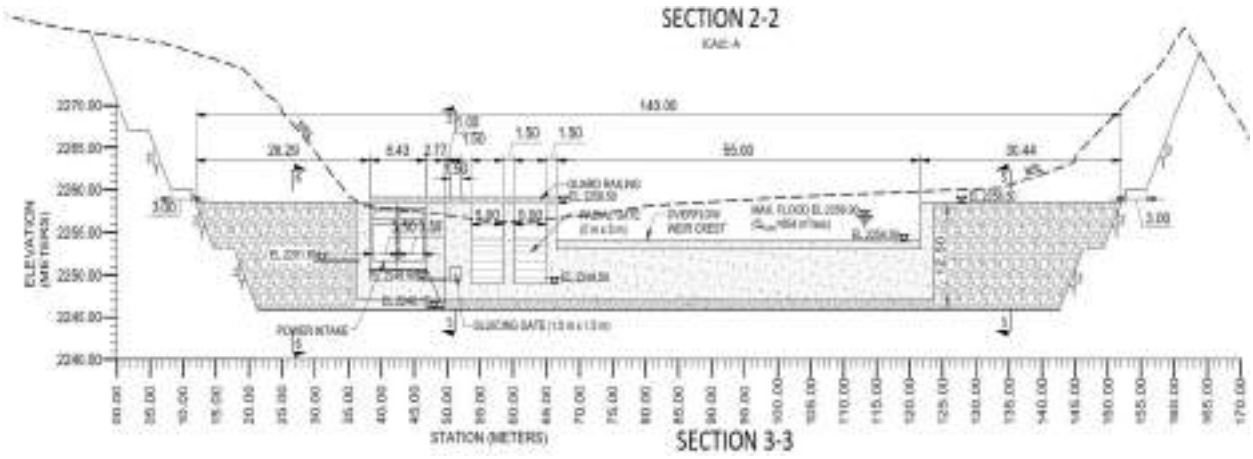


Figure 4-7: Sectional elevation of spillway, undersluices and intake

Table 4-3: Over flow weir discharge capacity calculation

Reservoir Level	H_e	H_e/H_o	Discharge Coefficient (Corrected)		Effective crest length	Discharge
			Other than design head C_e	Corrected coefficient $C=C_o \times C_e$		
(m)	(m)	-	-	(-)	(m)	(cumecs)
2254.00	0.00	0.00	0.78	1.70	55.00	0
2254.10	0.10	0.05	0.80	1.74	54.96	3
2254.20	0.20	0.09	0.82	1.78	54.92	9
2254.30	0.30	0.14	0.83	1.81	54.88	16
2254.40	0.40	0.18	0.85	1.85	54.84	26
2254.50	0.50	0.23	0.86	1.87	54.80	36
2254.60	0.60	0.28	0.87	1.90	54.76	48
2254.70	0.70	0.32	0.88	1.92	54.72	62
2254.80	0.80	0.37	0.89	1.94	54.68	76
2254.90	0.90	0.41	0.90	1.96	54.64	92
2255.00	1.00	0.46	0.91	1.99	54.60	108
2255.10	1.10	0.51	0.92	2.01	54.56	126
2255.20	1.20	0.55	0.93	2.02	54.52	145
2255.30	1.30	0.60	0.94	2.04	54.48	165
2255.40	1.40	0.64	0.95	2.06	54.44	186
2255.50	1.50	0.69	0.95	2.08	54.40	208
2255.60	1.60	0.74	0.96	2.09	54.36	230
2255.70	1.70	0.78	0.97	2.11	54.32	254

Reservoir Level	H_e	H_e/H_o	Discharge Coefficient (Corrected)		Effective crest length	Discharge
			Other than design head C_e	Corrected coefficient $C=C_o \times C_e$		
2255.80	1.80	0.83	0.98	2.12	54.28	278
2255.90	1.90	0.87	0.98	2.14	54.24	304
2256.00	2.00	0.92	0.99	2.15	54.20	330
2256.10	2.10	0.97	1.00	2.17	54.16	357
2256.20	2.20	1.01	1.00	2.18	54.12	385
2256.30	2.30	1.06	1.01	2.19	54.08	413
2256.40	2.40	1.10	1.01	2.20	54.04	443
2256.50	2.50	1.15	1.02	2.22	54.00	473
2256.60	2.60	1.20	1.02	2.23	53.96	504
2256.70	2.70	1.24	1.03	2.24	53.92	536
2256.80	2.80	1.29	1.04	2.25	53.88	569
2256.90	2.90	1.33	1.04	2.26	53.84	602
2257.00	3.00	1.38	1.05	2.28	53.80	636

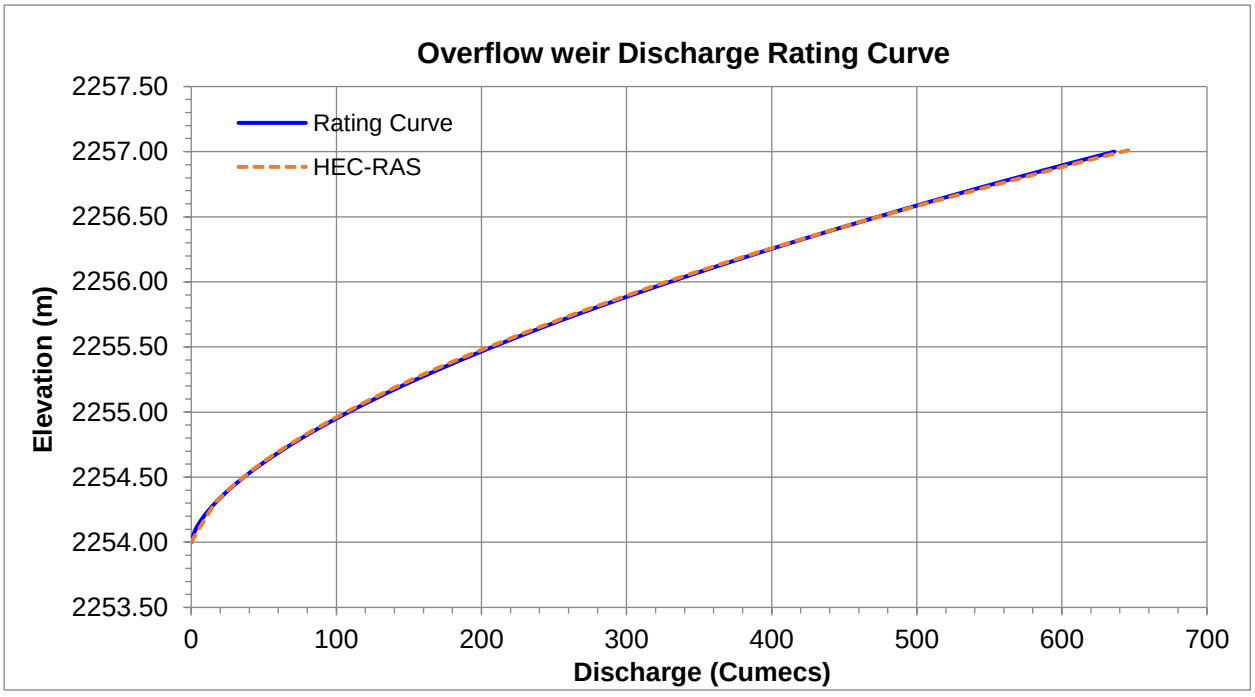


Figure 4-8: Discharge Rating curve of Ungated Overflow weir

4.6.3 Hydraulic Design of Undersluices

4.6.3.1 General

The Weir structure is equipped with two no of undersluices of size 5.0 m (w) x 5.0 m (h). The inverts of the undersluices have been set at an elevation of 2249.00 m and is at the river bed level. Each under sluice is equipped with radial gate for operation and control. The gates will be

operated from the platform at an elevation of 2258.50 m which is accessible through access road near left abutment.

The undersluices will be utilized for following purposes;

- To pass the design flood in combination with overflow ungated weir.
- Sediment flushing to keep the area upstream of the power intakes sediment clean and clear.
- To keep surcharge within permissible limits for avoiding social issues.
- For emptying of pond for maintenance and repair of structures.

For design purpose guidelines of IS-6934 (1998), USACE EM-1602 and Hydraulics of Spillway and Energy dissipaters by R.M. Khatsuria have been utilized.

Figure 4-9 shows the longitudinal section of the weir.

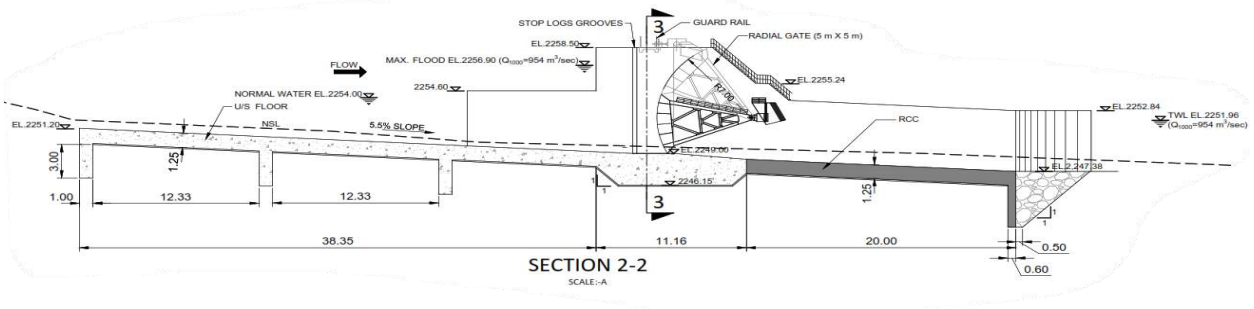


Figure 4-9: Longitudinal section along under sluice

4.6.3.2 Design Criteria

The following section presents the basic design criteria and methodology for the hydraulic design of the Undersluices.

Hydrological Conditions

The proposed configuration of uncontrolled overflow weir is such that is passes 602 m^3/sec of design flood at Maximum flood level of 2256.90 m. Since adopted inflow design flood is 954 m^3/sec, the remaining flow of 352 m^3/sec will be passed through undersluices.

Hydraulic Conditions

a) Discharge Capacity

The discharge through submerged orifice shall be calculated using the following equation;

$$Q = C_d B G_0 \sqrt{2g(H_U - Hd)} \qquad \text{Eq. 4-6}$$

Where;

C_d = Coefficient of discharge (0.60 to 0.80), Adopted value=0.71
B = Width of Radial Gate (m)
G_o = Radial Gate opening (m)
H_u = Upstream Design Water level (m)
H_d = Downstream Tailwater level (m)

Figure 4-10 shows typical sketch of Submerged Orifice:

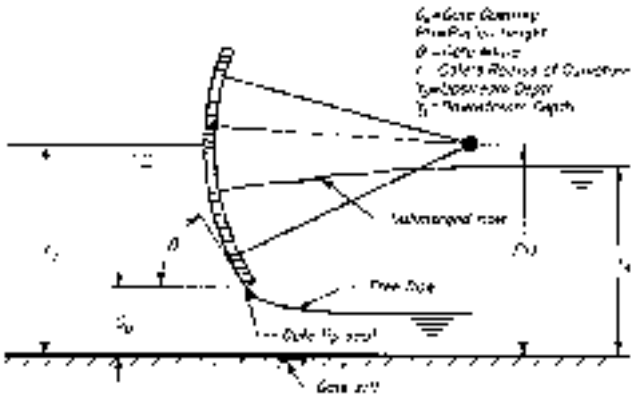


Figure 4-10: Typical Sketch of Submerged Orifice

b) Coefficient of discharge

Coefficient of discharge (0.60 to 0.80), Adopted value=0.71

4.6.3.3 Hydraulic Design of Under Sluice

The hydraulic design of undersluices involves discharge capacity evaluation and design of energy dissipation arrangement and is discussed in subsequent section.

4.6.3.4 Discharge Capacity Evaluation of Undersluices

Bottom Outlet Width, b	=	5.00	m
Height of Opening, h	=	5.00	m
Number of Bottom Outlets	=	2.00	
Maximum Flood Elevation	=	2256.90	m
Normal Reservoir Level	=	2254.00	m
Invert Level of Outlet	=	2249.00	m
River Bed Level	=	2249.00	m
Tail Water at Design Flood	=	2251.96	m
Coefficient of Discharge	=	0.72	
Discharge through single outlet	=	176	m^3/s
Discharge through two No of outlets	=	352.0	m^3/s

4.6.4 Discharge Capacity Evaluation of Weir using HEC-RAS

The discharge capacity of an overflow weir including undersluices has also been evaluated by placing an inline structure in HEC-RAS. **Figure 4-11** shows the layout plan of HEC-RAS model showing an inline structure. **Figure 4-13** shows inline structure with overflow weir and 2 no of undersluices with gates fully open.

Table 4-4 shows summary of results of HEC-RAS model. **Figure 4-12** shows combined discharge capacity curve of overflow and undersluices with gate open.

Figure 4-11: HECRAS Model showing Inline Structure (Overflow weir and Undersluices)

Table 4-4: Discharge Rating of Overflow Weir and undersluices calculate using HEC-Ras (2 No of under sluice gates at full gate opening)

Water Level (m)	Discharge overflow Weir (m^3/s)	Discharge through Undersluices (m^3/s)	Total Discharge (m^3/s)
2249.41	-	16	16
2249.48	-	20	20
2249.62	-	30	30
2249.87	-	50	50
2251.83	-	70	70
2252.35	-	90	90
2252.84	-	110	110
2253.29	-	130	130
2253.73	-	150	150
2254.03	1	169	170
2254.14	6	184	190
2254.24	12	198	210
2254.32	20	210	230
2254.41	28	222	250
2254.49	37	233	270
2254.57	47	243	290
2254.65	57	253	310
2254.72	68	262	330
2254.79	78	272	350
2254.87	90	280	370
2254.94	101	289	390
2255.01	113	297	410
2255.07	125	305	430
2255.14	138	312	450
2255.21	152	318	470
2255.29	169	321	490
2255.38	186	324	510
2255.46	204	326	530
2255.53	221	329	550
2255.61	239	331	570
2255.68	256	334	590
2255.75	274	336	610
2255.83	292	338	630
2255.89	310	340	650
2255.96	328	342	670
2256.03	346	344	690
2256.09	364	346	710
2256.16	382	348	730
2256.22	400	350	750
2256.28	418	352	770
2256.34	436	354	790
2256.40	454	356	810

Water Level (m)	Discharge overflow Weir (m^3/s)	Discharge through Undersluices (m^3/s)	Total Discharge (m^3/s)
2256.50	486	359	845
2256.51	491	359	850
2256.57	509	361	870
2256.62	527	363	890
2256.65	536	364	900
2256.73	564	366	930
2256.80	586	368	954

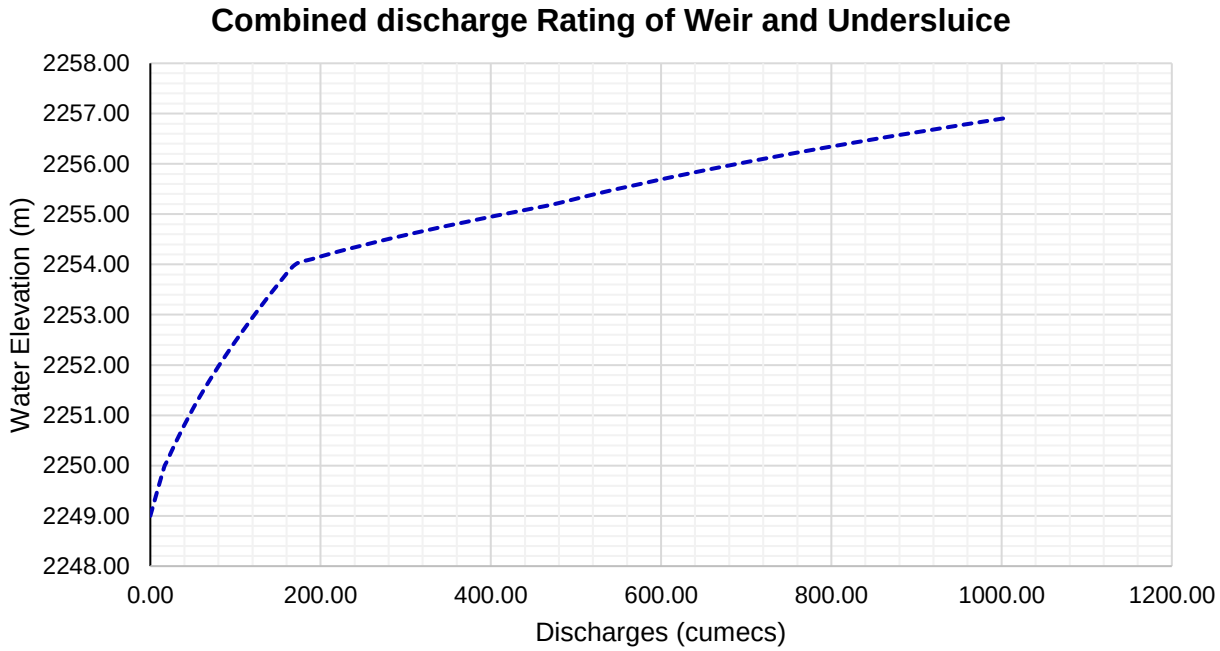


Figure 4-12: Combined Discharge Rating Curve of Overflow weir and Undersluices

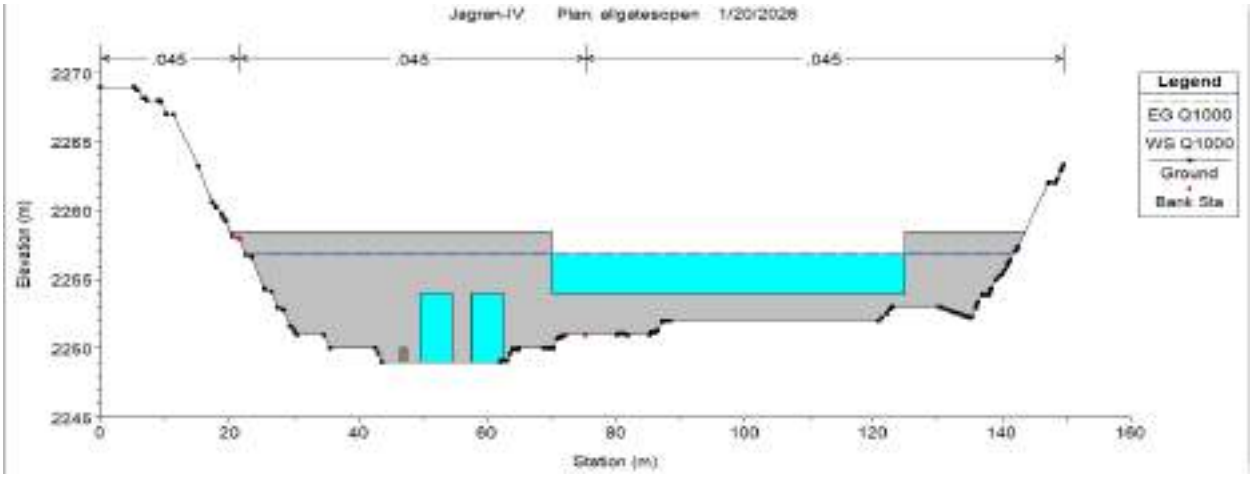


Figure 4-13: HECRAS Model showing Inline Structure (Overflow weir and Undersluices)

4.6.5 Energy Dissipation Structure

4.6.5.1 General

The riverbed downstream of the weir consists of gravels and boulders, and it would erode if the spillway discharges were released directly on to the bed. As such a stilling basin needs to be provided for energy dissipation.

The spillway has been designed considering 1000-year return period flood Q_{1000}=954 m^3/s

Hydraulic routing of the design flood indicates that:

- A portion of the flood is safely passed through undersluices, while 602 m^3/s is conveyed over the overflow weir section.
- Accordingly, the stilling basin is designed for a discharge of 602 m^3/s, representing the maximum flow expected to pass over the weir under extreme flood conditions.

This approach ensures that the energy dissipation system remains adequate, safe, and stable even under rare and extreme hydrological events.

Based on the hydraulic conditions of Jagran River, a USBR Type-V Stilling Basin has been adopted.

4.6.5.2 Approach for Design of Stilling Basin:

The approach to hydraulic design of the stilling basin is as per following guidelines.

- Design of Small Dams by USBR
- EM 1110-2-1603, Engineering and Design - Hydraulic Design of Spillways
- Hydraulic Design of Stilling Basins and Energy Dissipaters, by A. J. Peterka

By assuming a stilling basin floor level calculate flow velocity entering at the glacis of chute by using following formula;

$$V_T = \sqrt{(2g(Z - H/2)} \qquad \text{Eq. 4-7}$$

Where;

V_T = velocity of flow at the toe of glacis (m/s)

Z = fall between upstream flow level and stilling basin top level (m)

H = head over crest including velocity head, m

g = acceleration due to gravity (m/s^2)

Parameters are also shown in **Figure 4-14** given below;

To calculate actual flow velocity (V_A) a relationship between V_A/V_T and Z will be used as shown in Figure -15 of Engineering Monograph no.25 of USBR.

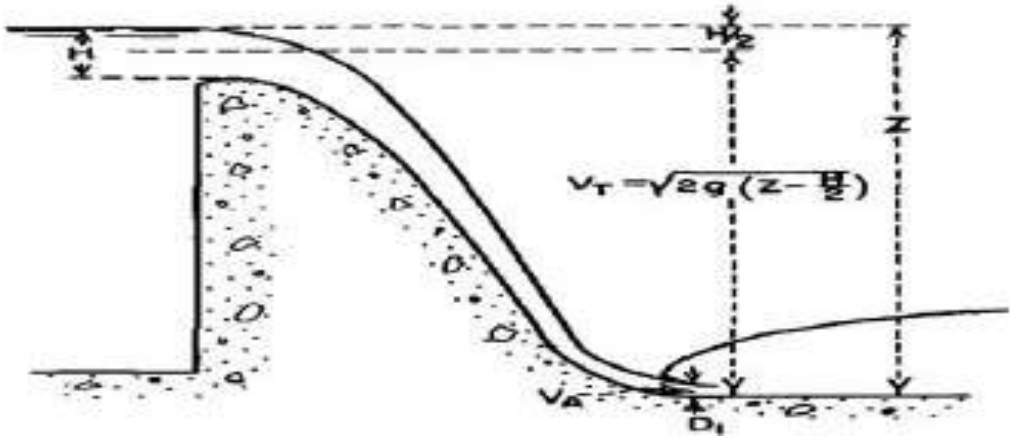


Figure 4-14: Parameters for computation of theoretical velocity at toe of glacis

The pre-jump depth, d_1, will be calculated by using formula:

$$d_1 = q/V_A \qquad \text{Eq. 4-8}$$

Where:

q = discharge intensity (cumecs/m)

Froude no will be calculated using following formula;

$$F = \frac{V_A}{\sqrt{g\ x\ d1}} \qquad \text{Eq. 4-9}$$

For Conjugate depth, d_2 will be calculated using following formula;

$$\frac{d_2}{d_1} = \frac{1}{2\cos\emptyset}\left[\sqrt{\frac{(8F_1^2\cos^3\emptyset)}{1-2Ktan\emptyset}+1}-1\right] \qquad \text{Eq. 4-10}$$

Where;

d_1 = flow depth at the toe of glacis (m)

d_2 = tail water depth above stilling basin (m)

F_1 = Froude number

K = Shape factor (Fig. 34, Hydraulic Design of Stilling Basins and Energy Dissipaters, by A. J. Peterka)

V_A = velocity of flow at the toe of glacis (m/s)

g = acceleration due to gravity (m/s^2)

The length of basin is calculated using graph between Froude no. F_1 and L/d_2 as available in Figure-33 in Hydraulic Design of stilling Basins and Energy Dissipation Structures, (A.J Peterka, EM-25) which is reproduced here as **Figure 4-15**.

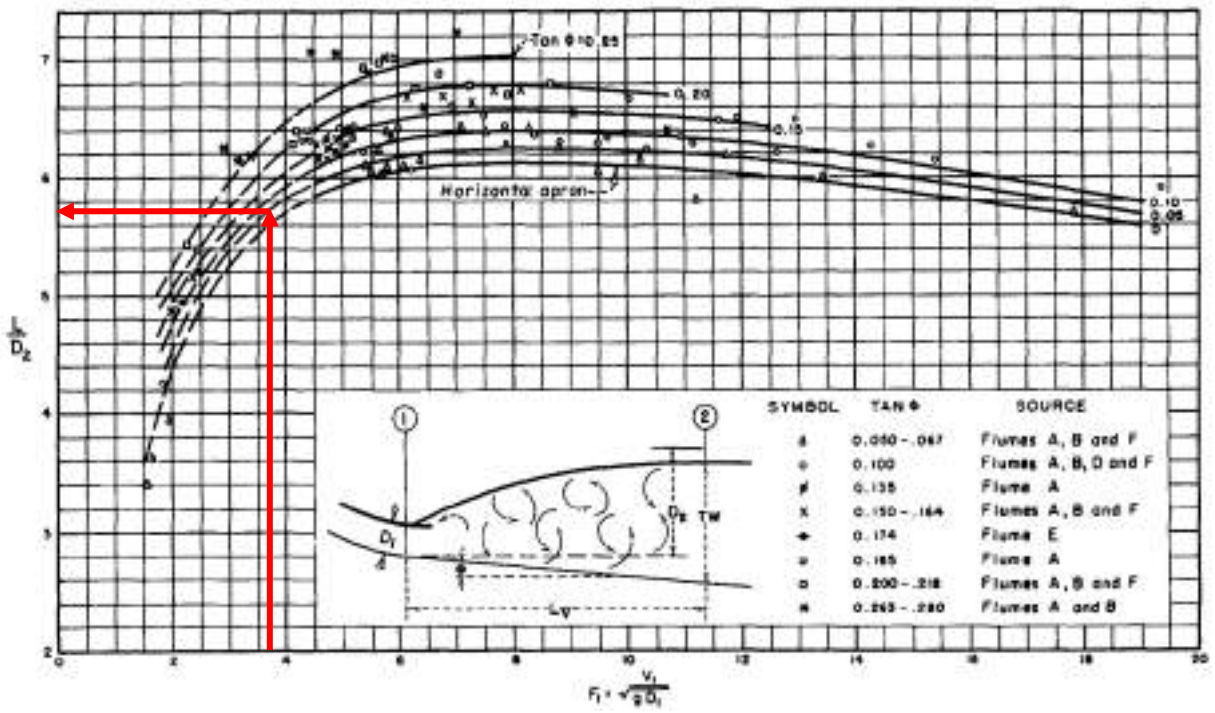


Figure 4-15: Length in terms of Conjugate depth, d_2 (Basin V, Case D)

4.6.5.3 Calculations for stilling basin design of Overflow Spillway

The calculation shown below design data of stilling basin proposed downstream of overflow weir. **Figure 4-16** and **Figure 4-17** shows plan and longitudinal section of spillway.

Discharge (Q_{1000})	=	602 m^3/s (Only Part overflowing from the weir crest is considered at Designed Maximum Flood elevation of 2256.90 m)
Crest width of overflow spillway	=	55.00 m
Crest Level of the weir	=	2254.00 m
Basin Invert at upstream end	=	2248.47 m
Apron slope	=	tanφ = 0.05450
Acceleration due to gravity	=	9.81 m/sec^2
Maximum Flood elevation (M.F.L)	=	2256.90 m
Surcharge (H)	=	2.90 m
Fall from Reservoir to Basin invert (Z)	=	8.43 m
Theoretical Velocity VT	=	11.70 m/sec
VA/VT	=	0.97
Actual Velocity before jump VA = V1	=	11.34 m/sec
Flow depth before jump (d1)	=	0.96 m

Froude No. (F)	=	3.70
Shape Factor	=	3.06
Conjugate Depths Ratio (d_2/d_1)	=	5.77
Depth of flow after Jump (d2)	=	5.56 m
Adopted basin type is Type-V (Case-D)		
L/d2	=	5.74
Length of the stilling basin required (L)	=	31.93 m
Provided Length of Stilling basin (L provided)	=	19.16 m (say 20 m)

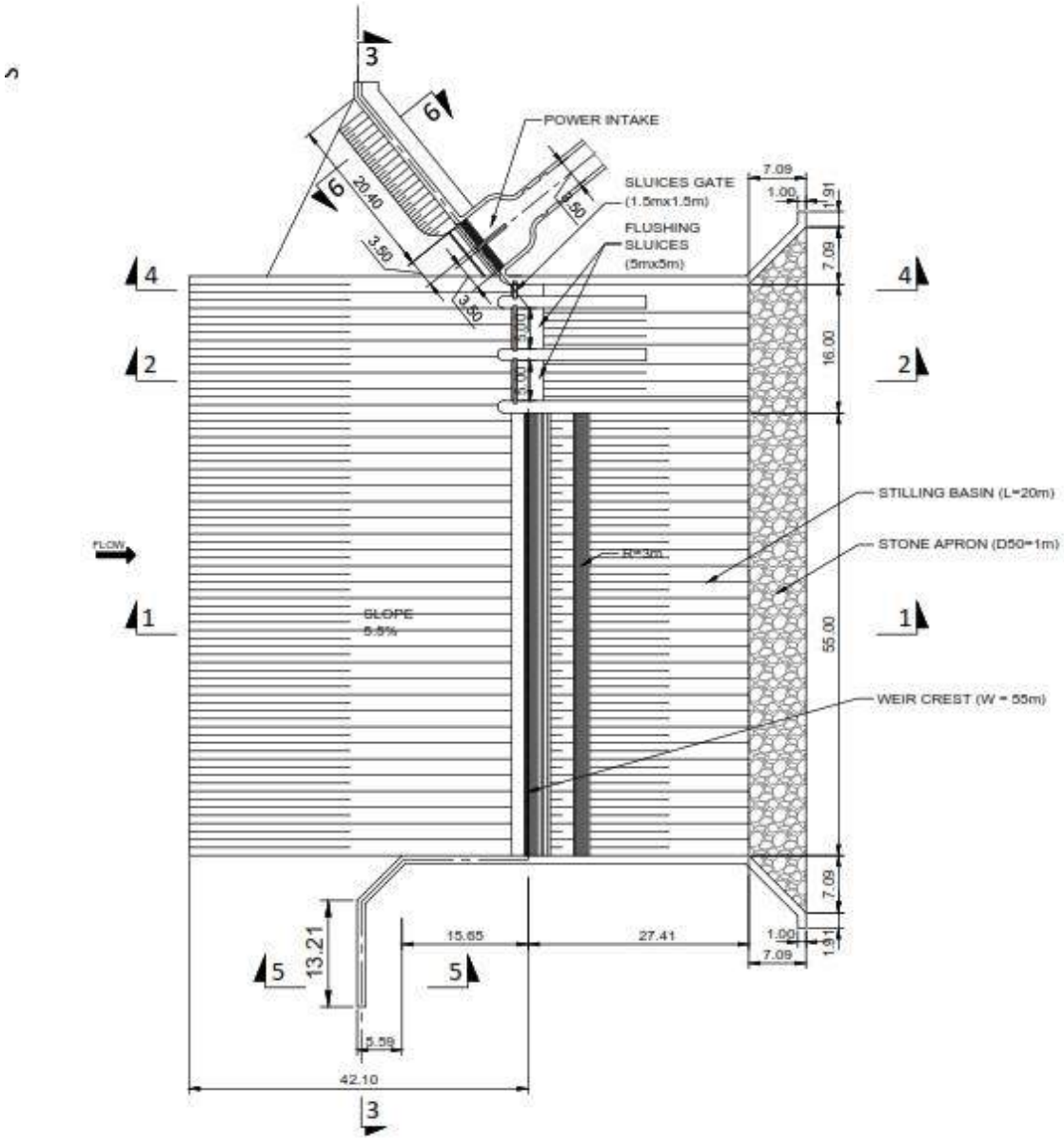


Figure 4-16: Plan of Spillway and Undersluices

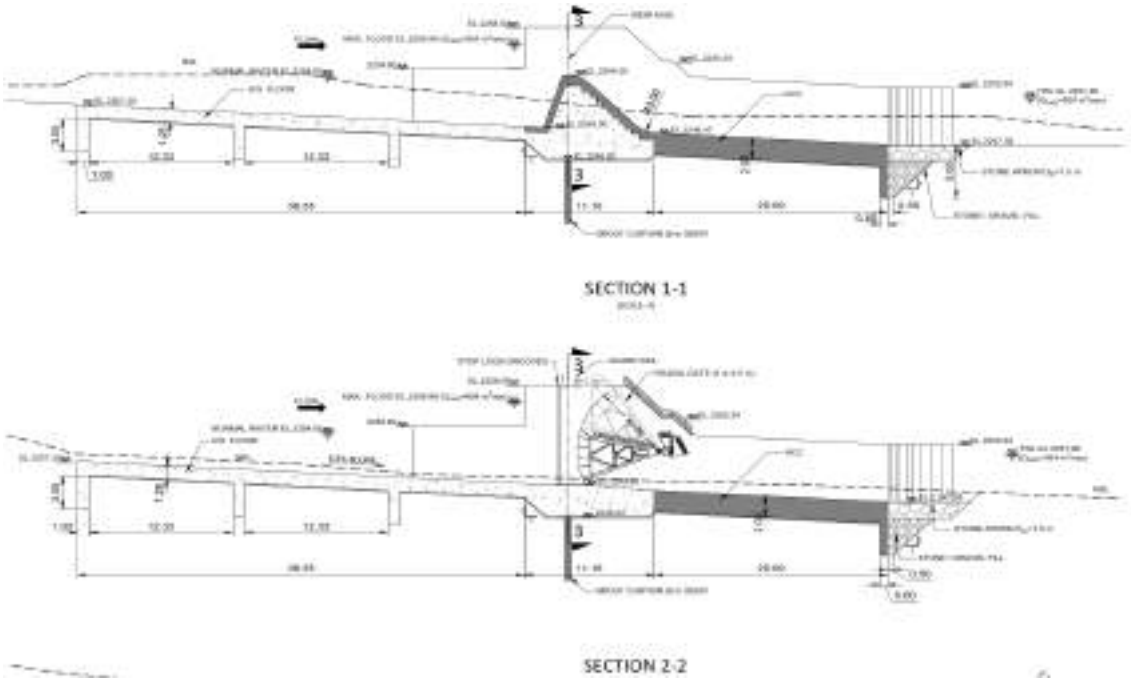


Figure 4-17: Longitudinal section along overflow Spillway

4.6.5.4 Protection Downstream of Stilling Basin

Due to the fact that the proposed length of stilling basin is less than the calculated length by USBR and A.J Peterka, there is a need to provide bed protection downstream of the stilling basin to prevent excessive erosion during extreme events. For the purpose of this study, it is proposed that rip rap of stone having d_{50} = 1 m may be provided for a length of 7 m on d/s of stilling basin. Size of stone apron has been calculated by approaches based on Isbash, USBR and USACE method.

Isbash's Equation

Isbash's equation from HDC 712-1 will be used to estimate the maximum stone size required as downstream apron. The lower limit of the W_{50} stone should not be less than the weight of stone determined using the Isbash's equation given below.

$$V = C \times \left(2g \times \frac{\gamma_s - \gamma_w}{\gamma_w}\right)^{0.5} \times (D_{50})^{0.5} \qquad \text{Eq. 4-11}$$

Where;

V = average flow velocity, ft/s

C (Isbash coefficient) = 0.86 for high turbulence zone and 1.20 low turbulence zone

γ_S = specific weight of stone, lb/ft^3

γ_w = specific weight of water, lb/ft^3

D_{50} = stone diameter, ft

The diameter of a spherical stone in terms of its weight W is estimated using the following equation;

$$D_{50} = \left(\frac{6W}{\pi\gamma_S}\right)^{1/3} \quad \text{Eq. 4-12}$$

USBR method

Alternatively, USBR method can be utilized to estimate the median stone size (D_{50})

$$D_{50} = 0.0122(V_a)^{2.06} \quad \text{Eq. 4-13}$$

Where;

V_a = average flow velocity (ft/sec)
D_{50} = median stone size, ft

USACE Method

$$W = \left(\frac{0.000041 G_S V^6}{(G_S - 1)^3 Cos^3\theta}\right) \quad \text{Eq. 4-14}$$

$$D_{50} = \left(\frac{6W}{\prod\gamma_s}\right)^{1/3} \quad \text{Eq. 4-15}$$

Calculation by above mentioned methods is based on following parameters used. Results obtained are shown in **Table 4-5**.

ISBASH METHOD

Flow velocity V	=	15.26 ft/sec
Stone density ϒs	=	165.00 lb/ft^3 (assumed)
Water density ϒw	=	62.43 lb/ft^3
Turbulence factor (C)	=	0.86 for High Turbulence
Median stone diameter (D_{50})	=	2.97 ft (0.91 m)

USBR METHOD

Median stone diameter (D_{50})	=	0.0122*15.26^2.06= 3.34 ft
	=	1.02 m

ASCE METHOD

Specific gravity of stone (G_s)	=	2.64
Θ	=	60
Weight of stone (W)	=	2464 lb
Stone Size (D_{50})	=	0.92 m
Factor of Safety, FOS used	=	1.20

Table 4-5: Result of Stone size calculations

Method	D_{50} (m)	FOS x D_{50} (m)
ISBASH	0.91	1.09
USBR	1.02	1.22
ASCE	0.94	1.11
Average	0.95	1.11
	Recommended stone size (m)	Say 1 m

4.6.5.5 Calculations for stilling basin design of Undersluices Section

The proposed undersluices section is on the left side of the overflow spillway and is separated from overflow spillway section through a divide wall of 1.5 m width. The overall internal width of undersluices section 11.5 m comprising of 2 gated section each of 5 m width with 1.50 m pier in between. The proposed stilling basin is of type-V and is of 20 m length. The calculated Froude no is 2.20 for maximum discharge capacity of undersluices (352 m^3/s) at Maximum Flood level of 2256.90 m.

The length of basin been computed based on same principles as already explained for main overflow weir section.

4.6.6 Weir Freeboard

4.6.6.1 General

Free Board has been provided on all weir or dams to ensure that overtopping of dam will not result from wind setup, wave action, and uncertainties in analytical procedures and in operation in combination with high reservoir elevations. Freeboard is categorized into “normal freeboard” and “minimum freeboard”. Normal freeboard is the allowance between the crest of the dam and normal reservoir level as fixed by design. The normal freeboard should satisfy the dam safety needs for long term storage and must be adequate to prevent overtopping in case of abnormal and severe wind action of even low probability that may result from unusual sustained winds of high velocity from a critical direction. Minimum freeboard is the difference in elevation between the crest of the dam and the maximum flood level for un-gated spillway.

4.6.6.2 Criteria of Minimum and Maximum Freeboard by USBR

The 1987 edition of Design of Small Dams contains freeboard guidelines dams based on calculated fetch. **Table 4-6** designates the least amount recommended for normal and minimum freeboard.

Table 4-6: Approximation of Normal and Minimum Freeboard (Ref: Design of Small Dam, 1987)

Longest fetch	Normal freeboard (added to the normal water surface)	Minimum freeboard (added to the maximum water surface)
(miles)	(feet)	(feet)
<1	4	3
1	5	4
2.5	6	5
5	8	6
10	10	7

Considering that the effective wind fetch of the reservoir is relatively small (less than 1 mile), wave generation and associated run-up are expected to be limited. Accordingly, a minimum freeboard of about 1.0 m above the Maximum Flood Level (MFL) has been considered adequate for the (N-1) operational scenario, i.e., with one undersluices rendered inoperable. Under the one gate closed flood scenario, the computed maximum flood level is 2257.6 m. Providing a freeboard of 0.9 m above this level results in a weir crest elevation of 2258.50 m.

4.7 Power Intake

4.7.1 General

The Power intake have been oriented on the left bank of Jagran River. Location of power intake is selected to ensure clear water entry into the power waterways and for this purpose it is oriented in proximity of under sluice section.

Power intake consists of an opening of size 7.5 m x 3.9 m which transition to gated section of size 3.5 m x 2.95 m. The intakes will be capable of discharging the total design discharge for the generating units plus 20% extra discharge for flushing the sand trap chambers. The total design discharge of intake is 19.2 m^3/s. Intake section has a set of two gates first working as emergency gate (Stop log) and second gate provided as service gate.

Trash racks cleaning machine will be installed at the intake to prevent entry of large size trash into the channel. The invert of power intake is placed at 2251.65 m corresponding to normal operating level of 2254.00 m. The intake will be controlled by control room accessible from the bridge. Plan and section of Power intake has been shown in **Figure 4-19** and **Figure 4-20**.

4.7.2 Hydraulic Design & Methodology

As the discharge for power generation is being conveyed by gravity flow. The intake is designed as un-submerged intake. As the intake remain unsubmerged then the flow will be open channel. Flow in an open-channel outlet works is similar to that in an open-channel spillway [USBR, Design of Small Dams (DOSD)]. Where unsubmerged radial or slide gates are used, discharges through the control with the gates completely open will be open crest flow as computed by equation given below;

$$Q = CLH^{3/2} \qquad \text{Eq. 4-16}$$

Where;

Q = Discharge

C = Coefficient of Discharge

L = Length of crest (width of opening in this case)

H = Head of water

Here the discharge coefficient is taken as 1.704 (Broad Crested weir, Ref. USBR DOSD).

4.7.2.1 Calculations

The following are the design parameters and calculations relevant to power intake design;

Discharge for Power Generation	=	16 m^3/sec
Design Discharge (including 20% for flushing)	=	19.2 m^3/sec
Invert level of Intake	=	2251.65 m
Normal Operating level	=	2254.00 m
Maximum Flood level	=	2256.90 m
H (head)	=	2.35 m
Width of control section	=	3.50 m
Width of section U/s of control section	=	7.50 m
Coefficient of Discharge	=	1.704
Velocity Head (ha)	=	0.076 m
Discharge Capacity (Q)	=	19.4 m^3/sec >19.2 m^3/sec

The discharge rating for the power intake has been shown in tabular and graphical form in **Table 4-7** and **Figure 4-18** respectively.

Table 4-7: Discharge rating of Power intake

HWL	Head above Crest, H (m)	Specific Discharge at Control Section	Specific Discharge at U/S section	V = q / (Weir Height+ head above crest)	Velocity Head, ha	Effective Crest Length, L (m)	Total Head including velocity head (m)	Q Calculated (cumecs)
2251.65	-	0.00	0.00	0.000	0.000	3.500	0	-
2251.89	0.24	0.19	0.09	0.385	0.008	3.451	0.243	0.7
2252.12	0.47	0.55	0.26	0.545	0.015	3.403	0.485	2.0
2252.36	0.71	1.01	0.47	0.668	0.023	3.354	0.728	3.5
2252.59	0.94	1.55	0.72	0.771	0.030	3.306	0.970	5.4
2252.83	1.18	2.17	1.01	0.862	0.038	3.257	1.213	7.4
2253.06	1.41	2.85	1.33	0.944	0.045	3.209	1.455	9.6
2253.30	1.65	3.60	1.68	1.020	0.053	3.160	1.698	11.9
2253.53	1.88	4.39	2.05	1.090	0.061	3.112	1.941	14.3
2253.77	2.12	5.24	2.45	1.156	0.068	3.063	2.183	16.8
2254.00	2.35	6.14	2.86	1.219	0.076	3.015	2.426	19.4

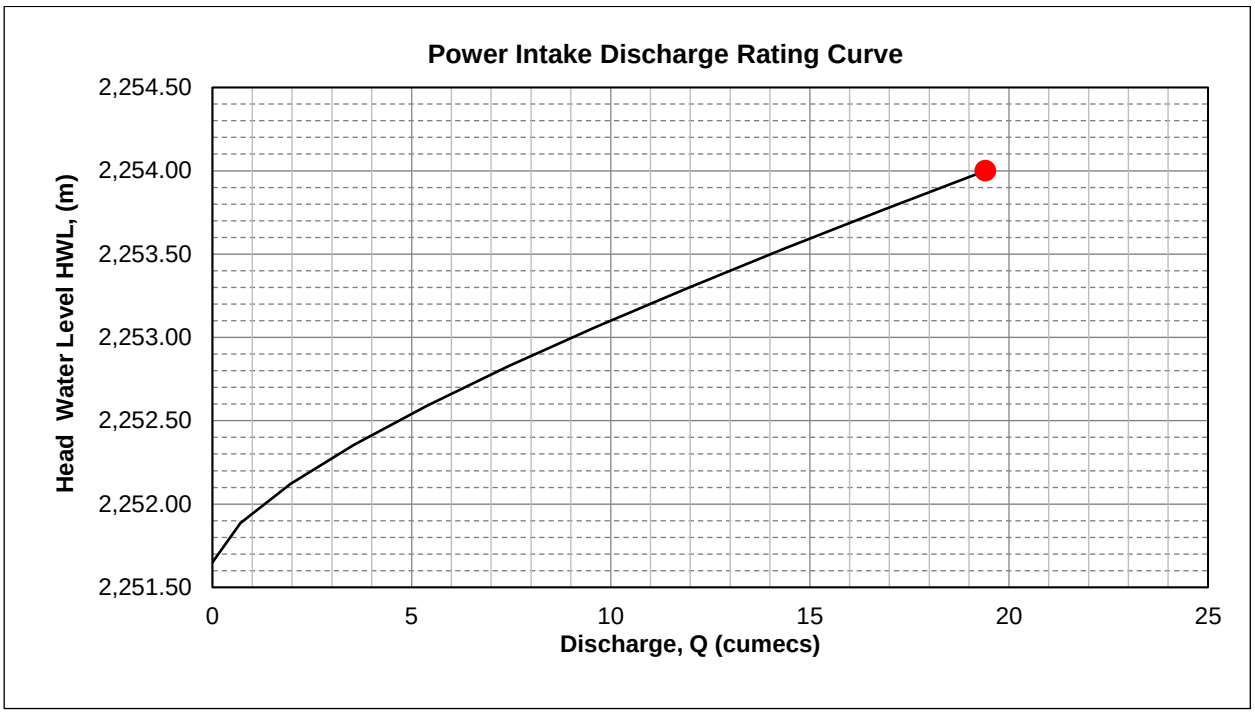


Figure 4-18: Discharge Rating Curve of Power intake

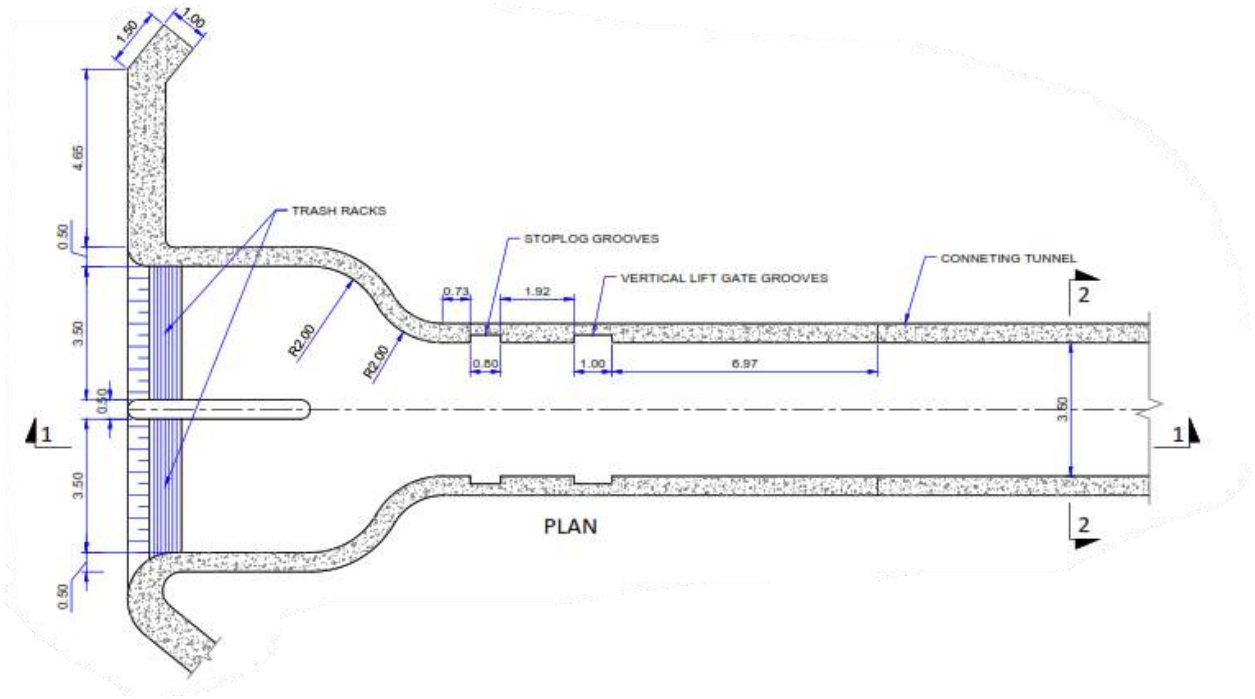


Figure 4-19: Section along Power Intake

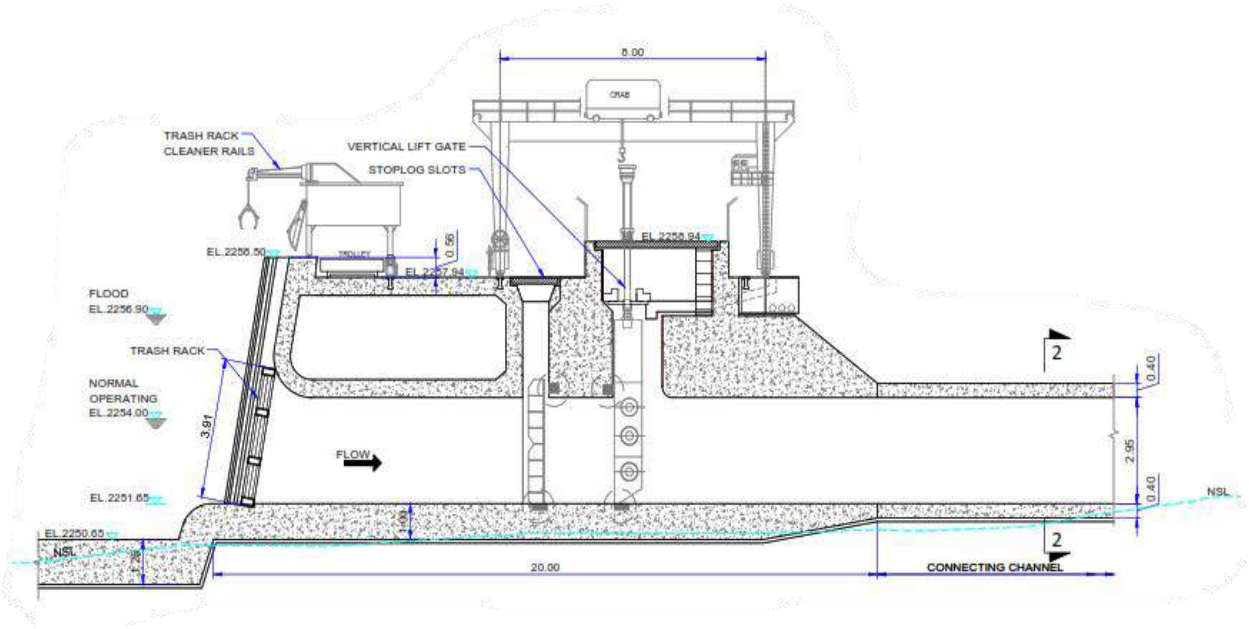


Figure 4-20: Section along Power Intake

4.8 Connecting Channel

The project conveyance system comprises a covered rectangular conduit located entirely on the left bank of the river. The conduit, with a total length of 83.5 m, provides hydraulic connectivity between the power intake and the inlet of the sand trap.

The design discharge of the conduit is 19.20 m³/s. The connecting conduit has been designed to safely convey the power generation discharge along with an additional flushing discharge of 3.20 m³/s. The conduit operates under gravity flow conditions and is constructed in reinforced cement concrete (RCC) with an internal cross-section of 3.5 m width and 2.95 m height. **Figure 4-21 and Figure 4-22** shows the layout and typical cross section of connecting channel.

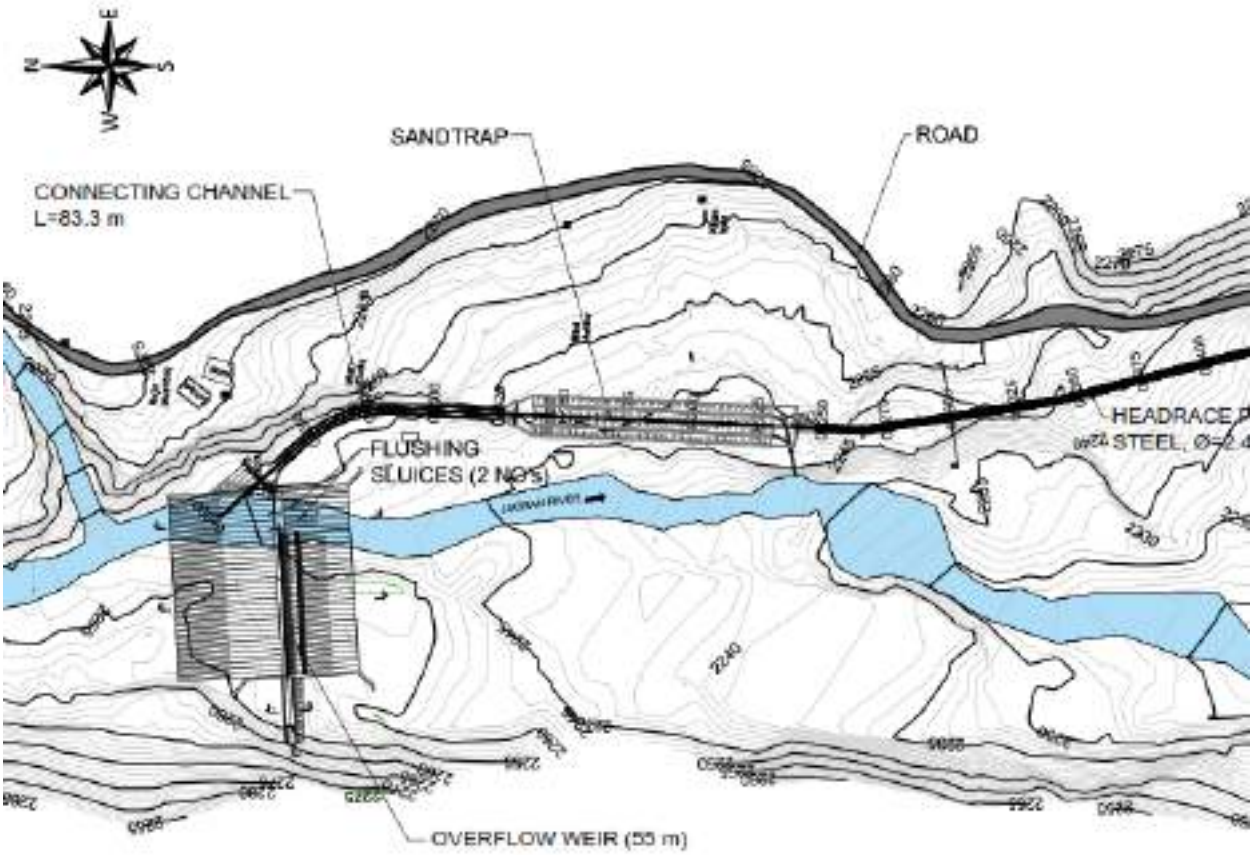


Figure 4-21: Conveyance system showing conduit

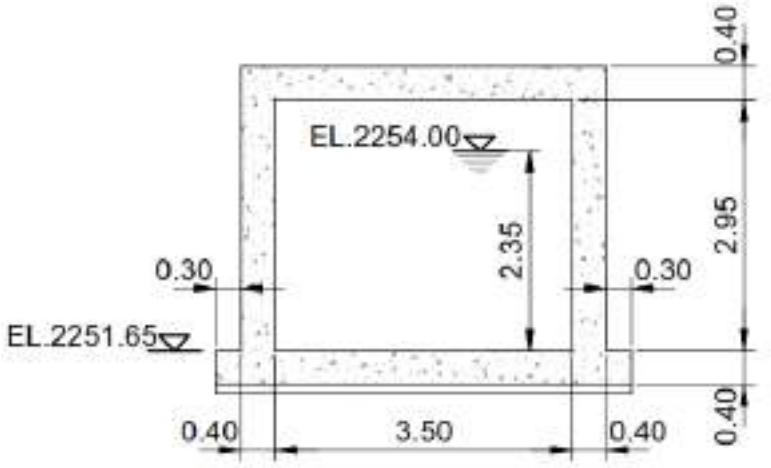


Figure 4-22: Typical Cross section of Connecting Channel

4.8.1 Design Considerations

The design procedure for connecting channel is in accordance with Design Guidelines for water conveyance system of hydropower projects. Basic considerations for the hydraulic design of connecting channel are as under:

- The average velocity of flow should be such that it will generally prevent deposition of silt.

- Freeboard should not be less than 0.3 m plus one-tenth of the full supply depth to accommodate fluctuations.
- For curves along alignment, the ratio of the radius of the curve (r) to width of canal (b) should be three or greater.
- Side wall angles for transitions should be such that tanφ equals one-third of freeboard. In general, transitions should be as smooth and gradual as possible to minimize turbulence and hydraulic losses. Rounded corners are preferable to sharp edges.
- For not allowing the entry of rainwater from the sloppy terrain to Channel, the provision of catch drain in the side of upstream slopes is essential.

Combined effect of the above-mentioned factors determines the location of control which in turn determines discharge characteristics of the channel.

4.8.2 Alignment

As the channel is passing through hilly area, the alignment of the channel is according to the terrain to save excavation and the shorten the possible lengths. The alignment of conduit has been coordinated with the Sandtrap and Headrace Pressure Pipe alignment.

4.8.3 Hydraulic Design Criteria

Connecting channel hydraulic design is based on the following criteria:

For Connecting Channel: Design flow (Q_c) = Turbine flow ($Q_{d=}$16 m^3/sec) +Flushing Discharge (Q_f=3.2m^3/sec) = 19.2 m^3/sec.

The design parameters have been adopted to maintain non-silting velocity in the Channel at design discharge.

Size and Design Velocities: Therefore, to avoid sediment deposition during the project operation, conduit has been designed with a velocity more than 2 m/sec with size of 3.5 m width and flow depth of 2.35 m height. The channel is composed of RCC with wall thickness of 0.40 m. **Figure 4-22** shows typical cross sections.

4.8.4 Hydraulic Design & Methodology

The channel has been designed using manning's equation. As the channel will be of R.C.C the value of n adopted is 0.014.

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \qquad \textbf{Eq. 4-17}$$

Where;

Q = Discharge=19.2 m^3/sec

n = manning's coefficient=0.014

A = Cross sectional area

R = Hydraulic Radius

S = Bed slope (1 in 800)

4.8.4.1 Calculations

Design capacity of channel	=	19.20 m^3/sec
Channel Invert elevation at start	=	2251.65 m
Channel Invert elevation at end	=	2251.55 m
Bed width	=	3.50 m
Depth of flow in connecting channel	=	2.35 m
Free board (F.B)	=	0.60 m
Longitudinal slope	=	1 in 800
Manning's friction factor (n)	=	0.014
Length of channel	=	83.50 m
Velocity	=	2.36 m/s
Froude no.	=	0.49

The discharge rating curve of Connecting channel has been shown in **Figure 4-23**.

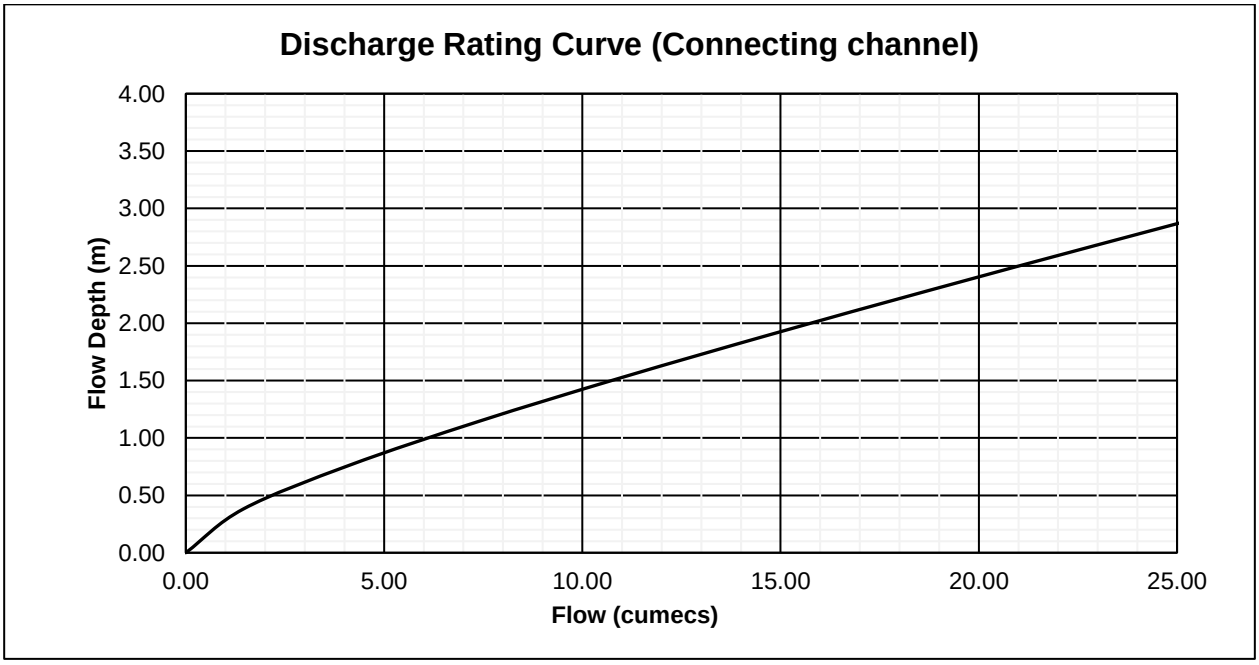


Figure 4-23: Discharge Rating Curve of Connecting channel

4.8.5 Cross Drainage

The layout of Connecting channel intercepts the natural drainage (nullah) at RD.0+325 on the left bank of the Jagran river. In order to allow passage of nullah over the headrace pipe cross drainage structure shall be planned. It is recommended to carry out comprehensive hydraulic and structural design of cross drainage structures at detail design stage.

4.9 Hydraulic Design of Sand Trap

4.9.1 General

Sediment laden water in the power waterways can cause severe abrasion to hydraulic machinery of all types which subsequently cause efficiency decline in turbines and effect valve and gate seals. In severe circumstances, sediments can even destroy runners after a limited time of operation.

The primary objective of the sand trap is therefore to remove abrasive sediment particles above a critical size before water enters the headrace tunnel. By reducing sediment concentration and controlling particle size, the sand trap significantly enhances the service life of turbines and associated hydraulic equipment.

4.9.2 Layout and Structural Configuration

For the present project, the sand trap has been located on the left bank of the river, considering topographical constraints, geological suitability, and hydraulic efficiency. The alignment has been selected such that the sand trap is oriented as close as practicable to the river, thereby minimizing the length of flushing galleries and conduits and improving flushing efficiency. The plan of sand trap along with longitudinal profile is shown in **Figure 4-24** and cross sections has been shown in the **Figure 4-25**.

The sand trap comprises the following main components:

- Two settling chambers operating in parallel
- One hopper beneath each settling chamber
- Flushing galleries located at the bottom of each hopper
- Flushing conduits discharging sediment-laden water back into the river
- Upstream and downstream control gates

4.9.2.1 Settling Chambers

Sand Trap having 2 chambers has been designed to settle the particles of dia 0.25 mm. Each chamber has width & depth (excluding the dimensions of hopper & flushing galleries) of 7 m.

4.9.2.2 Basin Hoopers

Each chamber has one hopper with a depth of 3 m and side slopes of 1V:1H.

4.9.2.3 Flushing Conduits and Pipe

A flushing gallery of 1 m width and height 1 m is proposed at the bottom of the hopper. These two galleries combine at the end of settling chamber conveying the sediment loaded water into flushing conduit of 1 m diameter. Flushing galleries bed has been provided with a slope of 2% to flush the sediments. Thus, for two chambers of sand trap there are 2 flushing galleries and 2 flushing conduits starting at the end of each chamber. These two conduits join gradually forming a single flushing steel pipe of 1m dia which carries the sediment loaded water into river. At the downstream end of each flushing gallery there is a gate of size 1.0 m x 1.0 m (W x H).

4.9.3 Gates and Flow Control

4.9.3.1 Upstream control gates

Two gates of size 4.3 m × 2.3 m (W × H) are provided at the sand trap inlet.

4.9.3.2 Flushing gates

One gate of size 1.0 m × 1.0 m is installed at the downstream end of each flushing gallery.

4.9.3.3 Downstream control gates

Single gate of size 7.2 m × 3.7 m is installed at the outlet of the sand trap to regulate discharge into the downstream gallery leading to the headrace pipe.

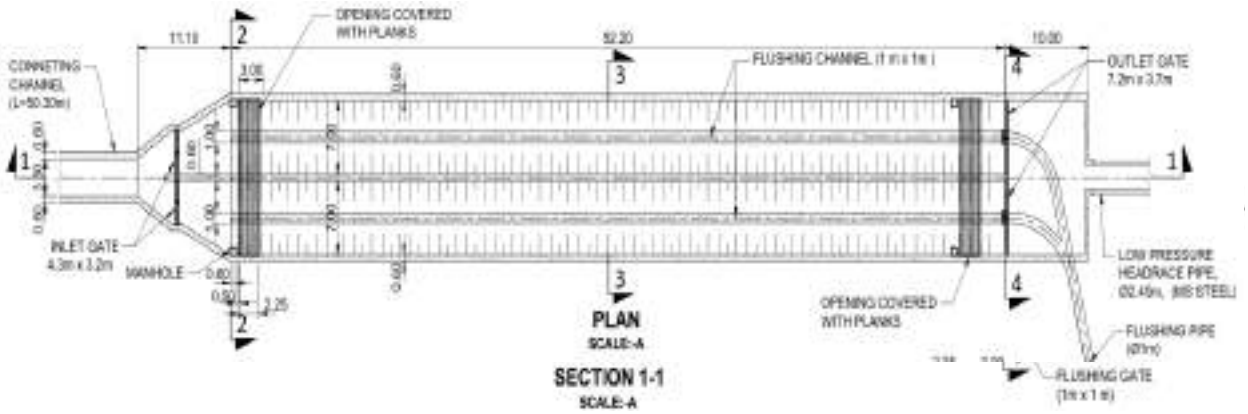


Figure 4-24: Plan and Longitudinal section of Sandtrap

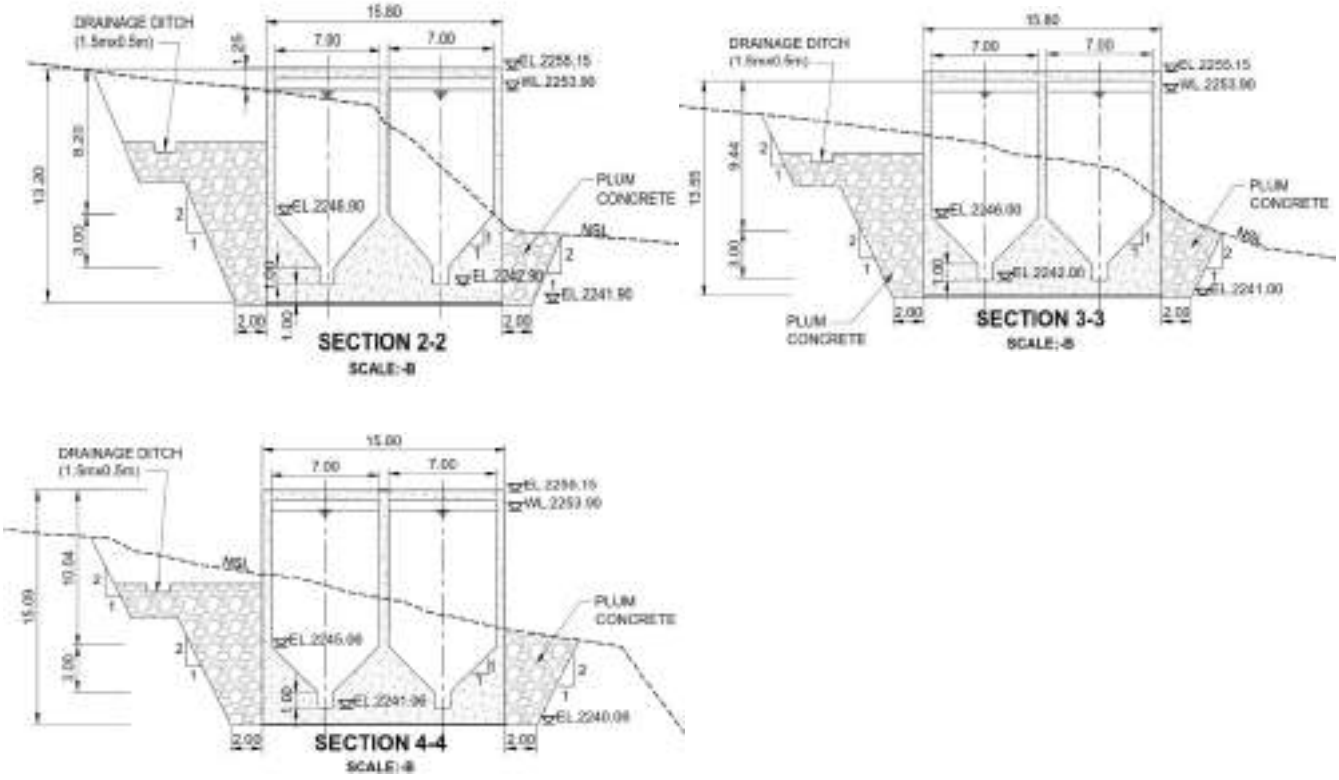


Figure 4-25: Plan, Longitudinal section and Cross section of Sandtrap

4.9.4 Design Criteria

4.9.4.1 Particle size to be removed

The critical particle size to be removed by the sand trap is governed by the project head and turbine erosion considerations. For the present project, a design particle size of 0.25 mm has been adopted for sizing of the sand trap, in line with international practice for medium to high head hydropower projects. The same particle size was recommended in the Feasibility Study as well as the Third-Party Validation Report, and has therefore been retained in the detailed design.

4.9.4.2 Flow velocity

Flow velocity is sand trap chambers can be calculated using Eq. 4-18 (Ref. Mosonyi).

$$V_d = a\sqrt{d} \qquad \text{Eq. 4-18}$$

Where;

V_d = flow velocity required (cm/s)

a = 36, for d > 1 mm,

a = 44, for 1 mm > d > 0.1 mm, and

a = 51, for 0.1 mm > d

4.9.4.3 Dimensions of settling Chambers

Cross section area of settling chamber is calculated using Eq. 4-19.

$$A = Q/V_d \quad \text{Eq. 4-19}$$

Width (B) and depth (H) are found by using suitable H/B ratio

4.9.4.4 Settling Velocity

Settling velocity in standing water can be calculate by using Eq. 4-20(Ref. ESHA guide) and Eq. Eq. 4-21 (Ref. Ferguson & Church 2004).

$$V_{s'} = \frac{100}{9d}(\sqrt{1 + 1.57 \times 100d^3} - 1) \quad \text{Eq. 4-20}$$

Where;

V_s' = Settling velocity in Standing water (mm/s)

d = Diameter of particle (mm)

$$V_{s'} = \frac{RgD^2}{C_1 \nu + (0.75 C_2 RgD^3)^{0.5}} \quad \text{Eq. 4-21}$$

Where;

Vs' = Settling velocity in Standing water (m/s)

D = Diameter of particle (m)

R = submerged specific gravity (1.65 for quartz in water)

C_1 = 18 & C_2 = 1 for sand

ν = kinematic viscosity= 1.004 x 10^{-6} m²/s.

4.9.4.5 Settling velocity in flowing water

Settling velocity of particles in the flowing water can be calculated using Eq. 4-22 (Ref. Mosonyi).

$$V_s = V_{s'} - \alpha V_d \quad \text{Eq. 4-22}$$

Where;

$$\alpha = 0.132/\sqrt{H} \quad \text{Eq. 4-23}$$

4.9.4.6 Length of Settling Chamber

Length of settling chamber can be calculated by Eq. 4-24 (Ref. Mosonyi).

$$L = \frac{V_d H}{V_{s'} - \alpha V_d} \quad \text{Eq. 4-24}$$

Alternatively;

$$L = \frac{H}{V_s - 0.04 V_d} \quad \text{Eq. 4-25}$$

4.9.4.7 Design Checks

$$v_{cr} = \frac{1}{n}\left(\frac{HB}{2H + B}\right)\sqrt{\frac{0.03(\rho_s - 1)d}{1000}} \quad \text{Eq. 4-26}$$

Where;

H = Height of Chamber (m) = 7 m

B = Width of Chamber (m) = 7 m

d = Diameter of particle (mm) = 0.25 mm

ρ_s= Density of sand = 2.60 tons/m^3

Manning's roughness coefficient = 0.014

4.9.4.8 Trap Efficiency

Trap efficiency is calculated using velikanov approach given in Emil Mosonyi. Velikanov's function is given by following formula;

$$\lambda = \sqrt{\frac{7.51\omega^2 L}{v_d^2 \left(H^{1/2} - 0.2\right)^2}} \quad \text{Eq. 4-27}$$

Veilkanov function values is calculated and from the trap efficiency can be calculated using **Table 4-8**. This table has been digitised from the veilkanov functions curve given in Mosonyi.

Table 4-8: Veilkanov's function (Ref. Mosonyi)

Trap Efficiency (P_s)	Λ
100.0	20.00
96.5	1.60
95.0	1.20
91.6	1.00
87.0	0.80
80.0	0.65
69.8	0.40
60.0	0.20
56.0	0.10
50.0	0.00
12.5	0.00
5.0	0.00

4.9.5 Hydraulic Calculations for Sand Traps

Input Data

Design discharge (turbines + Flushing) (Q_T) = 19.20 m^3/s

No. of chambers (n_c)	=	2 no.
Discharge per chamber (Q)	=	9.60 m^3/s
Critical sediment grain size (d)	=	0.25 mm
Density of sand (ρ)	=	2.60 ton/m^3
Manning's roughness coefficient	=	0.014
Calculation of Setting Velocities		
Maximum flow velocity in sand trap (v_d) for a = 44	=	0.22 m/s
Settling velocity in standing water (v_s')	=	0.0343 m/s (Using Eq. 4-20)
Settling velocity in standing water (v_s')	=	0.0381 m/s (Using Eq. 4-21)
Selected Minimum Settling velocity	=	0.0343 m/s (Using Min value)
Calculation of Dimensions of Sandtrap (Width, Height and Length)		
Required cross sectional area (A)=9.60/0.22	=	43.64 m^2
H/B	=	1.00 dimensionless
Width of chamber (B)	=	7 m (at start)
Effective settling depth of chamber (H)	=	7 m (at start)
Reduction factor (α)	=	0.050 (Using Eq. 4-23)
Settling velocity in flowing water (v_s)	=	0.0208 (Using Eq. 4-22)
Length of chamber (required) (L)	=	73.90 m (Using Eq. 4-24)
Or alternatively		
Length of chamber (required) (L)	=	66.91 m (Using Eq. 4-25)
Selected Length of chamber (L)	=	73.90 m

Some additional length is also provided to improve the efficiency. As per the guidelines given in Mosonyi the trap efficiency in no case should be less than 92%. Therefore, after checking the trap efficiency some additional length is provided in this case.

Additional Length	=	18.20 m
Length (Provided)	=	92.20 m
Trap Efficiency using Velikanov's function (λ)		
Velikanov's function (λ)	=	1.02
Trap eff. of chamber (Ps)	=	92 %
Design Checks		
L ≥ 8xB=92.20 ≥56	=	O.K.
Roughness coefficient (1/n=1/0.014=71.43)	=	71.43
Critical velocity (vcr)	=	0.577 m/s (Using Eq. 4-26)
Slope of sedimentation tank (S)	=	2.0 %
Effective depth of chamber at start (H1)	=	7.00 m

Effective depth of chamber at end (H2)	=	8.84 m
Mean area of chamber (A_m)	=	55.45 m^2
Mean velocity in chamber (v_m)	=	0.173 m/s
Check		
$v_{cr} \geq v_m$	=	O.K.

Sizing of Transitions, Sand Traps and Flushing arrangement

The following dimensions of the transition, sand trap and flushing system were obtained from the hydraulic design:

U/S Transition Angle	=	26.57 Degree
Length of Transition	=	11.10 m
Length of Sandtrap	=	113.30 m (incld. Transitions)
Width of Sandtrap	=	15.80 m
Effective settling depth of chamber (H)	=	12.80 m
Freeboard (F.B)	=	0.65 m
Width of divide wall	=	0.60 m
Hopper Depth	=	3.00 m
Width of side walls	=	0.60 m
Dimensions of flushing conduit	=	1.0 m x 1.0 m
No of flushing gates	=	2
Size of gate	=	1.0 m x 1.0 m
Diameter of flushing Pipe	=	1.0 m
Length of flushing pipe	=	26.30 m

4.10 Headrace Pipe

4.10.1 General

Headrace pressure pipe of 2.4 m diameter has been proposed to convey water from the sandtrap to powerhouse.

The conveyance system of Jagran Hydropower Project consists of 2,996 m long headrace pipe ending at Main Inlet valve of Turbine units. The proposed conveyance system has been designed for 16 m^3/sec for power generation.

4.10.2 General Design Considerations

Penstock is characterized by materials, diameter, wall thickness and type of joints. The basic considerations for the hydraulic design of penstock are as under.

- Due considerations are given to site conditions, accessibility, weight, jointing system and cost for selection of Penstock material.

- Designed for full Hydrostatic pressure due to static head at upstream plus water hammer.
- Friction losses are minimized in penstock by considering an optimal diameter.
- Steel lining thickness is estimated to resist maximum internal hydraulic pressure, including transient surge pressure.

4.10.3 Hydraulic Design of Headrace Pipe

Sizing of Headrace Pipe

For Hydraulic design of penstock, the most economical diameter is selected. The diameter is selected as the result of a trade-off between penstock cost and power losses. Several empirical formulas are available to compute the economical diameter. The details of formulas are mentioned below;

Larry W Mays

$$D_e = \frac{CP^{0.43}}{H^{0.60}} \qquad \textbf{Eq. 4-28}$$

C = 0.52

H = net head=166.1 m

$$D_e = CQ^{0.5} \qquad \textbf{Eq. 4-29}$$

C = 0.72

Mosonyi

$$D_e = 1.12\frac{Q^{0.45}}{H^{0.12}} \qquad \textbf{Eq. 4-30}$$

Sarkaria's equation (IIT Roorke, Guide)

$$D_e = 3.55\left(\frac{Q^2}{2gH}\right)^{0.25} \qquad \textbf{Eq. 4-31}$$

ESHA (Guide)

$$D_{\lim} = 2.69\left(\frac{n^2Q^2L}{H}\right)^{0.1875} \qquad \textbf{Eq. 4-32}$$

Where;

Q = Discharge

H = net head

L = Length of Penstock

n = manning's n (0.013 for welded steel)

The economical penstock diameter has been calculated using above formulas. **Table 4-9** show the summary of calculated diameters using various equations.

Table 4-9: Economical penstock diameter using various empirical formula

Ref of formulas	Eq. 4-28	Eq. 4-29	Eq. 4-30	Eq. 4-31	Eq. 4-32
Diameter (m)	2.40	1.80	2.11	1.90	2.00

Adopted Diameter of Penstock = 2.40 m

Flow Velocity in Penstock = 3.54 m/sec

With respect to abrasion, the velocities in penstock should be in range of 3- 5 m/sec, Ref: Emily Mosonyi.

Submergence (Figure 4-26)

A well-designed intake should not only minimise head losses but also preclude vorticity. Vorticity can appear for low-head pressurized intakes (power intakes) and should be avoided because it interferes with the good performance of turbines. Vortices may effectively:

- Produce non-uniform flow conditions
- Introduce air into the flow, with unfavourable results on the turbines: vibration, cavitation, unbalanced loads, etc.
- Increase head losses and decrease efficiency
- Draw trash into the intake

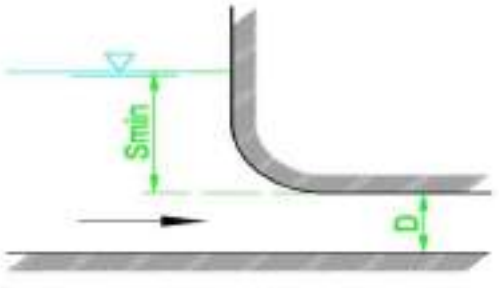


Figure 4-26: Submergence of Power Intake

The criteria to avoid vorticity are not well defined, and there is not a single formula that adequately takes into consideration the possible factors affecting it. According to the ASCE Committee on Hydropower Intakes, disturbances, which introduce non uniform velocity, can initiate vortices. These include:

- Asymmetrical approach conditions
- Inadequate submergence
- Flow separation and eddy formation
- Approach velocities greater than 0.65 m/sec
- Abrupt changes in flow direction

Lack of sufficient submergence and asymmetrical approach seem to be the most common causes of vortex formation. An asymmetric approach is more prone to vortex formation than a symmetrical one. When the inlet to the penstock is deep enough and the flow is undisturbed, vortex formation is unlikely. As per ESHA guide following formulas can be used to calculate minimum submergence.

Knauss

$$S_{\min} = D\left(1 + 2.3\frac{V}{\sqrt{gD}}\right) \qquad \textbf{Eq. 4-33}$$

Rohan formula

$$S_{\min} = 1.474V^{0.48}D^{0.76} \qquad \textbf{Eq. 4-34}$$

Gordon formula

$$S_{\min} = 0.7245V\sqrt{D} \qquad \textbf{Eq. 4-35}$$

Where;

V = Velocity

D = Diameter of Penstock

Design Discharge	=	16 m^3/s
Area, A	=	4.52 m^2
Velocity, V	=	3.54 m/s
Froud Number	=	0.7
Gravity constant, g	=	9.81 m/s^2

The results are provided in **Table 4-10** given below

Table 4-10: Checking Submergence of Headrace Pipe at Inlet

Author Name	Formula	Submergence (m)	Invert Level of Power Intake (masl)	Soffit Level (masl)	Min Req. Water Level (masl)
Gordon	Eq. 4-33	3.85	2242.10	2244.50	2248.35
Knauss	Eq. 4-34	6.42	2242.10	2244.50	2250.92
John S. Gulliver	Eq. 4-35	2242.10	2244.50	2246.18	2242.10

4.10.3.1 Penstock Thickness

The wall thickness required depends on the pipe material, its ultimate tensile strength (and yield), the pipe diameter and the operating pressure. In steady flows (discharge is assumed to remain constant with time) the operating pressure at any point along a penstock is equivalent to the head of water above that point. The wall thickness in this case is computed by the equation:

$$t_{min} = \frac{PD}{2\sigma_f} \qquad \text{Eq. 4-36}$$

Where:

e = Wall thickness in mm

P = Hydrostatic pressure in kN/mm

D = Internal pipe diameter in mm

σf = Allowable tensile strength =1400 kN/mm^2

In steel pipes the above equation is modified by:

$$t_{min} = \frac{PD}{2\sigma_f + K_f} + e_s \qquad \text{Eq. 4-37}$$

Where:

e_s = extra thickness to allow for corrosion=2 mm

k_f = weld efficiency

k_f = 1 for seamless pipes

k_f = 0.9 for x-ray inspected welds

k_f = 1.0 for x-ray inspected welds and stress relieved

σ_f = allowable tensile stress (1400 kN/mm^2)

$$P = \frac{\omega v^2}{g\left(\frac{d}{tE} + \frac{1}{K}\right)} \qquad \text{Eq. 4-38}$$

Where:

p = Pressure rise due to water hammer, N/m² (Pa)

ω = Specific weight of water= ρg≈9810N/m^3

v = initial flow velocity, m/sec

d = Internal Diameter of pipe= 2.4 m

t = Wall thickness in mm

E = Young's modulus of pipe material (Pa)= Steel ≈ 2.1 x 10^{11} Pa

Table 4-11 shows the summary calculations of Penstock thickness by estimating pressure rise due to water hammer considering instantaneous of one unit of turbine.

Table 4-11: Summary Result of Segment wise Penstock thickness

RDs Segments	Min Thickness of penstock (t)	Corrosion Allowance	Total Thickness	Thickness provided
	mm	mm	mm	mm
Start to RD.0+506	7.46	2.00	9.46	10
RD.0+506 to 1+175	9.75	2.00	11.75	12
RD.1+175 to 1+765	12.04	2.00	14.04	14
RD.1+765 to 2+690	14.33	2.00	16.33	18
RD.2+690 to 3+125	16.61	2.00	18.61	20
RD.3+125 to 3+222	18.90	3.00	21.90	22

It is recommended that at the detailed design stage, a comprehensive hydraulic transient analysis shall be carried out by the EPC Design Engineer using an appropriate numerical model. The analysis shall incorporate the specific turbine governor characteristics, including wicket gate closing/opening laws, response times, maximum rate of closure, inertia effects etc.

4.11 Debris Barrier Upstream of Weir

In view of the climate change and its significant impact in Pakistan, the excessive movement of large size boulders has sufficiently been recorded in the steep nullahs of glacial regions like Jagran River

In order to protect the weir structure from damage during floods by transferring of bed load consisting of gravel, cobbles and boulders during floods, it has been planned to construct debris barrier upstream of weir structure. The proposed location of debris barrier is approximately 250 m upstream of weir axis. The proposed location of Debris barrier is shown in **Figure 4-27**.

The MC recommend that Employer may consider said structure, if sufficient funds are available at present. Otherwise, such structures may be added on upstream of all existing or proposed HPPs in such steep valleys.

Figure 4-27: Proposed Debris Barrier Upstream of Weir

The debris barrier is of open structure type and consists of steel/Iron Pipes anchored in reinforced concrete foundations placed across the river flow (**Figure 4-28**). The spacing between pipes has been kept as 1m between the pipes the allows water flow under normal river discharges and also to restrict entry of bed material. The height of barrier is proposed as 3 m.

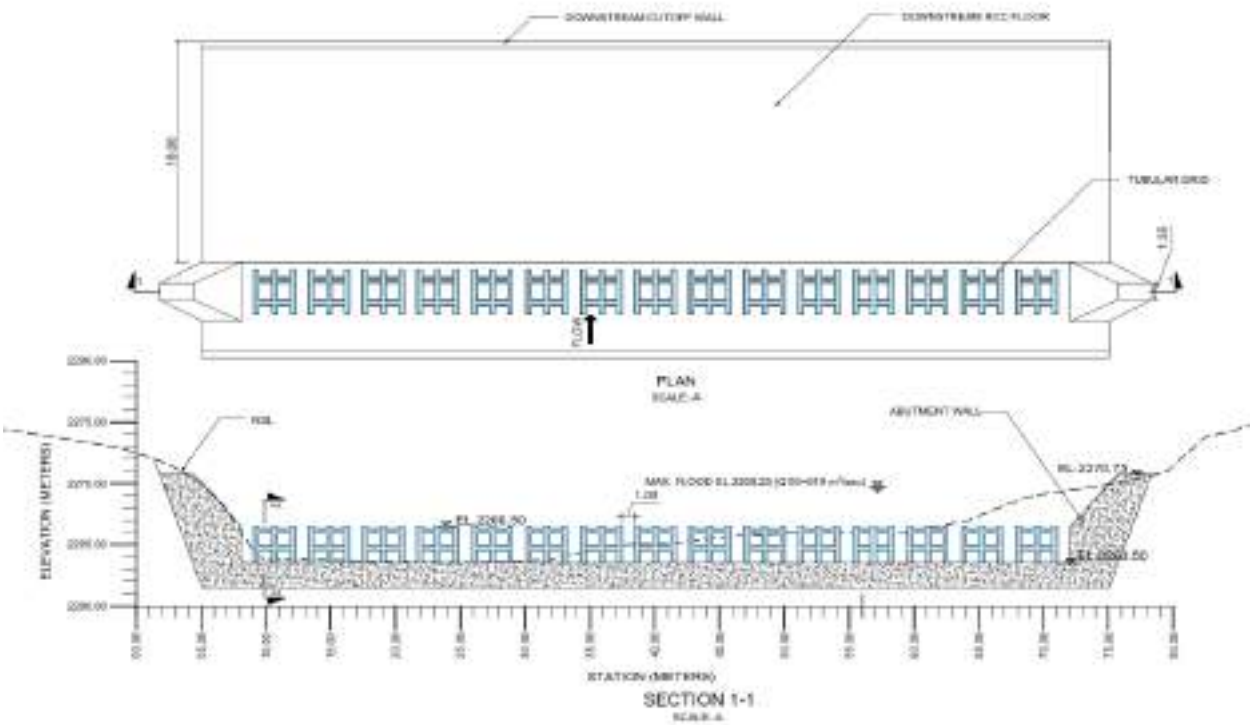


Figure 4-28: Proposed Typical Plan and Section of Debris Barrier

The associated mechanism allows the flow of water, soil, and small gravel for maintaining the flow of the river. But, when the debris flow occurs, the debris dam is expected to capture boulders which are concentrated in the front part of debris flow, and the following sand and gravels can be

caught by blocking the penetration part (slit part) of the open-type Sabo dam. Examples are shown in **Figure 4-29** given below.

Figure 4-29: Proposed Typical Plan and Section of Debris Barrier

4.12 Head Losses Through Water Ways

4.12.1 General

The Head loss through the water way has been assessed. This section describes the procedure for assessment of the Head loss and also shows the calculations of the Head Loss.

The conveyance system starts with Power intake followed by connecting Channel. Intake is provided with trash rack, which is 7.5 m wide and 3.90 m high having a 0.5 m wide pier. A connecting channel convey the discharge from intake to the sandtrap via connecting channel. The length of the connecting channel is 83.5 m with single radius of 50 m.

Losses within the Sand trap include expansion loss from intake section to full Sand trap section, friction loss, frictional losses in main chamber, convergence loss from Sand trap section to downstream chamber and trash rack losses. The Chamber is connecting with Headrace pressure pipe of 2.4 m. The Pipe runs along the road edge and end at the main inlet valve of powerhouse.

The main water conveyance system consists of a steel headrace pipe of 2.4 m diameter and about 2,996 m in length, laid along the left bank of the river. The alignment follows the natural contours of the terrain to minimize excavation and geological risks. The headrace pipe operates under pressure and is designed to safely withstand internal hydraulic loads, transient pressures, and thrust forces at bends, while delivering the design discharge efficiently to the powerhouse.

The main headrace pipe branches into 4 penstocks each leading to mainline valve of a Francis units.

4.12.2 Design Criteria for Calculation of Head losses

Frictional Headloss

Darcy-Weisbach equation

The Darcy-Weisbach equation is preferred for pressurized flows because of its applicability to all fully turbulent flow conditions. The Darcy-Weisbach equation is as follows:

$$h_f = \frac{fLV^2}{2gD}$$ Eq. 4-39

Where;

f = friction factor
g = gravitational constant, m/sec^2
v = velocity in pipeline, m/s
d = diameter of pipe, m
L = pipeline length, m
h_f = friction head loss, m

Colebrook White equation is used for the conversion of absolute roughness (e) to friction factor (f). Colebrook White equation is as follows:

$$\frac{1}{f^{0.50}} = -2\log\left(\frac{e}{3.7D} + \frac{2.51}{Rf^{0.50}}\right)$$ Eq. 4-40

Where,

e = absolute roughness, m
R = Reynolds Number
D = diameter of circular section, m

For concrete the roughness of 0.36 mm has been adopted. However, of steel surface an equivalent roughness of 0.045 mm has been adopted.

Manning's equation

Following equation has been used to determine the losses.

$$h_f = \frac{n^2V^2L}{R^{4/3}}$$ Eq. 4-41

Where;

h_f = Friction head losses, m
N = Manning's roughness coefficient
v = Velocity of flow in headrace tunnel, m/sec
L = Length of headrace tunnel, m
R = Hydraulic radius of the tunnel, m

Manning's roughness coefficient of 0.014 and 0.012 has been adopted for concrete and steel surface respectively.

Minor or Form losses

Entrance Loss

Entrance loss at intakes is calculated using following equation;

$$h_L = K_e \frac{V^2}{2g}$$ Eq. 4-42

The entrance loss coefficient depends on the type of the entrance. For calculation of local head loss at entrance of intake, loss coefficient of 0.04 has been adopted for considering well-rounded entrance.

Trash Rack Loss

The trash rack losses are calculated using formula developed by Krischmer:

$$h_{rack} = K_t \left(\frac{t}{b}\right)^{\frac{4}{3}} \left(\frac{v_b^2}{2g}\right) \sin \emptyset \qquad \text{Eq. 4-43}$$

Where;

t = bar thickness =25 mm
b = width between bars= 65 mm (assumed)
v_b = velocity through bars, m/s
Ø = angle of inclination with horizontal, degrees=80º
Kt = loss coefficient depending on bar shape (adopted value is 2.42 for rect bars)

v_b can be calculated as follows:

$$v_b = v_e \frac{t + b}{b} \qquad \text{Eq. 4-44}$$

Where:

v_e = entrance velocity at racks, m/s
t = thickness of rack bars, mm
b = clearance between rack bars, mm

Gate Slot Loss

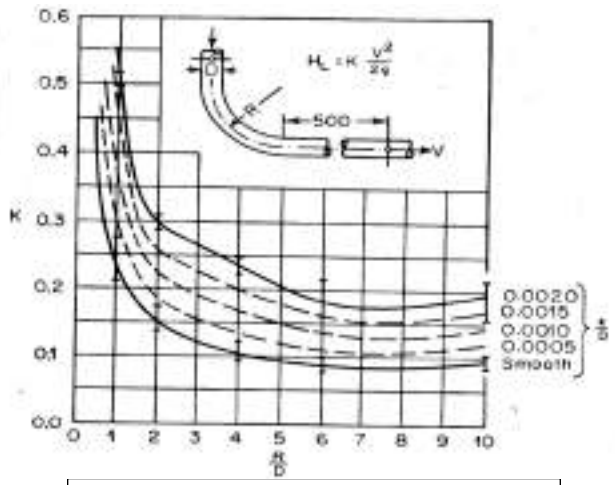
At the entry from power intake a slop log and a service gate has been provided. The size of the gate at each opening has been provided as 3.50 m x 2.95 m.

According to guidelines provided in USBR Design of Small dams (1987), For fully opened gates, the gate slot loss coefficient can be assumed as 0.10 for single gate and 0.15 for two gates in series (in close proximity). The gate loss coefficient has been adopted as 0.15.

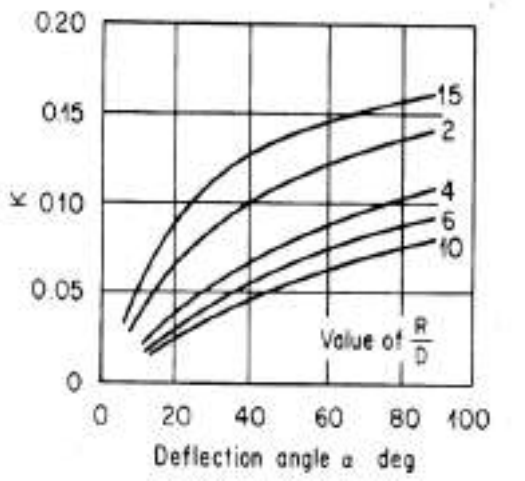
Bend Loss

According to guidelines provided in Davis' Handbook of applied Hydraulics (1993), the bend losses has been calculated.

For 90° bends, loss coefficients can be taken from the graph shown in Error! Reference source n ot found. (a). For bend angles other than 90°, loss coefficients will be taken from the Error! Reference source not found. (b) given below.



a. Resistance Coefficients for 90° Bend of Uniform Diameter



b. Resistance Coefficients for bends other than 90°

Figure 4-30: Resistance Coefficients for bends

Transition Loss

According to guidelines provided in Davis' Handbook of applied Hydraulics (1993), the gradual transition loss has been calculated.

$$h_t = K_t \frac{V^2}{2g} \qquad \text{Eq. 4-45}$$

Where:

h_t = Transition head loss (m)
K_t = Transition loss coefficient
D_1 = Diameter of larger pipe (m)
D_2 = Diameter of smaller pipe (m)
θ = Angle of Transition (Deg)

The loss coefficient can be estimated using **Figure 4-31** given below.

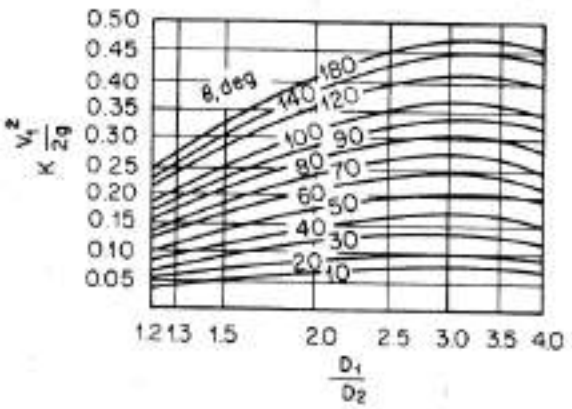


Figure 4-31: Loss Coefficient for gradual contraction

Valve Loss

According to guidelines provided in USBR Design of small Dams (1987), the valve loss has been calculated. At the entrance of penstock branch to the turbine a main inlet valve is provided (Butterfly valve) has been provided. According to USBR, the average value of valve loss coefficient for butterfly valve in wide open position is 0.15. However, the value varies between 0.1 to 0.50, depending upon the thickness of gate leaf in relation to gross area.

According to Technical paper 410 M (Fluids through valves, fittings, and pipe), CRANE, 2009, the representative value of loss coefficient for butterfly valve is 0.20 and the same has been adopted for the calculation of head losses.

4.12.3 Results of Head Loss Calculations

Total head losses through the waterway from power intake to the Turbine is calculated as 14.65 m. A summary of the calculated head losses is given in **Table 4-12**.

Normal Water level, NWL	=	2254.00 m
Normal tail water level (Q=16 m^3/sec)	=	2073.25 m
Maximum Gross Head	=	180.75 m
Head loss	=	14.65 m
Rated Net Head (average)	=	166.10 m

Table 4-12: Calculation of Head losses through Power Waterways

Components	Headloss (Major and Minor Losses) meters
Intake	0.153
Connecting Channel	0.082
Sandtrap	0.227
Headrace Pipe	13.34
Branch Pipe and Manifold and Draft tube	0.85
Total Headloss	**14.65**

4.13 Power House

The powerhouse will be built on the left bank of Jagran River having 4 horizontal Francis turbine units. Powerhouse size has Length x width x height of 34.5 m x 10 m x 18 m. The important parameters are shown below;

HWL at Weir	HWL	=	2254.00 m
Normal TWL at Powerhouse	TWL	=	2073.25 m
Design Discharge	Qd	=	16.00 m^3/sec
No of Turbine units	N	=	4.00
Maximum Gross head	$H_{g\ (max)}$	=	180.75 m

Head loss	H_{loss}	=	14.65 m
Rated Net Head	H_n	=	166.10 m
Installed Capacity	P_T	=	23.72 MW

4.14 Conclusions

1. The Tender Design defines a left-bank scheme comprising an ungated ogee overflow weir with two undersluices, lateral intake, RCC connecting channel, twin-bay surface sand trap, buried steel headrace (≈2.40 m ID, ≈2,996 m) and surface powerhouse; total conveyance headloss is ≈14.65 m, yielding a rated net head ≈166.10 m for 23.72 MW installed capacity.

2. Weir crest EL 2254.00 m (55 m length) passes ~67% of the 1,000-year design flood (Q≈954 m³/s) over the crest at MFL 2256.90 m, with the remaining ~33% routed through two 5 m×5 m undersluices; a USBR Type-V stilling basin with downstream rock protection is sized for the weir portion (Q≈602 m³/s).

3. The intake/approach–desander system is proportioned to deliver **Q=16 m³/s** (plus ~3.2 m³/s for flushing) and to remove **d≈0.25 mm** sediments using multi-bay settling with hopper flushing to river.

4. The buried steel headrace (ID≈2.40 m; v≈3.54 m/s) follows the left bank with anchor/blocks and localized surface run near the powerhouse where it bifurcates to four penstocks feeding Francis units; submergence, transitions and local losses are checked; headloss breakdown per component is tabulated.

5. POWER AND ENERGY CALCULATIONS

5.1 General

For power and annual energy estimates with the proposed project layout arrangement, a spreadsheet program was used. The details are provided as under:

5.2 Input Data

- The flow duration curve based on mean daily estimated flows at Jagran-IV weir site is used.
- The compensation flows of 0.30 m^3/s are subtracted from mean daily estimated flows.
- The design discharge of 16.00 m^3/s is adopted.
- Four turbine units each of 4.00 m^3/s have been assumed.
- The gross head of 180.75 m corresponding to weir and tail is used.
- The head losses of 14.65 m are considered.
- The net head of 166.10 m is used.

5.3 Operating Criteria

Following criterion was adopted for power and annual energy estimation:

- All four units were operated for 24 hours for 34.2% time (125 days/year).
- Three units were operated for 24 hours for 43.8% time (160 days/year).
- Two units were operated for 24 hours for 57.5% time (210 days/year).
- One unit was operated for 24 hours for 93.2% time (340 days/year).

5.4 Results

Annexure A attached at the end of this section gives the detailed results. The data given below shows the summary of the power simulation results;

- ✓ Design Flow = 16.00 m^3/s
- ✓ No of Units = 4
- ✓ Design Discharge (single unit) = 4.00 m^3/s
- ✓ Gross head = 180.75 m
- ✓ Head Loss = 14.65 m
- ✓ Net head = 166.10 m
- ✓ Turbine Efficiency = 91.0%
- ✓ Generator Efficiency = 95.0%
- ✓ Transformer Efficiency = 99.0%
- ✓ Flushing Period = 4 days
- ✓ Gross Power = 22.31 MW
- ✓ Annual Energy = 98.51 GWh
- ✓ Plant Factor = 50.40%

Annexure A – Power and Energy Calculations

22 MW JAGRAN-IV HYDROPOWER PROJECT

TABLE 8.3

POWER AND ENERGY CALCULATIONS

(FLOW DURATION CURVE METHOD)

Design Discharge	Q_D	=	**16.00**	m^3/sec
Environmental Flows	Q_E	=	**0.30**	m^3/sec
No. of Units		=	**4**	Nos
Design Discharge (single unit)	Q_{unit}	=	**4.000**	m^3/sec
Gross Head	H_g	=	180.75	m
Head Loss	H_L	=	14.65	m
Net Head	H_n	=	**166.10**	m
Turbine Efficiency at Design Discharge	η_T	=	91.0%	
Generator Efficiency	η_G	=	95.0%	
Transformer Efficiency	η_T	=	99.0%	
Flushing Period	T_{FL}	=	4	days

GROSS POWER	22.31	MW
ANNUAL ENERGY	98.51	GWh
PLANT FACTOR	50.398	%

TIME BLOCK		PERIOD	FLOW DURATION	NET HEAD	TURBINE - 1				TURBINE - 2				TURBINE - 3				TURBINE - 4				Total Power	ANNUAL ENERGY
					Q	η_T	Power	Energy	Q	η_T	Power	Energy	Q	η_T	Power	Energy	Q	η_T	Power	Energy		
(Nos)	(%)	(Nos)	(m^3/s)	(m)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(MW)	(GWh)
1	0.3%	4	175.000	166.1	4.000	93.3%	5.719	0.048	4.000	93.3%	5.719	0.048	4.000	93.3%	5.719	0.048	4.000	93.3%	5.719	0.048	22.877	2.196
5	1.4%	5	144.280	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
10	2.7%	5	104.086	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
15	4.1%	5	63.480	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
20	5.5%	5	38.133	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
25	6.8%	5	37.626	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
30	8.2%	5	34.913	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
35	9.6%	5	32.812	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
40	11.0%	5	31.300	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
45	12.3%	5	30.065	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
50	13.7%	5	28.922	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
55	15.1%	5	27.879	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
60	16.4%	5	26.934	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
65	17.8%	5	25.990	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
70	19.2%	5	25.046	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
75	20.5%	5	22.648	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
80	21.9%	5	21.513	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745
85	23.3%	5	20.570	166.1	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	4.000	93.3%	5.719	0.858	22.877	2.745

Sheet 2 of 3

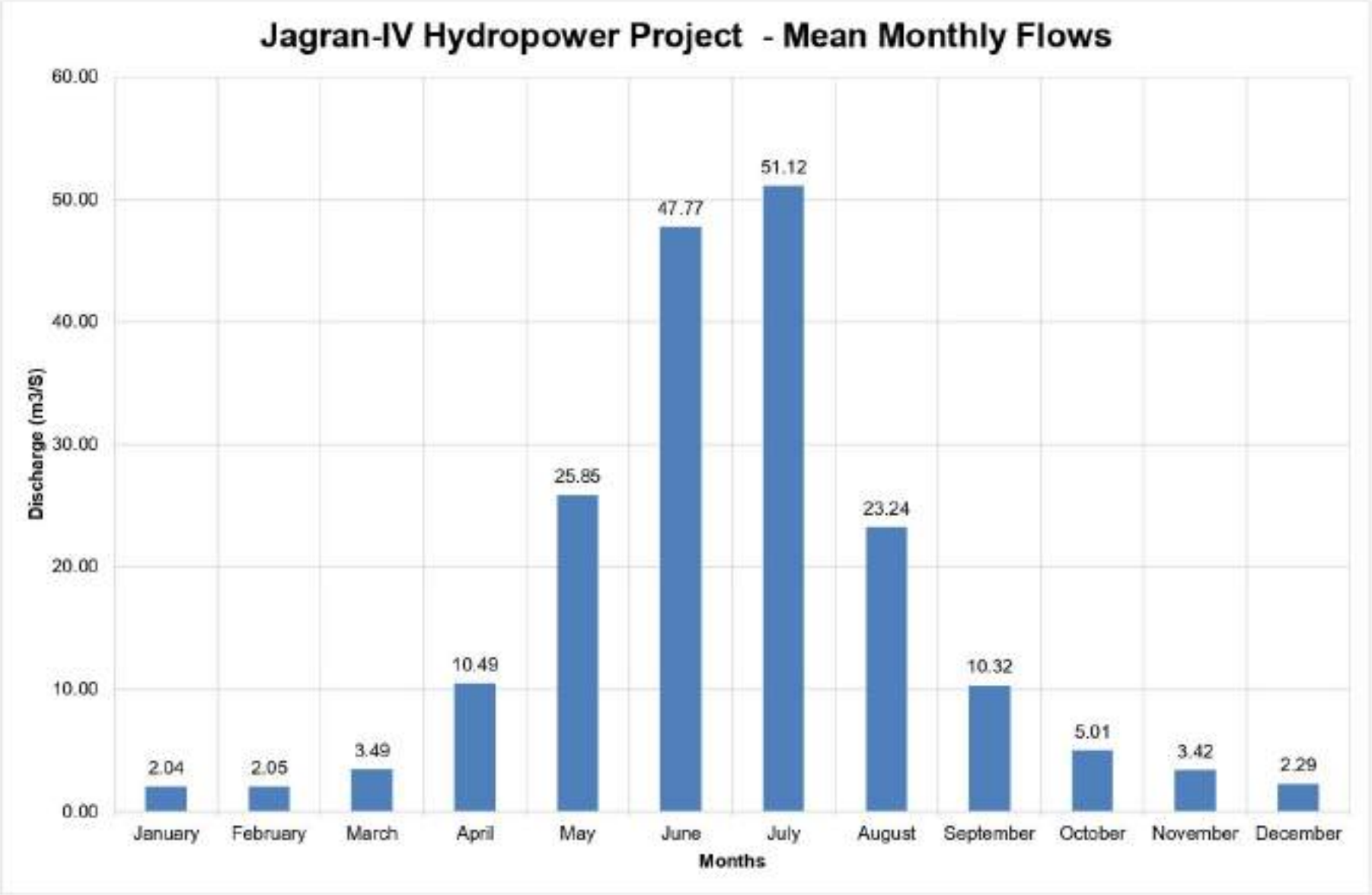
TIME (HOUR)		PERIOD	FLOW (CUMECS)	NET HEAD	TURBINE - 1				TURBINE - 2				TURBINE - 3				TURBINE - 4				TOTAL Power P=P1+P2 +P3+P4	ANNUAL ENERGY Total
			Q_1		η_1	Power$_1$	Energy$_1$	Q_2	η_2	Power$_2$	Energy$_2$	Q_3	η_3	Power$_3$	Energy$_3$	Q_4	η_4	Power$_4$	Energy$_4$		
Hours	(%)	(Days)	(m^3/s)	(m)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(MW)	(GWh)
00	24.7%	5	19.244	166.1	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	22.877	2.745
05	26.0%	5	18.109	166.1	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	22.877	2.745
100	27.4%	5	16.975	166.1	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	4.000	93.3%	5.719	0.686	22.877	2.745
105	28.8%	5	15.841	166.1	3.960	93.3%	5.665	0.680	3.960	93.3%	5.665	0.680	3.960	93.3%	5.665	0.680	3.960	93.3%	5.665	0.680	22.660	2.719
110	30.1%	5	14.749	166.1	3.687	93.6%	5.291	0.635	3.687	93.6%	5.291	0.635	3.687	93.6%	5.291	0.635	3.687	93.6%	5.291	0.635	21.166	2.540
115	31.5%	5	14.038	166.1	3.509	93.4%	5.036	0.603	3.509	93.4%	5.036	0.603	3.509	93.4%	5.036	0.603	3.509	93.4%	5.036	0.603	20.144	2.417
120	32.9%	5	13.327	166.1	3.332	93.1%	4.782	0.570	3.332	93.1%	4.782	0.570	3.332	93.1%	4.782	0.570	3.332	93.1%	4.782	0.570	19.130	2.295
125	34.2%	5	12.616	166.1	3.154	92.7%	4.481	0.538	3.154	92.7%	4.481	0.538	3.154	92.7%	4.481	0.538	3.154	92.7%	4.481	0.538	17.925	2.151
130	35.6%	5	11.965	166.1	2.968	92.3%	4.176	0.501	2.968	92.3%	4.176	0.501	2.968	92.3%	4.176	0.501					17.028	2.043
135	37.0%	5	11.154	166.1	2.731	93.6%	5.352	0.642	2.731	93.6%	5.352	0.642	2.731	93.6%	5.352	0.642					16.056	1.927
140	38.4%	5	10.483	166.1	3.494	93.4%	5.002	0.600	3.494	93.4%	5.002	0.600	3.494	93.4%	5.002	0.600					15.007	1.801
145	39.7%	5	9.772	166.1	3.257	92.9%	4.639	0.557	3.257	92.9%	4.639	0.557	3.257	92.9%	4.639	0.557					13.916	1.670
150	41.1%	5	9.219	166.1	3.073	92.5%	4.368	0.524	3.073	92.5%	4.368	0.524	3.073	92.5%	4.368	0.524					13.075	1.569
155	42.5%	5	8.705	166.1	2.903	91.4%	4.066	0.488	2.903	91.4%	4.066	0.488	2.903	91.4%	4.066	0.488					12.197	1.464
160	43.8%	5	8.192	166.1	2.731	88.7%	3.755	0.451	2.731	88.7%	3.755	0.451	2.731	88.7%	3.755	0.451					11.265	1.352
165	45.2%	5	7.679	166.1	3.039	93.5%	5.099	0.660	3.039	93.5%	5.099	0.660									10.999	1.320
170	46.6%	5	7.160	166.1	3.082	93.8%	5.118	0.617	3.082	93.8%	5.118	0.617									10.275	1.233
175	47.9%	5	6.651	166.1	3.325	93.1%	4.743	0.569	3.325	93.1%	4.743	0.569									9.485	1.138
180	49.3%	5	6.137	166.1	3.068	92.5%	4.352	0.522	3.068	92.5%	4.352	0.522									8.703	1.044
185	50.7%	5	5.730	166.1	2.865	91.1%	3.998	0.480	2.865	91.1%	3.998	0.480									7.996	0.960
190	52.1%	5	5.530	166.1	2.716	89.6%	3.727	0.447	2.716	89.6%	3.727	0.447									7.454	0.895
195	53.4%	5	5.130	166.1	2.565	88.1%	3.463	0.416	2.565	88.1%	3.463	0.416									6.926	0.831
200	54.8%	5	4.930	166.1	2.415	86.8%	3.265	0.392	2.415	86.8%	3.265	0.392									6.411	0.769
205	56.2%	5	4.530	166.1	2.265	85.1%	2.955	0.355	2.265	85.1%	2.955	0.355									5.909	0.709
210	57.5%	5	4.230	166.1	2.115	83.6%	2.711	0.325	2.115	83.6%	2.711	0.325									5.422	0.651
215	58.9%	5	3.930	166.1	3.000	93.4%	5.024	0.675													5.024	0.675
220	60.3%	5	3.687	166.1	3.687	93.7%	5.250	0.630													5.250	0.630
225	61.6%	5	3.494	166.1	3.494	93.4%	5.002	0.600													5.002	0.600
230	63.0%	5	3.331	166.1	3.331	93.1%	4.752	0.570													4.752	0.570
235	64.4%	5	3.160	166.1	3.160	92.7%	4.503	0.540													4.503	0.540
240	65.8%	5	3.005	166.1	3.005	92.4%	4.256	0.511													4.256	0.511
245	67.1%	5	2.842	166.1	2.842	90.8%	3.957	0.475													3.957	0.475
250	68.5%	5	2.679	166.1	2.679	89.2%	3.664	0.440													3.664	0.440
255	69.9%	5	2.510	166.1	2.510	87.6%	3.378	0.405													3.378	0.405
260	71.2%	5	2.422	166.1	2.422	86.7%	3.218	0.386													3.218	0.386

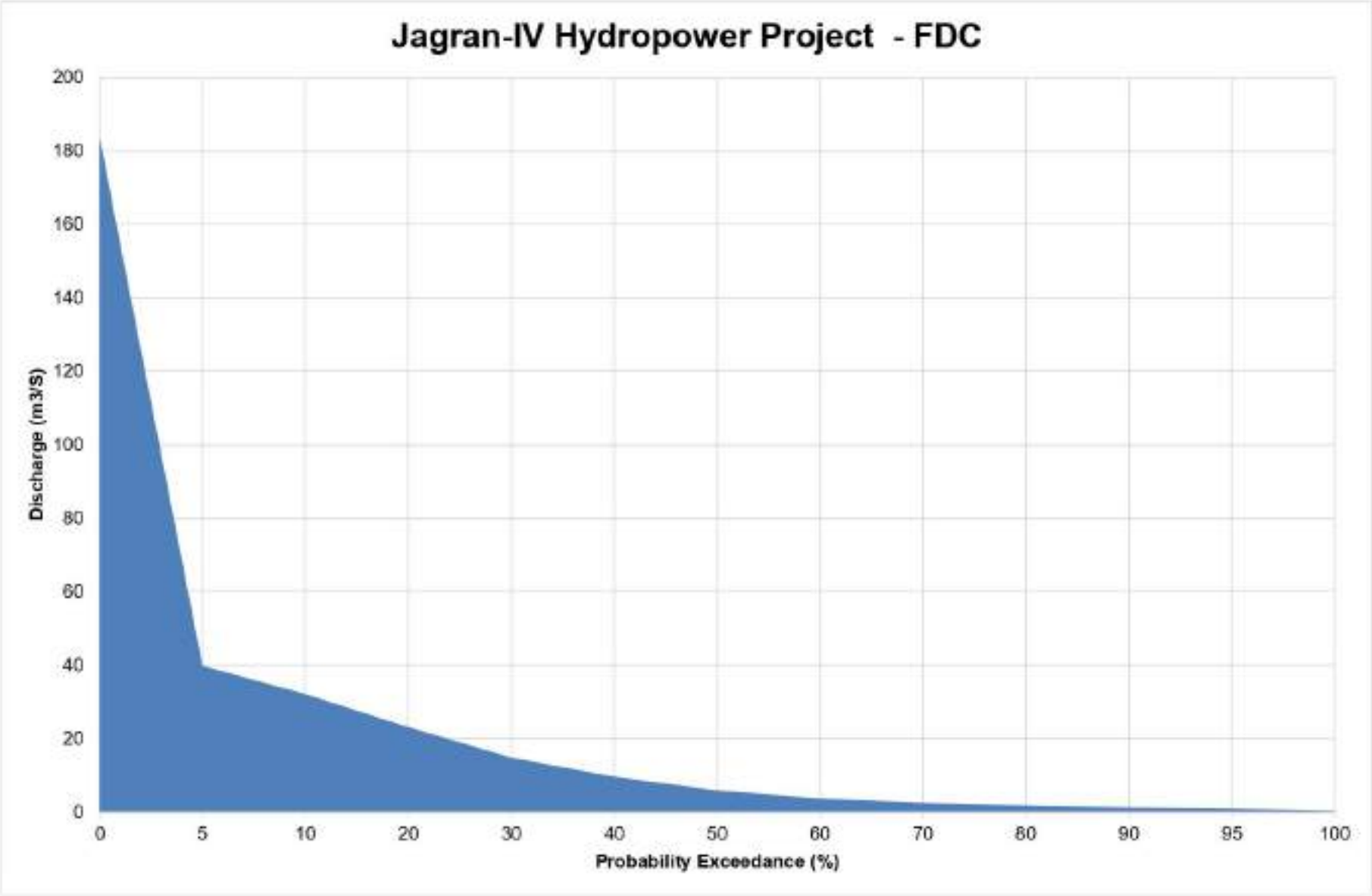
Sheet 3 of 3

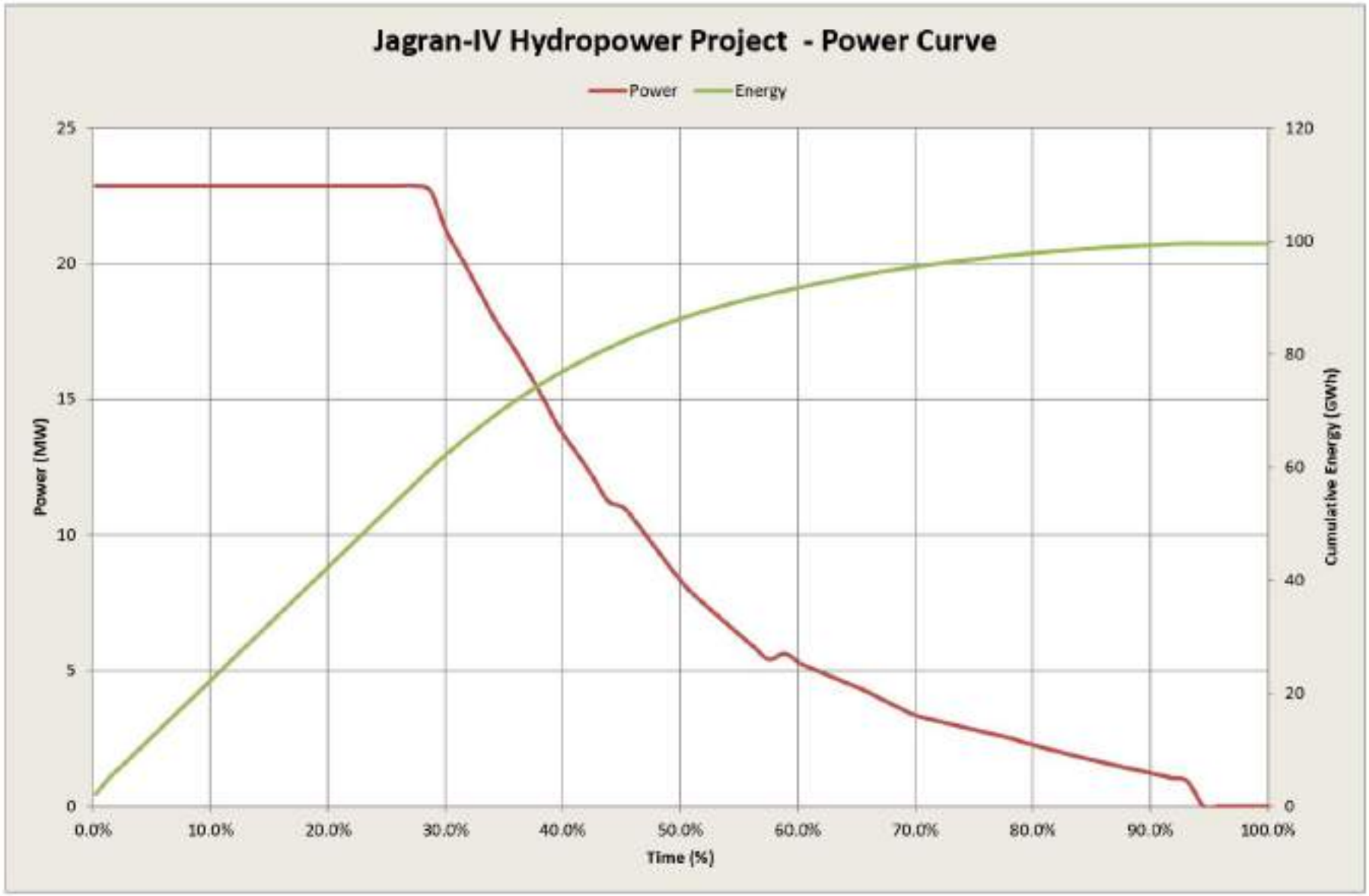
[illegible]		PERIOD	FLOW DURATION	NET HEAD	TURBINE - 1				TURBINE - 2				TURBINE - 3				TURBINE - 4				Total Power	ANNUAL ENERGY
					Q_1	η_1	Power$_1$	Energy$_1$	Q_2	η_2	Power$_2$	Energy$_2$	Q_3	η_3	Power$_3$	Energy$_3$	Q_4	η_4	Power$_4$	Energy$_4$	P1+P2+P3+P4	Total
[illegible]	(%)	(days)	(m^3/s)	(m)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(m^3/s)	(%)	(MW)	(GWh)	(MW)	(GWh)
265	72.6%	5	2.336	186.1	2.336	88.8%	3.073	0.369													3.073	0.369
270	74.0%	5	2.250	186.1	2.250	85.0%	2.930	0.352													2.930	0.352
275	75.3%	5	2.163	186.1	2.163	84.1%	2.789	0.335													2.789	0.335
280	76.7%	5	2.077	186.1	2.077	82.3%	2.650	0.318													2.650	0.318
285	78.1%	5	1.991	186.1	1.991	82.3%	2.510	0.301													2.510	0.301
290	79.5%	5	1.905	186.1	1.905	80.0%	2.335	0.280													2.335	0.280
295	80.8%	5	1.821	186.1	1.821	77.8%	2.171	0.261													2.171	0.261
300	82.2%	5	1.738	186.1	1.738	75.7%	2.016	0.242													2.016	0.242
305	83.6%	5	1.656	186.1	1.656	73.5%	1.866	0.224													1.866	0.224
310	84.9%	5	1.574	186.1	1.574	71.4%	1.722	0.207													1.722	0.207
315	86.3%	5	1.492	186.1	1.492	69.2%	1.583	0.190													1.583	0.190
320	87.7%	5	1.410	186.1	1.410	67.1%	1.449	0.174													1.449	0.174
325	89.0%	5	1.328	186.1	1.328	64.9%	1.321	0.159													1.321	0.159
330	90.4%	5	1.246	186.1	1.246	62.7%	1.191	0.143													1.191	0.143
335	91.8%	5	1.162	186.1	1.162	60.7%	1.052	0.126													1.052	0.126
340	93.2%	5	1.043	186.1	1.043	57.5%	0.920	0.110													0.920	0.110
345	94.5%	5	0.945	186.1	0.945																0.000	0.000
350	95.9%	5	0.805	186.1	0.805																0.000	0.000
355	97.3%	5	0.643	186.1	0.643																0.000	0.000
360	98.6%	5	0.482	186.1	0.482																0.000	0.000
365	100.0%	5	0.320	186.1	0.320																0.000	0.000
MEAN ANNUAL ENERGY (GWh)								=														99.69
Annual Downtime Losse 4 days closse)								=														1.10%
Actual Mean Annual Energy (GWh)								=														**98.5**

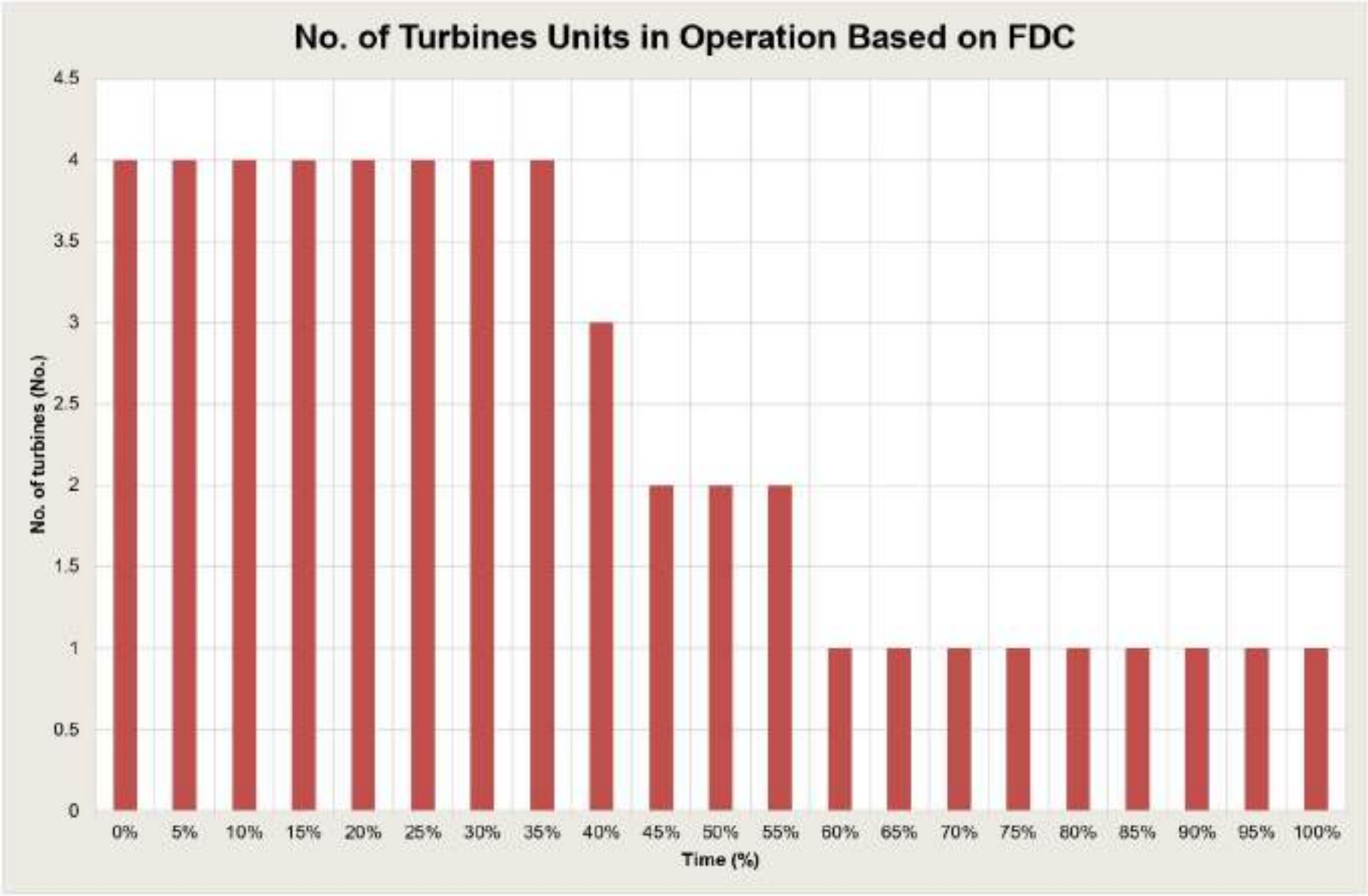
$$\text{Plant Factor} = \frac{98.5 \times 10^3}{22.31 \times 8760.00} = \frac{\text{Actual Energy}}{\text{Theoretical Energy}}$$

Plant Factor = **50.40%**

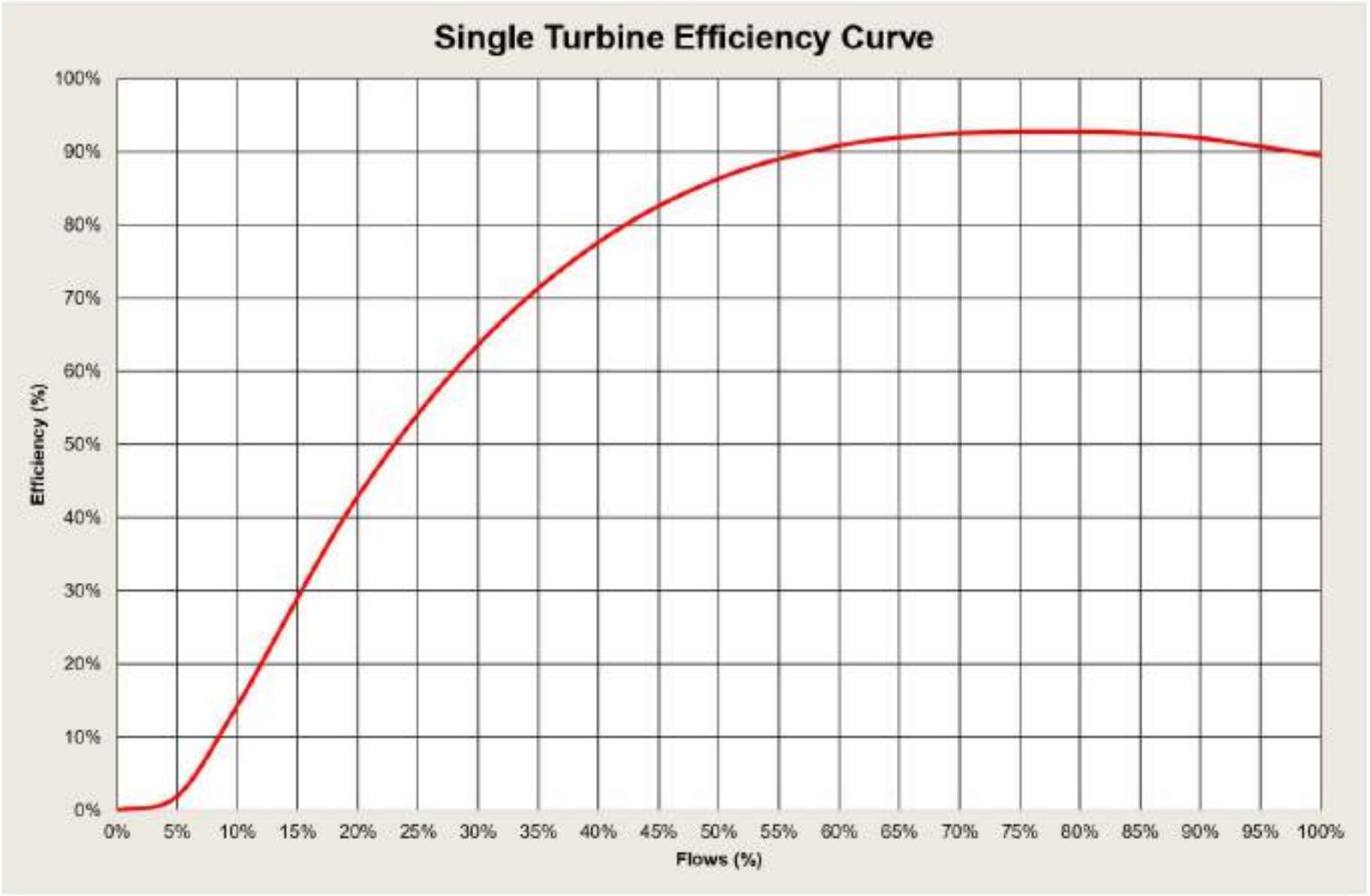

Jagran-IV Hydropower Project - Mean Monthly Flows
Discharge (m3/S)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2.04
2.05
3.49
10.49
25.85
47.77
51.12
23.24
10.32
5.01
3.42
2.29
January
February
March
April
May
June
July
August
September
October
November
December
Months


Jagran-IV Hydropower Project - FDC
Discharge (m3/S)
200
180
160
140
120
100
80
60
40
20
0
0
5
10
20
30
40
50
60
70
80
90
95
100
Probability Exceedance (%)


Jagran-IV Hydropower Project - Power Curve
Power
Energy
Power (MW)
Cumulative Energy (GWh)
Time (%)
0
5
10
15
20
25
0
20
40
60
80
100
120
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
100.0%


No. of Turbines Units in Operation Based on FDC
No. of turbines (No.)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
Time (%)

Combined Efficiency Curve
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
Flows (%)


Single Turbine Efficiency Curve
Efficiency (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
Flows (%)

6. STRUCTURAL DESIGN REVIEW

6.1 General

The following basic structures proposed for Jagran-IV Hydropower Project have been reviewed, namely:

a) Intake structure, comprising:

- Diversion Weir: Ungated-Overflow-Barrier
- Escape Channel: Roller-Bucket Energy Dissipator
- Gated Under-Sluice Flushing Device
- Power intake Channel connected to Sand-Trap Assembly
- Connecting Channel

b) Sand-Trap Assembly

- Intake Gate
- Chambers
- Flushing Pipes
- Headrace Low Pressure Pipe Intake Point

c) Headrace Low Pressure Pipe 2.4-meter internal dia steel liner, comprising:

- Intake point from Sand-Trap End:
- Around 3.0 KM long Buried part
- Around 180-meter-long supported Penstock
- Anchor Blocks (RCC Blocks)

d) Powerhouse, Comprising:

- Manifold Area
- Transformer area
- About four-storied Powerhouse, comprising Draft-Tubes, Turbine Floor, Generator Floor, Machine Hall, with multiple allied services, viz. dewatering Galleries, Overhead Crane assembly, etc.
- Tailrace Channel with retaining walls

6.2 3D Pictorial Illustration of aforementioned Structures

A schematic three-dimensional pictorial view of Intake Area and Powerhouse is illustrated in **Figures 6.1 & 6.2** below:

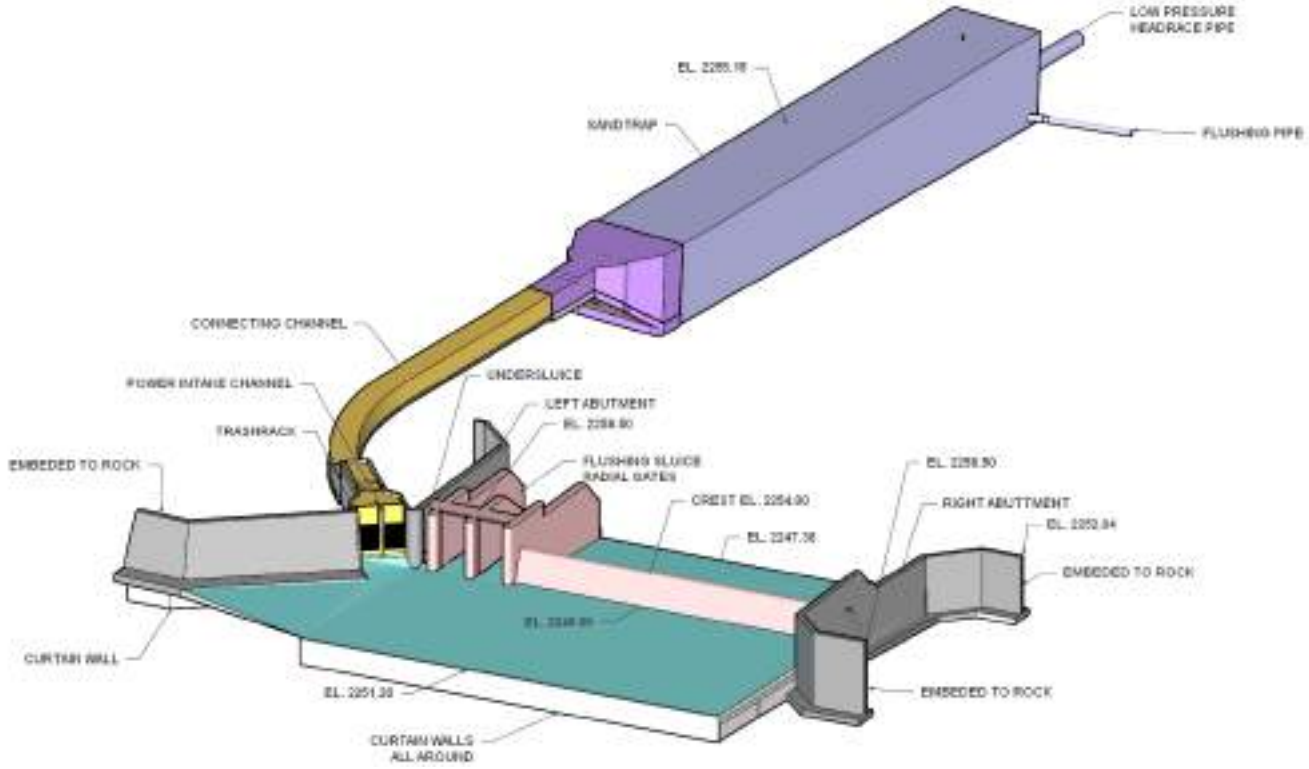


Figure 6-1: Three-dimensional Pictorial View of Intake Area

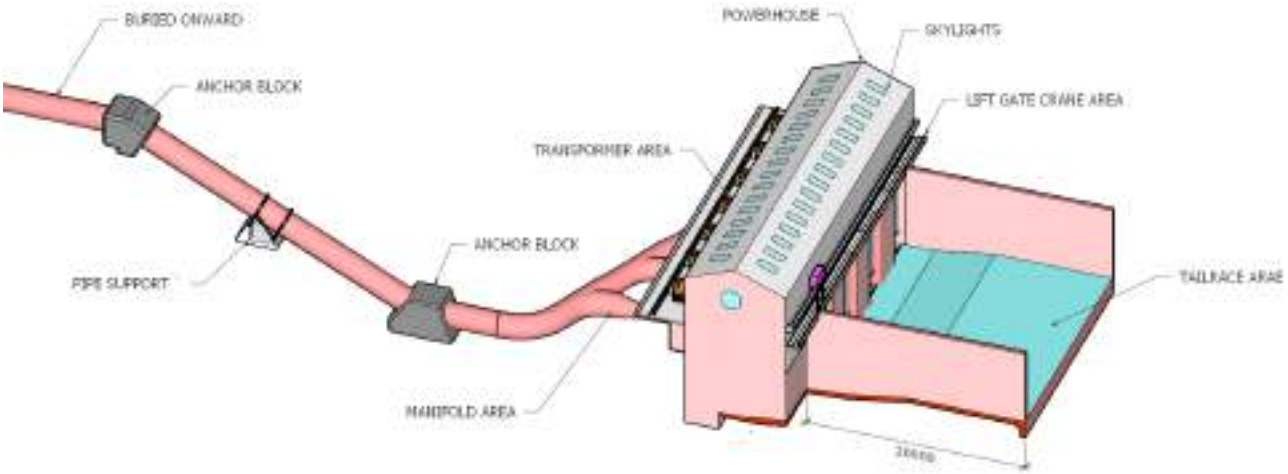


Figure 6-2: Three-dimensional Pictorial View of Powerhouse Area

6.3 Design Review Sources

The Structural Design Review is framed in the light of the following Standards and Specifications:

6.3.1 Proponent Standards & Specifications

- Jagran-IV Design Report (February 19, 2011)
- Design & Construction of Bridges & Culverts, Chief Engineer's Technical Memo No, 4 (Revised) Punjab Public Works Department Building & Road Branch

- Code of Practice Highway Bridge 1967 Government of West Pakistan Highway Department
- BCoP (2007) reviewed BCP2021-Final-Draft-dated-26.10.2021 Building Code of Pakistan, Government of Islamic Republic of Pakistan, Ministry of Housing & Works, Islamabad

6.3.2 Industry Codes & Standards

ACI 318-19	Building Code Requirements for Structural Concrete
ACI 350R	Environmental Engineering Concrete Structures
ACI 530-13	Building Code Requirements and specifications for Masonry Structure
TMS 402-13	Direct Design Handbook for Masonry Structures
ASCE 5-13	Building Code Requirements and Specification for Masonry Structures
ACI SP-17(14)	The Reinforced Concrete Design Handbook
ASCE 7-22	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
EM 1110-2-2014	Strength Design for Reinforced Concrete Hydraulic Structures
EM 1110-2-2902	Engineering and Design: Conduits, Pipes, and Culverts Associated with Dams and Levee Systems
IBC -2018	International Building Code
BS EN 1990:2002+A1:2005	Eurocode – Basis of Structural Design
SHA	Seismic Hazard Assessment September 2022 CRBC (Lift-Cum-Gravity) Project, NESPAK
TSS	Time-Saver Standards for Building Types
AWS D1.1	Structural Welding Code – Steel
AWS D1.	Structural Welding Code – Reinforcing Steel
AASHTO LRFD	Design Specifications for Bridges
ASTM A615	Standard Specification for Deformed and Plain Carbon-Steel
ASTM A416	Standard Specification for Steel Strand, Uncoated Seven-Wire for Pre-Stressed Concrete

- ASTM A421 — Standard Specification for Uncoated Stress-Relieved Steel Wire strands for Pre-Stressed Concrete
- ASTM A722 — Standard Specification for Uncoated High-Strength Steel Bars for Pre-Stressing Concrete
- ASTM A706 — Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
- ASTM A185 — Specification for Welded plain Steel Wire Fabric
- ASTM A497 — Specification for Welded Deformed Steel Wire Fabric

6.4 Soil Parameters

6.4.1 Earlier Site

The bore logs showed asymmetrical characteristics of stratification. However, it has been established that the sub-soil stratification is predominantly composed of Sand (SP), Sand with gravel, cobbles and boulders and Silty Sand with boulders.

Top layers showed lower penetration resistance, thereby showing very loose to lax compacted fills. Standard Penetration Resistance “SPT-N value” is generally between 4 to 12 in top 10m. Strata are medium dense to dense after these depths. Average SPT-N value is 23 to 32 in the entire boring depths in all boreholes. The average SPT N value increased due to higher SPT-N value at deeper depths.

Liquefaction potential was checked in all four boreholes and strata found mostly liquefiable in top 11 m.

In the powerhouse area, water and structure load is variable at different sections with maximum applied pressure at base level as 4.15 TSF. The structure is safe against liquefaction, uplift and soil is capable to bear applied loads safely on mat foundation considering the overburden relief and improved soil conditions with the replacement and compaction of sub-soil as per design drawings.

6.4.2 Newly Proposed Site for Intake and Powerhouse Areas:

As concluded in the geotechnical report that presence of highly permeable overburden deposits, viz. gravel, cobbles, boulders with silt, required deeper curtainwalls at upstream face and to control bearing capacity within allowable ranges under various loading scenarios.

6.5 Meteorological & Seismic Design Data

6.5.1 Wind

Basic Wind Speed, 3-sec gust speed	150 km/hr
Basic Wind Speed, Fastest-mile, (km/hr)	120 (km/ hr) 50 yr
Exposure Category	C
Prevailing Direction	W

6.5.2 Earthquake Data

Project Site lies in an area prone to highly seismic excitation. According to Building Code of Pakistan (2007), project site lies on confluence Seismic Zone 3 & 4 as per Figure 2.1of BCoP,

6.5.3 Selection of Seismic Design Parameters

a) Maximum Credible Earthquake (MCE)

The MCE is defined as the largest earthquake that can reasonably be expected to be generated by a specific source on the basis of seismological and geological evidence. The MCE is evaluated using Deterministic Seismic Hazard Analysis (DSHA) methods informed by results from a PSHA.

b) Maximum Design Earthquake (MDE)

The MDE is the maximum level of ground motion for which a structure is designed or evaluated. The associated performance requirement is that the project performs without loss of life or catastrophic failure (such as an uncontrolled release of a reservoir) although the severe damage or economic loss may be tolerated.

c) Operating Basis Earthquake (OBE)

The OBE is an earthquake that can reasonably be expected to occur within the service life of the project, typically a 50% probability of exceedance in 100 years. The purpose of the OBE is to protect against economic losses from damage or loss of service, therefore, alternative choices of return periods for the OBE may be based on economic considerations.

6.5.4 Seismic Design Parameters

a) Maximum Design Earthquake (MDE) Acceleration

As the Project site is categorized as highly Hazard Potential Hydraulic Structure, therefore for critical structures (if any) of the project, the recommended ground motion for MDE is 0.68g (corresponding to a return period of 975 year). For all other structures, the recommended ground motion for MDE is 0.32g (corresponding to a return period of 475 year).

b) Operating Basis Earthquake (OBE) Acceleration

The purpose of the OBE design is to protect against economic losses from damage or loss of service for all project structures. The performance requirement is that the project functions with little or no damage or interruption under OBE conditions.

As per definition of OBE given above, OBE accelerations corresponding to 50% probability of exceedance in 100 years (i.e. a return period of 145 years) may be adopted for which PGA value is 0.32g.

- Short Period Acceleration (SS): 35 %g 62%g 90%g
- 1-Sec Period Acceleration (PGA) (S1): 16 %g 27%g 34%g
- Site Class D

6.5.5 Ambient Air & Soil Temperatures, (°C): (Assumed Values)

- Average Annual Temperature 30°C

- Average Daily Maximum Temp. (Hottest month) 35°C
- Monthly Normal Max Temp (Hottest month) 40 °C
- Lowest Recorded Temperature -25°C
- Highest Recorded Temperature 45°C

Note: A linear temperature variation of up to 45°C across structural members may be presumed for analysis and assessment of thermal stresses with respect to assumed average installation temperature of 30°C. (10°C to 45°C)

6.5.6 Requirement of Concrete & Reinforcement for Pump Station:

Non-Structural Concrete

Unreinforced concrete of no significant structural value such as lean/ blinding concrete for sub-slabs, designated as Class 'D'. The minimum 28-day design compressive strength (ASTM C39) shall be 10.5 MPa (1500 psi).

Structural Concrete

All reinforced concrete including concrete with minimum reinforcement for temperature & shrinkage control. The 28-day design compressive strength (ASTM C39) shall be,

- 21 MPa (3000 psi) for lining, designated as Class 'C',
- 28 MPa (4000 psi) for structural concrete, designated as Class 'B',
- 35 MPa (5000 psi) for pre-cast concrete & second stage concrete, designated as Class 'A'
- 42 MPa (6000 psi) for Pre-stressed Concrete Members, designated as Class 'AA'.

Portland Cement shall conform to ASTM C150

a) Type-1, if concrete members exposed to: Sulfate SO4 less than 0.1% by weight of soil and less than 150 ppm in ground water and water with total dissolved solid more than 1000 PPM, Chemicals, water table less than three feet from the bottom of foundation, sewage treatment plant.

b) Type-1+Silica Fume: if concrete members exposed to: water soluble sulphate content more than 0.1% and water-soluble chloride more than 0.5% by weight of soil, sulphate more than 1500 ppm and chloride more than 10,000 ppm in ground water.

Curing Method

Curing method of Concrete elements shall be seven days water curing or three days water curing followed with curing compounds.

Reinforcement Steel Bars

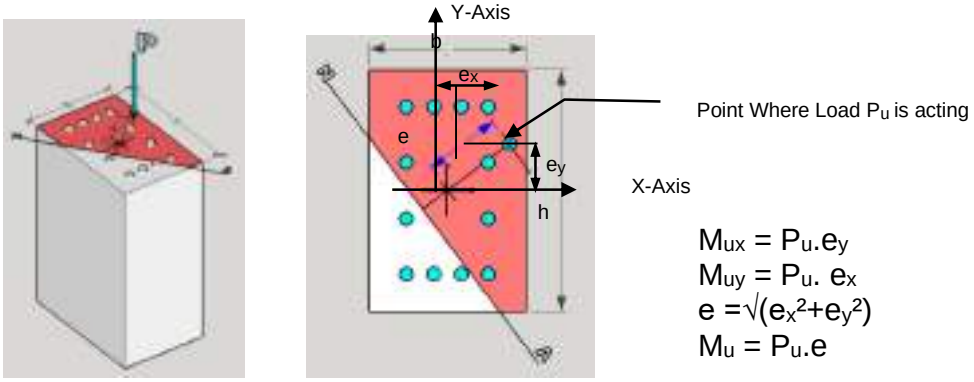
Reinforcement steel bars shall conform to ASTM A615, hot-rolled, high tensile, deformed steel. These bars shall be acceptable under the ACI 318M specified limitation of 422 MPa (60.0 ksi). Pre-stressing Steel shall conform to ASTM A416 (Grade 270), Uncoated Seven-Wire ordinary stress-relieved strands, giving area of strands 0.153 $in.^2$

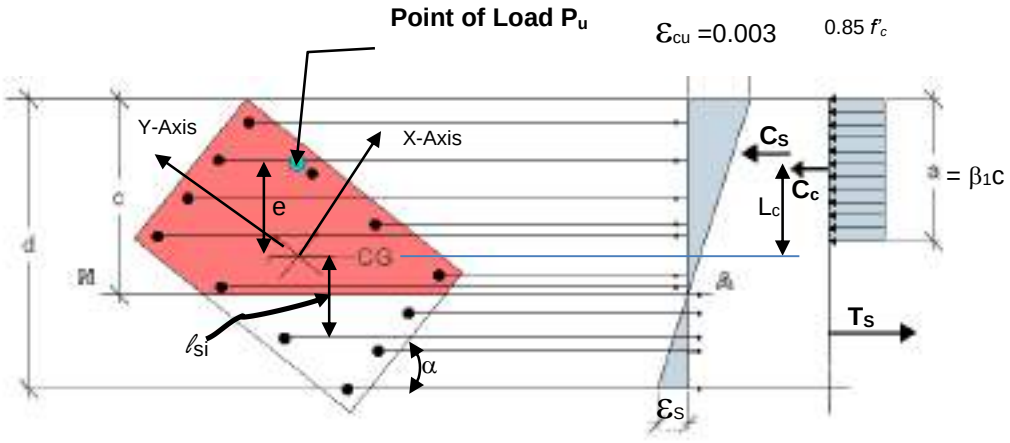
6.6 Philosophy of Structural Analysis & Design:

The structural frame above ground is configured with columns, beams, slabs with block masonry walls as shear elements and STAAD.Pro analysis program used for analysis and design of structural elements. Approximate analysis tools used to check accuracy of results obtained from STAAD.Pro. The crux of the Analysis & Design philosophy is to ensure that the resisting capacity of structural elements against worst possible loading scenarios i.e., applied loads in axial, shear, flexure and torsion or combination thereof, be always greater or equal.

6.6.1 Column Capacity

The Limit-State Design Strength of Columns depends upon the limiting strain in re-bars used in the column section at the time of crushing of concrete. A column subjected to a compressive force P near its ultimate nominal strength, as shown, can be visualized as equivalent to the Force P and Moment = P. e at its centroid.





The Internal Resistance developed against the external load Pu may be summarized as below:

The nominal Compression Strength Pn of Reinforced cement Concrete (RCC) Section at ts C.G:

$$P_n = C_C + C_S + T_S \qquad \text{------- ------ ---- ----1}$$

Wherein:

$$C_C = 0.85 f_c' A_c$$

$$C_S = \sum_1^m f_{Si} A_{Si}$$

$$T_S = \sum_1^n f_{Si} A_{Si}$$

The nominal Flexural Capacity M_n of RCC Section about its C.G.:

$$M_n = C_C . L_c + \sum_1^m f_{Si} A_{Si} . \ell_{si} + \sum_1^n f_{Si} A_{Si} . \ell_{si} \qquad \text{------- ------ ---- ----2}$$

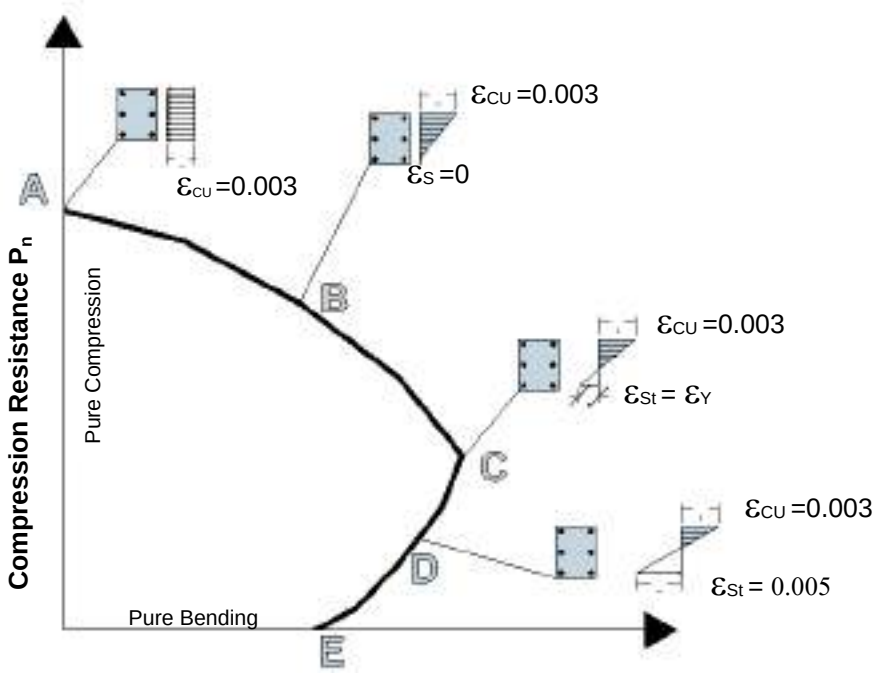
Where:
- n, m = Number of bars in tension and compression
- A_C = Area of concrete in compression
- f'_c = Compressive strength of concrete at 28 days
- A_{si} = Area of steel re-bars numbered as 'i'
- f_{si} = Stress in steel bar numbered as 'i' determined from strain in steel bars as per strain diagram such that $f_s \le f_y$
- f_y = Yield strength of Steel re-bars
- L_C = Center of Compression area w.r.t. to C.G, perpendicular to N.A.
- ℓ_{si} = Center of Steel Rebar numbered as 'i' from C.G, perpendicular to N.A.
- N.A = Neutral Axis
- α= Inclination of Cartesian Axes, X, Y with the Line of N.A.

The perpendicular distance of point defined in Cartesian coordinate system (x,y,) at C.G, inclined at angle α may be determined by the following Expression:

$$\ell_i = x_i \cos\alpha + y_i \sin\alpha$$

Note: As long as the external loads on column section fall nearby the Center of Gravity of the section, the moment induced in the section is minimal and load carrying capacity of the section is maximum, i.e. M = P.e, where (e is the eccentricity of Load P from the C.G of the section.

This phenomenon of Column loading is visualized from interaction Diagram.



Point A: Represents Pure Compression i.e. The Internal resistance in compression is maximum, in resisting compression to the externally applied load of Pu acting at C.G of the section. Hence the eccentricity e = 0 and Mu = Pu x 0 = 0.

Point B: The external loads shifted away from C.G of the section at distance 'e' perpendicular to the N.A, such that the strain in the farthest steel from extreme compression fiber of the concrete is zero. The point signifies that under externally applied loads to the maximum will not induce tension forces in the section. i.e. Ts = 0 and corresponding resisting compression forces

C = CC+CS will be optimum.

Point C: The external loads shifted a bit further away from C.G of the section at distance 'e' perpendicular to the N.A, such that the strain in the farthest steel from extreme compression fiber of the concrete is equal to yield strain of steel i.e.:

$$\varepsilon_s = \varepsilon_y = \frac{f_y}{E_s}$$

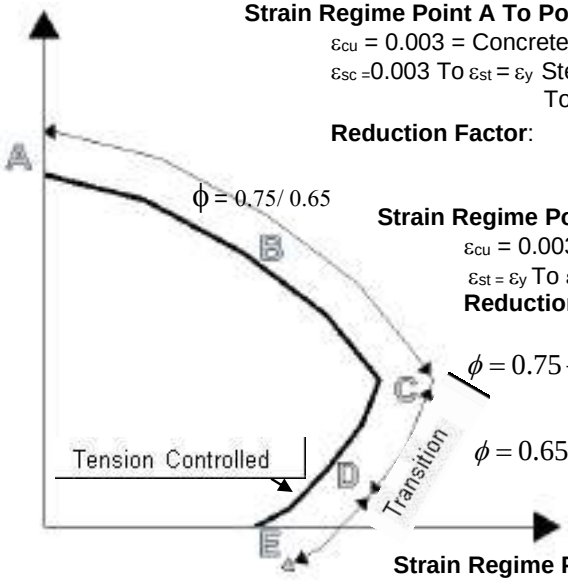
For Grade 60 Steel Re-bars, ε y =0.00207. The corresponding strain in compression fiber of concrete is ε_{CU} = 0.003. This point signifies the balanced failure stage, i.e. the crushing of concrete and yielding of steel starts simultaneously. The N.A now shifts in the direction of loading thus reducing the compression depth of the section.

Point D: The external loads shifted further away from C.G of the section perpendicular to the N.A, such that the strain in other steel bars reaches yield strain, and the farthest steel bar has strain equal to or greater than εy+0.003. A stage where it is called that tensioned controlled limit state has reached (Refer Table 21.2.2 ACI-318-19). The point signifies that the Tensile forces in the section are increasing and corresponding total compressive forces are decreasing gradually to a point E, as shown on the interaction diagram, is reached where Total tension equals total compression and the net axial load resistance capacity reduces to zero.

Point E: This stage signifies pure flexure in the column section. Beyond this point there will be no compression in the section and column section will be in tension

6.6.2 Strength Reduction Factor f

As strain in the extreme steel bars from the compression fiber of concrete changes from Compression (Point A) to Tension (Point beyond B) through zero strain at point B on the strain regime the failure mode changes from brittle to ductile behaviour. The Code, in view of in-situ limitations, implies capacity / strength reduction factors. Numerical value of Reduction factor ϕ is higher for brittle mode of failure and increases to figure of 0.9 gradually in ductile mode of failure.



Strain Regime Point A To Point C

ε_{cu} = 0.003 = Concrete Compressive Strain

ε_{sc} =0.003 To $\varepsilon_{st} = \varepsilon_y$ Steel Strain in compression To Steel Strain in Tension

Reduction Factor: ϕ = 0.75 for Spiral Ties

ϕ = 0.65 for other Ties

Strain Regime Point C To Point D (Transition)

ε_{cu} = 0.003 = Concrete Compressive Strain

$\varepsilon_{st} = \varepsilon_y$ To $\varepsilon_{st} = \varepsilon_y + 0.003$ Steel Tensile Strain

Reduction Factor:

$$\phi = 0.75 + 0.15\frac{\left(\varepsilon_{st} - \varepsilon_y\right)}{0.003}$$ Spiral Ties

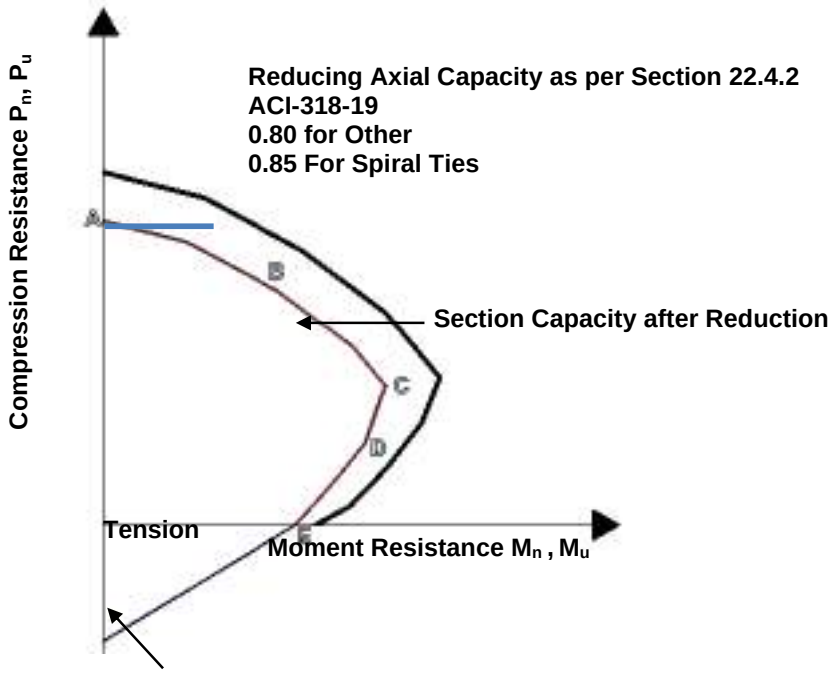
$$\phi = 0.65 + 0.25\frac{\left(\varepsilon_{st} - \varepsilon_y\right)}{0.003}$$

Strain Regime Point D To Point E (Tension Controlled)

ε_{cu} = 0.003 = Concrete Compressive Strain

$\varepsilon_{st} \geq \varepsilon_y + 0.003$ Steel Tensile Strain

Reduction Factor: ϕ = 0.9 for All



Reducing Axial Capacity as per Section 22.4.2
ACI-318-19
0.80 for Other
0.85 For Spiral Ties

$$P_t = 0.9 f_y \sum_{i=1}^{n} A_{si}$$

$$P_u = \phi P_n$$

$P_{u\max} = 0.85\phi P_n$ For Spiral Ties

$P_{u\max} = 0.80\phi P_n$ For Others

$$M_u = \phi M_n$$

------ ------- ------- -- 3

Invoking above noted algorithm and data into cells of Spreadsheet and correlating them through aforementioned relations will yield interaction diagram of column capacity (Pu, Mux & Muy) for various stages of strain variation at ultimate loading across the section of the column.

All loading combinations (LC), after structural analysis, can be compared on the Column Capacity Interaction Diagram to assess structural integrity of the column against various loading scenarios. Column is deemed safe if all LCs fall within the section capacity of column after applying reduction factors.

6.6.3 Section Flexural Capacity

Refer strain Diagram of a section at the limiting stage of loading scenario; crushing strain in concrete equal to 0.003, and strain in tensile steel at various amounts of tensile steel: - at yield strain of grade 60 steel; 0.00207, at the beginning ductility point; 0.00507; at the point when minimum steel is provided in the section.

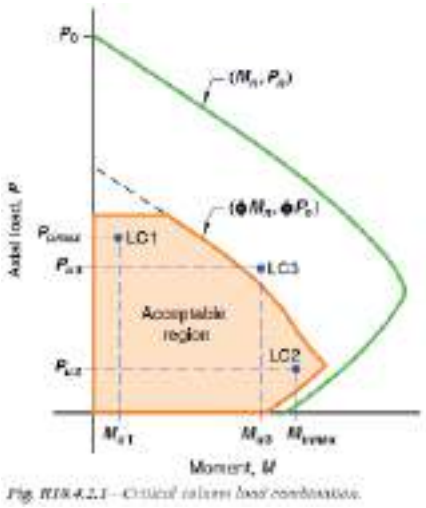
6.6.3.1 Overly Reinforced Section

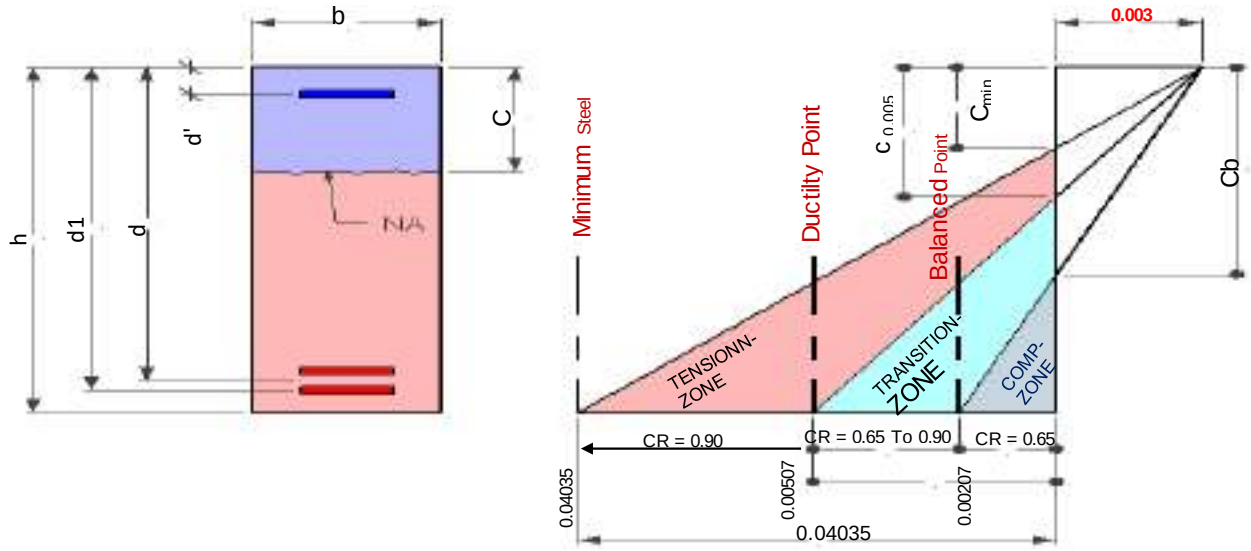
Sections are not recommended to be overly reinforced due to the fact that failure / instability is sudden without warning and Flexural capacity does not enhance appreciably by providing more reinforcement than recommended by the Code of Practice. Overly reinforced sections are those, wherein at failure, strain in steel is less than yield strain; $\varepsilon < \varepsilon_y$.

Maximum Capacity of overly reinforced section:

$$M_u \cong k\ bd^2 f_c^{'} \text{ Lbs-Ft or K-Ft. where } k = \frac{17\phi\beta_1}{240}\left(\frac{0.003}{\varepsilon+0.003}\right)\left(1-\frac{\beta_1}{2}\left(\frac{0.003}{\varepsilon+0.003}\right)\right)$$

Value of inverse of k; $[k]^{-1}$ ranges from 44.5 to 57.2 for $\varepsilon = 0.00001$ to $\varepsilon = 0.002$, an average value 1/k = 51.06





6.6.3.2 Minimum Reinforced Section

As per section ACI 318, §9.6.1.2, minimum reinforced section must have steel area as given below:

$$A_{S\min} > Max\left(\frac{3\sqrt{f_c'}}{F_y}, \frac{200}{F_y}\right) b_w.d \qquad \text{FOR } F_y \leq 80 \text{ ksi}$$

The corresponding strain in bars farthest from compression edge of beam is maximum, may be computed by the following relation:

$$\varepsilon_{\max} = \left(0.85\beta_1 \frac{bd_1}{A_{s_{\min}}} \frac{f_c'}{F_y} - 1\right) 0.003$$

Wherein β_1 can be estimated from the ACI 318, Table reproduced below:

Table 22.2.2.4.3—Values of β_1 for equivalent rectangular concrete stress distribution

f_c', psi	β_1	
$2500 \leq f_c' \leq 4000$	0.85	(a)
$4000 < f_c' < 8000$	$0.85 - \frac{0.05(f_c' - 4000)}{1000}$	(b)
$f_c' \geq 8000$	0.65	(c)

Corresponding to maximum strain value, the neutral Axis depth is the minimum and can be evaluated as:

$$C_{\min} = \frac{0.003}{\varepsilon_{s_{\max}} + 0.003} d_t$$

Where d_t is the location farthest tension steel from compression side

Corresponding to these values, the ultimate Moment Capacity is:

$$M_u = \phi A_{\varepsilon_{min}} F_y \left(d - \beta_1 \frac{c_{min}}{2} \right)$$

Wherein: ϕ = 0.9 (Tension Controlled Section) as per Table below:

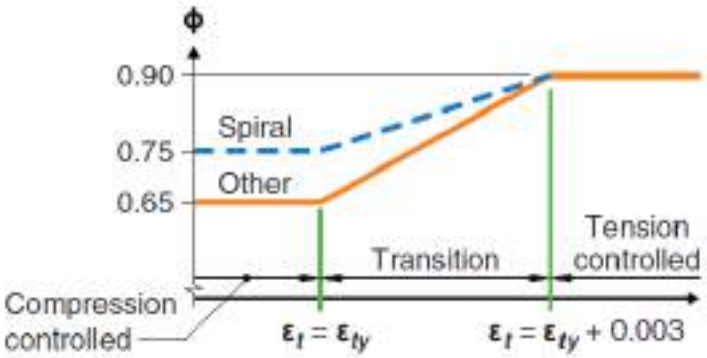


Fig. R21.2.2b—Variation of ϕ with net tensile strain in extreme tension reinforcement, εt.

Reduction Factor ϕ may be computed in the transition range by:

$$0.65 \le \phi = \phi_L + (\phi_U - \phi_L)\left(\frac{\varepsilon - \varepsilon_y}{0.003} \right) \le 0.9$$

Wherein $\phi_L = 0.65$ or $\phi_L = 0.75$ and $\phi_U = 0.90$

Flexural Ductility limit as per ACI 318-19 § 9.3.3.1 / R 9.3.3 for Tension Controlled Section; the limiting tension strain in steel is ≥ 0.004.

Corresponding value of ϕ at ε = 0.004 is:

$$\phi_{\varepsilon=0.004} = 0.817 \text{ For tied Sections}$$

$$\phi_{\varepsilon=0.004} = 0.850 \text{ For spirally tied Sections}$$

6.6.3.3 Tension Controlled Reinforced Section

As defined in the Code ACI 318 & 9.3.3.1, the ductility is ensured for limiting tension strain in the farthest steel layer at ε = 0.004 to $\varepsilon = \varepsilon_{max}$

Ideally Tension Controlled section as per definition of code, verbatim copy reproduced herein below for the facility of quick reference as;

> **tension-controlled section**—a cross section in which the net tensile strain in the extreme tension steel at nominal strength is greater than or equal to ε_{ty} + 0.003.

Therefore, at $\varepsilon = 0.003+\varepsilon_{ty}$ to $\varepsilon = \varepsilon_{max,}$ Capacity Reduction ϕ = 0.90

Code allows using $\varepsilon_{ty} = f_y/E = 0.002$ is:

Refer ACI 318-19 § 21.2.2.1 & 21.2.2.2

$\varepsilon = 0.005$ To $\varepsilon = \varepsilon_{max} = \left(0.85\beta_1 \frac{bd}{A_{s_{min}}} \frac{f_c^{'}}{F_y} - 1\right) 0.003$

Wherein:

$$A_{S\,min} > Max\left(\frac{3\sqrt{f_c^{'}}}{F_y}, \frac{200}{F_y}\right) b_w.d \quad \text{FOR } F_y \leq 80 \text{ ksi}$$

Tension Controlled Section at $\varepsilon = 0.005$ requires steel area:

$$A_{s_{\varepsilon=0.005}} = \frac{51}{160}\beta_1 b d_t \frac{f_c^{'}}{F_y}$$

Neutral Axis Depth at $\varepsilon = 0.005$, $C_{\varepsilon=0.005} = \frac{3}{8} d_t$

Flexural Capacity:

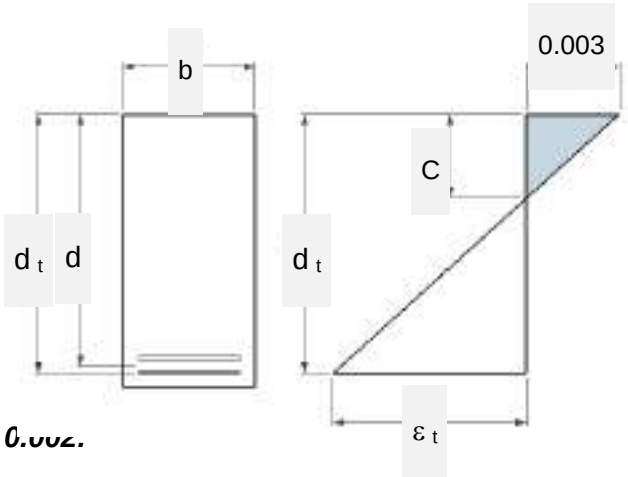
$$M_u = 0.9 A_{s_{\varepsilon=0.005}} d_t F_y \left(1 - \beta_1 \frac{3}{16}\right)$$

6.6.3.4 Tension Steel Required at Tension Strain ε=0.004:

$$A_{s_{\varepsilon=0.004}} = \frac{51}{140}\beta_1 b d_t \frac{f_c^{'}}{F_y} \quad \text{For } \phi_{\varepsilon=0.004} = 0.817$$

Neutral axis Depth:

$$C_{\varepsilon=0.004} = \frac{3}{7} d_t$$



Flexural Capacity:

$$M_u = \frac{49}{60} A_{s_{\varepsilon=0.004}} d_t F_y \left(1 - \beta_1 \frac{3}{14}\right)$$

6.6.3.4 Tension Steel Required at Yield Strain ε = 0.002:

This stage is called as balanced stage;

$$A_{s_{\varepsilon=0.002}} = \frac{51}{100}\beta_1 b d_t \frac{f_c^{'}}{F_y} \quad \text{For } \phi_{\varepsilon=0.002} = 0.65$$

Neutral axis Depth:

$$C_{\varepsilon=0.002} = \frac{3}{5} d_t$$

Flexural Capacity:

$$M_u = \frac{663}{2000} A_{s\,\varepsilon=0.002} d_t F_y \left(1 - \beta_1 \frac{3}{10}\right)$$

6.6.3.5 Summary

Generalized Expressions for flexural Capacity of Rectangular Sections:

Reduction Factor:

$$\phi_L \le \phi = \phi_L + (\phi_U - \phi_L)\left(\frac{\varepsilon_t - \varepsilon_y}{0.003}\right) \le \phi_U$$

Wherein $\phi_L = 0.65$ (Tied) or $\phi_L = 0.75$ (Spiral) and $\phi_U = 0.90$

Area of Tension Steel: $A_{s\,\varepsilon_t} = \left(\frac{0.00255}{0.003 + \varepsilon_t}\right) \beta_1 b d \frac{f_c'}{F_y}$

Flexural Capacity:

$$M_u = \phi\left(\frac{0.00255}{0.003 + \varepsilon_t}\right)\left[1 - \beta_1\left(\frac{0.0015}{0.003 + \varepsilon_t}\right)\right] \beta_1 b d^2 f_c'$$

Depth Factor Equivalent Stress Block:

$$0.0.65 \le \beta_1 = 0.85 - \left(\frac{f_c' - 4.0}{20}\right) \le 0.85$$

f_c' = Concrete Compressive Strength (KSi)

Neutral Axis Depth:

$$C = \left(\frac{0.003}{0.003 + \varepsilon_t}\right) d_t$$

ε_t	ϕ		C	A_S	M_U	
	Tied	Spiral			Tied, Spiral x	

0.002	0.650	0.750	$\frac{3}{5}d_t$	$\left(\frac{51}{100}\right)\left(f_c'/F_y\right)\beta_1 bd$	$\left(\frac{663}{2000}\right),\left(\frac{153}{400}\right)$	$\left(1-3/10\,\beta_1\right)\beta_1 bd^2 f_c'$
0.004	0.817	0.850	$\frac{3}{7}d_t$	$\left(\frac{51}{140}\right)\left(f_c'/F_y\right)\beta_1 bd$	$\left(\frac{119}{400}\right),\left(\frac{867}{2800}\right)$	$\left(1-3/14\,\beta_1\right)\beta_1 bd^2 f_c'$
0.005	0.900	0.900	$\frac{3}{8}d_t$	$\left(\frac{51}{160}\right)\left(f_c'/F_y\right)\beta_1 bd$	$\left(\frac{459}{1600}\right),\left(\frac{459}{1600}\right)$	$\left(1-3/16\,\beta_1\right)\beta_1 bd^2 f_c'$
0.040	0.900	0.900	$\frac{3}{43}d_t$	$\left(\frac{51}{860}\right)\left(f_c'/F_y\right)\beta_1 bd$	$\left(\frac{459}{8600}\right),\left(\frac{459}{8600}\right)$	$\left(1-3/86\,\beta_1\right)\beta_1 bd^2 f_c'$

Tension Reinforcement vis-à-vis Strain Range εt= 0.002 to εmax:

For Given Section and its mechanical properties (in, Kips), Area of tension Steel (in.²) may be computed using following expression:

$$A_s = 0.85bd\frac{f_c'}{F_y}\left(1-\sqrt{1-\frac{M_u}{0.425\phi bd^2 f_c'}}\right)$$

Compression Reinforcement:

Flexural capacity of a section with compression re-bars does not appreciate much, except deflections are controlled considerably.

Compression Steel yields if depth of center of compression steel d' fulfils the condition: $d' \le \frac{C}{3}$:

where C is neutral Axis Depth.

In case, Compression steel does not yield, Neutral Axis depth may be computed by the following relation:

$$C = \frac{\left(A_s f_y - 87A_{s'}\right)+\sqrt{\left(A_s f_y - 87A_{s'}\right)^2 + 295.8\beta_1 bd' A_{s'} f_c'}}{1.7\beta_1 b f_c'}$$

Flexural Capacity of Section with Compression Re-Bars:

$$M_u = 0.85\phi\beta_1 bcf_c'\left(d-\frac{\beta_1 C}{2}\right)+87\phi As'\left(1-\frac{d'}{C}\right)\left(d-d'\right)$$

In case compression steel yields, NA depth C is calculated by the expression:

$$C = \frac{(A_s - A_{s'})\, f_y}{0.85\beta_1 b f_c'} \quad \text{or} \quad C = \frac{A_s f_y - A_{s'}\left(f_y - 0.85 f_c'\right)}{0.85\beta_1 b f_c'}$$

Flexural Capacity of Section with Compression Re-Bars yield:

$$M_u = 0.85\phi\beta_1 b c f_c'\left(d - \frac{\beta_1 C}{2}\right) + \phi As'\, f_y\,(d - d') \quad \text{or}$$

$$M_u = 0.85\phi\beta_1 b c f_c'\left(d - \frac{\beta_1 C}{2}\right) + \phi As'\left(f_y - 0.85 f_c'\right)(d - d')$$

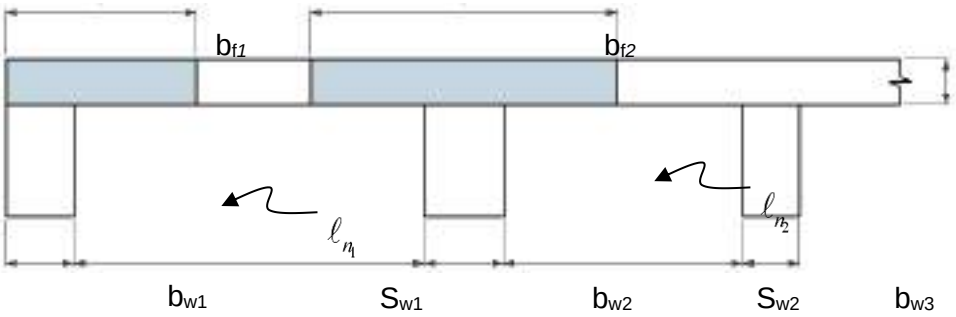
The second term for C and Mu gives more accurate results because these terms account for equivalent concrete stress deduction from steel stress. These expressions are valid for tension-controlled or ductile sections.

Tee Beams

The Analysis of Tee-Beams is similar to rectangular beam sections with following exceptions for effective flange width. Refer ACI 319-19 Table 6.3.2.1:

Table 6.3.2.1—Dimensional limits for effective overhanging flange width for T-beams

Flange location	Effective overhanging flange width, beyond face of web	
Each side of web	Least of:	$8h$
		$s_w/2$
		$l_n/8$
One side of web	Least of:	$6h$
		$s_w/2$
		$l_n/12$



$$b_{f1} = b_{w1} + \text{least of} \begin{cases} 6h \\ s_{w1}/2 \\ \ell_{n1}/12 \end{cases} \qquad b_{f2} = b_{w2} + \text{least of} \begin{cases} 16h \\ (s_{w1}/2) + (s_{w2}/2) \\ \ell_{n2}/4 \end{cases}$$

For minimum Reinforcement in flange in tension: Refer ACI 318-19 § 9.6.1.2 &§ 9.6.1.3, the value of $b_{w'}$ is Minimum (b_f , $2b_w$) and for flange in compression, $b_{w'} = b_w$

$$A_{S\min} > Max\left(\frac{3\sqrt{f_c^{'}}}{F_y}, \frac{200}{F_y}\right) b_{w'}.d \qquad \text{FOR } F_y \leq 80 \text{ ksi}$$

6.6.4 Shear & Torsional Capacity of Section

6.6.4.1 Nominal one-way shear strength at a section:

$$V_n = V_c + V_s$$

Cross-sectional dimensions shall be selected to satisfy Eq.22.5.1.2 ACI318-9

$$V_u \leq \phi\left(V_c + 8\sqrt{f_c^{'}} b_w d\right) \text{ ACI 318-19 Eq, 22.5.1.2}$$

One-way flexural shear capacity of concrete section shall be calculated by:

$$V_c = 2\sqrt{f_c^{'}} b_w d$$

Shear capacity is enhanced by providing steel stirrups and the Shear Capacity provided by vertical shear steel is computed by:

$$V_s = \frac{A_v f_{yt} d}{s} \qquad \text{ACI 318-19 Eq, 22.5.8.5.3}$$

Shear stirrups are required if the shear capacity of non-reinforced concrete is inadequate to sustain external shear at the section.

Shear Capacity Reduction Factor:

ϕ = 0.75 both for Shear and Torsion in flexure ACI 318-19 Table 21.2.1

Minimum Shear Stirrup Spacing: ACI 318-19 § 8.7.6.3

Table 8.7.6.3—First stirrup location and spacing limits

Direction of measurement	Description of measurement	Maximum distance or spacing, in.
Perpendicular to column face	Distance from column face to first stirrup	$d/2$
	Spacing between stirrups	$d/2$
Parallel to column face	Spacing between vertical legs of stirrups	$2d$

Maximum Shear Stirrup Spacing: ACI 318-19 & 9.7.6.2.2

Maximum spacing of legs of shear reinforcement along the length of the member and across the width of the member shall be in accordance with Table 9.7.6.2.2.

Table 9.7.6.2.2—Maximum spacing of legs of shear reinforcement

Required V_s		Maximum s, in.			
		Nonprestressed beam		Prestressed beam	
		Along length	Across width	Along length	Across width
$\le 4\sqrt{f'_c}b_w d$	Lesser of:	$d/2$	d	$3h/4$	$3h/2$
		24 in.			
$> 4\sqrt{f'_c}b_w d$	Lesser of:	$d/4$	$d/2$	$3h/8$	$3h/4$
		12 in.			

6.6.4.2 Shear - Torsional Capacity of Section:

ACI 318-19 & 9.5.4.3; Total transverse Re-bars shall be:

$$\text{Total}\left(\frac{A_{v+t}}{s}\right)=\frac{A_v}{s}+2\frac{A_t}{s} \qquad \text{(R9.5.4.3)}$$

ACI 318-19 & 9.6.4.2: Minimum Area of Transverse Rebar shall be:

$$\left(A_v+2A_t\right)_{\min} \ge Max\left(0.75\sqrt{f_c'}\frac{b_w}{f_{yt}},\ 50\frac{b_w}{f_{yt}}\right)$$

ACI 318-19 & 9.6.4.3: Minimum Area Longitudinal Rebars shall be:

$$A_{l\,\min} \ge Min\left(\left[5\sqrt{f_c'}\frac{A_{cp}}{f_y}-\left(\frac{A_t}{s}\right)p_h\frac{f_{yt}}{f_y}\right],\left[5\sqrt{f_c'}\frac{A_{cp}}{f_y}-\left(\frac{25b_w}{f_{yt}}\right)p_h\frac{f_{yt}}{f_y}\right]\right)$$

ACI 318-19 & 9.7.3.2 & 9.7.3.3:

Transverse torsional reinforcement shall extend a distance of at least (b_t + d) beyond the point required by analysis and Spacing of transverse torsional reinforcement shall not exceed the lesser of $p_h/8$ and 12 in.

ACI 318-19 & 22.7.4.1: The threshold torsion below which torsion can be ignored in a solid cross section is:

$$T_{th}=\phi\sqrt{f'_c}\left(\frac{A_{cp}^2}{p_{cp}}\right)$$

ACI 318-19 & 22.7.7.1: Cross Sectional Limits for Solid Sections:

$$\sqrt{\left(\frac{V_u}{b_w d}\right)^2+\left(\frac{T_u p_h}{1.7A_{oh}^2}\right)^2} \le \phi\left(\frac{V_c}{b_w d}+8\sqrt{f_c'}\right) \qquad (22.7.7.1a)$$

ACI 318-19 & 22.7.5: Cracking Torsion:

$$T_{cr} = 4\sqrt{f_c'}\left(\frac{A_{cp}^2}{p_{cp}}\right)$$

6.6.5 Bearing Strength of Sections

ACI 318-19, 14.5.6.1, & 22.8.3.2. Nominal Bearing strength of supporting surface is calculated by the expression given herein, provided supporting surface is wider than loaded area on all sides.

$$B_n = Min\left[\sqrt{\frac{A_2}{A_1}}\left(0.85 f_c' A_1\right),\ 2\left(0.85 f_c' A_1\right)\right]$$

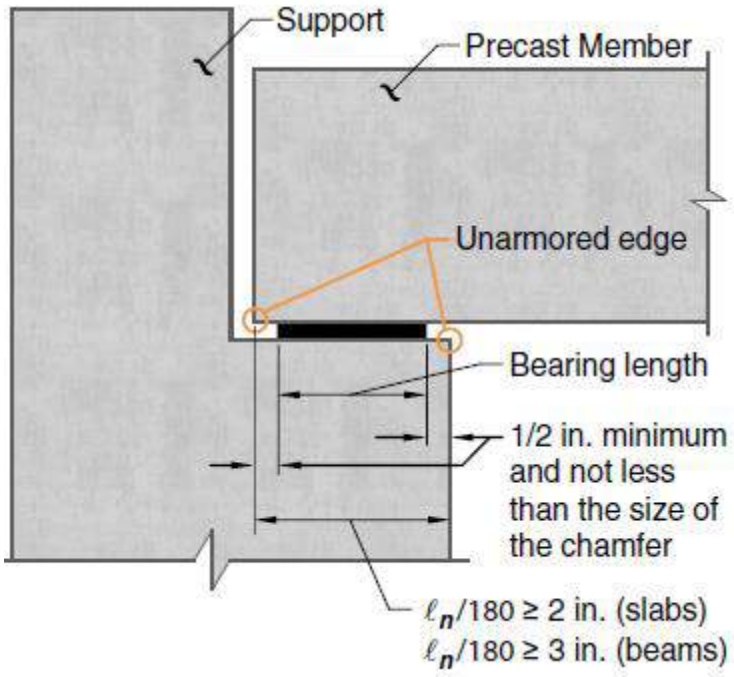
In other Case:

$$B_n = 0.85 f_c' A_1$$

ACI 318-19 & 16.2.6.2: Bearing pads adjacent to unarmoured faces shall be set back from the face of the support and the end of the supported member a distance not less than 0.5 in. or the chamfer dimension at a chamfered face. Refer Table 16.2.6.2

Table 16.2.6.2—Minimum design dimensions from face of support to end of precast member

Member type	Minimum distance, in.	
Solid or hollow-core slab	Greater of:	$\ell_n/180$
		2
Beam or stemmed member	Greater of:	$\ell_n/180$
		3



Strength Reduction Factor for Bearing: ACI 318-19, Table 21.2.1

$\phi = 0.65$

Maximum permissible Strength Reduction Factor can be increased as per ACI 318 19 & 27.3.2.1 Table 27.3.2.1:

$\phi = 0.80$

6.6.6 Punching Shear (Two-Way Shear Strength

ACI 318-19 & 22.6.5.2 & Table 22.6.5.2: two-way shear V_c of two-way-members without shear re-bars shall be as per expression given below:

$$V_c = Min\left[\left(4\lambda_s\lambda\sqrt{f_c'}\right), \left(\left(2+\frac{4}{\beta}\right)\lambda_s\lambda\sqrt{f_c'}\right), \left(\left(2+\frac{\alpha_s d}{d_o}\right)\lambda_s\lambda\sqrt{f_c'}\right)\right]$$

Wherein:

$\lambda = 1.0$ For Normal weight concrete

$\lambda_s = \sqrt{\frac{2}{1+\frac{d}{10}}} \leq 1.0$ Size effect modification factor:

ACI 318-19 & 22.5.5.1.3

$\beta = c_1/c_2$ Ratio of Long Side c_1 to short size c_2 of Bearing Area

α_s =ACI 318-19 § 22.6.5.3: 40 for Interior Column, 20 for Edge Columns, 20 for corner Columns

b_o = perimeter of critical section for two-way shear in slabs and footings, in.

$b_{o\ interior}$ = $2[c_1+c_2+2d]$

$b_{o\ edge}$ = $2[c_1+c_2+(3/2)d]$

$b_{o\ conner}$ = $2[c_1+c_2+d]$

6.7 Design Loads:

6.7.1 Dead Loads [D]

Dead loads are the actual weight of materials forming the structure, foundation, and all permanently attached appurtenances. Weights of fixed process equipment and machinery, piping, valves, electrical cable trays, and the contents of these items shall be considered as dead loads and as such dead loads include self-weight and partly superimposed dead loads. On this premise, dead loads are designated by the following nomenclature:

$$D_{SELF},\ D_{IMP},$$

Note: The existing sections used in the construction of steel structure (PEB) are non-standard AISC sections and nearest sections shall be used for simulation and analysis. D_{SELF} Loads are computed itself by the software and D_{IMP} Loads are taken minimum from the following list in the category of collateral loads.

6.7.2 Live Loads [L]

Live loads are those gravity loads produced by the use and occupancy of the structure. These include the weight of all movable loads; including personnel, tools, miscellaneous equipment, movable partitions, wheel loads, parts of dismantled equipment, stored material, etc.

Following Loads as deemed live loads are considered for various load combinations for the design of structural parts of the pump station.

- Workforce: 60 Lbs / SFt.
- Tools, Small Equipment etc. 100 Lbs / SFt.
- Heavy Tools and equipment etc. 250 PSF

6.7.3 Wind Loads [W]

6.7.3.1 Basic Wind Velocities:

Basic Wind Speed, 3-sec gust speed	150 km/hr
Basic Wind Speed, Fastest-mile,	120 (km/hr) 50 yr
Exposure Category	C
Prevailing Direction	NW

6.7.3.2 Velocity Pressure: qz

$q_z = 0.613\, K_z K_{zt} . K_d V^2 . I$ N/m², ASCE 7-22 Eq.26.101. SI

Ke =1 Ground Elevation Factor ASCE 7-22 § 26.9

Where:

V = Basic Wind Speed [m/sec] = 41.67 m/sec

K_z = Velocity Pressure Exposure Co-Efficient

ASCE 7-22 Tab.26.10-1

Height Above Ground Level (z), m	For Exposure Category C: K_z
0.0 to 4.6 (15 Ft)	0.85
4.6 to 6.1 (20 Ft)	0.90
6.1 to 7.6 (25 Ft)	0.94
7.6 to 9.1 ((30 Ft)	0.98
9.1 to 12.2 (40 Ft)	1.04
12.2 to 15.2 (50 Ft)	1.09
15.2 to 18.3 (60Ft)	1.13

Or Use Following expression for Exposure Category C

$15\ \text{Ft} \le z,\ K_z = 2.41\left(\frac{z}{2460}\right)^{(2/9.8)},\ z \ge 2460\ \text{Ft}$ Yields for Exposure C

K_z = 0.85 to 2.41 for Height z ≤ 15 Ft to Height z ≥ 2460 ft

K_{zt} = Topographic Factor = $(1+K_1K_2K_3)^2$ = 1.37

[K_1 = 0.17, K_2 =1, K_3 =1]

K_{zt} =1.0 (taken as per ASCE 7-22 § 26.8.2)

K_d = Wind Directionality Factor = 0.85 ASCE 7-22 Table 26.6-1

I = Importance Factor = 1.25 ASCE 7-22 Table 1.5-2

The expression for Velocity Pressure q_z reduces in terms of K_z as:

$q_z = (1.13)\ K_z$ kN/m²

The Wind Force F is determined from the basic equation ASCE 7 as:

$$F = q_z . G\, C_f\, A_f \qquad \text{A}$$

6.7.3.3 Gust Effect Factor: G

G = 0.85 ASCE 7-22 § 26.11.4

6.7.3.4 Net Force Co-Efficient: Cf: ASCE 7-22 Fig: 29.3-1

C_f = 2.0 For Structural Members

C_f = 0.7 For Pipes

C_f = 1.3 For Height to Width Ratio ≤ 3

6.7.3.5 Projected Area: Af:

A_f is the projected area normal to wind.

6.7.3.6 Final Wind Force Per Unit Area:

Invoking the termed values in the Equation A above reduces the expression for wind force per unit area taking K_z = 0.85 for height less than 4.6m as:

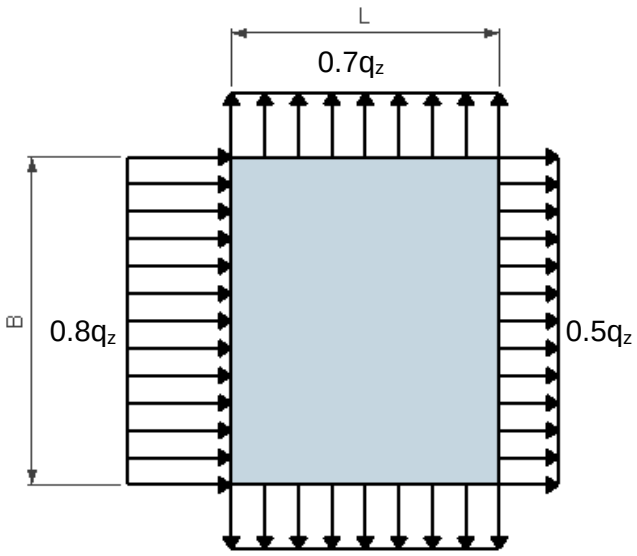
$$F/A_f = 1.13\ xK_z)x0.85x1.3 \cong 1.25\ K_z\ kN/m^2$$

For K_z = 0.85 F/A_f = 1.06 KN/m² (22 Lbs/SFt)

For K_z = 1.13 F/A_f = 1.41 KN/m² (30 Lbs/SFt)

6.7.3.7 Wind Loads in X and Z Directions:

The Wind loads on Windward face; rear and side faces of enclosed Building is distributed as per Figure 27.3-1 ASCE 7-22:



Total wind Force on the Sides = $q_z.L_x.L_z$

6.7.4 Seismic Loads [S]

6.7.4.1 Pseudo Static Seismic-Analysis

The force due to pseudo-static seismic acceleration may be approximated for the sake of simplicity of calculations as:

S = mass x acceleration

Where:

Acceleration is taken as: a = 16% or 27% or 34% of gravitational acceleration and

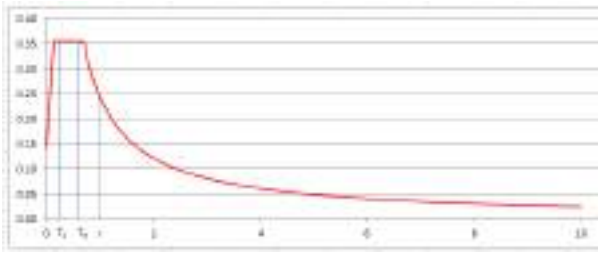
Mass = Weight / g

$$S = W/g \times [35 , 62 , 90]/100g$$

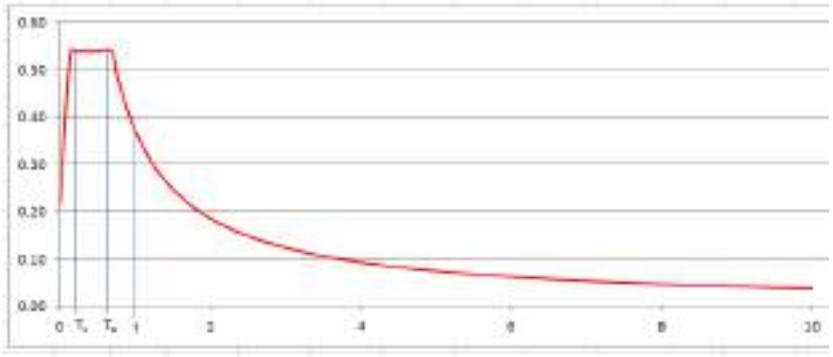
$$S = [\ 0.35, 0.62 , 0.90\ ]W$$

The forces on the joints are applied where the masses contribute their share accordingly.

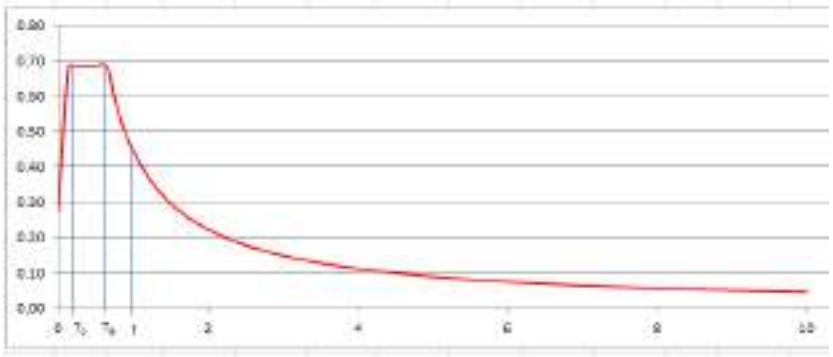
6.7.4.2 Response Spectral Acceleration OBE:



6.7.4.3 Response Spectral Acceleration MDE:



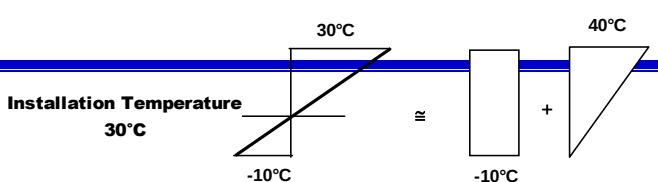
6.7.4.4 Response Spectral Acceleration MCE:



6.7.5 Temperature Loads [T]

The structural members are designed to take a linear thermal variation up to 50°C. Therefore, ΔT is reckoned from installation temperature of 30°C. During operation, the inside temperature may fall 10°C below installation temperature and may rise 20°C above the installation temperature.

STAAD.PRO Loading Shall be:



6.7.6 Fluid Loads [F]

Water flowing at speed "V" Ft /sec will exert a force of impact against a body of magnitude given below:

Volume of Water flowing per unit Area = AV; CFT/sec

Mass of water flowing = Density x Vol = ρAV

Change of Momentum per second per unit area is the impact force on the body:

Therefore:

$F/A = \rho V^2$; where $\rho = \gamma/g$

6.7.7 Soil Pressure Loads [H]

Earth Pressure is calculated:

$EP = K\gamma h$; wherein $k \cong 0.333$, $\gamma = 110$ Lbs/CFT;

$EP \cong 36.7\ h$; h is the depth of soil say (45 ft)

EP = 1.65 K/SFt

6.7.8 Soil Water (GWT) Pressure Loads [HW]

Earth Water Pressure is calculated:

$WP = K\gamma h$; wherein $k \cong 1.0$, $\gamma = 62.5$ Lbs/CFT;

$WP \cong 62.5\ h$; h is the depth of GWT (Expected) (23 ft)

WP = 1.44 K/SFt

6.8 Load Combinations and Load Factors

D =	Dead Loads (Self and Imposed)
L =	Live Loads (moveable, operational etc.)
Lp =	Live Pump Loads
Lr or R =	Roof Live or Rain load
E =	Earthquake (Seismic Loads)
H =	Earth Pressure due to Soil and Ground water
F =	Fluid / Liquid Loads (Contained/ Flowing water)
T =	Diurnal temperature variations loads

Following Load Combinations are used:

6.8.1 Service Design Load Combinations and Load Factors

Load	D	L	T	W	E	H	F	Lr or R
D	1.00	-	-	-	-	-	-	-
D + L	1.00	1.00	-	-	-	-	-	-
D + Lr or R	1.00	-	-	-	-	-	-	1.00
D + L + H + F	1.00	1.00	-	-	-	1.00	1.00	-
D + 0.75(L + Lr or R) +H + F	1.00	0.75	-	-	-	1.00	1.00	0.75
D + L + T + H +0.5 F	1.00	1.00	1.00	-	-	1.00	0.50	-
D+ 0.75 L + 0.75 W	1.00	0.75	-	0.75	-	-	-	-
D + 0.75 L + 0.45 W + 0.75 (Lr or R)	1.00	0.75	-	0.45	-	-	-	0.75
D+ T + 0.71E + H + F	1.00	-	1.00	-	0.71	1.00	1.00	-
D+ W or 0.71E + H +0.75 F	1.00	-	-	1.00	0.71	1.00	0.75	-
0.9D + 0.71E + 0.9H + 0.9F	0.9		-	-	0.71	0.90	0.90	-

6.8.2 Strength Design Load Combinations and Load Factors

Load	D	L/Lp	T	W	E	H	F	Lr or R
1.4D	1.40	-	-	-	-	-	-	-
1.2 (D + H + F)+ 1.6 L +0.5(Lr OR R)	1.20	1.60	-	-	-	1.20	1.20	-
1.2D +1.2(H+F) +1.6(Lr or R) + L or 0.5W	1.20	1.00	-	0.5	-	1.20	1.20	1.6
1.2D +1.2(H+F) +T + L or 0.5W	1.20	1.00	1.00	0.5	-	1.20	1.20	-
1.2D +1.2(H+F) +T or W+ Lp	1.20	1.00	1.00	1.00	-	1.20	1.20	-
1.2D +1.2(H+F) +1.6L + Lp + W	1.20	1.60	-	1.00	-	1.20	1.20	-
1.2 D+1.2(H+F) 1.6 W or E_{OBE}	1.20	-	-	1.60	1.00	1.20	1.20	-
D +H +F + Lp + E_{MCE}	1.0	1.0	-	-	1.00	1.00	1.00	-
1.2(D+H+F) +1.6Lp + E_{MDE}	1.20	1.20	-	-	1.0	1.20	1.20	-
1.2 D+ 1.2 T+1.2 (H +F)	1.20	-	1.2	-	--	1.20	1.20	-
0.9 D + 0.9 H +0.9F + E_{MCE}	0.9	-	-	-	1.00	0.90	0.90	-
0.9 D + 0.9H +0.9F 1.3 W	0.90	-	-	1.3	-	0.90	0.90	-

6.9 References

- SOIL INVESTIGATION REPORT of the nearby Plant Area
- REINFORCED CONCRETE MECHANICS AND DESIGN: by James G. Macgregor
- FOUNDATION ANALYSIS AND DESIGN by: Joseph E. Bowles

6.10 Annexures

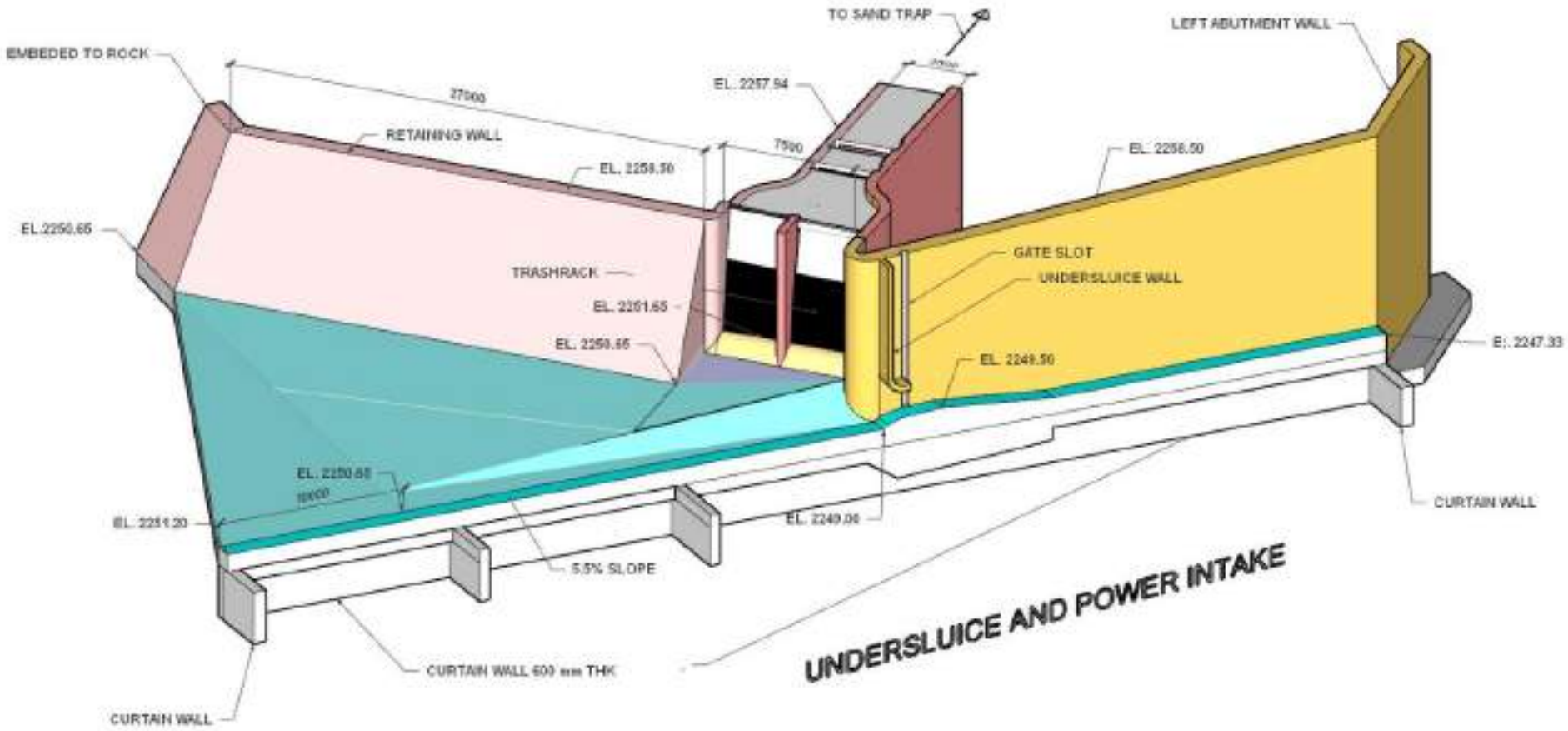
The following annexures are attached to this Section:

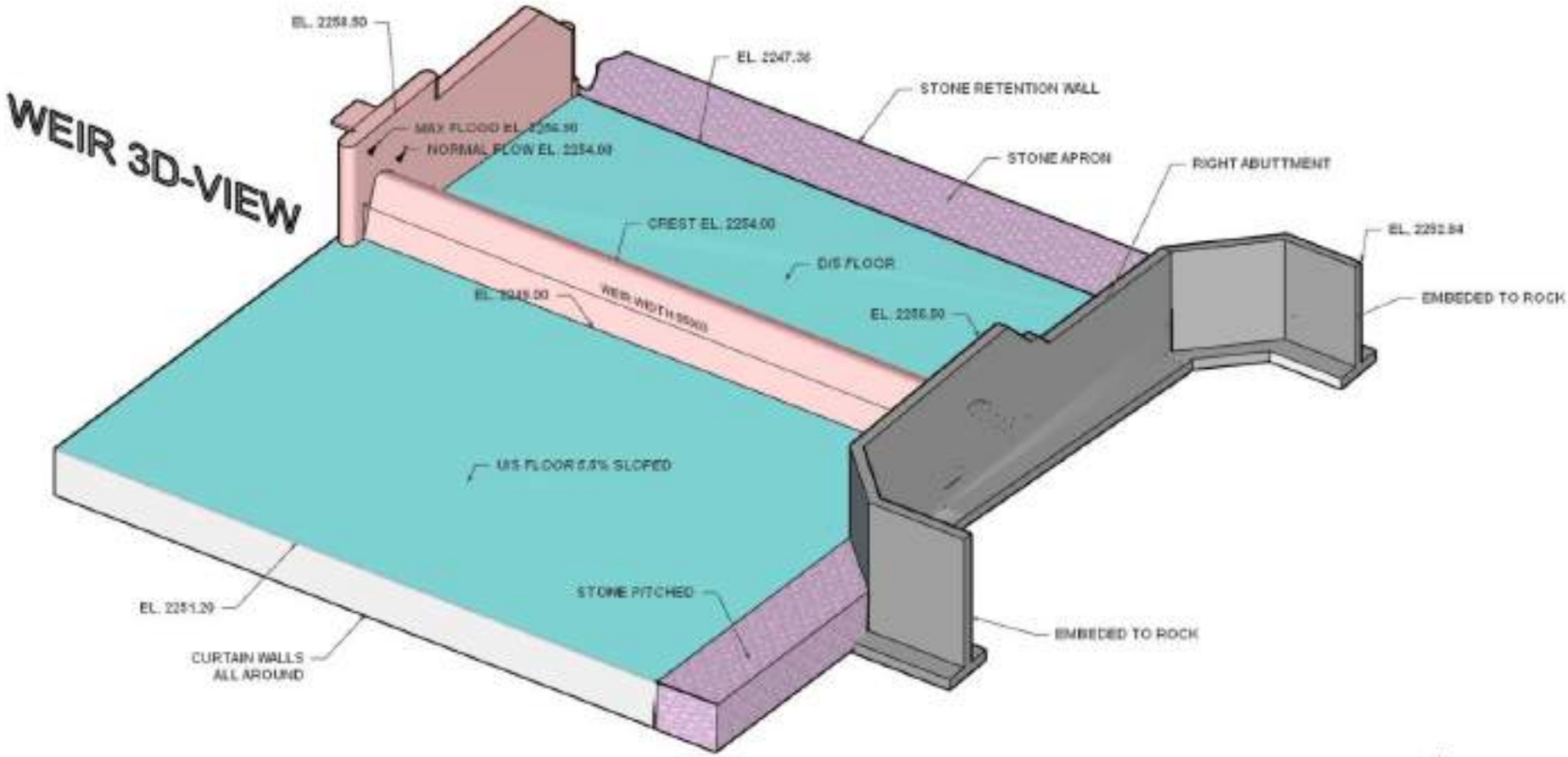
Annexure A - Sketches: Intake, Sand-Trap-Diversion Weir, Under-Sluice, Energy Dissipator

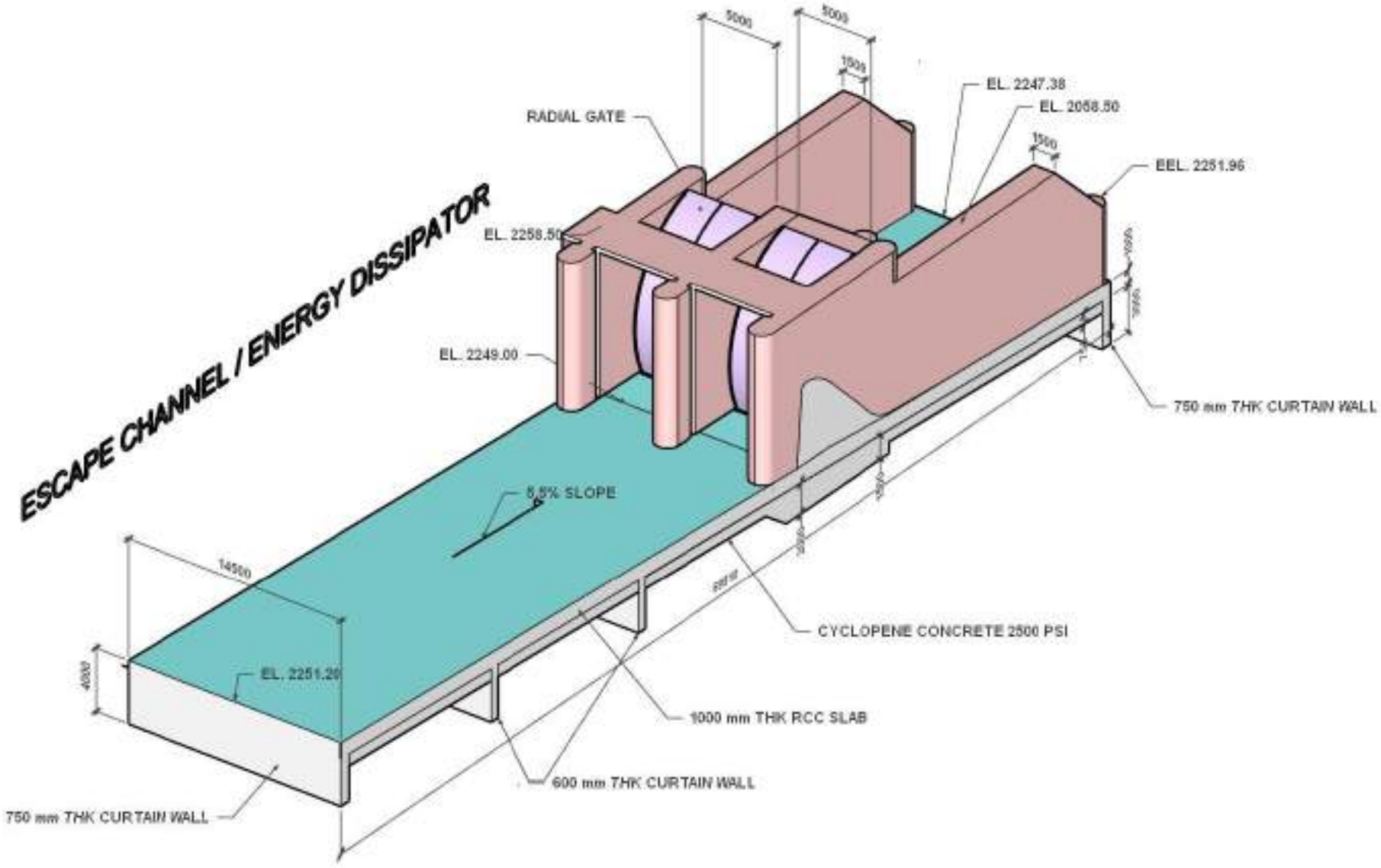
Annexure B - Concrete Supports for Exposed Steel-Liner

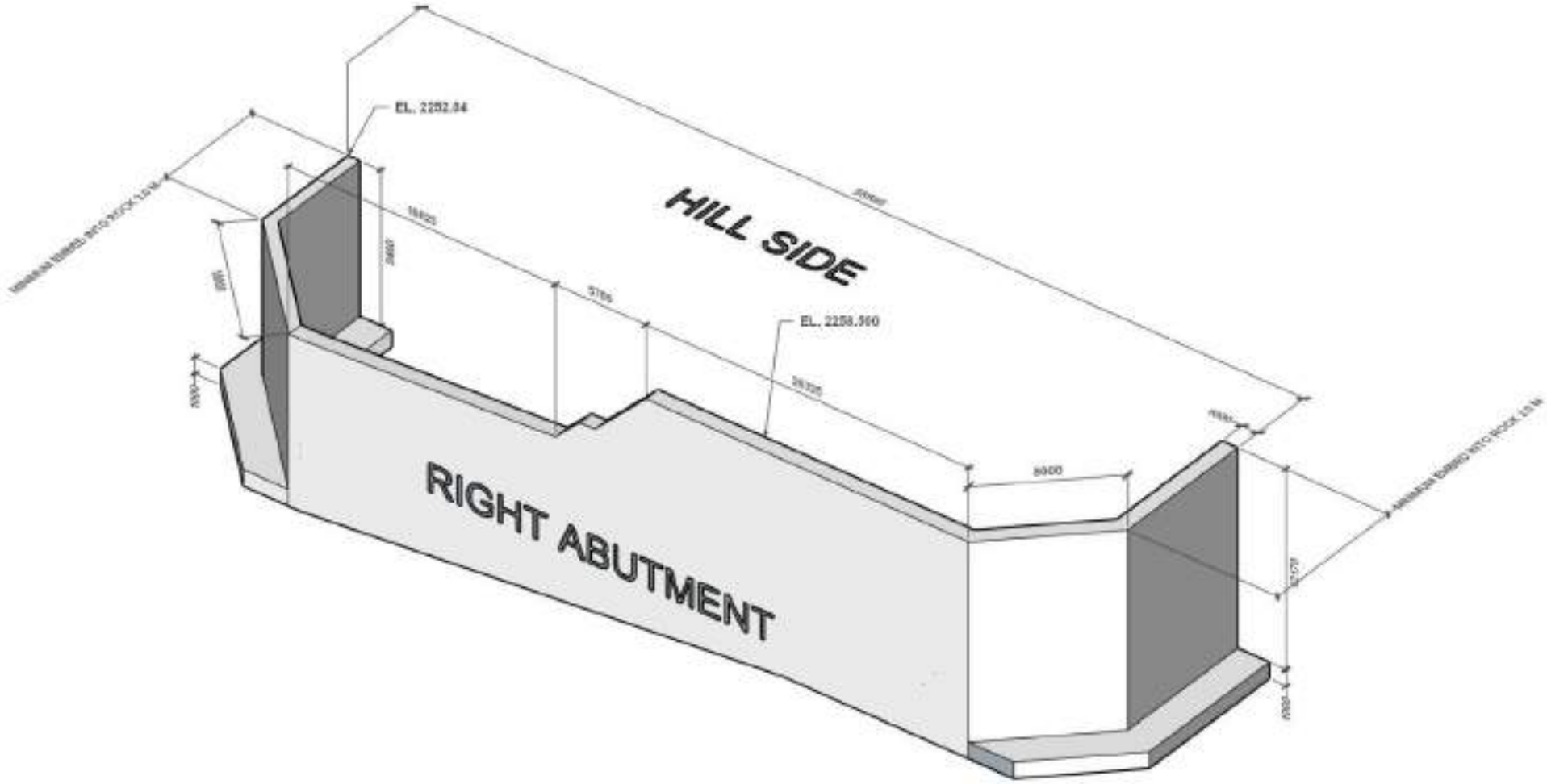
Annexure C - RCC Anchor Blocks

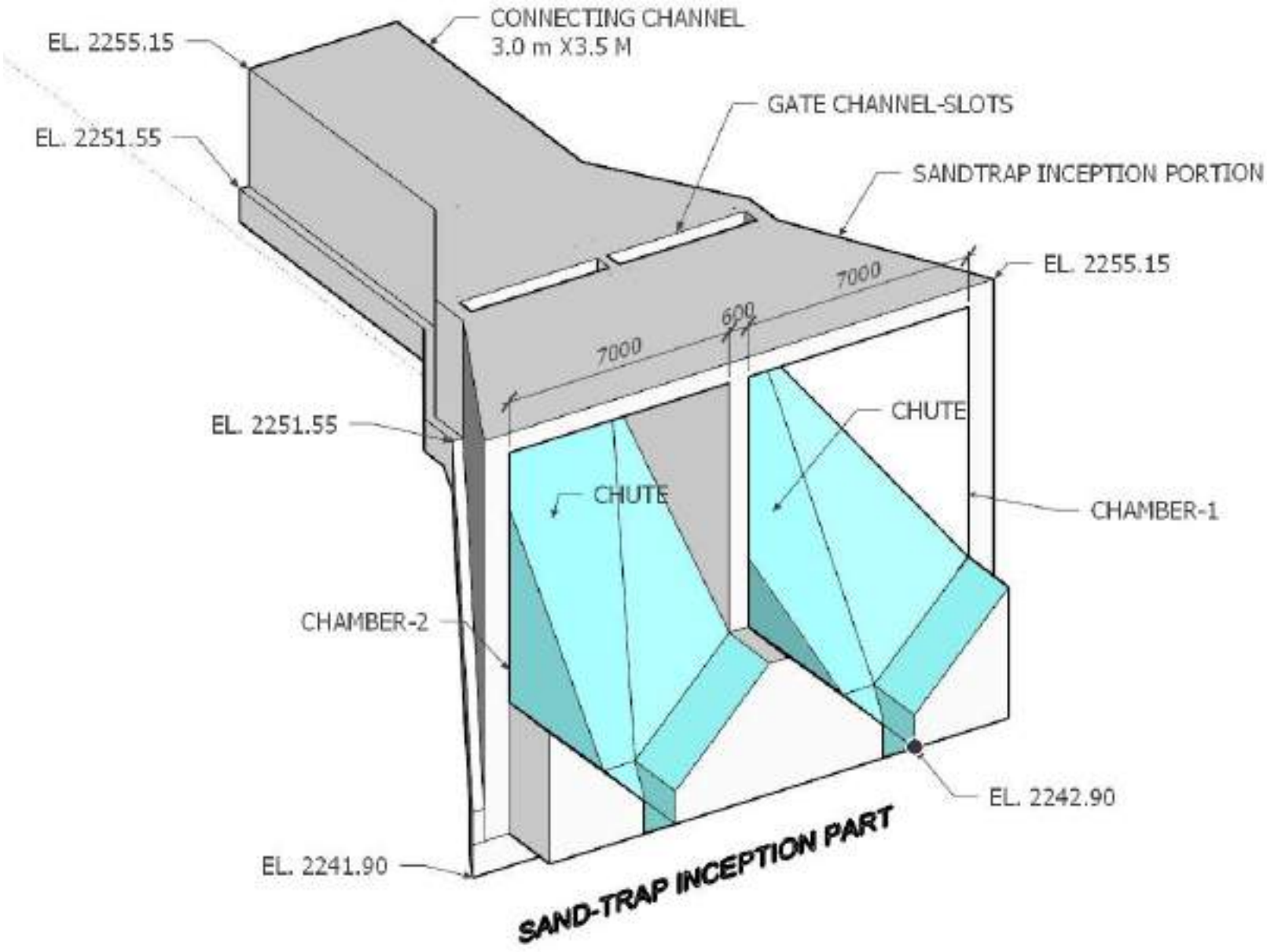
ANNEXURE A
SKETCHES OF INTAKE, SAND TRAP, DIVERSION WEIR, UNDERSLUICES AND ENERGY DISSIPATOR

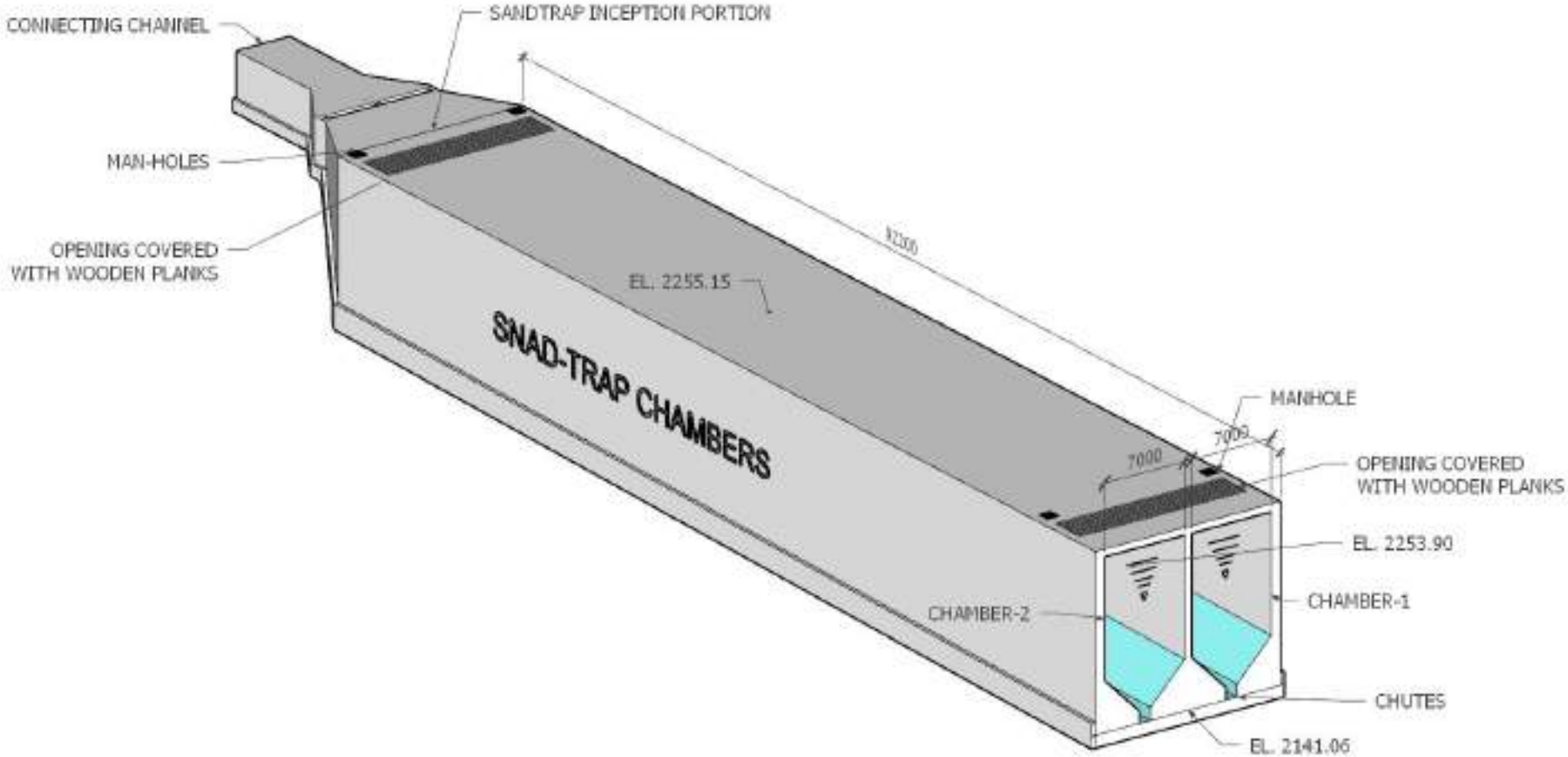

TO SAND TRAP
LEFT ABUTMENT WALL
EMBEDED TO ROCK
27500
EL. 2257.94
7500
RETAINING WALL
EL. 2258.50
EL. 2256.50
EL.2250.65
GATE SLOT
TRASHRACK
UNDERSLUICE WALL
EL. 2251.65
EL. 2250.65
EL. 2247.33
EL. 2249.50
EL. 2250.65
10000
EL. 2251.20
EL. 2249.00
5.5% SLOPE
CURTAIN WALL
CURTAIN WALL 600 mm THK
CURTAIN WALL
UNDERSLUICE AND POWER INTAKE

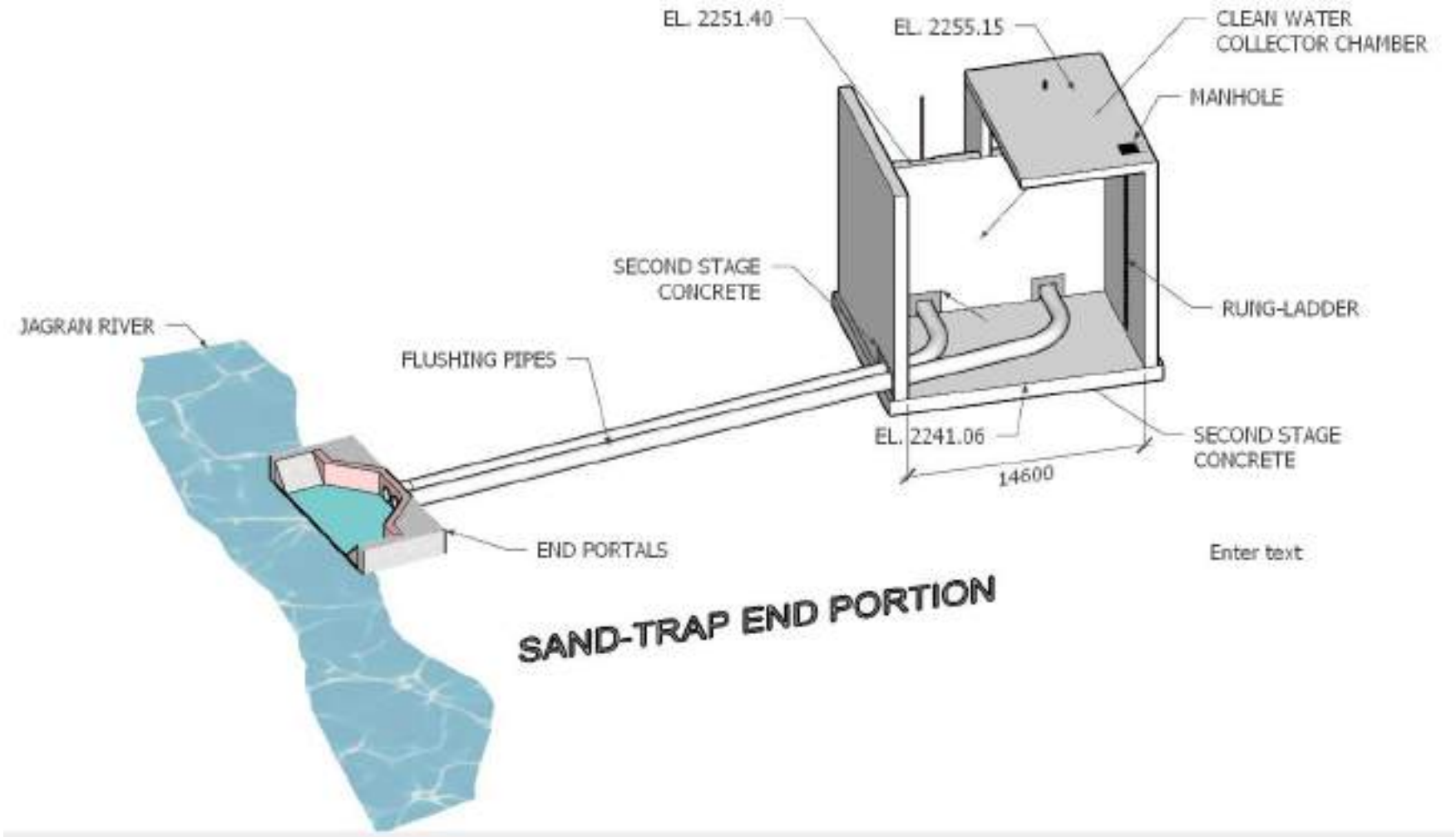

WEIR 3D-VIEW
EL. 2254.50
EL. 2247.36
STONE RETENTION WALL
NORMAL FLOW EL. 2254.00
STONE APRON
RIGHT ABUTTMENT
CREST EL. 2254.00
EL. 2252.84
D/S FLOOR
EMBEDDED TO ROCK
EL. 2256.50
U/S FLOOR 0.5% SLOPED
STONE PITCHED
EL. 2251.29
EMBEDDED TO ROCK
CURTAIN WALLS
ALL AROUND

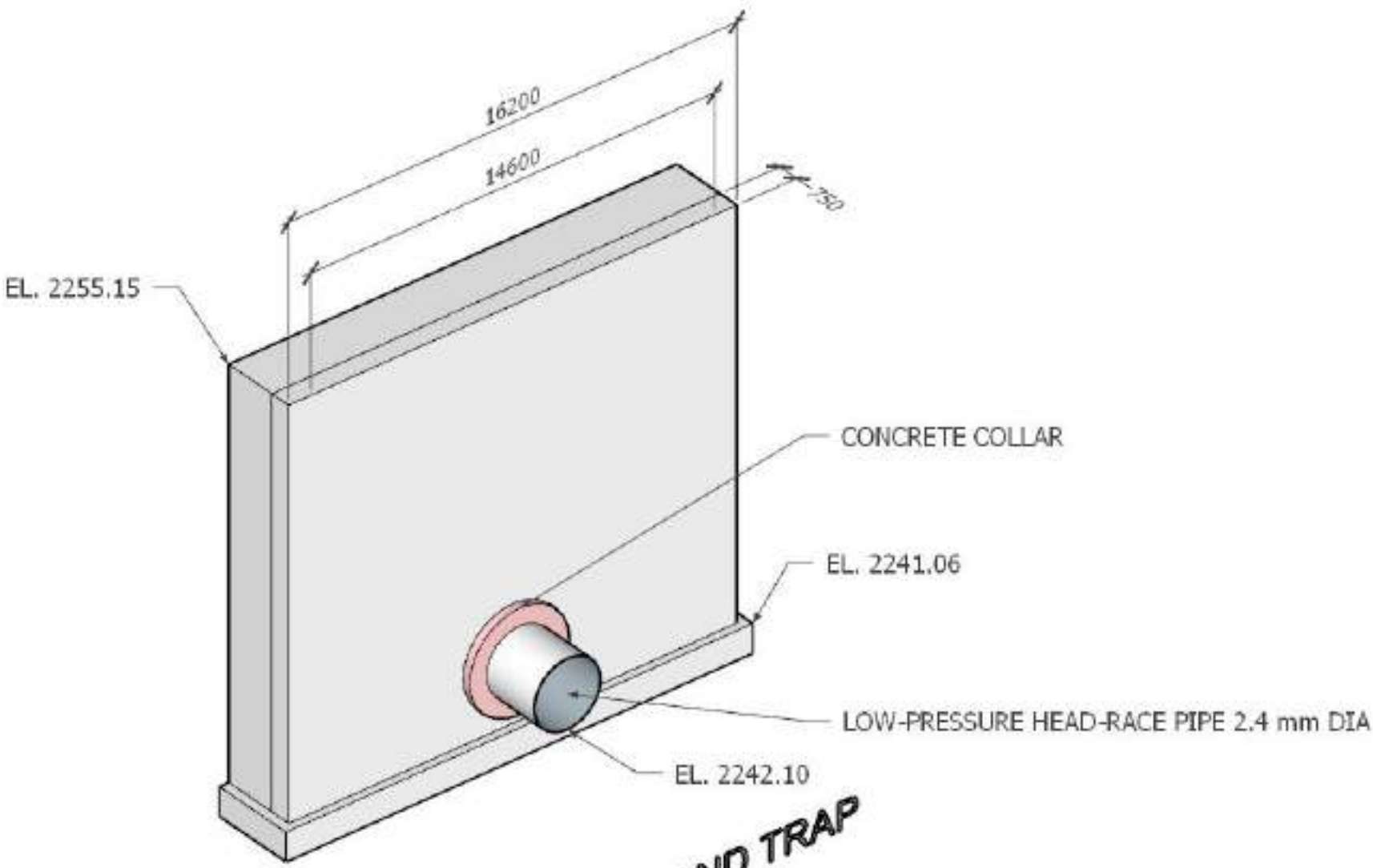

ESCAPE CHANNEL / ENERGY DISSIPATOR
RADIAL GATE
EL. 2247.38
EL. 2258.50
EL. 2249.00
EEL. 2251.96
750 mm THK CURTAIN WALL
5.5% SLOPE
14500
EL. 2251.20
CYCLOPENE CONCRETE 2500 PSI
1000 mm THK RCC SLAB
600 mm THK CURTAIN WALL
750 mm THK CURTAIN WALL


HILL SIDE
EL. 2252.84
EL. 2258.560
RIGHT ABUTMENT


CONNECTING CHANNEL
3.0 m X3.5 M
EL. 2255.15
EL. 2251.55
GATE CHANNEL-SLOTS
SANDTRAP INCEPTION PORTION
EL. 2255.15
7000
600
7000
EL. 2251.55
CHUTE
CHUTE
CHAMBER-1
CHAMBER-2
EL. 2242.90
EL. 2241.90
SAND-TRAP INCEPTION PART


CONNECTING CHANNEL
SANDTRAP INCEPTION PORTION
MAN-HOLES
OPENING COVERED
WITH WOODEN PLANKS
EL. 2255.15
SNAD-TRAP CHAMBERS
MANHOLE
OPENING COVERED
WITH WOODEN PLANKS
EL. 2253.90
CHAMBER-2
CHAMBER-1
CHUTES
EL. 2141.06

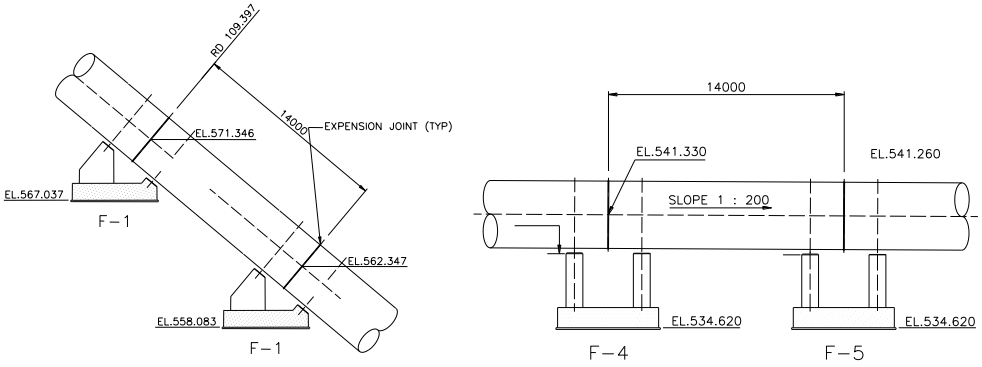

EL. 2251.40
EL. 2255.15
CLEAN WATER
COLLECTOR CHAMBER
MANHOLE
SECOND STAGE
CONCRETE
RUNG-LADDER
JAGRAN RIVER
FLUSHING PIPES
EL. 2241.06
SECOND STAGE
CONCRETE
14600
END PORTALS
Enter text
SAND-TRAP END PORTION


16200
14600
750
EL. 2255.15
CONCRETE COLLAR
EL. 2241.06
LOW-PRESSURE HEAD-RACE PIPE 2.4 mm DIA
EL. 2242.10
END WALL SAND TRAP

ANNEXURE B
EXPOSED PENSTOCK CONCRETE SUPPORTS

General Arrangements

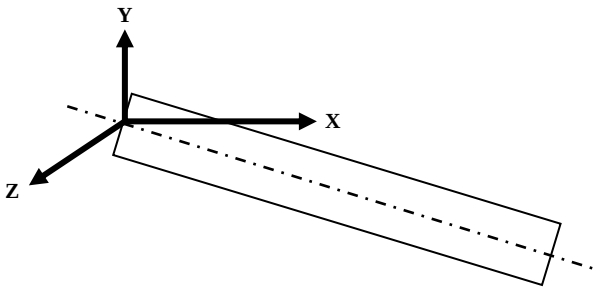
A segment of 14-meter-long Steel Liner is considered for analysis. The concrete supports are considered rigid enough to withstand deformations arising due to the forces from the penstock liner under various loading conditions. Following sketches are schematic for understanding the design analysis philosophy.



Analysis Methodology:
Three-dimensional Finite Element Method of Analysis of the steel liner is performed under various conditions of loadings. For the Analysis of concrete supports, the results of reactive forces at the top of concrete pedestals have been taken in the anti-direction as obtained from the analysis of steel liner. STAAD.pro 2003 software is used to model the steel liner assembly and analysis performed to obtain the state of stresses in each element of the model under different conditions of penstock operation.

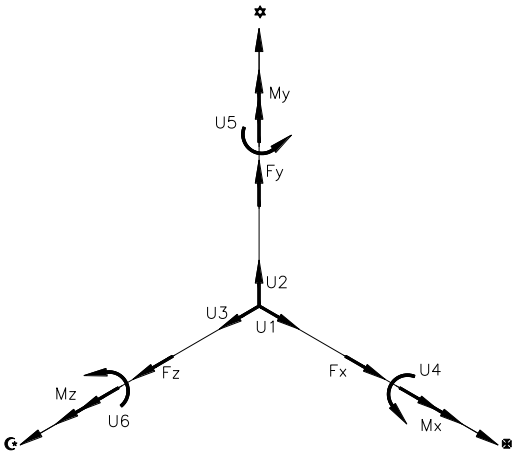
Global Frame of Axis

Global Frame of reference axis (x, y, z ≅ 0, 0, 0) is assumed to pass through the centre of the steel liner at its upper location of the coupling. Positive direction of Axis follows the right-hand rule).



Positive Direction of Forces and Moments:

Conventional Cartesian Co-Ordinates System is fiollowed with the concept of right hand rule to identify positive direction of forces and dispalcements. Positive sense of translational and rotational degrees of freedem and direction of forces and moments are illsutrated in the figure blow:

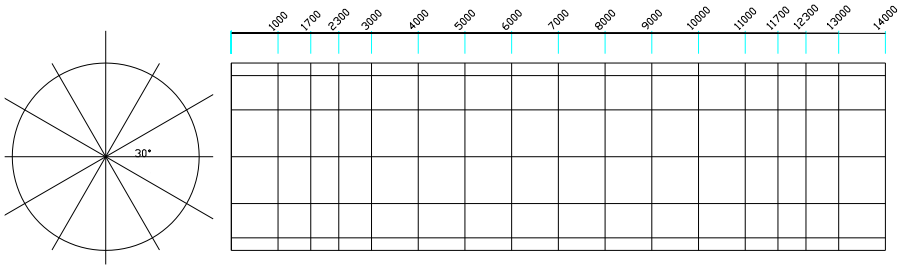


Finite Elements

Plate / shell elements triangular , rectangular and / or quadrilateral in shape are used to model the whole penstock segment along with its ring girder supports and stiffener rings.

Steel Liner:

Circumferential division of elements is made into 12 in order to maintain symmetry of elements about vertical y-axis



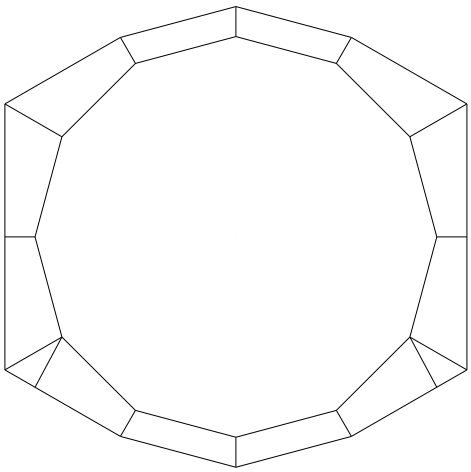
Longitudinal division of elements is made into 16, with a maximum length of 1 meter. The shell elements between the ring girders are made of shorter lengths.

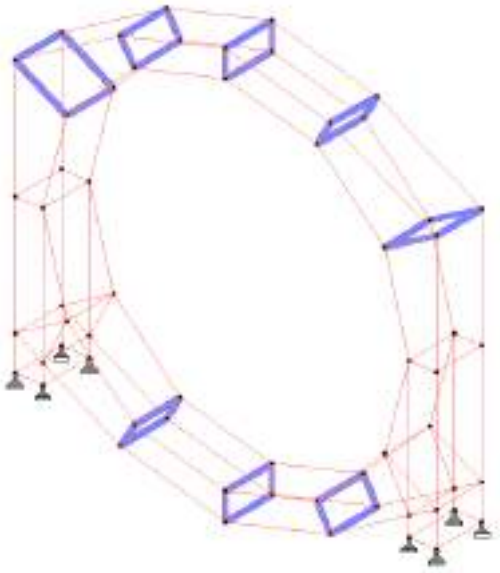
- Total shell elements of steel liner are: 12 x16 = 192 m
- Total nodes of the steel liner are: 12x17 = 204
- Thickness of shell elements is t = 15 mm, 20 mm, 25 mm, 30 mm and 35 mm

Ring Girders

Thick plate sizes, properly supported laterally with diaphragm plates are arranged diametrically around the steel liner in y-z plane and symmetric to y-axis to act as ring girder supports. Rings are spaced 600 mm apart with C.G at 2 meter from the end of the penstock segment:

- Total plate elements are: 2 x [2x14] = 56
- Thickness of plates: 50 mm





Ring Diaphragms

20 mm thick plates are used to connect ring girders: as shown

Total Upper Diaphragm Plates: 2x5 = 10

Total Lower Diaphragm Plates: 2x3 = 6

Total Diaphragm Plates = 16

Ring Girder Supports:

Built Up Section is used, discretized into finite plate elements and connected with ring girder plates at their nodal points

Lower supports are those occurring at ascending direction of flow in the penstock segment and upper supports are the first support in the segment. Lower supports are arranged fixed and upper supports are arranged sliding along the axial direction of the penstock segment.

Finite plate elements in all the supports of 14 m long penstock steel liner assembly are:

Total Plates: 2x [2x6] = 24

Thickness is tentatively taken 25 mm.

Stiffener Rings:

4 number stiffener rings are provided between the ringer girder supports on outside the steel liner at 2 m spacing. The ring height is assumed 100 mm and thickness 25 mm

Total plates in the stiffener rings are: 4x12 = 48

Gross Number of plates:

Steel liner:	= 192
Ring Girders:	= 56
Diaphragm:	= 16
Supports:	= 24
Stiffener rings:	= 48
Total	= 336

Total Nodes: = 324

Total Sliding Nodes: = 8

Total Fixed Nodes: = 8

Analysis Assumption for Concrete Supports:

In ascertaining the magnitude of forces at the top of the concrete pedestals, it is assumed that the resistive sliding force of magnitude of product of co-efficient of friction and normal reaction at the sliding support is to be resisted by the concrete pedestal and applied at its top in the appropriate direction in order to analyse its stability, base pressures etc. under various operating conditions.

Forces:
Following Loads and Forces are assumed to act on the steel Liner

Load-1 Self Weight:

STAAD.Pro computes self weight from the geometrical properties and the weight density of the materials being used. The format is:

LOAD 1 SELF WEIGHT
SELFWEIGHT Y -1 (Weight is directed downward globally)

The loads of concrete pedestals and pads act vertically downward. The normal and tangential component of these weights are computed and applied at the C.G of these items.

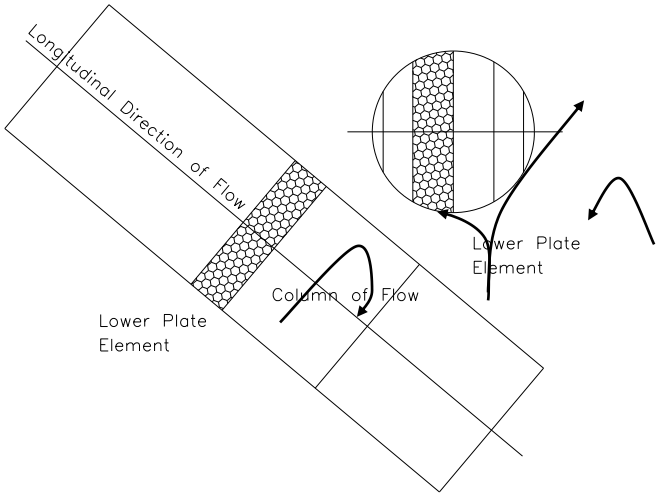
$w_n = w \cos \theta$ (Normal to the X-Axis, i.e. w_y)

$w_t = w \sin \theta$ (Tangential to X-Axis, i.e. w_x)

Where: θ = Inclination of the Penstock with the horizontal

Load-2 Static Weight of Water:

In the case of static weight of flowing water, it is assumed that the column of flowing water normal to the axis of flow is acting on the plate elements which are below the longitudinal plane of the flow. It is applied vertically at the C.G of the lower plates only as shown below:



The area of column of water on extreme lower plate elements is computed as:

$A_1 = \frac{R^2}{2}(\theta - \sin\theta)$, where $\theta = 60° = \pi/3$, R = 1.2 m: A1 = 0.362 m²

Static weight of column of water = 3.5 KN /m²

The area of column of water on next lower plate elements towards centre is:

$A_2 = \frac{R^2}{2}(\theta - \sin\theta)$-0.362 , where $\theta = 120° = 2\pi/3$, R = 2 m: A2 = 2.095 m²

of column of water = 20.5 KN /m²

The area of column of water on middle lower plate elements towards centre is:

$A_2 = \frac{R^2}{2}(\theta - \sin\theta)$-0.362-2.095, where $\theta = 180° = \pi$, R = 1.2 m: A2 = 3.826 m²

Static weight of column of water = 37.5 KN /m²

Check: Total weight of water = (3.5+20.5+37.5) x2x14 = 1722 KN
Also γ_w x Volume = 9.8xπ/4x (4)² x 14 = 1724 KN OK

Hence:

ELEMENT LOAD
4 16 28 40 52 64 76 88 100 112 124 136 148 160 172 184 PR GY -3.50
9 21 33 45 57 69 81 93 105 117 129 141 153 165 177 189 PR GY -3.50
5 17 29 41 53 65 77 89 101 113 125 137 149 161 173 185 PR GY -20.50
8 20 32 44 56 68 80 92 104 116 128 140 152 164 176 188 PR GY -20.50
6 18 30 42 54 66 78 90 102 114 126 138 150 162 174 186 PR GY -37.50
7 19 31 43 55 67 79 91 103 115 127 139 151 163 175 187 PR GY -37.50

Load-3 Hydrostatic Pressure:

Internal Pressure at any point may be computed as:

$$P_i = 9.8(Z_{FB} - Z_i - H_L - V_H)$$

Where,

Z_{FB} = Forebay Level: 642.06 m
Z_i = Level of the point where pressure is required
H_L = Mean value of Head Loss: To be conservative, may be neglected
V_H = Velocity Head = 0.84 m (assumed to be Constant)

Therefore,

$$P_i = 6290 - 9.8x\ Z_i$$

Change of pressure between upper and lower points of coupling of the penstock segment is:

$$\Delta P = 9.8.L.\sin\theta$$

The change of pressure is assumed linearly varying across the length of the penstock conduit. The pressure at any point X along the length of the pipe may be computed by:

$$P_X = P_o + 9.8.X.\sin\theta$$

Where,

Po = Pressure at the upper end of the Penstock conduit
X = the distance from the upper end to the point where pressure is required
θ = Angle of inclination of the penstock

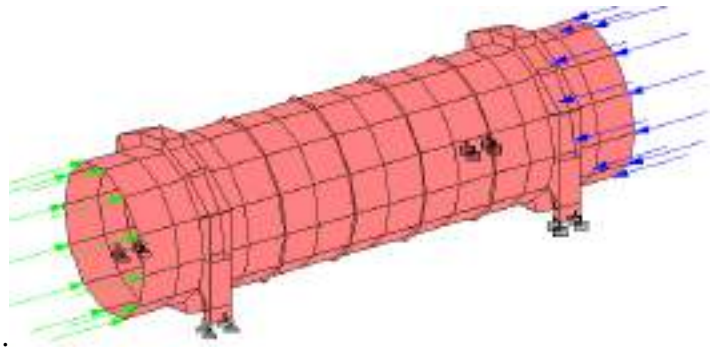
The internal pressure at each circumferential segment of the steel liner at Level A = 562.347 is given as:

ELEMENT LOAD

1	TO	12	PR	782
13	TO	24	PR	788
25	TO	36	PR	792
37	TO	48	PR	796
49	TO	60	PR	801
61	TO	72	PR	807
73	TO	84	PR	814
85	TO	96	PR	820
97	TO	108	PR	826
109	TO	120	PR	833
121	TO	132	PR	839
133	TO	144	PR	845
145	TO	156	PR	850
157	TO	168	PR	855
169	TO	180	PR	859
181	TO	192	PR	864

Load-4 Hydraulic Thrust:

The pressure force normal to the cross-section of the liner at the expansion coupling shall be applied to the nodal points of the plate along the axis of the penstock in the appropriate direction as shown below



.

On the inclined penstock, the nodal pressure forces are resolved along Global X-Axis and Y -Axis and applied at the nodes.

Pressue at Point A =	779	KN/m²					
Pressue at Point B =	867	KN/m²				F_{xi}	F_{yi}
Total Thrust at A = P_A x A_{SL}	147.23	KN	per 12 Nodes =	12.3	KN	**9.4**	**-7.9**
Total Thrust at B = P_A x A_{SL}	163.9	KN	per 12 Nodes =	13.7	KN	**-10.5**	**8.8**

1 TO 12 FX **Error! Not a valid link.** FY **Error! Not a valid link.**
193 TO 204 FX **Error! Not a valid link.** FY **Error! Not a valid link.**

Thermal Loads:

Change of temperature with respect to the initial penstock laying / fixing temperature causes free movement of the penstock along its axis. Restriction to the movement at the ends of the liner where each segments are connected with mechanical expansion couplings will induce thermal force between the mechanical expansion joint couplings. This force is neglected for other types of expansion couplings such as bolted sleeve type couplings Similarly the free movement is also restricted at the sliding supports in proportion to the magnitude of the co-efficient of the sliding friction.

The thermal force is applied in the same manner as the hydraulic thrust is applied at the nodal points at the expansion coupling

Note: Due Allowance is given to the stages of penstock full or empty for the fact that metal temperature is always different from the ambient temperature. Take Safety factor SF = 1.25 when penstock empty

Thermal Loads are subcategorised as:

Load 5 Thermal Exp-Coupling and Load 6 Thermal Internal Pressure:

As per standard practice, circumferential frictional load due to thermal movement at mechanical expansion joint coupling is taken to be 500 Lbs/inch = 88 KN/m. Therefore, total force along the circumference is 1120 KN for an average thickness of 25 mm of the steel liner. Force per node is 93 KN. Vertical and horizontal components are 60 KN and 71 KN for 40° inclined penstock. The nodal forces are:

JOINT LOAD
1 TO 12 FX -71 FY 60
193 TO 204 FX 71 FY -60

The sign indicates that the forces arise when the penstock shrinks from higher laying temperature to the low value of the ambient temperature.

Note: Mechanical expansion joint coupling can accommodate up to 10 inches of total movement. i.e. for a total change of steel liner temperature of 59°C, one such type of coupling will account for a length of 1200 ft (368 m). But the forces induced during diurnal thermal variation are high and malfunctioning may also induce high forces. It is therefore, proposed to use bolted sleeve type couplings, which accommodate total joint movements 3/8TH of an inch and no forces are induced at the expansion coupling joint at all. A length of 14-meter penstock segment is easy to maintain, repair and replace in the event of malfunctioning, particularly in case of high degree of declivity. Hence the force due to Mechanical Expansion Coupling friction or arising due to internal pressure against thermal displacements may be neglected if other types of couplings are employed.

Load 7 Thermal 39°C Penstock Full:

As long as the sliding supports function satisfactorily, the thermal variation in the penstock liner will not induce reactive forces at the supports. The forces are considered when the sliding support is restricted to move with temperature variation in the case of rusty supports.

In the case of full penstock, the temperature variation is 45-6 = 39°C and the load is:

TEMPERATURE LOAD
1 TO 192 TEMP -39

The sign indicates that the steel liner shrinks.

Load 8 Thermal 59°C Penstock Empty:

In the case of empty penstock, the temperature variation is 45+2 = 47°C and Taking 1.25 SF, the temperature Load is 59°C

The load is:

TEMPERATURE LOAD
1 TO 192 TEMP -59

Wind Loads:

Wind effect will be more pronounced in the lateral direction and hence its effect in the lateral direction is taken. The intensity of wind effect across the projected area of the penstock is considered for the two cases of normal wind and exceptional winds.

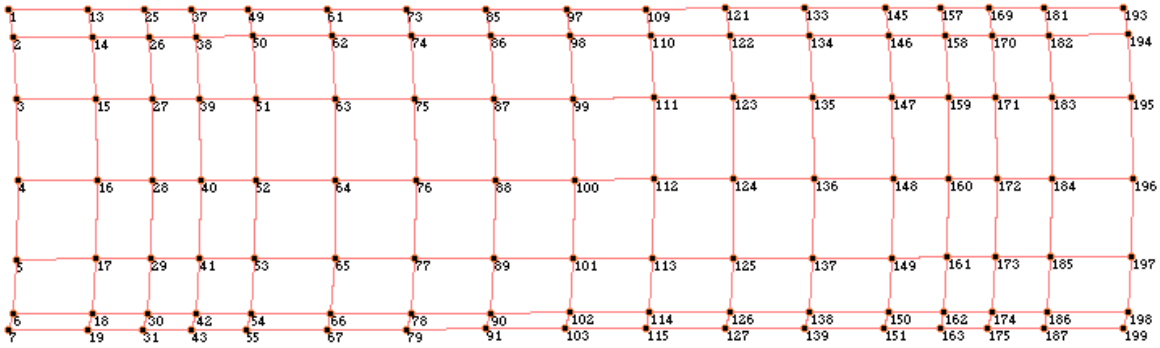
Force on each plate is computed and applied at the nodes. Wind Loads are subcategorised as:

Load 9 Wind Normal:

Normal wind intensity is taken as: 27.5 Lbs /ft² ≅ 1.32 KN/m²

Total projected area = 14x4 = 56 m² (Approx)

Total wind force = 74 KN



Distributing this force evenly as:

Nodes 1, 7, 193, 199, Load 0.2 KN along anti Z-direction
Nodes 13, 19, 25, 31, 37, 43, 49, 55, 61, 67, 73, 79, 85, 91, 97, 103, 109, 115, 121, 127, 133, 139, 145, 151, 157, 163, 169, 175, 181, 187, 2 TO 6, 194, 198, Load 0.4 KN along anti Z-direction
Nodes 14 TO 18, 26 TO 30, 38 TO 42, 50 TO 54, 62 TO 66, 74 TO 78, 86 TO 90 98 TO 102, 110 TO 114, 122 TO 126, 134 TO 138, 146 TO 150, 158 TO 162, 170 TO 174, 182 TO 186, Load 0.8 KN along anti Z-direction

Thus total Load = 4x0.2 + 40x0.4 + 75x0.8 = 76.8 KN OK

Load 10 Wind Exceptional:

Exceptional wind intensity is taken as: 45 Lbs /ft² ≅ 2.16 KN/m²

Total exceptional wind force = 121 KN

The Joint Loads are:

JOINT LOAD
1 7 193 199 FZ -0.30
2 TO 6 13 19 25 31 37 43 49 55 61 67 73 79 85 91 97 103 109 115 121 127 133 -
139 145 151 157 163 169 175 181 187 194 TO 198 FZ -0.7
14 TO 18 26 TO 30 38 TO 42 50 TO 54 62 TO 66 74 TO 78 86 TO 90 98 TO 102 110 -
111 TO 114 122 TO 126 134 TO 138 146 TO 150 158 TO 162 170 TO 174 182 TO 185 -
186 FZ -1.25

Thus total Load = 4x0.30 + 40x0.7 + 75x1.25 = 123 KN OK

Seismic Loads:

The effect of seismic forces is taken in both directions, i.e. along axial direction and in the lateral direction with the vertical component as well.

The horizontal component of seismic Force is computed and applied evenly over the plate and similarly the vertical component of the seismic force is applied evenly over the plate. The direction is taken as direction of seismic forces, once in x-y plane and then in y-z plane, as the case may be.

Seismic Load intensity in the horizontal plane is taken as 0.17.g and in the vertical plane its intensity is taken as 0.06.g.

Seismic Loads are subcategorised as:

Load 11 Seismic (Self Weight) Z-Axis:

The Weight density of steel is taken as 77 KN /m^3 and for thickness of the plates nearly equal to 25 mm (average), the horizontal component of seismic load becomes:

77 x0.025 x0.17 = 0.33 KN / m² (May be computed and applied as per plate sizes)

The load is applied as

ELEMENT LOAD
1 TO 336 PR GZ 0.33

Load 12 Seismic (Self Weight) X-Axis:

The load is the same and applied as:

ELEMENT LOAD
1 TO 336 PR GX 0.33

Load 13 Seismic (Self Weight) Vertical Component:

Vertical Component is:

77x0.025x0.06 = 0.12 KN/m² and applied as:

ELEMENT LOAD
1 TO 336 PR GY 0.12

Load 14 Seismic (Water) Z –Axis:

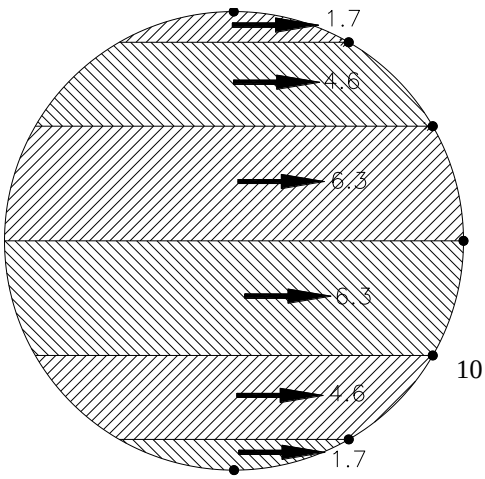
Seismic effect on the body of water in the penstock is applied in the manner described hereunder:

The wedge of weight of water as shown acts against the plate elements which fall across the direction of seismic forces:

The transverse seismic force on the wedge of water on extreme top and bottom right side plate elements is calculated as:

0.17x γ_w x Zi =0.17x9.8x1.0 = 1.7 KN m²

Zi is the average width of the wedge. The seismic forces on the next plate elements are:



0.17 x 9.8 x 2.732 = 4.6 KN /m²

and the middle plate elements experience the seismic forces:

0.17 x 9.8 x 3.732 = 6.3 KN/m²

Plates Loads are applied as:

ELEMENT LOAD
1 6 13 18 25 30 37 42 49 54 61 66 73 78 85 90 97 102 109 114 121 126 133 138 -
145 150 157 162 169 174 181 186 PR GZ 1.7
2 5 14 17 26 29 38 41 50 53 62 65 74 77 86 89 98 101 110 113 122 125 134 137 -
146 149 158 161 170 173 182 185 PR GZ 4.6
3 4 15 16 27 28 39 40 51 52 63 64 75 76 87 88 99 100 111 112 123 124 135 136 -
147 148 159 160 171 172 183 184 PR GZ 6.3

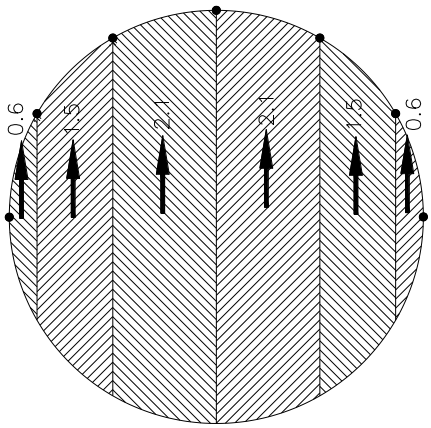
Load 15 Seismic (Water) Anti Z –Axis:

The Plates Loads are the same and applied in the opposite Z-Direction as:

ELEMENT LOAD
7 12 19 24 31 36 43 48 55 60 67 72 79 84 91 96 103 108 115 120 127 132 139 -
144 151 156 163 168 175 180 187 192 PR GZ -1.7
8 11 20 23 32 35 44 47 56 59 68 71 80 83 92 95 104 107 116 119 128 131 140 -
143 152 155 164 167 176 179 188 191 PR GZ -4.6
9 10 21 22 33 34 45 46 57 58 69 70 81 82 93 94 105 106 117 118 129 130 141 -
142 153 154 165 166 177 178 189 190 PR GZ -6.3

Load 16 Seismic (Water) Vertical Component Y-Axis

The Vertical component of the seismic force is applied in the same manner as the horizontal component is applied;



The force is computed as:

0.06 x 9.8 x Yi, where Yi is the height of the wedge of water along Y-axis. Yi = 1.0 m, 2.73 , and 3.73 m for the wedges from extreme locations to the middle.

The loads are applied on the upper plate elements as:

ELEMENT LOAD
1 12 13 24 25 36 37 48 49 60 61 72 73 84 85 96 97 108 109 120
121 132 133 -
144 145 156 157 168 169 180 181 192 PR GY 2.1
2 11 14 23 26 35 38 47 50 59 62 71 74 83 86 95 98 107 110 119 122 131 134 -
143 146 155 158 167 170 179 182 191 PR GY 1.5
3 10 15 22 27 34 39 46 51 58 63 70 75 82 87 94 99 106 111 118 123 130 135 -
142 147 154 159 166 171 178 183 190 PR GY 0.6

Load 17 Seismic (Water) Vertical Component Anti Y-Axis
The loads are applied to the lower plate elements

ELEMENT LOAD
4 9 16 21 28 33 40 45 52 57 64 69 76 81 88 93 100 105 112 117 124 129 136 -
141 148 153 160 165 172 177 184 189 PR GY -0.6
5 8 17 20 29 32 41 44 53 56 65 68 77 80 89 92 101 104 113 116 125 128 137 -
140 149 152 161 164 173 176 185 188 PR GY -1.5
6 7 18 19 30 31 42 43 54 55 66 67 78 79 90 91 102 103 114 115 126 127 138 -
139 150 151 162 163 174 175 186 187 PR GY -2.1

Load 18 Seismic (Water) X -Axis (Effect on Supports Only)

The effect of the seismic force along X-axis on the plate elements will be insignificant. However, to be on safe side, the effect is taken on the supports only. It is assumed that the whole effect is taken on either end of the penstock segment.

Total seismic force = $0.17 \times 9.8 \times \pi/4 \times 4^2 \times 14 = 293$ KN is distributed equally on the end nodes as $293/12 \cong 25$ KN / Node

The force is applied as: JOINT LOAD
193 TO 204 FX 25

Load 19 Seismic (Water) Anti X-Axis (Effect on Supports Only)

The force is the same and applied at the upper nodes as: JOINT LOAD
1 TO 12 FX -25

Load Cases:

Following Loading Cases are analyzed:

- **Normal Loading**

  1. D+P1: Dead Loads, Water Pressure including normal water hammer as stipulated under condition a-1, Tp-03 (Normal Operation) (Pressure rise as calculated by Norconsult for 07 seconds Guide Vanes Closure.)

  2. D+P1±W1±T1 Normal wind and temperature effects are added to the above loading case

- **Intermittent Loading**

  1. D+P1±W2 Dead Loads, Normal Operation and extreme wind pressure on the exposed penstock

  2. D+P1±T1±E Dead Loads, Normal Operation, Normal Temperature and Earthquake

  3. D±T2±E Exposed penstock empty, Dead Loads self, Temperature and Earthquake

  4. D+P2±W1 Dead Loads , Static Pressure, and Water hammer Pressure 45% of Static Pressure and Normal Wind.

- **Emergency Loading**

  1. D+P2+T1+W1 Dead Loads, Static Pressure, Water hammer 45% of Static Pressure, Normal Wind and Temperature.

- **Exceptional Loading**

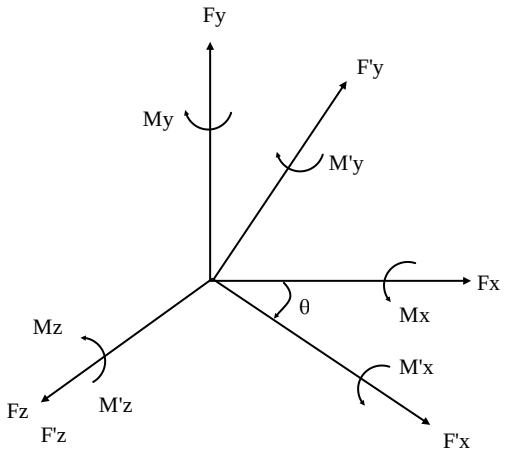
  1. D+P1+T3 Dead Loads, Static Pressure, Water hammer as calculated by Norconsult, Thermal loads as stipulated in para 1.5.3 (4) of the Design Criteria

  2. D+T3 Empty Penstock with extreme temperature variation.

Support Reactions:

The output File of reactive forces at the nodal support joints, obtained from the STAAD.Pro is opened in the MS Excel Sheet. These results are in the Global System of Axis, wherein the X-Axis is the horizontal Axis along the Azimuth and Y-Axis is vertical upward along the gravitational axis. For the Inclined Supports (Inclined Penstocks), these nodal forces are transformed, such that X'-Axis is inclined at the angle of declivity of the penstock and Y-Axis is perpendicular to X-Axis. Z-axis remains uninfluenced.

The transformation of forces is made as follows:



Y-X Plane has been rotated about Z-Axis at an angle θ , the transformed reactive forces may be obtained by:

$$\begin{pmatrix} Fx' \\ Fy' \\ Fz' \\ Mx' \\ My' \\ Mz' \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta & 0 & 0 & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \cos\theta & -\sin\theta & 0 \\ 0 & 0 & 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} Fx \\ Fy \\ Fz \\ Mx \\ My \\ Mz \end{pmatrix}$$

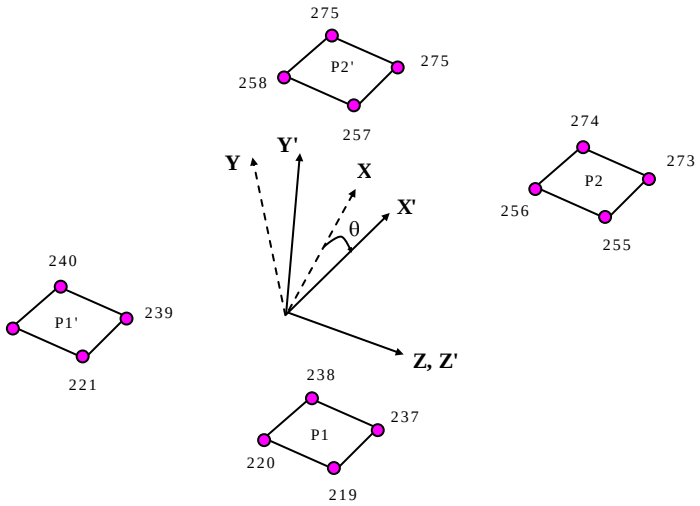
One Support consists of four nodes. The net reaction is additive of the nodal forces in that particular direction, i.e.

$$F'_J = \sum_{i=1}^{4} F'_i$$

Where,

J = is the Support, Viz, P1, P1', P2, P2'
i = Nodal Number
F is the force, Viz. Fx, Fy, Fz, Mx, My, and Mz

Nodal Support Joints are shown below:



X'-Axis follows the line of flow. Therefore, P1 represents the RHS sliding support and P1' represents the LHS sliding support. The force along X'-Axis will only be the sliding reaction in proportion to the magnitude of co-efficient of sliding friction times the normal reaction F'y at the sliding support.

The Force F'x at the Support P1 will be the sum of forces along X-Axis at the nodal points, 219, 220, 237 and 238. i.e.

$$F'_{x\,P1} = F'_{x\,219} + F'_{x\,220} + F'_{x\,237} + F'_{x\,238}$$

Similarly,

$$F'_{y\,P1} = F'_{y\,219} + F'_{y\,220} + F'_{y\,237} + F'_{y\,238}$$

Note: $F'_{x\,P1} = \mu \,.\, F'_{y\,P1}$ at the sliding supports P1 and P1'

Likewise other forces are computed.

The reactions are pasted at the top of the pedestals in the opposite direction in order to simulate the applied forces from the penstock onto the pedestal tops. These forces are used in conjunction with the self weights of the Supporting arrangements for establishing the safety and stability of the pedestals and the supporting arrangements.

Note: M'y force is not taken in the analysis of stability of supports, as it is very small and due to symmetry of the penstock in vertical plane, the torsional force about vertical axis is negligible.

Conditions of Stability for Supports and Anchor Blocks

Following Conditions of stability are satisfied. If the Safety Factors exceed the values shown in the table hereunder, adequate number of shear dowels and reinforcement is provided to augment the resistance of the supports and anchor Blocks to cater for tensile forces.

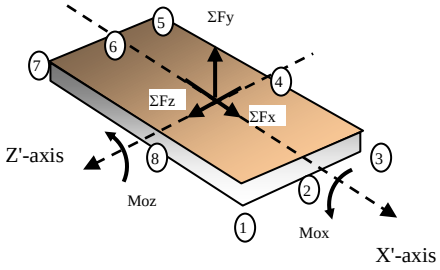
1. Sliding
2. Rotation
2. Uplift
3. Foundation Pressure

Sr. No.	Factor of Safety	Condition of Loading		
		Normal	Intermittent	Emergency / Exceptional
1	Sliding	1.5	1.3	1.2 / 1.05
2	Uplift	1.5	1.3	1.2 / 1.05
3	Rotation (Overturning)	1.5	1.3	1.2 / 1.05
4	Foundation Pressure	1.0	1.3	1.5 / 2.5

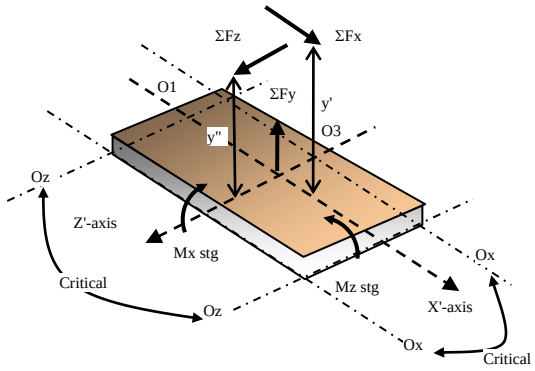
Stresses on the Bed of Foundation:

Following formula is used to ascertain Pressures at any point under the foundation:

$$f_{x,z} = \frac{\sum F_y}{A} + \left(\frac{M_{ox} I_z - M_{oz} I_{xz}}{I_x I_z - I_{xz}^2} \right) .z + \left(\frac{M_{oz} I_x - M_{ox} I_{xz}}{I_x I_z - I_{xz}^2} \right) .x$$



Factors of Safety against:



Sliding along X'-Axis:

$$SF_{SLDG} = \frac{\mu \sum F_y}{\sum F_x}$$

Sliding Along Z'-Axis:

$$SF_{SLDG} = \frac{\mu \sum F_y}{\sum F_z}$$

Overturning:

$$SF_{OVTG} = \frac{\sum M_{STG}}{\sum M_{OVTG}}$$

The Overturning Effect is taken about the edges of the pad i.e. edge 345 or edge 187 in the Z'-Y' Plane and edge 123 or edge 567 in the X'-Y' Plane.

Uplift:

$$SF_{uplift} = \frac{\sum F_{y\,DOWN}}{\sum F_{y\,UP}}$$

Eccentricity:

$$e = \frac{M_{c.g}}{\sum F_y}$$

Where, Mcg represents moment of forces about the centroid. Therefore:

$$e_x = \frac{M_{oz}}{\sum F_y} \quad \text{and} \quad e_z = \frac{M_{ox}}{\sum F_y}$$

Design of Steel Reinforcements:

1) Pedestals:

Concrete Pedestals are designed as column struts

Minimum reinforcement to be provided shall not be less than 0.5 % of the gross area of the column strut.

Maximum reinforcement shall not be greater than 8% of the gross area of the column strut in the seismic zones.

Minimum concrete cover to the ties or spirals shall be 1½" ≅ 40 mm

Minimum clear spacing between longitudinal bars, lap spliced bars or lap splices shall not be less than the following limitations, and whichever is greater:

i) 1.5 times the longitudinal bar diameter
ii) 1.5 inches ≅ 40 mm
iii) 1⅓ times the size of the coarse aggregate.

Ties:

Minimum size of ties shall be a #3 bar for longitudinal bars up to #10 and #4 for larger size longitudinal bars or as decided by the Engineer In-charge.

Spacing of ties shall not exceed:

1) 16 times the longitudinal bar diameter
2) 48 times the tie bars diameter
3) least dimension of the column
4) in seismic zone closer spacing shall be ensured

5) If the shear Vu/ϕ exceeds ½Vc, shear reinforcement is required and ties in lieu of shear reinforcement shall not be spaced farther apart d/2 and area shall satisfy the shear requirements.

Minimum size of the tied column shall not be less than:

$$A_g \geq \frac{P_u}{0.45(f_{c'} + \rho . f_y)}$$

Where: $\rho = A_s / A_g$, and an average load factor shall be taken as 1.5 to compute P_u.

2) Pads / Footings:

Reinforcement in the pads / footings shall cater for:

1) Flexural and punching shear requirements
2) Temperature shrinkage requirements
3) Shear dowels against sliding
4) Flexural dowels to check larger eccentricities greater than middle third base in case of emergency loading conditions

Minimum Steel area of flexural tensile reinforcement shall be the same as required for shrinkage and temperature reinforcements. For Grade 60,

$$A_{s\ min} = 0.0018\ b.h$$

Where, b.h is the gross area of the footing perpendicular the flexural reinforcement.

Maximum spacing of reinforcement shall be lesser of:

i) three times the thickness h of the footing
ii) 18 in.

Minimum concrete cover to bars shall be in accordance to para 3.9 of the proposed Design Criteria.

Minimum depth of footing above the bottom reinforcement shall be 6” for footings on soils.

Wherever required a lean concrete of 4” thickness shall be provided between the soil or rock mass and the footing base to act as an interface between the two strata.

One Way Shear:

Following condition shall be satisfied:

$$Vu \leq \phi\ (V_c + V_s)$$

Where $Vc = 2\sqrt{f'c}\ b_w d$

Two Way Shear:

The critical shear parameter for the assessment of punching shear shall be computed as:

$$b_o = 2(c_1+d) + 2(c_2+d)$$

Where: b_o = critical shear parameter

C_1, C_2 = size of the column pedestals

d = average depth of steel bars in both directions

If no web reinforcement to be provided in the footing, then $V_u \leq \phi V_c$

Where: Vc is the least value among the following values:

i) $$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f'_c}\, b_o .d$$

ii) $$V_c = \left(2 + \frac{\alpha_s d}{b_o}\right)\sqrt{f'_c}\, b_o .d$$

iii) $$V_c = 4\sqrt{f'_c}\, b_o .d$$

Where: $\beta_c = C_2/C_1$, ratio of long side C2 to short side C1 of the column
b_o = Critical Shear Parameter
$\alpha_s = 40$ for middle / centrally located columns
$= 30$ f or edge columns
$= 20$ for corner columns

Design for Shear Dowels:

In order to check against sliding, shear dowels shall be required. The net force required to be resisted by the shear dowels is given by:

$$H_{net} = SF.H - \mu V$$

Net Ultimate Load:

$$H_{u\,net} = 1.5\,(SF.H - \mu V)$$

Area of shear dowels required:

$$A_{s\,dowel} = \frac{L.F(SF - FOS)H}{f_y} \quad \text{(Yield Stress)}$$

$$A_{s\,dowel} = \frac{(SF - FOS)H}{f_{sV}} \quad \text{(Allowable Stress)}$$

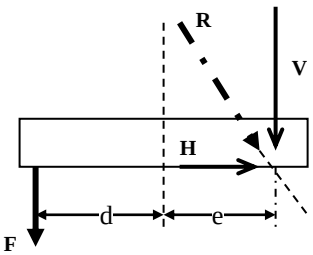
Whichever is greater shall be adopted.

Where: H = Total Horizontal Thrust
V = Total Vertical Load
f_{sV} = Allowable Shear Stress
f_y = Yield stress
μ = 0.65, the co-efficient of sliding friction
SF = Allowable Safety Factor
FOS = Calculated Factor of Safety
L.F = Load Factor

Design of Flexural Dowels

In case of Eccentricity beyond middle third of the base is encountered, the effective area of the base is reduced. In order to utilize the full area of the base effectively, flexural dowels are provided to check tensile stresses.

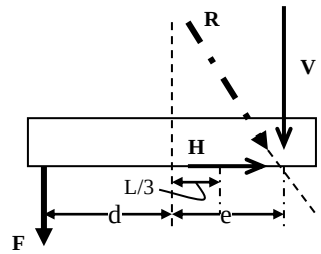
The Force F required to develop full stress in the Flexural dowels at distance 'd' from the centerline of the base oppsite to the incidence of the resultant R of the applied forces in order to check the eccentricty greater than L/3, may be approximated by the following relation:



F.d = V.e = M (Moment at the centroid of the base)

$$F = A_{sf} \,.\, f_s$$

$$A_{sf} = \frac{M}{f_s.d}$$



A_{sf} = maximum reinforcement required to keep a uniform intensity of stress at the base in case of exceptional loadings.
fs = maximum allowable stress in the flexural dowels

The minimum flexural dowels required to keep the resultant within middle third of the base may be approximated by the following relation:

$$A_{sf} = \frac{V\left(e - L/3\right)}{f_s.\left(d + L/3\right)}$$

Thus to check eccentricities greater than middle third of the base, flexural dowels are required in the range of:

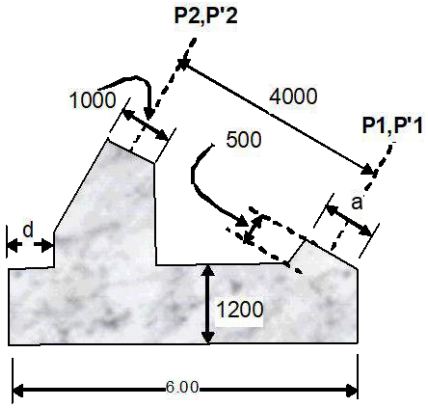
$$\frac{M}{f_s.d} \geq A_{sf} \geq \frac{V\left(e - L/3\right)}{f_s.\left(d + L/3\right)}$$

Note: It is recommended to provide average of the two values, i.e. average of max and min steel required to keep the resultant in middle third in case of extreme loading conditions.

Sample Design Calculations: [Inclined Footing at Level 562.348

Some critical Load Cases are dealt herewith to illustrate above mentioned design procedure.

Pedestal:



Data:

Proposed Size: 1x1 m² = 1,000,000 mm²
Height: Varies

Materials:
Concrete: f'c =3,000 Psi = 21.0 MPa
Fy = 60,000 psi = 415 MPa

Critical Load Case:

Structural Analysis for various loading combinations yields the forces on top of each concrete pedestal as:

Normal Loading Condition (1)
Dead + Internal Pressure P + W. Hammer

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-135.3	-450.9	292.3	-21.3	5.2	0.0	P1
-135.3	-450.9	292.5	-21.5	-4.7	0.0	P1'
668.7	-360.5	182.2	-13.0	6.5	-11.0	P2
670.6	-360.5	182.0	-13.3	-6.2	-11.4	P2'

Normal Loading Condition (2)
Normal Load Case 1 + Normal Wind and Temperature

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-132.8	-442.6	387.8	-19.7	5.3	0.0	P1
-137.9	-459.5	350.8	-17.4	-4.8	0.0	P1'

	-	-	-		-	
665.8	351.1	277.1	12.3	6.3	11.1	P2
	-				-	
673.5	369.5	237.3	10.5	-6.0	11.7	P2’

Intermittent Loading Case -1
Normal Load Case-1 +
Exceptional Wind

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
	-	-	-			
-131.2	437.3	337.7	24.2	5.3	0.0	P1
	-					
-139.3	464.4	278.3	20.3	-4.8	0.0	P1’
	-	-	-		-	
664.2	345.8	229.5	15.4	6.6	10.7	P2
	-				-	
675.1	375.2	166.0	12.3	-6.3	11.5	P2’

Intermittent Loading Case -2 (a)
NLC-1 + Normal Temperature+ EQ
GZ & GY

Fx’	Fy’	Fz’	Mx’	My’	Mz’	
	-	-				
-143.7	479.0	202.6	-8.0	4.5	0.0	P1
	-					
-115.5	384.7	412.4	22.5	-4.4	0.0	P1’
	-				-	
641.8	374.1	-86.5	-2.9	5.5	11.4	P2
	-				-	
602.8	272.1	312.4	14.8	-5.4	10.3	P2’

Intermittent Loading Case -2 (b)
NLC-1 + Normal Temperature+ EQ
GZ & -GY

Fx’	Fy’	Fz’	Mx’	My’	Mz’	
	-	-				
-158.8	529.1	215.5	-8.5	4.7	0.0	P1
	-					
-130.5	434.8	425.3	23.0	-4.6	0.0	P1’
	-				-	
736.4	436.9	-88.5	-2.9	6.3	13.3	P2
	-				-	
697.6	334.9	314.4	14.8	-6.1	12.3	P2’

Intermittent Loading Case -2 ©
NLC-1 + Normal Temperature+ EQ
GX & GY

Fx’	Fy’	Fz’	Mx’	My’	Mz’	P1
	-	-	-			
-128.6	428.7	376.2	18.9	5.5	0.0	P1’
-128.7	-	376.5	19.1	-5.0	0.0	P2

	428.7					
763.0	-207.2	-242.3	-10.9	7.2	-12.7	P2’
765.3	-207.3	-242.1	-11.1	-6.9	-13.2	

Intermittent Loading Case -2 (d)
NLC-1 + Normal Temperature+ EQ GX & -GY

Fx’	Fy’	Fz’	Mx’	My’	Mz’	
-143.7	-478.8	-389.2	-19.4	5.7	0.0	P1
-143.7	-478.7	-389.4	-19.6	-5.2	0.0	P1’
857.6	-269.9	-244.3	-10.9	8.0	-14.6	P2
860.2	-270.1	-244.1	-11.1	-7.6	-15.2	P2’

Intermittent Loading Case -2 (e)
NLC-1 + Normal Temperature+ EQ –GX & GY

Fx’	Fy’	Fz’	Mx’	My’	Mz’	
-170.0	-566.6	-374.4	-18.4	4.9	0.0	P1
-170.1	-566.6	-374.5	-18.6	-4.5	0.0	P1’
479.7	-307.3	-267.2	-11.9	4.8	-7.2	P2
481.1	-307.4	-267.1	-12.1	-4.7	-7.6	P2’

Intermittent Loading Case -2 (f)
NLC-1 + Normal Temperature+ EQ –GX & -GY

Fx’	Fy’	Fz’	Mx’	My’	Mz’	
-185.1	-616.7	-387.3	-18.9	5.1	0.0	P1
-185.1	-616.7	-387.5	-19.1	-4.6	0.0	P1’
574.3	-370.1	-269.2	-11.8	5.6	-9.1	P2
575.9	-370.2	-269.1	-12.1	-5.4	-9.5	P2’

Intermittent Loading Case -3 (a)
Empty Penstock + Temperature + EQ GZ & GY

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-18.2	-60.7	-92.5	6.0	0.4	0.0	P1
-13.7	-45.5	126.7	-3.6	-0.5	0.0	P1’
102.0	-73.7	-81.7	4.2	0.4	-2.4	P2
97.1	-57.4	117.9	-2.4	-0.3	-2.3	P2’

Intermittent Loading Case -3 (b)
Empty Penstock + Temperature + EQ GZ & -GY

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-20.8	-69.4	-94.1	5.9	0.5	0.0	P1
-16.3	-54.2	128.3	-3.6	-0.5	0.0	P1’
118.4	-84.6	-81.9	4.2	0.5	-2.7	P2
113.6	-68.3	118.2	-2.4	-0.4	-2.6	P2’

Intermittent Loading Case -3 (c)
Empty Penstock + Temperature + EQ GX & GY

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-12.0	-39.9	-109.8	4.8	0.5	0.0	P1
-12.0	-40.0	109.9	-4.7	-0.5	0.0	P1’
126.4	-55.9	-97.6	3.4	0.6	-2.9	P2
126.7	-56.1	97.5	-3.4	-0.5	-3.0	P2’

Intermittent Loading Case -3 (d)
Empty Penstock + Temperature + EQ GX & -GY

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-14.6	-48.7	-111.4	4.7	0.5	0.0	P1
-14.6	-48.7	111.4	-4.7	-0.6	0.0	P1’
142.8	-66.8	-97.8	3.4	0.7	-3.2	P2
143.2	-67.0	97.8	-3.4	-0.6	-3.3	P2’

Intermittent Loading Case -3 (e)
Empty Penstock + Temperature + EQ -GX & GY

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-21.7	-59.9	-110.4	4.7	0.4	5.4	P1
-20.5	-61.5	110.4	-4.6	-0.4	5.4	P1’
123.9	-60.0	-100.2	2.7	0.9	-2.9	P2
121.5	-56.8	100.1	-3.7	0.3	-2.9	P2’

Intermittent Loading Case -3 (f)
Empty Penstock + Temperature +
EQ -GX & -GY

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-22.5	-74.9	-111.0	4.8	0.4	0.0	P1
-22.5	-75.0	111.0	-4.8	-0.4	0.0	P1’
88.9	-85.9	-102.3	3.2	0.3	-2.1	P2
89.2	-86.1	102.3	-3.2	-0.2	-2.1	P2’

Intermittent Loading Case -4
Empty Penstock + Temperature
T3 Rusty Supports

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-132	-441	-312	-23	5	-132	P1
-137	-458	275	21	-5	-137	P1’
1440	-1261	-201	-15	7	1440	P2
685	-370	254	10	-5	685	P2’

Emergency Loading Case 1
Dead Loads, Normal Wind ,
Pressure Rise 45%
TP-03(b)

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
-133	-442	-379	-20	5	0	P1
-138	-459	342	18	-5	0	P1’
1440	-1261	-266	-13	6	-11	P2
685	-370	319	7	-4	-12	P2’

Exceptional Loading Case 1
Dead Loads Normal Pressure TP-03(a-1), Temperature T3

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
1569	-452	-340	-16	13	-32	P1
1574	-452	340	16	-11	-33	P1’
-900	-359	-223	-11	-8	19	P2
-904	-359	223	12	7	20	P2’

Exceptional Loading Case 2
Dead Loads Temperature T3
Rusty Supports

Fx'	Fy'	Fz'	Mx'	My'	Mz'	
1157	-57	-73	2	10	-22	P1
1160	-57	73	-2	-9	-23	P1’
-1049	-71	-65	2	-10	20	P2
-1052	-71	65	-2	9	21	P2’

Normal Loading Case -2 yields highest shear force at the fixed supports and sliding supports experience the shear force of magnitude μFy’.

Shear at Sliding Support: Fx’ = 138 KN, Fz = 388 KN, Net F = 412 KN
Shear at Fixed supports: Fx’ = 674 KN, Fz’ = 370 KN, Net =769 KN
Maximum Normal Load to the pedestal Surface: Fy = 460 KN

Intermittent Loading Case 2(d) yields following highest values:

Shear at Sliding Support: Fx' = 144 KN, Fz = 390 KN, Net F = 416 KN
Shear at Fixed supports: Fx' = 860 KN, Fz' = 244 KN, Net =894 KN
Maximum Normal Load to the pedestal Surface: Fy = 479 KN

However Maximum normal Load Reaction at the pedestal is 617 KN in intermittent Load Case 2(f).

Values of Moments are negligible, i.e of the order of 20 KN-m

Other Loading cases are associated with stress increase of 50 to 250% and hence not discussed.

Minimum Size of Column Strut required:

The load factor in these cases is = 1 to 1.4: Take 1.2 as the average value
Pu = 1.2 x 617= 740 KN Pu = 167 KIPS
Mu = 1.2 x 30 = Mu = 36 KN-m = 18 ft-K

Assume $\rho = 0.5$ %

1,000,000 mm² = $A_g \geq \frac{167}{0.45(3 + 0.005x60)} = 113$ in² ≅ 73,000 mm² OK

Steel Required:

As = @ 0.5% of Ag = 5,000 mm² =>> 12 #8 ≅ 6,000 mm²

Ties required:

Use #4 bar ties to catch every bar around as ties at spacing not greater than 400 mm, preferably at 200 mm on centres. Ties at the top shall be at closer spacing and flaring apart downward to the footing base.

Column Strut Capacity:

Using PCA Columns Software, the capacity at various axial loads is given below:

ϕPu		ϕMx	
ps	KN	Ft-K	KN-m
)	0	3317	980
70	9190	0	0
)2	-2234	0	0

Conclusion: Use 1000x1000 mm² Column Size, 40 mm cover to ties @ 200 mm spacing maximum, 12-#8 (25 mm) Longitudinal Bars. Spacing between main bras shall be about 300 mm OK. (Ties near the anchor bolts shall be at closer spacing of 3", 75 mm)

Column Footing Pad:

Minimum Steel Required:

Along Longer length: As min = 0.0018 x 1.5 x 6 = 0.0162 m² = 16200 mm²
Along Shorter length: As min = 0.0018 x 1.5 x 7 = 0.0162 m² = 16200 mm²

#6 bras @ 200 mm spacing each direction both ways will suffice.

Check Adequacy of Structural Depth:

The rigid depth of foundation is generally kept 1½ to 2 times the elastic depth required from the purview of punching shear or flexural requirements.

A: Punching Shear Requirement:

$C_1 = C_2 = 1000$ mm, $\beta_c = 1$, $\alpha_s = 20$, d = 1350 mm = 53 inches

Critical punching shear parameter: $b_o = 4(1000+1350) = 9400$ mm $\cong$ 370 inches

Critical Shear Stress is the minimum either of the following:

$v_c = (2+4)\sqrt{3000}$ = 329 psi or

$= (2+20x53/370)\sqrt{3000}$ = 267 psi or

$= 4\sqrt{3000}$ = 219 psi Take v_c = 219 psi

Minimum punching shear depth required:

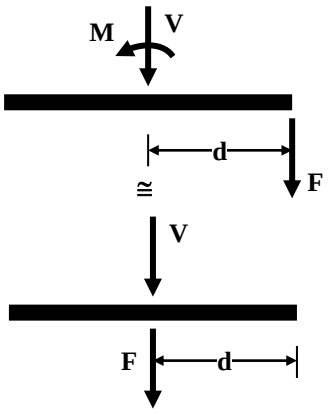
$d = Pu/(\phi v_c b_o)$, where Pu = 1.1xP

Maximum Pu encountered is 740 KN, P_u = 167 Kips

d = 167/(0.7*0.219*370) = 3.0 inches

Total thickness h = 3. + 6 = 9. inches =230 mm < 1200 mm provided OK

B: Flexural Requirement:



Considering the case when the flexural reinforcement / dowels produce the force F that will nullify the effect of M, i.e. M = F.d

The uniform pressure developed at the base is:

w = P/L:

Where P = V+F, w = P/L: F= M/d

OR

Assume a uniform intensity base pressure.

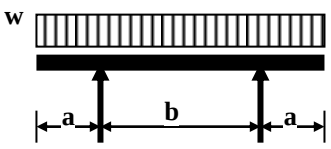
The bending moments at the places shown are:

$M_{max} = wa^2/2$ or

$M_{max} = w/2(b^2/4-a^2)$:

a = 1.25 m: b = 3.5 m

Uniform intensity of base pressure:



w= 250 KN/m² =1500 KN/m [LC # 2(d)]

M_{max} = 1172 KN-m = 865 k-ft

Mu = 1.2 * 865 = 1040 ft-k

Structural Depth required may be approximated by $d = \sqrt{(M/B.K)}$

Where k = 200 for f'c = 3000 psi and $\rho \cong 0.25\ \rho_b$, (balanced steel ratio)

B = 6 m ≅ 20 ft

Therefore: $d = \sqrt{(1040 \times 1000 / (200 \times 20))} = 16$": h =22 in= 560 mm

Rigid structural depth = 2.h = 1120 mm < 1200 mm OK hence h = 48 inches

Flexural Steel required:

$As = M/f_s.d$, where $fs = 0.8.f_y$ for Intermittent Loading condition = 48 ksi

$As = 1040*12000 / (48000*42) = 6.20\ in^2$

$\rho = As/Ag = 6.20/(240" \times 48) = 0.00054 < 0.0018$

Provide minimum reinforcement as recommended above.

Design for the Shear Dowels:

No condition warrants provision of shear dowels as established in the stability analysis.

Design of Flexural Dowels:

No condition warrants provision of flexural dowels as established in the stability analysis.

Check of Column pedestals for Shear Forces:

The flexural depth of pedestal at a distance 'x' normal to the pedestal top surface is given as:

d = a +x.tanθ –tc

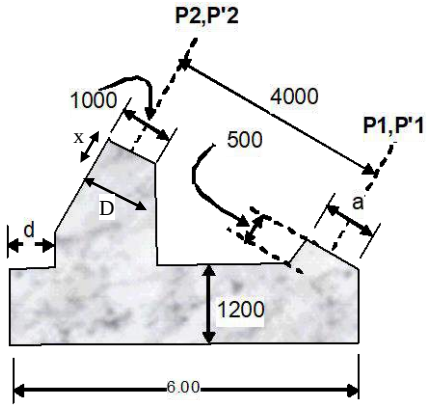
Where Cover thickness tc = 40 mm

A = 1000 mm Top width of pedestal

D = 960+0.84 . x for 40° inlined pedestal top

Maximum shear V = 1206 KN

Vu = 1.2 * 1206 = 1450 KN



At x = 0, D = 960 mm, 38 in. B= 1000 mm, 39.5 in.

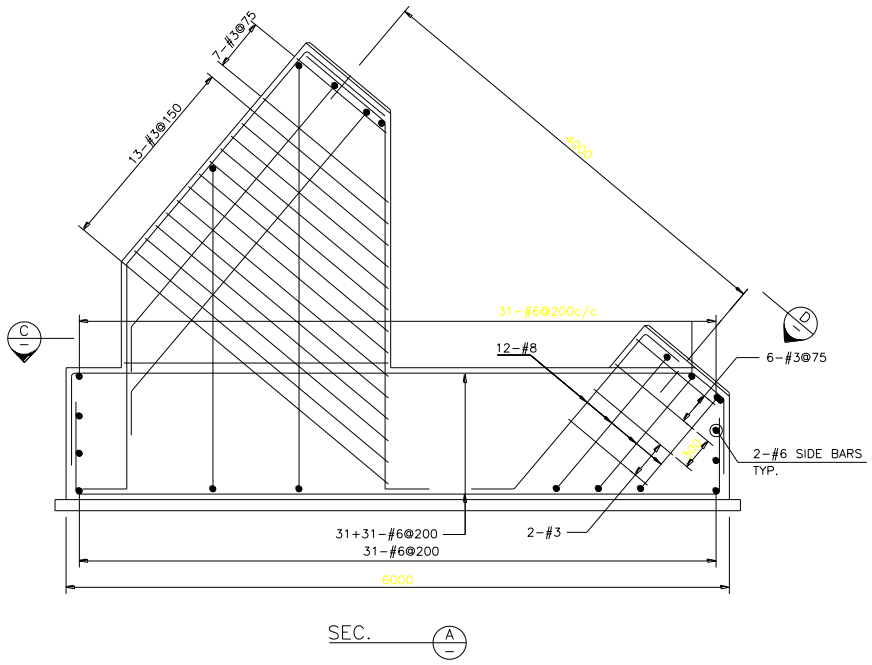
Shear stress applied at top of pedestal = 1450/0.96 = 1511 KN/m² = 1.511 MPa = 219 Psi

Shear capcity of concrete: $v_c = 2 \times (3000)^{½}$ = 110 psi

Area of shear bars required at top = Av = S . (Vu/ϕ – Vc) / fy.D

Let spacing S = 150 mm, 6 in:

Av = 6 .(219/0.7 -110) x 39.5 x 38 / (60000 .38) = 0.8 in², Provided is 4-legged #-4 Bars



Anchor Bolts ACI-318 Stipulations are reproduced hereunder**:**

7.10.5.6 Where anchor bolts are placed in the top of columns or pedestals, the bolts shall be enclosed by lateral reinforcement that also surrounds at least four vertical bars of the column or pedestal. The lateral reinforcement shall be distributed within 5 in. of the top of the column or pedestal, and shall consist of at least two No. 4 or three No. 3 bars.

Table 22-2 Minimum Reinforcement for Force Transfer Between Footing and Supported Member

	Cast-in-Place	Precast
Columns	$0.005A_g$ (15.8.2.1)	$\frac{200A_g}{f_y}$ (16.5.1.3 (a))
Walls	see 14.3.2 (15.8.2.2)	see 16.5.1.3(b) and (c)

ASTM A36 Bolts as anchor rods are recommended in view of their weld-able qualities and ease of local availability in any length up to 8inches diameter. ACI 349-90 section B 4.5.2 does not differentiate between ASTM A 36, A307 and high strength bolts.

ASTM A36 rods have one nut tack welded to the rod at the end ultimately embedded in concrete.

Dimensions:

Embedment Minimum embedment is 12 x bolt diameter

Minimum Edge Distance: 4 x bolt diameter for A36 Bolt and 6 x bolt diameter for high strength steel

Minimum Bolt Spacing : 8 x bolt diameter

Design Theory

The connection is considered as ductile. An anchorage is considered ductile if the capacity of the concrete is for each of the modes of failure is greater than the yield capacity of the bolt or reinforcement.

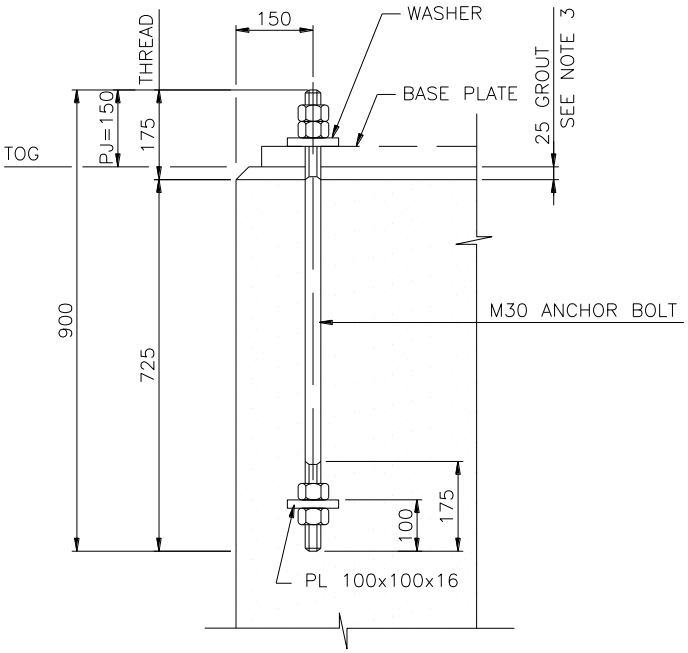
The highest shear at the top of the pedestal from the penstock assembly above is about 100 Tons, with almost nil moments at pedestals. The total area of bolts required is:

A_{bolt} = Shear / f_a , f a = 9.8 KSI A bolt = 100 x 2.24 / 9.81 = 22.83 in²

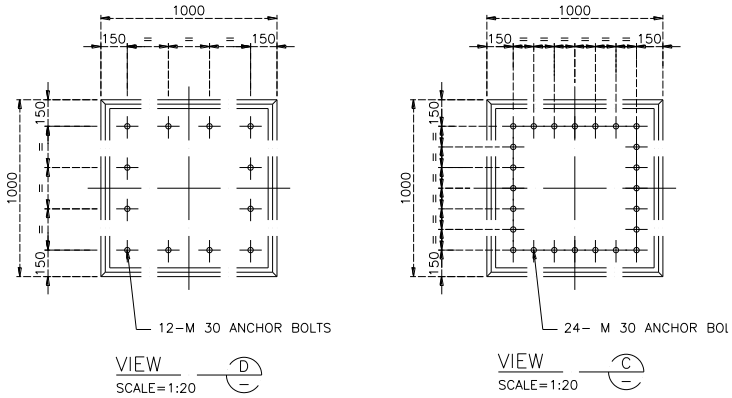
Provide 30 mm, 1.125 (0.99 in²) in diameter bolt, number of bolts required are: 23

Provide 24- 30 mm diameter anchor bolts at fixed supports.

Shear at the sliding supports is half of this value. Therefore provide 12-20 mm diameter bolts.

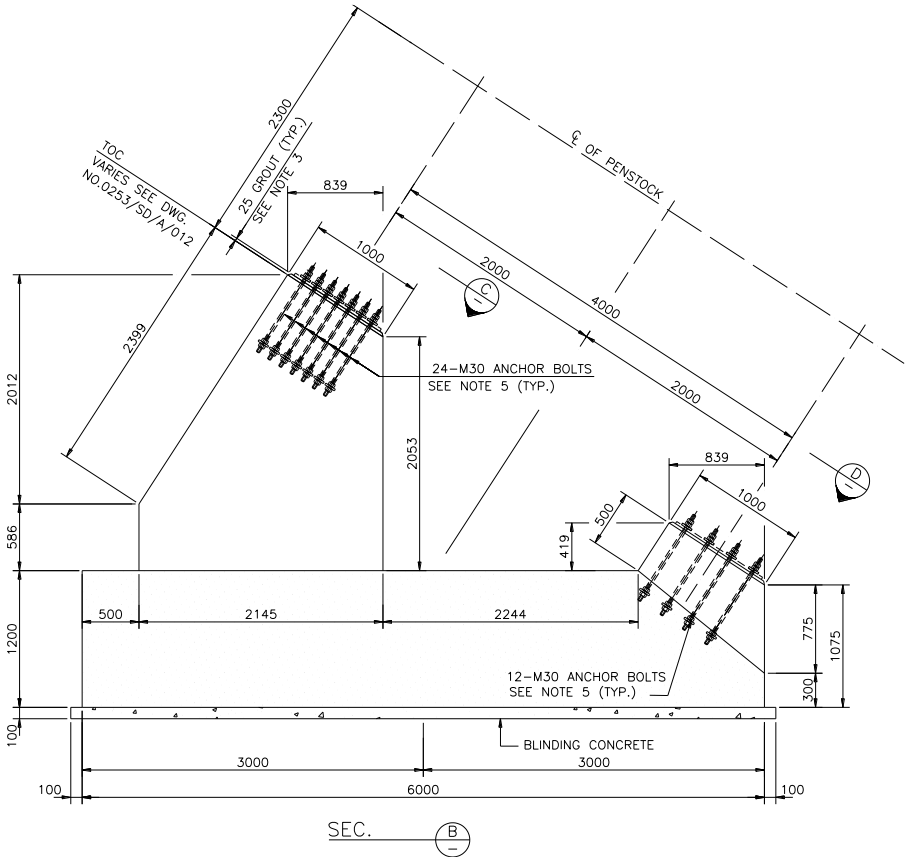


ANCHOR BOLT DETAIL
SCALE=1:10



VIEW D
SCALE=1:20

VIEW C
SCALE=1:20


TOC
VARIES SEE DWG.
NO.0253/SD/A/012
25 GROUT (TYP.)
SEE NOTE 3
2300
℄ OF PENSTOCK
839
1000
2000
4000
2000
C
2399
2012
24-M30 ANCHOR BOLTS
SEE NOTE 5 (TYP.)
2053
586
839
1000
500
419
D
1200
500
2145
2244
775
1075
300
12-M30 ANCHOR BOLTS
SEE NOTE 5 (TYP.)
100
BLINDING CONCRETE
3000
3000
100
6000
100
SEC.
B

ANNEXURE C - DESIGN REPORT ANCHOR BLOCKS

Anchor Blocks:

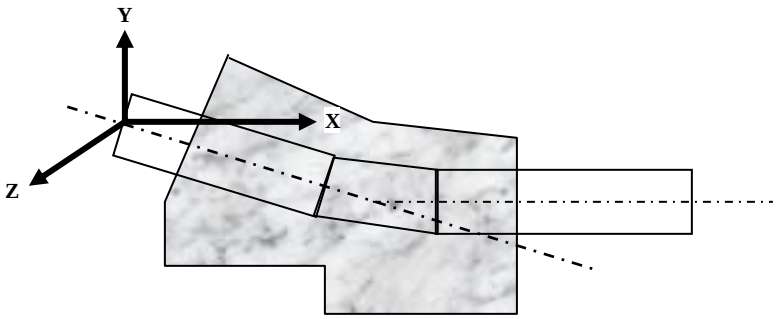
Anchor blocks are provided at each bend where huge magnitude of hydraulic forces is anticipated.

Analysis Methodology:

Conventional Stability analysis approach has been employed to evolve the economical proportions of the anchor blocks. The stability of the blocks is based on the gravity of the block and frictional resistance of the concrete and rock soil against the destabilising hydraulic forces and seismic excitations.

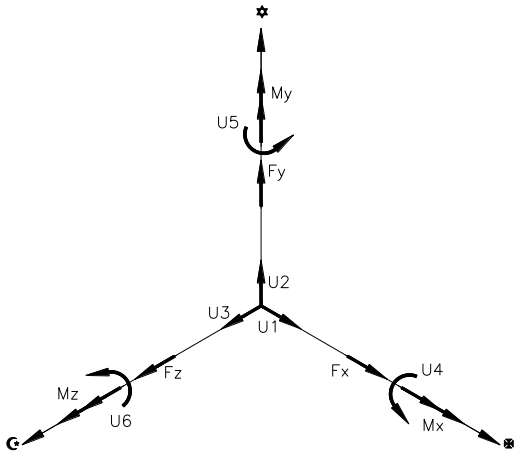
Global Frame of Axis

Global Frame of reference axis (x, y, z ≅ 0, 0, 0) is assumed to pass through the centre of the steel liner at its upper location of the coupling. Positive direction of Axis follows the Right-Hand-Rule).



Positive Direction of Forces and Moments:

Conventional Cartesian Co-Ordinates System is fiollowed with the concept of Right-Hand-Rule to identify positive direction of forces and dispalcements. Positive sense of translational and rotational degrees of freedem and direction of forces and moments are illsutrated in the figure blow:



Analysis Assumption:

Base Profile:

- The base of the anchor block is treated as a plain base without undulations and stepped configuration for computing stresses at the foundation level of the block

Reinforcement of the Concrete Block

- In accordance to the ACI Stipulations, minimum reinforcement shall be 0.28% of minimum Gross concrete section for the hydraulic structures, half on each face with a maximum area equivalent to # 9 bars @ 12" in each face. The anchor block is treated as a hydraulic structure.

- Reinforcement design requires approximating loading conditions for analysis with the assumption that concrete is placed while the penstock is under internal pressure and that shell deformations does not affect the block.

- Net total upward (Tensile) thrust of forces is balanced by the steel reinforcements. The upper block saddle weight minus the upward hydraulic thrust is resisted at the springing of the saddle through the reinforcement.

Loads and Forces:

Following Loads and Forces are assumed to act on anchor block.

Dead Weight:

- The block is segmented and weight of each segment is computed deducting the steel liner area. Total weight and the C.G of the entire block computed and entered into the computational work. The weight acts along Y-axis in negative direction.

- Similarly, the Steel liner is segmented and weight of each segment computed. C.G of the entire weight of the steel liner between the blocks is computed and entered into the computational work.

- Likewise, the weight of water in the steel liner is computed.

Hydraulic Pressure Forces:

Pressure force at the points of expansions couplings are computed and resolved along X and Y Axis. These forces are:

$F_A = P_A.A_W$

$F_B = P_B.A_W$

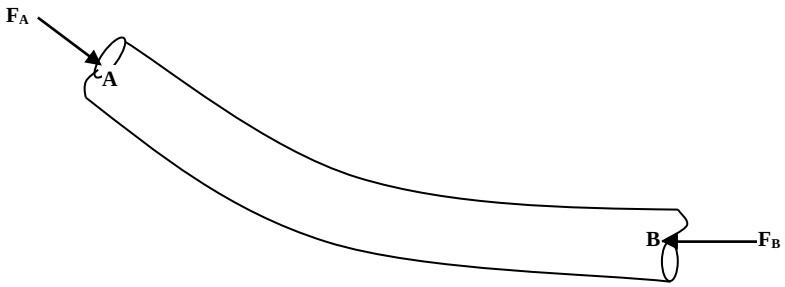
Where, P_A is the hydrostatic Pressure at the Expansion coupling A, and P_B is the hydrostatic Pressure at the Expansion coupling B. A_W is the Cross-sectional area of water at these sections.

The hydraulic thrust force at the expansion coupling on the cross-sectional area of the steel liner is also accounted for at these locations likewise.

The momentum force of water through the liner is equated by ρQV, assuming that velocity in the conduit is constant everywhere. The momentum forces occur only due to change of the direction of

the liner, i.e. at the bends. The parameters in the above relations are, mass density of flowing water, discharge and the flowing velocity respectively.

These forces are:



F = sum of pressure force, Hydraulic thrust at expansion coupling joint on the steel liner and the momentum force.

Component of these forces are:

$F_{xA} = +F_A \cdot COS\ \theta_A$ $F_{xB} = - F_B \cdot COS\ \theta_B$

$F_{yA} = -F_A \cdot SIN\ \theta_A$ $F_{yB} = F_B \cdot SIN\ \theta_B$

These forces along with their point of applications are entered into the computational work.

Thermal Forces:

The force of friction at the expansion couplings may be neglected for bolted sleeve type couplings. The effect of the sliding friction force at the sliding support is taken in the event if it is going to affect the stability of the block.

The net frictional force at the sliding support is given as:

$$F_{net} = (\mu \pm Tan\ \theta)\ W\ COS\ \theta$$

If the force is acting upward, Tan θ is taken negative. The force is transferred from the support to the centreline of the Penstock along with a couple or it is applied at its location with proper sign**.** Mostly the magnitude of this force is small. W contains the load of steel liner and the water for the portion of the conduit that will cause the reaction at the sliding support.

Wind Loads:

The intensity of wind load is multiplied with the projected area of the anchor block. Normal wind load and exceptional wind load intensities are 1.32 and 2.16 KN / m². The magnitude of these forces acting in Z-direction lateral to the penstock alignment along with the C.G of the projected area is entered into the computational work.

Earthquake Forces:

The pseudo-static co-efficient values of earthquake are applied on the dead loads. The values in X and Z direction is 0.17 and in Y direction 0.06 respectively.

F x = FZ = ± 0.17 .W and Fy = ± 0.06. W

Following load combinations of EQ Loads are analysed with other loads:

F_X and F_Y, F_X and $-F_Y$, $-F_X$ and F_Y, $-F_X$ and $-F_Y$

F_Z and F_Y, F_Z and $-F_y$

Condition of Stability of the Anchor Blocks

Following Conditions of stability are satisfied. If the Safety Factors exceed the values shown in the table hereunder, adequate number of shear dowels and reinforcement is provided to augment the resistance of the supports and anchor Blocks to cater for tensile forces.

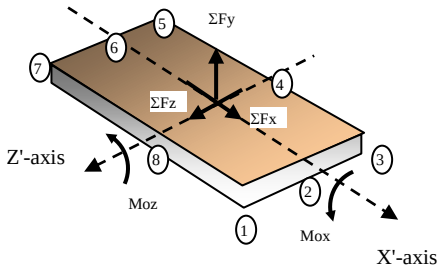
1. Sliding
2. Rotation
2. Uplift
3. Foundation Pressure

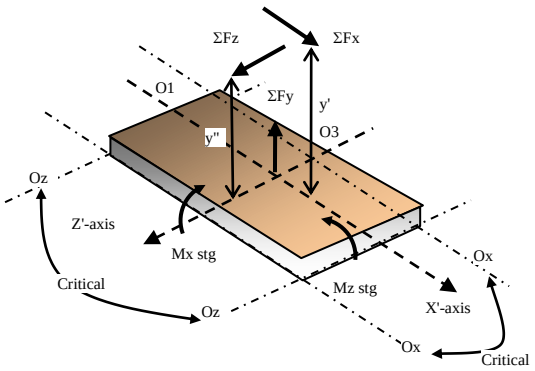
Sr. No.	Factor of Safety	Condition of Loading		
		Normal	Intermittent	Emergency / Exceptional
1	Sliding	1.5	1.3	1.2 / 1.05
2	Uplift	1.5	1.3	1.2 / 1.05
3	Rotation (Overturning)	1.5	1.3	1.2 / 1.05
4	Foundation Pressure	1.0	1.3	1.5 / 2.5

Stresses on the Bed of Foundation:

Following formula is used to ascertain Pressures at any point under the foundation:

$$f_{x,z} = \frac{\Sigma F_y}{A} + \left(\frac{M_{ox} I_z - M_{oz} I_{xz}}{I_x I_z - I_{xz}^2} \right).z + \left(\frac{M_{oz} I_x - M_{ox} I_{xz}}{I_x I_z - I_{xz}^2} \right).x$$





Factors of Safety against:

Sliding along X'-Axis: $$SF_{SLDG} = \frac{\mu \sum F_y}{\sum F_x}$$

Sliding Along Z'-Axis: $$SF_{SLDG} = \frac{\mu \sum F_y}{\sum F_z}$$

Overturning: $$SF_{OVTG} = \frac{\sum M_{STG}}{\sum M_{OVTG}}$$

The Overturning Effect is taken about the edges of the pad i.e. edge 345 or edge 187 in the Z'-Y' Plane and edge 123 or edge 567 in the X'-Y' Plane.

Uplift: $$SF_{uplift} = \frac{\sum F_{y\,DOWN}}{\sum F_{y\,UP}}$$

Eccentricity: $$e = \frac{M_{c.g}}{\sum F_y}$$

Where, Mcg represents moment of forces about the centroid. Therefore:

$$e_x = \frac{M_{oz}}{\sum F_y} \quad \text{and} \quad e_z = \frac{M_{ox}}{\sum F_y}$$

Design of Steel Reinforcements:

Note: Following design is provisional and shall be finalized during detailed design**.**

Pressure force at Point A:

$F_A = \gamma$ Aw. Z = 9.8 x π/4 (2.4²) . 102 = 4562 KN

Pressure Force at B:

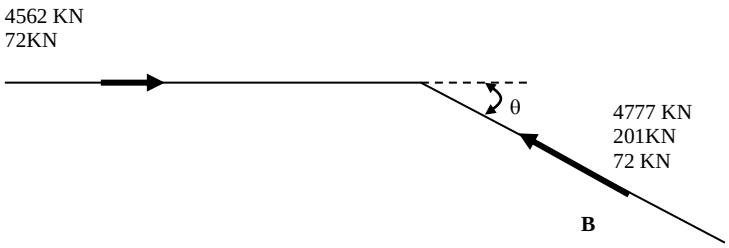
$F_B = \gamma$ Aw. Z = 9.8 x π/4 (2.4²) . 107.75 = 4777 KN

Pressure Force on the expansion coupling at B:

$F_B = \gamma$ Aw. Z = 9.8 x π/4 (2.45²-2.4²) . 107.75 = 201 KN (on the steel liner)

Momentum force at A and B = ρ Q V = 1.0 x 18 x 4.0 = 72 KN

The upward Force is:

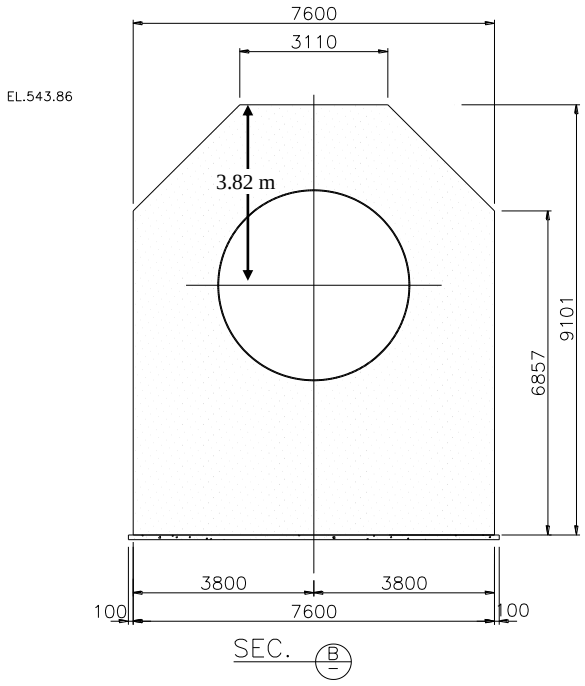


F_{up} = (4777+201+72) . sin 33° = 2750 KN

Force per unit length of the block = 2750 / 15 = 183 KN /m (15 m is the length of the block)

Taking water hammer effect 45% , the upward thrust = 266 KN / m

This force is to be resisted by the upper concrete block above the centreline of the penstock.



The weight of the upper block per unit length = 23.56 x (3.82 x 7.6 – 2.244²) = 565 KN

Thus the hydraulic thrust is less than the weight of the upper block. Therefore, provide minimum reinforcement.

Or To be conservative, assuming all the thrust is taken by the steel:
Ast = 1.7 x 266x2.24/(9.89x0.9x60 x3.28) = 1.16 in² / ft,
Provided is #9 @ 12" c/c Ast = 2.0 in² / ft OK

Proportioning Anchor Ring (Thrust Ring):

Anchor ring at the point of intersection of the bend is provided to resist the hydraulic thrust and safeguard against slippage of the conduit against the bearing surface of the anchor block concrete.

The average bearing stress should be less that 0.3 fc'.

$$\sigma = \frac{P.D^2}{D_O{}^2 - D^2} \leq 0.3 f'_c$$

Where:

σ = average bearing stress to be less than 0.3 f'c
P = internal pressure
D = outside diameter of the steel liner
Do = outside diameter of the anchor ring
f'_c = 21 MPa (Strength of concrete)

Rearranging the terms: $D_o = \sqrt{\frac{P.D^2}{0.3 f'_c} + D^2}$

Maximum Pressure P = 19.8 x 102.9 = 1008 KN/m²

f'_c = 21 000 KN/m², D = 4.06 m (average)

The minimum diameter of the stiffener ring required is:

$$D_o = \sqrt{\frac{1008x\,4.06^2}{0.3x21000} + 4.06^2} = 4.375m$$

Provided is 4.9 m OK

Therefore average depth of the ring is about 425 mm OK

Minimum thickness of the anchor ring:

Minimum thickness B = $\sqrt{(6.M_o/\sigma)}$, where Mo = PDA/12

P = internal pressure, D = outside diameter of the penstock liner, A = 420 mm computed above.

M_o = 1008 x4.06 x 0.42 / 12 = 143 KN-m /m

σ = 0.6 fy = 0.6 x415000 = 250,000 KN/m²

Minimum thickness comes out to be = $(6x143 / 250000)^{½}$ x 1000= 50 mm OK

7. HYDRO MECHANICAL EQUIPMENT

7.1 General

This Chapter provides the Tender level design for manufacturing, factory testing, packing for transportation, insurance, delivery to the Project site, storage at site, erection, site testing, commissioning, guarantees and rectifying all defects or shortcomings of Hydro-Mechanical Equipment for Jagran-IV Hydropower Project all in accordance with these specifications and complying with whole of the technical specifications enclosed with the bidding documents as part of the comprehensive EM Contract on EPC mode.

The Mechanical components of the Jagran-IV Hydropower Project for which this design is presented are:

A- Equipment for Power plant comprising:

- Three (03) vertical shaft Francis Turbines each with rated capacity of 7.16 MW
- One (01) vertical shaft Francis Turbine with rated capacity of 2.24 MW
- Four (04) electro-hydraulic digital governors based on the proportional, integral derivative (PID) regulations and allied accessories suitable for operation and regulation of proposed Francis Turbines
- Three (03) Globe type main inlet valves with internal diameter 1100 mm and design head of 250 mWC along with associated operating and regulating mechanism
- One (01) Globe type main inlet valves with internal diameter 610 mm and design head of 250 mWC along with associated operating and regulating mechanism
- Three (03) Howell Bunger (fixed cone) type pressure relief valves with DN 500, design pressure of 22 bar and pressure rating of PN40.
- One (01) Howell Bunger (fixed cone) type pressure relief valve with DN 300, design pressure of 22 bar and pressure rating of PN40.
- One (01) electric overhead travelling crane within powerhouse with double hoist 45/10 tons capacities
- Four (04) Sets of Bulkhead Stoplogs for draft tubes
- BOP-M / mechanical auxiliaries
- Workshop equipment along with spare parts and consumables required for five years trouble free operation of the Powerhouse and Intake

B - Equipment for Hydraulic Steel Structures - Weir, Intake & Stilling Basin Arrangements comprising:

- Two (02) hydraulically operated radial rates at Weir

- Two (02) Stoplogs for isolation of radial gates at Weir
- One (01) electrically operated Gantry Crane and lifting beam for Stoplogs of Weir
- One (01) electrically operated Gantry Crane and lifting beam for Stoplogs of Intake.
- Two (02) fixed wheel gates with operated with fixed electromechanical hoist for Power channel intake
- Two (02) Stoplogs for isolation of Fixed Wheel Gates at Intake
- Trash rack for Intake along with trash cleaning machine.
- Two (02) fixed wheel gates with manual hoisting for Sand trap-sediment flushing gates.
- One (01) intake slide gate at Sand trap inlet, operated with manual hoisting machine.
- One (01) outlet slide gate at Sand trap outlet to provide water to the Power Chanel; operated with manual hoisting.
- Four (04) vertical slide gates for Turbine Draft tubes, operated by gantry crane.

7.2 Turbines

Three vertical shaft Francis turbines each with rated capacity of 7.16 MW and one vertical shaft Francis turbine with capacity of 2.24 MW along with all associated components necessary for defect free and reliable operation for the guaranteed period of the plant have been proposed.

General arrangements of (3x7.16 MW + 1x2.24 MW) Francis turbines with vertical shaft connected Generators and associated equipment have been shown in Powerhouse general Layout arrangement drawings.

7.2.1 Design Standards

The turbines shall conform to the applicable requirements of the latest edition of the following Standards or to the recognised and equal standards shown in **Table 7.1**.

Table 7-1: Applicable Requirements from Standards

Subject	Standard
Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless	ASTM A 53 M
Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application	ASTM A 743 M
Standard Specification for Seamless Red Brass Pipe, Standard Sizes	ASTM B 43
Standard Specification for Seamless Copper Water Tube	ASTM B 88

ASME-Boiler and Pressure Vessel Code (*for* PENSTOCK and SPIRAL CASING)	BPVC Section VIII
Rotating electrical machines - Multiple parts	IEC 60034
Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines	IEC 60041
Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests	IEC 60193
IEEE Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Coupling and Shaft Runout Tolerances	IEEE 810
Industrial liquid lubricants - ISO viscosity classification	ISO 3448
Cranes and Related Equipment—Cableways, Derricks, Hoists, Hooks, Jacks, and Slings.	ASME B30
Crane Manufacturers Association of America, Inc.	CMAA

7.2.2 Type and Rating

The turbines shall be of the Francis, vertical shaft type and shall each deliver a continuous output of 7.2MW and 2.2MW (with full gate opening) when operating at 500 rpm and 750 rpm respectively at rated net head of 166m rated net head with all four turbines in operation.

7.2.3 Turbine Leading Design Parameters

The leading parameters of the turbines shall be as shows in **Table 7-2 & Table 7-3**:

Table 7-2: Jagran-IV HPP- Leading Parameters of Turbine

Parameters	Values				Units
	Turbine 1	Turbine 2	Turbine 3	Turbine 4	
Rated Head (H_n)	166.1	166.1	166.1	166.1	m
Rated Discharge (Q_r)	4.83	4.83	4.83	1.51	m^3/s
Acceleration (gravity)	9.81	9.81	9.81	9.81	m^2/s
Turbine Efficiency (η_t)	91.00%	91.00%	91.00%	91.00%	%
Generator Efficiency (η_g)	95.00%	95.00%	95.00%	95.00%	%
Transformer Efficiency (η_{tr})	99.00%	99.00%	99.00%	99.00%	%
Turbine Power (P_t)	7.16	7.16	7.16	2.24	MW
Net Power of all Units	23.72	-	-	-	MW
Generator Power (P_g)	6.80	6.80	6.80	2.13	MW
Power at Transformer (P_{tr})	6.74	6.74	6.74	2.11	MW
Net Power (Total)	22.330	-	-	-	MW
Internal losses and aux.	330	-	-	-	KW
Net Plant Capacity	**22**				**MW**

Table 7-3: Jagran-IV HPP- Turbine Salient Features

Parameters	Values				Units
	Turbine 1	Turbine 2	Turbine 3	Turbine 4	
Turbine Type	Francis	Francis	Francis	Francis	-
Configuration	Vertical	Vertical	Vertical	Vertical	-
Rotational Speed 'N'	500	500	500	750	RPM
Specific Speed 'Ns'	70.9	70.9	70.9	59.1	SI Units
Runaway Speed	796	796	796	1179	RPM
Runner diameter	967	967	967	560	mm
Weight of the Runner & Shaft	2566	2566	2566	879	Kg
Maximum Hydraulic Thrust (at Max. Net Head)	15.383	15.383	15.383	5.5	Ton
Velocity at DT Exit	1	1	1	1	m/s
Spiral Case Inlet Diameter	1100	1100	1100	610	mm

The corresponding parameters suggested by the renowned turbine manufacturers are generally in line with the above given parameters however the Turbine supplier shall re-evaluate these factors on the basis of data by his own Turbine Manufacturer and establish a deviation factor for Functional requirements & guarantees mutually agreed during Contract Award Meeting.

7.2.4 Design Requirements for Speeds and Balance

The complete rotating assembly (turbine and generator) shall be designed to accommodate the maximum runaway speed which can occur under any non-steady or transient condition.

Such conditions shall include the failure of the guide vanes to close on load rejection. Friction and windage losses of the generator shall be allowed for in the calculation of runaway speed. All parts of the turbine shall be designed to withstand safely this speed within the stress limitations.

In the calculations higher harmonics and combined critical speeds shall be considered. Calculations shall be presented in an easily understandable and concise manner. Amplitudes of vibration as measured on the turbine or generator bearing housings shall not exceed 0.1 mm peak to peak over the complete range of operation at normal speed. At all other speeds up to 70% over speed and including load rejection, amplitudes of vibration shall not exceed 0.125 mm peak to peak.

7.2.5 Vibration

The number of guide vanes, stay vanes, and runner blades shall be such as to ensure vibration-free operation.

7.2.6 Resonance

Based on the results of the hydraulic model tests and previous experience of the vendor for similar units in size, head (varying from 145m to 166m) and output, the Contractor shall conduct resonance studies covering the complete range of normal operation of the turbines up to and including full load rejection. These studies shall include but not be limited to the following criterion:

- Penstock hydraulic resonance due to excitation from part load and full load penstock pressure pulsations.
- Power swings due to excitation from part load and full load draft tube pressure pulsations and governor oscillations coupled with the generator natural frequency.
- Resonances due to unfavourable coupling of the passing frequencies of runner blades, guide vanes and stay vanes.
- Resonance caused by rotating pressure waves in the vane less space between runner - and guide vanes.
- Resonance of the stay vanes and runner blades due to Von Karman vortex shedding from the blade trailing edges.

7.2.7 Regulation

The total stored energy of the combined turbine and generator shall be the minimum necessary for stable governing and the attainment of the specified and guaranteed pressure and speed regulation. The combined turbine/shaft inertia shall not be less than 1199 Kg - m^2 (WR^2) for main units and 140 Kg.m2 for small unit respectively as estimated in accordance with the recommendations of US Bureau of Reclamation reported by US department of Interior.

Calculation for GD^2

GD^2 = 4xJ, where J= Mass moment of inertia

Mass Moment of Inertia = ½ ($m.r^2$)

m= rotating mass (combined weight of Runner and Shaft)

r= d/2 of the runner

For Main Units (7.16 MW)

J= ½ ($m.r^2$) = 1/2 x [2566 x $(0.4835)^2$] = 300$Kg.m^2$

$(GD^2)_{main}$ = 4J = 1200 $Kg.m^2$

For Small Unit (2.24 MW)

J= ½ ($m.r^2$) = 1/2 x [879 x $(0.0.28)^2$] = 34. 4$Kg.m^2$

$(GD^2)_{small}$ = 4J = 137.6 $Kg.m^2$

These values of Flywheel effect provide baseline for calculation of GD^2 for Generator Rotors.

7.2.8 Speed Regulation

The maximum speed which can occur when the generator output corresponding to the guide vane opening for maximum output is instantly rejected from a unit operating under the maximum net head shall not exceed 135% of the rated speed in the most unfavorable conditions.

7.2.9 Requirements for Pressure Regulation

Following consideration shall be made while finalizing the Pressure regulation criteria:

(a) The maximum pressure head which can occur in the waterway system is controlled by the design of the pressure tunnel and a surge tank provided at start of the pressure shaft to protect the whole Penstock and spiral casing against any thrust beyond its design limits.

(b) The water column in draft tube shall remain intact or be controlled by air valves such that maximum head under the runner on column return does not exceed the guaranteed value.

The transient conditions shall include:

(c) Instantaneous rejection of any load of which the unit is capable at any possible operating or transient condition in the reservoir and tailrace.

(d) Acceptance of any load which the unit is capable at any possible operating or transient condition in the dam / reservoir and tailrace.

The Contractor shall submit calculations for all transient conditions showing compliance with the above requirements. The transient analysis shall calculate the variation of pressure throughout the complete waterway from intake to draft tube exit up to maximum turbine-generator speed rise of 50% of the Synchronous speed.

If air valves are required to control draft tube under pressure, then their opening shall be controlled by the regulating gear. The valves shall act as a check valve or they shall be provided with a separate check valve.

7.2.10 Air Admission System

The air admission system shall be based on atmospheric pressure through open pipes / ducts open to sky outside the powerhouse with shut off valves and bird screens. Pipework shall be routed to minimise the noise within the power station and shall be taken to a point above the tail water level at suitable place either on downstream side or upstream side.

7.2.11 Efficiency

In addition to hydraulic losses, turbine efficiency shall include mechanical and volumetric losses attributed to the turbine supply.

For the thrust bearings the distribution of losses attributed to the generator and to the turbine shall be proportioned in accordance with IEC 60041. Calculations of thrust and guide bearing losses shall initially be in accordance with IEC 60041 and subsequently measured at site in accordance with IEC 60034.

Best turbine efficiency shall be at 91.0% of rated discharge and at not less than 3.4 MW output for each turbine. The turbine weighted efficiency shall be calculated as shown in **Table 7-4**:

Table 7-4: Turbine Weighted Efficiency

Condition	Net Head (m)	**Output**	Weighting Factor
A	166	Rated	5
B	164	Full Gate	3
C	167	Full Gate	2

The average weighted efficiency shall be determined from the efficiencies guaranteed for the conditions defined in Table 7-4 when entered into the following formula.

- Guaranteed efficiency = 0.1 (5 x Efficiency A + 3 x Efficiency B + 2 x Efficiency C)

The weighted average efficiency determined from the above shall be the guaranteed efficiency and not less than 90%.

7.2.12 Torque Fluctuations

Torque fluctuations measured at the turbine shaft shall not exceed the following:

- Between 50% and maximum output for a particular head 3% peak to peak
- Below 50% maximum output for a particular head 5% peak to peak

7.2.13 Stresses and Materials

Ample factors of safety shall be used throughout the design and especially in the design of all parts subject to alternating stresses or shock. The design of equipment shall include an allowance for the OBE earthquake loading under the most severe loading conditions expected in normal operation (including load rejection), stresses in the materials shall not exceed the values listed in the **Table 7-5** below.

Table 7-5: Allowable Material Stresses

Material	Tension	Compression	Shear
Cast iron	10% of ultimate strength	70 MN/m²	21 MN/m²
Cast mild steel	83 MN/m²	83 MN/m²	50 MN/m²
Alloy cast steel	20% of the ultimate strength or 33% of the yield point, whichever is less	20% of the ultimate strength or 33% of the yield point whichever is less	60% of the allowable tensile stress
Plate steel for spiral case or other principal parts	25% of the ultimate strength but not to exceed 100 MN/m²	25% of ultimate strength but not to exceed 100 MN/m²	60% of the allowable tensile stress

For materials not listed in the table the maximum stresses in tension or compression under the most severe normal and transient operating conditions shall not exceed 33.3% Yield or 20% Ultimate Tensile Strength (UTS).

Maximum shear stresses in other ferrous materials shall not exceed 60% of the allowable stresses in tension, except that the maximum torsional shear stresses in the turbine main shaft

shall not exceed 50% of the allowable stress in tension in normal operation including load rejection. Maximum combined stresses in the shaft under generator short circuit conditions shall not exceed 50% of the material yield stresses.

Under maximum runaway speed or under the hydrostatic test conditions, stresses shall not exceed 66.67% Yield.

Stresses at the junction of the runner vanes and crown shall not exceed 25% Yield under any operating condition. To the calculated thickness for this condition shall be added an allowance of 3 mm for attrition.

Stresses in the guide vanes, guide vane stems and guide vanes stem levers at the breaking point of the shear pin friction device combination shall not exceed 66.67% Yield.

The material for all important stressed parts including stay ring, spiral case, top cover, bottom cover, shaft, and runner shall have adequate impact value and the Contractor shall submit details of such critical components for approval by the Project Manager.

7.3 Design Requirements of Turbine Components

7.3.1 Runner

The Turbine Runner shall be of martensitic stainless-steel grade CA6NM to ASTM A743M, Francis type, one piece casting or shop assembled construction with runner diameter of 967 mm for main units and 560 mm for small unit respectively. If fabricated, runner parts shall be integral castings or formed plate. All shop welds shall be stress relieved. Material and the method of construction shall be to the approval of the Project Manager.

The fully heat-treated runner material shall have a minimum Charpy “V” notch energy of 55 J at -20^{o}C. In addition, following considerations shall be made while designing the Francis turbine runner profiles:

a. The runner shall be designed to withstand the forces encountered during all normal and abnormal conditions up to and including the guaranteed runaway speed.

b. All surfaces exposed to the flow of water shall be finished smooth over the entire plane by grinding or other means so as to be free from hollows, depressions, cracks and projections. The average surface finish shall be 4 microns or finer in areas subject to possible cavitation as determined in the model tests.

c. All other areas shall be finished to 10 microns or less. Surface undulations shall not cause S/L to exceed 0.01 where S is the deviation from the design profile measured normal to the surface and L is the distance along the surface over which S occurs.

d. The runner shall be statically balanced in the shop to a precision of at least 150 kg-m. Lead filled boxes shall not be used for balancing purposes. The balancing method shall be submitted for approval.

e. Holes may be provided in the runner crown for hydraulic thrust relief, if thrust balance pipes are not provided in the top cover. The site and location of the holes shall be confirmed in the turbine model test.

f. The outside diameters of the runner crown and band shall be machined to form the rotating wearing ring to provide a close fit with the fixed wearing rings.

g. The turbine runner, wicket gates, and guide vanes shall be provided with suitable high-performance surface protection systems to enhance resistance against abrasion and erosion

caused by sediment-laden flow. The type of surface treatment and coating materials shall be selected based on the findings of sediment transport and sedimentation studies, considering particle size, concentration, and mineral composition.

7.3.2 Turbine Shaft

The complete shaft assembly shall be designed to operate safely at any speed up to the maximum runaway speed without detrimental vibration or distortion.

The maximum torsional shear stress shall not exceed 50% of the allowable stress in tension.

The turbine shaft shall be of steel, either as an integral forging or fabricated from forged members. If the shaft is an integral forging, the central material shall be machined out to allow examination of the full length of the bore. If the shaft is fabricated, the design shall use full penetration welds only, of a form which can be readily radio-graphed.

Shall the shaft be hollow to allow for air admission if required as per OEM design the air admission as part of the Contractor's design, a pipe shall be provided to ensure the air admission taken from above Probable Maximum Flood (PMF) level.

The shaft shall have a coupling face to match the coupling flange on the generator shaft, and shall conform to IEEE 810 OR *ANSI Standard B-49-1 "Shaft Couplings integrally forged type for hydraulic units"*.

Shaft run out as checked in the works shall not exceed the recommendations of IEEE 810 OR *NEMA "A" Standard for Vertical Hydraulic Turbine Generator Shaft Run out Section "B"*

The same Standard shall be used for checking the coupled shaft run out at site.

7.3.3 Turbine Guide Bearing

7.3.3.1 General

The Turbine guide/support bearing shall be of oil lubricated self-pumping type tilting pad type mounted on segmented multiple shoes fixed on concrete pedestals. The design shall permit lateral movement of the line shaft system for adjustment and fixing the run out if found beyond permissible limits of the approved design.

A portion of the bearing shall be continually immersed in oil to provide initial lubrication during a unit start.

7.3.3.2 Specific Requirements

The turbine guide/support bearing housing shall be split horizontally and dowelled to facilitate dismantling and reassembly. Alternatively, the Contractor may propose his own design with complete procedures for removal, maintenance/overhauling and/or replacement of the bearing components.

Coolers shall be external to the oil reservoir with isolating valves to allow removal of any one without affecting the operation of the turbine.

There shall be an observation window in the bearing cover.

The turbine guide bearing shall be equipped with the following:

(a) Cooling water flow indicator with contacts for interlock and low flow alarm

(b) Bulb thermometers with contacts for high oil temperature alarm

(c) Water-in-oil sensors for alarm

(d) RTDs measuring oil temperature

(e) RTDs measuring discharge water temperature

(f) Local oil level indicator with contacts for first stage low level alarm and second stage low level trip

(g) Oil level transmitter for remote display at the purifier locations

(h) Dual RTDs in all bearing pads

(i) Means of adjusting the overall bearing clearance

7.3.4 Spiral Casing

The spiral casing shall connect to the Main Inlet Valve upstream of the turbine centreline via a make-up piece designed to allow correction of any minor misalignment and installation/removal of the Main Inlet Valve.

All welds shall be 100% radiographed except at locations which do not lend themselves to radiographic examination and those joints shall be ultrasonically examined. The efficiency of the welds shall be assumed to be 100%. Radial internal supports shall be provided for transport and erection of the component segments of the casing.

The spiral casing shall be pressure tested to 1.5 times the design pressure at the centre line of the spiral.

7.3.5 Covers

Side covers shall be made from welded steel or cast steel structures designed for the maximum operating pressure including water hammer. Likewise, the effects of frequent start-ups shall be considered when designing the equipment.

The covers shall be rigid to minimize the deflection under pressure, and a description of typical stress calculations as well as the calculated guide vane clearance shall be submitted for review and approval by the Project Manager before start of manufacturing.

The covers shall have self-lubricating bearings for the guide wicket gate shafts, which shall be well protected from sand intrusion by suitable seals. Contractor shall submit the detail design for Project Manager’s approval before start of execution.

Suitable labyrinth rings or similar sealing arrangements shall be provided in the covers.

7.3.6 Discharge Ring

The discharge ring shall be stiffened by external ribs to resist the design forces without any support from the surrounding concrete.

The ring shall be welded to the draft tube liner by means of an adjustable make up piece which can be cut to shape to accommodate any misalignment between the ring and draft tube liner. A stainless-steel liner shall extend 300 mm from discharge end of the runner.

7.3.7 Draft Tube

The Contractor shall be responsible for the profile of the complete draft tube (both steel lined and concrete sections) up to and including the exit into the tailrace. The complete draft tube shall be included in the turbine hydraulic model. The Exit diameter of draft tube shall be 2.35m The Contractor shall determine all draft tube dimensions such that the required performance is achieved, but should endeavor where possible to generally comply with the powerhouse dimensions indicated on the General arrangement drawings.

The Contractor shall supply and install all necessary brackets or pads and levelling screws for adjustment of the liner after erection together with all braces, turnbuckles and supports to retain the liner in position during embedment. After embedment the Contractor shall coordinate with the civil contractor to fill "drummy" areas (void areas identified between concrete and liner) in the draft tube. To the approval of the Project Manager the Contractor shall drill holes and install fittings for pressure grouting by the civil Contractor. After grouting the Contractor shall plug and grind flush the holes.

The draft tube liner shall be designed for full vacuum plus an external pressure equal to Probable Maximum Flood (PMF) in the tailrace.

7.3.8 Guide Vanes, Wicket gates and Regulating Mechanism

The guide vanes and regulating gear shall be designed to withstand the prototype forces and torques calculated from the measured torques on the model guide vanes during the turbine model tests, as well as any torques which may occur under turbine operation, including runaway speed.

Special attention shall be paid to the guide vane torques which may occur with one or more guide vanes out of synchronism with the others.

Suitable precautions shall be taken to prevent guide vanes out of synchronism interfering with adjacent turbine parts or colliding with the rotating runner.

7.3.9 Wicket gates

The guide vane wicket gates shall be of stainless steel or steel alloy, with a content of approximately 13% chromium and 4% nickel, and resistant to cavitation. They shall be designed to form a single unit, consisting of wicket gate leaf and stem. They shall be normalised.

The guide vanes shall have a self-closing tendency and observe “failsafe close mechanism” from fully open to the speed-no-load position.

The surface of guide vanes shall be finished to 12 microns or finer and surface undulation shall not cause S/L to exceed 0.01 where ‘S’ is deviation from design and from measured normal to the surface and ‘L’ is the distance along the surface over which ‘S’ occurred.

7.3.10 Guide Vane Leakage

The design shall be such as to minimise guide vane leakage.

Under the maximum static head of 166 m when unit is not in operation, the guide vane leakage shall not exceed 15 l/s

Verification of the leakage rate through the guide vanes at design net head when the unit is stopped and closed locked engaged shall be by measuring the drawdown of a penstock after taking account of the combined intake gate leakage.

7.3.11 Regulating Gear

The entire control mechanism for regulating the guide vanes shall be designed to be easily accessible for maintenance, inspection and repair. The design shall enable the safety features to be easily reset and allow dismantling of the entire regulating mechanism.

The operating mechanism shall protect the guide vanes from damage in case a foreign object is trapped between two closing wicket gates. Each wicket gate or its link shall be fitted with a limit switch arranged to initiate an alarm and protection if the vane becomes out of synchronism with the others.

Each guide vane shall be connected to the regulating ring by means of a link and lever system incorporating a shear pin and eccentric pin to facilitate guide vane adjustment and a friction device or slipping clutch mechanism. In the event of blocked guide vane and breakage of the shear pin the friction device shall permit movement of the operating mechanism but shall limit the movement of the free wicket gate. The design capacity of the shear pin/friction device combination shall be based upon the results of the turbine model test and shall be such as to limit movement of the free wicket gate for all misaligned vane positions under both opening and closing conditions. The shear pin/friction device combination shall be shop tested and means and equipment shall be provided for adjusting and checking the friction device setting on site. This device shall remain with the Client for periodic checking as necessary. End stops beyond the guide vanes fully open and fully closed positions shall also be provided on the upstream side cover.

The regulating ring shall be designed and dimensioned so that all guide vanes open simultaneously and by the same amount. It shall be safely and securely located by appropriate means to prevent tilting or bending. An electric operated detector system shall be provided for each turbine to indicate failure or cracking of the shear pins or slippage of the friction device.

7.3.12 Bearings for Guide Vanes and Regulating Gear

All bearings in the regulating gear and guide vanes shall be located in bearing casings mounted in the upstream side cover and discharge ring equipped with interchangeable bushings of self-lubricating material and necessary interchangeable sealing rings of stainless steel or synthetic material. Rubber shall not be acceptable.

Means shall be provided for individual adjustment of the guide vanes to give equal openings and for separately adjusting the top and bottom clearances between the guide vanes and cover liners. The gap dimensions shall be kept to a practical minimum.

7.3.13 Guide Vane Position Indication

A guide vane indicator plate shall be provided on the regulating ring scribed in 5% steps of guide vane opening up to 110% opening (when 100% is corresponding to the rated output).

7.3.14 Guide Vane Servomotors

Each turbine shall be equipped with two oil pressure operated double acting servomotors designed for the rated governor oil pressure of up to least 8 MPa or as suggested by OEM. The servomotors shall be mounted along the turbine on generator side.

All plates, anchors, and attachments for the servomotors shall be supplied by the Contractor for embedment in the block outs provided by the powerhouse civil contractor. Dowels shall be provided for locating the servomotors on their embedded base plates. The servomotors and the

complete regulating mechanism shall be capable of opening the guide vanes to 10% more than the opening indicated by the model test for rated output.

The servomotors shall be designed for at least 1.2 times the maximum calculated operating force. The servomotors shall be designed and manufactured to the ASME Boiler and Pressure vessel code. JIC Hydraulic Standards for Hydraulic Equipment shall be applied for piping and accessories modified accordingly to accepted ISO standard fittings and fastenings. All pipe works between the pumping sets, governor, and servomotors shall be supplied and installed by the Contractor.

7.3.15 Turbine Noise

Doors, covers and turbine/generator housings shall be provided to keep the noise levels less than 80 dB(A) when measured 2m from the turbine/generator housings.

7.4 Digital Governor

7.4.1 Scope

Two (02) digital turbine governors and their auxiliaries suitable for use with Francis turbines shall be provided.

7.4.2 Design Standards and Reference

The governor shall conform to the applicable requirements of the latest edition of the following Standards as listed in **Table 7-6** below or to recognised and equal standards as agreed and approved by the Project Manager.

Table 7-6: Design Standards for Governors

Subject	Standard
Guide to the Specification of Hydro turbine Control Systems	IEC 91362:1998
Boiler & Pressure Vessel Code	ASME BPVC

7.4.3 General

The digital electro-hydraulic with PID control governor operates with a hydraulic pressure supply system and local/remote control with indications.

The governor system shall set the turbine speed and servomotors positions smoothly and gradually so that no harmful oscillation shall occur.

The governor system shall provide stable operation of the turbine for all operating conditions and shall cope with worst condition on full load rejection. Interaction between closing of wicket gates, speed and pressure regulation shall be coordinated by the governor to keep the speed and pressure rise within limits.

The Contractor is required to submit computations to justify the unit inertia finally selected by him to prove that speed and pressure rises of the system shall be within safe operating limits.

7.4.4 Type and Description

The governor shall be the digital electro-hydraulic governor type, i.e., microcomputer governor, based on the proportional, integral derivative (PID) regulations. Two micro-processing control units shall be on standby for each other, so in case one fails, the other can take place automatically.

The governing system shall meet all requirements for the automatic control and the manual control of the Francis-turbine.

Digital Governor shall respond to Frequency with PID response. Frequency shall be controlled by Digital Governor to a signal from the network and when selected from an internally generated signal within the Governor. The source of frequency signal shall be selected at the Digital Governor. The internal frequency signal shall be adjustable from 0% to 200% normal speed to enable testing of the generating unit. Digital Governor's frequency response shall conform to Pakistan Grid Code. Means shall be provided to protect the Generator against damage if frequency excursions occur outside the permissible range.

7.4.5 Functional Requirements

The Governing system shall be designed for the following functions:

- Speed (Frequency) Control
- Output Control
- Flow Control
- Turbine Creep Detection
- Sequence Control
- Remote Control
- Manual Control
- Emergency Shutdown

7.4.6 Hydraulic Pressure Unit for Governor

Monoblock compact, package type Hydraulic Pressure Unit (HPU) shall be provided for smooth operation of the governor with hydraulic oil pumping system and pressure accumulators filled with Nitrogen on one side of the piston and oil on the other side.

The governor oil pressure systems are foreseen to operate at about 10 bars and Nitrogen is required to maintain the oil pressure at certain value and keep the pressure available for servomotors as well as Main Inlet valve hydraulic cylinders.

The contractor shall submit detail design for Project Manager's Approval

The control shall be possible as per following conditions:

- Locally at the governor for the control of individual components and for maintenance purposes
- From the main control board for starting, synchronizing, loading and stopping the unit

- From the control room for supervising the function and operating of a unit when connected to the main grid or for the local network.

7.4.7 Oil Pumping System

Each HPU shall have two (02) Screw type self-priming pumps, one in operation and other as standby, directly mounted on a sump tank having oil capacity not less than 110% of the total oil in all piping and in servomotor cylinders required for stable operation without any potential for bubbling.

The Contractor shall assure fine and effective, online, filtration of the oil at every cycle during Unit Operation. All impurities or suspended particles shall be removed after a fixed duration of time to enhance the operational life of the hydraulic oil thus minimizing the time for oil replacement or independent purification process.

All piping, tubing, flanges, fittings, valves, hangers, brackets, fasteners, and all necessary items for a complete, self-contained hydraulic pressure and actuator system shall be designed, manufactured and installed by the Contractor. The piping shall preferably be manufactured from standard “off the shelf” stainless steel components with appropriate high-pressure fittings.

7.5 Main Inlet Valves

7.5.1 Scope

Three (03) globe type Main Inlet Valves (MIVs) with diameter 1100mm and one globe type Main Inlet Valve with diameter of 610 mm shall be supplied along with operating equipment, suitable for use with each of turbine unit as part of Mechanical supply.

7.5.2 Type of Valves

Each turbine unit will be equipped with the corresponding 1100 mm and 610mm in diameter globe type main inlet valves which should be closed during longer stand-still periods and in emergency cases against the full water flow. Before the valve is opened, the pressure at upstream and downstream should be equalized via a bypass valve. The bypass valve should be firm flanged to the bypass line connected beyond the outer lines of the disc on upstream and downstream side. The foundation should enable a longitudinal displacement of the valve and should carry no forces in the axial direction

7.5.3 Hydraulic Power Unit for MIV

Separate mono-block compact type hydraulic power unit synchronized with the unit governor is recommended for smooth operation of Main Inlet Valve with hydraulic oil pumping system and pressure accumulators filled with Nitrogen on one side of the piston and oil on the other side.

The MIV hydraulic oil pressure systems are foreseen to operate at about 60 bars and Nitrogen is required to maintain the oil pressure at certain value and keep the pressure available for MIV hydraulic cylinders.

The control shall be possible as per following conditions:

- From the main control board for starting, synchronizing, loading and stopping of the unit.
- From the control room for supervising the function and operating of a unit when connected to the main grid or for the local network.

The MIVs will be provided with two double acting hydraulic cylinders for opening and closing, both operated by the commands from turbine governors but powered with separate accumulator. A counterweight for closing the valve in an emergency situation is recommended. The use of the headwater pressure for valve operation is not recommended due to the sediment content in the water.

A bypass pipe for the Inlet Valve with double isolating valves shall also be provided on upstream side of the valve for dewatering the pressure shaft during maintenance of Main Inlet Valve service seal during unit shutdown.

Table 7-7 shows the Key parameters for Main Inlet Valves

Table 7-7: Key Parameters for Main Inlet Valve

Total No of Valves	4
Valve type	Globe type
Design head)	250 mWC
03 valves with approximate diameter	1100 mm
01 valve with approximate diameter	610 mm
Sealing system	Stainless Steel
Expansion joint location	Down stream
Operating system	Pressurized oil

7.6 Howell Bunger type Pressure Relief Valves

As described in the scope of Mechanical works under sub-clause 7.1, total four (04) Howell Bunger (Fixed cone and movable sleeve type) pressure relief valves shall be provided. These valves will be flanged connected on a branch pipe directly welded with each spiral casing of the respective sizes. These valves will be operated with hydraulic actuators and pressure sensing units designed on the basis of transient studies to be conducted by EPC Contractor. The fixed cone size shape shall be proposed by Contractor such as to relieve water pressure on tail race side without harming any equipment or components in vicinity.

The Howell-Bunger (fixed cone) valve shall be designed specifically for high-head hydropower service and shall comply with the latest editions of the following standards:

– IEC 60545 (Hydraulic turbines – auxiliary equipment)
– USBR Design Standards and Engineering Monograph for fixed-cone valves
– ASME B31.1 / ASME B16.34 for pressure design
– EN 12516 for valve strength
– ISO 5208 for pressure testing
– AWWA standards for fabrication and actuators
– AWS D1.1 for welding

Where conflicts occur, hydropower-specific standards shall govern.

The relief valves shall be provided with vent piping, silencers and drain connections, as well as suitable gagging and locking devices for hydraulic testing after erection and for long-term maintenance of the plant. **Table 7-8** shows the key parameters for Pressure relief Valves.

Table 7-8: Key Parameters for Pressure Relief Valves

Total No of Valves	**4**
Valve type	Fixed cone, Howell Bunger
Design Pressure	22 Bar
Pressure Rating	PN40
03 valves with Nominal Diameter	DN500
01 valve with Nominal Diameter	DN300
Operating system	Hydraulic Actuator with pressure sensing units
Connection with Branch pipe	Flanged type with damper sleeves
Connection of branch pipe with Spiral Casing	Welded

7.7 Main Lifting Equipment

7.7.1 Powerhouse Crane

(a) An overhead electric operated bridge crane shall be provided to assemble and disassemble the heavy turbo generator components during the installation process and also during the repair and maintenance of the powerhouse items. The lifting capacity of the overhead bridge crane is based on the maximum possible weight of a single piece of equipment to be lifted / moved by the Crane. Based on the previous experience, a 45/10-ton double girder two hoist trolley, electric operated overhead bridge crane has been recommended for precision handling of items such as generator rotor, turbine runner and shaft assemblies. However, the lifting capacity shall be finalized on the basis of machine weights data provided by the manufacturers. The low-speed main hook will handle heavier loads and higher speed auxiliary hook will be used for lighter loads. The lifting height of the hoists shall be determined either by the height of the rotor or transformer or any other sub-assembly, which has greater height than the formers.

The main crane hook shall be capable of lifting the highest component of the transport – vehicle and both the main and auxiliary hooks shall be capable of reaching as far down as required to serve the inlet valve gallery. Access to the crane shall be provided through ladder located near the entrance door. The rail section and size shall be finalized corresponding to the wheel load as per FEM or CMAA standards.

(b) A Gantry Crane with lifting capacity of 10 ton is proposed to be installed outside of the D/S wall of the Powerhouse to operate the Draft Tube bulkhead gates /stoplogs as shown on the general arrangement drawings – layout and cross section of the Powerhouse. In accordance with the latest practice, all the station cranes and hoists are to be designed for standard industrial service as per the latest version of Crane Manufacturers Association of America (CMMA) Specification No. 70, FEM, ISO, IEC, AGMA and ASME B30 safety standards.

7.8 Mechanical Auxiliaries

7.8.1 Scope

Following auxiliary systems are foreseen for the Jagran-IV Power Station which shall be provided under the Contract of E&M package.

- Compressed Air system / High Pressure
- Service Air system / Low Pressure,
- Cooling Water system,
- Service water system,
- Dewatering System,
- Station Drainage System,
- Potable water and Sewage system,
- Firefighting system,
- Heating, Ventilation and Air conditioning system,
- Lubricating Oil Treatment / Oil Handling system,
- Powerhouse Elevators,
- Workshop and Workshop Equipment / Tools

Before start of any works under this Contract the Contractor shall submit the complete design to the satisfaction of the Project Manager along with all relevant documents including schematic diagrams, process flow and system principal diagrams, general arrangement drawings, equipment drawings, design calculations and description of design philosophy, material details, equipment brochures, Testing and Inspection plans for both site testing and inspections at manufacturer's facilities, O&M Manuals and all other necessary information as and when required by the Project Manager. The Contractor shall obtain official approval from Project Manager before commencement of works.

7.8.2 Applicable Codes and Standards

All international codes and standards given in technical specifications shall be applicable for the relevant works under Mechanical Auxiliaries unless specified otherwise.

7.8.3 Compressed Air system

Two compressed air systems are required in the power station for the following services:

1. Power tools for maintenance
2. Generator brakes (back-up supply)
3. Turbine shaft and maintenance seals
4. Isolated phase bus ducts pressurization back up supply

7.8.4 Functional Requirements of Service Air System

The station shall have a low pressure compressed air system at 6 to 8 bars working pressure that shall meet the requirement of the station for all maintenance works on the power plant. The system air shall also be used to replenish the generator brakes air receivers, operate the turbine maintenance seals, air scours and pneumatic operated valves. There shall be two reciprocating double acting compressors, one on normal operation mode and the other on standby mode. The compressors shall be air cooled, provided with un-loader valves, moisture traps, condensate drains, air receivers, air dryers and necessary protective devices.

To enhance the reliability of air supplied to equipment that is part of the generating units an operating air receiver for each generating unit shall be included in the service air system. If air is required for the IPBs (Insulated phase bus bars) it shall be dried to suit the requirement of the IPBs.

Capacity of the service air compressors is estimated to be 20 L/s. FAD. Final capacity shall be calculated at the detailed design stage by the Contractor and submitted to Project Manager for approval.

7.8.5 Design Considerations of Cooling Water System

Closed circuit cooling water systems shall be adopted.

Closed circuit cooling water systems comprise a primary cooling water circuit and a secondary cooling water circuit.

Each cooling water system must provide cooling water to the following equipment:

- generator air coolers
- generator bearing coolers
- turbine bearing coolers
- governor oil coolers (if needed)
- unit excitation rectifier
- unit excitation transformer
- unit transformer oil coolers

Generally cooling water is a once through system drawing water from the penstock or tailrace channel and discharging it into the tailrace channel. It is known however that sediment in the Jagran reservoir may be higher and during the flood season could become very high. Therefore, there is a potential risk that small particles can become trapped in pipe work and or associated fittings blocking the pipes if their size is too small. The size of the generator cooling water pipes shall be approximately 100 mm and the bearing cooling water pipes shall be less than 35 mm diameter. This latter size is considered small and likely to trap sediment. Moreover, it is understood that no clean water sources exist in the vicinity of the Jagran-IV Power Station Therefore the only practical option to avoid fouling/blockage of small cooling water pipes is to adopt a closed-circuit cooling water system.

Based on above facts the Contractor shall submit his own design to minimize the chances of any blockages with sedimentation through efficient filtration approach adopted for enhancing the service life of the equipment to optimum level.

A description of each circuit is outlined below:

7.8.5.1 Primary Cooling Water Circuit

Primary Cooling Water circuit shall be an open loop circuit that shall draw water from tail race and drain it back to the tail race after heat transfer from closed loop (Secondary cooling water circuit) through heat exchangers. Suitable sized auto strainers and hydro cyclones shall be provided in the open loop cooling circuit before heat exchangers to diminish the blockage of tubes. To minimize the length of pipe work associated with the primary cooling water circuit, the primary cooling water pumps shall be located on the Main inlet Valve Floor or other suitable place proposed by the Contractor and accepted by the Project Manager. Duplicate pumps and heat exchangers shall be provided to enhance reliability.

To facilitate cleaning, the heat exchangers shall include removable or hinged headers so the internal tubes of a heat exchanger can be pulled out. Bends and fittings shall be minimized so as to minimize the potential clogging.

7.8.5.2 Secondary Cooling Water Circuit

Each secondary cooling water circuit shall include two pumps (duty and standby). The pumps shall be located on the Turbine Floor and after the water passes through the duty heat exchanger it shall be reticulated to the equipment listed above.

Internal corrosion of pipe work and equipment in the secondary cooling water circuit shall be inhibited by chemical dosing. Make-up water for the circuit shall be drawn from a header tank located on the top of the admin block. This tank shall be replenished from the potable water tank also located on the top of the offices block Building. The make-up water tank shall be periodically dosed with requisite chemicals to inhibit corrosion.

7.8.5.3 Shaft Seal Cooling Water

Cooling water must also be reticulated to each turbine shaft seal. This must be a once through water system and hence water cannot be taken from the secondary cooling water circuit. It is recommended that this water be taken from Service Water Network. Accordingly, to ensure this water is free of debris and excessive sediment the cooling water for the shaft seal shall pass through twin auto-operated strainers and duplicate hydro-cyclone separators before being injected into the seal.

7.8.6 Service Water System

Service water is required for:

- Wash down and other applications where potable water is not needed.
- Air coolers and oil coolers of station air compressors.
- Oil purification plant

- Fire hose cabinets

The sources may be connected on the cooling water supply with a booster pump. Carbon steel pipe shall be used for lines over 35 to 75 mm, smaller lines shall be from brass pipe or copper water tubing.

7.8.7 Dewatering System

The function of unit dewatering system is to empty the draft tube and spiral for inspection or repair of the submerged parts. Principal factors affecting the dewatering time are tail water level, volume of the draft tube, volume of the spiral case, time to close and secure the turbine inlet valve, sump volume, pump capacity, pipeline size, and magnitude of the draft tube gate leakages.

Approximately 70 m^3 of water shall be pumped out to dewater the unit for maintenance/ inspection of runner.

The system shall include individual draft tube drain lines, manually operated shut-off valves, spiral case drain, vent piping, two vertical line-shaft pumps (one on standby mode) and all necessary control equipment. All the dewatering lines from spiral casing and draft tubes shall be connected to a common header located in the drainage sump. Dewatering pumps shall also be connected to this common header for pumping the water out to the tail race.

The system shall dewater the units between the draft tube gate and turbine inlet valve, and shall be designed to dewater this volume in approximately 3 hours. During dewatering operations, water shall be pumped into the tailrace beyond the closed draft tube gates.

Water leakage into the draft tube through the draft tube gate seals after dewatering shall be routed to the station dewatering sump by a valve-controlled drain line connected to the dewatering header. This line shall be sized to pass the estimated gate leakage with a head loss equal to the static head measured from the draft tube low point to the sump water level.

The filling of the unit shall be by gravity, first through common dewatering header all the way up to tail water level and then after removing the draft tube gates.

7.8.8 Station Drainage System

A station drainage system is required to handle waste water from the powerhouse and equipment in the powerhouse. The sources of waste water are:

- Leakage from plant cooling equipment.
- Condensate from the station compressed air systems.
- Seepage from MIV Flanges
- Turbine shaft seal

The waste water shall be collected through floor drains and piped to station drainage sumps. To enhance security and enable regular cleaning one drainage sump of appropriate size shall be provided between the units, equipped with two electrically driven water pumps, one pump in operation mode and the other at standby mode. The pumps shall be controlled by level switches

and reticulate wastewater to the tailrace. The capacity of each pump shall be approximately 25 L/s. For this study seepage has been estimated as 15 L/s.

7.8.9 Potable Water System

Potable water is required for drinking, washing and sanitation. Normally the water supply would be taken from a deep well or through a municipal supply. But for Jagran-IV hydropower project neither of these possibilities is available. Therefore, treating water from the service water system has been selected. The Contractor shall submit the detailed design for Engineer's approval.

Water supplied from the service water system shall be treated to a standard for bacteriological quality and physical, chemical and radiological characteristics based on WHO guidelines for drinking water quality (GDWQ 4th edition). The water treatment plant shall be located on top of the offices Building together with a header tank for distribution of potable water by gravity around the power station.

7.8.10 Sewage System

Septic tank for sewage disposal shall be located below the toilet areas in the services Building and accessible from the Turbine Floor. The septic tank shall be fabricated from antirust metal. Both sediment and sludge digestion shall take place in a single compartment. The settled sludge shall be removed from the power station using a sludge pump and piped out to the open septic disposal area as detailed in Civil Works. The effluent from the septic tank shall be pumped to the surface by enclosed duplex non clogging submersible pumps with external electric motors and level controls through a pipe to disposed of in a 'soak pit' to outside the building.

7.8.11 Fire Detection and Firefighting System

The basis for firefighting system is NFPA - 850 (Recommended Practice for Fire protection for Hydroelectric Generating Plants) Fire can occur at places wherever there is a source of fuel for combustion. Fuel sources can be:

- oil,
- combustible cable coatings,
- electrical equipment,
- chemicals,

Wood forms and skids used during construction and stored for reuse.

For a fire to start three conditions must be present:

- Presence of inflammable material
- Presence of oxygen
- Sufficient temperature level

Fire can be extinguished by removal of inflammable material, blanketing the burning substance / material by foam spray to reduce oxygen or cooling down the temperature by water spray.

For the safety of personnel, protection of equipment against fire and the rapid identification of fire, the following fire zones are envisaged:

- Machine Hall
- Upstream and or downstream galleries
- Control Room
- Cable Tunnel and or galleries

A combined manual and automatic fire detection and alarm system shall be provided in the station.

To ensure availability of water in accordance with NFPA 14 Class II System and in the event of a fire, a dedicated firefighting water supply tank with bottom level at 50 m. above the upper most fire hydrant in Machine Hall of Power House shall be constructed in accordance with NFPA 22. This shall provide the required net head for hydrants and water spray systems in the powerhouse. At least 2 water sources; one from Penstock and one from tailrace through pumps shall be provided for filling the overhead water storage tank. Both intake sources shall be equipped with proper purification system to minimize the infiltration of sediments and debris.

A water tank with an active firefighting water capacity of around 100 m^3 is envisaged. DN100 filling pipe from the header pipe connected to the Turbine inlet on the Turbine floor shall fill the firefighting water tank in less than 8 hours. Interchangeably a pumping system comprising of 2 pumps; one being standby, connected to the tailrace through 02 separate auto-filters shall be able to fill the water storage tank in 8 hours approximately.

Duplicate firefighting mains shall feed the ring mains and water spray systems in the Powerhouse.

No other water shall be able to be drawn from the firefighting tank. Water for filling the tank shall first pass through a sediment trap to remove sediment.

Ring mains for firefighting with fire hoses and water spray capability shall be installed on all floors of the Powerhouse and the Transformer Gallery. A sufficient quantity of hydrants and water hoses shall be provided on each floor of the Powerhouse. Water sprinkler systems that comply with NPFA 13 shall be provided for other areas within the powerhouse where there is a perceived fire risk. These areas include:

- cable galleries
- governor oil pumping sets
- Transformers
- lubricating oil storage containers
- All areas of the Generator Floor except main Generators.
- All areas of the Operating Floor.

Carbon dioxide (CO_2) or Argonite filled fire extinguisher shall be placed at each floor to extinguish electrical fires.

Oil storage rooms shall also be provided with CO2 or Argonite filled cylinders with auto release system initiated by smoke and fire detectors installed in the room.

7.8.12 Personnel Safety

All services shall be provided related to health & safety of personnel in accordance with international standards i.e., OSHA practices.

Personnel safety is of prime importance, therefore to ensure personnel safety during a fire; the station shall be equipped or marked with at least one smokeless room with rescue equipment. The smokeless room shall be marked on the fire plan.

Recommendations for this room are:

- At least one escape route.

A minimum area of 1 m² for each person normally present in the station.

- Shock valves which close automatically at a maximum of 0.2 bar (20 kN/m²). The valves should also be closed by the fire detection system.
- Cylinders with compressed air sufficient for a minimum of 6 hours.
- Emergency lighting.
- Telephone facilities separate from the other communication system in the station.
- First aid equipment, breathing apparatus, extinguishers and emergency equipment.
- Overpressure in the room of a minimum of 10 mm water column and maximum 30 mm.

In addition to the smoke free room it is important to have well marked escape routes. Each route marking shall be made with luminous paint on the floor and the stairs. In some locations it shall be necessary to provide a guide rail.

All stairwells shall be automatically pressurized on detection of a fire so that smoke shall not be able to enter the stairwells. The EPC Contractor shall design a complete failsafe firefighting system and submit for Engineer's approval in the initial stage of project execution.

7.8.13 Heating, Ventilation and Air Conditioning System

Main sources of heat gains (cooling load) are the solar, conduction, electrical, ventilation and mechanical equipment. To maintain the indoor temperature at acceptable levels for occupants and electrical & mechanical equipment a Heating, Ventilating and Air Conditioning System is recommended.

The space at the Machine Hall Floor in the powerhouse is ventilated all the time and is neither cooled nor heated except in cases where:

- Temperatures are required to protect the plant or equipment from freezing or excessive high temperature.
- Condensation or moisture might cause damage to the equipment.

Winter heating is normally not required in the power station as the equipment generates sufficient heat. In certain areas in the power station, such as administrative or occupied areas, control room and relay room, duct mounted electric resistance heaters shall be used for winter heating.

The Contractor shall propose two air cooled chillers (one stand-by) of appropriate capacity of refrigeration with smooth rotary compressor, twin-screw design and low noise aero acoustic fans to meet air conditioning requirements of Powerhouse, admin block and workshop areas.

To meet the various temperature and ventilating requirements, the powerhouse shall be provided with a forced, re-circulating / exhaust ventilation system. During the warm months, the system shall bring in fresh air and exhaust warm air continuously. During the cool months, the ventilation system shall re-circulate the powerhouse air with supplemental make up air to account for the small portion of air which shall be continuously exhausted from contaminated areas. When required, the ventilation system shall be modulated to regulate indoor temperatures. Duct heaters shall be furnished for cool weather operation.

The volume of air circulated through each room shall be determined by:

- The amount of air required to maintain the design temperatures, considering heat gain from equipment, lights, and personnel, and
- The requisite number of air changes per hour.

The largest air volume computed from these two criteria shall be used in design.

Wall mounted Fan Coil Units with fresh air shall be provided in all areas of the Power House. In the control room for the comfort of station operating personnel and for protection of control equipment, baseboard heaters shall be provided in the control room and occupied areas during cold weather operation.

To exhaust the smoke from the cable gallery in case of fire, a set of fan one duty and one as a standby shall be provided at the outlet of cable gallery.

Design criteria for the ventilating and the air conditioning system shall be as follows:

Outside air design temperatures shall be based on the latest edition of ASHRAE (2019) Fundamentals for Islamabad Pakistan {or other appropriate nearby location}. Cool season temperatures based on 2.5% occurrences:

Table 7-9 gives the Key Parameters for HVAC design.

Table 7-9: Key Parameters HVAC design

A- Inside Air Design Temperature	
Winter	Degrees C
Control room, toilet/locker room, and lobby	22
Powerhouse	21
Summer	
Control room	24

Powerhouse, toilet/ locker room and lobby	33
B- Relative humidity	45% average
C- Ventilation Rates	Minimum Air Changes per hour
Control room and lobby	4
Toilet/Locker room and sewage ejector room,	10*
Water treatment room	2*
Powerhouse	1
Battery /DC room	Minimum; to maintain hydrogen gas concentration <1%

*Exhausted to outside.

The ventilation equipment shall consist of one set of supply fan with filter and one set of exhaust fan. One set shall be active and one shall be as a standby with control dampers.

The ventilation equipment shall be designed to give fresh air minimum of 10 air changes / hour in dam grout gallery and 6 air changes /hour in de-sander gallery.

The EPC Contractor shall design a complete failsafe HVAC system and submit for Engineer's approval in the initial stage of project execution.

7.8.14 Lubricating Oil Treatment / Handling System

No permanent lubricating oil system shall be provided in the powerhouse. A common grade of oil shall be used for the bearing lubrication, governor and inlet valve pressurized oil system to facilitate the delivery of oil when replacement oil is required. Sufficient quantity of oil barrels shall be stored on site to provide make up oil. A portable oil purifier shall be provided to filter and purify the lubricating oil and hydraulic fluid prior to filling the various equipment reservoirs.

7.8.14.1 Oil Recovery System

Provision shall be made to guard against water pollution resulting from accidental oil spills in the powerhouse.

An oil separator shall be installed on the Main Inlet Valve side to recover any oil spilled and collected by the station drainage system. This oil separator shall be a pre-fabricated package unit. The oil separator shall be sized to store the volume of oil from the largest single source of spill in the powerhouse.

The oil separator shall be designed to maintain 10-ppm maximum oil in water effluent.

The EPC Contractor shall design a complete failsafe lubrication and oil handing system and submit for Engineer's approval in the initial stage of project execution.

7.8.15 Workshop, Tools and Spare Parts

The Mechanical workshop, inside the power house shall be supplied with the equipment sufficient for the following jobs:

- Dismantling and erection of all turbine parts.
- Repairing or renewal of minor components, not needing specialized skill or experience.

Major Workshop Equipment shall include the items as given in the following **Table 7-10**:

Table 7-10: Workshop Equipment

Item	Designation	Quantity	Specs / Remarks
1	Universal lathe Machine (CNC, horizontal flatbed)	1	1.5m Centre, Swing 400mm Max Turn Dia, 100 mm Spindle Bore
2	Pillar mounted drilling machine	1	Upto 100mm dia drill bits supported
3	Table drilling machine with supporting bench	2	Upto 1" dia drill bits supported
4	Double wheel rough grinding machine-heavy duty	2	
5	Tool grinding machines- different sizes	4	
6	Metal power hacksaw machine with three adjustable supports	2	
7	Manual bench type shears with support bench	4	
8	Work benches with vice – different sizes	4	
9	Tool cabinet	6	
10	Hand tools for mechanical workshop	6 sets	
11	Mechanical measuring tools	6 sets	
12	Manual operated monorail cranes with rails	1 set	
13	Chain blocks with slings and turn buckles	3 sets	
14	Tool trolley	3	
15	Fork lift trolley	3	1.5 ton lifting capacity
16	Electrical welding equipment with necessary tools and electrode oven, (1medium duty, 1 heavy duty)	2 sets	250A@100% 600A@100%
17	Gas welding equipment with necessary tools	2 sets	Light duty
18	Mobile air compressor with moisture trap.	1	5 bar,15 cfm
19	Hand drilling machines	2	10mm, 200W
20	Portable compressed air grinding machines	3	Different sizes

Item	Designation	Quantity	Specs / Remarks
21	Circular electric saw on mobile chassis with tire wheels	1 set	Medium size
22	Small dewatering pumps with hoses	3 sets	Submersible
23	General workshop tools	3 sets	

The associated store shall be provided with sufficient supply of the most common spare parts and consume-able items required for at least five years trouble free operation and maintenance of the powerhouse, intakes and other equipment covered under this contract

7.9 Hydraulic Steel Structures

7.9.1 General

Design of the Major components of hydraulic steel structure is presented as follows:

- Two (02) hydraulically operated radial rates at Weir
- Two (02) Stoplogs for isolation of radial gates at Weir
- One (01) electrically operated Gantry Crane and lifting beam for Stoplogs of Weir
- One (01) electrically operated Gantry Crane and lifting beam for Stoplogs of Intake.
- Two (02) fixed wheel gates with operated with fixed electromechanical hoist for Power channel intake
- Two (02) Stoplogs for isolation of Fixed Wheel Gates at Intake
- Trash rack for Intake along with trash cleaning machine.
- Two (02) fixed wheel gates with manual hoisting for Sand trap (sediment flushing gates).
- One (01) intake slide gate at Sand trap inlet, operated with manual hoisting machine.
- One (01) outlet slide gate at Sand trap outlet to provide water to the Power Chanel; operated with manual hoisting.
- Four (04) vertical slide gates for Turbine Draft tubes, operated by gantry crane.

This section presents the conceptual design and choice of equipment at each hydraulic steel structure listed above.

7.9.2 Standards

Latest revisions or editions of the following codes and standards shall be applicable for designing, fabrication, installation and testing & commissioning of the gates equipment:

Name	Abbreviation
American Gear Manufacturer's Association	AGMA
American Institute of Steel Construction, Inc.	AISC

American National Standards Institute	ANSI
American Iron and Steel Institute	AISI
American Society of Mechanical Engineers	ASME
American Society for Testing and Materials	ASTM
American Welding Society	AWS
Federal Specifications Board	U.S. Fed. Spec.
United States Bureau of Reclamation	USBR
Institute of Electrical and Electronics Engineers	IEEE
International Organization for Standardization	ISO
National Bureau of Standards	NBS
National Electrical Code	NEC
Crane Manufacturers Association of America	CMAA
National Electrical Manufacturer's Association	NEMA
Society of Automotive Engineers	SAE
Steel Structures Painting Council	SSPC
Antifriction Bearing Manufacturers Association	AFBMA
German Institute for Standardization.	DIN
Technical Standards for Gates & Penstocks	TSGP

7.9.3 Radial Gates for Under Sluicing of Weir

Functional requirement of the radial gates at Weir is to flush out the settled sediments from the Dam Flood Outlet and to control the reservoir level and keep it at safe level during expected flood seasons every year.

Each radial gate will consist of three components; the skin plate assembly, two arm assemblies with trunnion assemblies and Hydraulic operating system. Brief descriptions of these components are given below.

7.9.3.1 Skin Plate Assembly

The skin-plate assembly will be of welded construction with the skin-plate reinforced by horizontal beams. The horizontal beams will be supported by vertical and horizontal girders, which in turn will be supported by arm assemblies.

The curvature of the skin plate will be concentric with the gate trunnion. The arm assemblies will carry the reaction from vertical girders to the trunnion assemblies.

The skin plate assembly will be divided into a suitable number of sections for ease of transportation and handling at the site. These sections will be field assembled by bolting and seal welding.

7.9.3.2 Arm Assemblies

Two arm assemblies will be provided for each radial gate. Each arm assembly will consist of two box section compression members to transmit the hydraulic load to the trunnion assemblies. The arm assemblies will be designed for normal hydraulic thrust as well as the forces resulting from stalled gate during lifting or lowering. The arm assemblies will be arranged for field bolting to the gate leaves vertical girders and the trunnion flanges.

7.9.3.3 Trunnion Assemblies

The trunnion assemblies act as a pivot for the radial gate. Each trunnion assembly will consist of a trunnion hub with self-lubricating bushing and heavy flanges to transmit the arm reactions, a trunnion yoke and a trunnion pin. The hub and flanges will be either of forged, structural or cast steel. The bushings will be self-lubricating and will be designed to withstand stresses generated from operation of the gate. The trunnion yoke will be of cast & welded steel. The yoke will be supported on the trunnion girders. Anchor bolts will be provided to fix the yoke to the girder. Jackscrews will be provided to permit horizontal and vertical alignment of the yoke before final fixing. The trunnion pin will be of stainless steel with a 5 mm thick stainless-steel sleeve.

7.9.3.4 Seals and Sealing Surfaces

The sill seals will be mounted on the downstream face of the skin plate, while the side seals will be mounted along the gate's sides.

Each radial gate will be fitted with 'L' type rubber side seals with fluorocarbon cladding and compression or wedge type bottom seals. The side, bottom and top sealing surfaces will be mounted flush with the bay walls. The side sealing surfaces will be corrosion resisting steel plates embedded in the concrete walls and will extend from the bay floor to a little below the top of the pier. Guide rollers and guide shoes mounted on each side of the gate will bear against the sidewall sealing surfaces. These guide rollers and guide shoes will limit lateral gate movement. The bottom sealing surface will be corrosion resisting steel plate attached to the sill beam embedded in concrete floor of the bay.

The preliminary design data for the Stilling Basin radial gates are given in **Table 7-11**.

Table 7-11: Under Sluices - Radial Gates for Weir

Radial Gate	
Type of gate	Radial gate
No. of gates	2
No. of embedded parts	2 set
Maximum PMF level	2256.90 m.a.s.l.
Maximum reservoir level	2254.60 m.a.s.l.

Elevation of radial gate sill	2249.00 m.a.s.l.
Width of gate	5.50 m
Height of gate	5.20 m
Radius from trunnion center to upstream face of skin plate	7.50 m
Elevation of trunnion	2253.50 m.a.s.l.
Elevation of top of gate in closed position	2255.00 m.a.s.l.
Elevation of bottom of gate in fully open position	2254.80 m.a.s.l.
Type of hoist	Hydraulic cylinder
No. of hydraulic hoist cylinder per gate	2
Interlocking devices per gate	2
Gate operation	Local / Control Room
Power equipment for gate operation	415 v from power station
Normal rate of gate opening	0.3 m per minute
Normal rate of gate closing	1.0 m per minute

7.9.4 Stoplogs for Isolation of Weir Radial Gates

Two (02) stoplogs shall be provided for isolation of under sluices at Weir. Stoplog slots, guides and other embedded metalwork will be provided in the piers upstream of each radial gate. One stoplog set having three sections will be provided. Each stoplog section will be of welded steel construction with downstream skin plates reinforced by vertical and horizontal girders. The stoplog will have wedge type bottom seals and 'J' type side seals. Guide shoes will be provided at the top and bottom of each side of the stoplog sections to engage the guides embedded in the concrete. The stoplogs will be designed to be handled by a lifting beam and gantry crane. A filling valve will be provided in the bottom section of the stoplog to achieve a balanced head condition for raising the stoplogs. Capacity of the Gantry Crane will be based on calculated load of the Weir Radial Gate; however, it is estimated as 15 tons. Details are shown in **Table 7-12**.

Table 7-12: Stoplogs and Gantry Crane for Weir

Stoplog	
Type	Vertical lift
No. of stoplogs	2 sets
No. of sections per set	3
No. of embedded parts	3 set
Sill elevation	2249.00 m.a.s.l.
Design width of stoplog opening	5.20 m
Design height of stoplog opening	5.20 m
Design height of stoplog section	175 m
Handling (installation, storage)	By lifting beam and gantry crane
Gantry Crane and Lifting Beam	

Type	Electrically Operated
No. of Gantry Crane	1
Main hoist capacity	15 tons
Length of runway (approx.)	20 m
Height of lift	11 m
No. of lifting beams	1

7.9.5 Fixed Wheel Gates for Intake

Fixed wheel gates are the most common type of gate used as intake gate. Upstream sealing gates have been chosen as they minimize down-pull during closure into flow and give easy access for inspection of the downstream side of the gate when the gate is closed from the gate shaft.

The main advantage of a hydraulic hoist is that they can be installed in a narrow space. Double acting hydraulic hoist cylinders also have a distinct advantage that the gate can be pushed to closed during an emergency.

Each gate hoist will include a hydraulic cylinder, pipes, hoist support, servomotor, hydraulic power unit, piping, gate position indicator, electric control panel for command and signaling.

Each hydraulic hoist will be designed with enough lifting capacity to lift a gate under any foreseeable operating conditions. Hydraulic fluid for raising the fixed wheel gate will be supplied by motor-driven oil pumps. Two oil pumps will be provided for each hoist to enhance reliability.

Lowering of the gate will be accomplished by gravity as well as with oil below the hoist piston exhausting under controlled flow rate to the oil reservoir.

A hoist control module will be provided with each gate, which will control the operation of the hoist. It will include hydraulic and electrical controls. A local control panel will be provided near each gate and a common remote-control panel for all the power intake fixed wheel gates will be installed in the local control room. The remote-control panel will include one selector switch for each gate. The selector switch will provide two operating modes, normal and maintenance.

Provision will also be made for emergency closure of the diversion tunnel intake gate from the powerhouse central control room.

The fixed wheel gate will be of welded steel construction with upstream skin plate reinforced by horizontal and vertical members/beams. If necessary, the skin plate assembly will be divided into two sections for ease of transportation and handling at the site. These sections will be field assembled by bolting and seal welding.

The gate will be provided with upstream caisson rubber bottom and side seal with fluorocarbon cladding. A flat bar or compression type seal will be mounted at the bottom of the skin plate. Wheels will be corrosion resisting steel mounted on both sides of the gate. Wheels will be cylindrical rotating on stainless steel spherical bearings.

Embedded metalwork for each intake gate will include anchorages for hoist cylinders, anchor bolts for gate sealing plates and guide bars. The side, bottom and top sealing surfaces will consist of corrosion resisting steel plates embedded in concrete. The bottom sealing surface will also be

corrosion resisting steel plate attached to a structural steel sill beam embedded in the concrete floor.

A “gantry crane” of 15 ton approx. will be deployed for intake for lifting/lowering of stoplogs as shown on the relevant drawings. These stoplogs shall be required for erection and maintenance purposes of fixed wheel gates at intake and under sluices at stilling basin.

The preliminary design data for the fixed wheel gates used at intake are given in **Table 7-13**.

Table 7-13: Fixed Wheel Gates for Intake

Fixed Wheel Gates	
Type of gate	Fixed Wheel Gate
No. of gates	2
No. of gates embedded parts	2 set
Elevation of sill	2251.65 m.a.s.l.
Maximum PMF level	2256.90 m.a.s.l.
Maximum water level – Normal Operation	2254.00 m.a.s.l.
Gate operating floor level	2258.00 m.a.s.l.
Design width of gate opening	3.50 m
Design height of gate opening	2.95 m
Gate operation	Hydraulic cylinder
Condition of lifting	Under pressure differential
Fixed Hoist on a Gantry Crane	
Type of hoist	Motorized Mechanical Hoist
Power equipment for gate operation	415 V from Power Station
Normal rate of gate opening	0.3 m per minute
Normal rate of gate closing	1.0 m per minute

7.9.6 Stoplogs for Isolation of Fixed Wheel Gates at Intake

Two (02) stoplogs shall be provided for isolation of fixed wheel gates at intake. Stoplog slots, guides and other embedded metalwork will be provided in the piers upstream of each fixed wheel gate. One stoplog set having three sections will be provided. Each stoplog section will be of welded steel construction with downstream skin plates reinforced by vertical and horizontal girders. The stoplog will have wedge type bottom seals and 'J' type side seals. Guide shoes will be provided at the top and bottom of each side of the stoplog sections to engage the guides embedded in the concrete. The stoplogs will be designed to be handled by a lifting beam and gantry crane. A filling valve will be provided in the bottom section of the stoplog to achieve a balanced head condition for raising the stoplogs. Capacity of the Gantry Crane will be based on the calculated load of the Intake Fixed Wheel Gate, however it is estimated as 15 tons. Details are shown in **Table 7-14**.

Table 7-14: Stoplogs and Gantry Crane for Intake

Stoplog	
Type	Vertical lift
No. of stoplogs	2 sets
No. of sections per set	2
No. of embedded parts	3 set
Sill elevation	2251.65 m.a.s.l
Design width of stoplog opening	3.50 m
Design height of stoplog opening	3.00 m
Design height of stoplog section	1.50 m
Handling (installation, storage)	By lifting beam and gantry crane
Gantry Crane and Lifting Beam	
Type	Electrically operated
No. of gantry cranes	1
Main hoist capacity	15 tonne
Length of runway (approx.)	20 m
Height of lift	10 m
No. of lifting beams	1

7.9.7 Intake Trash rack and Trash Cleaning Machine

Two (02) sections of Stainless-Steel Trash racks of suitable sized mesh shall be provided at the intake to stop the intrusion of floating debris and biomass trash into the power channel for protection of the head race tunnel, penstocks, MIVs and Turbines. Total size of the inclined opening at intake is 3.50 m x 2.95m and bars spacing shall be 200mm x 150mm (Horizontal x Vertical) such that the corresponding head loss at entrance will not increase the total head loss beyond 2.54 m. Taking into account these limitations, the EPC Contractor will submit the detailed design. Details are shown in **Table 7-15**.

Table 7-15: Trash racks and Cleaning Machine

Trash Racks	
Type of Trash racks	Fixed (with sliding arrangements for cleaning)
No. of Trash rack sections	2
No. of embedded parts	2 sets
Highest Flood Level	2256.90 m.a.s.l.
Maximum reservoir level (normal)	2254.00 m.a.s.l.
Elevation of bottom edge of trash racks	2251.65 m.a.s.l.
Width of each Trash rack	3.50 m
Height of each Trash rack	2.95 m.
Design Head	180.65 m
Handling	Trash cleaning Machine

7.9.8 Sand-trap Flushing Gates

Two (02) simple slide gates each with sizes (1.0m X 1,0m) shall be provided for flushing out the sandtrap sedimentation as shown on the relevant drawings of the sandtrap.

These are simple slide gates with double handle manual hoisting machines installed inside the access gallery. The gates shall be of welded construction with reinforced skin plate by truss of horizontal beams and vertical members along with sealing arrangement with rubber sealing.

The manual hoisting machines shall be designed such that the gates can be operated by the effort of a single person. Details are shown in **Table 7-16**.

Table 7-16: Simple Slide Gates for Flushing the Sandtrap

Type of gate	Simple Slide Gate
No. of gates	2
No. of gates embedded parts	2 sets
Elevation of sill (Lower Gate)	2242.00 m.a.s.l.
Elevation of operating platform level	2255.15 m.a.s.l
Design Width of Gate (opening)	1.00 m
Design height of Gate (opening)	1.00 m
Design Head	12 m
Gate operation	Manual Hoist with Dual handle
Condition of lifting	Under pressure differential
Normal rate of gate opening	0.2 m per minute
Normal rate of gate closing	0.2 m per minute

7.9.9 Sand-trap Inlet and Outlet Gates

One (01) simple slide gate (4.1m X 2.75m) shall be provided at inlet and one similar size gate at outlet of the sand trap. However, the design head for outlet gate is 180m which is very high as compared to the inlet gate being only 5m. This aspect must not be ignored while designing these gates by EPC Contractor.

These are simple slide gates with double handle and double stem rod manual hoisting machines installed inside the access gallery. The gates shall be of welded construction with reinforced skin plate by truss of horizontal beams and vertical members along with sealing arrangement with rubber sealing.

The manual hoisting machines shall be designed such that the gates can be operated by the effort of a single person. Details are shown in **Table 7-17**.

Table 7-17: Simple Slide Gates for Inlet & Outlet of the Sand-trap

Type of gate	Simple Slide Gate
No. of gates	2
No. of gates embedded parts	2 sets
Elevation of sill (Inlet Gate)	2251.55 m.a.s.l.
Elevation of sill (outlet Gate)	2251.55 m.a.s.l.
Elevation of operating platform level	2242.10 m.a.s.l
Design Width of Gate (opening)	4.10 m
Design height of Gate (opening)	2.75 m
Design Head (Inlet Gate)	5.00 m
Design Head (outlet Gate)	170.00 m
Gate operation (Inlet Gate)	Manual Hoist with Dual handle & Double stem rods
Gate operation (outlet Gate)	Dual Stem rod Motorized Hoist with option of manual operation
Condition of lifting	Under pressure differential
Normal rate of gate opening	0.2 m per minute
Normal rate of gate closing	0.3 m per minute

7.9.10 Draft Tube Gate Equipment

7.9.10.1 Functional Requirements

Draft tube gates are required to facilitate, maintenance, inspection and repair of turbines. Draft tube gates are also required to act as bulkhead which prevents water entering from tailrace in case of high flood.

7.9.10.2 General Arrangement

Draft tube gates shall be of vertical lift bulkhead type gate designed for operation under balanced head conditions. Draft tube gate equipment shall consist of bulkhead gate, lifting beams and gantry crane. Draft tube gate shall be installed at the outlet of the turbine draft tube. Draft tube gate shall be installed in the gate slots provided in the draft tubes discharge channel at powerhouse.

The draft tube discharge tunnel of each turbine shall transition into a rectangular opening as shown in powerhouse drawings. Gantry crane shall be mounted above draft tube gate slots.

Gate locking and holding mechanism inside the gate slots shall be for long term storage. A removable latching arm will be attached slots upper frames. The EPC Contractor shall propose his design and get approval from Project manager / the Engineer for these storage chambers.

Draining of a draft tube shall be done through a unit dewatering system or through one of the drainage sumps in the power station. Filling of a draft tube shall be done from a by-pass pipe with valve through the draft tube gate.

The general arrangement of the draft tube gate equipment is shown on tender drawings.

7.9.10.3 Gate Leaf

The draft tube gates shall have downstream skin plates and seals; gate shall be designed to close a waterway of 3.15m wide and 2m high for main units whereas 2m wide and 1.3m high for small unit. Each section shall be of welded steel construction. The top section of gate shall have compression or wedge type bottom seals and caisson type side and top seals with fluorocarbon cladding. Guide shoes shall be provided at the top and bottom of side of the gate to engage the guides embedded in the concrete. Lifting pins shall be provided to handle the gate by a lifting beam.

7.9.10.4 Embedded Metal Work

A set of embedded metalwork shall consist of a sill beam, a lintel beam, and two side seal plates, two guide rails for installation of draft tube gate and two guide rails and bottom supports for storage of draft tube gates. Welding pads shall be embedded in first stage concrete to facilitate the alignment of the parts embedded in the second stage concrete. The sill and lintel beams shall provide sealing surfaces for bottom and top seals of the gate respectively. All sealing surfaces shall be of corrosion resisting steel.

7.9.10.5 Gantry Crane

Electrically operated gantry crane of 8 tons capacity shall be provided for handling draft tube gates with the help of lifting beams. The crane will travel along the powerhouse downstream wall on rails installed parallel to the D/S wall. The lifting beam shall operate in the slots and guide rails provided for the draft tube gate. The gantry crane shall be designed to FEM Standards, Class A4. The preliminary design data for Draft tube gates and gantry crane are given hereunder; however, the EPC Contractor shall obtain approval of the detail design from Project Manager before starting fabrication.

Details are shows in **Table 7-18** as below:

Table 7-18: Draft Tube Stoplogs

Bulkhead	
Type	Vertical lift bulkhead
No. of bulkheads (main units)	3
No. of Sections for each bulk head (main units)	2
Size of bulkheads (main units)	HxW = 2m X 3.15m
No. of embedded parts sets (main units)	3 set
No. of bulkheads (small unit)	1
No. of sections for bulk head (small unit)	
Size of bulkheads (small unit)	HxW = 1.3m X 2m
No. of embedded parts sets (small unit)	
Sill elevation	2068.50 m..a.s.l.
Max. tail water level	2076.36 m.a.s.l.
Min. Tail Water Level	2073.25 m.a.s.l.

Max. Flood Level (500 years) –	2076.36 m.a.s.l
Design Head	8 m
Bulkhead gate Handling	By lifting beam & gantry crane
Type	Electrically operated
Main hoist capacity	8 tons
Lift Height	9 m
Normal speed of gate opening	0.3m per minute
Normal speed of gate closing	1.0 m per minute

Annexure- A

Technical Data of Turbines

Note:

The corresponding parameters suggested by the renowned turbine manufacturers are generally in line with the above given parameters however the Turbine supplier shall re-evaluate these factors on the basis of data by his own Turbine OEM.

TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: No File Name

TURBINE SIZING CRITERIA

Rated Discharge:	169.5	cfs	/	4.8	m3/s
Net Head at Rated Discharge:	544.6	feet	/	166.0	meters
Gross Head:	593.0	feet	/	180.8	meters
Site Elevation:	6795	feet	/	2071	meters
Water Temperature:	57	Degrees F	/	14	Degrees C
Setting to Tailwater:	-6.6	feet	/	-2.0	meters
Efficiency Priority:	10				
System Frequency:	50	Hz			
Minimum Net Head:	541.3	feet	/	165.0	meters
Maximum Net Head:	549.5	feet	/	167.5	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement:	VERTICAL WITH RUNNER ON TURBINE SHAFT				
Intake Type:	SPIRAL CASE				
Draft Tube Type:	ELBOW				
Runner Diameter:	38.1	inches	/	967	mm
Unit Speed:	500.0	rpm			
Multiplier Efficiency Modifier:	1.000				
Flow Squared Efficiency Modifier:	0.0000				

Specific Speed at Rated Net Head -

	(US Cust.)	(SI Units)
At 100% Turbine Output:	18.6	70.9
At Peak Efficiency Condition:	18.6	70.9

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 544.6 feet / 166.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 120.0	8389	89.5	203.3	5.8
100	7136	91.3	169.5	4.8
* 100.0	7136	91.3	169.5	4.8
75	5247	89.5	127.1	3.6
50	3218	82.3	84.7	2.4
25	1255	64.2	42.4	1.2
+ 49.6	3189	82.2	84.1	2.4

** - Overcapacity
* - Peak Efficiency Condition
+ - Peak Draft Tube Surging Condition

At Maximum Net Head of: 549.5 feet / 167.5 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.043	8465	89.5	203.3	5.8

At Minimum Net Head of: 541.3 feet / 165.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.043	8250	89.5	201.2	5.7

Solution File Name: No File Name

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head): 796 rpm

Turbine Discharge at:
- Runaway Speed (at Rated Net Head & 100% gate): 70 cfs / 2.0 m3/s
- Synchronous Speed-No-Load (at Rated Net Head): 14 cfs / 0.4 m3/s

Site's Atmospheric Pressure minus Vapor Pressure: 25.9 feet / 7.9 meters

Sigma Allowable (at 100% Output & Rated Net Head): 0.027
Sigma Plant (at 100% Output & Rated Net Head): 0.060

Maximum Hydraulic Thrust (at Max. Net Head): 33843 lbs / 15383 kg

Approximate Runner and Shaft Weight: 5646 lbs / 2566 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge): 3.1 fps / 1.0 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/ mm
Inlet Diameter:	42.0	1067
Inlet Offset:	70.4	1788
Centerline to Inlet:	95.2	2418
Outside Radius A:	91.4	2321
Outside Radius B:	87.2	2214
Outside Radius C:	82.6	2098
Outside Radius D:	76.1	1932

Draft Tube Type: ELBOW

	inches	/ mm
Centerline to Invert:	124.1	3152
Shaft Axis to Exit Length:	182.7	4642
Exit Width:	114.2	2901
Exit Height:	68.5	1741

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

	inches	/ mm
Centerline to Shaft Coupling:	96.0	2438
Turbine Shaft Diameter:	11.7	297

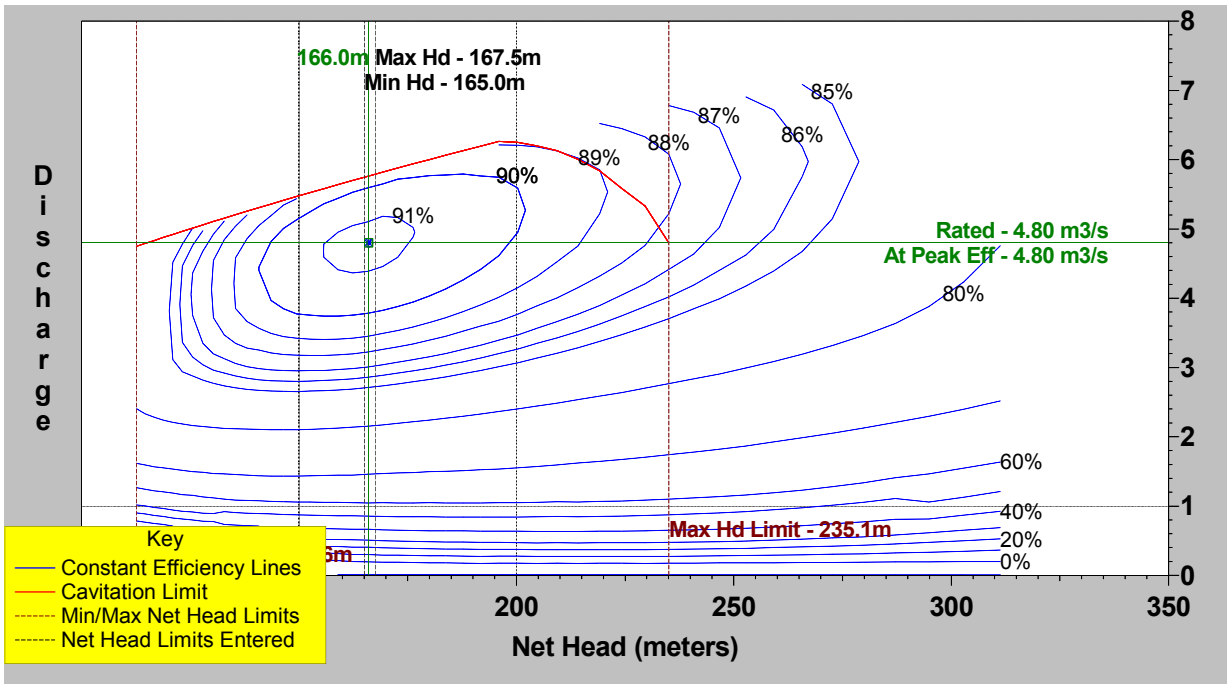
Miscellaneous:

	inches	/ mm
Wicket Gate Height:	5.7	144
Wicket Gate Circle Diameter:	69.7	1770

**** All information listed above is typical only. Detailed characteristics will vary based on turbine manufacturer's actual designs.

Solution File Name: No File Name

Runner Diameter:	967	mm
Net Head at Rated Discharge:	166.00	meters
Unit Speed:	500.0	rpm
Peak Efficiency:	91.3	%
Multiplier Efficiency Modifier:	1.000	
Flow Squared Efficiency Modifier:	0.0000	

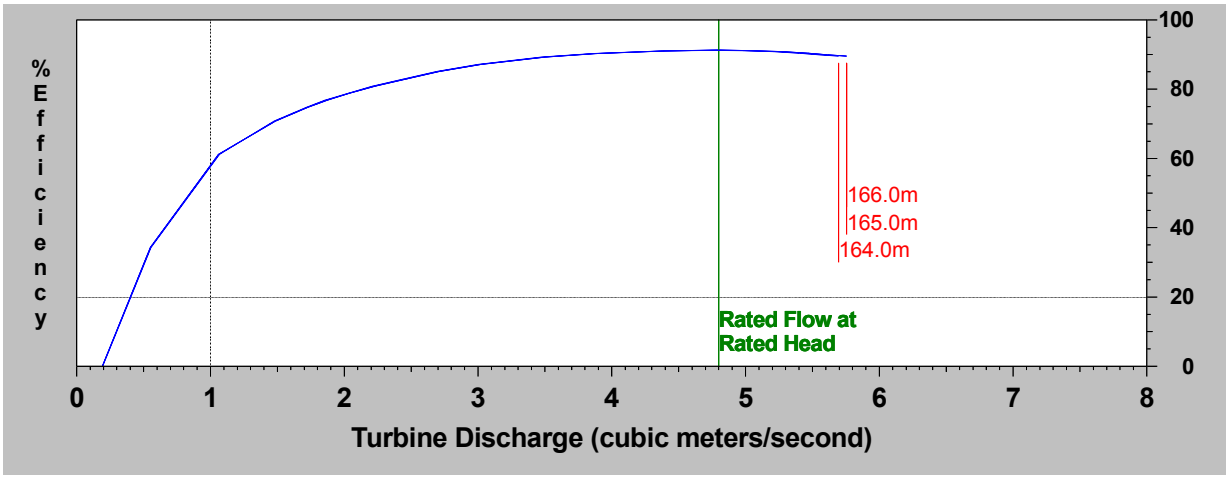


NOTE: Discharge is in cubic meters per second

Solution File Name: c:\users\hp\desktop\jagran.exe
Runner Diameter: 967 mm
Net Head at Rated Discharge: 166.00 meters
Unit Speed: 500.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Performance Data Shown is for a Net Head of: 164

Power (KW)	Efficiency (%)	Discharge (m3/s)	Notes
8200	89.5	5.70	-
7867	90.3	5.41	-
7500	90.9	5.13	-
7101	91.1	4.84	-
6966	91.2	4.75	Best Efficiency Condition
6680	91.1	4.56	-
6247	90.9	4.27	-
5805	90.5	3.99	-
5354	89.9	3.70	-
4894	89.0	3.42	-
4422	87.7	3.13	-
3946	86.1	2.85	-
3462	83.9	2.56	-
2986	81.5	2.28	-
2514	78.4	1.99	-
2050	74.6	1.71	-
1593	69.5	1.42	-
1151	62.8	1.14	-
687	49.9	0.85	Low efficiency; not used in energy calculation
321	35.0	0.57	Low efficiency; not used in energy calculation
39	8.6	0.28	Low efficiency; not used in energy calculation



TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: No File Name

TURBINE SIZING CRITERIA

Rated Discharge:	53.0	cfs	/	1.5	m3/s
Net Head at Rated Discharge:	544.6	feet	/	166.0	meters
Gross Head:	593.0	feet	/	180.8	meters
Site Elevation:	6795	feet	/	2071	meters
Water Temperature:	57	Degrees F	/	14	Degrees C
Setting to Tailwater:	-6.6	feet	/	-2.0	meters
Efficiency Priority:	10				
System Frequency:	50	Hz			
Minimum Net Head:	541.3	feet	/	165.0	meters
Maximum Net Head:	549.5	feet	/	167.5	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement:	VERTICAL WITH RUNNER ON TURBINE SHAFT				
Intake Type:	SPIRAL CASE				
Draft Tube Type:	ELBOW				
Runner Diameter:	22.1	inches	/	561	mm
Unit Speed:	750.0	rpm			
Multiplier Efficiency Modifier:	1.000				
Flow Squared Efficiency Modifier:	0.0000				

Specific Speed at Rated Net Head -	(US Cust.)	(SI Units)
At 100% Turbine Output:	15.5	59.1
At Peak Efficiency Condition:	15.5	59.1

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 544.6 feet / 166.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 119.9	2589	88.4	63.5	1.8
100	2202	90.2	53.0	1.5
* 100.0	2202	90.2	53.0	1.5
75	1621	88.5	39.7	1.1
50	1001	81.9	26.5	0.8
25	396	64.9	13.2	0.4
+ 48.2	956	81.2	25.5	0.7

** - Overcapacity
* - Peak Efficiency Condition
+ - Peak Draft Tube Surging Condition

At Maximum Net Head of: 549.5 feet / 167.5 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.038	2612	88.4	63.5	1.8

At Minimum Net Head of: 541.3 feet / 165.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.038	2547	88.4	62.9	1.8

Solution File Name: No File Name

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head): 1179 rpm

Turbine Discharge at:
- Runaway Speed (at Rated Net Head & 100% gate): 21 cfs / 0.6 m3/s
- Synchronous Speed-No-Load (at Rated Net Head): 4 cfs / 0.1 m3/s

Site's Atmospheric Pressure minus Vapor Pressure: 25.9 feet / 7.9 meters

Sigma Allowable (at 100% Output & Rated Net Head): 0.023
Sigma Plant (at 100% Output & Rated Net Head): 0.060

Maximum Hydraulic Thrust (at Max. Net Head): 12026 lbs / 5466 kg

Approximate Runner and Shaft Weight: 1933 lbs / 879 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge): 2.9 fps / 0.9 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/	mm
Inlet Diameter:	24.0		610
Inlet Offset:	45.3		1150
Centerline to Inlet:	60.1		1527
Outside Radius A:	57.3		1455
Outside Radius B:	54.9		1395
Outside Radius C:	52.1		1325
Outside Radius D:	48.5		1232

Draft Tube Type: ELBOW

	inches	/	mm
Centerline to Invert:	72.5		1841
Shaft Axis to Exit Length:	106.0		2693
Exit Width:	66.3		1683
Exit Height:	39.8		1010

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

	inches	/	mm
Centerline to Shaft Coupling:	96.0		2438
Turbine Shaft Diameter:	6.9		175

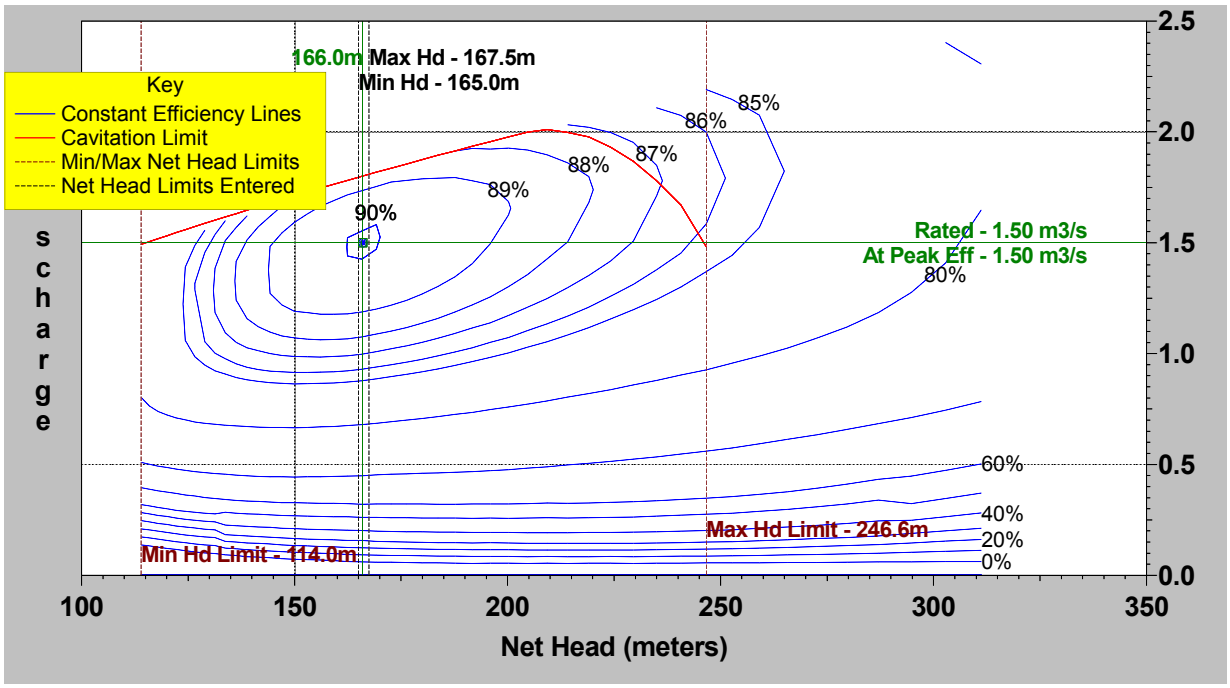
Miscellaneous:

	inches	/	mm
Wicket Gate Height:	3.0		76
Wicket Gate Circle Diameter:	43.6		1108

**** All information listed above is typical only. Detailed characteristics will vary based on turbine manufacturer's actual designs.

Solution File Name: No File Name

Runner Diameter:	561	mm
Net Head at Rated Discharge:	166.00	meters
Unit Speed:	750.0	rpm
Peak Efficiency:	90.2	%
Multiplier Efficiency Modifier:	1.000	
Flow Squared Efficiency Modifier:	0.0000	



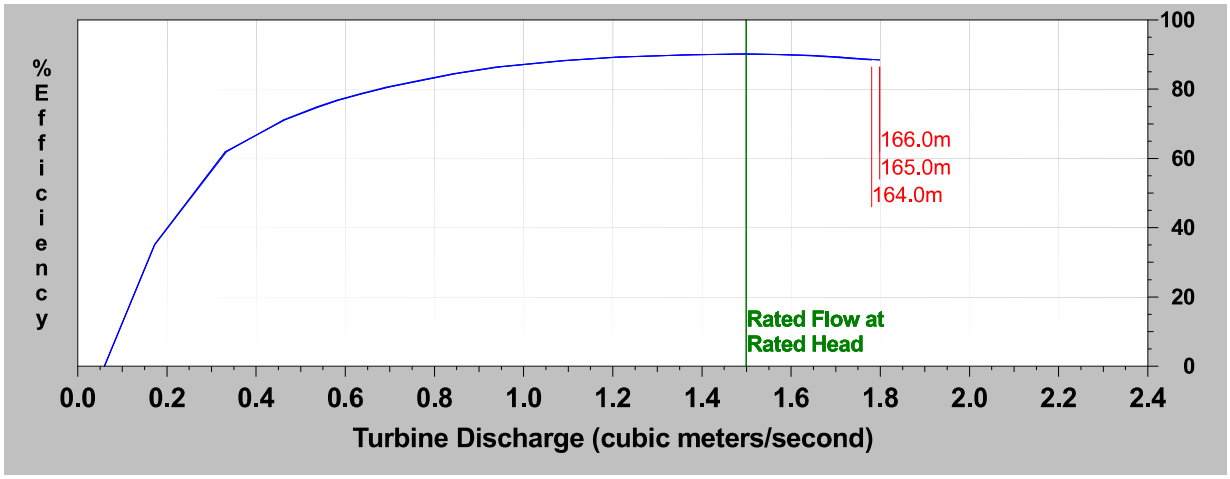
NOTE: Discharge is in cubic meters per second

TURBNPRO Version 3 - FRANCIS TURBINE CROSS PLOT

Solution File Name: No File Name
Runner Diameter: 561 mm
Net Head at Rated Discharge: 166.00 meters
Unit Speed: 750.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Performance Data Shown is for a Net Head of: 164

Power (KW)	Efficiency (%)	Discharge (m3/s)	Notes
2531	88.4	1.78	-
2429	89.2	1.69	-
2315	89.8	1.60	-
2192	90.0	1.51	-
2150	90.1	1.48	Best Efficiency Condition
2062	90.0	1.42	-
1929	89.8	1.34	-
1793	89.4	1.25	-
1654	88.8	1.16	-
1513	88.0	1.07	-
1369	86.9	0.98	-
1223	85.4	0.89	-
1075	83.4	0.80	-
929	81.1	0.71	-
785	78.2	0.62	-
642	74.7	0.53	-
501	69.9	0.45	-
364	63.5	0.36	-
218	50.7	0.27	Low efficiency; not used in energy calculation
103	35.8	0.18	Low efficiency; not used in energy calculation
13	8.8	0.09	Low efficiency; not used in energy calculation



8. ELECTRICAL EQUIPMENT

8.1 Generator and Excitation System

8.1.1 Generator

Four number AC Synchronous Generators with Vertical-shaft arrangement, hydraulic driven turbine, with unit capacity of 3 main units as 8.50 MVA (6.8 MW) and one auxiliary unit as 2.66 MVA (2.13 MW) has been selected for 22 MW Jagran-IV Hydropower Project. The Generator output shall be matched with the maximum output of the selected turbine. The generation voltage for the generating units has been selected as 11 kV with 0.80 power factor (p.f range of 0.80 lagging & 0.90 leading) in accordance with NEPRA Grid Code 2023 and IEC standard 34-1. The units are connected to 11- kV busbar system to independent unit breakers and voltage is increased to transmission level through Four number step-up transformer installed in switchyard and further transmitted to Substations via proposed 132 kV double circuit transmission Line. Technical Data of Generators is shown in **Table 8-1**.

Table 8-1: The Technical Data of Generators

Operating duty		**Continuous**
No of Units	No	4
Rated unit Capacity	MVA/MW	8.50 / 6.80 & 2.66 / 2.13
Plant Capacity	MVA / MW	28.16 / 22.53
Efficiency	%	95
Power factor	%	80
Frequency	Hz	50
Number of Phases	No	3
Rated voltage	kV	11
Rated Current	Amp	446-139
Rated Speed	rpm	500-750
Runaway speed	rpm	616-924
Number of Poles	No	12-8
Efficiency	%	95
Continuous overload	%	10
Winding		Star-Connected, neutral point grounded through grounding transformer
Cooling of stator and rotor		Air/water heat exchanger
Protection Class		IP 44
Excitation		Static
IEC Insulation Class		F (Insulation Level) – B (Temp. rises)
Rotor weight	Ton	30

The values specified above shall be regarded as preliminary. The final values, and technical specifications of the generators will be given by the bidder/turbine manufacturer, in the bidding document.

The bidder shall also acquaint himself of the access condition such as roads Culverts and bridge capacities for transportation of the heaviest part to their respected sites prior to submission of bid.

8.1.1.1 Generator Rated Output and Efficiency

The continuous rating of generators after final installation, measured at the rated values of frequency, power factor and terminal voltage will be 8.50 MVA (3) and 2.66 MVA (1), with temperature rises within Class B limits.

The efficiency shall be in accordance with latest IEC publication 34-2 but shall not be less than 95 %. The rated and average weighted efficiency shall take into account the losses of the excitation system. The thrust bearing losses shall not be included in the efficiency calculation. The permissible tolerances shall be in accordance with latest IEC Publication 34-1. The maximum continuous output within Class B temperature rise with all heat exchangers operational will be stated in the Tender.

8.1.1.2 Insulation and Temperature Rise Limits

The stator and rotor pole winding insulation will be of epoxy type Class F, and the stator and rotor winding temperature rise (Class-B), while delivering continuously the rated plant power output, at any voltage and frequency in the specified operating range will not exceed the following temperature rises over the temperature of the cooling air not exceeding 40°C:

- Stator 80 K
- Rotor 90 K

The cooling raw water temperature is expected not to exceed 20°C. The Contractor will guarantee the above temperature rise limits and suitable means for their measurement will be provided in the stator and rotor.

8.1.1.3 Short Circuit Withstand Capability

The generator and all accessories shall be capable of withstanding without permanent deformation, mechanical or electrical damage, or dangerous temperature rise while operating at any load under following fault conditions without exceeding permissible material yield stress under the following fault conditions.

- Single-phase or phase to phase short circuits for two minutes.
- Full voltage sudden three-phase short-circuits at its terminals for 3 seconds.

8.1.1.4 Stability and Performance

The generators will operate satisfactorily in parallel with each other, units connected to the grid as well as in isolated mode. The generators will be capable of operating on sudden application or loss of maximum load and during momentary short circuits and sustained earth faults without causing any abnormal vibration or resonant conditions. The generators shall be designed for stable operation at rated voltage connection with the system network via the generator transformer with a maximum phase angle displacement of 120 electrical degrees.

8.1.1.5 Runaway Speed Withstand Capability

The generators will be designed and constructed to safely withstand, without incurring damage, the maximum runaway speed of the turbine for a duration of 5 min, with cooling water flow available. The runaway speed test shall be considered as satisfactory if no permanent abnormal deformation is apparent subsequently, and no other deformation is detected which would prevent the machine from operating normally and provided that the rotor windings after the test comply with the required dielectric tests. After this test the generator will withstand the high voltage test at 80% of the dielectric test voltage. The duration of any overspeed test will not be less than 2 min.

8.1.1.6 Generator Brakes

Each generator shall be provided with pneumatically operated mechanical brake with air to be supplied from station compressed air system.

The braking system shall be electrically interlocked with the turbine guide-vane locks and the generator main circuit breaker so that the brakes cannot be applied either automatically or from the manual control switch, unless the guide-vanes are closed, and the generator circuit breakers are open. Each brake pad shall be provided with at least two interlock and alarm position switches.

The brake linings shall be suitable for 25,000 braking operations before they require to be renewed/replaced

8.1.1.7 Anti-Condensation Heaters

To avoid water condensation during long non-operative periods of the machine, heating elements shall be installed in the air circuit and in the excitation cubicles. These elements shall be connected to the 400/230 V A.C., 50 Hz power source, via contactors.

The number of these heating elements and their energy requirements are to be stated in the Technical Schedules.

Necessary contactors for switching the heating power ON and OFF, as well as the necessary internal wiring, shall be part of the generator supply. Terminal blocks for external connections of power shall be located centrally.

8.1.1.8 Generator Cooling System

The generators shall be based on a closed-circuit ventilation system with air-water heat exchangers. The circulation of air being by means of fans attached to the rotor or by a ventilated rim shall dissipate the machine losses, to limit the temperatures to the values defined by the class of temperature rise. Manually operated valves must be provided to allow isolating of the individual coolers from the cooling water system for removal and cleaning of the coolers.

8.1.2 Excitation System

The excitation system shall be of the static, constant-voltage type with controlled thyristors. It shall feature a very sensitive, quick acting control of the generator voltage and reactive power respectively. The excitation cubicles shall be metal enclosed, rigid, self-supporting, free-standing panels and shall provide easy access to the equipment for installation and maintenance.

Excitation power shall be taken directly from the generator terminal and supplied to the excitation rectifier via the excitation transformer. The excitation system shall be independent of any outside power supply except short-time external supply for voltage build-up. The excitation system shall be of well-proven design with operational records from similar installations and service conditions. The excitation systems with the related parameters, performances, scope and methods of testing the excitation system components will be in conformity with IEEE 600421.

8.1.2.1 Excitation Transformer

The excitation transformer shall be Air Natural (AN) cooled and of dry insulated type using non-flammable Class B insulating material. It shall be encapsulated/cubicle mounted or installed in a cage, to achieve personnel safety. Embedded temperature detectors (Pt-100) for monitoring winding temperatures shall be included.

Rated secondary voltage and rated output of the excitation transformer shall be determined by the Contractor to conform to the required rectifier ceiling voltage and current during dynamic load conditions.

8.1.2.2 Automatic Voltage Regulator (AVR)

The control of generator voltage shall be achieved by comparing continuously the generator voltage with a reliable reference voltage. Adjustment of the reference voltage, set point shall be performed locally by a switch on the AVR front, or remote by a voltage signal. Switches for remote adjustment of set points for the regulator will be installed in the respective Local Control Units.

The AVR shall respond quickly and accurately to any fluctuations in generator load including sudden application or throw-off of load. The static accuracy shall lie within the range of $\pm$ 0.5% of the set value of the generator voltage at normal operating conditions. The generator voltage shall be maintained at or below 110% of rated value with the generator disconnected and at maximum over speed condition.

8.1.2.3 Fire Fighting System

CO_2 system is proposed as the fire protection system for the generating units. Bank of CO_2 cylinders shall be installed and the arrangements shall also contain built in indication, and signalling devices, piping and all accessories. In addition, trolley mounted CO_2 cylinders with all accessories shall be provided for each generator as standby arrangement. Portable and wall mounted CO_2 cylinder shall also be placed in all locations such as switchgear room, control room, DG set Room in Machine Hall, Battery room, switchyard etc. for emergency use.

8.1.2.4 Measuring and indication Devices

The generator will be provided with instruments, control and protection devices and switches as necessary for operation with high degree of safety, reliability, and continuity of service. A list of instruments will be furnished for each generator, providing local and remote indication.

All signal contacts shall be potential-free, normally open contacts, rated for 220 V D.C. Dial indicators and gauges shall be mounted together in a common instrument panel, as far as possible.

8.1.2.5 Control and Instrumentation

The Contractor shall supply and install all the necessary auxiliary equipment, pipework, tubing, fittings, orifice plates, flanges, pockets and other items to provide the complete control and instrumentation for each unit.

Air-gap monitoring system and vibration detection system shall be provided with full options.

The bearings shall be equipped with necessary instrumentation i.e. flowmeters, oil level indicators, water level indicator, etc.

Temperature detectors shall be located in the area of maximum predicted temperature, in each component or part. Where limitations imposed by electrical safety or mechanical integrity at the measuring point dictate otherwise, measuring point locations shall be subject to the Engineer's approval.

Temperature detectors other than those in the windings and core shall be housed in suitable pockets, and in all cases a second pocket with a screwed protection cap shall be provided alongside to accommodate a liquid-in-glass thermometer for temperature detector calibration.

8.2 Transformers

The 22 MW Jagran-IV Power Plant shall feed power to three Substations where power transformers shall be used to step down the voltage and shall distribute the power to the load centres through 11 kV feeders. The detail of step-up and Step-down Power Transformers proposed for the project is given below in **Table 8-2**.

Table 8-2: Technical Data of Step-Up and Step Down Transformers

Sr. No	Quantity	Detail of Power Transformer	Location
1	4 No	10/13 MVA, 11/132 kV Step up Transformer	Jagran-IV Switchyard

The following Station Supply transformers shown in **Table 8-3** have selected for the power plant, intake, and Substations

Table 8-3: Technical Data of Auxiliary Transformers

Sr. No	Quantity	Detail of Station Supply Transformer	Location
1	2 Nos	250 kVA, 11/0.4 kV distribution Transformer	Jagran-IV Switchyard
2	1 No.	200 kVA, 11/0.4 kV distribution Transformer	Weir Intake
3	1 No	200 kVA, 11/0.4 kV distribution Transformer	Spare
4	4 Nos	150 kVA,11/0.4 kV dry type excitation T/F	Powerhouse

The Power and Station Service Transformers shall be pad mounted to be installed in the open-air switchyard/substations and the excitation transformer shall be dry type installed indoor. The Contractor shall provide foundations, pads and other concrete/civil works for the transformers of powerplant, intake and Substations complete in all respect.

8.2.1 Technical Data of Power Transformers

The technical data of power and distribution (station supply) Transformers to be installed in the powerhouse's switchyard and 132 kV Substations including local grid supply transformer.

The station auxiliary supply system of Power Plant shall be fed from the two station service transformers (SST), each rated for 100% of the station and auxiliary loads.

The transformers with capacity of 150 kVA shall be dry type air cooled for indoor installation and 200 kVA shall be hermetically sealed tank construction with air cushion with bolted cover and shall be suitable for pole/pad mounting installation. The 250 kVA transformer shall be of conservator type tank construction fitted with breather bolted cover and shall be suitable for pad mounting installation.

The transformers shall be designed to supply full rated output at rated frequency, rated terminal voltage and at any tapping shall be confirmed to the nominal capacity in MVA /kVA as specified for each transformer under the specific site and climatic conditions given in technical specification.

8.2.2 Transformer Oil

The transformer oil shall be of the standard mineral, uninhibited type oil class-I conforming to IEC-600296 and shall be free from synthetic additives of all types. and shall be of the same make and type for all transformers. The transformer oil shall be free from water, sediments, foreign materials, PCB and petroleum fractions which may be injurious to equipment or to any of its components, such as insulation, paint, varnish and metallic or other parts.

The transformer shall be suitable for use with the oil specified above and for satisfactory service shall not require oil of dielectric strength above 40 kV, when tested with 2.5 mm standard gap.

8.2.3 Oil Conservator Tank

The conservator shall preferably be of the diaphragm scaled type, complete with all necessary fittings. Oil conservators shall have a capacity of at least 10% of the transformer oil volume. The conservator assembly shall be complete with drain cock and shut off valve on the feed pipe to the transformer tank. The tank shall be installed with its minimum oil level higher than the highest oil filled part of the transformer in order to avoid air pockets.

8.2.4 Gas Relay

Gas relays will be installed in the pipe between the transformer tank and the conservator. The relay shall have separate contacts for alarm and for shutdown, at high gas development. The relay shall have valves for taking gas samples and for air impression for testing the relay.

8.2.5 Resistance Temperature Detectors

The transformers shall be equipped with resistance temperature detectors shall be of the three-wire Pt-100 type. They shall be located in specially designated oil filled measuring pockets in the transformer tank cover.

8.2.6 Cooling Systems

The ONAN cooling system shall comprise radiators connected to the transformer tank. Shut-off valves shall be mounted at the oil inlet and outlet so that each radiator can be removed from service or replaced without disturbing major parts of the transformer and without the need of interruption of the transformer operation. Lifting lugs, drain and vent plugs shall be provided for each radiator.

The ONAF cooling system shall be used for main power transformers and the Substation transformers. The Transformers shall be capable of operating under the natural cooled condition up to the specified load.

8.2.6.1 Water Spray sprinkler system

The firefighting system for the power transformers shall be designed for a spray pattern covering the complete transformer and appurtenances and taking into account localized wind patterns. The fire protection system shall be complete and ready for trouble free operation in case of eruption of fire. The Contractor shall furnish detailed catalogue, literature, and characteristics for every apparatus for the Engineer’s approval.

8.2.7 Joints and Gaskets

All joint faces shall be arranged to prevent ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air. Oil resistant synthetic rubber gaskets are not permissible except where the synthetic rubber is used as a bonding medium for cork or similar material or where metal inserts are provided to limit compression.

8.2.8 Tape Changers

The switchyard power transformer (step up) shall be provided with ON LOAD tap changer whereas the grid transformers shall be equipped with OFF LOAD tap changers. The off-load tap changer shall be manually operated from the ground level. The tap changer shall include an operation crank or hand wheel, tapping position indicator and means for locking the tap changer in any tapping position. The locking device shall be arranged to prevent blocking of the tap changer in an intermediate or off-tapping position.

The on-load tap changers shall be of the vacuum type design vessel fitted inside the transformer tank, motor operated mechanism and controls in accordance with IEC Publication 60214 and preferably be located inside the transformer tank, so that only the drive shaft end of the load breaker is protruding. The load breaker shall be mounted in a separate oil container to prevent contamination of the insulating oil.

The motor drive shall be mounted outside the tank and have suitable shafts and gears up to the drive shaft end. The motor drive assembly shall be complete with motor protection, limit switches, position indicator and electrical connection terminals. A detachable crank handle for emergency operation shall be provided.

All contacts and connections shall allow at least 120% current loading, compared to the transformer rated current.

8.2.9 Rating Plates

A corrosion-resistant nameplate and diagram/rating plate shall be provided on each transformer. The rating nameplates shall bear the data, specified in IEC 76 Part - I

In addition to the rating nameplate of the transformers, each major transformer part shall also carry an identification plate giving serial number and other relevant information needed for identifying the said transformer component.

8.3 Switchgears

8.3.1 High Voltage (HV) Switchgear

All 132 kV switchgear shall be rated for 145 kV maximum system voltage. The High Voltage switchgear equipment such as SF6 circuit breakers, disconnectors, earthing switches, CT's, CVT/ PTs, Surge Arrestors, PLC equipment, Gantries, Busses, Clamps for interconnection shall rated for short circuit current of 40 KA. Complete foundation work and all other civil works shall be provided for the following systems.

- 11/132 kV, Single busbar system with Four (4) Transformer Bay, Two (2) Line Bays and one PT bay with all switchyard equipment complete in all respect at powerhouse Switchyard

8.3.1.1 Ratings and Characteristics

The HV equipment and their accessories shall be so designed as to comply with the following ratings, characteristics and to meet all test requirements with respect to insulation strength, current carrying capacity, making, breaking currents & mechanical & electrical operations etc.

The equipment shall be suitable for continuous operation on a three-phase, 50 Hz system.

The switchgear shall have rated impulse and power frequency withstand voltages equal to or greater than the levels specified below in **Table 8-4** at the minimum operating SF6 gas density or pressure.

Table 8-4: Rated Impulse & Power Frequency Withstand Voltages

Nominal system voltage	**kV, rms**	**132**
Rated voltage	kV, rms	145
Rated insulation level:	To be design by incorporating insulation factor for 2100 m.a.s.l	
Rated lightning impulse withstand voltage:		
to earth	kV, peak	650
across open breaker	kV, peak	750
Rated one-minute power frequency withstand voltage		
to earth	kV, peak	275
across open breaker	kV peak	315
Rate Current	A	2000
Short Circuit Current	kA	40

8.3.1.2 Clearances

For the design and erection of the conductors and equipment in the HV outdoor 145 kV switchyard the following minimum distances shown in **Table 8-5** shall be observed:

Table 8-5: Minimum Distances

Nominal Voltage	**132 kV**
From ground to un-insulated live parts	4000mm
From ground to lower end of apparatus insulation	2500 mm
Minimum insulation clearance between phases in air	3500 mm
Min. clearance between bays	4750 mm

8.3.1.3 HV Busbar System

The HV busbar shall be of flexible all Aluminium Conductors. The conductors shall be concentric-lay stranded, flexible conductors made of round alloy conductors. Two bundle all aluminium “Hawthorn" Conductor (604 mm^2) shall be used for main busbars of 132 kV Switchyards and Substations. High level and low-level overhead buses to be used for line/transformer feeder may use all aluminium stranded Conductor “Coreopsis” (1075 mm^2). The AAC (All Aluminium Conductor) to be supplied shall conform to requirements of ASTM designation B 231-64, latest publication of IEC standard 61089 and WAPDA specification P:63:2007

8.3.1.4 Equipment support Steel Structures

The steel structures for the switchyard and sub stations equipment shall be of structural steel. Design and admissible stresses shall be according to DIN 1050 VDE Standards "Determinations for the construction of high-voltage transmission lines and substation Gantry, and equipment support structure” or equivalent similar approved standard.

The steel structures shall be hot dip galvanized. All materials incorporated in the supply shall be new and free from defects. They shall conform to the relevant standards. Materials not specially designed shall be suitable for the purpose.

8.3.1.5 Conductors for Busbar and Dropouts

All Aluminium Conductor “Hawthorn”

The conductors shall be concentric-lay stranded, flexible conductors made of round alloy conductors. Two bundle all aluminium " Hawthorn" Conductor (604 mm^2) shall be used for main busbars of 132 kV Switchyards and Substations. High level and low-level overhead buses to be used for line/transformer feeder may use all aluminium stranded Conductor “Coreopsis” (1075 mm^2) if deemed necessary. The AAC (All Aluminium Conductor) to be supplied shall conform to requirements of ASTM designation B 231-64, latest publication of IEC standard 61089 and WAPDA specification P:63:2007

The conductor shall be constructed of hard-drawn aluminium wire having the mechanical and electrical properties specified herein. The material shall contain not less than 99.5 percent aluminium by weight. The aluminium wires shall be clean, smooth, and free form harmful defects prior to being stranded. the bidder may propose cross-sectional area of the conductors according to the electrical and mechanical requirements after short circuit calculation.

The dimension and characteristics of the conductor is given below.

Conductor name	Hawthorn	
Nominal size of conductor	600	mm2
Nominal breaking Load	8966	kg
Overall Diameter	32	mm
Calculated area of Complete Conductor	604	mm2

Strand and Wire diameter	61/3.55	mm
DC Resistance at 20 OC	0.0479	ohm/km
Weight of Conductor	1668	kg/km

All Aluminium "Coreopsis" Conductor

The All-Aluminium Standard Conductor (Coreopsis) shall be used for the high/low level conductors and shall conform to the requirements of ASTM Designation B 231-64.

- Conductor name Coreopsis
- Calculated area of Complete Conductor 1075 mm2
- Nominal breaking Load 13670 kg
- Overall Diameter 37 mm
- Strand and Wire diameter 61/4.11 mm
- DC Resistance at 20 OC 0.0356 ohm/km
- Weight of Conductor 2241 kg/km

8.3.2 Medium Voltage (MV) Switchgears

Indoor mounted metal clad trolly mounted horizontally draw out vacuum type MV Switchgear equipment (11 kV and 33 kV, 3 phase ,50 Hz) shall require for the powerhouse and Substations. The MV switchgear shall comprise metal-clad cubicle assemblies including all apparatus and requisite accessories, circuit breakers, disconnectors, busbars, conductors, cables insulators, bushings, clamps and connections, lightning arrester, instrument transformers, earthing devices, internal wiring and terminals, base frames fixing materials, all switching devices and their combination with associated control, measuring, indicating, alarm, protective and regulating equipment and all those components/parts, not mentioned herein but requires for a complete functional system. Details given in technical specification

Each cubicle shall be equipped with an instrument compartment including mimic diagram, indicators, control switches, instrumentation, transducers, and protection relays.

8.3.2.1 Technical Data

Technical requirement of MV Switchgear panel follows as under shown in **Table 8-6**.

Table 8-6: Technical Requirements of MV Switch Gears

Switchboard Type	Metal clad
Installation	Indoor
Service	Continuous, uninterrupted
Degree of protection	IEC 60529, IP 32
Device type	Withdrawable
Nominal system voltage	11 kV
Max. operating voltage	12 kV
Earthing system	Solid
Frequency	50 Hz
Rated lightning Impulse withstand voltage,1.2/50 mms	95 kV peak
Rated power-frequency short- duration withstand voltage (1 minute)	28 KV rms

8.3.2.2 Units Synchronization

The unit synchronizing will be performed at the generator circuit-breakers at 11 kV busbar. The unit synchronizing equipment will be installed with the unit local control panels. Synchronizing will normally be initiated from the power plant control room, but local facilities will be provided in the event of a data highway failure.

Synchronization test facility shall also be provided. In the test position all functions of the system shall be executed without the breaker closing control with indication of closing signal. Provision shall also be made to over-ride the synchronizing check relays for dead bus/line conditions.

8.3.2.3 Protection Relays

Protection relays shall be equipped with two independent adjustable current settings for instantaneous and delayed tripping for each protection relay function. The time delay setting shall be independent of the current setting.

8.3.3 LV Switchgear

The low voltage A.C. distribution system will be designed as a 400 V, 3 phase four wire plus protective (earth) conductor system. The LV switchboards for the power plant, intake and substations shall comprise of MCB and MCCB's including all apparatus and requisite accessories, busbars, conductors, clamps and connections, earthing devices, internal wiring and terminals, base frames, and fixing materials

The powerhouse LV distribution systems shall be designed with a normal main bus and an essential load bus interlocked with a bus-breaker for automatic separation in failure situations. If a black-out occurs in the main system, the feeder connected to the essential load bus-bar will feed all essential loads from the standby diesel generator through station service transformers.

8.3.4 DC Power Supply System

The DC supply system for Powerhouse, switchyard and Substations shall provide uninterruptible power for control, protection, instrumentation equipment, miscellaneous equipment and to power critical DC operated equipment. An uninterruptible AC system shall be provided to feed uninterrupted, transient free regulated AC power, during all normal and abnormal plant operating conditions, to specific critical AC loads.

For control and protecting equipment and for providing emergency lighting, in case of AC power failure, a bank of lead acid batteries will be used for DC power supply system in the power plant. Voltage level of this system will be 220 V for control, emergency lighting, closing, and opening of circuit breakers and 48 Volts will be used for communication system.

8.3.4.1 Batteries

The main characteristics of the storage batteries will be as shown in **Table 8-7**:

Table 8-7: Gears Main Parameters of Storage Batteries

Type	**Lead Acid**	
Installation	Stationary Indoor	
System Nominal Voltage	Volts	220
Nominal Voltage of Cell	Volts	2.0
Open circuit voltage of cell at full charge,	Volts	2.055
Number of cells in battery	No	110
End voltage after 10 h discharge at rated current/cell	Volts	1.8
Trickle charging voltage (floating)/cell	Volts	2.2
Maximum self-discharge rate at 40°C/ month	%	< 5

8.3.4.2 Battery Chargers and DC converter

The battery charger shall consist of a solid-state static rectifier, designed to supply the power converter at nominal load and to simultaneously recharge the batteries from 10 % to 95 % of full capacity in 24 hours (rated under full load) at low end of input voltage range; 400 V - 1 0%.

The rated current of the chargers shall be selected to allow recharging of a fully unloaded battery in 5 hours, in addition to simultaneously supplying the total connected DC load. The chargers shall be of constant voltage type with current limiting device.

The 220/48 V D.C./D.C. converters shall be used for 48 Volts DC power from the station battery system. The Contractor shall calculate the power ratings of Battery bank based on each unit's actual load with 50 % spare capacity for future use, and 100 % redundancy (two converters in parallel).

8.3.4.3 DC/DC Converter

The 220/48 V D.C./D.C. converters shall be used for 48 Volts DC power from the station battery system. The Contractor shall calculate the power ratings based on each unit's actual load with 50 % spare capacity for future use, and 100 % redundancy (two converters in parallel).

8.4 Plant Control and Automation System

The overall Control and Monitoring of the entire power plant shall be carried out through a computerized Plant Control and Monitoring System. The capacity of the systems shall be designed to handle in the context of linkage of the project with the Regional/National Grid System.

The Plant Control and Monitoring System for the Power Plant and Substations shall comprise a complete functional and state of the art equipment with latest software including SCADA system, capable of carrying out entire control functions of the power plant and substations, even not mentioned in the specification, for efficient operation of the power plant. The system shall include but not necessarily restricted to the following equipment:

8.4.1 Plant Control Levels

The power plant Automation and Control System shall function in the following three tiers.

1. The Plant Control System (PCS) shall consist of a computerized system located in the main control room for supervisory control of the entire power plant. The PCS shall monitor and control the complete power plant, and cover the generating units in the powerhouse, the HV switchyard & MV switchgear system, the 132 kV Substation, and the weir intake

2. The local control system shall consist of computerized Unit Control System (UCS) with local mimic board, one for each generating unit, one for the HV switchyard / 11 kV switchgear one for the auxiliary systems. One for Intake weir. The protection relays shall be part of the unit control system but operationally independent from the local computer.

3. The manual control system shall function through manual operation from the object control board and Emergency Stop from separate, independent panels. A Local Control Box with Local/Remote selector switch with key and ON-OFF Push Buttons will be provided near the electrical actuators (motors or valves).

Provision shall be made for remote control from NPCC to the project area so that the NPCC will be able to start/ stop individual units which were set to automatic control in the central control room.

Each substations control room shall be provided with independent workstation and all interface equipment with SCADA system.

8.4.2 System Architecture

The PCS will be designed in consistent hierarchical and decentralized structure. Dividing the control scheme into autonomous functional areas will increase the availability and guarantee all time pre-defined and safe operating modes in case of emergency situations. The PCS will be designed to ensure maximum availability by the inclusion of built-in redundancy for both hardware and software. This will include duplicated control processors, bus systems and power supplies with automatic change-over to the standby device upon detection of a fault or failure. Where appropriate, I/O cards will also be duplicated.

The PCS will be connected to a GPS master clock system to guarantee synchronization of all PCS components. The UCS will be equipped with instruments for active and reactive power, stator voltage, stator current, field voltage, field current, turbine discharge, speed measurement, trash-rack differential pressure measurement and wicket gate position indication etc. The relevant input signals will be taken directly from the transducers. For position indications of the circuit breakers and disconnecting switches, a mimic diagram will be provided on the unit control board. The signals to the position indicators will be supplied from interposing relays.

8.5 Telecommunication and Security Systems

Two independent telephone exchanges and networks will be provided. One for the power plant and power system operations and the second one for normal local telephone traffic with connection to the public network.

The main telecommunication from the Powerhouse to the Intake will be provided by fibre-optic link for voice and Data communication along with VHF local radio system as back-up arrangement.

The main communication link between the power station and the NPCC/ substations will be provided by PLC system.

The communication and security systems will comprise the following:

- Interface equipment to PLC
- VHF local radio system
- Power Line Carrier System (PLC)
- Permanent Telephone Equipment and Network
- Closed Circuit Television System (CCTV);
- Access control system;

Separate PABX telephone system shall be provided in all the substations, along with PLC system for voice and data communication between the power plant and the substation.

8.6 Protection System of Power Plant, Switchyard and Substation

The protection systems will cover the entire components of Power Plant, Switchyard, Substation and the Transmission line. The protection system shall have state of the art equipment and shall be complete in every respect and include the specified protection devices, the necessary auxiliary relays, interposing transformers and power supply units. The protection devices will be of the numerical, microprocessor-controlled type of a competent manufacturer with at least 5 years proven track record.

The relay assemblies will be grouped in a logical manner to provide a good overview and facilitate the identification. Test plugs for measuring and test injection will be easily accessible from the front side. For the power supply to each relay or group of devices redundant DC/DC converters will be provided.

The protection system shall cover all range of equipment including Generator, transformers, switchgear, Busbar system, station service and local power supply system, emergency diesel generating unit,132/11 kV overhead lines, DC supply system etc. complete in all respect, of the following project components

- Power station and 11/132 kV Switchyard.
- Proposed 132 kV Transmission line as per Employer’s requirements.
- Protection systems to provide the complete range of electrical protection for the 11 kV switchgear, 11 kV overhead line, Auxiliary AC/DC systems, local distribution transformers station service transformer and emergency diesel generator set.

8.6.1 Protection Devices

Only relays of a recognized make and of a high quality which has been duly demonstrated in actual service will be accepted. The protection relays and associated auxiliary relays shall be the standard product of an experienced and reliable protection relay manufacturer. The relays shall be electronic, or microprocessor based, rack mounted and based on modern technology. The relays shall preferably be of the same make (manufacture) to build a uniformed modular system

The protection systems will preferably be based on a common data bus with digital signal processing and interfaces to the primary sensors such as CT, VT and other digital sensors. For system redundancy in a centralized system two programmable microprocessors will work on-line in parallel. The individual protection functions will be stored in a library of software which may be modified and complemented using a PC with serial interfaces and recorded using a second serial printer interface.

8.7 Main Earthing Lightning Protection System

8.7.1 Earthing System

A complete earthing system shall be installed in the power plant, switchyard, and substations for satisfactory and safe operation of the plans. The earthing system shall be designed and constructed to protect persons and equipment/material having resistivity less than or equal to 1 ohms and to allow for the correct service, operation, and maintenance of the installations. The system design shall be based on the maximum earth fault current that is expected to occur during the design life of the station including generating station and transmission system contributions.

All building steel, crane and track rails, fixed handrails, gates and pipe work shall be connected to the embedded earthing mesh. All metallic conduits shall be grounded at one end. Mechanical piping systems not served by motor-driven equipment shall be grounded by exposed conductor from an earth electrode to one point on the piping or associated equipment. Earthing conductor shall be connected to the piping and equipment. Exposed earth conductor shall be clamped to surfaces. Joints of crane and other track rails flanged pipe work and of cable tray shall be bonded together.

The earthing system design indicating buried and embedded earthing mesh, electrode system with risers, earthing conductors above- ground, and connection to all equipment /structures in respect of the following sites.

- Powerhouse area
- HV Switchyard area
- Intake area
- Forebay area
- Individual Towers/poles of Transmission Lines
- Transmission Line

The contractor shall measure the earth resistivity at all the sites mentioned above and shall carry out the earthing design calculations to ensure that the touch and step potentials are within the safe acceptable limits.

8.7.2 Lightning Protection system

Lighting protection system shall be provided at all locations specified above for the following purposes.

- To protect personnel, electronic and electrical equipment from the effects of lightning strokes the plant will be equipped with a lightning protection system.
- The lightning protection system will be subdivided into lightning protection zones and consist of roof conductors, air terminals and down conductors.

- All materials will especially be suitable and approved for this type of system.
- The lightning protection system will be connected to the station main earthing electrodes as appropriate.

8.7.3 Earthing Points

Subject to the design calculations based on the earth resistivity determined by tests at the Site, a minimum of two earthing points shall be installed for intake and forebay gate structure. Each earthing point shall consist of 16 mm diameter, copper rod electrodes, of extensible standard length, driven where possible into undisturbed soil. Each electrode shall be complete with an approved non-ferrous terminal clamp for connection to the earthing conductors and with a hardened steel cap and tip for driving by means of a power hammer.

8.8 Cables and Cable Trays

Power and control cable systems will be provided for the entire hydropower plant switchyard and substations with all related buildings and structures. The cable systems will comprise of all Medium Voltages (11kV & 33 kV) and Low Voltage (400/230 V) power, communication, control and instrumentation cables, the necessary accessories such as cable terminations, cable trays, conduits, supports, fixing and mounting materials complete, ready for service systems. The scope under cable shall also include cables for for ventilation, street lighting, internal and external electrification of powerhouse, switchyard, intake, forebay and the substations.

The MV cable, the control and low voltage cables in the power station, the switchyard, and substations, shall be laid on cable racks in the cable channel and the cable ducts or trenches, cable tray, cable ladder etc as per the site requirement.

Cable ducts with cover will be provided for the following facilities

- Within the powerhouse
- Between the powerhouse and the HV switchyard.
- Within the HV switchyard
- Between the substation and Control buildings
- In the Intake area and all other locations deemed necessary.

8.8.1 Cable Supports and other Steelwork

All cable supports including racks, trays, sunshields and other steelwork with all necessary fixings, bolts, nuts, screws, and clamps shall be supplied by the Contractor. Metal work shall be galvanized. The Contractor shall take all precautions to prevent damage to the galvanizing. Where steelwork, racks or trays supplied in standard lengths are cut or minor damage has occurred to the galvanizing the exposed steel shall be treated with zinc rich paint or other method approved by the Employer’s Representative. Heavily damaged items shall be replaced as directed by the Employer’s Representative at no extra cost to the Employer.

8.9 Emergency Diesel Generator Set

A 250 kVA, 11 kV, 1500 rpm, 0.8 pf, Emergency diesel generating units (DG unit) will be provided at the powerhouse and shall be installed in enclosed and ventilated Emergency Diesel Generator Room adjacent to the machine hall. The DG set shall be connected to 11 kV system through EDG switchgear which will also supply power to the intake through 11 kV intake line. The DG set will contain the complete installations including the cooling system, control equipment, starting battery and battery charger.

8.9.1 Diesel Engine

The diesel engine shall be of heavy-duty solid injection, compression ignition, exhaust gas turbocharged with intercooler, water-cooled closed circuit with radiator, air starting, four stroke, multi-cylinder with exchangeable cylinder liners, forced lubrication with lubrication oil cooler, electronic governor, suitable flywheel for flicker-free operation and exhaust silencer with necessary piping etc. all parts shall be easily accessible for inspection and repairs.

Technical Data of Diesel Engine is given as under.

Type	Diesel 4-stroke
• Rated output	200 kW
• Rated speed	1,500 rpm
• Cooling system	Closed water circuit, radiator with motor fan
• Fuel supply	By gravity or fuel supply pump
• Fuel	Commercial diesel
• Starting system	24 V DC, battery, and charger
• Day tank capacity	1,000 L
• Storage tank capacity	Suitable for 5 days operation
• Battery Type	lead acid type, or gel-acid type

8.9.2 Generator

The AC generator shall be of constant voltage, 50 Hz, three phase, four wire, internally air cooled, solidly grounded neutral, self-excited type with a power factor of 0.85. Damper windings shall be uniformly distributed round the rotor. Temperature rise of the windings shall not be more than 90°C for class-F insulation with an ambient temperature of 40°C under rated conditions.

The generators shall have the following ratings:

- Type 3 Phase synchronous directly coupled with Diesel Engine
- Design Horizontal
- Cooling Air-cooled
- Rated output 250 kVA
- Rated voltage 400 kV
- Rated frequency Hz 50
- Voltage regulation ± % 5
- Rated speed 1,500 rpm
- Power Factor 0.80 lagging
- Insulation Class F
- Protection class IP42
- Excitation System Brushless with rotating diodes, Self-regulating
- Neutral grounding Solidly grounded

8.9.3 Parallel Operation

The Emergency Diesel Generator Set shall form part of the Station Supply system and shall be capable of parallel operation with another supply. The EDG set shall provide standby power in case of complete loss of normal power and shall have the facility for auto-start in the event of failure of the normal supplies to the 11 kV switchgear

8.10 Electrification of Powerhouse, Switchyard and Intake

The electrification work includes installation of entire electrification works of powerhouse, switchyard, substations, forebay and intake etc. including substation control buildings. This section covers general requirements for furnishing, installation and testing of items of electrification works in Power station Building, switchyard and intake consisting of:

- Internal electrification work
- External electrification work

Electrification works for the power plant, the switchyard and the intake and forebay including internal and external lighting fixtures, bracket fans, exhaust fans, wiring, poles and power outlets as well as associated civil works.

The work shall also include Indoor and outdoor lighting systems with small power service installations for all components of the Project and the associated roadways as per following:

- Internal /External Lighting and small power installations for the entire power plant with all pertinent buildings and structures, including the weir site and Forebay.

- Internal /External and security lighting and small power installations for the substation control buildings and operator's quarters/colony.

The lighting fixtures will be arranged neatly without interference with other equipment to provide a substantially uniform level of illumination throughout the room or area illuminated, eliminating dark corners.

8.11 Civil Works of Switchyard

This section covers detail survey, design, engineering, drawing and construction of complete civil works of switchyard. All civil works shall be carried out as per applicable Standards and Codes. All materials shall be of best quality conforming to relevant International Standards and Codes.

The contractor shall carryout detail design / drawing to be approved by the engineer and accordingly all civil work shall be carried out in accordance with the approved drawings. The Contractor shall also prepare necessary layout and details for all buildings, structures, foundations etc. keeping in view the functional requirement of the substation facilities and providing enough space and access for operation and maintenance. The requirement given in this specification is indicative, the Contractor shall assess the complete requirements for a fully functional project.

The contractor shall provide all civil and architectural work of 132 kV switchyard complete in all respect, including geotechnical investigation site preparation, all E&M Equipment foundations, fencing/ boundary wall, entrance gate, Control building and staff accommodations etc.

8.12 Power Dispersal and Transmission Lines

8.12.1 132 kV Transmission Line

The 132 kV transmission line was proposed from Jagran-IV Hydropower Project to Grid Station Rampura, Muzaffarabad under AJK PDO. The case was initiated in April 2022 and must be under consideration for construction. Therefore, the subject design is finalized keeping in view that the above transmission line will be constructed and available for interconnection and power dispersal from the main plant of Jagran-IV Hydropower Project.

8.12.2 11 kV Transmission Line

A 11kv Transmission Line feeder shall be constructed from switchyard to Intake-Weir through Colony Area\Staff Quarters on standard 11 kV lattice structure in accordance with WAPDA specifications, Disc and Pin type Insulator shall be used for 11 kV line.

The 11 kV galvanized steel pins made by process of forging suitable for 11 kV pin insulators having maximum failing load of 5 K.N. with small steel head as per fig IB of IS 2486 (ii)/1974 shall be used. The dimension of pin shall conform to ref L-306N fig 69IS-2486 (ii)/1974. The pin shall

be provided with nut (hot dip galvanized) one plain washer and one spring washer (electro galvanized). The disc insulators should be fitted with 11 kV Hardware for tensioning the conductor 11 kV hardware should be fixed in the disc insulators as per the standard practice and in the correct position to bear the tension of conductor. The 11 kV strain hardware fitting of aluminium alloy suitable for required size of Conductor (ACSR) should be used conforming to IS-2486 (Part-II) 1989.

All conductors sagging shall be preferred in accordance with the sag and tension tables. After the conductors have been pulled to the required sag, intermediate spans shall be checked to determine the correct sag. The conductor shall be installed on insulators secured to it by means of 6 SWG aluminium binding wire. The jumpers at the tension locations should also be bound by 6 SWG aluminium binding wire. Before fixing the conductor on insulator and strain hardware, aluminium tape should be wrapped on the conductor.

The 11 kV guarding cross arm is to be fitted on the pole as per the drawing in the CSEB for guarding the line with 8 SWG GI wire as guard wire and 10 SWG GI wire for lacing. Guarding cross arm made of 75x40x6 mm angle 5 feet long should be clamped at 300mm below the bottom arm of 'V' cross arm.

Barbed wire weighing 3.5 Kg per pole should be wrapped at a height of 3000 mm above ground level stretching in 900 mm length. Both ends of barbed should be clamped suitably to avoid coming down from its location.

Danger Board for 11KV voltage and danger mark conforming to IS:2551-1963 should be fixed on each location.

8.12.2.1 Specification for LT Line on 140 Kg 8-meter long RCC Pole

Scope

Planning, supply, installation, testing and commissioning of 415 Volt over-head low tension line on 140 Kg. 8-meter-long PCC Pole and necessary iron fitting etc. complete. All relevant supports fittings and fixtures, conductors shall conform to their respective IS specifications.

Pole

The overhead LT line shall be supported on 140 Kg. 8-meter-long PCC pole as specified in the schedule of item conforming to ISS. Normally one sixth of the pole length shall be buried in the ground. The supports shall suitable be spaced depending on the number and size of the conductors, number of in between plots, road crossings etc. in general, the spacing of supports shall be approximately 50-60 meters depending upon road crossing, telephone crossing etc, and in no case the inter-distance between two consecutive supports shall exceed 65 meters as per rule 85 of the Indian Electricity Rules, 1956.

L.T. Porcelain shackle insulators of size 90x75mm conforming to IS: 1445-1977 shall be provided and fixed in 'U' clamps for holding the conductors. LT shackle hardware galvanizing shall conform to ISL 2633-1964 for 4 dip tests.

For holding neutral conductor Aluminium bobbin insulators of size 60x50mm size with nuts bolts shall be provided.

For single phase three wire line ACSR 20 Sqmm Cu.Eq. (Weasel) conductor will be used for phase and 13 Sqmm Cu.Eq. Squirrel for neutral. Similarly for three phase four wire line ACSR 20 Sqmm Cu.Eq. (Weasel) conductor will be used for phase and 13 Sqmm Cu.Eq. Squirrel for neutral. Also for three phase four wire line ACSR 30 Sqmm Cu.Eq. (Rabbitl) conductor will be used for phase and 20 Sqmm Cu.Eq Weasel for neutral in some of the locations. The conductors shall be laid out in such a manner that there is no damage to the conductors in any form. While stringing overhead conductors, there should not be any kinking. Reels of conductor should be handled carefully, so that there is no cutting, nicking or fraying of the conductor strands. Conductor should be laid out from a rotating wheel supported on jacks for easy unwinding of the conductor. The conductor shall be binded to its respective shackle insulator by means of binding wire at one of the terminal ends of span. The nuts shall be unscrewed in such a manner that top of nut gets flushed with bolts surface, so as to enable the 'U' clamp to be at maximum distance from the brackets. Aluminium sheaves fitted with ball bearing should be used at all points of conductor support for easy pulling and to ensure uniform tension throughout the conductor length. The conductor should be pulled with a proper "come along clamps". Conductor shall be pulled upto a proper sag in span at or near the dead-end section of the line and then binds with the shackle insulator by means of adequate size of binding wire. The tension should then be adjusted threading of nut of MS 'U' clamp until correct sages chained in spacing near the pulling end. The conductor shall then be binded with the shackle insulators of mid span poles maintaining proper sag and tension. The overhead line shall be correctly aligned. Where there is any deviation more than 30-Degree from straight line the overhead conductor shall be shackled of at the support. Similarly terminal and function poles shall also be provided with shackle insulators.

'D' loops shall be provided on each conductor on both sides of each LT pole and all jumpers of LT line and service line shall be done on these loops only. The size of 'D' loop shall generally be 200mm wide, 100mm high with 150mm additional length on both sides for binding. The cross-sectional area of conductor of 'D' loop shall be the same as that of conductor to which it is being binded.

Aluminium tape shall be used for each contact/jumpers on lines. Binding at all places shall be done neatly by Aluminium binding wire of size 8 SWG.

8.12.2.2 Earthing of PCC Pole

- 11KV – Every pole should be earthed by earthing coil at the bottom and fittings at the top.
- LT – Every third pole should be earthed by earthing coil at the bottom and fittings at the top.

9. CONSTRUCTION PLANNING

9.1 General

The construction planning for 22 MW Jagran-IV hydropower project is largely dependent on the following major factors:

- Construction of weir, intake structure, sand traps, low pressure pipeline, the powerhouse and electrical and mechanical works are on the critical path.
- Excavation and backfilling of headrace steel pipe.
- Manpower, equipment and other resources available with the contractors.
- The winter season in the project area is quite severe with snow fall. Some of construction activities like concreting shall not be possible during winter season. The main working season is from March to October each year

There are following main components of the project:

- Weir
- Connecting Channel from Intake to Sand trap
- Sand Trap
- Headrace Steel Pipe
- Penstock and Manifolds
- Powerhouse
- Transmission lines

The work on all these components can be carried out independently and the schedule has been prepared in such a way, that the work can be taken up simultaneously on various sites in order to complete the project in the shortest possible time.

The construction work of cofferdam starts during low flow period, as indicated in the construction schedule. For civil works, about 28 months will be needed and erection of electromechanical works will start from the 22th month of construction period. As such the first unit will be available for wet testing and commissioning by 36th month of construction schedule.

It is anticipated that the construction of the entire project will be completed in 40 months period. The sequence, in which the construction of various components of the project will be taken up, has been shown in **Figure 9-1** and described in the following paragraphs.

9.2 Land Acquisition

No major problem is envisaged in acquisition of land. It is anticipated that land required for the project will be acquired / purchased in 10 months. To streamline the project implementation and to avoid delays, it is desirable that the land acquisition process is accomplished and possession of the land is taken at least one month before start of construction work. It is envisaged that the land required for the establishment of camps, stores and workshops will be acquired on temporary basis by direct negotiation and agreement with the owners. Temporary acquisition will principally be the responsibility of the contractor and the cost should be reflected in the bid.

9.3 Mobilization and Preparatory Works

It is envisaged that the contractor will mobilize to the site within 15 days after signing of contract agreement. Having procured the land for the camping and other facilities within the first two months, the contractor will start establishing facilities. A period of about 08 months has been allocated for this purpose. The main activities in this period, to be undertaken by the contractor, are briefly outlined below:

- The construction of access roads, to weir site and powerhouse location. A period of 08 months has been provided for the contractor to complete this activity.
- Simultaneously, the contractor is required to construct residential and storage facilities for his manpower, equipment, material and erection of concrete batching plant. This will take a period of 06 months.
- As the contractor will need power supply to run his equipment and to provide electricity for his camp, he has to arrange proper power supply facility within one month.
- In addition, the EPC contractor will start work on additional investigations, detailed designing of the project components and demarcating the layout of the project.

9.4 Exploration for Borrow Areas and Construction Materials

In the light of feasibility/ tender design studies, the contractor has to confirm, further explore and test materials to check their suitability for use in construction. It is envisaged that this activity will be completed during the mobilization period.

9.5 Coffer Dams and Care of Water

The construction of the Jagran-IV weir, is estimated to take approximately 25 months, divided into two seasons. River diversion works will begin in the low flow season (October-March) and start in October. The construction of stage-I coffer dams has been planned to start in 8th month.

9.6 Weir and Intake Structure Works

Construction of weir which includes weir crest, under sluices and intake. This activity has been planned to start in 10th month. It is proposed that excavation of rock, preparation of weir foundation & stilling basin, concreting of weir, intake structure, stilling basin floor and wing walls will be completed. By the end of 34th month the structure will be ready to regulate the river flow.

9.7 Connecting Channel from Intake to Sand trap

As the cut and cover channel is about 85 m long, it is proposed that separate/ independent crew shall be deployed for this part of the work. A period of about 9 months is foreseen for completion of conduit. It is proposed that this activity should be started by the contractor immediately after the mobilization and the connecting channel should be ready by the time other components are completed so that water is available for testing and commissioning.

9.8 Sand Tap

As per Consultant’s planning, it is proposed to initiate work on this activity along with the construction of the diversion structure. The surface sand trap is located at downstream of weir on the left abutment of the river. Excavation for sand trap will be completed in 03 months while the

structures will be constructed in another 16 months period. Installation of lift gates and fixing of trash racks will take another 08 months.

9.9 Low Pressure Headrace Steel Pipe

As the headrace steel pipe is about 2,996 m long, it is proposed that separate/ independent crew shall be deployed for aligning, fabrication and erection of the penstock which will take about 21 months.

9.10 Penstock and Manifolds

Fabrication of the penstock and construction of anchor blocks would simultaneously be started to accomplish the work well in time to allow about 14 months for erection of the penstock and completion of the activity by the end of 31th month.

9.11 Powerhouse

Civil works for powerhouse are also on the critical path. Installation work of electromechanical equipment, embedded parts of the turbines and generators and construction of the superstructure, are part of this activity. Construction of the powerhouse has been planned in such a manner that it should be ready by the time other structures are completed. The powerhouse is to be constructed on the left bank of the river. Excavation will be taken up during the dry period in order to avoid flooding. This activity will start immediately. The completion of excavation including preparation for foundations is proposed to take about 04 months. Concreting will be started in 13th month of construction period and construction of the powerhouse is expected to be completed by the end of 32th month. Fabrication of steel and aluminium doors and windows and architectural work will also be completed by this time. Total period to complete the civil works of the powerhouse has been taken as 25 months.

9.12 Tailrace

The excavation of the tailrace will begin concurrently with the excavation of the powerhouse. The construction of the tailrace will be coincided with the completion of the powerhouse.

9.13 Installation of E&M Equipment

Full manufacturing of electro-mechanical equipment is expected to take 30 months; however, the deliveries will start to materialize at site by 16th month as shown in construction schedule. The manufacturing of E&M equipment particularly the turbines and generators are again on the critical path and as such the work for these has to be awarded at the time of award of civil works. It is also essential for the equipment to be delivered in stages starting with embedded parts. Placement of embedded parts will start with second stage concrete. The installation of units has been proposed to be carried out in stages. As soon as curing of concrete around embedded parts is complete the generator and turbine for the first unit will be installed.

9.14 Transmission Line

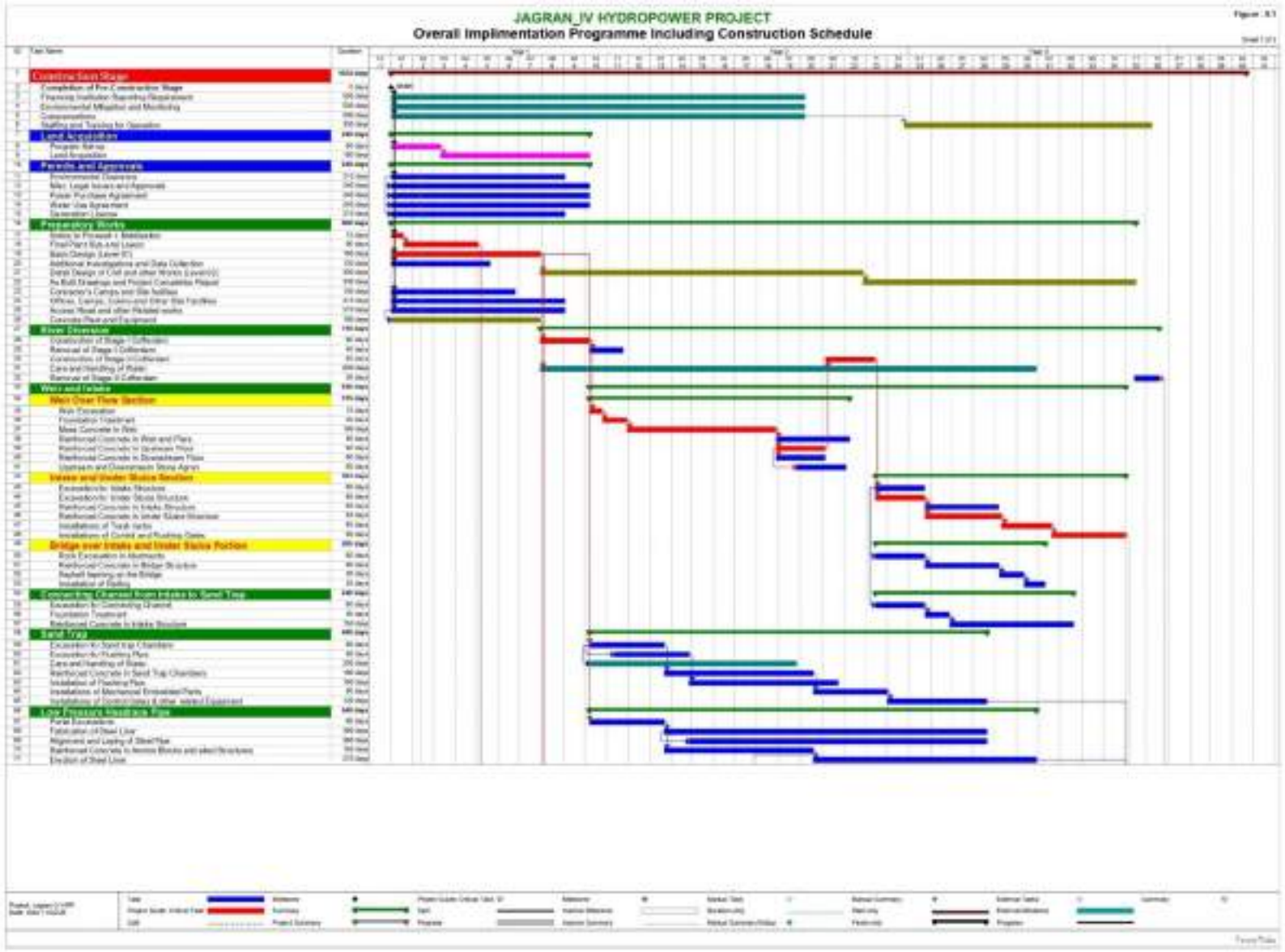
Work on 11 KV overhead transmission lines, double circuit from power plant to Intake of about 3 km will start by 8th month and shall be completed by 8th month. Total construction time for this activity will be 19 months.

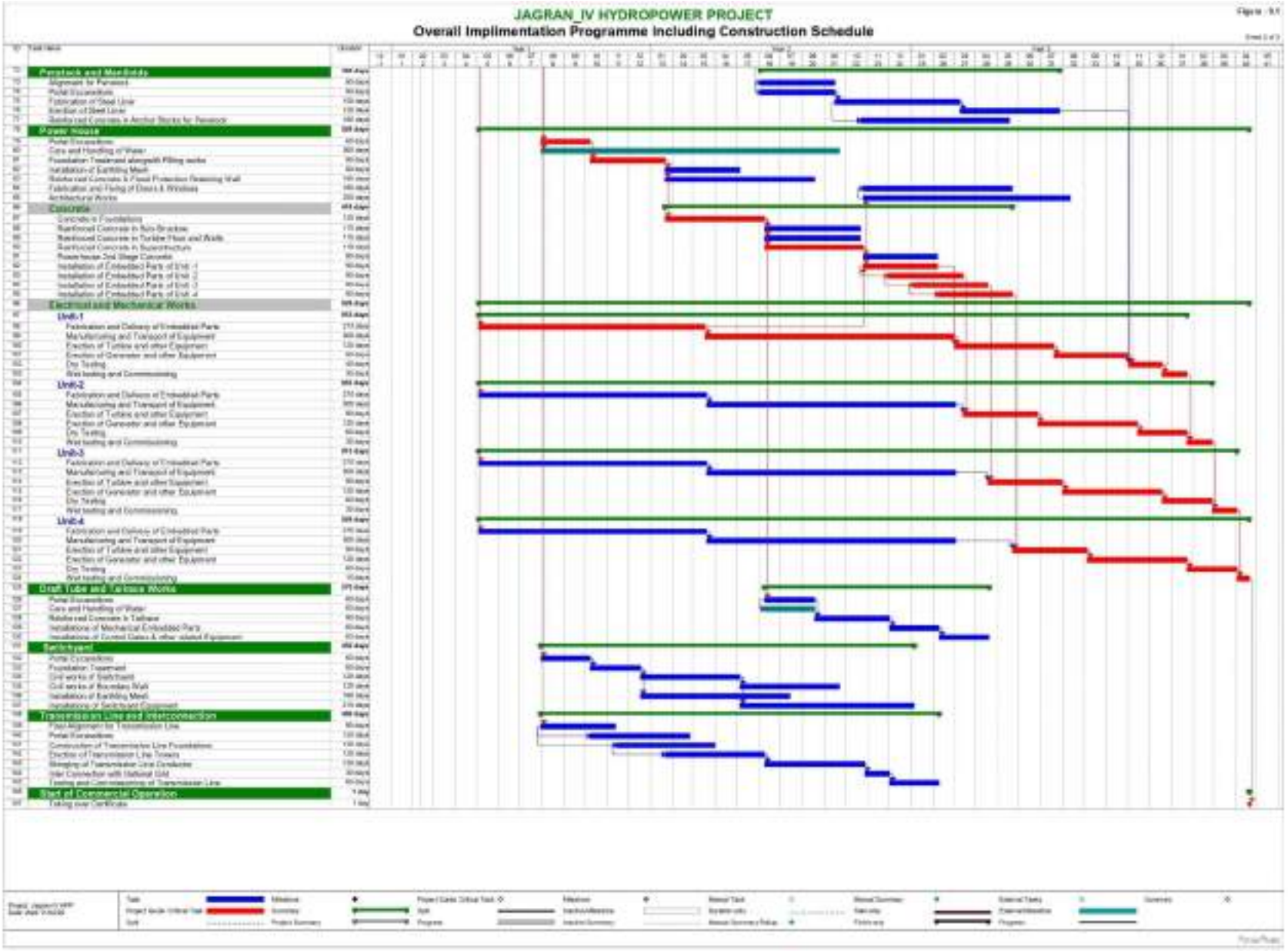
9.15 Testing and Commissioning

The work on commissioning of the units will be taken up in stages starting from 35th month and will include dehydration of the transformers and testing of switchgear. All relays will be calibrated by secondary injection tests. Primary current injection tests will be applied to all CT's and their ratios verified. Relay wiring will be checked and breakers tripped by manual operation of each relay. The turbines will be given no-load mechanical runs to ensure vibration free operation and to check temperature rise of all bearings. Generators will be dried out using standard procedure. After dry out, voltage will be built up and phase sequence checked, and if correct, each machine will be synchronized with the system.

Load runs will be executed to ascertain smooth operation and normal temperature rise of all bearings and windings. If possible, response of each unit to stepped changes of load and voltage will be checked. Full load rejection will be compared with predicted values. If all the above tests and observations give satisfactory results, the station would be certified as fully commissioned. The activity is expected to be completed in three months period.

Figure 9-1: Construction Schedule Jagran IV Hydropower




JAGRAN_IV HYDROPOWER PROJECT
Overall Implimentation Programme Including Construction Schedule

JAGRAN-IV HYDROPOWER CONSULTANTS - (JHC)
Project Office: 36-M, Civic Centre, M Block, Model Town Extension, Lahore-54700
Phone: 92-42-35210147-48 Email: acejagranivhpp@gmail.com

Ref. No. DHS/31/185

Date: November 14, 2025

Project Director

22 MW Jagran-IV Hydropower Project
AJ&K Power Development Organization (AJ&K PDO),
PDO Complex, Upper Chatter,
Muzaffarabad, Azad Kashmir, Pakistan

Project: **CONSULTANCY SERVICES FOR DESIGN REVIEW, CONSTRUCTION SUPERVISION AND MANAGEMENT OF 22 MW JAGRAN-IV HYDROPOWER PROJECT**

Subject: **Submission of Feasibility Study and Design Review Report**

Dear Sir,

As per Appendix-B of the Consultancy Services Agreement (CSA), we are pleased to submit two copies of the subject Feasibility Study and Design Review Report for your review, comments and approval.

Based on the updated Feasibility Study Report, we will firm up the tender level design, prepare tender drawings and incorporate in the draft tender documents.

Thanking you and assuring you of our best professional services at all times, we remain.

Best Regards,

Farooq Ahmad
Dy. Regional Head (North)
ACE Regional Office (N), Lahore

Encl: As stated above

Copy for information:
1. Regional Head (North) ACE Regional Office (N), Lahore
2. JV Partners

AJK POWER DEVELOPMENT ORGANIZATION

JAGRAN-IV HYDROPOWER PROJECT (22 MW)
DISTRICT NEELUM, AZAD JAMMU & KASHMIR

Feasibility Study and Design Review Report

November 2025

Associated Consulting Engineers - ACE Limited (Lead Firm)
1-C/2, M.M. Alam Road, Gulberg-III, Lahore – Pakistan. Tel: +92 42 35759417 - 19

Saud Consult Saudi Consulting Services Company, KSA

Rehman Habib Consultants (RHC) Lahore
160 Khayaban e Jinnah, Airline Society, Lahore - Pakistan. Tel: +92 42 35229624 - 25

Documents / Report Control Form:

Project Name	Jagran-IV Hydropower Project
Report Name	Feasibility Study and Design Review Report
Execution	Azad Jammu & Kashmir Power Development Organization (AJ&K PDO)
Report for	PD Jagran-IV Hydropower Project (AJ&K PDO)

Preparation, Review and Authorization:

Revision	Date	Prepared by	Reviewed by	Approved for Issue by
0-00	14th November, 2025	Project Team	Farooq Bhutta	Muhammad Abbas

Issue Register:

Distribution List	Date issued	Number of Copies
PD Jagran-IV Hydropower Project (AJ&K PDO)	14th November, 2025	2

MANAGEMENT CONSULTANCY SERVICES FOR CONSTRUCTION OF

22 MW JAGRAN-IV HYDROPOWER PROJECT AT JAGRAN RIVER

FEASIBILITY STUDY AND DESIGN REVIEW REPORT

Table of Contents

SECTION - 1: INTRODUCTION 1

1.1 Background 1

1.2 Salient Features of Jagran-IV Hydropower Project 3

SECTION - 2: TOPOGRAPHIC SURVEY 6

2.1 General 6

2.2 Review of Feasibility Study, 2010 6

2.3 Review of Third Party Validation Study, 2021 6

2.4 Comparison of Previous Studies 6

2.5 MC Observations 7

SECTION - 3: HYDROLOGY AND SEDIMENTATION STUDIES 5

3.1 General 5

3.2 Review of Previous Studies 5

3.3 Catchment Conditions 5

3.4 Hydro meteorological Stations 7

3.5 Climatic Data 8

3.5.1 Precipitation Data 8

3.5.2 Temperature Data 10

3.6 River Flows 11

3.6.1 Review of Feasibility Study, 2010 11

3.6.2 Review of Third Party Validation Study, 2021 12

3.6.3 MC Observations 14

3.7 Design Flood Studies 16

3.7.1 Review of Feasibility Study, 2010 16

3.7.2 Review of Third Party Validation Study, 2021 16

3.7.3 Review of Flood Studies of Jagran-I Hydropower Project 16

3.7.4 Review of Preliminary Flood Studies of Jagran-II Hydropower Project 17

3.7.5 Review of Detailed Design Flood Studies of Jagran-II Hydropower Project 17

3.7.6 MC Observations 20

3.8 Sedimentation Studies 21

3.8.1 Review of Feasibility Study, 2010 21

3.8.2 Review of Third Party Validation Study, 2021 23

3.8.3 Review of Sedimentation Studies of Jagran-II Hydropower Project 23
3.8.4 MC Observations 24
SECTION - 4: GEOLOGICAL & GEOTECHNICAL STUDIES 25
4.1 General 25
4.2 Review of Geological Data 25
4.2.1 Regional Geology and Tectonics 25
4.2.2 Site-specific Geologic Mapping 26
4.2.3 Rock Units 28
4.2.4 Rock Mass Assessment 29
4.2.5 MC Observations on Geological Data 33
4.3 Review of Geotechnical Data 33
4.3.1 Borehole Investigations 34
4.3.2 Test pits 34
4.3.3 Subsurface Strata Characterization 34
4.3.4 MC Observation on Geotechnical Data 40
4.4 Review of Construction Material Studies 45
4.4.1 MC Observations on Construction Material Studies 46
4.5 Review of Seismic Hazard Study 47
4.5.1 MC Observations on Seismic Hazard Study 47
4.6 Review of Geotechnical Design of Hydraulic Structures–Previous Studies 47
4.6.1 Geotechnical Aspects of the Proposed Diversion Weir 47
4.6.2 Geotechnical Aspects of the Proposed Connecting Channel and Sand trap 48
4.6.3 Geotechnical Aspects of the Proposed Pressure Pipe 49
4.6.4 Geotechnical Aspects of the Proposed Powerhouse 50
4.6.5 MC Observation on the Geotechnical Design of Hydraulic Structures 52
4.7 MC Summary Observations 55
SECTION - 5: PROJECT LAYOUT AND HYDRAULIC DESIGN REVIEW 59
5.1 General 59
5.2 Review of Feasibility Study, 2010 59
5.2.1 Weir (Overflow Structure & Under Sluice) 59
5.2.2 Power Intake Structure 62
5.2.3 Connecting Channel 63
5.2.4 Sand Trap / Desilting Basin 63
5.2.5 Low-Pressure Pipe 65
5.2.6 Penstock Pipe 67

5.2.7 Surge Pipe 68
5.3 Third Party Validation Study, 2021 70
5.3.1 Project Layout 70
5.3.2 Weir & Intake 72
5.3.3 Approach Channel 72
5.3.4 Desilting Basin (Sand Trap) 73
5.3.5 Headrace Conveyance (Embedded Pressure Pipe) 74
5.3.6 Surge Arrangement & Penstock Concept 75
5.4 MC Observations 76
5.4.1 Weir 76
5.4.2 Power Intake 79
5.4.3 De-silting Basin 81
5.4.4 Lowe Pressure Pipe and Penstock 82
5.4.5 MC Proposed Project Layout 85
5.5 MC Key Observations 85
5.6 Way Forward 86
SECTION - 6: PROJECT SIZING AND POWER POTENTIAL 89
6.1 General 89
6.2 Review of Feasibility Study Report, 2010 89
6.3 Review of Third Party Validation Study, 2021 89
6.4 MC Observations 90
6.5 Way Forward 91
SECTION - 7: STRUCTURAL DESIGN REVIEW 98
7.1 General 98
7.2 Powerhouse 98
7.3 Tailrace: 99
7.4 Low Pressure Head Race Penstock: 99
7.5 Road Crossing: 100
7.6 Anchor Blocks: 100
7.7 Surge Pipe: 100
7.8 Diversion Weir: 101
7.9 Miscellaneous Devises on Diversion Weir 101
7.10 Intake Structure, Connecting Channel and Desander Assembly 102
7.11 Pressure Pipe: 102
7.12 MC Observations 103

SECTION - 8: HYDRO MECHANICAL EQUIPMENT 104

8.1 General 104

8.2 Selection of Type of Turbine 106

8.3 Main Design Parameters 107

8.3.1 Turbine 107

8.4 Horizontal OR Vertical Francis Turbine 109

8.5 Inlet Valve 109

8.6 Codes and Standards 109

8.7 Mechanical Auxiliaries 110

8.8 Hydraulic Steel Structures 110

8.9 MC Observations 111

SECTION - 9: ELECTRICAL EQUIPMENT 112

9.1 General 112

9.2 MC Observations 112

9.2.1 Generating Common Bus-bars Comparison with Direct Connection to Own Transformer 112

9.2.2 Synchronous Generator 113

9.2.3 Generator Grounding Transformer 113

9.2.4 Generator Step- Up Transformer 113

9.2.5 Neutral Grounding Current Transformer 113

9.2.6 Switchyard (132kV) 113

9.2.7 Synchronization of Generators 113

9.2.8 Auxiliary Transformers (Station Transformers) 113

9.2.9 Diesel Generator 114

9.2.10 Medium Voltage Switchgear (11kV) 114

9.2.11 Grounding System 114

9.2.12 Low Voltage Boards 114

9.2.13 DC Power Supply 114

9.2.14 Plant Control Unit Control and Alarm System 115

9.2.15 Protection Equipment 115

9.2.16 Metering Scheme 115

9.2.17 11kV feeder to Intake 115

9.2.18 Fire detection and alarm system 115

9.2.19 Security surveillance system 115

9.2.20 Transmission Line 115

9.3 Feasibility Level Drawings 116
9.4 Way Forward 116
SECTION - 10: INITIAL ENVIRONMENTAL EXAMINATION (IEE) REPORT 117
10.1 General 117
10.2 Regulatory Background 117
10.3 Conditions of Environmental Approval 117
10.4 Review of Environmental Approval Validity 117
10.5 MC Observations on Environmental Approval 118
10.6 Reconfirmation of Institutional Arrangements: 118
10.7 Social Aspect 118
10.7.1 Land Requirements and Asset Impacts 119
10.7.2 Affected Persons and Assets 119
10.7.3 Project-Affected Persons (PAPs) and Households (PAHs) 119
10.7.4 Resettlement Planning and Compensation 120
10.7.5 Quantification of Livelihood Losses 120
10.7.6 Stakeholder Engagement and Consultation 120
SECTION - 11: COST ESTIMATES 127
11.1 General 127
11.2 Review of Feasibility Study, 2010 127
11.3 Review of Third party Validation Study, 2021 128
11.4 MC Observation 130
SECTION - 12: CONSTRUCTION PLANNING 131
SECTION - 13: ECONOMIC AND FINANCIAL ANALYSIS 133
13.1 Economic Analysis 133
13.2 Financial Analysis 133
13.3 Tariff 133
13.4 Other Parameters 133
SECTION - 14: CONCLUSION AND RECOMMENDATIONS 135
14.1 Conclusions 135
14.2 Recommendations 139
14.2.1 Recommendation for Tender Level Design Studies 139
14.2.2 Recommendation for Detailed Engineering Design Studies by EPC Contractor 140

List of Tables

Table 1-1: Salient features of the proposed Jagran-IV Hydropower Project....4
Table 2-1: Comparison of Previous Studies....7
Table 3-1: List of Hydro meteorological Station in the Region....7
Table 3-2: Long Term Climatic Stations in Jhelum River Basin....8
Table 3-3: MC Proposed Flow Duration Curve at Weir Site Jagran-IV HPP....15
Table 3-4: Comparison of Flood Estimates (FS, 2010)....16
Table 3-5: Annual Maximum Observed Floods at Muzaffarabad (1963-14)....17
Table 3-6: Annual Maximum Estimated Floods at Jagran-II Weir Site (1963-14)....18
Table 3-7: Adopted Floods at the Weir and Powerhouse sites of Jagran-II HPP....20
Table 3-8: MC Proposed Design Floods at Weir site of Jagran-IV HPP....21
Table 4-1: Rock Units in the Neelum Valley (Nausehri to Kel)....27
Table 4-2: Factors contributing to the RSR Calculations....30
Table 4-3: RMR Values for the Pipe Outlet Area (FS, 2010)....31
Table 4-4: Factors contributing to the RMR Calculations....31
Table 4-5: Factors contributing to the Q-Index Calculations....32
Table 4-6: MC Summary Observations on Geotechnical Studies....55
Table 5-1: Salient Features Weir and Under Sluice / Flushing Channel-FS 2010....59
Table 5-2: Salient features for the Power Intake –FS 2010....62
Table 5-3: Salient Features of the Connection Channel-FS 2010....63
Table 5-4: Salient Features for Sand Trap-FS 2010....64
Table 5-5: Salient Features of Low Pressure Pipe-FS 2010....66
Table 5-6: Salient Features of Penstock Pipe-FS 2010....67
Table 5-7: Salient Features of Surge Pipe-FS 2010....69
Table 5-8: Salient Features of TPV Proposed Layout....70
Table 5-9: Salient Features Weir and Intake Structures-TPV 2021....72
Table 5-10: Salient Features of the Approach Structures-TPV 2021....73
Table 5-11: Salient Features of the Desilting Basin-TPV 2021....73
Table 5-12: Salient Features of the Headrace Conveyance-TPV 2021....74
Table 5-13: Salient Features Surge Arrangements and Penstock Pipe-TPV 2021....76
Table 5-14: Comparison of the Studies – Weir Layout....78
Table 5-15: Comparison of the Studies – Power Intake Layout....79
Table 5-16: Comparison of the Studies – Desilting Basin Layout....81
Table 5-17: Comparison of the Studies – Low Pressure Pipe Layout....83
Table 7-1: Concrete Classes, Tender Design Report (Feasibility Study, 2010)....99

Table 7-2: ASTM A 516 Four Grades of Pipes.....102
Table 8-1: A matrix of the gap analysis of the FSR -2010.....104
Table 8-2: Comparison of Turbine Salient Features.....108
Table 10-1: Summary of Affected Assets and Structures.....119
Table 11-1: Component Wise Cost Updated July 2021 (TPV, 2021) 129

List of Figures

Figure 3-1: Catchment Area of Jagran River (FS, 2010) 6
Figure 3-2: Location of Hydro Meteorological Stations (Jagran-II Project Report) 7
Figure 3-3: Total Annual Precipitations at Muzaffarabad Climate Station 9
Figure 3-4: Total Annual Precipitations at Naran Climate Station 9
Figure 3-5: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station 10
Figure 3-6: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station 10
Figure 3-7: Mean Annual Flows at Proposed Weir Site– Jagran River (FS, 2010) 12
Figure 3-8: Mean Monthly Flows at Proposed Weir Site– Jagran River (FS, 2010) 12
Figure 3-9: Nausehri Viz Thunian Correlation (TPV, 2021) 13
Figure 3-10: Comparison of Observed & Extended Flows at Thunian Station (TPV, 2021) 14
Figure 3-11: Estimated Mean Annual Flows at Proposed Weir Site of Jagran-IV HPP 14
Figure 3-12: Flood Estimated with Log Pearson Type-III Data (Jagran-II Flood Study) 20
Figure 3-13: Suspended Sediment Rating Curve for Nausehri Station (FS, 2010) 22
Figure 4-1: Tectonic map of Northern Pakistan (FS, 2010) 26
Figure 4-2: Geological Map of the Site 27
Figure 4-3: Typical view of the large boulders along the riverbanks (FS, 2010) 35
Figure 4-4: Cored samples from boulders at greater depths (17.0-26.0 m) (FS, 2010) 35
Figure 4-5: Typical view of the glacial/moronic overburden deposits exposed in a test pit excavated at the site (FS, 2010) 36
Figure 4-6: Surface geological map of the proposed weir area, showing the extent of the overburden strata (yellow) and the granite rock outcrop (red) 37
Figure 4-7: Geological section of the proposed weir area (FS, 2010), showing the extent of the overburden strata and the granitic gneiss bedrock 37
Figure 4-8: Geological section along the proposed pressure pipe (FS, 2010), showing the extent of the overburden strata and the granitic gneiss bedrock. 38
Figure 4-9: Geological section along the proposed penstock and surge pipe (FS, 2010), showing the extent of the overburden strata and the granitic gneiss bedrock. 39
Figure 4-10: The proposed powerhouse location according to FS, 2010 & TPV, 2021 40
Figure 4-11: Proposed ERTs at the MC proposed diversion weir location 42
Figure 4-12: Proposed ERTs at the MC proposed powerhouse location 42
Figure 4-13: Designed Weir Section according to FSR 2010 and 2021 TVR. 48
Figure 4-14: Subsurface Cross-section at the proposed Sand trap location (FS, 2010) 49
Figure 4-15: Subsurface cross-section along proposed low-pressure pipe (FS, 2010) 49
Figure 4-16: Proposed powerhouse locations according to FS, 2010 & TPV, 2021 51

Figure 4-17: Subsurface cross-section along the proposed powerhouse showing the required excavation in the overburden material (FS, 2010). 52

Figure 4-18: An active slide on the right bank of the river at the proposed weir site in TPV, 2021 (yellow line). MC's proposed site is marked with a blue line, while the one proposed in the FS, 2010 is marked with a red line. 53

Figure 4-19: Powerhouse locations based on FS 2010, TPV, 2021 and MC, 2025 54

Figure 5-1: Plan and Sections of Weir (FS, 2010) 61

Figure 5-2: Plan and Sections of Power Intake – FS 2010 62

Figure 5-3: Layout and Sections of the Sand Trap (FS-2010) 65

Figure 5-4: Low Pressure Pipe (FS-2010) 67

Figure 5-5: Penstock Pipe (FS-2010) 68

Figure 5-6: Layout and Section of Surge Pipe (FS-2010) 69

Figure 5-7: Layout Plan of Weir and Powerhouse Locations (TPV-2021) 71

Figure 5-8: Layout Plan and X-section of the Low Pressure Pipe (TPV-2021) 75

Figure 5-9: Location of the Weir Site 77

Figure 5-10: Photographs of the proposed Weir Site by the MC (looking upstream of the Jagran River) 77

Figure 5-11: MC Proposed Project Layout Plan 85

Figure 7-1: Illustration of Check Dams 101

Figure 8-1: Hill Chart for Selection of Turbine Types 107

SECTION - 1: INTRODUCTION

1.1 Background

Pakistan since long facing an affordable and sustainable Energy generation and distribution crises though Almighty Allah has blessed our country. Total hydropower potential in Pakistan is assessed to be more than 60,000 MW, of which more than 8,000 MW is available in the Pakistani-administrated territory of Azad Jammu & Kashmir (AJ&K). Water and Power Development Authority (WAPDA) is the main central Government body responsible to develop power sector at federal level.

To explore and develop hydropower potential, the government of AJ&K created Hydro Electric Power (HEP) Board in 1989 which was later re-organized to Azad Jammu & Kashmir Power Development Organization (AJK PDO) under the AJK PDO Act 2014.

The Government of Azad Jammu & Kashmir has decided to undertake the implementation of 22 MW Jagran-IV Hydropower Project through AJK PDO. The project is being financed by Saudi Fund for Development (SDF). National objective of the project is to add a cheap and environment friendly, hydropower project into the system. This may help to reduce load shedding in the country up to some extent. In addition to national 'objective, Azad Jammu & Kashmir will be able to explore its valuable renewable resource and earn revenues from this project by selling power to the national grid.

District Neelum

The proposed Jagran-IV Hydropower Project is situated on the Jagran River in District Neelum, Azad Jammu and Kashmir. Neelum District is the northernmost and largest district by land area in the Pakistani-administered territory of Azad Kashmir, located in the disputed Kashmir region. It is famous for the Neelum Valley, a picturesque area along the Neelum River, known for its natural beauty and a destination for tourists. The district headquarters is in Athmuqam.

The Project

The proposed Jagran-IV Hydropower Project is identified on the intermediate stretch of Jagran River and forming the most upstream project in the Jagran river cascade hydropower projects. In the downstream, the **Jagran-I Hydropower Project** has already been constructed. In the further downstream, the **Jagran-II hydropower project** is currently under construction. At the most downstream, the **Jagran-III hydropower project** has been proposed, however, yet no construction activities have been started.

The official name of the project is

"Construction of 22 MW Jagran-IV Hydropower Project at Neelum River".

Jagran-IV project is located on the left bank of Jagran River about 18 km from its confluence with Neelum River at Kundal Shahi. Kundal Shahi is a main village on Neelum valley road located about 74 km from Muzaffarabad. The travel time from Muzaffarabad to Jagran River at Kundal Shahi is about 4 hours and 1 ½ hours is required from Kundal Shahi to the proposed diversion weir. The powerhouse has been identified just about 0.20 km upstream of existing intake of Jagran - I HPP.

The Project Feasibility Study was prepared by M/s Fida Hussain Chaudry (FHC) Consulting Engineers in associated with M/s Scott Wilson Limited in October 2010. The capacity of the proposed project is determined as 22 MW.

In April 2021, the Power Development Organization (PDO) Azad Jammu and Kashmir contracted with M/s INTEGRATION e&e, PES and Integration Energy (Consultant) was contracted to Review and Validate the FS report, conduct the Topo Survey and supervise the Geotechnical investigation executed by sub-contractor, M/ Universal Drilling Engineers.

Based on the new Topo Survey, and site visits of consultant's experts, the Third-Party Validation (TPV) Consultant reviewed the feasibility study project layout and designs and proposed changes to the salient features of the project conceived in the Feasibility Studies.

AJK Power Development Organization (AJK PDO) intended to implement the hydro power project namely "Jagran-IV Hydropower Project at Jagran River" through International Competitive Bidding (ICB).

Consultants were invited through a Request of Proposal (RFP) for the Consultancy Services. A joint venture (JV) of Associated Consulting Engineers - ACE Limited, Saud Consultant and Rehman Habib Consultants (RHC) Lahore submitted their Technical and Financial Proposal.

After a nationwide competitive process by AJK Power Development Organization (AJK PDO) and Government of AJK, the Consultancy Services Agreement of Management Consultancy Services for 22 MW Hydro Power Project Jagran-IV, District Neelum (AJK) was awarded to joint venture (JV) of ACE, Saud Consult and RHC Consultants. Contract Agreement was signed between the Client and Consultants on August 15, 2025.

In accordance with the Consultancy Agreement, the Feasibility Study (FS) Report, 2010 and Third Party Validation (TPV) Report 2021 have been reviewed by the Experts of the Management Consultants (MC) and prepared this Feasibility Study and Design Review Report. This report identifies the deficiencies in the Feasibility study and design and proposes required improvements. The detailed comments follow this introduction; however, some important comments which have a major bearing on the Project are outlined:

1. The Client and the MC experts performed a site reconnaissance visit from 15 to 19, October, 2025 to the Jagran-IV hydropower project area. The visiting experts performed visual observation of the various layouts already studied in previous studies and authenticates all the locations at site for major components of the proposed layout. The visiting experts also performed visual observation of various structures of existing Jagran-I and under construction Jagran-II Hydropower Projects.

   Based on above site reconnaissance visit, the MC has proposed relocating the weir upstream from the TPV, 2021 position to bypass an active right-abutment landslide. The site chosen by the MC has relatively stable abutments.

   Based on above site reconnaissance visit, the MC also witnessed that the proposed powerhouse site in Feasibility Study, 2010 may face slope stability problems due to the necessary slope cutting for the powerhouse and penstock. The Third Party Validation Study, 2021 proposed site was found situated right at the mouth of a watershed valley. Therefore, considering the overall landslide activity in the valley and the specific characteristics of this watershed, mudflows or debris flows are highly likely. Due to these potential hazards, the MC has proposed moving the powerhouse further downstream.

2. The Third Party Validation (2021) consultants conducted topographic survey refined project elevations and sitting compared with Feasibility Study, 2010. Therefore, for preparing the tender level design and drawings, the MC has proposed to utilize the TPV consultants conducted topographic survey. However, for Detailed Engineering Design to be conducted by the EPC Contractor, it is proposed to conduct fresh topographic, bathymetric and LiDAR survey (along the route of the penstock pipe) by using the most

updated available techniques. This item will be included in the employer requirements of the EPC contractor.

3. During the above site reconnaissance visit, the MC experts witnessed the devastating effects of flood 2010 in the Jagran River. During the flood 2010, the under sluice gates installed at the weir of Jagran-I hydropower project were washed away. The flood 2010 also caused destruction to houses and switchyard of Jagran-I hydropower project was completely demolished. The rehabilitation of damaged infrastructure resulted in loss of money as well as shutdown of the power plant for about 1-year period. Therefore, estimation of reliable floods for the Jagran River is crucial to ensure the safe operation of the hydropower structures e.g. weir and powerhouse.

   On the other hand, the review of the flood studies undertaken in the Feasibility study, 2010 revealed that these studies are outdated as no flood data of 2010 has been considered. Also, no flood updation studies were undertaken in the Third Party Validation Study, 2021. Therefore, the MC has also reviewed the flood studies of the existing Jagran-I and under construction Jagran-II hydropower projects.

   Based on above, the MC has proposed to enhance the design flood to 954 m^3/s for the design of weir (catchment area =205 Km^2) and 979 m^3/s for the design of powerhouse flood protection wall (catchment area = 216 Km^2). The proposed flood protection level corresponds to 1000 return period flood. The above proposed design floods for Jagran-IV hydropower project are found in line with the design flood of 1000 m^3/s adopted at Jagran-I weir site (catchment area = 221 Km^2). The proposed design floods are also found in line with design floods of 1078 m^3/s and 1253 m^3/s adopted at the weir site (catchment area = 262 Km^2) & powerhouse site (catchment area = 354 Km^2) of Jagran-II hydropower project.

4. Based on information and data from boreholes, test pits, and geological mapping provided in the previous studies, it is confirmed that rock is not exposed at any of the proposed project sites. The available geological and geotechnical data from the Feasibility Study, 2010 and Third Party Validation Study, 2021 do not seem to be sufficient to develop the tender designs and drawings. Several key inputs needed for the design of the foundations and other structural elements require additional and targeted investigations.

   In light of above, the Consultants has already sent request to the Client vide letter No. DHS / 31 / 168 Dated 20-10-2025 for additional investigation including ERT (Electrical Resistivity Tomography), SRT (Seismic Refraction Tomography) and Construction Material Testing to be performed on priority before weather conditions become unfavorable for further investigations. Similarly, for Detailed Engineering Design to be conducted by the EPC Contractor the MC has also proposed geological and geohazard mapping and drilling of bore holes of at least 50 m depth. This item will be included in the employer requirements of the EPC contractor.

1.2 Salient Features of Jagran-IV Hydropower Project

The salient features of the project in the FS and Third-Party Validation Study (TPV), 2021 have been reviewed by the MC. Based on the above reviews and site reconnaissance visit of consultant's experts, these features have been reviewed which shall be updated during the preparation of tender level design and drawings of the project. For comparison purposes it has been summarized in **Table 1.1**.

Table 1-1: Salient features of the proposed Jagran-IV Hydropower Project

Description	Project Features		
	Feasibility Study (FS), 2010	**Third Party Validation Study (TPV), 2021**	**Feasibility Study and Design Review Report (This Report)**
Catchment Area	Weir site = 214 Km^2 PH site = Not proposed	Weir site = 205 Km^2 PH site = Not proposed	Weir site = 205 Km^2 PH site = 216 Km^2
Gross Head	156 m	169 m	Approx. 180 m
Net Head	144.2 m	158.44 m	To be firm up in the tender level design
Total Design Flow	18 m^3/s	16 m^3/s	16.1 m^3/s
Design Flow per Unit	4.9 m^3/s for three units & 3.27 m^3/s for one unit	4.83 m^3/s for three units & 1.45 m^3/s for one unit	To be firm up in the tender level design
Turbines	Francis-Vertical,	Francis Horizontal proposed as land is available at the proposed site	Francis-Vertical,
Units	3x6MW & 1x4MW	3x6.67 MW & 1x2 MW	To be firm up in the tender level design
Efficiency of Turbine	91 %	92.5%	92.5% (To be firm up in the tender level design)
Efficiency of Generator	96 %	97 %	97% (To be firm up in the tender level design)
Firm Power	2.3 MW	1.25 MW	To be firm up in the tender level design
Total Energy Generation/annum	93.29 GWh	91.8 GWh	91.04 (To be firm up in the tender level design)
Plant Factor	51.25 %	50%	47.231% (To be firm up in the tender level design)
Design Floods	• Design discharge of weir = 419 m^3/s • PH flood protection wall = Not proposed :	• Design discharge of weir = Not proposed • PH flood protection wall = Not proposed	• Design discharge of weir = 954 m^3/s • PH flood protection wall = 979 m^3/s
Weir	H=6 m L=24 m	Weir axis is proposed 120 m downstream of previous location and with change in weir location, dimensions may change	Weir axis is proposed to be relocated upstream of TPV, 2021 study proposed location.
Connecting Channel	3.4x2.8 RCC and L=110 m	With change in weir location, dimensions may change	The alignment and sizing shall be firm up in the tender level design.

Description	Project Features		
	Feasibility Study (FS), 2010	**Third Party Validation Study (TPV), 2021**	**Feasibility Study and Design Review Report (This Report)**
Sand Trap	2 (7mx56m)	To be changed according to 16 m^3/s design flow	The alignment and sizing shall be firm up in the tender level design. The sediment removal upto 0.25 mm dia shall be considered.
Headrace Pipe	L= 3,075m, Dia 2.5 m	Steel Penstock pipe 2.4 m dia. is proposed instead GRP with reduced length of 2,730 m	The alignment and sizing shall be firm up in the tender level design.
Surge Pipe	L= 52m, Dia = 5 m	Surge pipe is to be increased to 180 m or bypass surge relief valve to be installed with each turbine to ensure continuity of flow for the downstream power stations to avoid break down.	To be firm up in the tender level design
Penstock	L = 180m, Dia = 2.5 m	This Pressure pipe penstock is not required.	MC principally agrees with the TPV study approach
Powerhouse	L=35.4m W10m	Powerhouse site is proposed 40 m upstream of previous location with orientation favoring outflow into Jagran River.	Relocation from TPV site is proposed to avoid mouth of a watershed valley
Tail Race	L=20 m	Will change according to new location	Will change according to new location.
Generation Voltage	11 kV	11 kV	11 kV
Power Dispatch	132 kV	132 kV	132 kV
Project Cost	$US 43.249 million	$US 49.173 million	To be firm up in the tender level design

SECTION - 2: TOPOGRAPHIC SURVEY

2.1 General

This chapter reviews and synthesizes the topographic and surveying performed during the Feasibility Study, 2010 and Third Party Validation Study, 2021 and proposes further studies using state-of-the-art practice. The review covers (i) survey datasets and methods; (ii) baseline terrain and longitudinal river profile; (iii) changes since 2010 (including flood-related geomorphic shifts); (iv) accuracy, control, and data management; and (v) survey requirements to support detailed design and construction.

2.2 Review of Feasibility Study, 2010

The Feasibility Study, 2010 survey established plan and height control at the weir and powerhouse through terrestrial traverses and precise spirit leveling, referenced to UTM-43N on WGS-84. Where the headrace corridor was inaccessible, the team bridged gaps with satellite-derived elevation models tied back to the ground control.

The core base consisted of ASTER stereo DEM (~10 m pixels, practical vertical accuracy on the order of 5–10 m) complemented by SPOT-5 imagery (2.5 m panchromatic, 10 m multispectral), which was pan-sharpened and orthorectified. Processing involved DEM mosaicking, void filling, and smoothing for stable contour generation; orthorectification and map compilation were carried out in ERDAS/ ArcGIS, with drafting in AutoCAD.

The end product was a corridor-wide surface with 2 m contours, locally merged to the terrestrial survey at structure pads.

2.3 Review of Third Party Validation Study, 2021

The Third Party Validation Study, 2021 introduced a dedicated topographic campaign spanning Shaal Nullah to the Jagran-I weir. Using digital total stations with EDM and auto-levels, the team established permanent benchmarks and survey marks, executed closed traverses and differential levelling, and produced longitudinal and cross-sections for river hydraulics alongside structure-scale mapping.

The working reference frame remained UTM-43N on WGS-84 for plan, with elevations reported as orthometric heights. The deliverables included 1:1000 mapping with 1 m contours within structure influence zones (roughly 100–600 m wide strips), plus L- sections and X-sections tied to control for design. Instrument calibrations and closure results were documented to confirm fitness for engineering use.

2.4 Comparison of Previous Studies

Table 2-1 gives comparison of survey work performed during the Feasibility Study, 2010- and Third-Party Validation Study, 2021:

Table 2-1: Comparison of Previous Studies

Aspect	FS, 2010	TPV, 2021
Survey scope	Structure areas (weir, powerhouse) by terrestrial survey; corridor infill via satellite DEM/imagery	Dedicated campaign from Shaal Nullah to Jagran-I; full L/X-sections + detailed structure mapping
Control & datum	Local traverses + spirit leveling; UTM-43N on WGS-84	Permanent BMs & marks; closed traverses; differential leveling; UTM-43N on WGS-84); orthometric heights
Primary data	ASTER stereo DEM (~10 m); SPOT-5 (2.5 m pan/10 m MS); pan-sharpened, orthorectified	Total station/EDM, auto-levels; ground sections and feature surveys
Mapping products	2 m contours; merged with ground survey near structures	1:1000 plans with 1 m contours (100–600 m strips); L/X-sections
Hydraulic sections	Long profile derived from mixed sources	Systematic L/X-sections tied to control
Banks/slope condition	Recognized steep, vegetated terrain; limited access	Confirms colluvial/fluvial overburden; large boulders; active slopes
QA/QC & metadata	Tool chain listed; limited closure reporting in text	traverse/levelling closures documented

2.5 MC Observations

1. Post 2010 morpho-dynamics and active slopes necessitate updated, high resolution topography prior to finalizing structure dimensions and river training works, as flagged in the Updated FS.
2. The Third Party Validation Study, 2021 topographic survey refined project elevations and sitting compared with Feasibility Study, 2010.
3. For preparing the tender level design and drawings, it is proposed to utilize the TPV consultant's topographic survey.
4. For Detailed Engineering Design to be conducted by the EPC Contractor, it is proposed to conduct fresh topographic, bathymetric and LiDAR survey (along the route of the penstock pipe) by using the most updated available techniques. This item will be included in the employer requirements of the EPC contractor.

SECTION - 3: HYDROLOGY AND SEDIMENTATION STUDIES

3.1 General

Hydrology and Sedimentation study presented in the Feasibility Report provide the hydro-meteorological parameters including; meteorological data, catchment area, river flows, flow duration curve, flood magnitudes for different frequencies and estimate of suspended as well as bed sediment load.

The ensuing paragraphs provide a review of key aspects dealt in the Feasibility study, 2010- and Third-party validation study, 2021:

3.2 Review of Previous Studies

The following reports and data have been collected and referred in this report:

1. Feasibility Report, Volume-1, October 2010 of Jagran-IV Hydropower Project
2. Third Party Validation of Feasibility Study & Design of 22 MW Jagran-IV Hydropower Project titled “Third Party Validation Report, July 12, 2021”.
3. Detailed Design Report prepared by Jirc Consortium and MMP Pakistan, 15 June, 1996, Main Report and Appendices I, II & III of Jagran-I Hydropower Project
4. Preliminary Design Report prepared by Jirc Consortium and MMP Pakistan, 30 January, 1998 of Jagran-II Hydropower Project.
5. Updation of Hydrology and Sedimentation Study Report of Jagran-II Hydropower Project titled as “Hydrology and Sedimentation, E314-B-D-002-Rev0, February 24, 2018”.

3.3 Catchment Conditions

The Jagran River basin falls in the climatological region called as subtropical continental high lands. The climate in the region is arid and characterized by cold snowy winters with general winter and spring rains. At higher altitudes, mountains are perpetually clad with snow.

The description of catchment show that river descends from mountain peaks at elevations of 5030.70 and 5021.00 m asl. The river along its length has a few tributaries joining the main stream from either bank.

The flows of Jagran River are generated with snow fall and rainfall in the catchment. Several glaciers are in its upper catchment above El. 4,000m. The catchment of Jagran River experience snowfall in winter months and receive rainfall in summer months. The intensive rainfall and snow results in high flows during summer months.

The elevation at its confluence with Neelum River is 1330 m asl. The average gradient of Jagran River in the project area is about 4.4%. Generally, the ground slopes on either bank of river are very steep.

Catchment area of the river at its confluence with Neelum River is about 430 km^2 & up to weir intake of Jagran-IV hydropower Project, it is 205 km^2. The MC has also confirmed the catchment area of 205 km^2 at the weir site of Jagran-IV hydropower Project by using the SRTM data with 30 m by 30 m through conducting watershed analysis with GIS technique.

Figure - 3.1 gives the catchment area map of Jagran River as given in Feasibility Study, 2010:

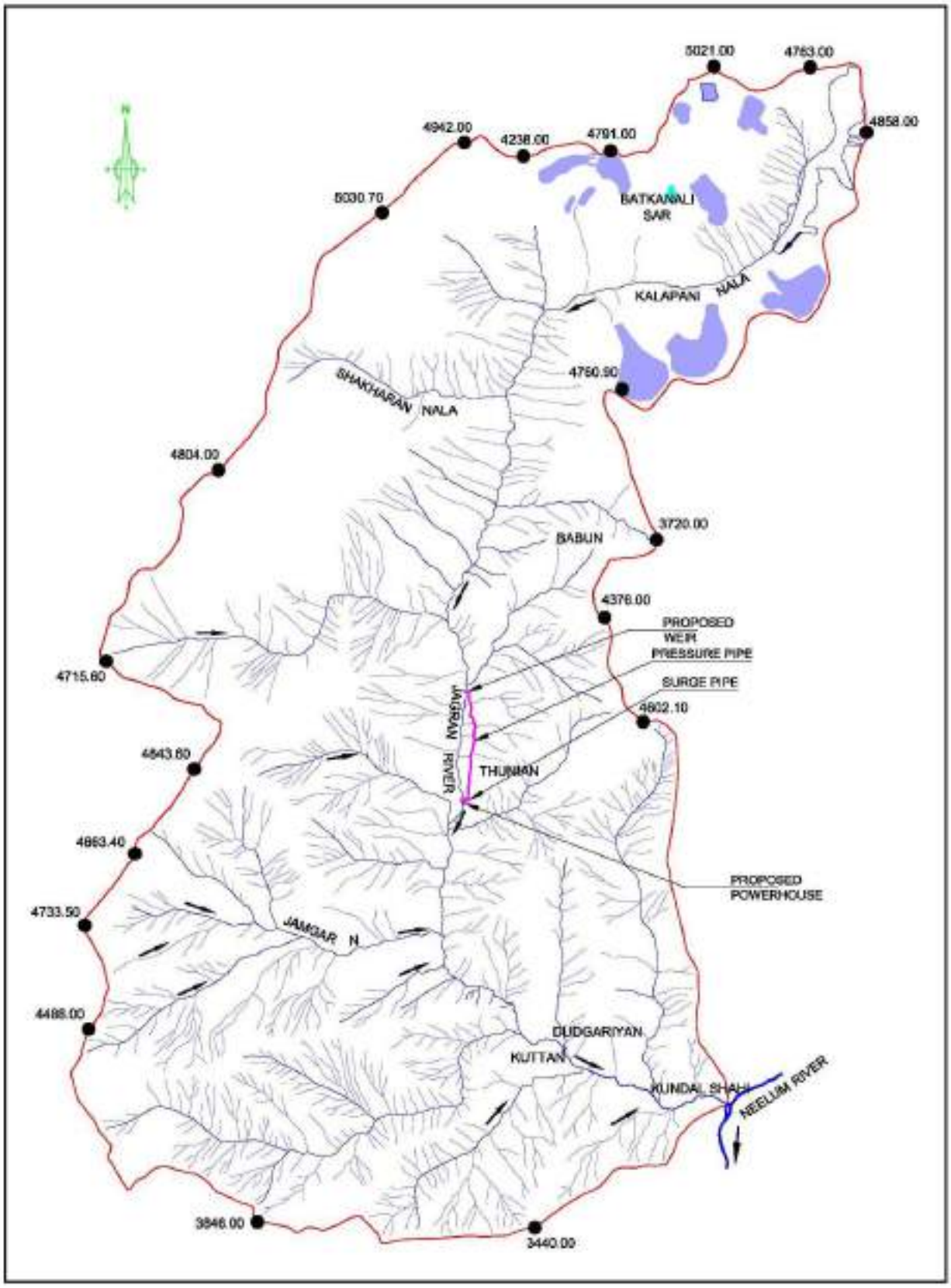


Figure 3-1: Catchment Area of Jagran River (FS, 2010)

3.4 Hydro meteorological Stations

The climatic and river flow measurement data in Neelum valley is very scarce. One station in Neelum valley with limited climate record is at Dudhnial. The nearest stations to project area with long term record are located at Muzaffarabad and Naran. The Kundal Shahi and Thunian stations installed on Jagran River provide valuable records but for very limited time period, these stations are no more operative. The list of hydro meteorological stations in the region as reported in Feasibility study, 2010 is presented in **Table 3-1**. The locations of the stations are shown in **Figure 3-2**. The coordinates needs to be confirmed.

Table 3-1: List of Hydro meteorological Station in the Region

Station / River	Location		Elevation (m asl)	Area (km²)	Period of Record	Mean Annual Flow (m^3/s)	Specific Flows ($l/s/km^2$)
	Latitude	Longitude					
Muzaffarabad	34°22’	73°28’	670	7278	1963-2006	337.6	46.2
Nausehri	34°23’	73°43’	1030	6809	1990-00	306.0	44.9
Dudhnial	34°42’	74° 7’	1823	4905	1980-92	259.2	52.8
Naran	35°27’	75°25’	2341	1036	1960-2000	48.0	46.3
Thunian	35°35’30”	75°18’50”	2150	219	July 94 to June 96	17.26	78.8
Kundal Shahi	35°27’22	75°18’40	1360	430	July 94 to June 96 Sep 82 to Aug	27.0	62.8
Taobut (Gagai)	35°35’30”	75°8’20”	2250	275	Jan 92 to June 95	19.35	70.4

Figure 3-2: Location of Hydro Meteorological Stations (Jagran-II Project Report)

3.5 Climatic Data

The climatic data in Neelum valley is very scarce. The nearest stations to project area with long term records are located at Muzaffarabad and Naran. The list of Climatological stations in the region is presented in **Table 3-2.**

Table 3-2: Long Term Climatic Stations in Jhelum River Basin

Station	Mean Annual Rainfall (mm)
Balakot	1718
Garhi Dopatta	1602
Dudhnial	1541
Muzaffarabad	1534
Bagh	1415
Sehr Kakota	1386
Rawalakot	1375
Kotli	1255
Palandri	1230
Mangla Dam	1221
Rehman Bridge	1132
Naran	1118
Kallar	945
Jhangi	921

Source: SWHP, WAPDA as reported in Feasibility Study, 2010

3.5.1 Precipitation Data

The one meteorological station with long record of precipitation is located at Muzaffarabad, at a distance of about 85 km from the project area. The precipitation data upto 2004 was available from the feasibility study, 2010. The data has been updated upto 2009 using the records available in the detailed design study report of Jagran-II hydropower project referred at Sr. No 5 in Section 3.2 of this report.

The total annual precipitation data of Naran stations was also collected from the above detailed design report and used.

Figure 3-3 and **3-4** gives the total annual precipitations measured at the Muzaffarabad and Naran stations respectively.

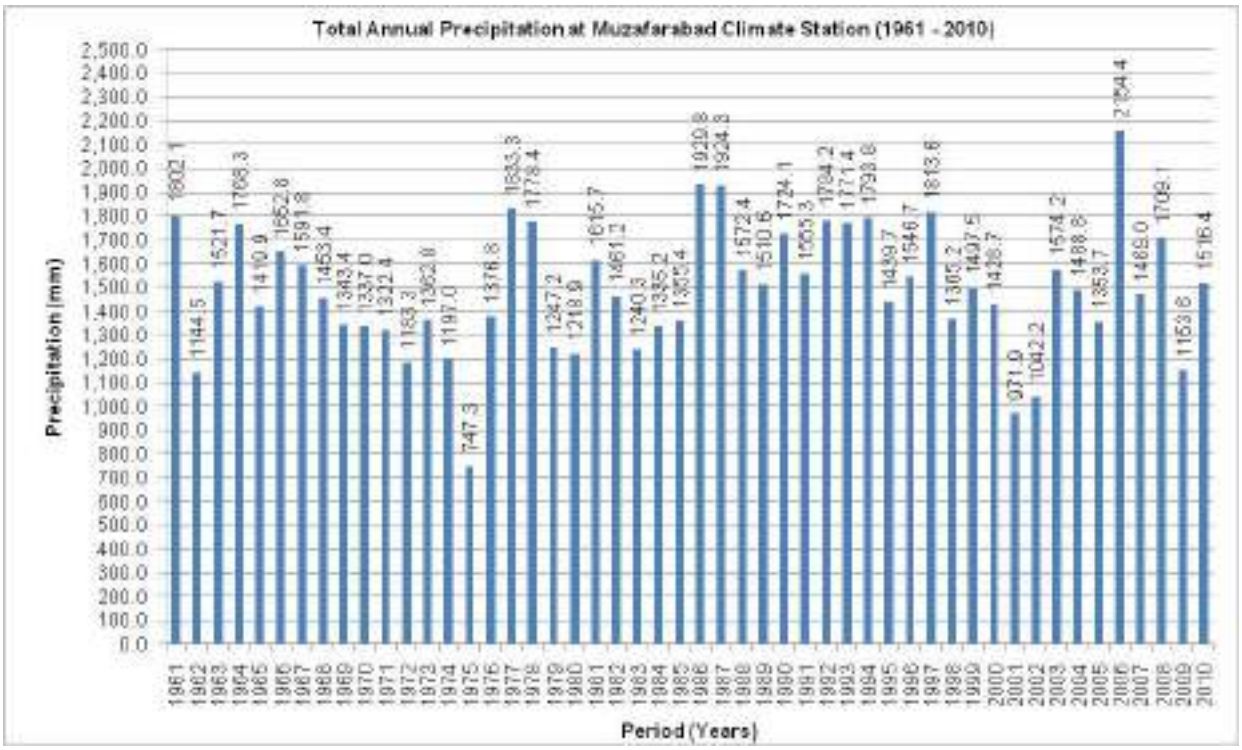


Figure 3-3: Total Annual Precipitations at Muzaffarabad Climate Station

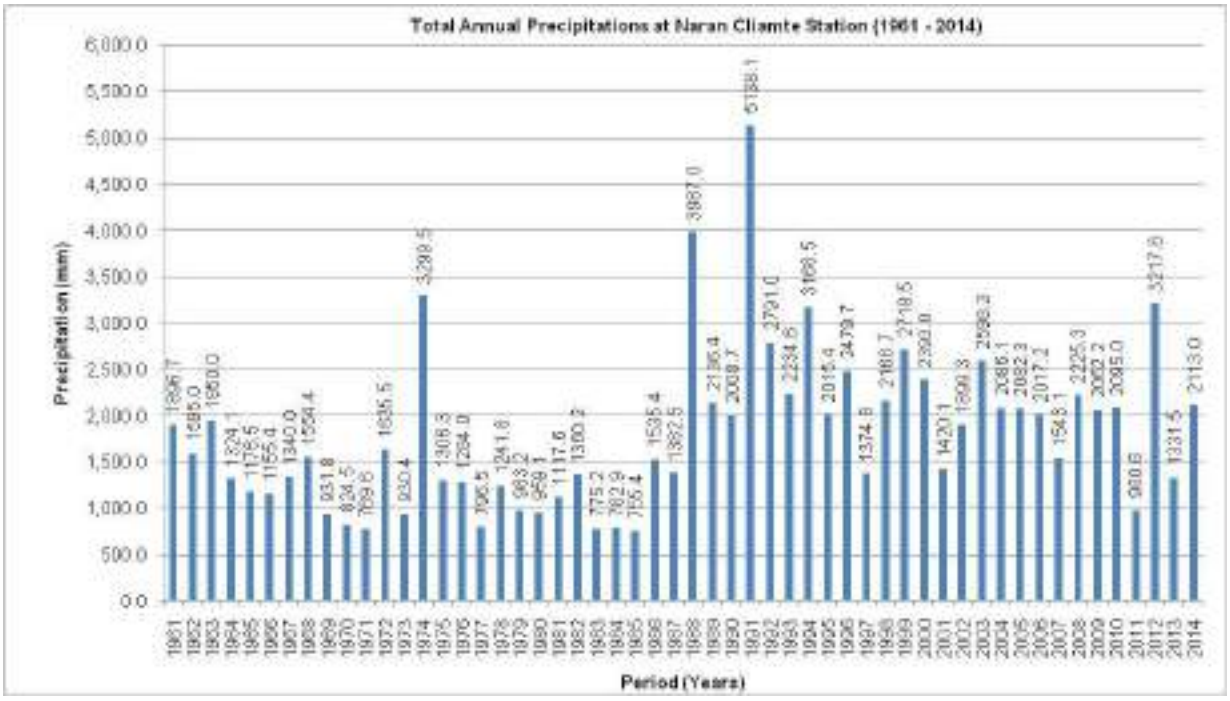


Figure 3-4: Total Annual Precipitations at Naran Climate Station

In Figure 3-3, the total annual precipitations at Muzaffarabad vary from 747.3 mm in 1975 to 2154.4 mm in 2006. The mean annual precipitation is 1488.0 over a period from 1961 to 2010.

In Figure 3-4, the total annual precipitations at Naran vary from 755.4 mm in 1985 to 5138.1 mm in 1991. The mean annual precipitation is 1795.40 over a period from 1961 to 2014.

3.5.2 Temperature Data

The one meteorological station with long record of temperature is located at Muzaffarabad, at a distance of about 85 km from the project area. The temperature data upto 2006 was available from feasibility study, 2010. The data has been updated upto 2010 using the records available in the detailed design study report of Jagran-II hydropower project referred at Sr. No 5 in Section 3.2 of this report. The temperature data of Naran station was also collected from the above detailed design study report and used.

Figure 3-5 and **3-6** gives the mean max minimum and maximum temperatures observed at the Muzaffarabad and Naran stations respectively.

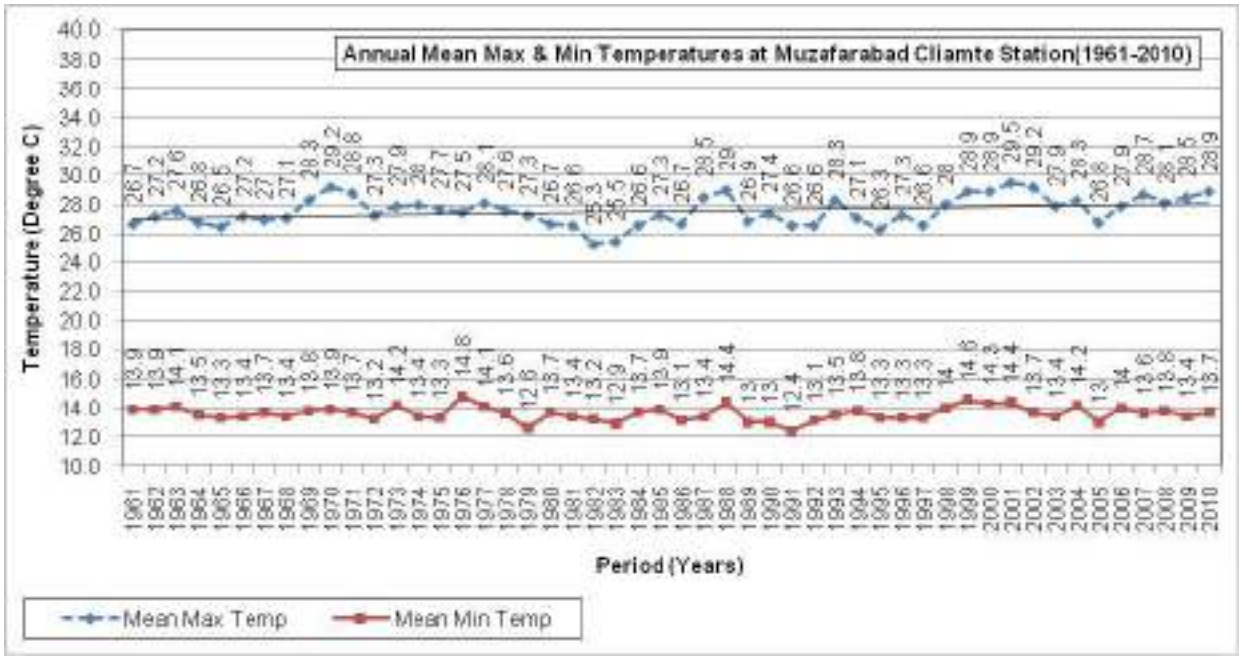


Figure 3-5: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station

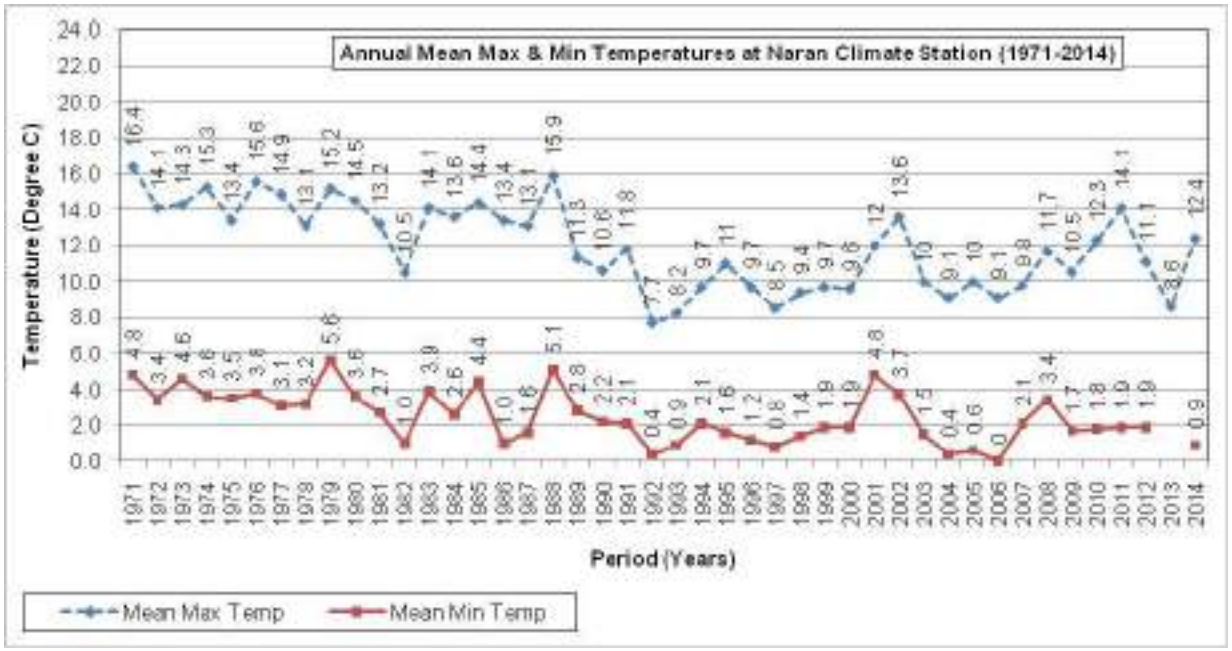


Figure 3-6: Annual Mean Min & Max Temperatures at Muzaffarabad Climate Station

In Figure 3-5, the annual mean maximum temperatures at Muzaffarabad vary with the minimum value of 25.3 °C in 1982 and maximum value of 29.5 °C in 2001. Similarly, the annual mean minimum temperatures at Muzaffarabad vary with the minimum value of 12.4 °C in 1991 and maximum value of 14.8 °C in 1976.

In Figure 3-6, the annual mean maximum temperatures at Naran vary with the minimum value of 7.7 °C in 1992 and maximum value of 16.4 °C in 1971. Similarly, the annual mean minimum temperatures at Naran vary with the minimum value of 0 °C in 2006 & 2013 and maximum value of 14.8 °C in 1976.

3.6 River Flows

3.6.1 Review of Feasibility Study, 2010

The Feasibility Study, 2010 has adopted following approach for estimation of long-term river flows of Jagran River at the proposed weir site of Jagran-IV Hydropower Project:

- Measured river flow data was available at the Thunian (Record: 1994-96) and Kundal Shahi (Record: 1982-84 & 1994-1996) gauge stations located on the Jagran River.
- The measured flow data of the Jagran River was found short for the planning of hydropower studies; therefore, the long term flows were estimated by carrying out correlation analyses.
- The river flow data at the Dudhnial (Record: 1980-92), Nausehri (Record: 1990-2000) and Muzaffarabad (Record: 1963-06) stations located on Neelum River and Naran (Record: 1960-2000) station located on Kunhar River was collected and used.
- Comparisons and correlation analyses were made between the 10-daily specific flows at Nausehri, Dudhnial, and Muzaffarabad with the 10-daily specific flows at Thunian and Kundal Shahi by using the river flow data of the same period and observed the variation in winter and summer flows.
- Based on above analyses, the correlation between 10 daily specific flows of Jagran River at Thunian station and Kunhar River at Naran station was found more realistic and used in the estimation of ten (10) daily flows from 1960 to 2000 at the proposed weir site of Jagran-IV Hydropower Project. The following equation was developed with the correlation analysis:

  $Y = 0.8399X^{1.274}$ $(R^2 = 0.832)$,

  Where,

  Y = represents the 10-daily specific flows of Jagran River at Thunian station, and

  X = represents the 10-daily specific flows of Kunhar river at the Naran station.
- The catchment area of Naran station, Thunian station and at the proposed weir site of Jagran-IV hydropower project respectively are taken as 1036 Km^2, 219 Km^2 and 214 Km^2.
- Using above equation & catchment area ratio method, long term 10-daily flows are estimated from 1960 to 2000 at the proposed weir site of the Jagran-IV hydropower project. The estimated 10-daily flows have been converted into mean annual and mean monthly flow and shown in **Figure 3-7 & 3-8** respectively.
- In Figure 3-7, the estimated mean annual flow at weir site of Jagran – IV Hydropower Project varies from 9.8 to 21 m^3/s with average value of 15.81 m^3/s.

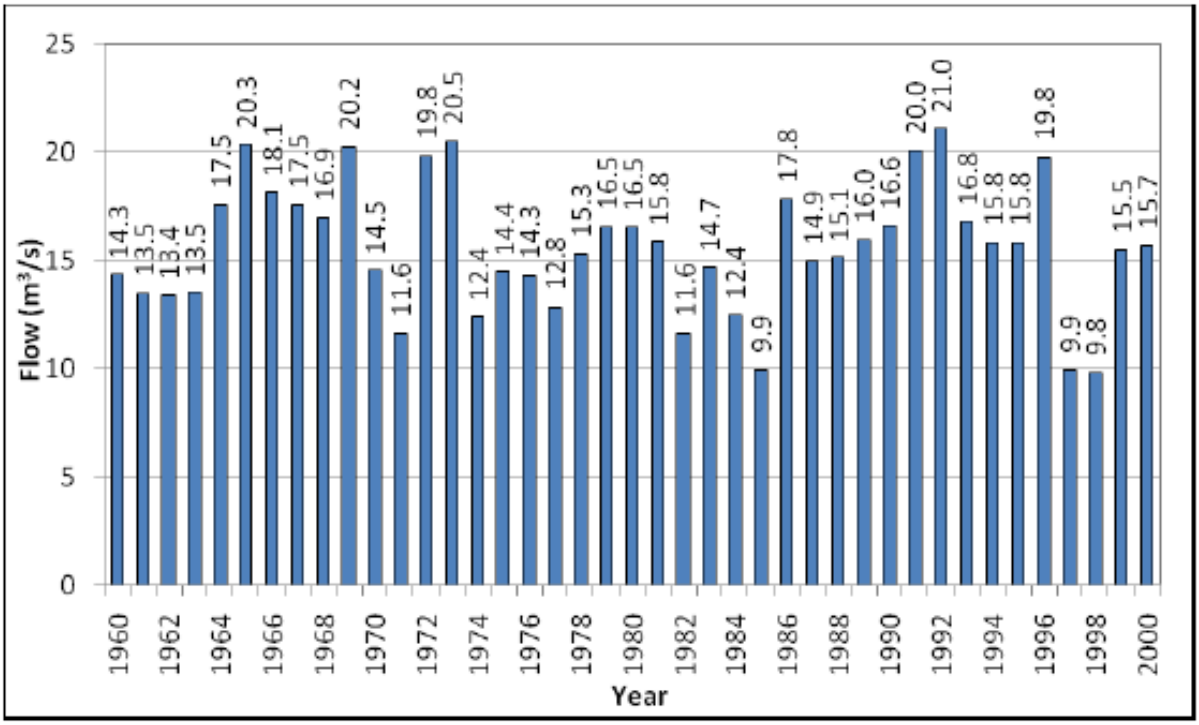


Figure 3-7: Mean Annual Flows at Proposed Weir Site– Jagran River (FS, 2010)

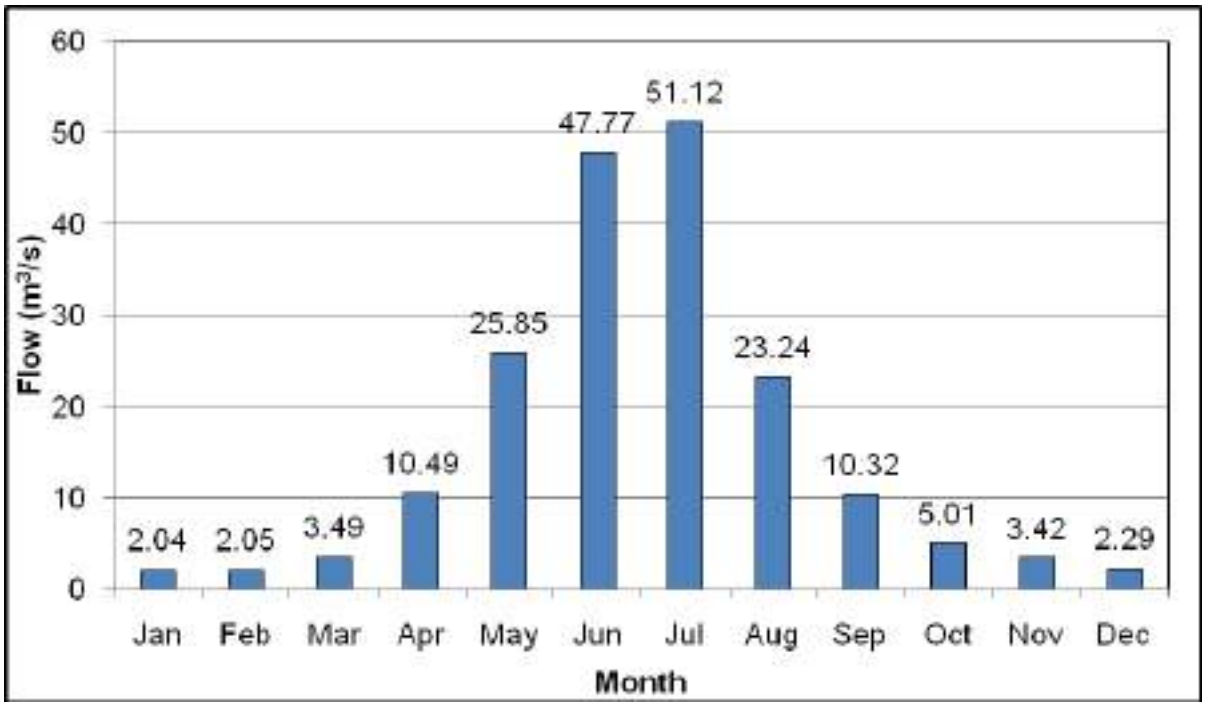


Figure 3-8: Mean Monthly Flows at Proposed Weir Site– Jagran River (FS, 2010)

3.6.2 Review of Third Party Validation Study, 2021

The Third party validation study, 2021 has offered comments on the Feasibility study, 2010 and adopted following approach for estimation of long term river flows at the proposed weir site of Jagran-IV hydropower project:

- The correlation so developed between Thunian and Naran stations is acceptable considering the available flow data of nearby hydrological stations.

- The estimated flows need to be reviewed as the observed flow period is relatively short. It is proposed to use the updated flow records available from Jagran-I power station.
- For establishing correlation between gauging stations, 10 daily data have been used that gives error in the estimated flows. It is proposed to use daily flow data for establishing correlation and extension of flows.
- The Third Party Validation Study, 2021 also collected the updated daily flow records of Naran station (Record: 1960-2008) on Kunhar River and Nausehri station (Record: 1991 to 2015) on Neelum River and has carried out the correlation analyses between the daily specific flows of Naran and Nausehri stations with the Thunian station.
- Based on above analyses, the correlation between daily flows of Neelum River at Nausehri station and Jagran River at Thunian station (**Figure 3-9**) was found more realistic and adopted for the estimation of daily flow record from 1991 to 2015 at the proposed weir site of Jagran-IV hydropower project. The following equation has been developed and used:

$$Y = 0.01665054\ x^{1.15282841} \quad (R^2 = 0.848)$$

Where,

Y = represents the 10-daily specific flows of Jagran River at Thunian station, and

X = represents the 10-daily specific flows of Neelum River at the Nausehri station.

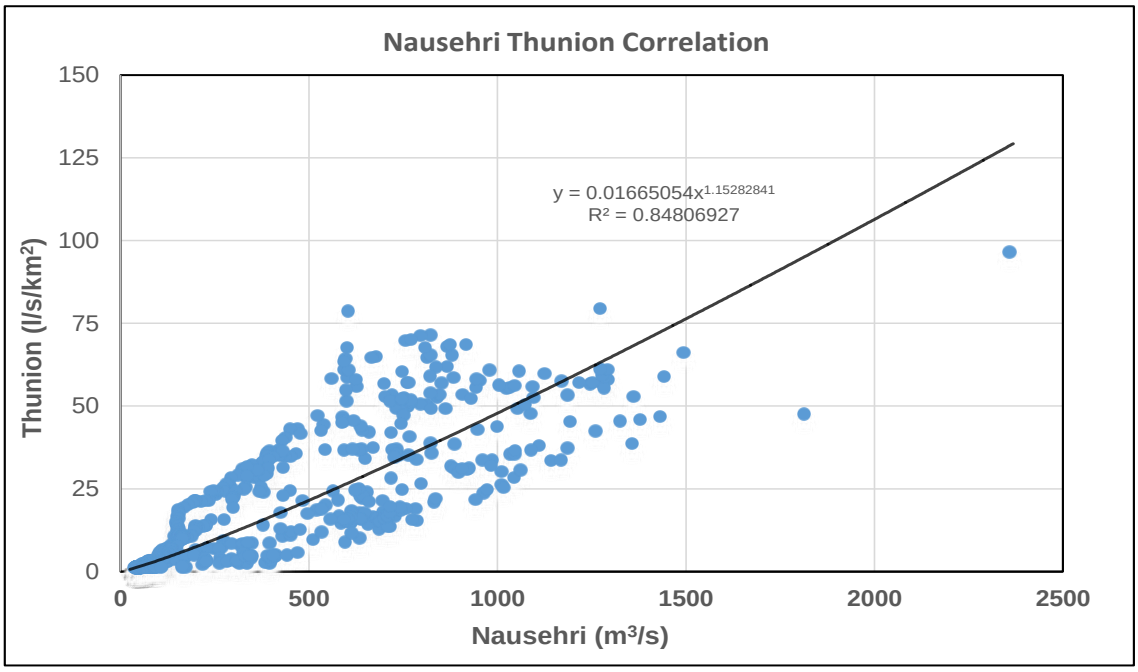
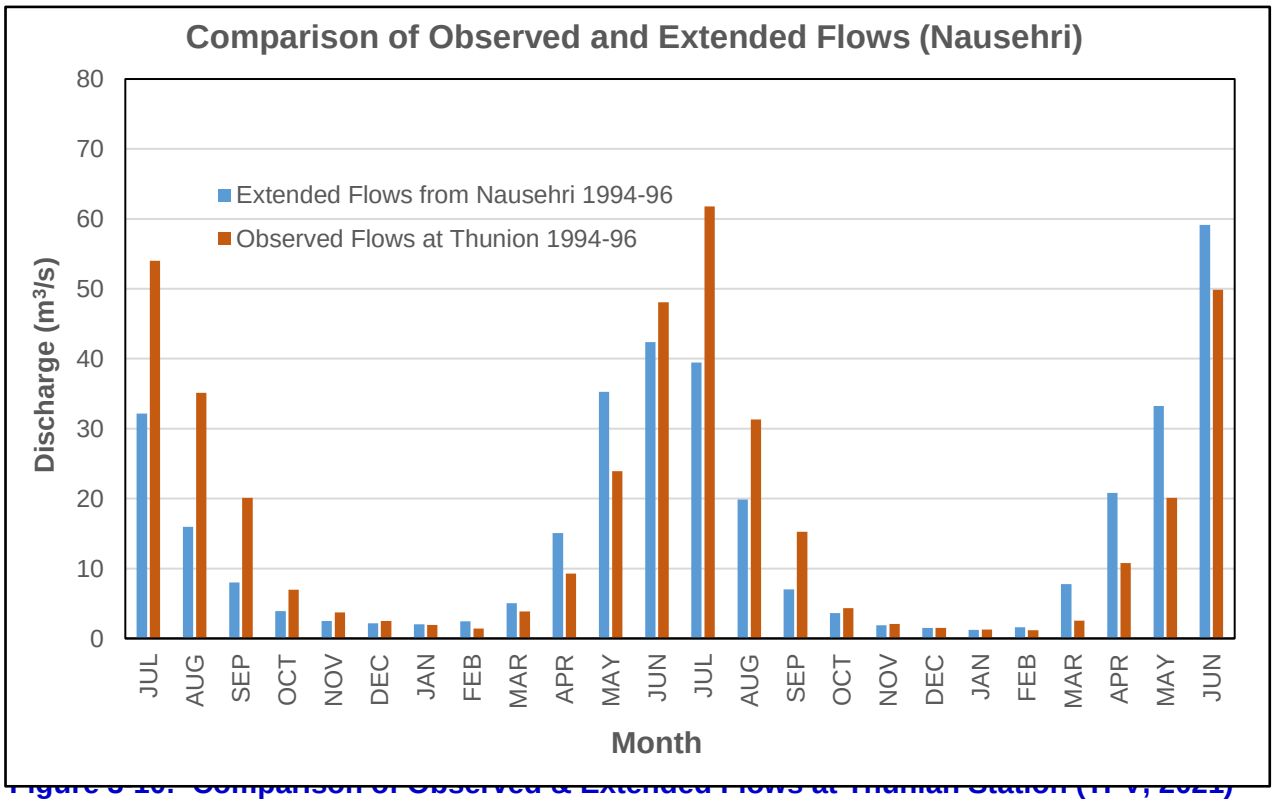


Figure 3-9: Nausehri Viz Thunian Correlation (TPV, 2021)

- The catchment area of Nausehri station, Thunian station and at the proposed weir site of Jagran-IV hydropower project respectively are 6,809 Km^2, 219 Km^2 and 205 Km^2.
- Using above equation & catchment area ratio method, long term daily flows are estimated from 1991 to 2015 at the proposed weir site of the Jagran-IV hydropower project.
- **Figure 3-10** gives the comparison of observed viz extended mean monthly flows at the proposed weir site of Jagran-IV hydropower project.



- **Figure 3-11** shows the variations in the mean annual flows of the extended flow series at the proposed weir site of Jagran-IV hydropower project. The figure shows that the estimated mean annual flow at proposed weir site of Jagran-IV hydropower project varies from 4.9 to 17.7 m^3/s with average value of 12.30 m^3/s.

Figure 3-11: Estimated Mean Annual Flows at Proposed Weir Site of Jagran-IV HPP

3.6.3 MC Observations

- Keeping in view the importance of onsite observed flow data, which has also been emphasized in the Third Party Validation Study, 2021, the MC Consultants particularly

visited the Jagran-I power station while performing the reconnaissance site visit (15th to 19th October 2025) in order to collect the flow records of the Jagran River. However, it was noted that both Kundal Shahi and Thunian gauge stations are inoperative. It was also noted that only energy generation is recorded by the operators of Jagran-I power station, whereas no mechanism is available for recording the river flows passed over the spillway and under sluice sections.

- The review of Feasibility study, 2010 and Third party validation study, 2021 indicate that both the studies have adopted the correlation method which is acceptable due to unavailability of observed flows records of the Jagran River.
- The review of Feasibility study, 2010 revealed that estimated flows at the proposed weir site of Jagran-IV hydropower project are based on outdated flow records upto 2000. It has also used the 10 daily flow data for establishing correlation between gauging stations that gives error in the estimated flows.
- The review of Third party validation study, 2021 revealed that it has used latest available flow records upto 2015. It has also used the daily flow data for establishing correlation between gauging stations that incorporates daily variations and found most reliable method. The regression coefficients (R^2) of 0.848 achieved with correlation is also high as compared to the value of 0.832 given in the Feasibility study, 2010.
- Based on detailed review, it may be proposed to adopt the extended flow series (1991 to 2015) of the Third party validation study, 2021 for preparing the tender level design and drawings. The mean annual flows of the proposed extended series are shown in **Figure 3-11** above. **Table 3-3** gives the proposed flow duration curve which is developed in the Third party validation study, 2021 using the extended long term daily flow series at the weir site of Jagran-IV hydropower project.

Table 3-3: MC Proposed Flow Duration Curve at Weir Site Jagran-IV HPP

Time (%)	Flow (m^3/s)	Time (%)	Flow (m^3/s)
0	183.98	55	4.9
5	40.17	60	3.99
10	32.48	65	3.28
15	27.46	70	2.8
20	23.4	75	2.45
25	18.87	80	2.17
30	15.12	85	1.85
35	12.2	90	1.57
40	9.93	95	1.21
45	7.91	100	0.62
50	6.18	Mean	12.39

Source of Data: Third Party Validation Study, 2021

3.7 Design Flood Studies

3.7.1 Review of Feasibility Study, 2010

The Feasibility study, 2010 has adopted a statistical approach to estimation of the design floods required for design. The peak annual floods of Muzaffarabad station are transformed at the proposed weir site of Jagran-IV hydropower by using catchment area ratio.

The flood frequency is then carried by Gumble and Log Pearson Type-III methods.

Table 3-4 gives a comparison of various return periods estimated. The floods estimated by Log Pearson Type-III method were giving high values, hence adopted. Based on statistical analysis, the design flood for the weir of Jagran-IV hydropower Project is adopted as 418.6 m^3/s with catchment area of 214 $Km^{2.}$

Table 3-4: Comparison of Flood Estimates (FS, 2010)

T-Return Period	Floods using Gumble MOM(m^3/s)	Floods using Log Pearson Type-III Method (m^3/s)
2	77.7	86.6
5	125.3	117
10	158	142.7
20	189.7	182.8
50	230.9	218.7
100	261.8	260.6
500	333.3	418.6
1000	364.1	479.1
PMF	748.1	

3.7.2 Review of Third Party Validation Study, 2021

The Third party validation study, 2021 has offered the following comments on the estimated floods provided in the Feasibility study, 2010; however no flood updation study was carried out:

- The flood data of Muzaffarabad is not given in the feasibility report and ratio method is not properly defined how to extend the data at the project site.
- The flood data should be screened to test for the presence of high outliers in the data and then treated to reduce the effect of these on the distribution.
- The flood frequency analysis needs to be reviewed with observed data rather than on data transposed to the intake site.

3.7.3 Review of Flood Studies of Jagran-I Hydropower Project

In the detailed design report stage II (1996) prepared by the Jaric Consortium France and MMP Pakistan Pvt. Ltd., the design flood for the weir of Jagran-I hydropower project is adopted as 1000 m^3/s with catchment area of 221 Km^2. No further details are available.

Considering the above design flood standard & using the catchment area ratio, design flood for proposed weir of Jagran-IV hydropower project with catchment area of 205 Km^2 is calculated as 928 m^3/s.

3.7.4 Review of Preliminary Flood Studies of Jagran-II Hydropower Project

In the Preliminary Feasibility Study (1998), prepared by the Jaric Consortium France and MMP Pakistan Pvt. Ltd., the design flood for the weir of Jagran-II hydropower project is adopted as 1300 m^3/s with catchment area of 317 Km^2. No further details are available.

Considering the above design flood standard & using catchment area ratio, design flood for weir of Jagran-IV Hydropower Project with catchment area of 205 Km^2 is calculated as 840 m^3/s.

3.7.5 Review of Detailed Design Flood Studies of Jagran-II Hydropower Project

The updated Hydrology and Sedimentation Study Report, 2018 prepared by the EPC Contractor as part of the Stage-II detailed design studies for Jagran-II hydropower project was collected and reviewed. In the report, the following approach has been is implied in the estimation of various return period design floods at the weir and powerhouse sites:

- The statistical approach has been adopted in estimation of floods.
- The annual maximum observed flood data from 1963-14 as shown in **Table 3-5** is used.

Table 3-5: Annual Maximum Observed Floods at Muzaffarabad (1963-14)

Year	Date	Flood (m^3/s)	Year	Date	Flood (m^3/s)
1963	14-Jun	1375	1989	3-Jul	1347
1964	15-Jul	1538	1990	17-May	1345
1965	22-May	1767	1991	9-Jun	1560
1966	17-Jun	1721	1992	10-Sep	3766
1967	9-Jul	1675	1993	10-Jul	1431
1968	11-Jul	1310	1994	20-May	1127
1969	2-Jun	1661	1995	26-Jul	2351
1970	22-May	937	1996	21-Jun	2029
1971	9-Jun	812	1997	27-Aug	1294
1972	17-Jun	1534	1998	26-Apr	1053
1973	12-Jun	1307	1999	20-May	930
1974	19-Jun	846	2000	9-May	578
1975	16-May	1308	2001	11-May	453

Year	Date	Flood (m^3/s)	Year	Date	Flood (m^3/s)
1976	2-Aug	1565	2002	18-May	782
1977	12-Jun	1118	2003	6-Jun	1139
1978	25-May	1438	2004	20-May	784
1979	26-Jun	968	2005	28-Jun	1399
1980	21-Jun	1064	2006	16-May	1312
1981	6-May	1265	2007	30-Jun	815
1982	9-May	841	2008	30-May	1050
1983	2-Jul	1412	2009	21-May	1180
1984	3-Jul	1344	2010	10-Jul	3330
1985	7-Aug	990	2011	20-May	1136
1986	25-Jun	1531	2012	18-Sep	1003
1987	22-May	1542	2013	27-May	1133
1988	26-Jun	2237	2014	5-Sep	1563

- The catchment area of the Neelum River at Muzaffarabad station is taken as 7270 Km^2. The catchment area of the Jagran River at Jagran-II project weir is taken as 262 Km^2.
- A so called “factor of square root” of 0.19 is calculated from catchment area of Muzaffarabad station and Jagran-II Project weir and used to estimate annual peak floods at the Jagran-II project weir site. The factor of square root of catchment area gives more weight to smaller catchments, meaning the smaller the catchment, the higher will be specific discharge. The historic maximum flood was presented in 2010 with peak value of 850 m^3/s.
- **Table 3-6** gives the observed floods at Muzaffarabad station and estimated floods at the weir site of Jagran-II hydropower project.

Table 3-6: Annual Maximum Estimated Floods at Jagran-II Weir Site (1963-14)

Year	Date	Flood (m^3/s)	Year	Date	Flood (m^3/s)
1963	14-Jun	261	1989	3-Jul	256
1964	15-Jul	292	1990	17-May	255
1965	22-May	335	1991	9-Jun	296

Year	Date	Flood (m^3/s)	Year	Date	Flood (m^3/s)
1966	17-Jun	327	1992	10-Sep	715
1967	9-Jul	318	1993	10-Jul	272
1968	11-Jul	249	1994	20-May	214
1969	2-Jun	315	1995	26-Jul	446
1970	22-May	178	1996	21-Jun	385
1971	9-Jun	154	1997	27-Aug	246
1972	17-Jun	291	1998	26-Apr	200
1973	12-Jun	248	1999	20-May	177
1974	19-Jun	161	2000	9-May	110
1975	16-May	248	2001	11-May	86
1976	2-Aug	297	2002	18-May	149
1977	12-Jun	212	2003	6-Jun	216
1978	25-May	273	2004	20-May	149
1979	26-Jun	184	2005	28-Jun	266
1980	21-Jun	202	2006	16-May	249
1981	6-May	240	2007	30-Jun	155
1982	9-May	160	2008	30-May	199
1983	2-Jul	268	2009	21-May	224
1984	3-Jul	255	**2010**	**10-Jul**	**850**
1985	7-Aug	188	2011	20-May	216
1986	25-Jun	291	2012	18-Sep	190
1987	22-May	293	2013	27-May	215
1988	26-Jun	425	2014	5-Sep	297

- Flood frequency analysis was then carried out using the above estimated annual maximum floods at the weir site the Jagran-II hydropower project. The **Figure 3.12** which is reproduced from the flood study of Jagran-II project shows the fitting of the flood data with the Log Pearson Type-III method.

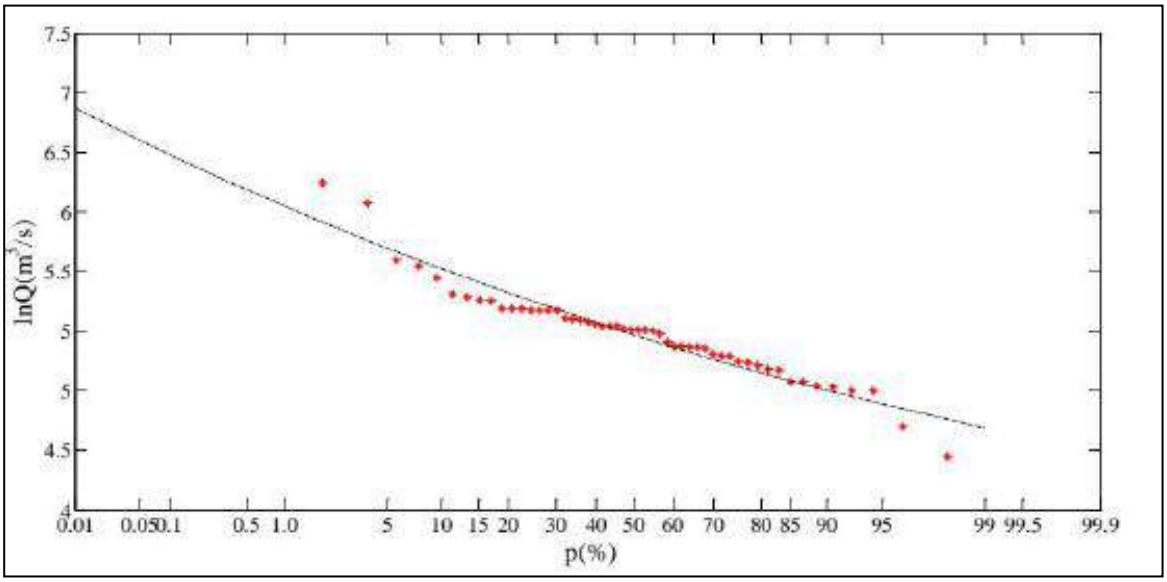


Figure 3-12: Flood Estimated with Log Pearson Type-III Data (Jagran-II Flood Study)

- Based on above frequency method, the various return period design floods at the weir site of Jagran-II hydropower project are estimated. The estimated floods at the weir site are also transferred at powerhouse site with so called factor of square root of catchment area of the weir and powerhouse sites.
- **Table 3-7** shows the various return period design floods estimated and adopted at the weir and powerhouse sites of Jagran-II hydropower project.

Table 3-7: Adopted Floods at the Weir and Powerhouse sites of Jagran-II HPP

Return Period (Years)	Weir Site	PH Site
	Catchment area = 262 Km^2	Catchment area = 354 Km^2
2	236	274
5	336	391
10	412	479
20	491	571
50	605	703
100	700	814
500	952	1107
1000	1078	1253

3.7.6 MC Observations

- The Jagran River has been subjected to several flooding in the past. During the flood 2010, the under sluice gates installed at the weir of Jagran-I hydropower project were washed away. The flood 2010 also caused destruction to houses and switchyard of Jagran-I

hydropower project was completely demolished. The rehabilitation of damaged infrastructure resulted in loss of money as well as shutdown of the power plant for about 1-year period. Therefore, estimation of reliable floods for the Jagran River is crucial which not only results in economy but also ensure the safe operation of the hydropower structures e.g. weir and powerhouse.

- The review of the flood studies undertaken in the Feasibility study, 2010 revealed that these studies are outdated as no flood data of 2010 has been considered. Also, no flood updation studies were undertaken in the Third party validation study, 2021.
- In light of above situation, the MC Consultants have collected and reviewed the relevant previous studies reports prepared for the existing Jagran-I and under construction Jagran-II hydropower projects located as cascade on Jagran River in the downstream of the proposed Jagran-IV hydropower project.
- Based on above comprehensive review of previous flood studies, the MC are of the opinion that the detailed design stage II studies undertaken by the EPC Contractor for the Jagran-II hydropower project gives the most complete records and found based on site specific and reliable flood estimation procedures. This study also considers the historic maximum flood in 2010 with peak value of 850 m^3/s.
- Therefore, the factors of square root are calculated from catchment areas of weir and powerhouse sites of Jagran-VI hydropower project. The factor are then multiplied with the estimated floods at weir site of Jagran-II hydropower project to get the estimated floods at the proposed weir and powerhouse sites of Jagran-IV hydropower project. **Table 3-8** gives the various return periods design floods which are proposed to be adopted for preparation of tender level design & drawings for Jagran-IV hydropower project.

Table 3-8: MC Proposed Design Floods at Weir site of Jagran-IV HPP

Return Period (Years)	Weir Site	Powerhouse
	Catchment area = 205 Km^2	Catchment area = 216 Km^2
2	209	214
5	297	305
10	364	374
20	434	446
50	535	549
100	619	636
500	842	864
1000	954	979

3.8 Sedimentation Studies

3.8.1 Review of Feasibility Study, 2010

The Feasibility study, 2010 has adopted the following approach to determine the suspended and bed load at the proposed weir site of Jagran-V hydropower Project:

- No sediment sampling measurements was available for the Jagran River; therefore the sediments data available at Nausehri hydrological station has been used.
- The Nausehri station is located on the main Neelum River and is about thirty (30) km downstream of confluence of Jagran River and Neelum River.
- The sediment data was also made available at Dudhnial and Muzaffarabad hydrological stations located on Neelum River, however Nausehri station was found the nearest downstream station of the Jagran River; therefore, sediment transport data of this station was considered to estimate suspended and bed load at weir site of Jagran River.
- The relationship was developed between flows and sediment concentration in ppm from the above data and applied to get suspended sediment load at Jagran River.
- The **Figure 3-13** gives the rating curve drawn at the Nausehri station. The relation between discharge and sediment is shown below:

$$Y = 1.881X^{0.841} \text{ (R2 = 0.432)},$$

Whereas, Y represents sediment concentration (ppm) and X represents flow (m^3/s).

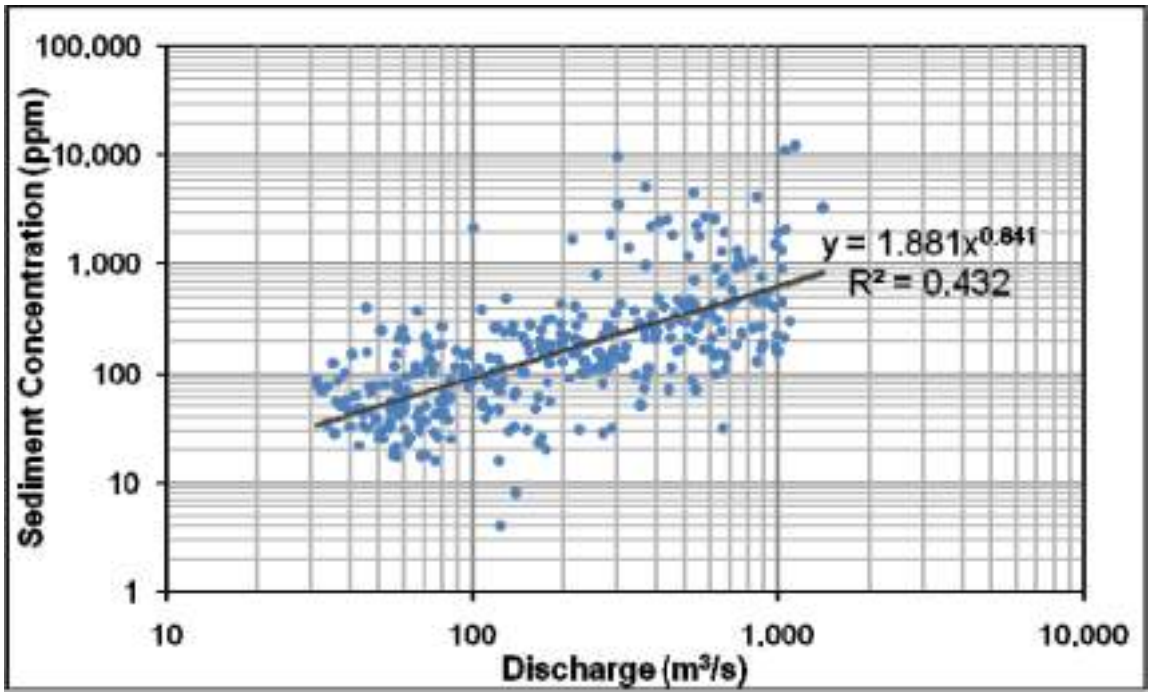


Figure 3-13: Suspended Sediment Rating Curve for Nausehri Station (FS, 2010)

- By applying the above relationship, the sediment load at the weir site on Jagran River was calculated from the available sediment data and the detail is as under:
  - ✓ Average flow (1991-2005) at Nausehri = 289.2 m^3/s
  - ✓ Average ppm (1991-2005) at Nausehri = 436
  - ✓ Suspended Sediment Load at Nausehri = 12017 Tons/day
  - ✓ Suspended Annual Sediment Load at Nausehri = 4.38 M ST
  - ✓ Therefore, the Annual Suspended Sediment Load at Weir Site = 0.1376 M ST
  - ✓ Assuming 20% suspended bed load, total Sediment Load at Weir Site = 0.1651 M ST
  - ✓ The average %age value (composition of suspended sediment) for sand, silt and clay respectively are estimated as 13%, 64% and 23%.

3.8.2 Review of Third Party Validation Study, 2021

The Third party validation study, 2021 has offered the following comments on the sediment studies provided in the Feasibility study, 2010; however no updation study was carried out:

- No sediment measurements have been carried out in the past in Jagran River, neither for suspended load nor for bed load.
- The sediment load at the project site has been estimated from the Nausheri gauging station up to the year 2005, it should be updated. Sediment simulation study should also be carried out for Jagran-IV hydropower project before detail design, to estimate how much sediment will be deposited in front of weir and intake.

3.8.3 Review of Sedimentation Studies of Jagran-II Hydropower Project

The updated Hydrology and Sedimentation Study Report, 2018 prepared by the EPC Contractor as part of the Stage-II detailed design studies for Jagran-II hydropower project was collected and reviewed. In the report, the following approach is implied in the estimation of sediment load at the weir site of Jagran-II hydropower project. The following section provides review of the key aspects of the sediment study undertaken in above study:

- No bed material data was available only suspended sediment data was analysed as measured by SWHP, WAPDA at Nausehri hydrological station.
- No bed load data was available; therefore bed load is taken as 20% of the sediment load as measured by WAPDA.
- The suspended sediment data available from the Nausehri hydrological station is used to estimate the suspended sediment load the weir site of Jagran-II hydropower project.
- A sediment rating curve was drawn at Nausehri with the available suspended sediment data 1991 to 2014. The relation between discharge and sediment is shown below:

$$Y = 0.2306X \ (R2 = 0.479),$$

Whereas, Y represents sediment concentration (ppm) and X represents flow (m^3/s).

- By applying the above relationship, the sediment load at the weir site on Jagran-II is calculated as under:
  - ✓ Average flow (1961-2014) at Jagran-II weir site = 18.6 m^3/s
  - ✓ Suspended Sediment Load at Jagran-II weir site (assumed) = 100 ppm
  - ✓ 1-year Total suspended sediment = 0.6614 M ST
  - ✓ Add 20% suspended bed load, the total annual sediment load at weir site of Jagran-II is calculated as 0.7801 M ST.
  - ✓ The estimated sediment load at Jagran-II weir site was then compared to that of Sukhi Kinari Hydropower Project , which was 0.345 M ST /per year and found practicable and implementable.
  - ✓ Suspended sediment concentration as measured by WAPDA varies from 5 ppm to 800 ppm a few values are greater than 1000 pm. All the sediment concentration less than 800 ppm consist of fine sediment. The sediment gradation in term of %sand, %silt and%

clay in suspended sediment is only report when the sediment concentration is more than 1000 ppm, this data values are less than 2% of total observations.

3.8.4 MC Observations

- As noted in the Third party validation study, 2021 no suspended sediment and bed load measurement data is available from Jagran-IV.
- The Feasibility study 2010 has used the data of Nausehri hydrological station (1992-96) and estimated total sediment load of 0.1651 MST / year at the proposed weir site of Jagran-IV hydropower. The average %age value (composition of suspended sediment) for sand, silt and clay respectively are estimated as 13%, 64% and 23%.
- The updated Hydrology and Sedimentation Study Report, 2018 prepared by the EPC Contractor as part of the Stage-II detailed design studies for Jagran-II hydropower project has also used the data of Nausehri hydrological station (1991-14) and estimated total sediment load of 0.7801 MST / year at the proposed weir site of Jagran-II hydropower.
- Both the sediment studies given in the Feasibility study, 2010 of Jagran-IV hydropower and Updated Hydrological and Sedimentation Report, 2018 of Jagran-II hydropower project has used the data of Nausehri station, however former study is based on few year of measured data, whereas the later study has used the long term sediment data records. Therefore, the later study results may be proposed for estimation of sediment load at the Jagran-II hydropower project.
- Based on above review, the following sediment load and gradation may be proposed for use in the preparation of tender level design and drawings:
  - ✓ Average flow (1991-2015) at Jagran-IV weir site = 12.3 m^3/s
  - ✓ Suspended Sediment Load at Jagran-IV weir site (assumed) = 100 ppm
  - ✓ 1-year total suspended sediment = 0.4374 M ST
  - ✓ Add 20% suspended bed load, the total annual sediment load at weir site of Jagran-IV is calculated as 0.5249 M ST.
  - ✓ The average %age value (composition of suspended sediment) for sand, silt and clay as 13%, 64% and 23% given in the Feasibility study may be proposed.

SECTION - 4: GEOLOGICAL & GEOTECHNICAL STUDIES

4.1 General

The acquisition of pertinent geological, geotechnical, and seismological data at the proposed facility structures, along with the assignment of the representative geotechnical design parameters, is a crucial input for the safe and economical design of the hydraulic structures. The scheme's various proposed structures, including the diversion weir, connecting channel, desander/sand trap, pressure pipe intake, buried pressure pipe, pipe outlet, surge pipe/pressure relief valve, penstock, surface powerhouse, and tailrace, require detailed and focused geological, geotechnical, and seismological studies.

The following sections summarize, evaluate, and review the existing geological, geotechnical, and seismological data from the Feasibility Studyt, 2010 and the Third-Party Validation Study, 2021. Additionally, the investigations and discussions on construction materials conducted during these studies are thoroughly examined.

These sections also provide a critical assessment of the studies from geological, geotechnical, and seismological perspectives. The key findings by the MC are included at the end of each section and summarized in **Table 4.6**.

4.2 Review of Geological Data

Geological mapping of the site was conducted during the Feasibility Study, 2010, but no additional geological studies were conducted during the Third Party Validation Study, 2021. The key aspects related to the area's general and specific geology, according to these studies, are summarized below.

4.2.1 Regional Geology and Tectonics

The collision between the Eurasian and Indian plates has caused significant deformation, including complex folding, strike-slip, and thrust faulting, along with crustal thickening, visible through a series of thrust faults. These include the Main Karakoram Thrust (MKT), Main Mantle Thrust (MMT), Main Boundary Thrust (MBT), Panjal Thrust (PT), Main Central Thrust (MCT), Himalayan Frontal Thrust (HFT), and Salt Range Thrust (SRT). Based on these regional thrust faults associated with the intercontinental collision, five major fault zones have been identified in Northern Pakistan and AJ&K (**Figure 4-1**). These are the Northern Suture Zone (NSZ), the MKT, the MMT (Indus Suture Zone, ISZ), the MCT, the MBT, the HFT, and the SRT.

The Neelum Valley and the proposed project area are situated in the Himalayan Crystalline Schuppen Zone, which is part of the Karakoram-Himalaya Crystalline and Thrust Zone. The zone is bordered to the north by the MMT and to the south by the Panjal Thrust.

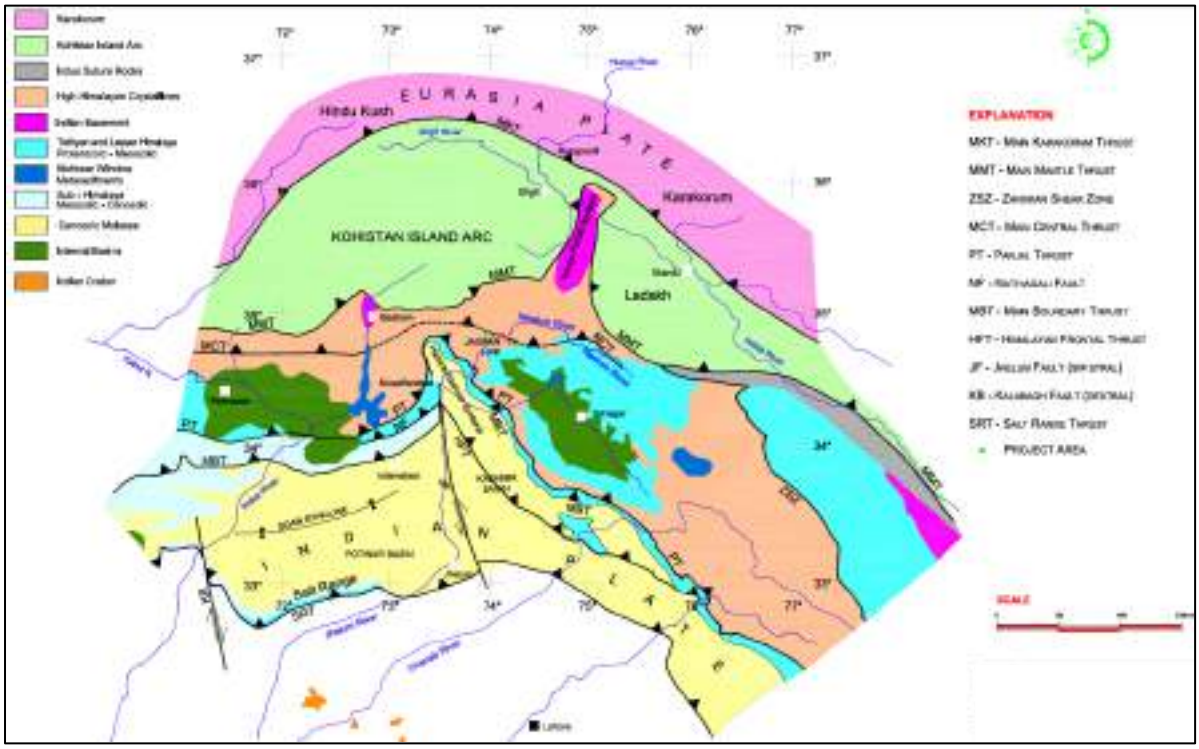


Figure 4-1: Tectonic map of Northern Pakistan (FS, 2010)

4.2.2 Site-specific Geologic Mapping

In the Feasibility study, 2010, most of the inferences and conclusions for the structures' geotechnical design were based on geological mapping data. This data includes a reconnaissance geological survey, identification of main geological features, and a surface geological map at a scale of 1:1000.

The geological mapping results of this study indicate that the metamorphic crystalline rocks exposed in the valley form the cover and the basement (**Table 4-1** and **Figure 4-2**). The crystalline rocks found in Neelum Valley mainly belong to the Salkhala series of Precambrian age, with some younger igneous intrusions in specific areas. The lithostratigraphic units present in Neelum Valley, from Nauseri to Kel, include the Precambrian Naril Group, the Precambrian-Cambrian Kundal Shahi Group, the Upper Paleozoic to Mesozoic Surgun Group, the Cambrian-Ordovician Manshera Granite, and the Carboniferous to Triassic Panjal Traps Metabasites.

The surface geological map a scale of 1:1000 shows soil and rock units. Some structural discontinuities, joints, and foliation trends are also marked. Based on these maps, the soil and rock units exposed at the site are described in the following sections. In most areas, the rock units are covered by sediments transported through glacial or alluvial processes.

Table 4-1: Rock Units in the Neelum Valley (Nausehri to Kel)

COVER	BASEMENT
Surgun Group (Upper Paleozoic - Mesozoic): **Unit C:** Paragneiss, quartzites and minor metaconglomerates with minor levels of amphibolites. Garnet, staurolite-bearing micaschists, garnet-bearing micaschists with minor levels of amphibolites. **Unit B:** Calcschists with minor levels of marble and amphibolite. Marbles, white marbles, yellowish marbles, alternance of white marbles and quartzites with minor levels of amphibolites. **Unit A:** Paragneiss, schists and impure quartzites with minor marble and amphibolites levels. **Panjal Traps Metabasites (Carboniferous - Triassic)** Metabasites, amphibolites with relics of doleritic texture and pillow lava structures	**Mansehra Granite (Cambrian - Ordovician):** Two micas, garnet-bearing metagranites and gneiss. **Kundal Shahi Group (Precambrian - Cambrian):** Kattha unit comprising Impure quartzites and metapsammites with minor metaconglomerate levels. Kuttar unit comprising alternance of metapelites and metapsammites with minor marble levels. **Naril Group (Precambrian):** Gneissic complex with relics of granulitic textures and minor levels of metabasites and marbles.

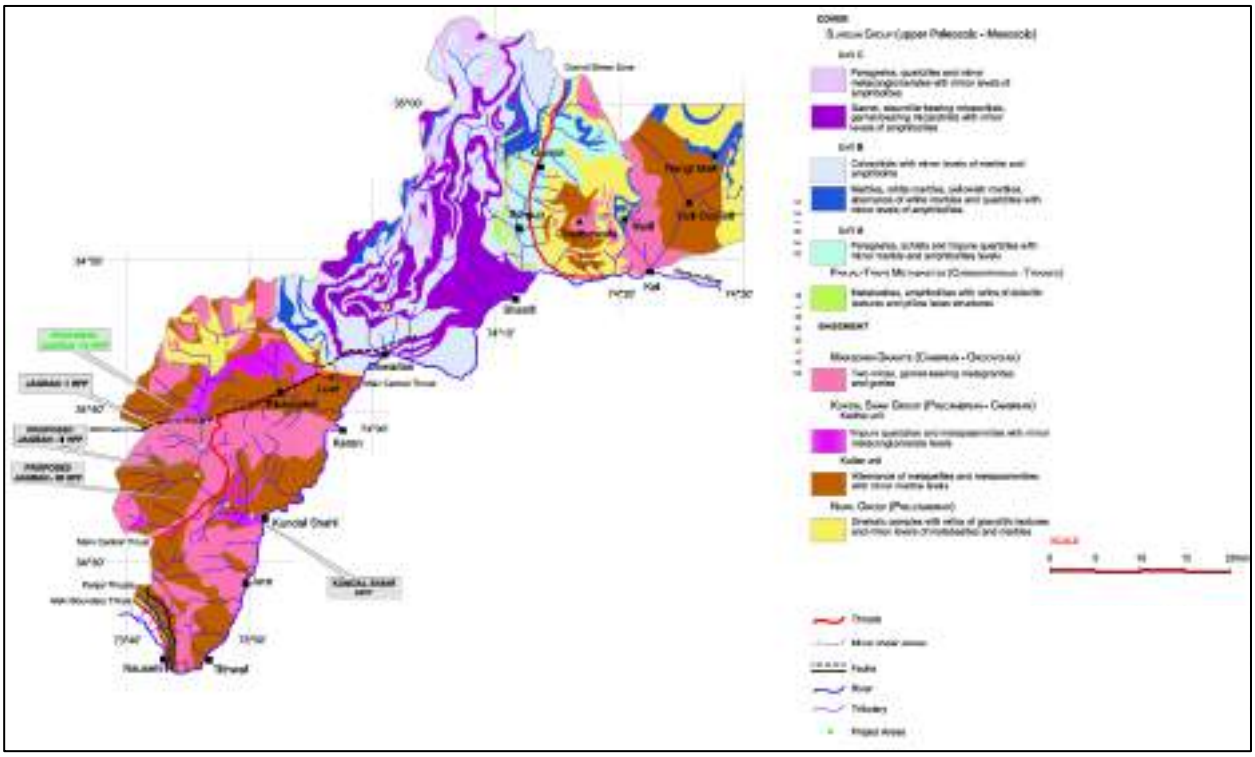


Figure 4-2: Geological Map of the Site

4.2.2.1 Lithological Units at Site

Soil Units

The recent deposits are the most widespread soil units in the proposed project area, covering the bedrock and valley slopes and ranging in thickness from about 5 to 40 meters or more. Terrace deposits consist of mixtures of clay, silt, sand, gravel, and boulders in various proportions.

ABGM: Most of the slopes are covered with material consisting of angular boulders, gravel with sand, and a significant amount of fines. These materials are mainly of talus and glacial origin, resulting from the avalanches. The largest boulders in the area measure up to 8 x 7 x 6 meters.

RBGM: It consists of alluvial material with rounded to sub-rounded, loose to semi-consolidated boulders and gravel with sand and a significant amount of fines. These are found upstream of the proposed weir site in the form of terraces, as well as in the proposed powerhouse area and in the riverbed.

ABG: Overburden material comprising mainly of the large-sized angular / sub-angular boulders and gravel with a minor amount of fines. These are found at the base of slopes.

RBG: Alluvial material deposited by streams is composed of rounded to sub-rounded boulders and gravel with a small amount of sand. These are loose and highly permeable, primarily found in the riverbed.

4.2.3 Rock Units

Primarily, the metamorphic rock unit, granitic gneiss, is exposed in the project area. Igneous intrusions of granite and granodiorite are also visible in some locations. The description of rock units exposed within the project area is provided in the following sections.

Gneiss: The gneiss found on the site appears dirty white to whitish gray on the weathered surface. Light-colored bands alternate with dark bands on the fresh surface. The flaky minerals indicate preferred orientation. The rock is medium to coarse-grained, hard, and sparsely jointed. Numerous granitic veins intrude into the surrounding rocks. Small pegmatitic dykes are also present within the gneissic granite. Mineralogically, it consists of a granular mixture of quartz, feldspar, muscovite, biotite, and accessory minerals such as tourmaline, garnet, magnetite, and apatite. Gneiss contains less mica, more quartz, and exhibits high strength.

Granite: It ranges from light gray to brownish in color. Fresh rock exposures display a whitish-gray hue. However, closer inspection reveals brownish-black biotite specks against a whitish-gray background. In some areas, black tourmaline is also present within the granite.

Rock Structure

Data on rock discontinuities and joint sets were gathered during surface geological mapping of the Feasibility Study, 2010. The most important aspect of a discontinuity is its orientation, indicated by strike and dip. Most of the observed discontinuities have a medium to steep dip angle. Three major and two minor discontinuity sets were identified.

Major Sets

Strike	Dip
J1 N 45° W	51° SW
J2 N 35° W	75° NE
J3 N 40° E	54° SE

Minor Sets

Strike	Dip
J4 N 59° W	Vertical
J5 N 17° E	13° SE

4.2.4 Rock Mass Assessment

In addition to the joint sets determination, the rock mass assessment has been carried out using the following rock mass classification systems for the various components.

- Rock Structure Rating (RSR).
- Geo-mechanics classification or Rock Mass Rating (RMR).
- Rock Tunnelling Quality Index “Q” system.

For the site, since the rock is mostly exposed near the pipe outlet area, the rock mass assessment has been conducted only for this region.

RSR Calculations

The RSR rating of the rock exposed at the pipe outlet area is determined using the parameters listed in **Table 4-2**.

Table 4-2: Factors contributing to the RSR Calculations

Rock: Granitic Gneiss

	Basic Rock Type							
	Hard	Medium	Soft	Decomposed		Geological Structures		
Igneous	1	2	3	4		Slightly	Moderately	Intensively
Metamorphic	1	2	3	4		Folded or	Folded or	Folded or
Sedimentary	2	3	4	4	Massive	Faulted	Faulted	Faulted
Type 1					30	22	15	9
Type 2					27	20	13	8
Type 3					24	18	12	7
Type 4					19	15	10	6

	Strike I to Axis					Strike II to Axis		
	Direction of Drive					Direction of Drive		
	Both	With Dip		Against Dip		Either Direction		
	Dip of Prominent Joints [a]					Dip of Prominent Joints		
Average Joint Spacing	Flat	Dipping	Vertical	Dipping	Vertical	Flat	Dipping	Vertical
1. Very closely jointed, < 2 in	9	11	13	10	12	9	9	7
2. Closely jointed, 2-6 in	13	16	19	15	17	14	14	11
3. Moderately jointed, 6-12 in	23	24	28	19	22	23	23	19
4. Moderate to blocky, 1-2 ft	30	32	36	25	28	30	28	24
5. Blocky to massive, 2-4 ft	36	38	40	33	35	36	24	28
6. Massive, > 4 ft	40	43	45	37	40	40	38	34

	Sum of Parameters A + B					
	13 - 44			45 - 75		
	Joint Condition [b]					
Anticipated water inflow pgm/1000 ft of tunnel	Good	Fair	Poor	Good	Fair	Poor
None	22	18	12	25	22	18
Slight, < 200 gpm	19	15	9	23	19	14
Moderate, 200-1000 gpm	15	22	7	21	16	12
Heavy, > 1000 gp	10	8	6	18	14	10

a. Dip: flat: 0-20°; dipping: 20-50°; and vertical: 50-90°
b. Joint condition: good=tight or cemented: fair=slightly weathered or altered: poor=severely weathered, altered or open

A+B+C=20+25+19
RSR=64

Structure	**RSR (A+B+C)**
Pipe Outlet area	64 (20+25+19)
(Granitic Gneiss)	

RMR Calculations

The RMR value for the pipe outlet area, determined from the parameters provided in **Table 4-3** is calculated as follows. The Factors contributing to RMR calculation are provided in **Table 4-4**.

Table 4-3: RMR Values for the Pipe Outlet Area (FS, 2010)

S. No.	Parameter	Value	Rating
1	Point Load Index	10 MPa	12
2	Rock Quality Designation (RQD)	64	13
3	Spacing of Discontinuities	0.6 – 2.0 mm	15
4	Condition of Discontinuities	-	25
5	Groundwater Conditions	Wet	7
6	Adjudgment for joint Orientation	-	-5

Total = 67

Table 4-4: Factors contributing to the RMR Calculations

Rock: Granitic Gneiss

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
Parameters				Range of Values					
1	Strength of intact rock material	Point load strength index	> 10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	> 250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill Core Quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		> 3m	0.6 - 3 m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5mm thick or Separation 1-5 mm Continuous	Soft gouge >5mm thick or Separation >5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press) / (Major principal σ)	0	<0.1	0.1 - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

(***Continued***)

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)						
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	
C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS						
Ratings		100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21
Class number		I	II	III	IV	V
Description		Very good rock	Good rock	Fair rock	Poor rock	Very poor rock
D. MEANING OF ROCK CLASSES						
Class number		I	II	III	IV	V
Average stand-up time		20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)		> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)		> 45	35 - 45	25 - 35	15 - 25	< 15
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS						
Discontinuity length (persistence) Rating		< 1m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Rating		None 6	< 0.1 mm 5	0.1 - 1.0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Rating		Very rough 6	Rough 5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating		None 6	Hard filling < 5mm 4	Hard filling > 5mm 2	Soft filling < 5mm 2	Soft filling > 5mm 0
Weathering Rating		Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0
F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELING**						
Strike perpendicular to tunnel axis			Strike parallel to tunnel axis			
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°		Dip 45 - 90°		Dip 20 - 45°	
Very favourable	Favourable		Very unfavourable		Fair	
Drive against dip - Dip 45 - 90°	Drive against dip - Dip 20 - 45°		Dip 0 - 20 - Irrespective of strike*			
Fair	Unfavourable		Fair			

* Some conditions are mutually exclusive. For example, if in filling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A-E directly.
** Modified after Wickham et al (1972).

The rock mass class is determined from the total rating (RMR = 67). **An RMR value of 67 categorizes granitic gneiss as Class II, described as "Good Rock."**

Tunnelling Quality Index (Q) Calculations

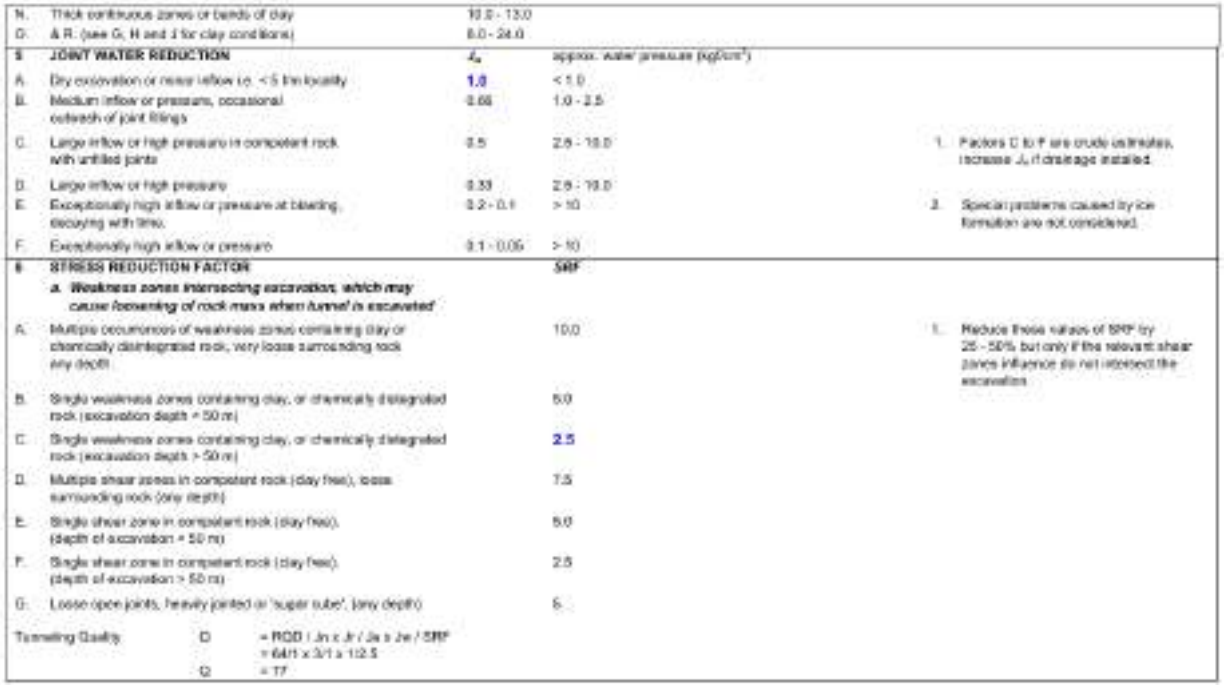
The rock classification based on the Tunneling Quality Index (Q) is determined using the factors listed in **Table 4-5**. The Q-Index worked out to be 77.

Table 4-5: Factors contributing to the Q-Index Calculations

Rock: Granitic Gneiss

DESCRIPTION		VALUE	NOTES
1	**ROCK QUALITY DESIGNATION**	RQD	
A.	Very poor	0 - 25	1. Where RQD is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate Q.
B.	Poor	25 - 50	
C.	Fair	50 - 75	
D.	Good	75 - 90	2. RQD intervals of 5, i.e., 100, 95, 90 etc. are sufficiently accurate.
E.	Excellent	90 - 100	
2	**JOINT SET NUMBER**	J_n	
A.	Massive, no or few joints	0.5 - 1.0	
B.	One joint set	2	
C.	One joint set plus random	3	
D.	Two joint sets	4	
E.	Two joint sets plus random	6	
F.	Three joint sets	9	1. For intersections use (3.0 x J_n)
G.	Three joint sets plus random	12	
H.	Four or more joint sets, random, heavily jointed, 'sugar cube', etc.	15	2. For portals use (2.0 x J_n)
I.	Crushed rock, earthlike	20	
3	**JOINT ROUGHNESS NUMBER**	J_r	
	a. Rock wall contact		
	b. Rock wall contact before 10 cm shear		
A.	Discontinuous joints	4	
B.	Rough and irregular, undulating	3	
C.	Smooth undulating	2	
D.	Slickenside undulating	1.5	1. Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m.
E.	Rough or irregular, planar	1.5	
F.	Smooth, planar	1.0	

(***Continued***)



N.	Thick continuous zones or bands of clay	10.0 - 13.0		
O.	& R. (see G, H and J for clay conditions)	5.0 - 20.0		
5	**JOINT WATER REDUCTION**	J_w	approx. water pressure (kg/cm²)	
A.	Dry excavation or minor inflow i.e. < 5 litre/minute	1.0	< 1.0	
B.	Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C.	Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates, increase J_w if drainage installed
D.	Large inflow or high pressure	0.33	2.5 - 10.0	
E.	Exceptionally high inflow or pressure at blasting, decaying with time.	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered.
F.	Exceptionally high inflow or pressure	0.1 - 0.05	> 10	
6	**STRESS REDUCTION FACTOR**		**SRF**	
	a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated			
A.	Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth		10.0	1. Reduce these values of SRF by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation
B.	Single weakness zones containing clay, or chemically disintegrated rock (excavation depth < 50 m)		5.0	
C.	Single weakness zones containing clay, or chemically disintegrated rock (excavation depth > 50 m)		2.5	
D.	Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)		7.5	
E.	Single shear zone in competent rock (clay free). (depth of excavation < 50 m)		5.0	
F.	Single shear zone in competent rock (clay free). (depth of excavation > 50 m)		2.5	
G.	Loose open joints, heavily jointed or 'sugar cube', (any depth)		5	
Tunneling Quality	Q	= RQD / Jn x Jr / Ja x Jw / SRF = 64/1 x 3/1 x 1/2.5		
	Q	= 77		

4.2.5 MC Observations on Geological Data

The surface geological maps and cross-sections included in the Feasibility study, 2010 provide only a broad overview of the area's geology. After reviewing the geological data, MC identified the following gaps in the necessary information:

1. Since most of the structures are planned to be built on overburden deposits, it would have been more helpful to provide a detailed classification and mapping of the different types and characteristics of overburden at the proposed structures. This information should have included categorization by type (e.g., alluvial, glacial, terrace deposits) and should have been indicated on the site-specific geological maps. This would have helped in the design of the interface between the diversion weir and its abutments.
2. Considering the recent cloud bursts and flash flood scenarios due to climate change, the site-specific geological maps should identify the locations and extent of major geological hazards, such as landslides, mudflows, debris flows, slope failures, and rockfalls. To aid in foundation design, an assessment of these hazards should also have been conducted along the pressure pipeline route.
3. Although a rock structural and mass description is provided for the pipe outlet area, it would have been more useful if such details were included for the rocky terrain near other hydraulic structures. This information could have aided better decision-making and design, such as relocating the powerhouse underground.

4.3 Review of Geotechnical Data

The geotechnical investigations were conducted during the Feasibility Study, 2010 and Third Party Validation Study, 2021. These investigations consisted of drilling boreholes and excavating test pits at the selected locations. The details are provided below:

4.3.1 Borehole Investigations

A geotechnical investigation involving nine boreholes with a total depth of 290 meters was conducted for the Feasibility Study, 2010 and Technical Design Report, 2011. An additional investigation was performed in 2021 as part of the validation study. During this phase, five boreholes totalling 121 meters in depth were drilled. The boreholes were drilled at the left abutment of the proposed weir location, water conduit, sand trap, and powerhouse site. Samples obtained from the boreholes primarily consisted of cuttings from percussion drilling, core samples from the boulders, and additional sand samples. Standard Penetration tests (SPTs) and permeability tests were performed in the drilled boreholes.

4.3.2 Test pits

To visually classify foundation soils at shallow depths and determine the depth of fill material, test pits were manually excavated at the project site. A total of ten (10) test pits were dug to a depth of 3.0 m. All the test pits were located along the proposed pipeline or channel route. Field density tests were also conducted in the excavated test pits. Bulk and disturbed soil samples were collected from each test pit at the site and analysed in the laboratory.

4.3.3 Subsurface Strata Characterization

Based on information and data from boreholes, test pits, and geological mapping, it is confirmed that **rock is not exposed at any of the proposed project sites, and there is insufficient site-specific geotechnical data for a proper geotechnical assessment.**

At the proposed weir site, the area on both the left and right banks of the river is covered with overburden containing large sub-rounded and sub-angular boulders (ABGM, RBGM, and ABG, RBG), along with rock debris and sand from fluvial and colluvial deposits. Both abutments are heavily vegetated and feature small cultivated terraces. The strata explored in the boreholes drilled at the abutment and nearby terrace deposits consisted of a thin, surficial layer approximately 1.5 to 3.0 meters thick, classified as greyish-brown to dark-brownish grey, silty SAND with trace gravels. SPT-N values suggest that the compactness of this layer is medium dense. Beneath this sandy layer lies the general soil or weathered rock overburden, made up of whitish to brownish-gray, sandy gravel containing pebbles and cobbles that are subrounded to subangular in shape, derived from various rocks, metasediments, phyllite, and granite.

There is no rock exposure at the proposed sites for the Intake Weir, Water Conduit Path, Sand Trap, and Powerhouse. However, the geological rock units exposed in the project area include metamorphic units, with granitic gneisses, granite, and granodiorite intrusions present at certain locations, but at considerable elevations. The only accessible site for rock examination is on the road near the proposed powerhouse location. The rock in this area, according to ISRM standards, is very strong to extremely strong, thickly bedded, slightly to moderately weathered, closely jointed, and fractured. Although the rock exists on the left bank of the river, it was not encountered in the borehole drilled in the riverbed at the proposed powerhouse location to a depth of 34 meters.

The river surface is covered with large boulders, the largest of which measures up to 8 x 7 x 6 meters (**Figure 4-3**). The rocks making up these boulders can be visualized in the core samples (**Figure 4-4**). The nature of the overburden material of glacial origin is observable from the strata exposed during the excavation of a test pit **(Figure 4-5**). The permeability of the overburden strata, determined in the drilled boreholes, ranges from 2 to 10^{-2} cm/s. The strata ascertained at each of the proposed structure sites are explained in the following sections.

Figure 4-3: Typical view of the large boulders along the riverbanks (FS, 2010)

Figure 4-4: Cored samples from boulders at greater depths (17.0-26.0 m) (FS, 2010)

Figure 4-5: Typical view of the glacial/moronic overburden deposits exposed in a test pit excavated at the site (FS, 2010)

Subsurface Conditions at the proposed Diversion Weir

The valley at the weir is in its mature stage according to geo-morphological classification. The weir would most likely be founded on overburden, as the thickness in this area appears to exceed 40 meters. The riverbed comprises medium to large-sized boulders and gravel, with a small amount of sand (RBG), which is loose and highly permeable; the permeability of the overburden material ranges from 2 to 10^{-2} cm/s. The largest boulder here measures up to 8 x 7 x 6 meters. As identified in the Feasibility Study, 2010 and the Third Party Validation Study, 2021, the proposed weir sites are marked on the surface geological map (**Figure 4-6**). A geological section along the weir axis (**Figure 4-7**) indicates that the bedrock beneath the overburden is probably Granitic Gneiss; the depth of the bedrock still needs to be confirmed through drilling and/or seismic refraction surveys. Both abutment slopes are generally stable and form angles between 35° and 45° with the horizontal.

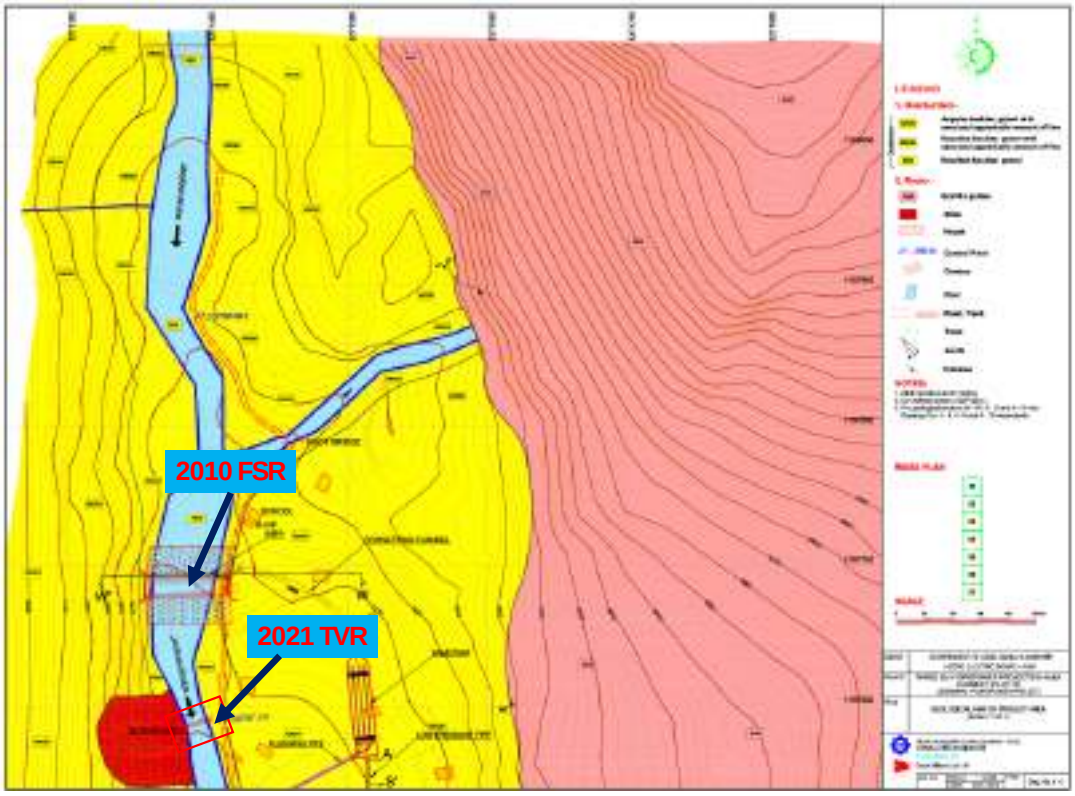


Figure 4-6: Surface geological map of the proposed weir area, showing the extent of the overburden strata (yellow) and the granite rock outcrop (red)

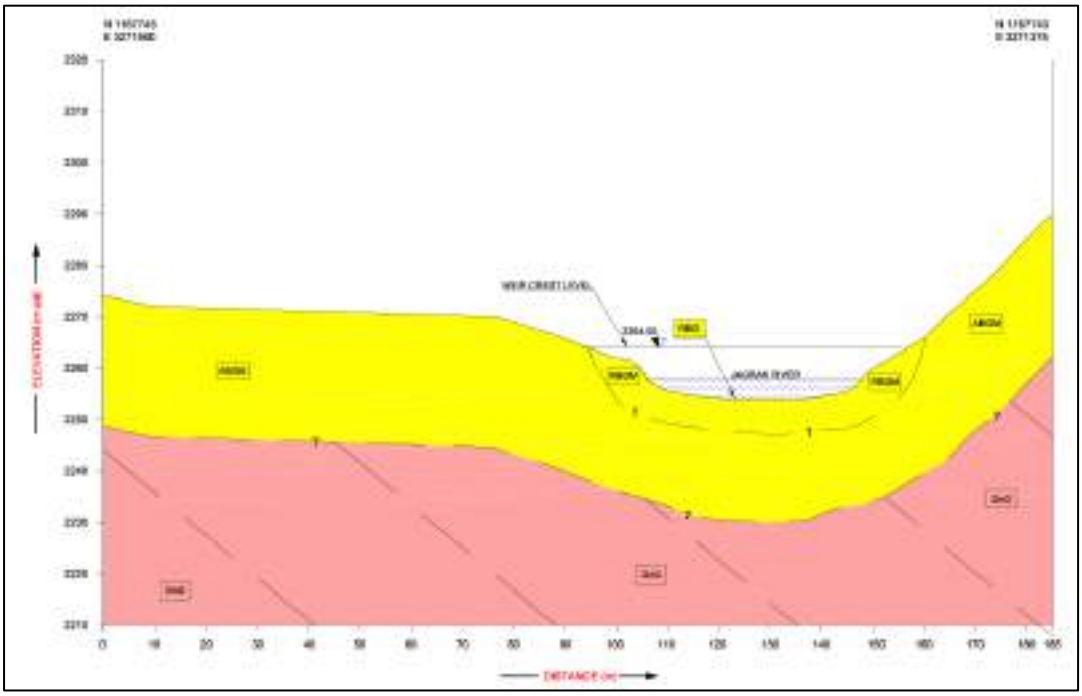


Figure 4-7: Geological section of the proposed weir area (FS, 2010), showing the extent of the overburden strata and the granitic gneiss bedrock

Subsurface Conditions at the proposed Connecting Channel

The proposed connecting channel is located on the left bank of the Jagran River (**Figure 4.6**). Based on the geological mapping, it is anticipated that the channel will be excavated through overburden (ABGM) of moronic origin.

Subsurface Conditions at the proposed Sand trap/Desander

The surface geological mapping of the sand trap was conducted at a 1:1,000 scale and is presented in a report at a 1:2,000 scale (**Figure 4-6**). The surface area of the proposed sand trap location is covered by the overburden material composed of angular boulders, gravel, sand, and a significant amount of fines (ABGM) overlying the granitic gneiss.

According to the Third Party Validation Study, 2021, it might be possible to place the desander/sand trap on the Granitic Gneiss bedrock. However, the thickness of the overburden or the depth of the bedrock has yet to be determined through drilling of boreholes or geophysical surveys. Most of the excavation for the sand trap will be through the overburden (ABGM), which seems to be present in a loose to semi-consolidated state.

Subsurface Conditions along the Pressure Pipe

The buried pressure pipe, approximately 3075 meters long, will primarily rest on overburden and partially on granite gneiss rock. According to **Figure 4-8**, the pipeline will traverse the rocky terrain from a chainage of about 2300 to 3075 meters. In the Feasibility Study, 2010, surface geological mapping of the pipe has been documented on maps created from satellite imagery with a superimposed Digital Elevation Model (DEM) at a scale of 1:1,000.

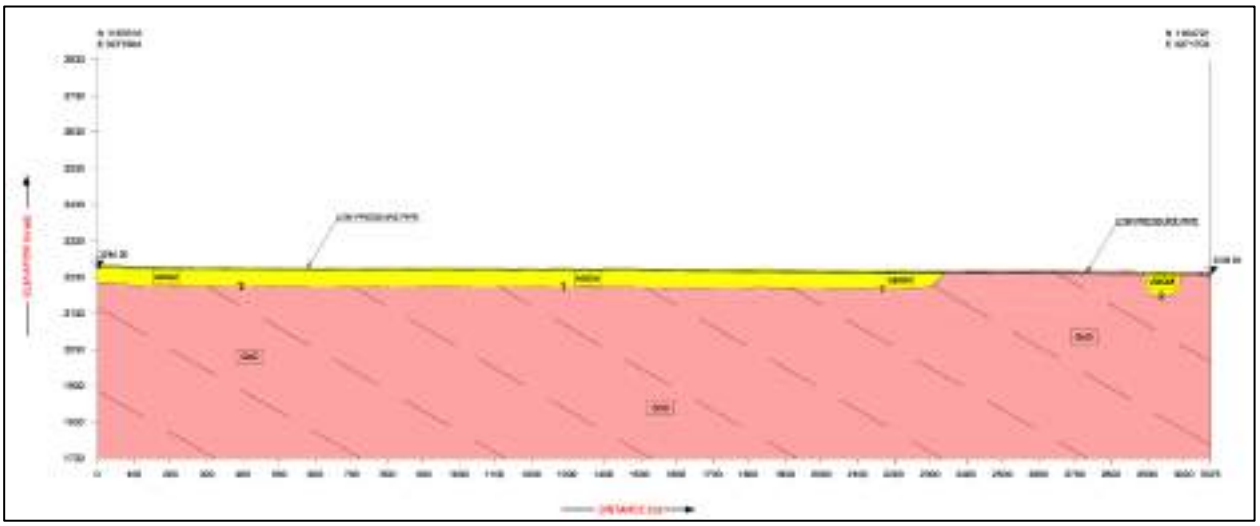


Figure 4-8: Geological section along the proposed pressure pipe (FS, 2010), showing the extent of the overburden strata and the granitic gneiss bedrock.

Generally, the slopes along the pipe's route are considered stable. However, heavy snowfalls and snow avalanches are common in this area. Therefore, the Feasibility Study, 2010 proposed, and the Third Party Validation Study, 2021 has endorsed, that the entire length of the pressure pipe route be buried. Although the pipe will be buried, further study is needed to assess the overall global and local stability of the strata along the pipeline.

Subsurface Conditions at the Surge Pipe and Penstock

Based on the geological mapping results in the Feasibility Study, 2010 (**Figure 4-9**), the proposed surge pipe is expected to sit on the granitic gneiss rock. In contrast, the penstock will mainly be founded on rock and partially on the overburden.

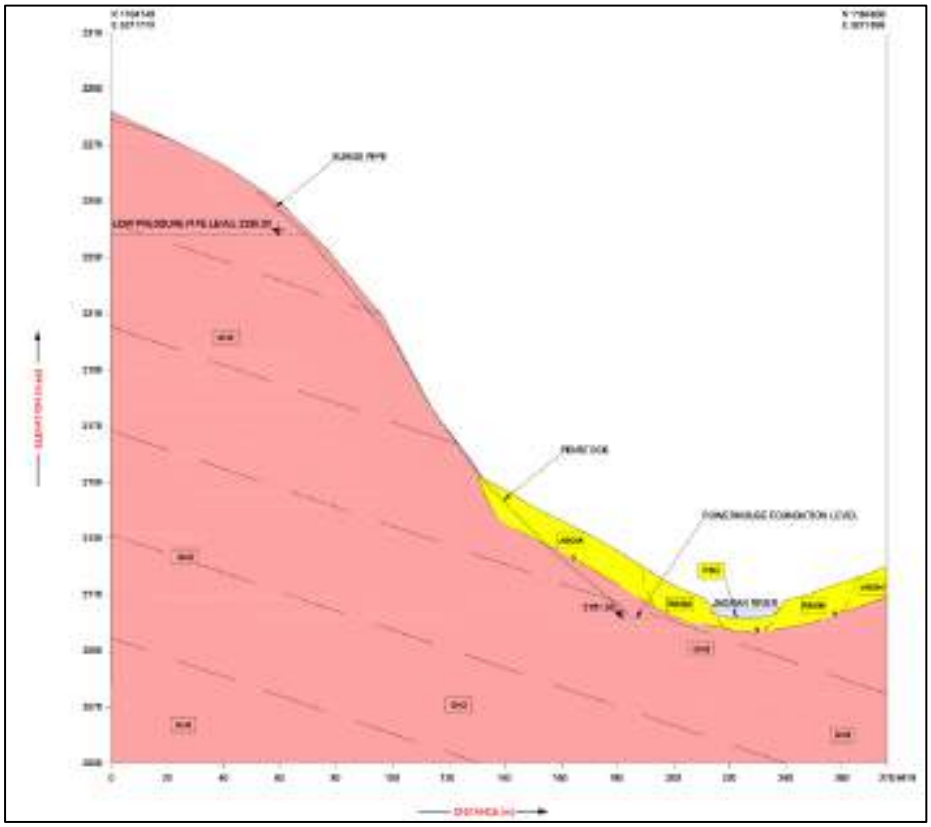


Figure 4-9: Geological section along the proposed penstock and surge pipe (FS, 2010), showing the extent of the overburden strata and the granitic gneiss bedrock.

Subsurface Conditions at the Proposed Surface Powerhouse

According to the Feasibility Study, 2010, the powerhouse is planned to be located in the riverbed, about 300 meters from the Jagran-1 intake Weir (**Figure 4-10**). The riverbed area features large sub-rounded to sub-angular boulders (ABGM, RBGM, and ABG, RBG), along with rock debris and sand composed of fluvial and colluvial materials. At the left abutment, rock is exposed at road level; however, none is found exposed at the powerhouse site.

The surface area at the proposed powerhouse (FS, 2010) is covered by the overburden material composed of rounded boulders and gravel with a significant amount of fines (RBGM), probably overlying the granitic gneiss. Although the thickness of this overburden has not yet been determined through drilling, the powerhouse could likely be built on the granitic gneiss if the overburden is thin enough.

An alternative site for the powerhouse is suggested in the Third Party Validation study, 2021 (**Figure 4-10**). This location is upstream of the spot proposed in the Feasibility Study, 2010. The Third Party Validation Study, 2021 has stated that the site, located at the widest part of the riverbed at the end of the alluvial fan, not only reduces the risk of flood damage during peak season but may also mitigate the adverse effects of falling slide material.

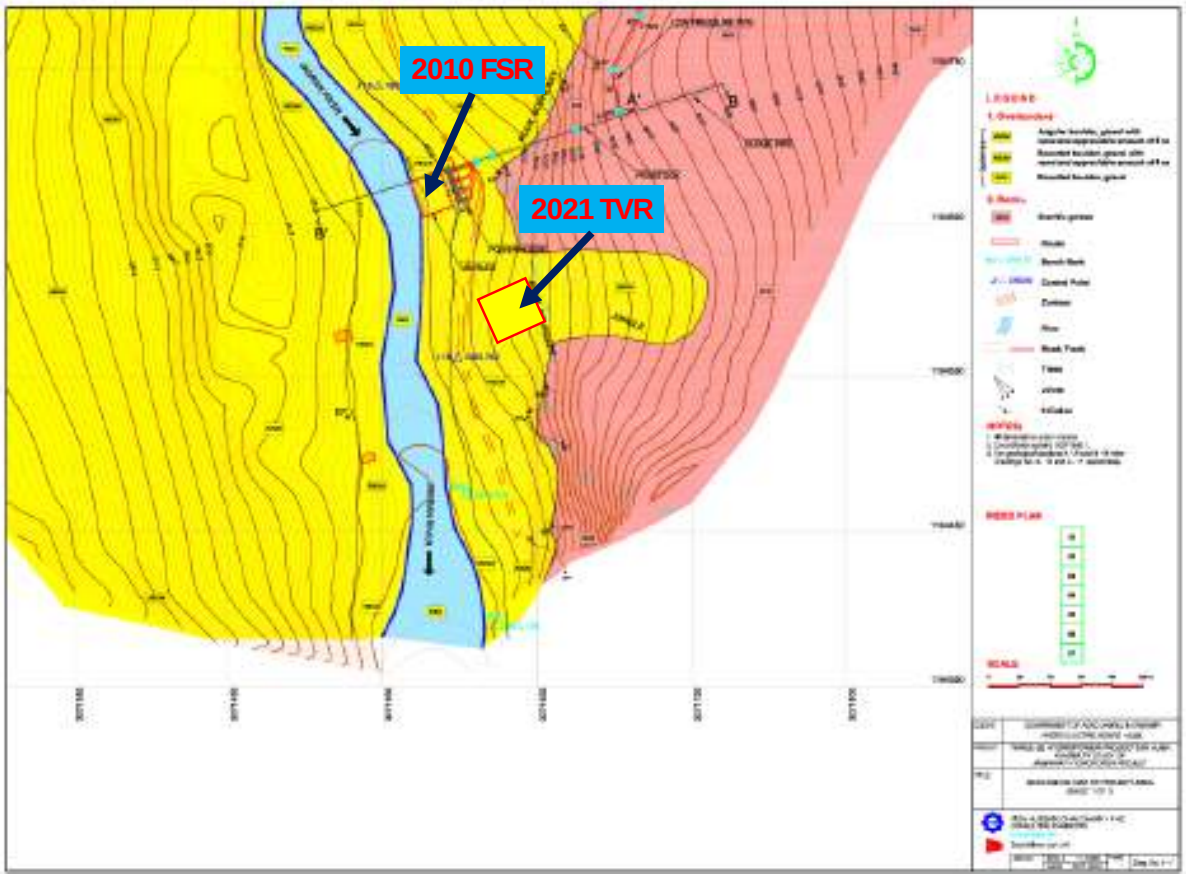


Figure 4-10: The proposed powerhouse location according to FS, 2010 & TPV, 2021

Subsurface Conditions at the proposed Tailrace

The tailrace for the Jagran-IV Hydropower Project will be excavated through overburden (RBGM). The outgoing water will be discharged into the left bank of the Jagran River.

4.3.4 MC Observation on Geotechnical Data

The available geological and geotechnical data from the Feasibility Study, 2010 and Third Party Validation Study, 2021 do not seem to be sufficient to develop the tender level design and drawings for the Project.

Several key inputs needed for the design of the foundations and other structural elements require additional and targeted investigations. Given the type and characteristics of the strata and the specific information required for the project structures, these additional investigations should combine both geophysical and geotechnical methods. Additional detailed geological mapping may also be required along the penstock. The detailed requirements for the further investigations are outlined in the following sections.

A. Proposed ERT Survey

Given the availability of general geological and geotechnical data for the project, a non-invasive investigation method would be a quick and effective way to specifically explore these sites. Electrical Resistivity Tomography (ERT) is one of the non-invasive techniques that could be quickly performed on these sites before weather conditions become unfavourable for further investigations. Combined with existing geological and geotechnical information, the ERT survey

would provide essential data for the design of these structures. The required ERT survey requirements and specifications are provided below.

ERT Survey Specifications

An Electrical Resistivity Tomography (ERT) survey is required to be conducted at the locations of the proposed structures for the Jagran-IV HPP. The purpose of the ERT survey is to determine the type and nature of the subsurface overburden soil layers, as well as the depth and nature of the bedrock.

General Equipment Requirement

An ERT multi-electrode resistivity imaging system with a compatible switching unit

Stainless steel electrodes

A multi-core cable with electrode take-outs at designated spacing

The number, location, and specifications of the ERT tests are provided below.

ERT at Weir Location

Total of four (4) ERTs: two (2) on the right bank and two (2) on the left bank.

Spread length = 150 m, electrode spacing = 3 m, Protocol: Dipole-Dipole

The proposed locations are indicated on the attached sketch (**Figure 4-11**).

ERT at Pipeline Location

Total of four (4) ERTs: one ERT at each chainage of 500, 1000, 1500, and 2500 m.

Spread Length = 50 m, Electrode Spacing = 1 m, Protocol: Dipole-Dipole.

ERT at Powerhouse Location

Total of three (3) ERTs

Spread Length = 200 m, electrode spacing = 4 m, Protocol: Dipole-Dipole.

The proposed locations are indicated on the attached sketch (**Figure 4-12**).

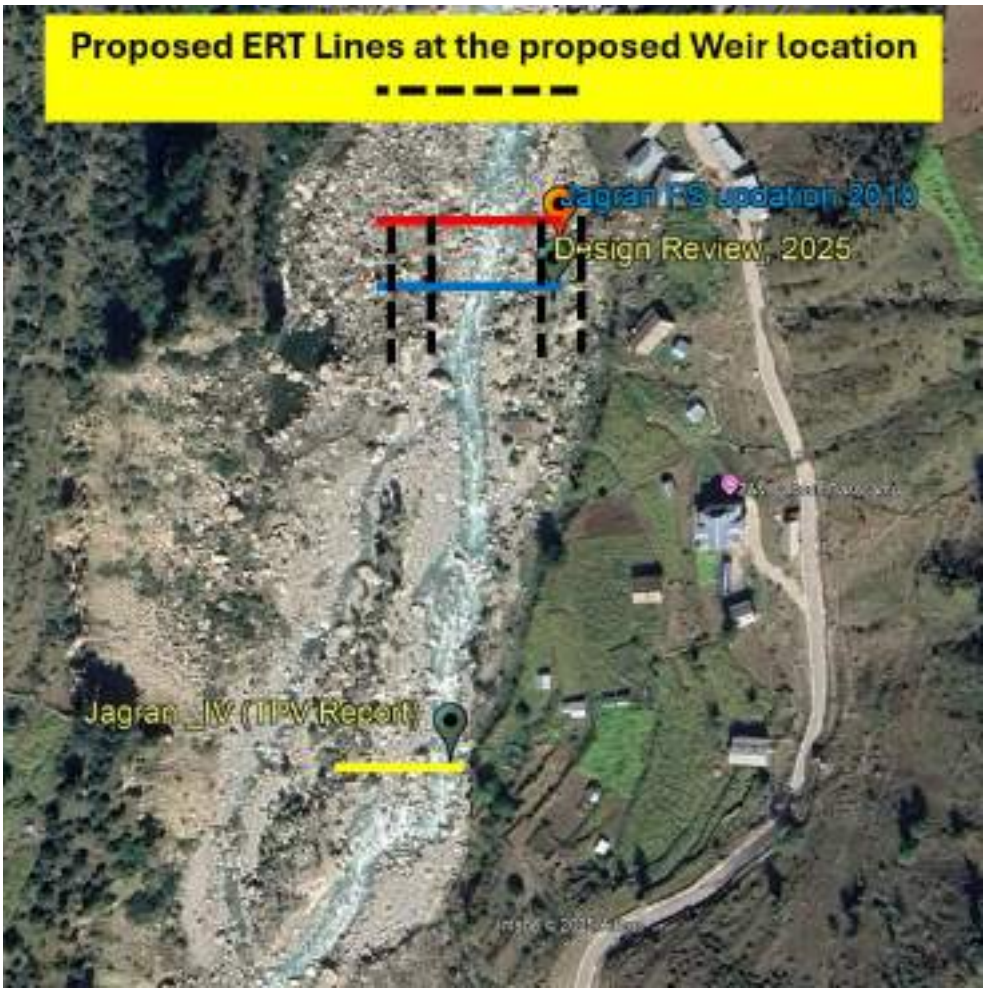


Figure 4-11: Proposed ERTs at the MC proposed diversion weir location

Figure 4-12: Proposed ERTs at the MC proposed powerhouse location

B. Proposed SRT Survey

Although rock appears to be exposed only along the section of the pressure pipe (from chainage 2300 to 3075 m) and the penstock, it is essential to understand the rock's characteristics from multiple perspectives, including foundation type and excavatability. In this regard, the previous geotechnical reports from the Feasibility Study, 2010 and the Third-Party Validation Study, 2021 did not provide sufficient information about the rock's nature. Moreover, since an underground powerhouse option is also being considered, it also requires the knowledge of the excavatability of the rock for the construction of a cavern and the connecting cut-and-cover penstock or a tunnel.

Surface-borne Seismic Refraction Test (SRT) is among the most effective tools for evaluating the requirements mentioned above. The purpose of the SRT is to determine the thickness and likely composition of the overburden or weathered material, as well as the depth to bedrock at the locations of the proposed pipeline, penstock, and powerhouse. These tests are also essential for assessing the nature of excavation (normal excavation, ripping, rock breaking, or blasting) for different types and conditions of strata. Additionally, these tests will provide information on the overburden thickness, depth, and kind of bedrock at the tested locations.

The required SRT survey requirements and specifications are provided below:

Total number of tests = Seven (7)

- Two (2) SRTs along the proposed pipeline at chainages of 2500 and 2800 m
- Three (3) SRTs along the proposed penstock or tunnel alignment
- Two (2) SRTs at the proposed cavern for the underground powerhouse location

SRT Survey Specifications

- A seismic refraction survey at the specified locations will be conducted to determine the overburden thickness, its expected composition, and the depth to bedrock.
- The length of each seismic profile will be approximately 50 meters, or will vary based on site conditions at each project location.
- Coordinates for the start and end points of each profile should be collected using appropriate survey equipment.
- The tests will be carried out and overseen by a team of experienced geologists.
- The field data will be analysed based on the thickness and seismic wave velocity of the subsurface soil and rock layers.
- The seismic refraction survey results will be used to determine the overburden thickness and bedrock depth, and a comprehensive report will be submitted to the Client.

C. Proposed Additional Boreholes

Although several boreholes were drilled in the previous studies, none of these could provide information on the depth of the bedrock at the river bed under the proposed weir location. So, at least one borehole should be drilled at the bedrock to a depth of fifty (50) meters to assess the bedrock depth if encountered. Additional boreholes would be required to determine the subsurface strata information at the proposed underground powerhouse location.

- Drilling should be carried out in the river bed using the percussion method. The borehole logging should be based on the type and nature of the cuttings obtained during drilling. Whenever the rock is encountered, drilling should continue using a double-tube core

barrel. All core samples should be logged, preserved, and transferred to the laboratory for further testing and evaluation.

- Geotechnical laboratory tests on selected samples should be performed to verify field classification and to assist in establishing geotechnical design parameters. All tests should be conducted in accordance with the applicable ASTM standards. Laboratory testing will include the following tests:

  a. Soil classification tests (Grain Size Analysis, Atterberg Limits, Natural Moisture Content)
  b. Unconfined Compression tests (Soil and Rock samples)
  c. Direct Shear Test (Soil samples)
  d. Uniaxial compression testing (Rock samples) – loading direction with respect to the schistose planes.
  e. Hoek Triaxial Compression tests (Rock samples)
  f. Point load index test (Rock samples)
  g. Slake Durability Tests
  h. Petrographic Analysis
  i. Chemical Tests on Soil and Water for the construction purposes

D. Proposed Additional Geological Mapping at Specific Locations

At least four (4) scanline survey lines should be run at the powerhouse location. The geological mapping will be overlaid on topographic survey sheets at an appropriate scale, depending on the project's structure and requirements. However, the contractor would be required to adhere to the standard guidelines for conducting engineering geological mapping and project studies.

The geological maps will display different lithological boundaries and geological structures, including major joint patterns, fractures, faults, primary shear zones, major folding features, and schistosity.

The geological and structural information of the site that impacts the design needs to be reviewed, including but not limited to the following:

- Location of small-scale faults, folds, shears, shear zones, and river bed topography.
- Groundwater regime and its impact on the project
- Geo-hazard assessment at weir, powerhouse sites, and along headrace conduit and tunnel.

E. Discontinuity/Scanline Survey

A discontinuity is a plane of weakness within a rock mass where the rock material is structurally discontinuous. To evaluate the in-situ behaviour of the granite and gneiss, a discontinuity survey, including scanline surveys, is proposed. Although discontinuities are not always planes of separation, they often have little or no tensile strength. Discontinuities range in size from small fissures to significant faults. The most common types are joints and bedding planes. Other significant discontinuities include planes of cleavage and schistosity, fissures, and faults.

Before starting a discontinuity survey, the area must be geologically mapped to identify rock types and key structures. Only after understanding the geology can the most effective and accurate method for conducting the survey be proposed.

One of the most common ways to collect discontinuity data is through direct field measurement. A direct survey can be conducted, subjectively, only for those structures that appear important and are measured and recorded. In a subjective study, the effort can be concentrated on the

seemingly significant joint sets. However, there is a risk of overlooking important sets. Conversely, in an objective survey, all structures intersecting a fixed line or area of the rock face are measured and recorded.

Various methods have been employed to perform direct discontinuity surveys. The fraction set mapping technique records all discontinuities within 6-meter by 2-meter zones, spaced every 30 meters along the face. Using a series of line scans provides an effective way to survey joints. This method involves stretching a metric tape across an exposure, levelling it, and securing it to the face. Two additional scan lines are set as close as possible at right angles to the first—one more or less vertical, and the other horizontal. The distance along the tape where each discontinuity intersects is recorded, along with the direction of the pole to each discontinuity, which indicates the dip direction. The dip of the pole from vertical is noted, as it reflects the plane's dip from horizontal. The strike and dip direction of discontinuities can be measured onsite with a compass, and the amount of dip can be measured with clinometers. Measuring a discontinuity's length offers insight into its extent. It has been suggested that measurements will be taken over roughly a 30-meter distance and, to ensure the survey is representative, they will be continuous throughout that span. The scanning line method provides more detailed information on the occurrence and orientation of discontinuities compared to other approaches (Priest and Hudson, 1981). A minimum of 200 readings per location is proposed to ensure statistical reliability.

To evaluate the behaviour of cut slopes and penstock tunnel excavations, relevant stability assessment data must be collected during the scanline surveys. Using borehole drilling and scanline survey data, the stability of these strata will be assessed for various configurations.

E. Proposed Geo-Hazard Mapping

A detailed geohazard mapping is proposed to evaluate the risks associated with increased built-up exposure and the expected recurrence of geohazards during the project's service life, covering a range of regional and localized hazard scenarios.

Engineering geological hazard mapping for the associated structures, including the weir, sand trap, pressure pipe, surge pipe, penstock, powerhouse, and tailrace locations, should be conducted by a team of experienced engineering geologists. Different types and forms of hazards, such as rockfalls, mudflows, debris flows, and landslides, should be mapped.

4.4 Review of Construction Material Studies

According to previous studies, the construction materials required for the various structures of the proposed Jagran-IV Hydropower Project are considered to be available in sufficient quantities. Boulders and gravel (ABGM) and (RBGM) types are found at slopes and in the riverbed, respectively. Additionally, per the Client's instructions, the Shamkoli site was investigated as another source during Third Party Validation Study, 2021 for the suitability of construction materials. To evaluate the quality of crushed aggregates, a total of eight (8) samples were collected for laboratory testing.

Laboratory testing

- Particle Size Analysis or Sieve Analysis (ASTM D – 422)
- Specific Gravity and Water Absorption Test (AASHTO T – 85)
- Crushing Value Test (BS-812; Part 110)
- Ten Percent Fine Value Test (BS-812; Part 111)

- Los Angeles Abrasion Test (AASHTO T 96 and ASTM C131)
- Sulphate Content (BS 1377 Part 3)
- Chloride Content (BS 1377 Part 3)
- Flakiness & Elongation Index (BS-812; Part 105)

The laboratory test results provided in the Third Party Validation Study, 2021 generally confirm the suitability of aggregate from the Shamkoli site for construction purposes. The discussions in both the Feasibility Study, 2010 and Third Party Validation Study, 2021 about the general availability of construction materials in the area are detailed in the following sections:

Coarse Aggregate

Boulders and cobbles are available in large quantities on both the upstream and downstream sides of the Jagran I & IV weir sites. The coarse aggregate is also found at the terraces. The river bed mainly consists of sub-rounded to rounded boulders and gravel with a small amount of sand (RBG). These boulders and gravel include granitic gneiss, phyllites, and granite. Phyllites cannot be used as aggregates, so they might be separated before crushing to achieve the desired grading. The maximum size of a boulder is up to 8 x 7 x 6 meters. These are generally very hard and may be crushed to the required size for use as coarse aggregate in concrete.

Fine Aggregate (Sand)

Natural sand is not locally available near the project structures. Sand may be excavated from terraces composed of RBGM and ABGM materials. It can also be sourced from the Jagran River bed during the low-flow season. All necessary tests will be conducted on sand and other aggregates to ensure the durability and strength of the concrete.

Building Stone

Granitic gneiss is available in adequate quantities for masonry work near the project area.

Fill Material

For protection measures along slopes and structures, fill material of various gradations is available from the riverbed and nearby terraces within proximity of the project area. Boulders or angular stones can be collected from the riverbed and hillside slopes, respectively, and used in accordance with project specifications and requirements.

Cement and Steel

Cement and steel may not be available in sufficient quantities in Muzaffarabad for the construction of the Jagran-IV Hydropower Project. Therefore, these materials will need to be sourced from Rawalpindi or the Khyber Pakhtunkhwa region. It is proposed that laboratory testing be performed on a representative sample to assess the material's physical and mechanical properties.

4.4.1 MC Observations on Construction Material Studies

Generally, there appears to be an ample supply of rock boulders on the site that can be used for construction after crushing to the required gradation. However, depending on their origin, these rock boulders contain different mineral types. The most commonly available types are Granite, Granitic Gneiss, Gneiss, Gneissic Granite, Schist, and Phyllite. Based on their mineralogical compositions, not all rock boulders are suitable for construction purposes, especially for concrete aggregate. Additionally, there is insufficient data in the Feasibility Study, 2010 and the Third-Party Validation Study, 2021 on the testing of the material available on the

site. Therefore, a material testing investigation is necessary to determine the suitability of all available rock boulders as a source of construction material. These investigations will help identify the specific types of boulders suitable for use as concrete aggregate and other construction applications. The proposed material investigation program is outlined as follows.

Proposed Field Sampling

Representative samples of all types of rock boulders in the area, including alluvial (rounded) and glacial (angular) varieties, should be collected. Samples should be taken from both the nearby terraces and the riverbed. The sampling may involve excavating pits or trenches. A total of twelve (12) samples is expected from the areas near the proposed weir and powerhouse. An experienced geologist or materials engineer must supervise the sampling.

Proposed Laboratory Tests

- Petrographic Analysis – 12 tests
- Alkali-Silica Aggregate Reaction – 12 tests
- Slake Durability – 5 tests
- Sodium-sulphate Soundness – 12 tests
- Specific Gravity and Water Absorption – 12 tests
- Los Angeles Abrasion – 12 tests

4.5 Review of Seismic Hazard Study

Feasibility Study, 2010 has conducted a seismic study. The seismic survey summary and the final findings are provided below.

Since the Jagran-IV Hydropower Project is located in a tectonically active zone affected by the ongoing northward movement of the Indian Plate and its subduction beneath the southern margins of the Eurasian Plate, seismic hazard assessment based on Probabilistic and Deterministic Seismic Hazard Analysis (PSHA & DSHA) was performed to determine realistic seismic design parameters for the safe construction of project structures in accordance with ICOLD guidelines 2010. A summary of the seismicity study results is provided below:

- Maximum Credible Earthquake (MCE) based on a 1000-year return period = 0.68g
- Operating Basis Earthquake (OBE) based on 145-year return period = 0.26g
- Design Basis Earthquake (DBE) = 0.35g

4.5.1 MC Observations on Seismic Hazard Study

MC proposes a site-specific analysis of all structures involved in the project, using the above results and a synthetically prepared seismic event likely in the area.

4.6 Review of Geotechnical Design of Hydraulic Structures–Previous Studies

All the structures were initially designed during the Feasibility Study, 2010 and reviewed in Third Party Validation Study in 2021. These are discussed individually in the following sections:

4.6.1 Geotechnical Aspects of the Proposed Diversion Weir

According to the Feasibility Study, 2010, the weir is proposed approximately 120 meters downstream of where the Baihk nullah joins the Jagran River (**Figure 4-6**). At the proposed

weir axis, the riverbed level is 2258 meters above sea level, and the river in this stretch flows with an average gradient of about 5.5%. To divert the design discharge of 18 m^3/s first into a connecting channel and then into a low-pressure pipe, a concrete weir 6 meters high above the riverbed has been proposed. The intake structure is designed to handle the design discharge, with excess flow spilling over the weir back into the river.

According to the geological investigation of the weir site, the structure seems to be founded on alluvial strata (**Figure 4-7**). Based on the measured permeability values, the alluvial strata have a high subsurface percolation/seepage rate. To reduce seepage to the desired level and control possible piping effects, a cutoff wall up to 6 meters deep along the weir axis was proposed in the Feasibility Study, 2010 and was endorsed by the Third Party Validation Study, 2021 (**Figure 4-13**).

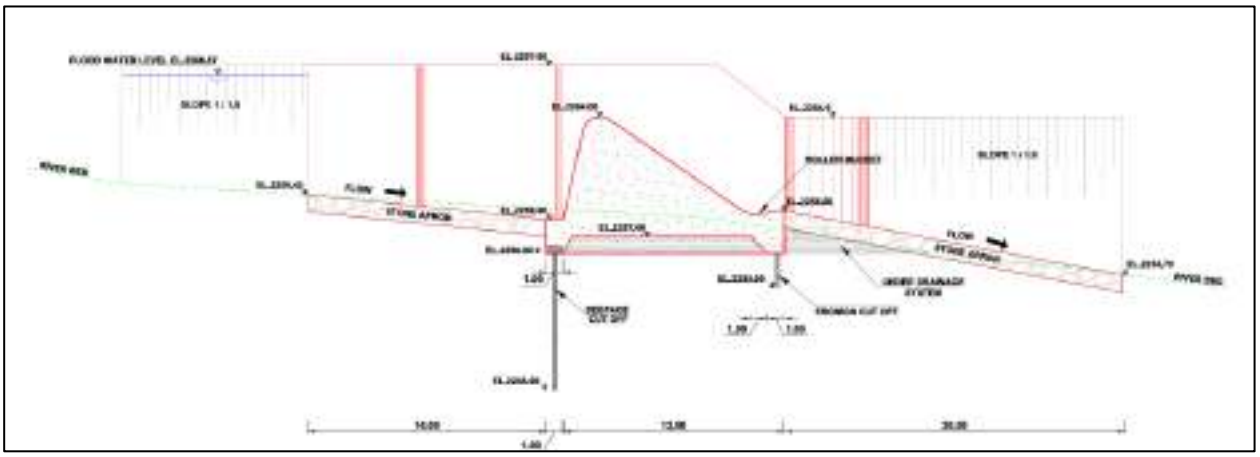


Figure 4-13: Designed Weir Section according to FSR 2010 and 2021 TVR.

In the Third Party Validation Study, 2021 the proposed weir site was changed to a location 150 m downstream of the proposed axis during the Feasibility Study, 2010. They justify the relocation with the premise that the relocated weir site features a steep slope and hard strata on the left bank, with a relatively narrow river width. According to them, the site is more suitable for river diversion on the right bank, with an intake structure and under sluices on the left bank.

The Third Party Validation Study, 2021 suggests that the stability analysis of the weir structure, including under sluices and the power intake, should be conducted using data from the geological investigation at the weir site. The Feasibility Study, 2010 suggests that foundation treatment will be performed through traditional grouting. However, Third Party Validation Study, 2021, considering the foundation's composition—loose material and boulders— indicated that this technique may be inadequate and unlikely to meet the objectives. They suggested that the need for a cut-off should be analysed more thoroughly. Given the limited height of the weir, the requirement for such treatment should be confirmed through seepage and uplift pressure analysis. An alternative solution could involve designing a deeper foundation or extending the upstream apron to increase the seepage path. Additionally, the necessity for drainage and the release of uplift pressure under the energy dissipation basin should be evaluated.

4.6.2 Geotechnical Aspects of the Proposed Connecting Channel and Sand trap

Based on the geological mapping results, the connecting channel appears to be constructed in the overburden sediments; therefore, a culvert has been designed to ensure structural stability,

and a rectangular cross-section has been chosen. It seems that the proposed sand trap will be constructed within the overburden deposits, with a lower likelihood of encountering the bedrock at the foundation depth (**Figure 4-14**).

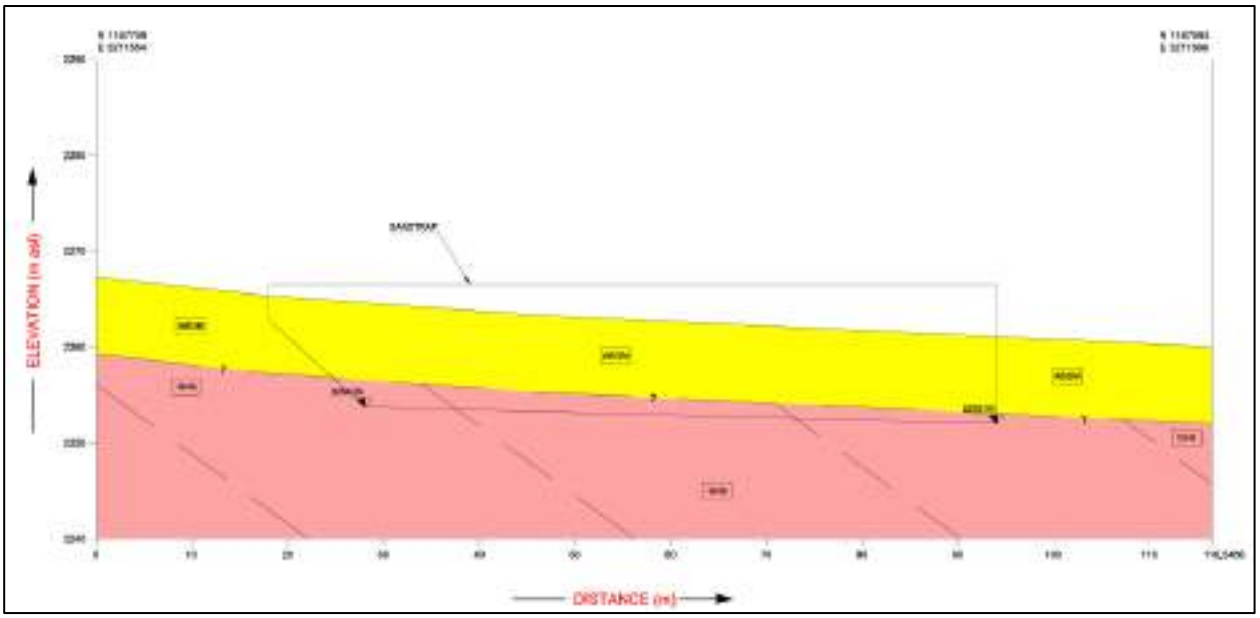


Figure 4-14: Subsurface Cross-section at the proposed Sand trap location (FS, 2010)

4.6.3 Geotechnical Aspects of the Proposed Pressure Pipe

A 2.5-meter-diameter glass fiber reinforced plastic (GRP) pressure pipe, about 3075 meters long, has been proposed to run from the desander to the surge area. The entire pipe will be embedded and laid in a trench excavated with a gentle slope on left bank of the Jagran River.

Along the entire length of the low-pressure headrace pipe from the desander to the surge pipe, 27 anchor blocks have been designed at each bend in the alignment. The low-pressure headrace pipe, extending to the surge area, will be embedded and laid with a gentle slope.

Based on the geological information obtained from the Feasibility Study, 2010, the last about 800 m of the pipe will be laid on rock, while the rest will be founded on overburden deposits (**Figure 4-15**).

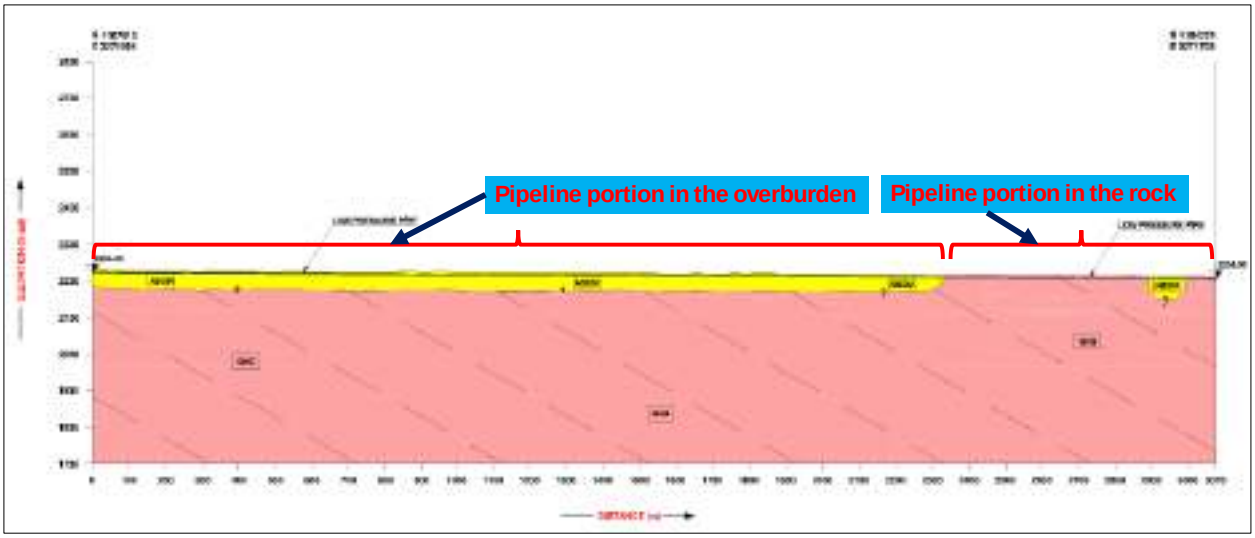


Figure 4-15: Subsurface cross-section along proposed low-pressure pipe (FS, 2010)

4.6.4 Geotechnical Aspects of the Proposed Powerhouse

The powerhouse is planned to be constructed on the left bank of the Jagran River. It will feature a reinforced concrete frame structure measuring 35.4 meters long and 10 meters wide. The building will stand 16.5 meters tall from the foundation to the roof. It will house four Francis turbines, consisting of three 6.0 MW units and one 4.0 MW unit. The powerhouse foundation will be at an elevation of 2101.5 meters above sea level, with the turbine level at 2,105.0 meters. The machine hall floor will be at 2111.0 meters, and the top of the powerhouse will be at 2118.0 meters. The main hall will contain four Francis units, along with generators, a flywheel, switch cabinets, an erection bay, and other facilities.

According to the Feasibility Study, 2010, the powerhouse is proposed to be located in the riverbed approximately 300 m from the Jagran-I intake weir (Figure 4-16). The riverbed area is covered with large, rounded, and sub-angular boulders (ABGM, RBGM, and ABG, RBG), along with rock debris mixed with sand from fluvial and colluvial materials. At the left abutment, rock is exposed at road level, but at the powerhouse site, there is no visible rock exposure. The subsurface cross-section along the proposed powerhouse location is shown in Figure 4.17.

The Third Party Validation Study, 2021 proposed an alternative location for the powerhouse, situated a bit downstream of previously suggested site in Feasibility Study, 2010 (Figure 4-16).

The revised location is closer to the Jagran-I intake weir, and according to Third Party Validation Study, 2021, it reduces the likelihood of flood damage during peak season, as it lies in the broadest part of the riverbed, near the end of an alluvial fan, where the impact of sliding material is less.

According to the Third Party Validation Study, 2021, the powerhouse's outflows would be discharged into the Jagran River.

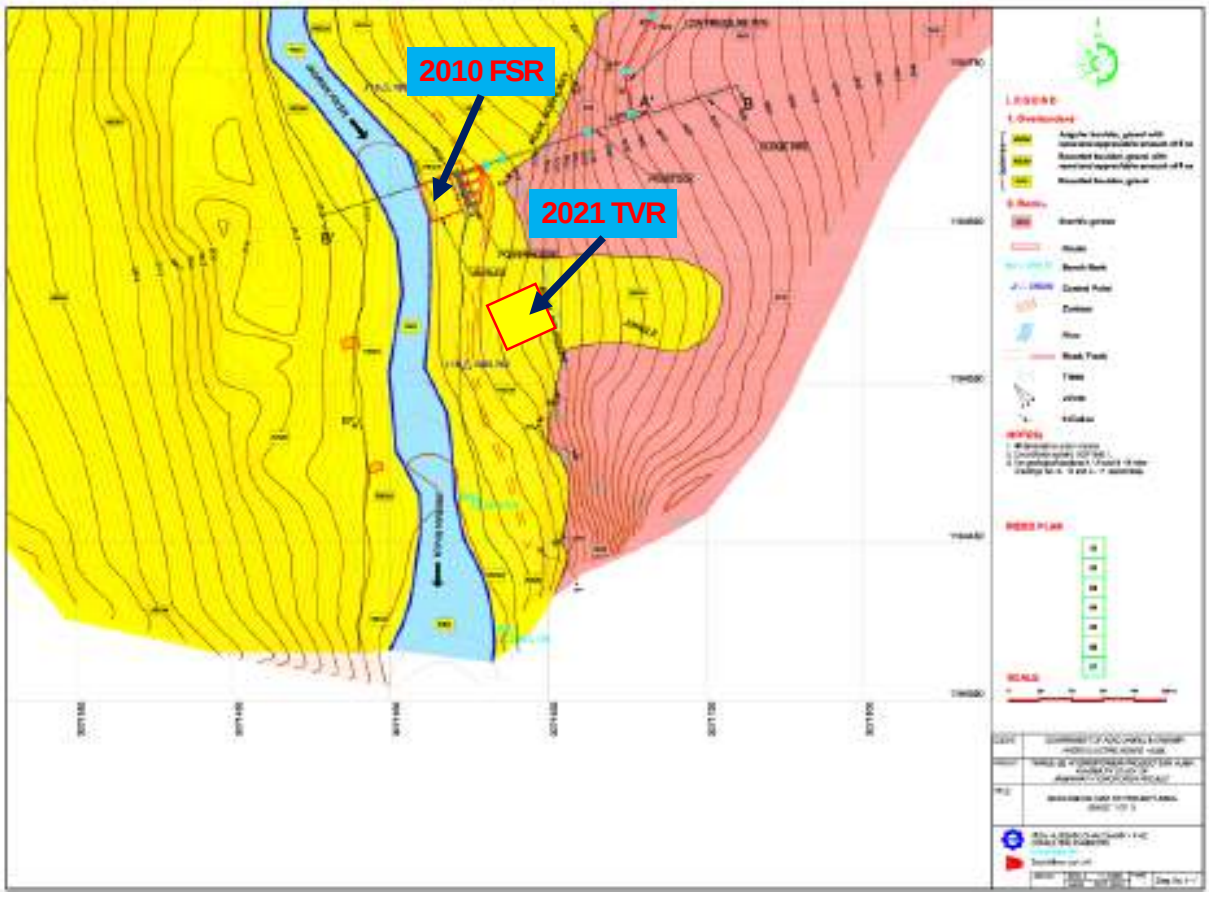


Figure 4-16: Proposed powerhouse locations according to FS, 2010 & TPV, 2021

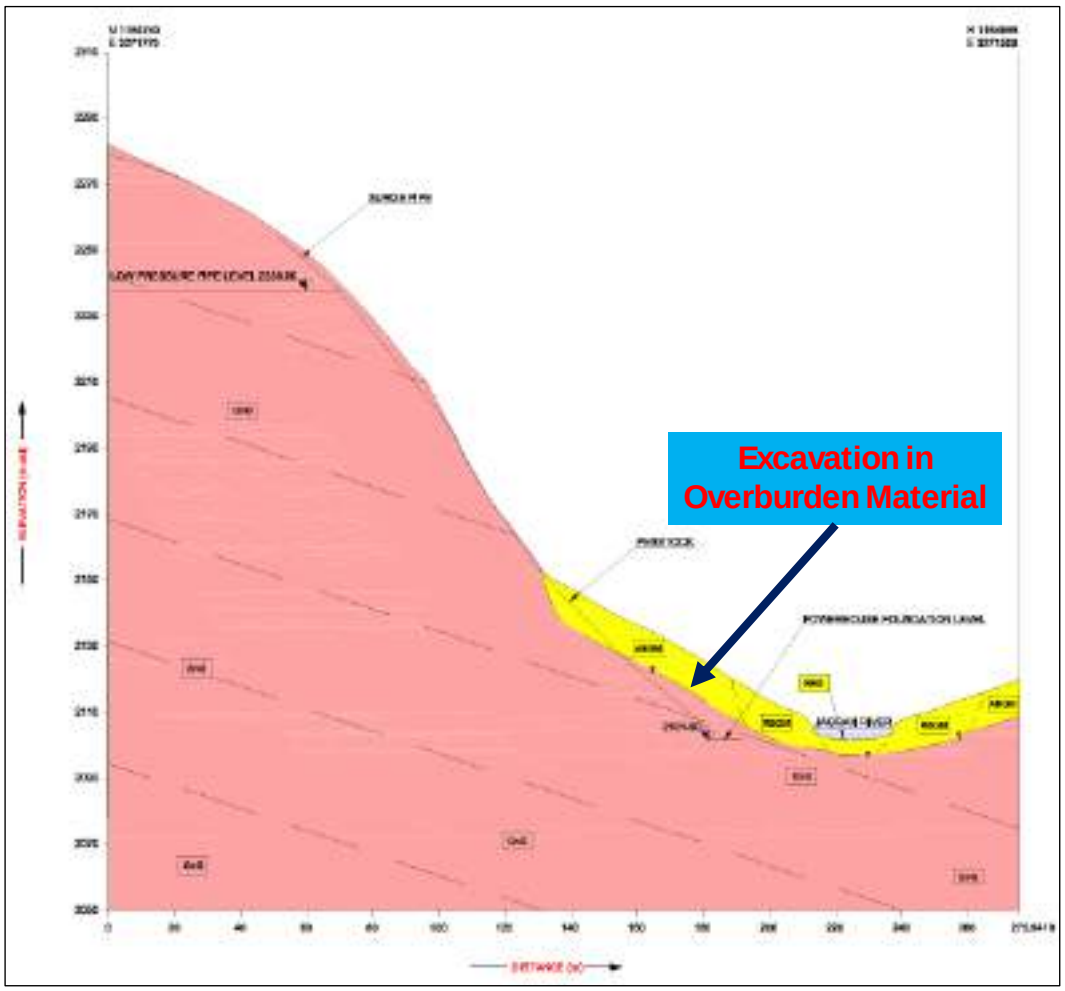


Figure 4-17: Subsurface cross-section along the proposed powerhouse showing the required excavation in the overburden material (FS, 2010).

4.6.5 MC Observation on the Geotechnical Design of Hydraulic Structures

This review discusses the geotechnical factors involved in site selection and foundation decisions for the various hydraulic structures and their components that comprise this project.

Geotechnical Aspects of the Diversion Weir

The right bank of the river at the weir location proposed in the Third Party Validation Study, 2021 has an active landslide area (Figure 4-18). This landslide was also marked on the geological map included in the Feasibility Study, 2010 (Figure 4-6).

The MC has therefore proposed to move it upstream from the location proposed in the Third Party Validation Study, 2021 (Figure 4-18). The site chosen by MC has relatively stable abutments. However, due to the presence of overburden deposits at the abutments, the concrete weir is not proposed to be abutted directly with the overburden deposits.

A mass concrete wall or an equivalent arrangement should be provided as a transition between the weir ends and the overburden deposits. This should prevent the erosion of the abutments during the maximum flood conditions. To investigate the nature and extent of the strata required for the design of this transition, a geophysical investigation involving four (4) ERTs has been proposed (Figure 4-11).

The site proposed by MC is located slightly downstream of the site suggested in the Feasibility Study, 2010. This adjustment is made to accommodate the upstream floor within the land already acquired by the Client for the diversion weir.

Due to the high permeability of the subsurface alluvial strata in the riverbed, it is expected that an arrangement with a longer upstream floor and multiple shallow cutoff walls will be necessary.

This should help reduce the water head to the desired level on the downstream apron or floor. A shorter upstream stone apron and an eight-meter-deep grout curtain, as suggested in the previous studies, do not seem sufficient to reduce the water head on the downstream floor.

Figure 4-18: An active slide on the right bank of the river at the proposed weir site in TPV, 2021 (yellow line). MC's proposed site is marked with a blue line, while the one proposed in the FS, 2010 is marked with a red line.

Geotechnical Aspects of the Pressure Pipe

Although the pressure pipe is planned to be buried along its entire 3 km length, it passes through terrain that remains vulnerable to landslides, mudslides, avalanches, and debris flows. Such global phenomena in the area could lead to significant ground movements, causing significant displacement and/or damage to the buried pipeline. To prevent such damage, The MC proposes supporting all anchor blocks and a few pipe supports on pile foundations. These pile foundations should either be socketed into shallow bedrock or designed as friction piles. The MC also proposes conducting an SRT survey along the pipeline to determine the nature of the bedrock and the overburden layers for pile foundation design.

Geotechnical Aspects of the Powerhouse

The proposed powerhouse site in the Feasibility Study, 2010 may face slope stability problems due to the necessary slope cutting for the powerhouse and penstock. This concern was also supported by Third Party Validation Study, 2021, who proposed a site just downstream of the one in the Feasibility Study, 2010. However, the location suggested by the Third Party Validation Study, 2021 is situated right at the mouth of a watershed valley. Given the overall landslide activity in the valley and the specific characteristics of this watershed, mudflows or

debris flows are highly likely. Due to these potential hazards, the MC has proposed moving the powerhouse further downstream (Figure 4-19).

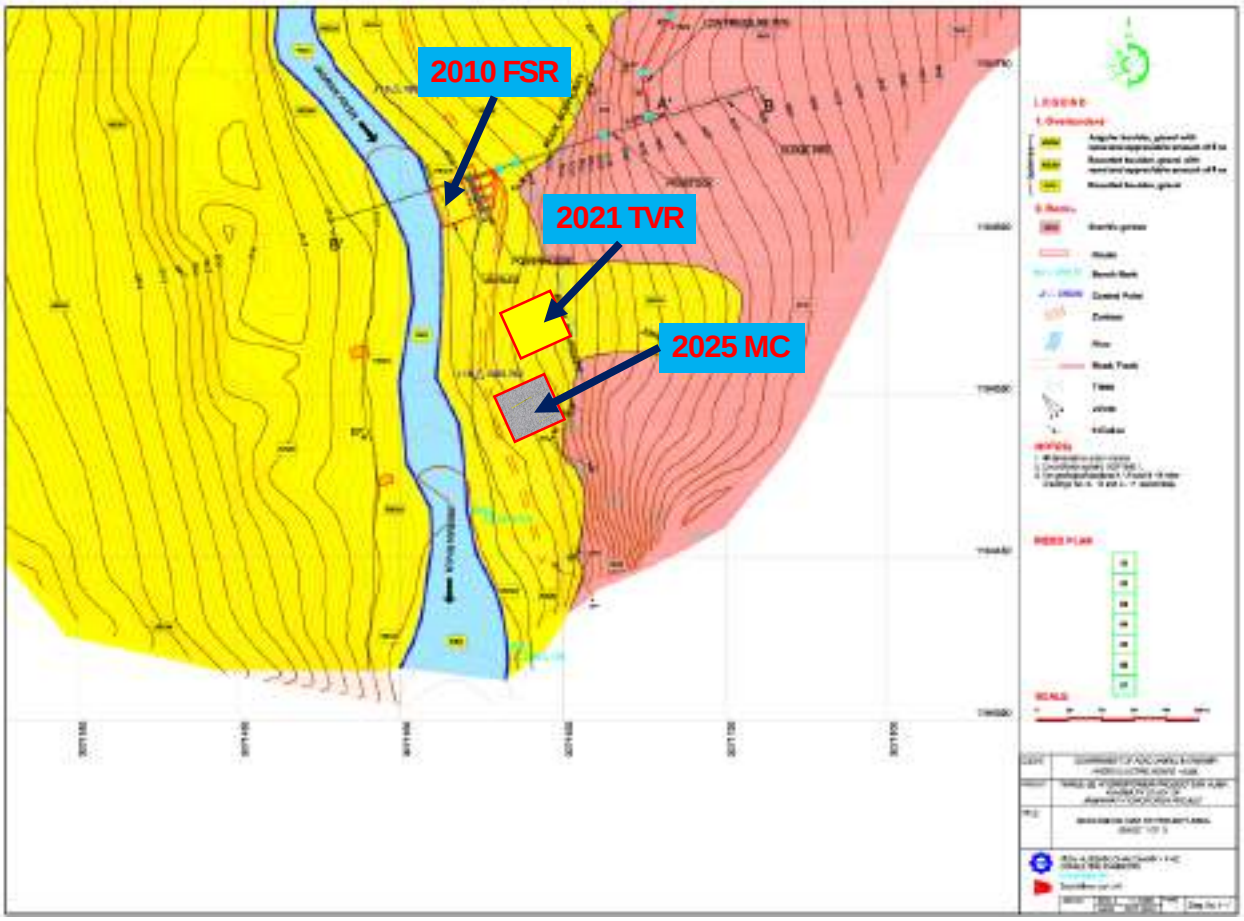


Figure 4-19: Powerhouse locations based on FS 2010, TPV, 2021 and MC, 2025

To protect it from the maximum expected flood, the powerhouse is proposed to be placed on a raised platform. This platform would, in turn, be supported by a piled-raft foundation. The number and depth of piles could be determined based on the thickness of the alluvial deposits and the probable presence of bedrock at shallow depths. It is anticipated that the bedrock may dip beneath the proposed powerhouse location from the nearby hills. To assist in the design of deep foundations, an ERT geophysical survey has been proposed for the powerhouse site (**Figure 4.12**).

During its service life, the powerhouse may face high flood levels associated with the movement of large boulders. To safeguard the powerhouse from these boulders and the debris flows, a protective wall will also be proposed upstream of the powerhouse location. To protect against scour and the impact of the boulders, MC proposes building this wall on the pile foundations.

Considering the flood history of the Jagran River and the damage to the Jagran-I powerhouse area in 2010, there is also an option of shifting the powerhouse underground. The powerhouse will be housed in a cavern in the adjacent hills on the left bank of the river. In that case, the penstock would either be constructed using cut-and-cover option or, for long-term safety, replaced with a tunnel. Although the latter option appears safer, it will present numerous construction challenges. Due to the rock type, its characteristics, and the generally unfavourable bedding conditions, designing and installing the rock support system would be practicability challenging and costly. Given these challenges, the MC does not favour this option.

4.7 MC Summary Observations

Table 4.6 gives the summary of perspectives from Feasibility Study, 2010 and Third-party Validation Study, 2021. The MC observations on each aspects also provided.

Table 4-6: MC Summary Observations on Geotechnical Studies

S. No.	Perspective of		Review by MC 2025	Comments by MC
	FS, 2010	TPV, 2021		
1	Weir Location (Fig. 4.18)		The right bank of the river at the weir location proposed in the Third Party Validation Study, 2021 has an active landslide area (**Figure 4.16**). This landslide was also marked on the geological map included in the Feasibility Study, 2010 (**Figure 4.6**). The MC has therefore proposed to move it upstream from the location proposed in the 2021 Third Party Validation Study, 2021 (**Figure 4.18**). The site chosen by MC has relatively stable abutments. However, due to the presence of overburden deposits at the abutments, the concrete weir is not proposed to be abutted directly with the overburden deposits. A mass concrete wall or an equivalent arrangement should be provided as a transition between the weir ends and the overburden deposits. This should prevent the erosion of the abutments during the maximum flood conditions. To investigate the nature and extent of the strata required for the design of this transition, a geophysical investigation involving four (4) ERTs has been proposed (See Para A of Section 4.3.4). The site proposed by The MC is located slightly downstream of the site suggested in the Feasibility Study, 2010. This adjustment is made to accommodate the upstream floor within the land already acquired by the Client for the diversion weir. Due to the high permeability of the subsurface alluvial strata in the riverbed, it is expected that an arrangement with a longer upstream floor and multiple shallow cutoff walls will be necessary. This should help reduce the water head to the desired level on the downstream apron or floor. A shorter upstream stone apron and an eight-meter-deep grout curtain, as suggested in the previous studies, do not seem sufficient to reduce the water head on the downstream floor.	
2	Power House Location		The proposed powerhouse site in the Feasibility Study, 2010 may face slope stability problems due to the	

	(Figure 4.19)		necessary slope cutting for the powerhouse and penstock (**Figure 4.17**). This concern was also supported by Third Party Validation Study, 2021, who proposed a site just downstream of the one in the Feasibility Study, 2010. However, the location suggested by the Third Party Validation Study, 2021 is situated right at the mouth of a watershed valley. Considering the overall landslide activity in the valley and the specific characteristics of this watershed, mudflows or debris flows are highly likely. Due to these potential hazards, MC has proposed moving the powerhouse further downstream (**Figure 4.19**). To protect it from the maximum expected flood, the powerhouse is proposed to be placed on a raised platform. This platform would, in turn, be supported by a piled-raft foundation. The number and depth of piles could be determined based on the thickness of the alluvial deposits and the presence of bedrock at shallow depths. It is anticipated that the bedrock might be dipping beneath this location from the nearby hills. To assist in the design of deep foundations, an ERT geophysical survey has been proposed for the powerhouse site (see Para A of Section 4.3.4). During its service life, the powerhouse may face high flood levels associated with the movement of large boulders. To safeguard the powerhouse from these boulders and the debris flows, a protective wall is also proposed upstream of the powerhouse location. To protect against scour and the impact of the boulders, The MC has also proposed building this wall on the pile foundations. Considering the flood history of the Jagran River and the damage to the Jagran-I powerhouse area in 2010, there is also an option of shifting the powerhouse underground. The powerhouse will be housed in a cavern in the adjacent hills on the left bank of the river. In that case, the penstock would either be constructed using cut-and-cover option or, for long-term safety, replaced with a tunnel. Although the latter option appears safer, it will present numerous construction challenges. Due to the rock type, its characteristics, and the generally unfavourable bedding conditions, designing and installing the rock support system would be practicability challenging and costly. Given these challenges, the MC does not favour this option.
3	Buried Pipeline – *Only Shallow*	Buried Pipeline – *Only Shallow*	Buried Pipeline – *Anchor Blocks and Pedestals are proposed to be on Pile Foundations* Although the pressure pipe is planned to be buried along

	Foundations or Anchorage	*Foundations or Anchorage*	its entire 3 km length, it passes through terrain that remains vulnerable to landslides, mudslides, avalanches, and debris flows. Such global phenomena in the area could lead to significant ground movements, causing significant displacement and/or damage to the buried pipeline. To prevent such damage, the MC proposes supporting all anchor blocks and a few pipe supports on pile foundations. These pile foundations should either be socketed into shallow bedrock or designed as friction piles. The MC also proposes conducting an SRT survey along the pipeline to determine the composition of bedrock or overburden layers for pile foundation design (Para B of Section 4.3.4).
4	Construction Materials *Additional Investigations Suggested by MC*		Generally, there appears to be an ample supply of rock boulders on the site that can be used for construction after crushing to the required gradation. However, depending on their origin, these rock boulders contain different mineral types. The most commonly available types are Granite, Granitic Gneiss, Gneiss, Gneissic Granite, Schist, and Phyllite. Based on their mineralogical compositions, not all rock boulders are suitable for construction purposes, especially for concrete aggregate. Additionally, there is insufficient data in the Feasibility Study, 2010 and the Third-Party Validation Study, 2021 on the testing of the material available on the site. Therefore, a material testing investigation is necessary to determine the suitability of all available rock boulders as a source of construction material. These investigations will help identify the specific types of boulders suitable for use as concrete aggregate and other construction applications. The details of the proposed investigations are provided in Section 4.3.4.
5	Geological and Geohazard Mapping *Additional Investigations Suggested by MC*		The surface geological maps and cross-sections included in the Feasibility Study, 2010 provide only a broad overview of the area's geology. After reviewing the geological data, the MC identified the following gaps in the necessary information. 1. Since most of the structures are planned to be built on overburden deposits, it would have been more helpful to provide a detailed classification and mapping of the

		different types and characteristics of overburden at the proposed structures. This information should have included categorization by type (e.g., alluvial, glacial, terrace deposits) and should have been indicated on the site-specific geological maps. This would have helped in the design of the interface between the diversion weir and its abutments. 2. Considering the recent cloud bursts and flash flood scenarios due to climate change, the site-specific geological maps should identify the locations and extent of major geological hazards, such as landslides, mudflows, debris flows, slope failures, and rockfalls. To aid in foundation design, an assessment of these hazards should also have been conducted along the pressure pipeline route. 3. Although a rock structural and mass description is provided for the pipe outlet area, it would have been more useful if such details were included for the rocky terrain near other hydraulic structures. This information could have aided better decision-making and design, such as relocating the powerhouse underground. Therefore, MC proposes the following for further geological investigations. A corridor of 100 m is suggested along the proposed penstock, while a 200 x 200 m section should be mapped for the powerhouse area. At least four (4) scanline survey lines should be run at the powerhouse location. Engineering geological hazard mapping for the associated structures, including the weir, sand trap, pressure pipe, surge pipe, penstock, powerhouse, and tailrace locations, should be conducted by a team of experienced engineering geologists. Different types and forms of hazards, such as rockfalls, mudflows, debris flows, and landslides, should be mapped.
6	Geotechnical Investigations *Additional Investigations Suggested by MC*	Although several boreholes were drilled in the previous studies, none of these could provide information on the depth of the bedrock at the river bed under the proposed weir location. Based on the information and data from boreholes, test pits, and geological mapping, it is confirmed that rock is not exposed at any of the proposed project site locations, and there is insufficient site-specific geotechnical data for a proper geotechnical assessment. So, at least one borehole should be drilled at the bedrock to a depth of fifty (50) meters to assess the bedrock depth if encountered.

SECTION - 5: PROJECT LAYOUT AND HYDRAULIC DESIGN REVIEW

5.1 General

This chapter presents a comparative layout and hydraulic design review of the weir, power intake, sand trap/ desilting basin, penstock, and tailrace using evidence from Feasibility Study, 2010 and Third Party Validation Study, 2021.

Each component is benchmarked against current guidance (USACE, USBR, ASCE/ICOLD), while accounting for post-2010 morpho dynamic changes, the refined gross head (~169–170 m), and the ~120 m downstream shift of the weir axis reported by TPV, 2021.

5.2 Review of Feasibility Study, 2010

5.2.1 Weir (Overflow Structure & Under Sluice)

The diversion arrangement comprises a 6 m-high RCC overflow weir (crest EL 2264 m) founded on alluvium, with energy dissipation by a roller bucket and downstream stone pitching. The overflow portion (24 m crest) conveys ~190 m^3/s, while a gated flushing/ under sluice section on the left bank conveys the balance of the 500-year design flood (total 419 m^3/s).

The layout places the intake and flushing facilities on the left bank; construction sequencing diverts flow to the right bank via a dyke to construct the left-bank works in low-flow season. An 8 m deep cutoff wall is foreseen along the axis to control seepage/piping in the alluvium.

The flushing section consists of two rectangular bays (clear width 4.0 m, bed EL ~2258→2256 m over ~14 m), each fitted with hydraulically operated radial gates ~4.5 m high × 4.0 m wide.

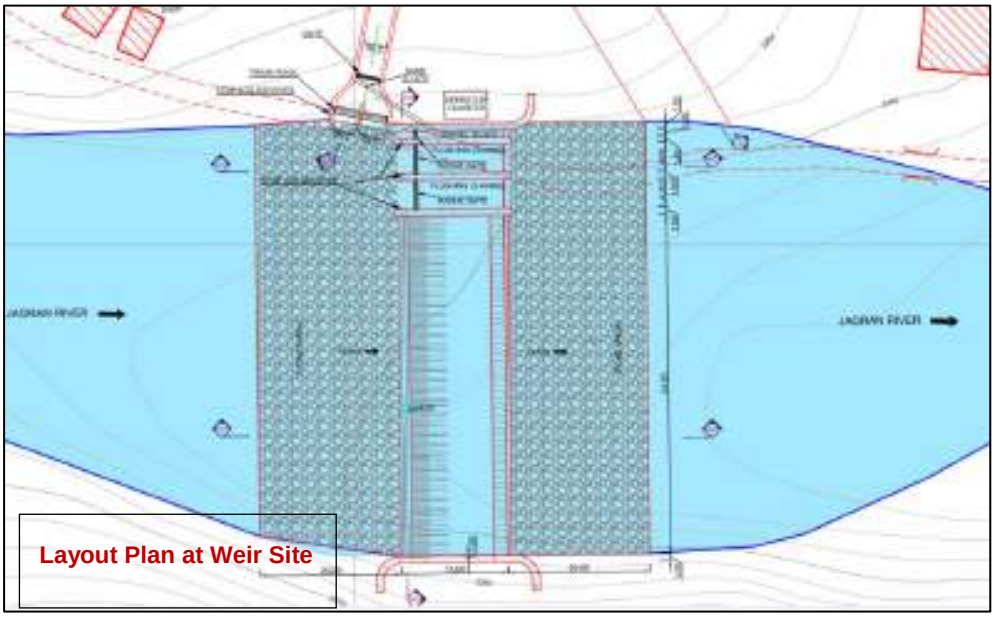
The salient hydraulic computations give a head over crest h≈2.57 m at Q=190 m^3/s; associated levels, flows and gate sizing are tabulated in the report.

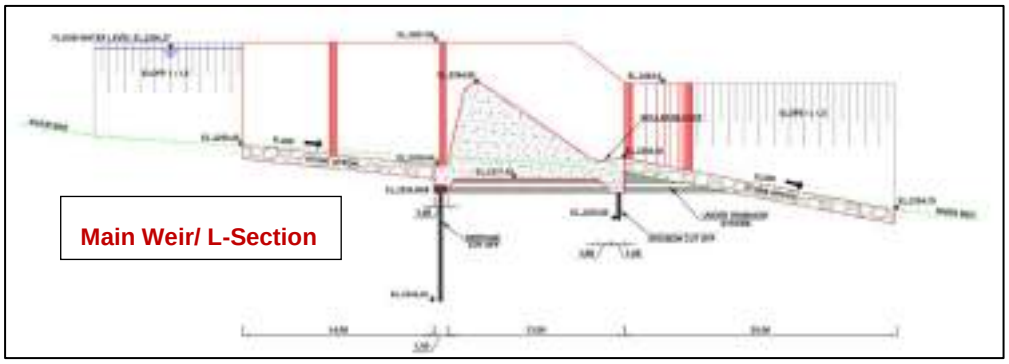
The salient features are described in **Table 5-1** and shown in **Figure 5-1**.

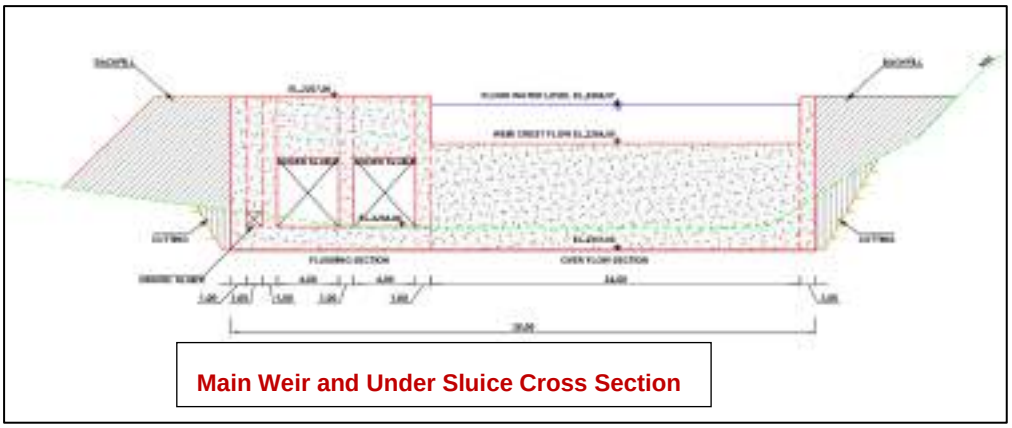
Table 5-1: Salient Features Weir and Under Sluice / Flushing Channel-FS 2010

Component	Feature	Value / Description
Diversion Weir (Overflow Portion)	Type & Material	RCC overflow weir with roller bucket; downstream riprap/stone pitching (~20 m)
	River Bed Level	~EL 2258 m
	Crest Level (EL)	**EL 2264 m**
	Sidewall / Top of Training Walls	~EL 2267 m
	Height Above Bed	~6 m
	Crest Length	**~24 m** (overflow portion)
	Design Flood (AEP 1:500)	**Q = 419 m^3/s** (total)
	Overflow Share of Q	**≈ 190 m^3/s** over crest

Component	Feature	Value / Description
	Head Over Crest at Qoverflow	**h ≈ 2.57 m**
	Energy Dissipation	Roller (trajectory) bucket; toe protection with pitching
	Seepage/Foundations	Cutoff wall along axis (depth ~8 m) to control piping/under seepage
	Plan Arrangement	Overflow section central/right; intake and flushing on **left bank**
	Construction Staging	Divert flow to **right bank** via temporary dyke; construct left-bank works in low-flow season
Flushing / Under sluice & Flushing Channel	Purpose	Sediment sluicing / approach protection; convey balance of design flood
	Number of Bays	**2 bays** (left of overflow)
	Clear Bay Width	**4.0 m** each
	Gates	Radial/segmental gates, **~4.5 m (H) × 4.0 m (W)**; hydraulically operated
	Sill / Bed Levels	Flushing channel bed grades **~EL 2258** → **2256 m** over ~14 m
	Water Levels (Design)	Upstream WL max ~EL 2266 m; downstream WL ~EL 2260 m (indicative)
	Capacity via Sluices	**≈ 229 m³/s** (balance of the 419 m³/s)
	Isolation & O&M	Stop log grooves for isolation/maintenance; access provisions
Integration & Operations	Intake Proximity	Flushing on intake side to maintain low-sediment core flow into approach
	Debris Management	Verify passage during monsoon; coordinate with rack cleaning strategy







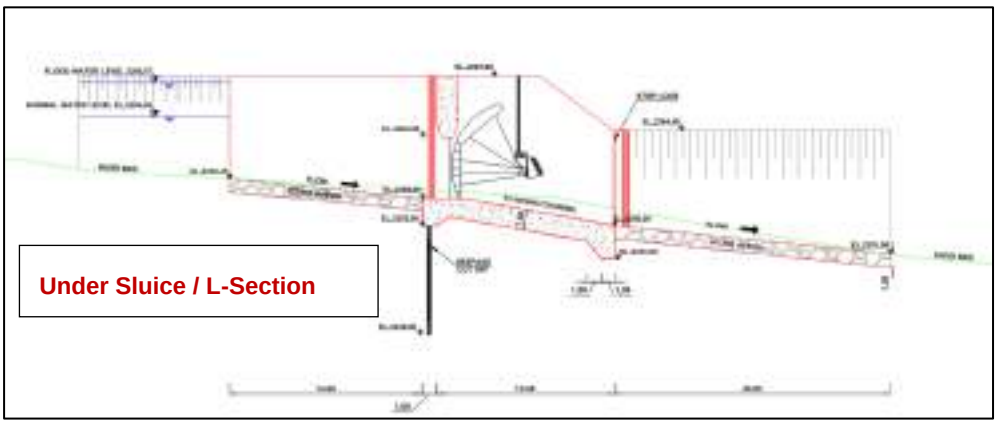


Figure 5-1: Plan and Sections of Weir (FS, 2010)

5.2.2 Power Intake Structure

The power intake is sized to pass Q = 18 m³/s into the connecting/approach channel with controlled head loss and minimized sediment entrance. The concept sets the gross intake area = 19.6 m², limits entrance velocity to ≈0.92 m/s at design flow and places the lower sill 3.40 m above the flushing bed to suppress bed-load entry. The intake is oriented at an angle to the main river to deflect sediment-rich core flow away from the opening and includes trash rack panels (round bars Ø10 mm at 10 mm spacing) with stop-log grooves and a maintenance platform at EL 2267.5 m for manual cleaning. The salient features are described in **Table 5-2** and shown in **Figure 5-2**.

Table 5-2: Salient features for the Power Intake –FS 2010

Salient feature	Value / Description
Design discharge & velocity	Q = 18 m³/s, Vmax ≈ 0.92 m/s at entrance
Sill elevation concept	Sill +3.40 m above flushing bed to reduce bed-load entry
Trash rack	Ø10 mm bars @ 10 mm spacing; maintenance platform EL 2267.5 m
Stop-logs / gate	~3.7 m × 3.0 m roller/stop-log; hydraulic operation; stainless rails

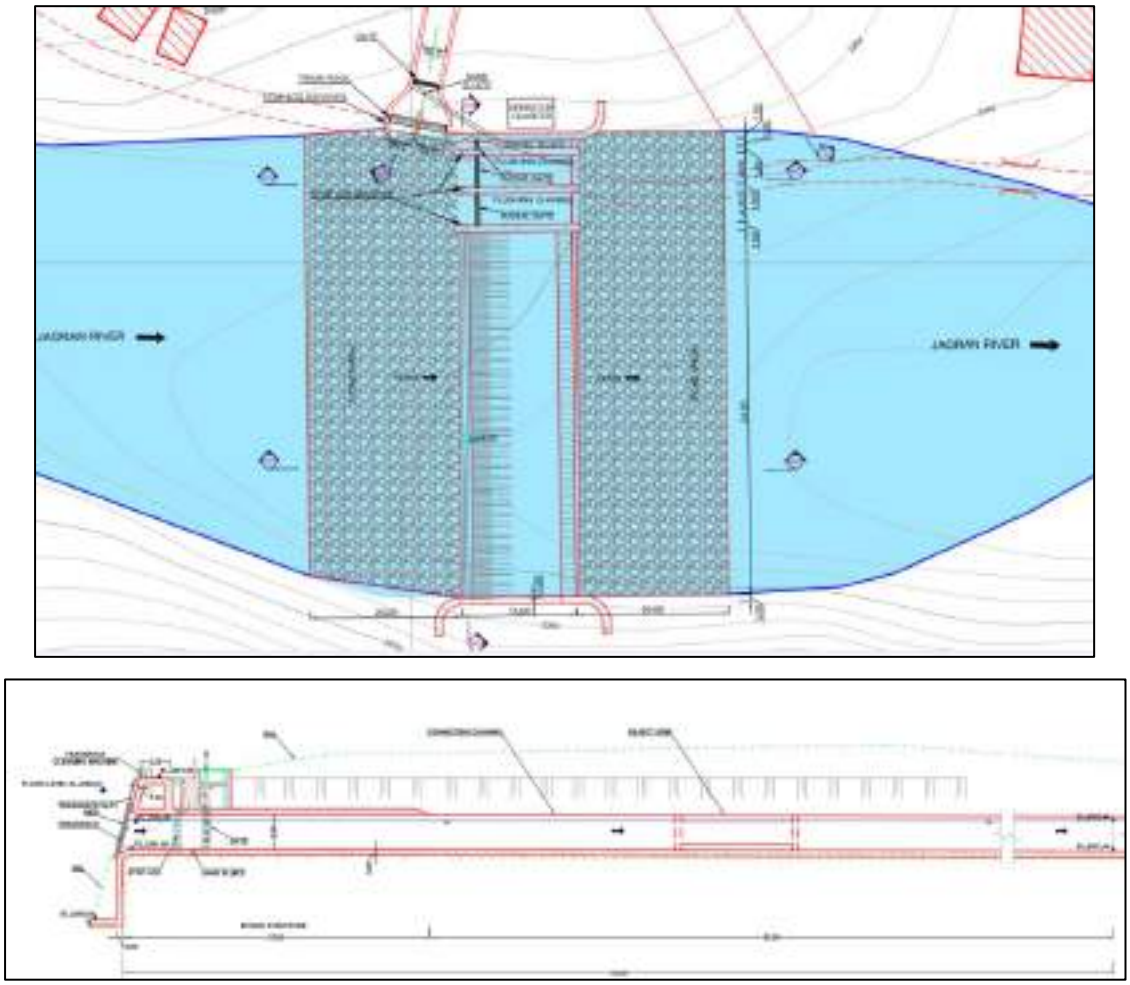


Figure 5-2: Plan and Sections of Power Intake – FS 2010

5.2.3 Connecting Channel

Section 7.4 of the Feasibility Study, 2010 defines the conveyance immediately downstream of the intake—an **approach/connecting reach** that conditions flow toward the desilting arrangement while maintaining stable, uniform hydraulics and controllable head loss. The layout keeps the channel in the inside of the bend to avoid bank attack, uses a mild longitudinal slope matched to the energy grade line, and provides sufficient freeboard for monsoon levels and wave action. Lining (RCC/masonry as specified in the report) is selected to resist abrasion and minimize seepage; transitions (from intake to approach, and approach to desander) are lengthened to limit separation and secondary currents. Bed and side protection are detailed for the local bed material and design shear stress, and appurtenances (stop logs/guide slots where applicable, access walks, debris handling provisions) are included to enable isolation and safe maintenance. The salient features are described in **Table 5-3**, and shown in **Figure 5-2** above.

Table 5-3: Salient Features of the Connection Channel-FS 2010

Item	Salient Feature	Design Intent / Notes
Functional role	Approach / connecting reach between intake and desilting arrangement	Deliver uniform, subcritical flow to desander with controlled head loss
Design discharge	Q (project design flow)	Sized to pass plant discharge with ±15% operating band
Hydraulic regime	Subcritical (Fr < 1) with uniform velocity profile	Avoids vortices and short-circuiting into desander
Velocity targets	Typically ~0.8–1.5 m/s (project-specific)	Limit bed shear and head loss; avoid sediment pick-up
Cross-section	Trapezoidal/rectangular with gentle transitions	Transitions designed to be separation-free
Lining	RCC / masonry (as per report)	Abrasion and seepage control; smoothness for head loss management
Bank/bed protection	Riprap/toe keys, filters as required	Sized by computed shear and gradation stability checks
Transitions	Intake→approach and approach→desander	Expansion/contraction ratios per good practice; no recirculation pockets
Access & O&M	Walkways, isolation slots/stoplogs (if applicable)	Safe inspection and debris management provisions

5.2.4 Sand Trap / Desilting Basin

The feasibility design provides a two-chamber, rectangular sand trap sized for Q = 18 m^3/s with target removal size d ≥ 0.25 mm. Each chamber is 56 m long and 7.0 m wide, with depth increasing from ~6.43 m to 8.11 m (mean flow area ≈ 50.88 m^2, mean v ≈ 0.177 m/s at 9 m^3/s per chamber). The computed settling length (e.g., Mosonyi / Giesecke-Zanke approach) yields Ls ≈ 46.8 m, checked against 8 b = 56 m, confirming an adequate safety margin. Key elevations

include top of trap 2265.0 m asl, inlet gate invert 2261.44 m asl, chamber floor from 2257.41 m asl (upstream) to 2255.73 m asl (downstream), and flushing pipe invert 2252.73 m asl. Flushing is provided via trapezoidal channels (area ≈ 12 m², slope 3%) with a Ø1.5 m flushing pipe returning to the river. Hydraulic steelworks comprise two inlet gates 4.3 m × 3.2 m, two outlet gates 7.2 m × 3.8 m, and two 1.2 m × 1.2 m sand-flush gates, all oil-pressure operated with stainless steel sealing surfaces and remote indication. The salient features are described in **Table 5-4**, and shown in **Figure 5-3**.

Table 5-4: Salient Features for Sand Trap-FS 2010

Item	Value / Description
Design discharge	18 m³/s total; 2 chambers @ 9 m³/s each.
Target sediment removal size	d ≥ 0.25 mm.
No. & size of chambers	2 chambers; each 56 m (L) × 7.0 m (B).
Depth range	~6.43 m (upstream) to 8.11 m (downstream).
Mean flow area & velocity	A ≈ 50.88 m²; v ≈ 0.1769 m/s (per chamber).
Settling checks	Vs, standing ≈ 0.032 m/s; Vs, flowing ≈ 0.0205 m/s; Ls ≈ 46.83 m, Selected L = 56 m, and Ls = 8b = 56 m satisfied; v_mean < v_critical.
Floor/elevation controls	Top EL 2265.0 m; inlet gate bottom EL 2261.44 m; chamber floor EL 2257.41→2255.73 m; flushing pipe invert (upstream) EL 2252.73 m.
Flushing arrangement	Trapezoidal channels A ≈ 12 m², 3% slope; Ø1.5 m flushing pipe to river.
Inlet gates	Two, 4.3 m (W) × 3.2 m (H), oil-pressure operated; guided with stainless sealing strips; remote/position control.
Outlet gates	Two, 7.2 m × 3.8 m, oil-pressure operated; remote/position indication.
Sand-flush gates	Two, 1.2 m × 1.2 m, oil-pressure operated; local hand control + remote position indication.
Structural notes	Outer wall thickness ~0.60 m.

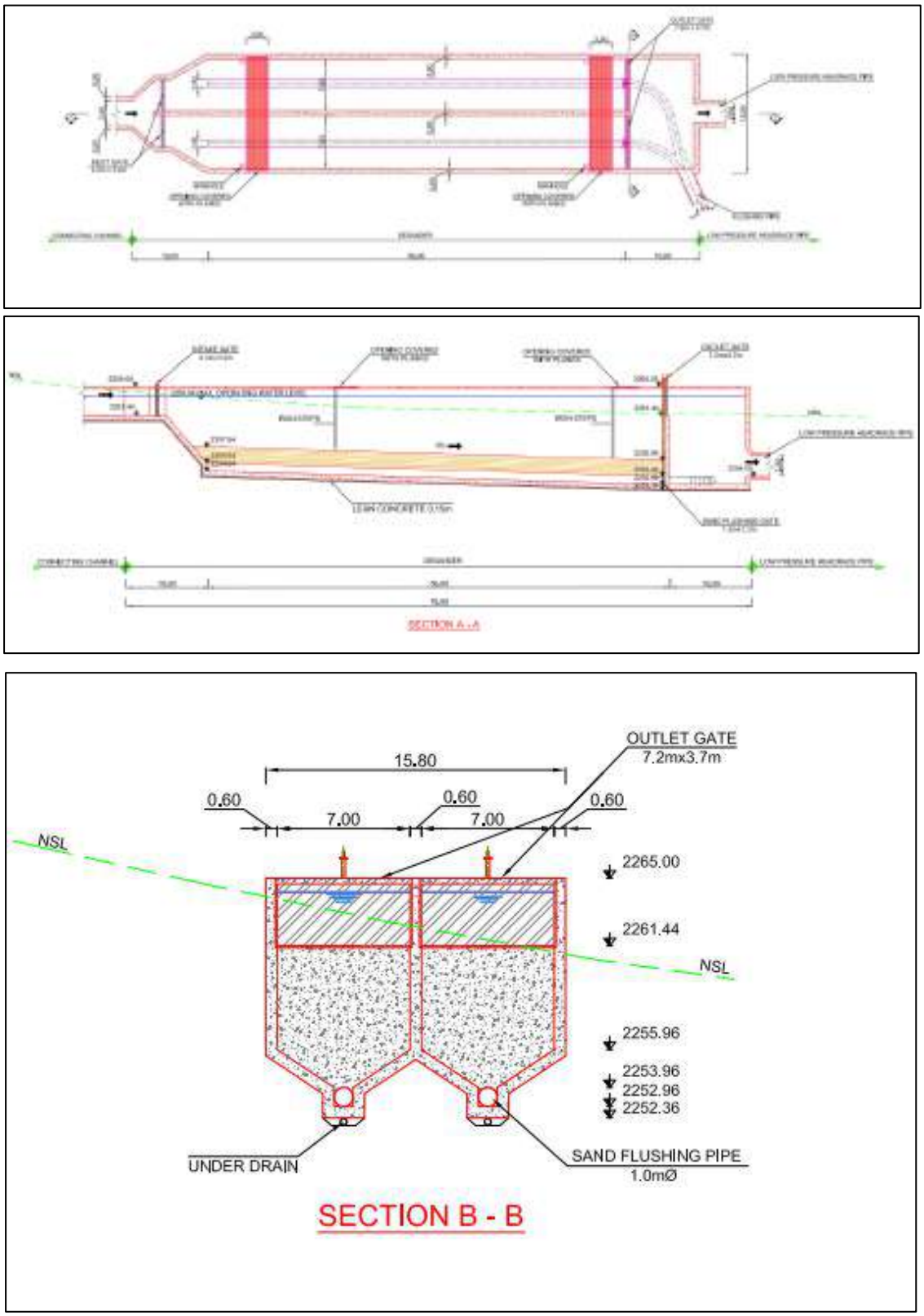


Figure 5-3: Layout and Sections of the Sand Trap (FS-2010)

5.2.5 Low-Pressure Pipe

The headrace is conceived as a buried GRP low-pressure conduit that starts in a small trapezoidal drop tank immediately downstream of the sand trap and then conveys flow to the surge area. The alignment follows the left bank, laid in a trench with mild longitudinal grade;

anchor blocks are provided at every change in direction. The scheme fixes ID ≈ 2.5 m, wall thickness ≈ 8 mm, design discharge = 18 m³/s, and a computed mean velocity ≈ 3.67 m/s over a total length ≈ 3,075 m. Invert levels step from ~EL 2254 m near the intake to ~EL 2238 m at the surge junction, where the surge pipe branches. The narrative indicates the layout and sizing were set considering terrain/geology, steady head-loss budgeting, and constructability for a fully embedded GRP line.

The salient features are shown in **Table 5-5**, and its section is already described in **Figure 5-4**.

Table 5-5: Salient Features of Low Pressure Pipe-FS 2010

Feature	Value / Description
Function	Low-pressure headrace from desander drop tank to surge area (buried)
Material	GRP (glass-fiber reinforced plastic) pipe, embedded in trench
Total length	≈ 3,075 m
Internal diameter	≈ 2.5 m
Wall thickness	≈ 8 mm (uniform along length)
Design discharge	18 m³/s (plant design flow)
Mean velocity	≈ 3.67 m/s (at design flow)
Invert levels	~EL 2254 m (intake end) → ~EL 2238 m (near surge)
Plan alignment	Left bank of Jagran valley; mild slope; anchor blocks at turns
Upstream hydraulic tie-in	Trapezoidal drop tank immediately downstream of sand trap
Sediment control dependency	Upstream desander designed to remove d ≥ 0.25 mm, supporting abrasion control in the GRP reach

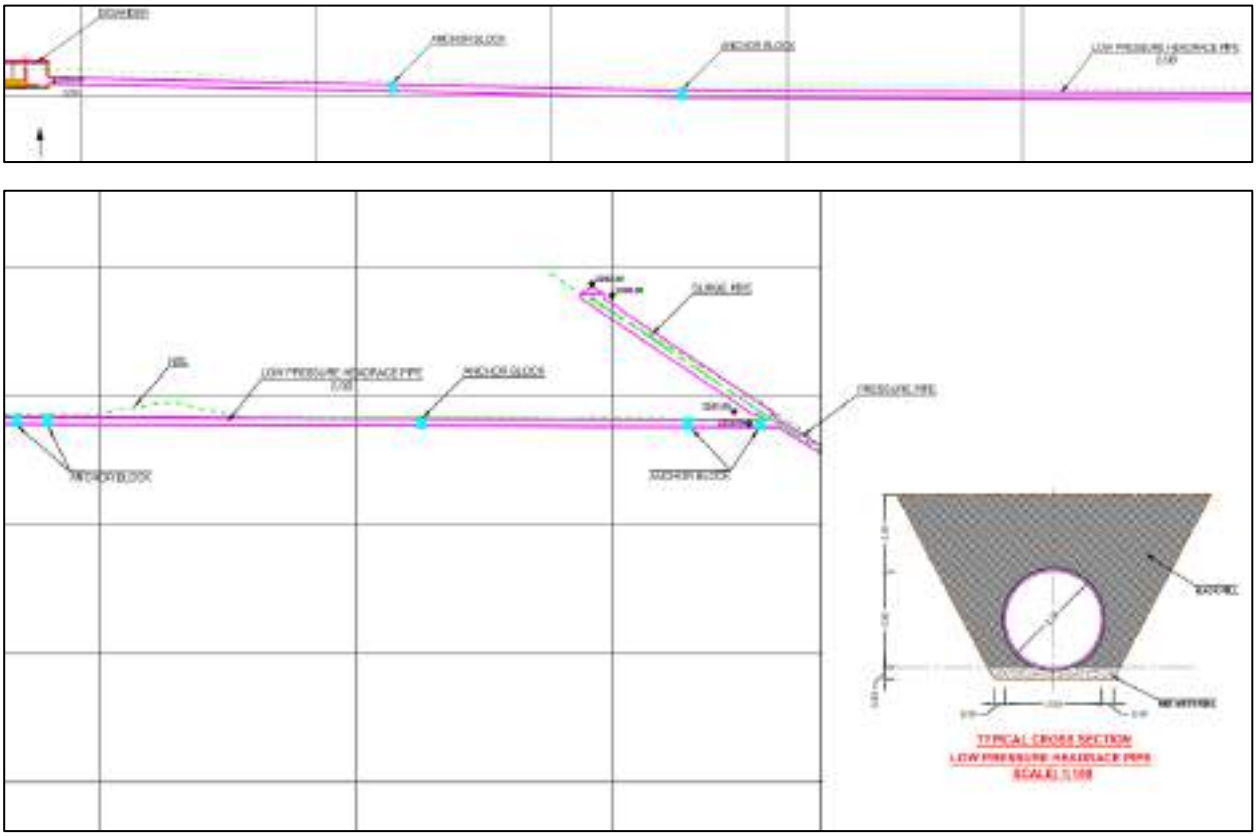


Figure 5-4: Low Pressure Pipe (FS-2010)

5.2.6 Penstock Pipe

The FS, 2010 adopts a **steel penstock** from the surge pipe outlet down to the turbine inlet, laid mostly on **terraces** and supported on **concrete saddles** with **anchor blocks at bends**. The **internal diameter is 2.50 m** for **Q = 18 m³/s**, giving **V ≈ 3.68 m/s** over a **~180 m** run; feasibility calculations assume a **head loss ≈ 10.2 m** for the design discharge. Fabrication is to **ASTM pressure-vessel quality** plate (proposed **ASTM A516 Grade 51**), with **spiral-welded** pipe strings, **6 m** shop lengths for handling, and **expansion joints** at intervals. Thickness is graded for head and surge: **≈10 mm at the top increasing to ≈15 mm near the powerhouse**, with a **15% pressure-rise allowance** in sizing. The salient features are shown in **Table 5-6**, and shown in **Figure 5-5**.

Table 5-6: Salient Features of Penstock Pipe-FS 2010

Item	Value / Description
Function & extent	Pressurized conduit from surge pipe to turbine inlet; laid on terraces; supported on saddles.
Length	≈ 180 m.
Internal diameter	2.50 m (design).
Design discharge & velocity	Q = 18 m³/s, V ≈ 3.68 m/s.
Head loss (feasibility calc.)	≈ 10.2 m from surge to powerhouse at Q = 18 m³/s.

Item	Value / Description
Supports & restraint	Concrete saddles; anchor blocks at each change in direction (three anchors between surge and powerhouse).
Fabrication & joints	Spiral-welded steel; 6 m shop lengths; expansion joints at intervals.
Material & grade	ASTM A516 Grade 51 pressure-vessel quality plate (fine-grain).
Thickness schedule	≈10 mm (top) increasing to ≈15 mm (bottom); +15% surge allowance in design.
Interfaces	Upstream from surge pipe; downstream to powerhouse inlet valve/turbine.

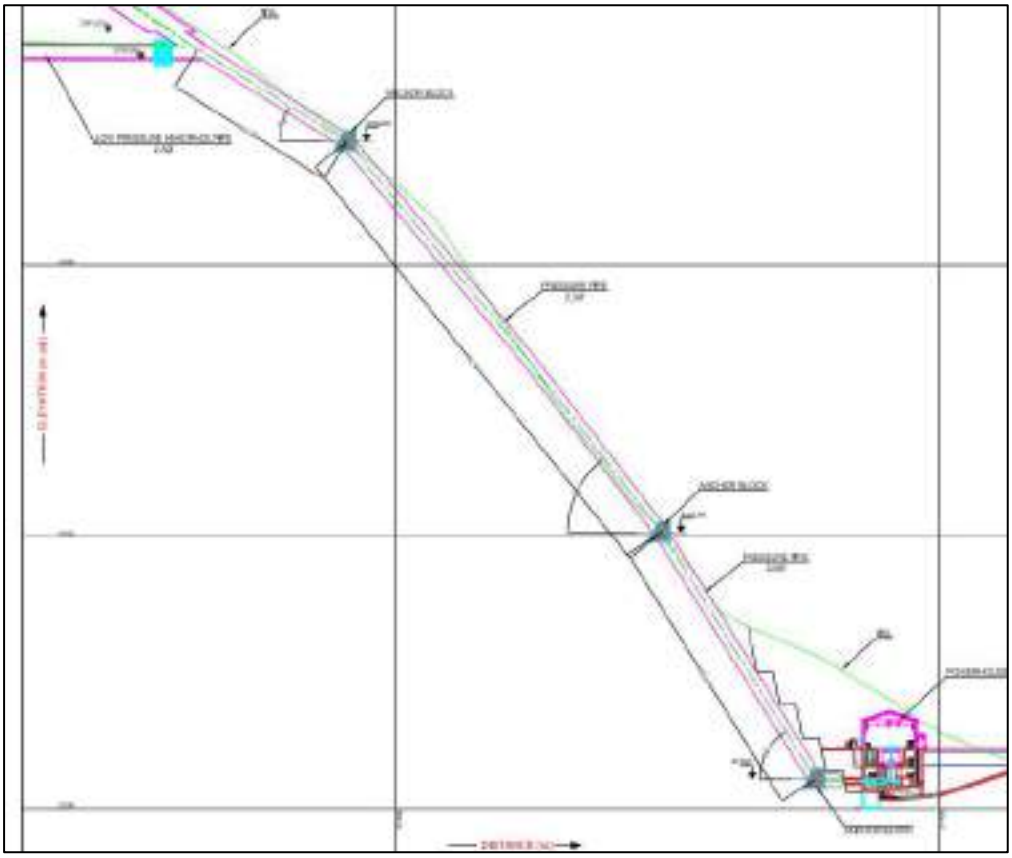


Figure 5-5: Penstock Pipe (FS-2010)

5.2.7 Surge Pipe

The scheme provides a **vertical surge pipe** branching from the buried GRP headrace to moderate transients and stabilize water levels in the low-pressure conduit. The branch occurs at **EL ≈ 2238 m asl**, with a **surge pipe internal diameter of 5.0 m** and **height ≈ 52 m**. Transient assumptions at feasibility stage link nozzle/deflector timing to acceptable pressure rise envelopes (goal: **≤10% of gross head**), with preliminary operating times (nozzles open/close; deflectors) defined for computation. The resultant **maximum and minimum surge levels** are reported, and the text flags that **final dimensioning and timing must be optimized at detailed design** with manufacturer data and refined water-hammer modeling.

The salient features are shown in **Table 5-7**, and its drawing is shown in **Figure 3-6**.

Table 5-7: Salient Features of Surge Pipe-FS 2010

Feature	Value / Description
Branch elevation	Surge pipe tees from headrace at EL ≈ 2238 m asl.
Geometry	Vertical cylindrical surge pipe.
Internal diameter	5.0 m.
Height	≈ 52 m.
Connected conduit (upstream)	GRP headrace: L ≈ 3075 m, ID 2.5 m, V ≈ 3.67 m/s (at Q=18 m^3/s).
Design discharge (plant)	18 m^3/s (all units operating).
Transient control intent	Pressure rise ≤10% of gross head; oscillations considered in setting nozzle time-strokes.
Preliminary operating times used	Nozzles: close 21 s / open 19 s (conservative runs: close 13 s, open 12 s). Deflector: close 2 s.
Computed surge levels (example set)	Max surge ≈ 2286.4 m asl; Min surge ≈ 2243.2 m asl (with Thoma safety factor referenced).
Note on operations	Staggered unit starts (~200 s interval) proposed due to long oscillation period from headrace inertia.
Foundation context	Surge pipe rests on granitic gneiss; one borehole proposed to confirm rock behavior at location.

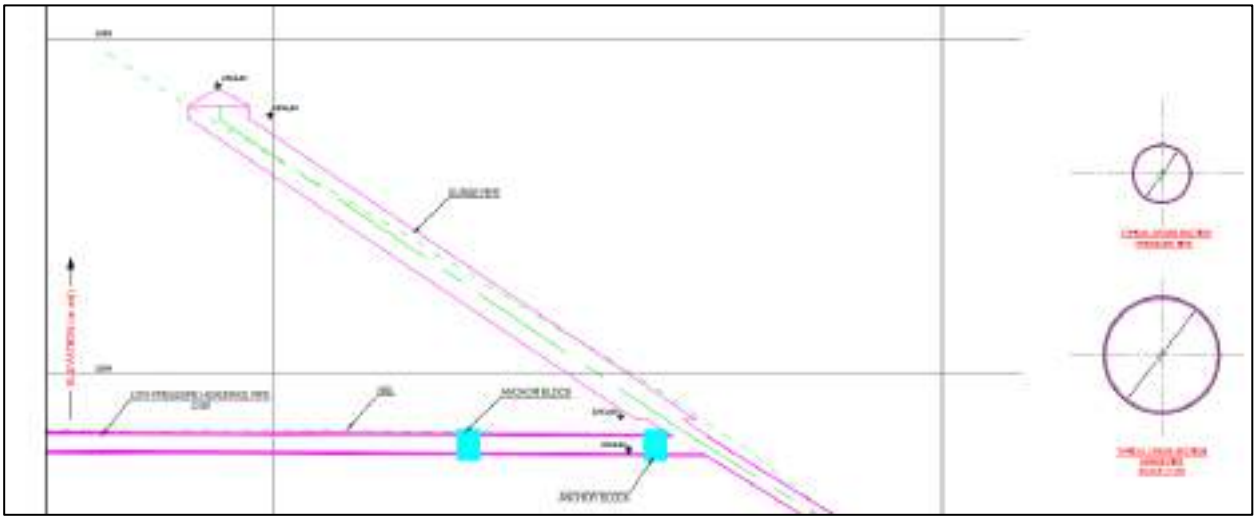


Figure 5-6: Layout and Section of Surge Pipe (FS-2010)

5.3 Third Party Validation Study, 2021

5.3.1 Project Layout

The Jagran-IV hydropower scheme develops ~3.6 km of the left bank reach upstream of Jagran-I, comprising a diversion weir, lateral intake, short RCC approach channel, surface sand trap, embedded headrace pressure pipe (with surge arrangement), and a surface powerhouse discharging back to the Jagran River. The TPV, 2021 confirms an improved gross head of ~169 m after relocating the weir axis ~120 m downstream of the FS, 2010 axis and proposed revising the design discharge to **16.0 m³/s** (plant capacity retained at **22 MW**) based on the updated flow duration and head survey; the corresponding **net head is ~158.4 m**.

Two primary conveyance arrangements were examined historically: (i) low-pressure headrace tunnel and (ii) a largely embedded low-pressure pipe. Given length (< 3 km), terrain, and losses, TPV, 2021 considers an embedded pressure-pipe solution feasible; however, it cautions against a GRP penstock for this medium-head, rugged setting and outlines steel-penstock options with surge/bypass strategies to manage transients and ensure cascade continuity.

Topographic re-optimization slightly shifts the powerhouse (≈ 40 m upstream with rotated orientation) to reduce flood exposure; rating curves at the tailrace and in the main river are required to anchor tail water levels and performance estimates under daily flow variability.

The salient features of the TPV, 2021 proposed layout and its comparison with the FS, 2010 are shown in **Table 5-8**, and its drawing is shown in **Figure 5-7**.

Table 5-8: Salient Features of TPV Proposed Layout

Feature	TPV 2021 (recommended / observed)	Notes (TPV vs. FS)
Weir axis	Relocated ≈ 120 m downstream of FS axis to a narrower valley section with harder left-bank strata	Improves head and hydraulics vs. FS site.
Gross head	~169 m	FS used 156 m; TPV head gain stems from topo re-survey.
Net head	~158.4 m	Up from ~144.2 m in FS.
Design discharge	16.0 m³/s	Revised FDC suggests 16 m³/s at ~28.6% exceedance for ~50% Plant Factor; FS used 18 m³/s.
Approach channel	~100–110 m RCC, ~3.4 m (w) × 2.8 m (h), slope ≈ 0.01%, freeboard 0.8 m, v≈ 2.1 m/s at 16 m³/s	Geometry supports delivery to sand trap.
Sand trap (surface)	Designed to remove d ≥ 0.2 mm; recommended flow velocity ≤ 0.2–0.3 m/s within basins; relocate with weir	Propose to remove d ≥ 0.25 mm;
Headrace conveyance	Embedded pressure pipe (re-aligned near valley road; reduced length vs. FS; gentler bends; avalanche/snow-safe routing)	Hydraulic checks at Detailed Engineering Design to fix dia/thickness; anchor blocks per force points.

Feature	TPV 2021 (recommended / observed)	Notes (TPV vs. FS)
Penstock / surge concept	Steel penstock recommended; GRP not recommended for medium-head rugged terrain. Surge handled via header + branch options and synchronous bypass valves to protect cascade	Options I–IV listed; Option-IV favored for cascade O&M; transient analysis required.
Powerhouse sitting	≈ 40 m upstream of FS location; rotated to be safer from high floods	Tailrace rating curve required.
Capacity & energy	22 MW; mean annual ≈ 96.6 GWh; PF ≈ 50% (before outages)	Based on 16 m³/s and 158.4 m net head.

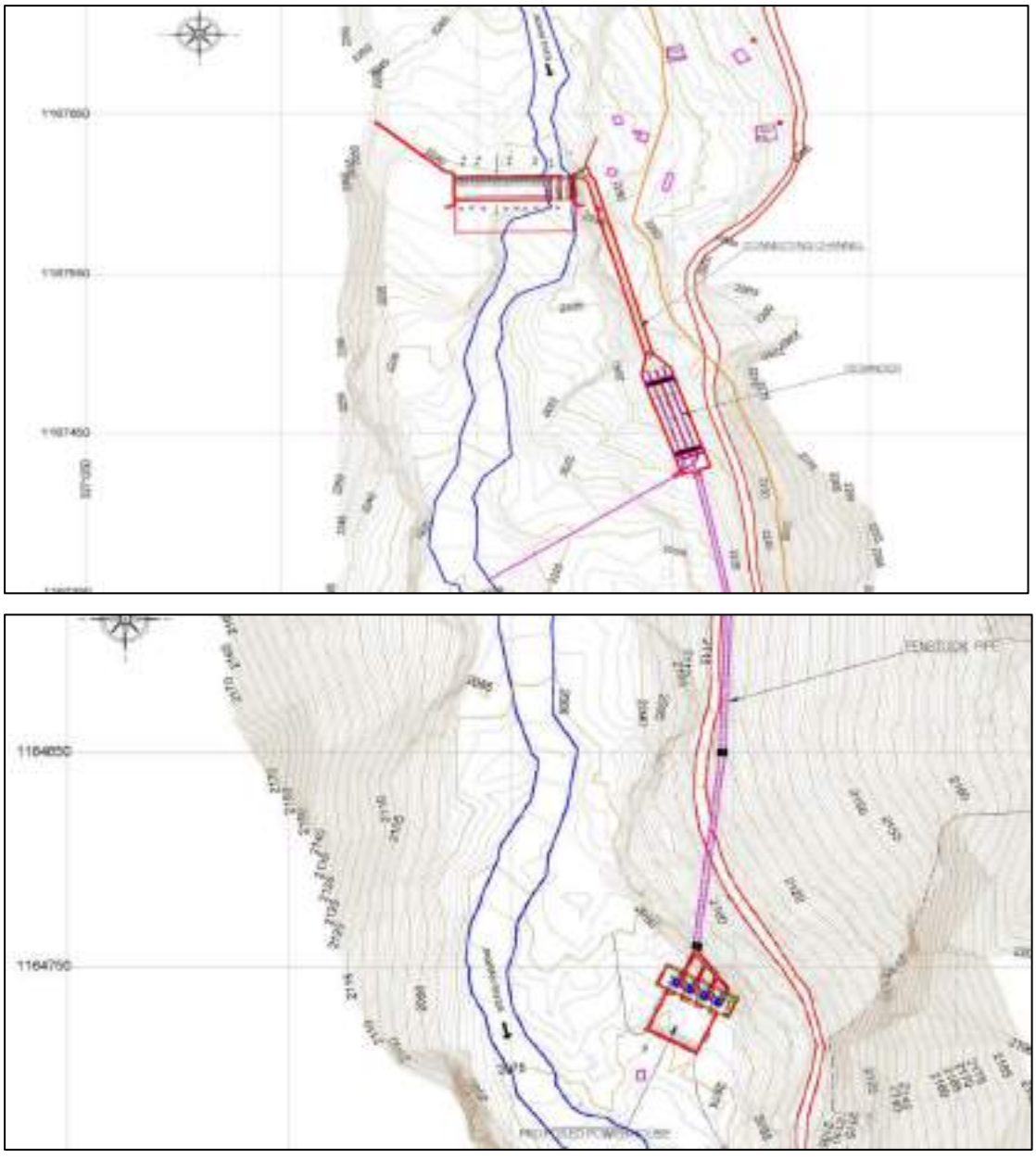


Figure 5-7: Layout Plan of Weir and Powerhouse Locations (TPV-2021)

5.3.2 Weir & Intake

The TPV, 2021 shifts the **weir axis ~120 m downstream** of the feasibility location to a hydraulically tighter cross-section with better abutment conditions, which lifts scheme head and improves approach hydraulics to the intake. At the new axis, the crest and river-training geometry are to be re-proportioned for the updated design discharges, with an undersluice/flushing arrangement on the intake side to maintain a low-sediment core toward the intake opening. The **lateral intake** remains on the left bank, co-optimized with the re-aligned approach channel so that near-rack velocities are uniform and vortex-free; the TPV, 2021 layout also refines platform levels and transitions to deliver the revised project design flow (TPV, 2021 basis) toward the surface desander.

The salient features are shown in Table 5-9.

Table 5-9: Salient Features Weir and Intake Structures-TPV 2021

Item	TPV 2021 / Validation takeaway
Weir sitting	Axis relocated ≈120 m downstream of FS axis
Head basis	Gross head ~169 m; net head ~158.4 m (TPV)
Design discharge (power plant)	16.0 m³/s (revised from FS 18 m³/s)
River training	Guide/training walls re-tuned to new axis
Under sluice / flushing	Flushing on intake side retained
Intake type & bank	Lateral intake on left bank
Approach channel	RCC, ~100–110 m long; typical v≈ 2.1 m/s at TPV design flow
Sediment strategy	Desander target d ≥ 0.2 mm with low internal velocities
Downstream integration	Intake → approach → desander kept surface-type

5.3.3 Approach Channel

The approach (connecting) channel conveys the **TPV design discharge** from the lateral intake to the surface desilting basin while preserving **uniform, subcritical hydraulics** and tight head loss control. Planform and cross-section are tuned to avoid secondary currents and local acceleration; transitions at the **intake→approach** and **approach→desander** interfaces are lengthened to suppress separation and skew. The channel is **RCC-lined** (abrasion and seepage control), set on a **mild longitudinal slope** compatible with the project EGL, and provided with **freeboard** and **bank protection** sized for monsoon stages. Isolation (stoplog slots, if applicable), safe walkways, and debris interception are integrated for operations and maintenance.

The salient features are shown in **Table 5-10**.

Table 5-10: Salient Features of the Approach Structures-TPV 2021

Item	Value / Description
Function	Convey flow from intake to desilting basin with uniform, subcritical hydraulics
Discharge basis	TPV design flow (± operating band)
Hydraulic regime	Subcritical; target velocity uniformity CV ≤ 10–15% at desander entrance
Typical velocity	~0.8–1.5 m/s (project-specific confirmation)
Section & lining	Rectangular/trapezoidal; RCC lining for abrasion & seepage control
Longitudinal slope	Mild, matched to EGL to limit headloss and avoid controls
Transitions	Separation-free intake→approach and approach→desander transitions; guide walls if needed
Freeboard	Includes monsoon stage + wind/wave allowance
Bank/bed protection	Riprap/toe keys with filter; sized by shear/gradation
O&M & isolation	Walkways, debris interception, stoplog slots (if provided)

5.3.4 Desilting Basin (Sand Trap)

The surface desander is a **multi-bay rectangular basin** targeting removal of **fine to medium sands** (TPV context commonly **d ≥ 0.20–0.30 mm**) at the plant discharge with a conservative internal velocity band. Inlet diffusers and flow-distribution baffles achieve **uniform inflow**; outlet skimming weirs prevent re-entrainment. Floor slopes, **hoppers**, and **undersluices** are arranged for efficient flushing with one bay operational while the other is cleaned.

The salient features are shown in **Table 5-11**.

Table 5-11: Salient Features of the Desilting Basin-TPV 2021

Item	Value / Description
Configuration	Multi-bay rectangular basin (2 bays) for availability during cleaning
Design cut size	Target d_{50},design ≈ 0.20 mm
Internal velocities	≤ 0.2–0.3 m/s in bays (project-specific)
Sizing criteria	L/H and residence time to achieve target removal at

Item	Value / Description
	Qdesign ± 15%
Inlet distribution	Diffusers/baffles to achieve uniform inflow across bay width
Outlet control	Skimming weirs/ports to prevent re-entrainment
Floor & flushing	Hoppered floor; undersluices sized to get ≥ 1.5–2.0 m/s near floor during flush
Headloss allowance	ΔH (clean) < ~0.5–0.7 m; check fouled & partial-bay operation
O&M & safety	Bay isolation (stoplogs/gates), dewatering routes, crane/platform access
Ops rules	Codified bypass/sluice rules for high-SSC monsoon events
Instrumentation	SSC sampling points, flush-out timers/sequence interlocks

5.3.5 Headrace Conveyance (Embedded Pressure Pipe)

The TPV favors an **embedded pressure pipe** (low-pressure reach) over a tunnel for the site length and terrain, aligned along the **left bank** in a trench with proper bedding and haunch support. Diameters are selected to maintain an **economic velocity band** (commonly **~2.0–2.5 m/s** in TPV practice for low-pressure pipes) and a controlled steady head loss budget. Anchor/thrust blocks are provided where the soil mass cannot take hydraulic thrust.

The salient features are shown in **Table 5-12**, and its drawing is shown in **Figure 5-8**.

Table 5-12: Salient Features of the Headrace Conveyance-TPV 2021

Item	Value / Description
Function	Convey desander outflow to surge junction (fully embedded)
Alignment	Left-bank trench; gentle curvature; minimize summits/sags
Design velocity	~2.0–2.5 m/s (clean; confirm vs final Q & diameter)
Hydraulics	Full steady loss ledger (Darcy–Weisbach + minors) to protect net head
Transient basis	Method-of-characteristics (MOC) envelopes for start/stop/trips need to be done before finalization of design
Appurtenances	Air-release/vacuum valves at summits; drains/blow-offs at sags/low points

Item	Value / Description
Thrust & restraint	Anchor/thrust blocks at bends; restrained joints where soil cannot take thrust
Trench works	Bedding/haunch support spec; trench stability & buoyancy checks (high GW)
Materials	Steel pipe is proposed. However, pipe class & rating tied to surge/strain; abrasion/lining tied to desander performance
Access & O&M	Valve vaults, blow-off access, safe isolation & fill/empty procedures

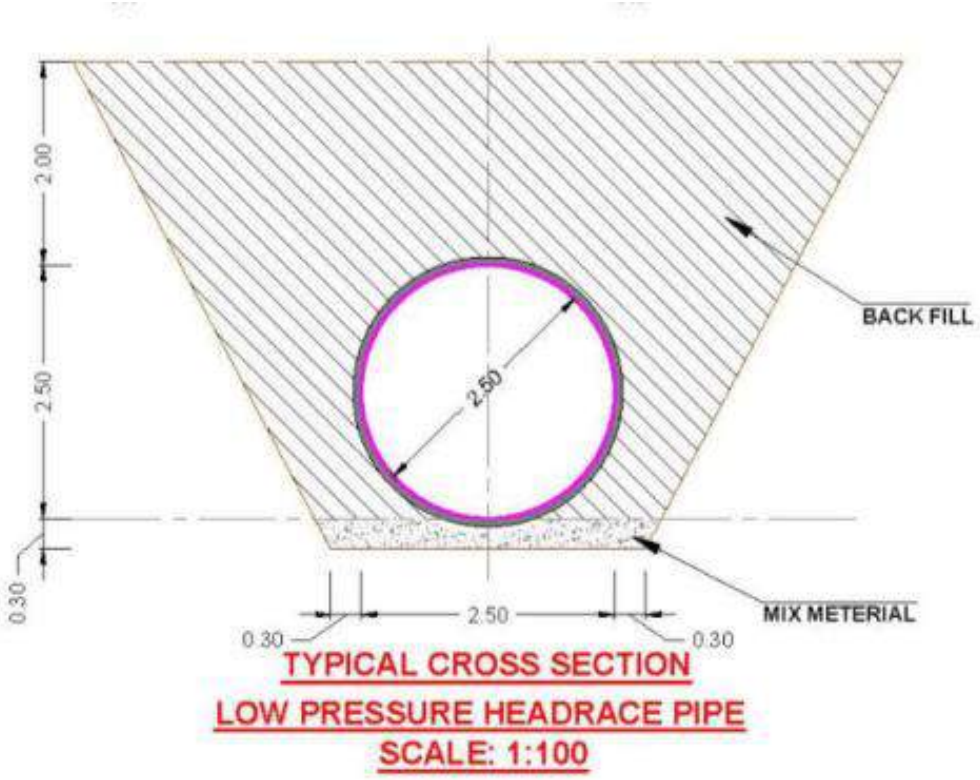


Figure 5-8: Layout Plan and X-section of the Low Pressure Pipe (TPV-2021)

5.3.6 Surge Arrangement & Penstock Concept

A **surge device** (vertical tank/pipe) is provided at the downstream end of the low-pressure pipe to absorb rapid flow mismatches during unit start/stop and grid events. Downstream, a **steel penstock** conveys flow to the powerhouse; thickness and supports are graded to static head plus **water-hammer envelopes**. The TPV favors **steel** for the penstock in this medium-head, rugged setting, with options for header/branch layouts and **synchronous bypass** strategies to protect the cascade during trips. The salient features are shown in **Table 5-13**.

Table 5-13: Salient Features Surge Arrangements and Penstock Pipe-TPV 2021

Item	Value / Description
Surge device	Vertical tank/pipe at end of low-pressure pipe; sized for up-surge/down-surge control
Penstock material	Steel penstock on terraces; spiral/longitudinal welded per spec
Penstock velocity	~3–4 m/s (short run; confirm vs head loss/economics)
Thickness schedule	Graded to static head + surge envelopes; code factors & joint efficiency
Supports/anchors	Concrete saddles; anchor blocks at bends; thermal/seismic combinations checked

5.4 MC Observations

This section describes the MC, 2025 review comments, comparison with previous two studies and hydraulic design guidelines to be considered for the further design stages.

5.4.1 Weir

During the October 15–19, 2025 site reconnaissance visit, the MC proposed relocating the weir upstream from the TPV, 2021 position to bypass an active right-abutment landslide, with abutment transitions to be verified by four electrical resistivity tests (ERTs). The proposed location for different studies is shown in **Figure 5-9 and 5-10**. **Table 5-14** presents the comparison of the studies to discuss the weir design and proposed location for the tender design.

The site team also observed that the FS, 2010 design flood of 419 m³/s (500-yr) is based on outdated flood data and does not considers the flood 2010. The FS, 2010 estimated flood was also found underestimated when viewed against neighboring cascade projects i.e. existing Jagran-I and under construction Jagran-II hydropower projects. In light of above, detailed review of the flood studies is undertaken and provided in Section-3 of this report. Based on above review of previous flood studies, the updating the design flood to 954 m³/s corresponding to 1000-year return period is proposed for the design of weir and preparation of tender drawings, stage routing and freeboard setting.

Figure 5-9: Location of the Weir Site

Figure 5-10: Photographs of the proposed Weir Site by the MC (looking upstream of the Jagran River)

Table 5-14: Comparison of the Studies – Weir Layout

Item	FS, 2010	TPV, 2021	MC 2025 (Tender Proposal)
Sitting / Axis	Original axis derived from feasibility DEM + local ground control.	Recommends ~120 m downstream relocation from FS axis.	Relocate weir upstream (relative to TPV-2021) to bypass active right-abutment landslide; adopt this MC location as the tender baseline.
Crest Elevation & Length	Screening crest and length; feasibility routing basis.	To be re-sized with refined sections and tail water based on new location and topographic data.	Size crest both for the over flow section and the gated under sluices at MC location using updated design floods; confirm nappe aeration and freeboard.
Design Flood Basis	Legacy design floods (to be re-evaluated).	Flood basis still to be confirmed.	Update design discharges and re-route through MC weir; these govern freeboard, training walls, and stilling basin.
Energy Dissipation	Conceptual apron / roller bucket.	Roller bucket to be selected per revised regime.	Select USBR Type I or V (Sloping apron) based on Froude No. at MC location and updated tail water.
River Training & Approach	Conceptual guide walls / spurs.	Geometry to be re-tuned for new axis.	Re-optimize guide walls at MC site to suppress oblique attack and confine departure; update riprap/aprons/cutoffs.
Underseepage / Filters / Cutoffs	Indicative only.	To be detailed with new sitting.	Detail upstream/downstream cutoffs combined with blanket, graded filters, and drains reflecting thick overburden at MC site.
Boulder Trap at suitable location Upstream of the weir	Not discussed	Not discussed	MC will propose the boulder trap at suitable location upstream of the weir location.
Surveys / Sections	DEM + local ground near structures.	Control + L/X-sections improved.	Use TPV 2021 topographic survey, tied to MC 2025 axis for tender design.

Decision for Tender	Not fit (screening).	Good technical basis but not a final tender location.	Adopt MC 2025 weir location as the tender design site; finalize routing/crest/training using MC proposed Q_{1000} RI flood.

5.4.1.1 Proposed Hydraulic Design Review

Before finalization of the Tender Design following hydraulic aspects related to the weir will be reviewed.

- Verify crest length of the overflow spillway and gated under sluices by developing the rating curves using the most updated guidelines of the USACE, abutment tie-ins, and freeboard under debris/ice passage.
- Select stilling basin type (e.g., USBR Type I or V) based on Froude number and tail water rating; check flow velocity on the glacis.
- Optimize guide walls/spurs to align approach/exit flow; size riprap, aprons, and cutoffs for computed shear and local/contraction scour using accepted methods.

5.4.2 Power Intake

Following the October 2025 site reconnaissance visit, the MC's proposal to relocate the weir has direct implications for the intake layout and hydraulics. The revised axis and local planform require re-orienting the approach to suppress skewed approach and secondary circulation, with guide walls extended or reshaped to align streamlines onto the trash rack face.

Intake invert and transition lengths should be recalibrated against the updated energy grade line, ensuring adequate submergence across the full operating band—especially under the **updated design discharges**. Final confirmation should pair river reach modelling (reflecting the relocated weir hydraulics) with numerical analysis to assess the discharge capacity of the intake structure. **Table 5-15** presents the comparison of the studies to discuss the power intake design and proposed location for the tender design.

Table 5-15: Comparison of the Studies – Power Intake Layout

Item	FS 2010	TPV 2021	MC 2025 (Tender Proposal)
Location / Orientation	Bank-side intake placed by topo opportunity; short forebay assumed.	Intake refined with weir ~120 m downstream; sitting adjusted with new head.	Relocate intake with the MC weir relocation; adopt this intake site/orientation as the tender baseline.
Approach Channel Alignment	Treated as straight/quasi-uniform reach.	Improved but not fully modeled with debris cases.	Re-orient channel to deliver uniform approach; extend/reshape guide walls for streamline alignment.

Item	FS 2010	TPV 2021	MC 2025 (Tender Proposal)
Invert & Transition Geometry	Preliminary invert and simple bell-mouth.	Transition lengths updated to new head.	Recalibrate invert and bell-mouth/compound transition at MC site.
Racks / Stop logs	Coarse trashrack + stop logs concept.	To be confirmed with refined sitting.	Set project-specific bar spacing; confirm clean/fouled K-values and stop log isolation.
Approach Velocities (Uniformity)	Screening values only.	Partial verification.	Design for near-rack V ≤ 0.5–0.8 m/s; uniformity CV ≤ 0.10–0.15.
Vortex Control & Submergence	Conceptual only.	To be checked across MDDL–FRL.	Meet USBR S/D submergence
Head loss Budget	Indicative head loss.	Not fully closed.	Calculate the rack/transition losses (clean & fouled) vs allowance.
Debris Management	Mentioned qualitatively.	Not fully integrated.	Provide boulder trap upstream of the weir location.
Integration with Weir / Training	Not co-modeled.	Improved geometry.	Co-optimize intake with MC weir & guide walls to eliminate recirculation.
Surveys / Sections	DEM + spot ground.	Control + L/X-sections available.	Use TPV 2021 survey section tied to MC 2025 axis for tender.
Decision for Tender	Not fit (screening).	Good basis but not final.	Adopt MC 2025 intake location/orientation for tender design.

5.4.2.1 Hydraulic Design Review

Before finalization of the Tender Design following hydraulic aspects related to the intake structure will be reviewed.

- Target near-rack velocities ≤ 0.5–0.8 m/s with coefficient of variation ≤ 0.10–0.15; approach channel alignment must suppress secondary currents.
- Maintain USBR submergence criteria (S/D) across reservoir levels; include anti-vortex baffles and air vents if needed.

- Set rack bar spacing by debris/fish criteria; compute clean/fouled loss coefficients; adopt smooth bell-mouth/compound transitions to minimize separation.

5.4.3 De-silting Basin

The relocation of the weir and intake confirmed during the October 2025 site reconnaissance visit requires relocating and re-tuning the approach channel, intake structure and desilting basin accordingly. The new sitting alters approach hydraulics, available head, and platform envelope; therefore invert/roof levels, bay count/width, and transition geometry from the approach channel must be recalibrated to the updated energy grade line and revised design discharges.

The intake-to-basin junction should be re-oriented to suppress secondary currents and deliver uniform inflow distribution to each bay; the outlet skimming arrangement must prevent re-entrainment during maintenance flows. Given observed debris and coarse bed material, adopt funnel floors to hoppers with high capacity undersluices and clear isolation so one bay can be cleaned while others remain in service.

The proposed target (d_{50},design) for exclusion of sediment is 0.25 mm and abrasion allowances; updated numerical model should demonstrate (i) target removal efficiency at Q_{design} ±15 %, (ii) head loss within allowance, and (iii) reliable flush-out times. The revised layout should also secure pragmatic O&M—overhead access for silt-grabs or jetting, safe dewatering routes, and codified bypass rules for extreme monsoon events—so the basin remains operable and protective across the full hydrologic envelope.

Table 5-16 presents the comparison of the studies to discuss the desilting basin design and proposed location for the tender design.

Table 5-16: Comparison of the Studies – Desilting Basin Layout

Item	FS 2010	TPV 2021	MC 2025 (Tender Proposal)
Location / Coupling with Intake	Basin immediately downstream of approach channel; feasibility sitting.	Sitting revisited after ~120 m weir shift; basin envelope noted.	Relocate basin with the MC intake/approach channel; adopt this location as the tender baseline.
Design Sediment Diameter (through basin)	Implicit fine/medium sand; not measured.	Retains target d_{50},design with validation requirement.	Adopt d_{50},design ≈ 0.25 mm at MC site;
Hydraulic Ratios	L/H and t_res (indicative).	Requires optimization with new geometry.	For the tender design, meet L/H ≥ 12–18 and t_res ≥ H/Vs for target d_{50},design at Q_{design} ±15%.
Approach Channel → Basin Transition	Conceptual diffuser; no modeling.	Uniformity improvement acknowledged.	Re-orient transition at MC site for uniform distribution.

Item	FS 2010	TPV 2021	MC 2025 (Tender Proposal)
Flushing System	Conceptual undersluices; no velocities.	Floor crossfall and hoppers suggested.	Funnel floors to hoppers; undersluices sized for ≥1.5–2.0 m/s near floor; sequenced flush operation.
Platform / Invert Levels	Indicative; feasibility EGL.	To be recalculated with new head.	Re-calibrate platform/invert to updated EGL and updated design discharges at MC site.
Decision for Tender	Not fit (screening).	Stronger basis but incomplete.	Adopt MC 2025 sand trap location (with relocated intake/approach) for tender design.

5.4.3.1 Hydraulic Design Review

Before finalization of the Tender Design following hydraulic aspects related to the sand trap structure will be reviewed.

- Define d_{design} and ensure residence time and geometric ratio (L/H ≥ 12–18 typical) achieve target removal efficiency.
- Use inlet diffusers/baffles and outlet skimming weirs to keep velocity non-uniformity within ±10–15% and limit total headloss to < 0.5–0.7 m.
- Size under-sluices for ≥ 1.5–2.0 m/s near floor/hoppers; include hoppers and crossfall; plan bypass/sluicing during high suspended sediment concentration events.

5.4.4 Lowe Pressure Pipe and Penstock

The MC's October-2025 site reconnaissance visit confirmed the relocation of the weir and a consequential shift of the approach channel and sand trap/desilting basin, which cascade directly into the penstock's inlet elevation, stationing, and head budget. With the low-pressure reach remaining buried steel penstock, the TPV velocity basis (~2.0–2.5 m/s) should be re-checked against the updated design discharges and revised minor-loss inventory for the new alignment; if the tender-stage flows or fittings increase losses, either diameter needs up-sizing or allowances must shift elsewhere in the head budget.

The transient model should be re-run for the relocated intake boundary conditions to verify maximum surge pressures to calculate the pipe thickness and minimum pressures safely above vapor pressure (no column separation), and to confirm air-valve sizing/locations at any new summits introduced by the reroute.

Update the thrust/anchor scheme at new bend stations, confirm buoyancy and trench stability for groundwater/high-flow construction stages, and re-position drains/blow-offs and access points so the buried line can be safely dewatered, inspected, and recommissioned under the new geometry.

Table 5-17 presents the comparison of the studies to discuss the low-pressure conduit / pressure shaft & steel penstock design and proposed location for the tender design.

Table 5-17: Comparison of the Studies – Low Pressure Pipe Layout

Item	FS 2010	TPV 2021	MC 2025 (Tender Proposal: Powerhouse Relocation)
Overall Alignment & Profile	Concept route along steep bank; feasibility DTM; generic benches.	Route refined with weir shift; benched segments preferred.	Re-derive full profile and stationing to new powerhouse location; shorten unsupported spans; avoid tight curvature and unnecessary summits/sags.
Conduit Types	Low-pressure conduit + surface steel penstock (concept).	Buried steel pipe for both for low-pressure reach and for high-pressure/penstock with difference in thickness.	Maintain buried steel penstock both for the low-pressure and high pressure penstock with thicker near the powerhouse. Conduct transient analysis a the Detailed Engineering Design stage to confirm the thickness of the pipe at several locations and for the design of the supports.
Diameter & Design Velocity	Screening diameter; economic V concept only.	Adopted V ≈ 2.0–2.5 m/s (low-pressure); penstock sized to head.	Re-check diameter vs updated discharges/lengths; keep V ≈ 2.0–2.5 m/s for low pressure pipe.
Head loss Budget	Allowance only.	Losses reconciled to refined head.	Update head losses based on updated layout and confirm net head.
Material & Rating	Generic steel; nominal allowances.	steel pipe with variable thickness	Confirm steel grade & thickness schedule vs updated head/surge.
Supports, Saddles & Anchors	Conceptual spacing; generic anchors.	Benched supports; anchor/thrust at changes in momentum.	Re-site saddles & thrust blocks for new bends/elevations; add restrained joints where soil cannot take thrust.
Air-Release & Drains	Diagrammatic only.	Locations improved.	Re-position air-release/vacuum valves at any new summits; drains/blow-offs at sags/low points; size for rapid filling/emptying.
Constructability & Access	Deferred.	Benches and lifts identified.	Update lifts, road access, stringing yards, cold-bend limits; trench stability/groundwater control for

Item	FS 2010	TPV 2021	MC 2025 (Tender Proposal: Powerhouse Relocation)
			buried pipe.
Interface with Desander & Powerhouse	Concept levels.	Interfaces corrected after weir shift.	Re-calibrate inlet/outlet elevations to be relocated desander and powerhouse centerline; confirm nozzle/spider/scroll fit.
Conveyance and Load Rejection	Surge pipe has been proposed to accommodate surges and will facilitate to maintain water level in headrace pipe. From surge pipe to inlet to the turbine, penstock pipe is designed.	Single-header penstock (no surge tank) to the powerhouse, splitting into four turbine branches, each with a synchronous, governor-controlled bypass/surge-relief valve to limit water-hammer on full load rejection and discharge to the tailrace to maintain downstream flow continuity.	For avoiding 5 m diameter 52 m long surge pipe, the proposed arrangement of TPV will be re-evaluated for finalizing the tender design.
Instrumentation & Monitoring	Not defined.	Basic taps foreseen.	Add permanent pressure/air monitoring ports; settlement markers on buried pipe; strain gauges at critical steel bends (optional).
Decision for Tender	Not fit (screening).	Stronger basis but pre-relocation.	Adopt MC 2025 powerhouse-relocated layout as tender baseline (buried pipe low-pressure + steel penstock), subject to updated surge/ loss checks.

5.4.4.1 Hydraulic Design Review

Before finalization of the Tender Design following hydraulic aspects related to the water conveyance conduit will be reviewed.

1. Size diameter of the pipe for turbine flow with economic velocity (≈2.5–4.5 m/s) balancing Darcy–Weisbach losses and net head; include fittings and bends in loss budget.
2. Update full loss ledger for new route and fittings; confirm net head.

3. At the stage of Detailed Engineering Design stage, perform full unsteady (water-hammer) analysis for load rejection, emergency trip, and valve stroking.

5.4.5 MC Proposed Project Layout

Due to proposed relocation of weir and powerhouse site, the project layout will also change. The **Figure 5-11** gives the MC proposed tentative project layout plan. The map shall be further refined during the preparation of tender level design and drawings.

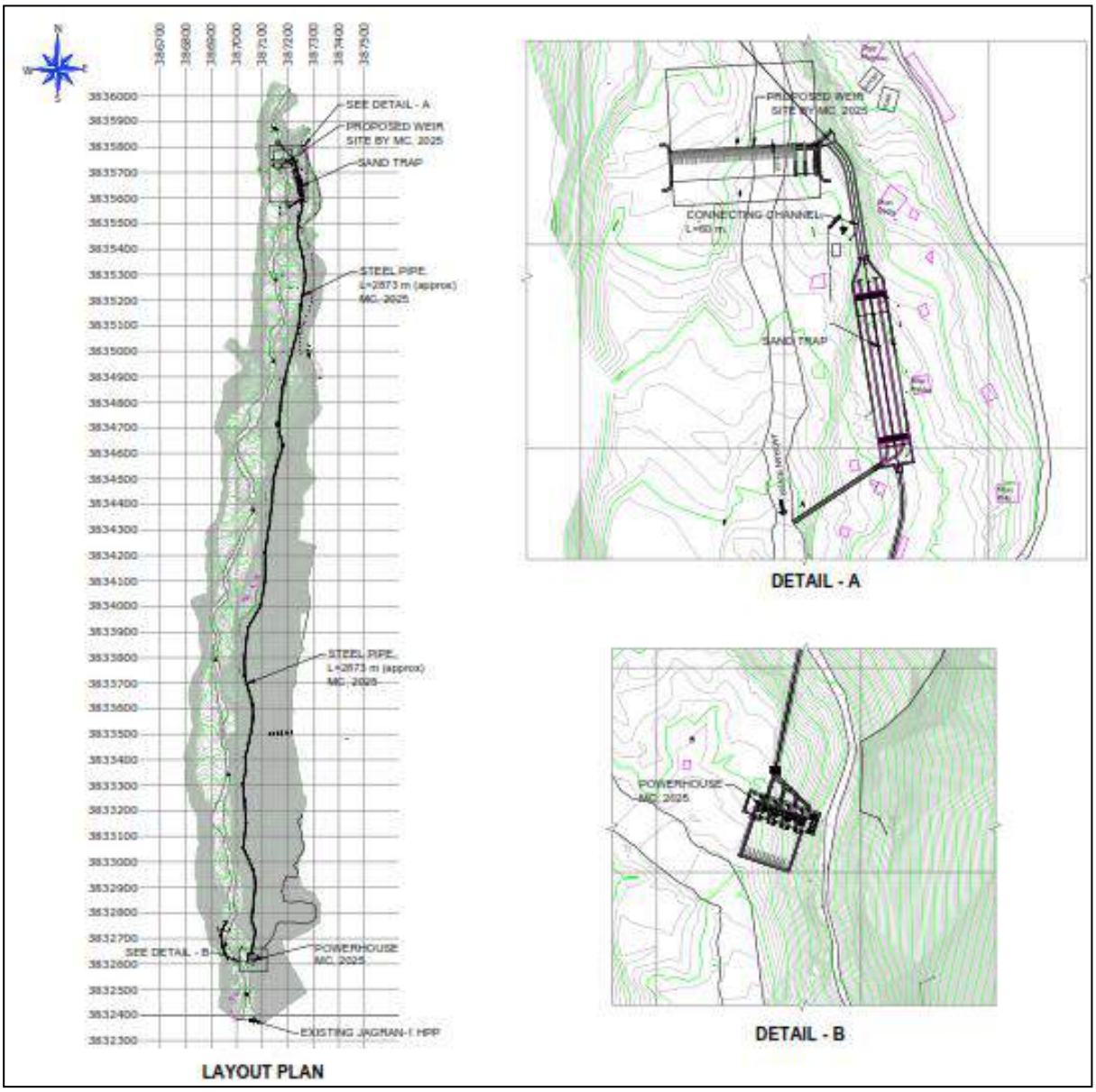


Figure 5-11: MC Proposed Project Layout Plan

5.5 MC Key Observations

- The TPV, 2021 refined sitting and elevations (gross head ≈169–170 m) and recommended shifting the weir ≈120 m downstream versus FS 2010; these updates correct feasibility-scale assumptions.

- The site visit endorsed relocating the weir farther (relative to TPV) to avoid an active right-abutment slide and flagged the need to update the design-flood basis for routing/freeboard, direction accepted in the client follow-up.
- Intake approach alignment, sand-trap performance (with d_{design} ≈0.25 mm exclusion target), and the steel pipe conveyance (with transient/strain checks) have clear acceptance paths but require confirmation at the relocated sites before finalizing the tender drawings.

5.6 Way Forward

- **Adopt MC-2025 locations as tender baselines.** Fix the *weir–intake–sand trap* at the MC 2025 positions and carry them into tender documents, with flood routing based on the **updated** design discharges (superseding legacy FS values).
- **Hydrology updates to govern crest, training works, and stilling.** Re-compute design floods and route through the MC weir to set crest length/elevation, freeboard, training walls, and basin selection against the revised tail water curve.
- **Weir hydraulics—defines acceptance checks in tender.** Provide spillway/ undersluices rating curves, confirm nappe aeration and cavitation indices, and select USBR stilling basin per Froude regime at the new axis; include scour and seepage defense (cutoffs, graded filters, drains).
- **Intake/approach—uniformity and submergence criteria.** Re-orient the approach channel and guide walls to eliminate skew/recirculation; design for near-rack velocities ≤0.5–0.8 m/s with CV ≤0.10–0.15 and meet USBR submergence (S/D) across operating levels; compute clean/fouled head loss.
- **Sand trap—performance anchored on d_{50},design and O&M.** Set $d_{50,design}$ ≈0.25 mm for exclusion, verify L/H and residence-time ratios, optimize diffuser/baffles for uniform inflow, and size undersluices for ≥1.5–2.0 m/s near the floor; limit basin headloss to <0.5–0.7 m and provide isolation for bay-wise cleaning.
- **Conveyance—steel pipe and penstock.** Hold steel pipe both for low-pressure reaches and for the penstock. For avoiding 5 m diameter 52 m long surge pipe, Keep TPV proposed, single-header penstock (no surge tank) to the powerhouse, splitting into four turbine branches, each with a synchronous, governor-controlled bypass/surge-relief valve to limit water-hammer on full load rejection and discharge to the tailrace to maintain downstream flow continuity.
- **Add debris/boulder management upstream.** Include a boulder trap upstream of the weir in tender drawings to protect the intake and undersluices during debris pulses.

SECTION - 6: PROJECT SIZING AND POWER POTENTIAL

6.1 General

This section covers the results of the review of the Feasibility Study, 2010 and Third Party Validation Study, 2021 with respect to the project sizing and power potential aspects. The proposed selection of key parameters including flow duration curve, design discharge, gross and net head, efficiency of turbines, generators and transformers, ect. is also discussed.

6.2 Review of Feasibility Study Report, 2010

The Feasibility study has undertaken a comprehensive study of project sizing and estimating the power potential by considering various design discharges ranges from 10 m^3/s to 28 m^3/s with an interval of 2 m^3/s. The benefits and costs have been estimated for the various discharges and the plant has been optimized on the basis of marginal cost and average cost of generated units.

The discharge data near weir site is taken as varying from 2.04 m^3/s to 51.12 m^3/s with average value of 15.59 m^3/s. Compensation flows of 0.30 m^3/s in winter six months and 0.60 m^3/s in summer months have been considered to be released from weir as residual flows.

The project is operated as run-of-river plant. The gross head and net head are estimated from difference of head and tail water levels. The reservoir level has been considered constant as 2264 m asl and tail water level is considered as 2108 m. The losses from intake to turbine axis vary from 1.97 to 11.82 m.

Project benefits have been estimated equivalent to the cost of alternative gas turbine generation. The cost of not constructing gas power generation is taken as benefits to hydropower generation. Capacity and energy benefits for each design discharge have been estimated and added up to get the total benefits.

For the selected alternative, cost estimation has been carried out by a computer programme for various design discharges ranging from 10 m^3/s to 28 m^3/s with interval of 2 m^3/s.

The optimum discharge of 18 m^3/s is taken to be the one at which generation cost, that is cost per kWh, is minimum and the NPV is maximum. At the selected design discharge, the following optimal parameters have been chosen:

- Design Discharge = 18 m^3/s available 28.7% time of the year
- Gross head = 156 m
- Gross head = 144.2 m
- Capacity = 22 MW (Vertical Francis turbines: 3 units of 6 MW and 1 unit of 4 MW)
- Total Energy = 98.20 GWh
- Plant Factor = 51.25

6.3 Review of Third Party Validation Study, 2021

The Third Party Validation Study, 2021 has conducted fresh topographic survey and found that previous survey carried out in Feasibility study, 2010 was rather preliminary & with less details.

With newly conducted topographic survey and relocated weir axis 120 m downstream of previously proposed axis, the normal and minimum operation levels upstream of weir are assumed as 2,242.0 m.a.s.l and 2,241.0 m.a.s.l respectively.

Minimum and normal tail water variation is from 2,073 m to 2,075 m. The gross head varies from 167 m to 169 m.

The Third Party Validation study, 2021 has also reviewed the estimated flows at the weir site and proposed design discharge of 16 m^3/s available 28.7% time of the year. With 10.56 m losses at design discharge, the net head has been taken as 158.44 m.

The Third Party Validation study, 2021 has also commented on the Feasibility study, 2010 adopted efficiency for turbine as 91%, for generator as 96%, for transformer as 99% and combined efficiency as 86.4% and has proposed to be revised with 92.5% for turbine, 97.0% for generator and 99% for transformer. The combined efficiency has thus taken as 88.8%.

With design discharge of 16.0 m^3/s, the proposed capacity is 22.0 MW. The plant factor maximum power would be 50.38%. The net head as per revised survey and weir location and powerhouse tail water level is 158.4 m. An installed capacity of 22.0 MW can be recommended with mean annual energy of 96.6 GWh. With 5% outage, the annual energy to be delivered is 91.8 GWh.

6.4 MC Observations

- The MC has carried out the detailed review of the topographic survey and hydrological studies conducted in the Feasibility Study, 2010 and Third Party Validation Study, 2021.
- Based on review of topographic surveys given in Section-2 of this report, it has been observed that the topographic survey carried out in Third Party Validation study, 2021 was latest & more detailed as compared to that conducted in the Feasibility study, 2010. Therefore, the MC has proposed to adopt the topographic survey data based on the Third Party Validation study, 2021 for preparation of tender level design and drawings.
- Similarly based on review of water availability studies given in Section-3 of this report, it has been observed that the Third Party Validation Study, 2021 has used the recent daily flow data of Naran upto 2009 and Nausehri upto 2015 as compared to the Feasibility study, 2010 wherein 10-daily flow data of Naran upto 2000 has been used. Therefore, the MC has proposed to use the daily estimated flows in the Third Party Validation Study, 2021 for power and energy calculations, preparation of tender level design and drawings.
- Based on above assumptions, the MC has re-calculated the power and energy generation and the results are provided at Annexure-A attached below. The following are the summary results:
  - ✓ Design Flow = 16.10 m^3/s
  - ✓ No of Units = 4
  - ✓ Design Discharge (single unit) = 4.025 m^3/s
  - ✓ Gross head = 169 m
  - ✓ Head Loss = 10.56 m
  - ✓ Net head = 158.44 m
  - ✓ Turbine Efficiency = 92.5%
  - ✓ Generator Efficiency = 97.0%
  - ✓ Transformer Efficiency = 98.0%
  - ✓ Flushing Period = 30 days
  - ✓ Gross power = 22 MW
  - ✓ Annual Energy = 91.04 GWh
  - ✓ Plant Factor = 47.231%

6.5 Way Forward

The selection of above parameters and the energy calculations are based on preliminary studies carried out by the MC for the preparation of this Feasibility Study and Design Review Report.

The above preliminary based power and energy calculations generally conforms the power potential and energy estimates provided in TPV, 2021 studies except the plant factor which is showing below 50%.

The MC shall further work on the refinement of the assumptions, collect the TPV, 2021 study based estimated daily flow data at the weir site and perform the detailed power and energy calculations during the preparation of tender level design and tender documents.

Annexure A – Power and Energy Calculations

Summary Calculations

Design Discharge	QD	=	16.1	m^3/sec
No. of Units		=	4	Francis
Design Discharge (single unit)	Qunit	=	4.025	m^3/sec
Gross Head	Hg	=	169	m
Head Loss	HL	=	10.56	m
Net Head	Hn	=	158.44	m
Turbine Efficiency at Design Discharge	hT	=	92.5	%
Generator Efficiency	hG	=	97.0	%
Transformer Efficiency	hTr	=	98.0	%
Flushing Period	TFL	=	30	days
Gross Power		=	22	MW
Annual Energy (before deducting 30 days downtime loss)		=	99.19	GWh
Annual Energy (after deducting 30 days downtime loss)		=	91.04	GWh
Plant Factor		=	47.231	%

Annexure A – Power and Energy Calculations

TIME		PERIOD	FLOW	NET	TURBINE - 1				TURBINE - 2				TURBINE - 3				TURBINE - 4				Total Power	ANNUAL ENERGY
INCR.			DURATION	HEAD	Q1	hT1	Power1	Energy1	Q2	hT2	Power2	Energy2	Q3	hT3	Power3	Energy3	Q4	hT4	Power4	Energy4	P=P1+P2	Total
(days)	(%)	(days)	(m 3 /s)	(m)	(m 3 /s)	(%)	(MW)	(GWh)	(m 3 /s)	(%)	(MW)	(GWh)	(m 3 /s)	(%)	(MW)	(GWh)	(m 3 /s)	(%)	(MW)	(GWh)	(MW)	(GWh)
1	0.3%	4	176.1	158.4	4.025	93.3%	5.549	0.533	4.025	93.3%	5.549	0.533	4.025	93.3%	5.549	0.533	4.025	93.3%	5.549	0.533	22.194	2.131
5	1.4%	5	144.58	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
10	2.7%	5	105.18	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
15	4.1%	5	65.78	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
20	5.5%	5	39.433	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
25	6.8%	5	37.326	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
30	8.2%	5	35.219	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
35	9.6%	5	33.112	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
40	11.0%	5	31.609	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
45	12.3%	5	30.365	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
50	13.7%	5	29.122	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
55	15.1%	5	27.878	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
60	16.4%	5	26.634	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
65	17.8%	5	25.39	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
70	19.2%	5	24.146	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
75	20.5%	5	22.946	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
80	21.9%	5	21.812	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
85	23.3%	5	20.678	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663

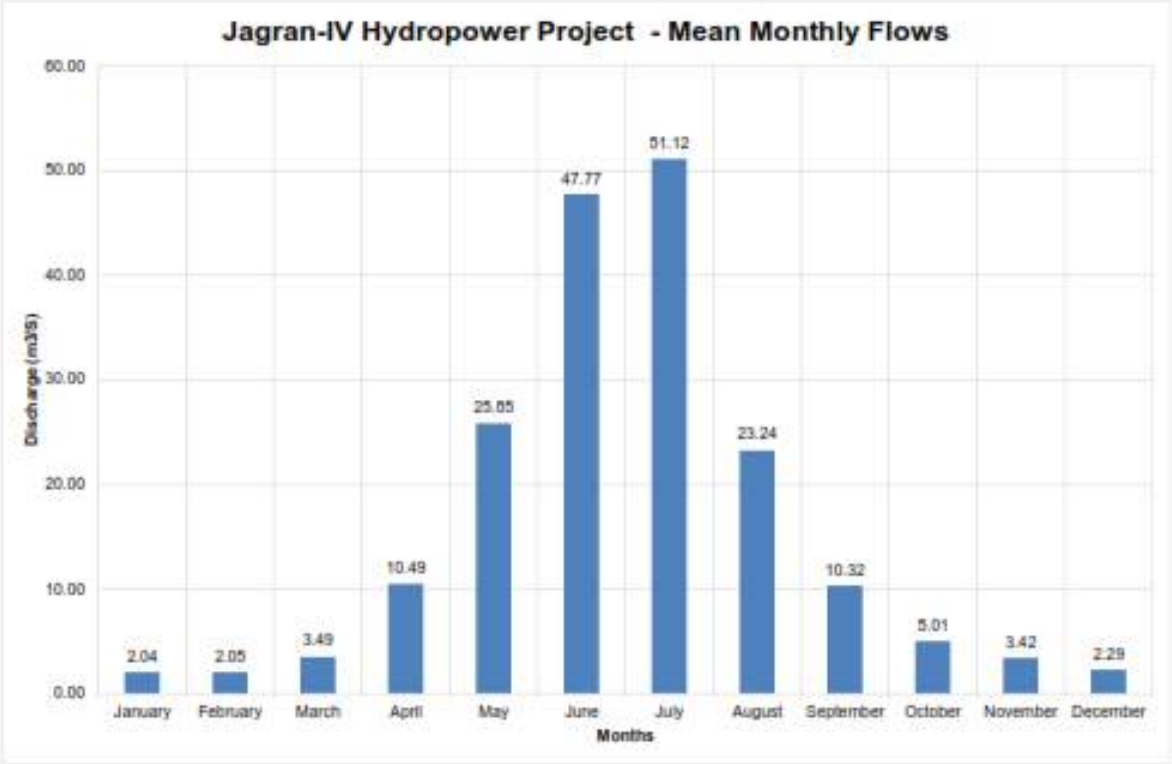
Annexure A – Power and Energy Calculations

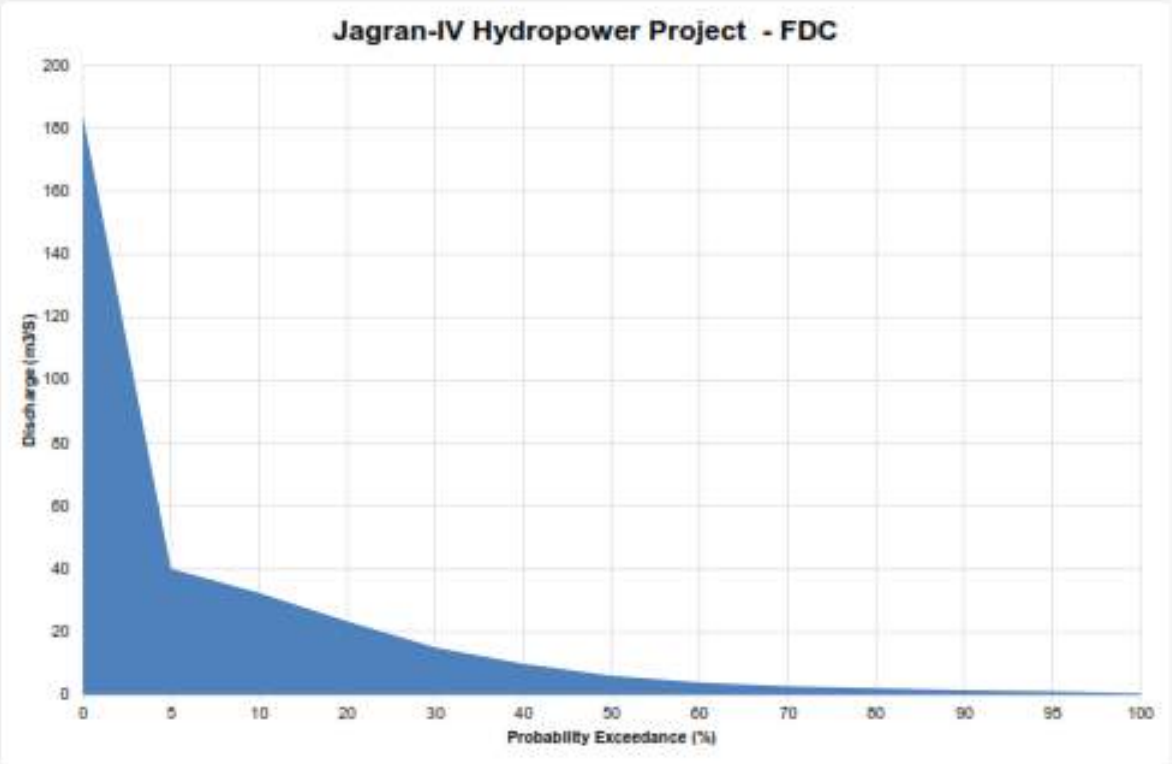
TIME		PERIOD	FLOW	NET	TURBINE - 1				TURBINE - 2				TURBINE - 3				TURBINE - 4				Total Power	ANNUAL ENERGY
INCR.			DURATION	HEAD	Q1	hT1	Power1	Energy1	Q2	hT2	Power2	Energy2	Q3	hT3	Power3	Energy3	Q4	hT4	Power4	Energy4	P=P1+P2	Total
(days)	(%)	(days)	(m3/s)	(m)	(m3/s)	(%)	(MW)	(GWh)	(m3/s)	(%)	(MW)	(GWh)	(m3/s)	(%)	(MW)	(GWh)	(m3/s)	(%)	(MW)	(GWh)	(MW)	(GWh)
90	24.7%	5	19.544	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
95	26.0%	5	18.409	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
100	27.4%	5	17.275	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
105	28.8%	5	16.141	158.4	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	4.025	93.3%	5.549	0.666	22.194	2.663
110	30.1%	5	15.049	158.4	3.762	93.6%	5.202	0.624	3.762	93.6%	5.202	0.624	3.762	93.6%	5.202	0.624	3.762	93.6%	5.202	0.624	20.809	2.497
115	31.5%	5	14.338	158.4	3.584	93.5%	4.954	0.595	3.584	93.5%	4.954	0.595	3.584	93.5%	4.954	0.595	3.584	93.5%	4.954	0.595	19.818	2.378
120	32.9%	5	13.627	158.4	3.407	93.2%	4.691	0.563	3.407	93.2%	4.691	0.563	3.407	93.2%	4.691	0.563	3.407	93.2%	4.691	0.563	18.763	2.252
125	34.2%	5	12.916	158.4	3.229	92.8%	4.429	0.531	3.229	92.8%	4.429	0.531	3.229	92.8%	4.429	0.531	3.229	92.8%	4.429	0.531	17.715	2.126
130	35.6%	5	12.205	158.4	3.051	92.5%	4.169	0.5	3.051	92.5%	4.169	0.5	3.051	92.5%	4.169	0.5	3.051	92.5%	4.169	0.5	16.675	2.001
135	37.0%	5	11.494	158.4	3.831	93.5%	5.294	0.635	3.831	93.5%	5.294	0.635	3.831	93.5%	5.294	0.635	0	0.0%	0	0	15.881	1.906
140	38.4%	5	10.783	158.4	3.594	93.6%	4.969	0.596	3.594	93.6%	4.969	0.596	3.594	93.6%	4.969	0.596	0	0.0%	0	0	14.908	1.789
145	39.7%	5	10.072	158.4	3.357	93.1%	4.618	0.554	3.357	93.1%	4.618	0.554	3.357	93.1%	4.618	0.554	0	0.0%	0	0	13.853	1.662
150	41.1%	5	9.519	158.4	3.173	92.7%	4.347	0.522	3.173	92.7%	4.347	0.522	3.173	92.7%	4.347	0.522	0	0.0%	0	0	13.04	1.565
155	42.5%	5	9.005	158.4	3.002	92.2%	4.091	0.491	3.002	92.2%	4.091	0.491	3.002	92.2%	4.091	0.491	0	0.0%	0	0	12.272	1.473
160	43.8%	5	8.492	158.4	2.831	90.5%	3.787	0.454	2.831	90.5%	3.787	0.454	2.831	90.5%	3.787	0.454	0	0.0%	0	0	11.361	1.363
165	45.2%	5	7.978	158.4	3.989	93.3%	5.501	0.66	3.989	93.3%	5.501	0.66	0	0.0%	0	0	0	0.0%	0	0	11.002	1.32
170	46.6%	5	7.464	158.4	3.732	93.6%	5.162	0.619	3.732	93.6%	5.162	0.619	0	0.0%	0	0	0	0.0%	0	0	10.325	1.239
175	47.9%	5	6.951	158.4	3.475	93.3%	4.792	0.575	3.475	93.3%	4.792	0.575	0	0.0%	0	0	0	0.0%	0	0	9.584	1.15
180	49.3%	5	6.437	158.4	3.218	92.8%	4.413	0.53	3.218	92.8%	4.413	0.53	0	0.0%	0	0	0	0.0%	0	0	8.826	1.059
185	50.7%	5	6.03	158.4	3.015	92.4%	4.115	0.494	3.015	92.4%	4.115	0.494	0	0.0%	0	0	0	0.0%	0	0	8.229	0.987
190	52.1%	5	5.73	158.4	2.865	90.9%	3.847	0.462	2.865	90.9%	3.847	0.462	0	0.0%	0	0	0	0.0%	0	0	7.695	0.923
195	53.4%	5	5.43	158.4	2.715	89.4%	3.587	0.43	2.715	89.4%	3.587	0.43	0	0.0%	0	0	0	0.0%	0	0	7.173	0.861
200	54.8%	5	5.13	158.4	2.565	87.9%	3.333	0.4	2.565	87.9%	3.333	0.4	0	0.0%	0	0	0	0.0%	0	0	6.665	0.8
205	56.2%	5	4.83	158.4	2.415	86.5%	3.085	0.37	2.415	86.5%	3.085	0.37	0	0.0%	0	0	0	0.0%	0	0	6.17	0.74
210	57.5%	5	4.53	158.4	2.265	85.0%	2.844	0.341	2.265	85.0%	2.844	0.341	0	0.0%	0	0	0	0.0%	0	0	5.688	0.683
215	58.9%	5	4.23	158.4	2.115	83.5%	2.61	0.313	2.115	83.5%	2.61	0.313	0	0.0%	0	0	0	0.0%	0	0	5.219	0.626
220	60.3%	5	3.957	158.4	3.957	93.4%	5.46	0.655	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	5.46	0.655
225	61.6%	5	3.794	158.4	3.794	93.6%	5.245	0.629	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	5.245	0.629
230	63.0%	5	3.631	158.4	3.631	93.6%	5.024	0.603	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	5.024	0.603
235	64.4%	5	3.468	158.4	3.468	93.3%	4.782	0.574	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	4.782	0.574
240	65.8%	5	3.305	158.4	3.305	93.0%	4.541	0.545	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	4.541	0.545
245	67.1%	5	3.142	158.4	3.142	92.7%	4.302	0.516	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	4.302	0.516
250	68.5%	5	2.979	158.4	2.979	92.0%	4.05	0.486	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	4.05	0.486
255	69.9%	5	2.816	158.4	2.816	90.4%	3.762	0.451	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	3.762	0.451
260	71.2%	5	2.722	158.4	2.722	89.5%	3.599	0.432	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	3.599	0.432

Annexure A – Power and Energy Calculations

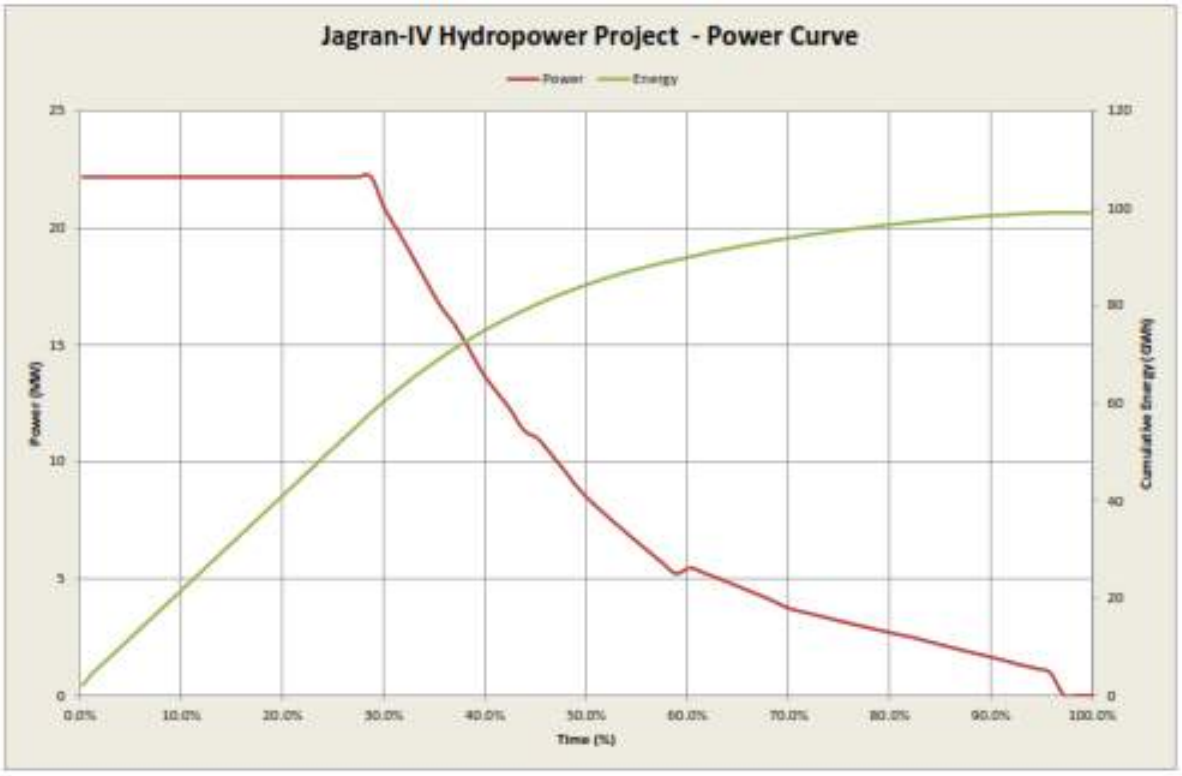
TIME		PERIOD	FLOW	NET	TURBINE - 1				TURBINE - 2				TURBINE - 3				TURBINE - 4				Total Power	ANNUAL ENERGY
INCR.			DURATION	HEAD	Q1	hT1	Power1	Energy1	Q2	hT2	Power2	Energy2	Q3	hT3	Power3	Energy3	Q4	hT4	Power4	Energy4	P=P1+P2	Total
(days)	(%)	(days)	(m3/s)	(m)	(m3/s)	(%)	(MW)	(GWh)	(m3/s)	(%)	(MW)	(GWh)	(m3/s)	(%)	(MW)	(GWh)	(m3/s)	(%)	(MW)	(GWh)	(MW)	(GWh)
265	72.6%	5	2.636	158.4	2.636	88.6%	3.452	0.414	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	3.452	0.414
270	74.0%	5	2.55	158.4	2.55	87.8%	3.307	0.397	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	3.307	0.397
275	75.3%	5	2.463	158.4	2.463	86.9%	3.164	0.38	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	3.164	0.38
280	76.7%	5	2.377	158.4	2.377	86.1%	3.024	0.363	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	3.024	0.363
285	78.1%	5	2.291	158.4	2.291	85.2%	2.885	0.346	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.885	0.346
290	79.5%	5	2.205	158.4	2.205	84.4%	2.749	0.33	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.749	0.33
295	80.8%	5	2.121	158.4	2.121	83.6%	2.618	0.314	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.618	0.314
300	82.2%	5	2.038	158.4	2.038	82.8%	2.493	0.299	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.493	0.299
305	83.6%	5	1.956	158.4	1.956	81.0%	2.342	0.281	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.342	0.281
310	84.9%	5	1.874	158.4	1.874	78.9%	2.185	0.262	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.185	0.262
315	86.3%	5	1.792	158.4	1.792	76.8%	2.033	0.244	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	2.033	0.244
320	87.7%	5	1.71	158.4	1.71	74.6%	1.886	0.226	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	1.886	0.226
325	89.0%	5	1.628	158.4	1.628	72.5%	1.744	0.209	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	1.744	0.209
330	90.4%	5	1.54	158.4	1.54	70.3%	1.599	0.192	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	1.599	0.192
335	91.8%	5	1.442	158.4	1.442	67.7%	1.442	0.173	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	1.442	0.173
340	93.2%	5	1.343	158.4	1.343	65.1%	1.293	0.155	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	1.293	0.155
345	94.5%	5	1.245	158.4	1.245	62.6%	1.151	0.138	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	1.151	0.138
350	95.9%	5	1.105	158.4	1.105	59.0%	0.963	0.116	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0.963	0.116
355	97.3%	5	0.943	158.4	0.943	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0
360	98.6%	5	0.782	158.4	0.782	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0
365	100.0%	5	0.62	158.4	0.62	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0.0%	0	0	0	0
MEAN ANNUAL ENERGY (GWh) =																						99.19

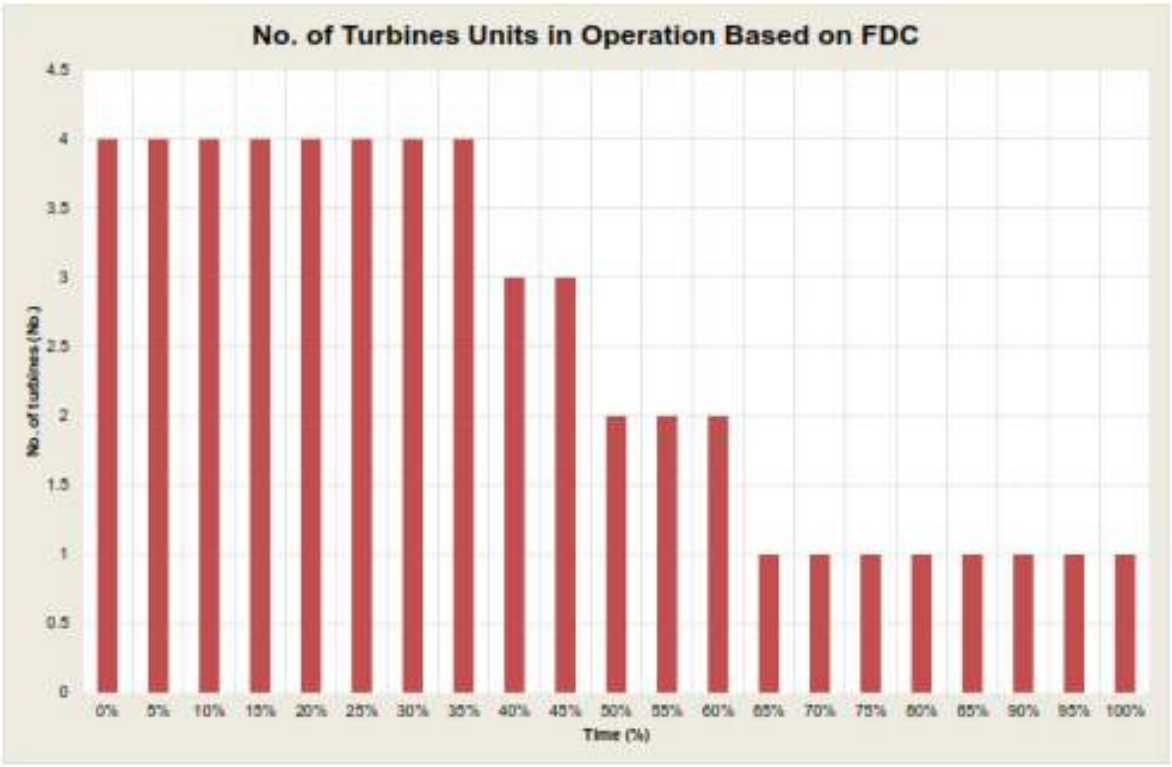
Annexure A – Power and Energy Calculations



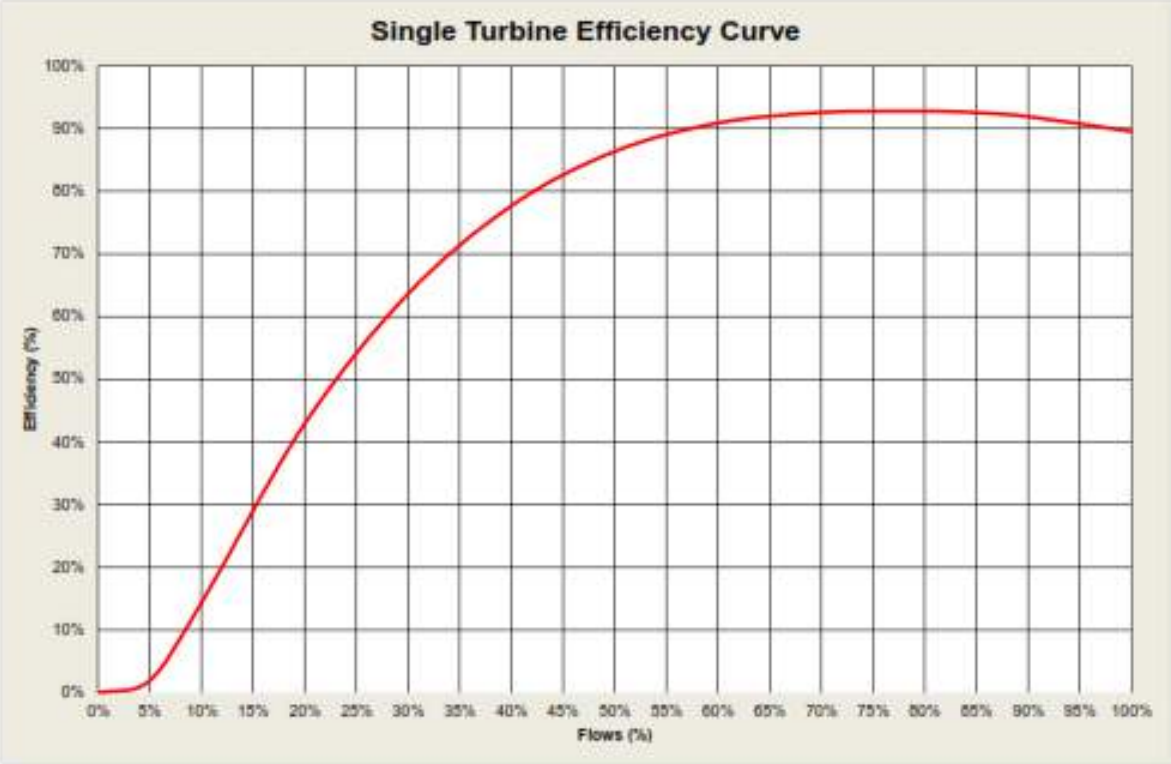


Annexure A – Power and Energy Calculations





Annexure A – Power and Energy Calculations



SECTION - 7: STRUCTURAL DESIGN REVIEW

7.1 General

Structural design review comprehends the design review of structural portion of Jagran-IV hydropower project presented in the Feasibility study, 2010, Technical design report, 2011 and Third Party Validation Study, 2021 besides, other documents presented for review subsequently. The design review of Technical design report is realized in the light following code of practice, Google search website, etc.

- ✓ ACI 318 -Building Code Requirements for Structural Concrete
- ✓ ACI 350-Code Requirements for Environmental Engineering Concrete Structures
- ✓ ACI 315 – Details Detailing of Concrete Reinforcement
- ✓ ASTM Standards, A615 and A516 (ASME SA-516)
- ✓ Relevant USACE Manuals of Engineering.
- ✓ ASME B31.1 – Power Piping Code
- ✓ USBR Design Standards DS-9, DS-14
- ✓ ASCE Manual 79 – Steel Penstocks
- ✓ AWWA M11 – Steel Pipe–A Guide for Design & Installation
- ✓ AWWA M45 – Fibreglass Pipe Design
- ✓ AWWA C950 – Specification for fibreglass pressure pipe
- ✓ ISO 10467–Buried GRP pipelines for pressure and non-pressure applications
- ✓ BS EN 1796 / BS EN 14364 – GRP piping for buried and pressure systems

7.2 Powerhouse

- Structural Stability Analysis of the Entire Powerhouse is missing.
- Structural Design of Powerhouse elements, viz. foundation and its thickness, wall, beam and column sizes and rebars calculations not provided.
- As per site geological strata, type of foundation is not available.
- Data Vide Para 2.10 of Technical Design Report, 2011, powerhouse would be R.C.C. Frame structure of size 35.4 m length and 10 m wide and 16.5 m high. As per Drawing No. JAG-PWR-003, the powerhouse structure consists of Steel Structure above Machine Hall Floor at EL. 2111.00 to Steel Frame Top at EL. 2118.00 and From Foundation at EL. 2101.5 to Machine Hall Floor EL. 2111.00 is RCC framed structure.
- Concrete Cylinder Strength at 28 days for various class of concrete components of Powerhouse, viz, Columns, Foundations, Slabs, Beams and mass concrete not mentioned anywhere in the Report, except, vide paragraph 2.18.2 only for plain concrete and paragraph 2.18.3 for lean concrete. Drawing No. JAG-MIS-001 and JAG-MIS-0022, shows a **Table 7-1** for class of concrete, verbatim reproduced:

Table 7-1: Concrete Classes, Tender Design Report (Feasibility Study, 2010)

CLASS	STRENGTH	NOMINAL PROPORTION
CLASS A (P.C.C.)	28 MPa	1 : 1 1/2 : 3
CLASS B (R.C.)	21 MPa	1 : 2 : 4
CLASS C (P.C.C.)	15 MPa	1 : 4 : 8
CLASS D (P.C.C.)	10 MPa	1 : 4 : 8

- First Stage and second stage concrete should be delineated on drawings
- The bar sizes in beams, walls, slabs and columns and their center-to-center spacing's do not follow ACI code limits for hydraulic and environmental structures. In highly seismic zones, the main bar sizes are higher and spacing's closer with reinforced concrete strength greater than 30 MPa (4500 psi).
- The units shown on drawings are MPa and in the Report these are in psi. Consistent units have not been used in the Tender Design Report and Feasibility Study Drawings.
- The ACI Code for environmental structures is ACI 350 (350.1 to 350.6), wherein stringent specifications are to be followed for minimum limits on Steel Rebars, cracks, and Structural thicknesses. The limits as per paragraph 2.18.5 of Tender Design Report have to be revisited per relevant ACI Code.
- Joints, viz., Expansion, Contraction, lift and Construction joints, on the drawings not shown. Typical details are covered in the Drawing No. JAG-MIS-001

7.3 Tailrace:

- Structural analysis of Tailrace Channel is missing with the Report.

7.4 Low Pressure Head Race Penstock:

- Maximum and / or minimum Pressure values (numerical values) are not mentioned in the Tender Design Report.
- Proposed Specs for Low Pressure Penstock is Glass Fiber Reinforced Plastic Pipe of 2.5 m diameter and around 3075 m long and carries water at speed 3.68 m/sec. Characteristic physical and mechanical properties of GRP are not provided in the Report. However, a few technical specs are provided in the Updation of Feasibility Study, July 02, 2020
- GRP Pipe Penstock has been successfully utilized in hydropower projects in the world for low pressure sections, viz., Rino di Sonico Hydropower Plant 1990 (Brescia province, Italy), Riva Hydroelectric Power Plant (Norway), 3 KM long GRP Penstock etc., however, it requires careful design, handling and supporting arrangements. Per degree change in temperature cause GRP pipe to expand twice than steel pipes. It is more flexible and requires closer supports, and buckles under external or buried loads, as well as, vacuum pressure. Its impact resistance can lead to brittle failure,

- No calculations provided for GRP to verify its structural characteristics and behaviour under various loading conditions of the project.

7.5 Road Crossing:

- There are places where GRP Penstock alignment intersects the existing road trajectory. The drawings do not show the details of road crossings.
- However, in updation of Feasibility Study, 2020 Figure-4.7– shows typical trench details of GRP Conduit at heavy vehicle crossing. This arrangement requires validation by structural analysis and stability of GRP under various loading scenarios.

7.6 Anchor Blocks:

- There are 27 numbers of anchor blocks of area 16 m² of lengths varying from 4 m to 7 m, provided on the GRP Penstock as written in paragraph 2.7.1, whereas 28 shown on the Drawings, No. JAG-HR-001 to JAG-HR-006. Three anchor blocks provided on Steel liner used as high-pressure Penstock 180 m long that bends at three points on its trajectory at angles 32°, 52° and 58° with the horizon. No Calculations and details provided for Design and stability Appraisal.
- Buried Conduits normally do not require anchor blocks except on the part of breathing lengths; the length on each end of the conduit where elongation in the pipe length is inevitable and can cause breakage of valves, joints and connections etc. Therefore, the feasibility report requires substantiation of the provision of 27 / 28 numbers of anchor blocks for detail review.
- In the Updation of Feasibility Study of June-2020, Paragraph 4.4.4.1.3, the phrase; verbatim copy of which is reproduced as, *"At all changes of either vertical or horizontal alignment, reinforced concrete anchor blocks are required to carry the forces generated underground for unrestrained pressure systems and these anchor blocks will need to be constructed on rock to provide the necessary stability.",* needs corroboration of stability calculations, as well as, geological evidence that at each anchor block location, foundation rock is available.

7.7 Surge Pipe:

- Surge pipe is discussed in paragraph 2.9 of the Technical Design Report. Table 1.2 shows its diameter 5.0 m and length 90 m inclined. The design aspects are given in paragraph 2.9.2, wherein it is mentioned that pressure in the shaft should never exceed 10% of the gross head.
- Provision of Surge Pipe should be revisited on the face of little rise of surge pressure in the pressure penstock, either by increasing its structural thickness and / or by providing pressure relieve valves for dissipating effects of pressure surge in the penstock steel liner.

7.8 Diversion Weir:

- The Design and Drawings are compatible, except the river width shown on the drawing at the point of diversion weir is 38 m, whereas described width in the Technical design report is 33 m vide paragraph 2.3.
- Upstream stone apron length of 14 m (DRWG No. JAG-WE-003) at slope of 1:9.655 (10.35%) seems structurally inadequate. The design requires complete revision. Cut-Off Wall and upstream apron ought to be revisited and updated.
- A 20-meter length of downstream stone apron should also be reviewed vis-à-vis, upstream apron.
- Intermittent cut-off walls under 14-meter-wide weir structure will enhance stability of the whole Diversion Weir.
- On the face of erodible hill slopes along the river trajectory, particularly, on right abutment of the weir needs appropriate safety measures, in the form of toe-walls, slope pitching, growing adequate numbers of tree to check soil erosion during rains and floods, and / or alike safety measures.
- In the event of catastrophic rainfalls or cloud burst in the valley, to check debris, boulders from wreaking havoc to the downstream installation, provision of upstream check dams, Sabo dams, Gabion check dams, along with bioengineering measures may be considered as shown in **Figure 7-1**.

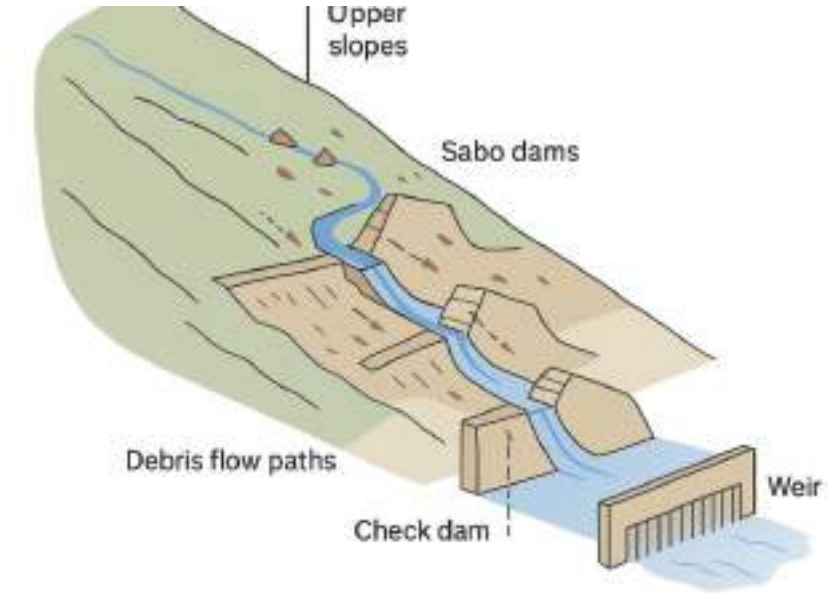


Figure 7-1: Illustration of Check Dams

7.9 Miscellaneous Devises on Diversion Weir

1. Over-Flow Section
2. Flushing Section
3. Gravel Sluice
4. Diversion Channel during Construction

- Design Drawings do not show erosion protection layer with reinforced concrete on the entire upstream and downstream face of the overflow section. This piece of structural element is either missing or overlooked in the feasibility report.
- Roller bucket section is to experience a velocity of flow around 14.08 m/s as written under paragraph 2.3.3 of Tender Design Report. This speed is enough to erode ordinary concrete of strength 4000 psi (28 MPa) or less. The sort of measures to combat this fact of flowing water through flushing channel sections and roller buckets is not mentioned anywhere in the report.
- The sort of lining in the gravel scour section 1.0 m x1.0 m should have been mentioned in the Report.
- Diversion Channel as proposed to be 10 m wide x 2.5 m high with free board of 0.7 m with discharge velocity 1.8 m/s to divert 40 m^3/s flow of Jagran River during construction is shown on drawing no JAG-WE-006 and JAG-WE-007. The section A-A of cofferdam as shown has to be reviewed in subsequent studies.
- Embedment length of abutment particularly on right hand side of weir has to be reviewed in the light of erodible side slope strata and protection works has to be devised.

7.10 Intake Structure, Connecting Channel and Desander Assembly

- Designed for 18 m^3/s discharge into the low-pressure GRP penstock 2.5 m internal diameter and wall thickness 8 mm through connecting channel and desander assembly.
- The whole arrangement has not been provided with structural evaluation report, with foundation arrangement vis-à-vis the underlying soil strata.
- The rebars are not consistent with ACI 350 Manual.

7.11 Pressure Pipe:

- 180 m inclined pressure pipe of Steel grade ASTM A516 is recommended for penstock that launches into Quadrifurcation before entering into the powerhouse turbine area.
- ASTM A516 (also known as ASME SA-516) is produced in four main grades, which correspond to different minimum tensile and yield strengths as given in **Table 7.2**:

Table 7-2: ASTM A 516 Four Grades of Pipes

Grade	Tensile Strength (MPa)	Yield Strength (MPa)	Typical Use
55	380 – 515	≥ 205	Low-pressure vessels, moderate service
60	415 – 550	≥ 220	Common in low-temperature tanks
65	450 – 585	≥ 240	Medium strength, better notch toughness
70	485 – 620	≥ 260	Most widely used grade — balance of strength and weldability

- A516 Gr. 70 is commonly used in Hydropower system; the preferred material for penstocks, surge tanks, and pressure parts because it combines:
    - Good weldability
    - High toughness at low temperature
    - Widely available plate thicknesses (up to ~150 mm)
- Under paragraph 2.8 of Technical Design Report, the grade mentioned is 51. Its availability has to be reaffirmed. The relevant drawings are JAG-PP-001 and JAG-PP-002. These are misprinted in the report as JAG-PS-001 and JAG-PS-002.
- It is reported in the Technical Design Report that the pressure rise taken for evaluation of pipe thickness is 15%, whereas the maximum surge is 10%, as per paragraph 2.8 and paragraph 2.9.2 respectively. It appears that a loaf factor of 1.5 is adopted.
- Pressure pipe is anchored with three thrust blocks to counterbalance velocity forces at change of bend angles. The stability analysis of thrust blocks is not provided with the report.

7.12 MC Observations

- Structural design presented in the Feasibility Study, 2010 Drawings and Technical Design Report, 2011 is not compatible with the highly seismic zone and as per relevant IBC / UBC & ACI codes and detailing manual.
- Structural design and Stability Calculations for various portions of the project, viz., Desander, Connecting Channel, anchor blocks and powerhouse not provided for review.
- The types of foundation are missing for all portions of the project components in view of the soil strata available at site.
- Providing suitable foundations will impact overall cost of the project.
- As proposed in the reconnaissance site visit report (15-19 October, 2025) of the MC, the locations of diversion Weir, as well as, powerhouse are to be reassessed, fresh geotechnical evaluation and investigations are required. Type of foundations may be shallow isolated and / or Raft to deep foundations, along with replacement of uncompromising underlying strata with engineered fill-material / select fill material tantamount to cost increase.
- Flood protection measures are not discussed in the Technical Design Report, 2011. Flood protection aspects have to be discussed and will have cost effect substantially.
- Snow melts/ glacier slides and their impact on the buried penstock and other superstructures and substructures have not been addressed in the Technical Design Report, 2011. These items have to be critically analysed in the current study. Their cost effect has to be evaluated.
- Jagran–IV HPP lies in a highly seismic zone, besides, Probabilistic and Deterministic Seismic Hazard Analysis (PSHA & DSHA), Site Specific Analysis for each important structures, viz. Weir and Powerhouse structures be conducted keeping in view the regional tectonic framework for 145 years, 475 years and 975 years return period.

SECTION - 8: HYDRO MECHANICAL EQUIPMENT

8.1 General

This section covers the review of Feasibility Study, 2010, Technical Design Report, 2011 & Third-Party Validation Study, 2021 for the Mechanical components proposed for Jagran-IV Hydropower project.

Considering all three documents & provided data and information for this review report, a gap analysis (**Table 8-1**) has been conducted to identify a number of potential areas for improvement & provision of base line information for next phase; the preparation of Tender Documents.

Table 8-1: A matrix of the gap analysis of the FSR -2010

FSR -2010	Observation / Gaps	Proposed / Required Action	Responsibility (Who/When)
8.2-Main Design Parameters	Flow Duration Curve and mean monthly flow are referenced but data source and analysis method missing.	A hydraulic model based on mean daily flows (10 years x 365 days) is required to estimate the actual plant factor and operational scheme of the plant.	MC - during tender documentation
	Head loss (11.82 m) mentioned without calculation basis, pipe material, or friction factor reference.	Detailed head loss calculations are required on the basis of updated locations of Weir and Powerhouse; using Darcy-Weisbach or equivalent; defining pipe roughness, material, and flow regime.	MC - during tender documentation
	Tailwater level variation described qualitatively only.	Tailrace rating curves and relationship between discharge and TWL need to be established.	MC - during tender documentation
8.3-Plant Capacity	Plant capacity (22 MW) and annual generation (98.2 GWh) lack supporting load duration or plant factor analysis.	A hydraulic model based on mean daily flows (10 years x 365 days) is required to estimate the actual plant factor and operational scheme of the plant.	MC - during tender documentation
8.4-Turbine Selection	Selection of Francis turbine is justified on the basis of head and Turbine Specific Speed. There are different criteria for this selection, others may be implied.	Endorsed by TPV rightfully	Rechecked and found to be correct
	Figures 8.1&8.3 referenced but only 8.1 is included, Figure 8.3 is missing.	May be a typo	-
8.4.3 Number of Units	Table 8.1 inconsistent (mix of 3×7.33 MW, 3×6 MW + 1×4 MW, etc.); unclear rating and unit discharge.	To be Rechecked and corrected the table with consistent turbine ratings and discharge data to be provided.	Corrected and a comparison table is included at 8.2

FSR -2010	Observation / Gaps	Proposed / Required Action	Responsibility (Who/When)
	Efficiency values (91 % turbine, 86.49 % overall) appear generic.	Efficiency curves or Turbine rating curves of renowned OEMs to be provided.	MC - Hill charts will be provided during tender documentation
	Transportation discussion lacks dimensional study or route analysis.	Transport route survey is required, max load/clearance data, and handling plan.	MC - during tender documentation
8.5-Turbine Parameters & Calculations	Formulas for specific speed, runner dia., etc., not referenced to standards; constants inconsistent.	Verify equations with IEC 61116 / USBR references and show sample calculations.	MC - during tender documentation
	No proof of efficiency validation or model test data.	Reference model test or typical manufacturer data for similar head range should be referred.	MC - Efficiency curves (Hill charts) or Turbine rating curves from renowned OEMs will be provided for tender documents.
	Runaway speed factor (K = 1.8–2.0) used without justification.	Confirm with manufacturer or empirical test data; ensure design safety margins.	MC- Empirical calculations will be furnished during tender documentation.
8.6-Turbine Components	Material specifications (ASTM/DIN grades) not identified.	Define material grades and welding standards (ASTM A743, A240, etc.).	MC - during tender documentation
	No mention of abrasion protection for runner and guide vanes under high sediment flow.	Include erosion-resistant coating plans (e.g., HVOF: High Velocity Oxy Fuel coating or stainless-steel overlay).	MC - during tender documentation; based on latest sediment analysis reports
8.7-Governor System	Conceptual description only; no control logic, schematic, or redundancy philosophy provided	Control diagram, set-point philosophy and integration details with SCADA to be added.	EPC Contractor- during detail design stage, however it will be mentioned in tender documents
	Governor oil pressure system (65 bar) not supported by sizing or component selection.	Provide hydraulic circuit, accumulator sizing, and emergency hand-pump capacity.	EPC Contractor- during detail design stage, however it will be mentioned in tender documents
8.8-Inlet Valve	Valve type and size given but no pressure rating or sealing class.	Specify pressure class, torque, actuator type, and testing standard (AWWA C504 / IEC 60041).	MC - during tender documentation
8.9 Powerhouse Crane	20 ton crane capacity proposed without justification vs. heaviest component weight.	Re-evaluate crane capacity based on heaviest lift (generator rotor or transformer) plus 10 % margin.	MC - during tender documentation

FSR -2010	Observation / Gaps	Proposed / Required Action	Responsibility (Who/When)
8.10 Cooling & Dewatering	System description generic; no pump sizing, redundancy, or hydraulic layout.	Provide schematic, capacity calculation, and redundancy plan for cooling/dewatering pumps.	EPC Contractor- during detail design stage, however it will be mentioned in tender documents
8.11 HVAC System	Table 8.3 uses generic ASHRAE data; lacks site-specific temperature and altitude correction.	Update with actual site climatic data (°C, humidity, elevation); perform load estimation.	MC - during tender documentation
	Ventilation system not integrated with equipment heat load or dust-filtration requirement.	Add detailed HVAC load and filtration design based on powerhouse heat gain.	MC - during tender documentation
8.12 Auxiliary Systems	Workshop tools and firefighting systems described generally; no capacity, layout, or standard cited.	Include equipment list, layout plan, and reference NFPA/IEC standards.	MC - during tender documentation
	No preventive maintenance or spare parts philosophy.	Add list of critical spares, maintenance schedule, and O&M strategy.	MC - during tender documentation
General	The refences to the applicable international codes of the industry are missing.	All relevant, international industrial and engineering codes must be referred for the detailed design by EPC	MC – a list of applicable codes has been provided at 8.6

8.2 Selection of Type of Turbine

Both in the Feasibility Study, 2010 and Third-Party Validation Study, 2021, the type of turbine is rightfully selected as Francis which is correct as per criteria of Rated Head and Rated Discharge given in USBR. The assumptions made for this selection also align with the renowned OEMs and established industrial practices.

The **Figure 8.1** shows that the Francis Turbine Selection range (yellow trapezoidal shape) rightfully covers the rated net head of 144 m (FS, 2010) to 158.4 m (TPV, 2021) and rated discharge ranges of 1 m^3/s – 4.8 m^3/s

Though there are some overlapping among Pelton, Turgo and Francis, however, there are some other factors as well which favours the selection of Francis turbine over the Pelton or Turgo as outlined below:

- For a given head, Francis turbines operate at higher specific speed than impulse turbines, allowing higher rotational speed and thus smaller, lighter generators.

- Efficiency of Francis turbines remains in high ranges (90–93%) over a wider operating range compared to Pelton/Turgo (which drop efficiency sharply below rated load).

- Francis turbines favour Compact powerhouse layout resulting in cost-effective electromechanical equipment.

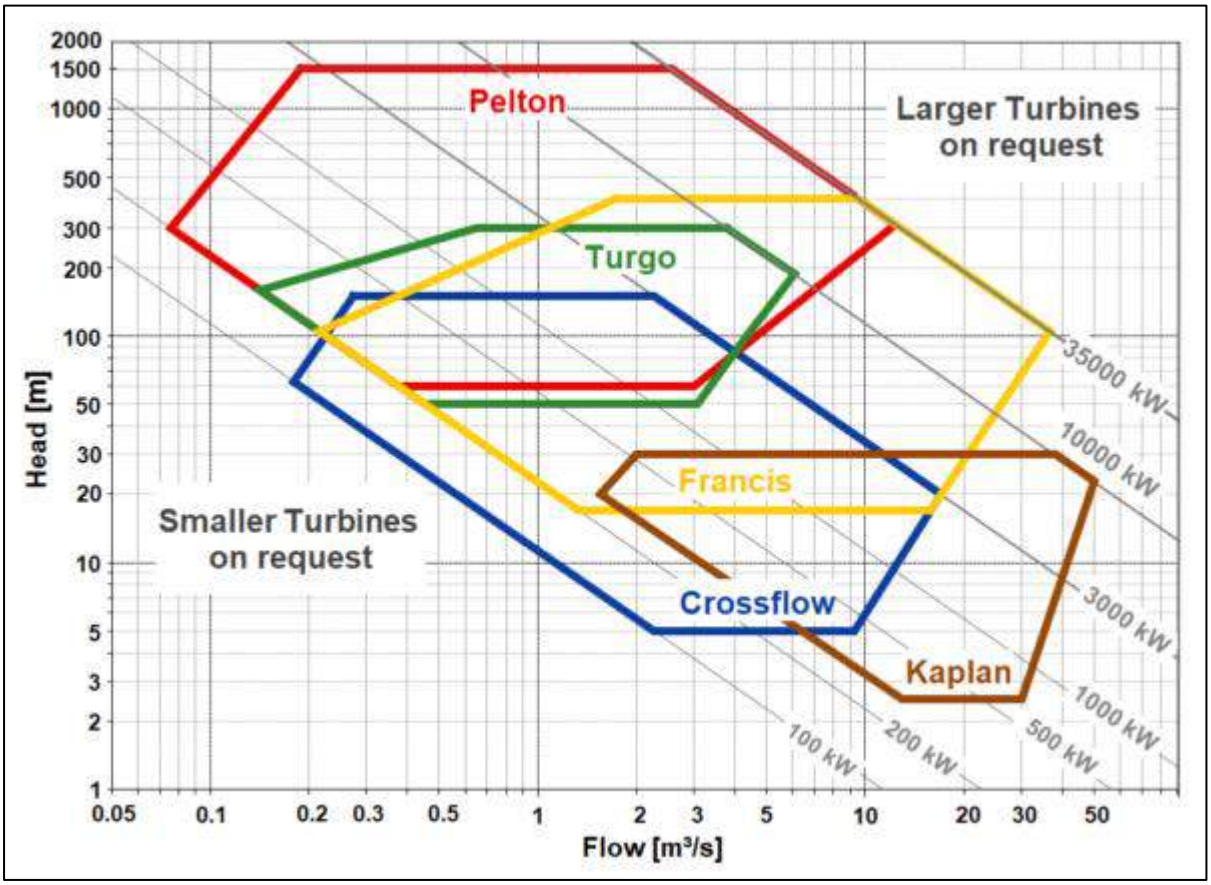


Figure 8-1: Hill Chart for Selection of Turbine Types

8.3 Main Design Parameters

8.3.1 Turbine

Feasibility Study, 2010: For the proposed Jagran-IV hydropower project site, Francis turbine has rightly been selected for rated net head of 144.2 m & design discharge of 18 m^3/s. A mix of 3 vertical Francis turbines each with capacity of 6 MW and one with 4 MW have been proposed. The smaller Turbine is intended for tapping in the minimum discharge ranges of 2.04 -3.49 m^3/s likely to be available during Nov-Dec, Jan - Mar every year.

Third Party Validation Study, 2021: The proposed design flow has been reduced to16 m^3/s whereas the minimum flow for 1.7% period is about 1m^3/s, therefore the number of units are kept four sets with three units of 6.67 MW capacity & one unit of 2 MW capacity. The orientation of the main E&M equipment has been kept vertical, which involve higher construction & maintenance cost.

The site of powerhouse has been proposed to be located on a flat area having more space available where horizontal orientation of the main E&M equipment is possible. It has been proposed that the prospects of horizontal alignment of the turbines generators sets may be assessed during final and detail design of the project.

MC Observations: If the flow duration curve and the location of the weir/intake structure and powerhouse remain the same as considered in TPV, 2021, the selection of turbines will remain the same as 3 x 6.7 MW and 1 x 2 MW. However, both FS, 2010 and TPV, 2021 have not considered the difference between design capacity of the plant and net installed capacity of the plant. There are certain internal losses and auxiliary consumptions of the power and it is usually

deducted from the design capacity for indicating the actual net capacity at the metering points.

It is assessed that by slightly improving the efficiency of turbines, generators and transformers the design capacity of the Jagran-IV power plant may be enhanced up to 22.4 MW which can provide some additional power of around 400 KW to compensate for the internal losses and in-house consumption of the power.

The speed of the turbines generators set has been proposed as 1,000 rpm in FS, 2010. According to the specific speed of the turbine having the net head & flow mentioned above the nearest rated speed comes between to be 750 & 1,000 rpm. This aspect may be investigated at detail design stage as lower speed having lesser vibration & lesser speed transients is better from operation point of view.

Table 8-2: Comparison of Turbine Salient Features

S.N	Parameters	Units	FS, 2010	TPV, 2021	MC, 2025
1	Type of Turbine	-	Francis	Francis	Francis
2	Turbine configuration	-	Vertical	Horizontal	Vertical
3	No. of Units	No.	4	4	4
4	Plant Capacity	MW	22	22	22.4
5	Plant Discharge	m^3/s	18	16	16
6	Unit Discharge	m^3/s	3.27 & 4.91	1.6 & 4.8	(1.6 & 4.8) *
7	Min Unit Discharge	m^3/s	1.74	1	1
8	Rated Net Head	m	144.2	158.4	158.4*
9	Rated Generator Output	MW	3 x 6 + 1 x 4	3 x 6.67 + 1 x 2	(3 x 6.67 +1 x 2) *
10	Rated Turbine Speed	N (rpm)	1000	750 - 1000	750
11	Turbine Runaway Speed	N (rpm)	1800	-	(to be provided by OEM)
12	Turbine Efficiency	%	91%	-	~91%
13	Combined Unit Efficiency	%	86.49 %	-	87 %
14	Plant Installed Capacity	MW	22	22	22.4
15	Internal losses and in house consumption	KW	-	-	400 KW
16	Plant Net Capacity at metering	KW	-	-	22,000

* Parameters with will be rechecked and re-established on the basis of revised hydrology and hydraulic data during next design stage.

8.4 Horizontal OR Vertical Francis Turbine

In Feasibility Study, 2010, the Vertical Francis Turbines have been selected whereas the Third Party Validation Study, 2021 advocates the Horizontal Francis Turbines.

The MC has analyzed prose and cones for both configurations and concluded to select the vertical configuration based on the following key advantages for this configuration:

1. **Hydraulic Performance:**
    - Vertical configuration ensures symmetrical flow into the runner, improving efficiency and reducing wear.
    - Suitable for heads between 100–600 m, which fits the Jagran case.
2. **Mechanical & Operational Benefits:**
    - The vertical shaft allows better bearing arrangement and alignment at higher rotational speeds.
    - Less prone to shaft bending and vibration compared to a horizontal shaft under similar load.
3. **Maintenance & Access:**
    - Easier to dismantle and inspect the runner and guide vanes from above.
    - Common configuration for power stations in the 5–10 MW/unit range and above.
4. **Proven Industry Practice:**
    - For 6–7 MW Francis units with heads >100 m, most of the modern hydropower plants prefer vertical layout (examples: Asian, European, and Latin American small hydropower schemes).

8.5 Inlet Valve

Butterfly Inlet Valve(s) have been selected in Feasibility Study, 2010, which will be replaced with Spherical Valve(s) for the Francis turbine proposed for the project. Butterfly Valves are susceptible to high surge pressure at the time of full load rejection. The ball valves functions well without restriction of flow and pressure drop. In addition, the ball valves provide tight seal at high pressure, while butterfly valves are prone to leakages at high pressure.

8.6 Codes and Standards

The references to the applicable international standards/codes of the industry are missing in the Feasibility Study, 2010 and Third Party Validation Study, 2021. These engineering codes are essential part of the design process and a mandatory requirement for EPC stage design. The EPC design must conform to the applicable portions of the following codes and standards:

1 DIN - Deutsche Industrial Normen.

2 EN - European Standard.

3 ISO - International Organization for Standardization.

4 FEM - Federation European de la Mauntention.

5 ASTM - American Society for Testing and Materials.

6 ACSE - Americans Society for Civil Engineers. Manuals and Reports on Engineering Practice No. 79-Steel Penstocks, 2012.

7 AWWA - American Water Works Association.

8 CMAA Crane Manufacturers Association of America. Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling cranes - No. 70.

9 ABMA - Americans Bearing Manufactures Association.

10 AGMA - Americans Gear Manufactures Association.

11 NEC - National Electric Code.

12 NEI - National Elevator Industry, Inc.

13 NFPA - National Fire Protection Association.

14 PPI - Plastic Pipe Institute.

15 SSPC - Steel Structures Painting Council.

16 UL - Underwriters Laboratories Inc.

17 FM - Factory Mutual Engineering and Research Corporation.

18 IAPMO - International Association of Plumbing and Mechanical Officials:

19 IEC - International Electro Technical Commission.

8.7 Mechanical Auxiliaries

Following mechanical auxiliary systems are the basic requirement of a hydropower project which will be deeply investigated and necessary information will be furnished for Tender documents.

- Cooling Water System
- Drainage and Dewatering System
- HVAC System
- Potable/Service Water System
- Compressed Air System
- Fire alarm and smoke detection system
- Fire Fighting System
- Lubrication and Oil Handling System
- Sewage/Sanitary System
- Workshop equipment

8.8 Hydraulic Steel Structures

Mechanical part of the Feasibility Study, 2010 is silent about the hydraulic steel structures which are preliminary assessed and a list is given below:

1- Trash-racks, Stoplogs and Inlet gates at Weir- to be operated by a gantry crane.

2- Stoplogs and Under-sluices (radial gates) for flushing out the Weir – Stoplogs to be operated by gantry crane

3- Flushing gates for Stilling basin – to be operated by fixed hoisting machines

4- Draft tube gates - to be operated by gantry crane or fixed hoisting system.

Basic Design parameters will be added in the tender documents and drawings to facilitate the EPC contractor for optimizing the design of these hydraulic steel structures.

8.9 MC Observations

(i) The sizing and design of the electro-mechanical and auxiliary equipment shall be carried out with precision to ensure maximum energy output, taking into account the site's topography and hydrology.

(ii) A comprehensive hydraulic model shall be developed utilizing mean daily flow data over a period of ten-years (10 years × 365 days) or more to accurately evaluate the plant factor and define the operational scheme of the power plant, in accordance with the latest hydrological records and the finalized hydraulic layout.

(iii) Vertically oriented Francis turbines with a rated speed of 750 rpm are proposed for further evaluation, considering the available powerhouse space and the geological conditions of the foundation bed at the proposed construction site.

(iv) Spherical / Ball valves are proposed instead of butterfly valves to avoid pressure transients during opening & closing of the inlet valve.

(v) List of tools & spares are required to be made part of the Tender documents.

SECTION - 9: ELECTRICAL EQUIPMENT

9.1 General

The major Electrical equipment as proposed for 22MW Jagran-IV Hydropower Project consists of four (04) synchronous generators, generator step-up transformers, medium voltage and 132kV Switchgear etc. with the following arrangement and details:

- Four vertical shaft synchronous generators of having 7.06MVA (for Three Main Units) capacity and 4.7MVA (for One Auxiliary Unit) capacity and having generation voltage of 11kV.
- Two Unit Step-up transformers each of having capacity 10/13MVA with voltage ratio of 11/132kV.
- A Diesel Generator Set (having rated capacity 300kVA, 400V) for black start operation and essential loads with voltage ratio 0.4kV.
- Two No. station Auxiliary transformers proposed with voltage ratio 11/0.4kV
- Two No. of transformer bays to be connected with the 132kV common bus-bar
- Two No. of Line bays (132kV).
- One PT bay at 132kV bus-bar
- One circuit of transmission line having connected with the existing Grid station (Kundal Shahi) via Jagran-I substation.
- Control, protection and measuring devices for the Hydropower plant including 132kV switchyard

9.2 MC Observations

The following observations / comments are made pertaining to powerhouse electrical equipment, switchyard, transmission line and interconnection with existing Grid (located at Kundal Shahi).

9.2.1 Generating Common Bus-bars Comparison with Direct Connection to Own Transformer

Two options related to generating voltage connections are available in general practice as quoted hereunder:

- *Each generator connected to its own unit transformer.*
- *The generators feeding the group of transformer system through a common bus bar of 11kV.*

If we move forward with the option (1) as indicated above, the auxiliary transformers need to be coupled with the generator's own line (11kV) independently so in the event of tripping of the same Unit; will cause to the failure of unit auxiliaries power supply. This problem may be minimized by means of installing two auxiliary transformers with any of two units, but the availability of the both units to be ensured.

The concept of energization of auxiliary transformers with the help of back charging from Kundal Shahi Grid can be considered, but the required load to feed the essential supply of Jagran-IV HPP to be available consistently.

In view of above, the selection of option-2 in the Feasibility Study Report under para 9.1 that a common bus-bar of 11kV will meet the requirement of continued operation of Auxiliary Transformer, stands satisfactory.

9.2.2 Synchronous Generator

The power rating capacity(s) of 3 main units and 1 Auxiliary unit mentioned in the Feasibility study, 2010 under Para 9.2.1 is 6 MW each and 4 MW respectively but the same ratings mentioned in the Third Party Validity Study, 2021 is 6.67 MW each and 2 MW respectively. As the cumulative installed capacity of the plant remains the same i.e. 22 MW in both the cases and does not make big difference in following the electrical specifications and protection parameters, however, the structural stability parameters and mechanical coupling will be finalized in detailed design stage.

9.2.3 Generator Grounding Transformer

It states that grounding of generator neutral through resistors is proposed. The Grounding resistors shall be installed in a separate housing with proper insulation provided. It is proposed that the Generator Neutral should be grounded through neutral grounding transformer to limit the fault current.

9.2.4 Generator Step- Up Transformer

The proposed power rating of Generator Step-Up Transformers is three phase “10/13MVA” with the power factor 0.85, stands justified. However, cooling system shall be ONAN/ONAF.

9.2.5 Neutral Grounding Current Transformer

A neutral grounding current transformer may be proposed for restricted earth fault protection.

9.2.6 Switchyard (132kV)

The Feasibility study, 2010 is silent regarding the type of switchyard whether it would be Air Insulated Switchgear (AIS) or Gas Insulated Switchgear (GIS). However, the single bus-bar scheme with sectionalizer stands appropriate. The type of switchgear in respect of AIS and GIS is under consideration and to be confirmed on later stage.

9.2.7 Synchronization of Generators

The synchronization of electrical generators to be proposed through Generator circuit breakers by means of synchro check relay device.

9.2.8 Auxiliary Transformers (Station Transformers)

The power ratings of auxiliary transformers is not mentioned in the Feasibility study, 2010. The actual required rating of auxiliary transformers shall be assessed later as per actual load demand based on unit auxiliaries, common systems and essential loads.

Keeping in view the higher cost of auxiliary transformers connected with 132kV bus as well as the cable cost for routing the power supply from switchyard to powerhouse is not advisable.

However, the proposed voltage ratio of auxiliary transformers shall be coupled with the 11kV generator common bus with the voltage ratio and power capacity 11/0.4kV and 1MVA respectively.

The Auxiliary transformers to be proposed inside the powerhouse with the Dry type transformers along with the air forced cooling system (AF).

9.2.9 Diesel Generator

It appears that the proposed capacity of diesel Generator set of 300kVA mentioned under Para 9.4.3 is over rated. It is proposed to propose a 250kVA instead of 300kVA DG set considering the load requirement of plant. A separate room shall be constructed with the provision of ventilated louvers and exhaust fans. This DG set shall be coupled with the LV boards and give supply to essential loads as well as operation of auxiliaries of single unit. However, the final power rating of DG set shall be determined after carrying out the load demand calculations.

9.2.10 Medium Voltage Switchgear (11kV)

It has already been proposed that the Generator output to be coupled with the common Bus-bar of 11kV and the arrangement of bus-bars to be provided with the incoming generator circuit breakers and outgoing breakers for further connection with the generator Step-up Transformers.

In addition to above, two no. of auxiliary transformers shall also be connected with the same bus 1 & 2 separately along with an outgoing feeder (11kV) to intake power supply.

9.2.11 Grounding System

A combined grounding network of switchyard, powerhouse and intake areas shall be provided to avoid the short circuit current. The earthing resistance of the system must be less than 1-ohm. The exact value of earthing resistance shall be confirmed after designing calculations of earthing mesh.

9.2.12 Low Voltage Boards

There are various low voltage boards to be installed for operating the different type of consumers in and outside the plant. The following Boards shall be provided:

1- Unit Auxiliary Boards
2- Common Service Boards
3- Essential Service Boards
4- Intake service Boards

The Auxiliary transformers of 11/0.4kV capacity has been planned to feed low voltage bus bars. Further, an emergency diesel generator set of 300kVA capacity will also feed the 0.4kV bus to meet emergency requirement.

9.2.13 DC Power Supply

Two DC supply system (110V each) is proposed in the Feasibility study, 2010 in Section 9.4.4. It is proposed to have one 220V DC supply system which shall comprise battery bank and chargers complete with all accessories. The proposed dual battery bank would provide power to complete plant control system, i.e. the local control system, excitation system, protective numerical relays, lighting and small power, and other DC equipment.

Different type of 220V DC bus bars to be energized for the unit auxiliaries, common services and essential services.

9.2.14 Plant Control Unit Control and Alarm System

The feasibility study is silent in Control and Alarm System of the whole station.

The following elements shall be proposed for Jagran-IV Power Station:

i. Plant Control System

ii. Unit Control System

iii. Data Communication System

The dual channel control system to be proposed for unit local control and remote control. All control system shall be monitored with the SCADA system with the two main servers.

9.2.15 Protection Equipment

It appears that the protection system given for the different equipment in the Feasibility study, 2010 is not sufficient and to be re-checked as per WAPDA and IEC standards.

However, protection equipment shall comprise state of the art numerical relays for the protection of main electrical equipment like generators, transformers, transmission lines, 11kV switchgear, LV Switchgear etc.

9.2.16 Metering Scheme

A metering panel to be provided inside the powerhouse for direct reading. The PT's and CT's at 132kV side shall be used for the metering purpose in order to get the net energy excluding the Plant auxiliary load, generator and transformer losses.

9.2.17 11kV feeder to Intake

The Feasibility study, 2010 is silent regarding 11kV feeder to Intake. A 11kV line is proposed from medium voltage common bus to Intake structure for operation of different consumers installed at plant.

9.2.18 Fire detection and alarm system

In the Feasibility study, 2010 only areas were mentioned for the subject system with no further detail. The type of fire detectors as per site requirements and effective alarm system will be finalized on later stage.

9.2.19 Security surveillance system

The scope of security surveillance system is mandatory part of powerhouse but the Feasibility study, 2010 is silent in this regard. A central control security system (CCTV) to be proposed with the state of the art technology cameras connected with the network video recorder

9.2.20 Transmission Line

The scope of transmission line is clearly indicated that initially the 132kV transmission line to Kundal Shahi grid station shall be constructed. However, a strip survey is proposed for finalization of the route.

9.3 Feasibility Level Drawings

In the Feasibility Level Drawings the DC distribution system, MV switchgear arrangement in power plant, station service supply and plan (Top View) of 132kV switchyard are missing. These shall be incorporated in the detailed design stage.

9.4 Way Forward

The MC will update the relevant studies and furnish the Tender Level Designs, Drawings and Specifications so that EPC Contractors should be fully aware of the Project and Employer's Requirements at the International Competitive Bidding (ICB) Stage and later on to provide EPC Detailed Design, Manufacture/Procure, Install and Commission the Project for Taking Over by Client.

SECTION - 10: INITIAL ENVIRONMENTAL EXAMINATION (IEE) REPORT

10.1 General

The Jagran-IV Hydropower Project, with a proposed installed capacity of 22 MW, is planned on left bank of Jagran River in District Neelum, AJK. The diversion weir is proposed approximately 300 meters downstream of the confluence of Baihkl Nullah with the Jagran River near Shaal Village, whereas the powerhouse is located about 300 meters upstream of the existing Jagran-I weir intake at Thunian Village.

10.2 Regulatory Background

The environmental assessment process for the Jagran-IV Hydropower Project has followed the applicable legal and institutional framework of Azad Jammu & Kashmir, particularly the AJK Environmental Protection Act, 2000, and the Review of Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) Regulations, 2009.

- The Initial Environmental Examination (IEE) prepared in 2010 at the Feasibility stage was later comprehensively updated and integrated into the Environmental Impact Assessment (EIA) finalized in 2021.
- The EIA 2021 report was duly submitted to the AJK Environmental Protection Agency (EPA) for review and approval.
- The AJK-EPA issued a Conditional Environmental Approval (No Objection Certificate – NOC) on 2 August 2022, under Section 11 of the AJK Environmental Protection Act, 2000.
- The scanned copy of the NOC has been attached as **Annexure-B** to this report.

10.3 Conditions of Environmental Approval

The Conditional Environmental Approval mandates compliance with environmental, social, and occupational safeguards throughout all phases of the project. The key requirements include:

- Maintenance of minimum environmental flow (E-Flow) of 1.0 m^3/s downstream during lean flow periods.
- Establishment of a Grievance Redress Mechanism (GRM) to address community and stakeholder concerns.
- Implementation of full compensation and resettlement plans for project-affected persons (PAPs).
- Compliance with State Environmental Quality Standards (SEQS) during construction and operation.
- Implementation of the Environmental Management Plan (EMP) as outlined in the EIA.
- Periodic monitoring and reporting through the Independent Environmental Monitoring Consultant (IEMC).

10.4 Review of Environmental Approval Validity

According to the Review of IEE and EIA Regulations, 2009, Section 16 (Validity Period of Approval) specifies the following:

Sub-Section (1): Approval shall be valid for the commencement of construction for a period of three years from the date of issue.

Sub-Section (2): If construction commences during the initial three-year period, validity extends for another three years.

Sub-Section (4): The proponent may apply for extension if construction has not commenced within the validity period, provided project conditions have not significantly changed.

Sub-Section (5): The Agency may require submission of a fresh IEE or EIA if substantial changes in project design, location, or operation have occurred.

10.5 MC Observations on Environmental Approval

The Environmental Approval (No Objection Certificate – NOC) represents a critical regulatory requirement under the Azad Jammu and Kashmir Environmental Protection Agency (AJK-EPA) framework, ensuring that the proposed project aligns with applicable environmental standards prior to the commencement of construction activities. As part of the environmental compliance review, the validity and current status of the NOC issued for the Jagran–IV Hydropower Project were examined with reference to the Environmental Protection Agency (Review of IEE/EIA) Regulations, 2009.

The Environmental Approval (NOC) for the project was issued on 2 August 2022. The contract for the project i.e., Review of Feasibility & Design, Preparation of Bidding Documents, Selection of EPC Contractors, Construction Supervision, Testing, Commissioning & Management of 22 MW Jagran–IV Hydropower Project, was signed on 28 August 2025, i.e., three years and twenty-three (23) days after the issuance of the NOC.

As per Section 16 (1) of the 2009 Regulations, the approval validity for commencement of construction is limited to three years from the date of issuance. Since construction activities have not commenced within this validity period, the NOC has already been lapsed. Therefore, it is required that the Proponent (Project Director's Office – PDO) formally apply for renewal or extension of the NOC validity to the AJK-EPA prior to the project mobilization or commencement of works.

10.6 Reconfirmation of Institutional Arrangements:

Appointment of the Independent Environmental Monitoring Consultant (IEMC) and clear delineation of environmental responsibilities need to be reaffirmed before site activities.

10.7 Social Aspect

The project requires the acquisition of land for various components and entails certain social implications, including temporary and permanent land use changes, tree cutting, and minor asset relocation.

This review assesses the adequacy of the current social considerations and identifies gaps against standard social safeguard requirements. The details are provided below:

10.7.1 Land Requirements and Asset Impacts

The proposed project involves land acquisition for the construction of the weir, approach channel, sand trap, penstock, powerhouse, and access roads. Based on available information, a total of 22 acres of land will be required for project facilities. However, the land categorization, whether private, community, or state-owned, has not been clearly specified and requires verification through cadastral and revenue records.

In addition, approximately 4 electric poles located at the weir area in Shaal village will need to be relocated during the construction period in coordination with the local electricity department.

10.7.2 Affected Persons and Assets

The available data indicate limited but tangible social impacts within the project area.

Table 10-1 summarizes the affected structures and assets.

Table 10-1: Summary of Affected Assets and Structures

Sr. No.	Type	Number	Remarks
1	Houses	3	Located near the proposed access road alignment
2	Shelters	4	Temporary animal or storage shelters
3	Shops	1	Small roadside shop near Shaal village
4	Land	22 acres	Includes both permanent and temporary acquisition
5	Fruit Trees	12 (2 apricot, 7 walnut, 3 apple)	Owned by locals at the weir site
6	Forest Trees	30	Affected along the penstock alignment

Source: EIA Report, 2021 of this project.

10.7.3 Project-Affected Persons (PAPs) and Households (PAHs)

No specific identification, enumeration, or quantification of Project-Affected Persons (PAPs) and Project-Affected Households (PAHs) has been conducted to date. The absence of such data presents a key gap in understanding the scope and extent of social impacts, including potential livelihood losses, economic displacement, and land ownership implications.

Although the project does not appear to involve large-scale resettlement or physical displacement, the acquisition of land and removal of fruit trees suggest the potential for economic displacement and loss of livelihood sources.

To address this gap, it is proposed that a detailed socio-economic survey and census be conducted to accurately identify all affected individuals and households, along with the extent and nature of impacts.

10.7.4 Resettlement Planning and Compensation

Despite the evident land and asset impacts, a Resettlement Action Plan (RAP) has not yet been prepared. Preparation of a RAP or, if the impacts remain limited, an Abbreviated RAP (ARAP) is necessary to ensure compliance with the Land Acquisition Act (LAA) 1894 (as adopted in AJ&K), which governs land acquisition for public purposes, outlines notification, valuation, and compensation procedures. Sections 4–6 for notification, Section 11 for award of compensation, and Section 23 for market-based valuation.

10.7.5 Quantification of Livelihood Losses

Additionally, livelihood losses remain unquantified, particularly for those dependent on agricultural land, trees, or other local resources. It is essential to assess the livelihood dependence of affected persons and provide appropriate compensation or livelihood restoration support to ensure their socio-economic stability.

10.7.6 Stakeholder Engagement and Consultation

The review also revealed no formal record of stakeholder engagement. It is proposed to conduct focused consultations with affected households and local communities, ensuring that their concerns and suggestions are properly documented and incorporated into project planning and implementation.

Annexure – B

Azad Jammu & Kashmir
Environmental Protection Agency

DIRECTOR GENERAL
Phone 05822-921082
Fax 05822-921688
Email: dgepa.ajk@gmail.com

Ref #: EPA/460-67/2022
Date: 02-08-2022

1. Name & Address of Proponent:	AJ&K-Power Development Organization(PDO)
2. Description of Project:	Construction of 22 MWJagran-IV Hydropower Project (J-IV HPP) District Neelum
3. Location of Project:	Weir on Jagran Nullah Near Shaal Village & Surface Power House at Village Thonia Jagran
4. Date of Filing of Application:	06-12-2021

CONDITIONAL ENVIRONMENTAL APPROVAL

(Under Section11 of AJK-Environmental Protection Act, 2000 read-with AJK EPA Review of IEE/EIA Regulations, 2009)

5. In exercise of powers conferred under Section 11 of the Azad Jammu & Kashmir Environmental Protection Act 2000, after the careful review of Environmental Impact Assessment (EIA), the undersigned hereby accord Environmental Approval in favor of ***Power Development Organization (PDO) AJ&K*** *(the proponent)* for the **Construction Phase** of *22 MW Jagran-IV Hydropower Project (J-IV HPP) (the Project)*; subject to the fulfillment of conditions by the proponent as enumerated hereunder. -

A. **Environmental Flow (E-Flow):**

(i). As the Project is designed with 0.34 m^3/s Environmental (Ecological) Flow (E-Flow) downstream but, due to environmental sensitivities of project area, the Proponent shall implement J-IV HPP with E-Flow during Operational Phase not less than 1.0 m^3/s, in lean period;

(ii). To ensure that 1.0 m^3/s E-Flow will remain available downstream during lean period, the Proponent shall install a Gauging/Metering Station or Facility at any suitable location to verify and record the flow data for sharing with EPA, accordingly;

(iii). In case, during operational phase, the reduced flow affects the functioning of Watermills and Mini Hydropower Plants situated downstream; the Proponent shall be liable to rehabilitate these or compensate to the satisfaction of owners.

B. **Compensations, Resettlement Action Plan (RAP) and Grievance Redressal System:**

(i). As the J-IV HPP envisages resettlement of 03 Houses, 04 Shelters and one shop for the construction of Weir/Power House, establishment of PMU and construction of Residential Colony, therefore, the Proponent shall pay

Continuation Sheet

Azad Jammu & Kashmir
Environmental Protection Agency

compensations to the owners in such rates and with terms & conditions, as agreed upon under prevalent laws & practices, but to the best satisfaction of affectees;

(ii). The Proponent shall pay compensation to the owners for land, loss of crops, business, livelihood, property, usage rights etc. with rates as agreed upon under prevalent laws & practices to the satisfaction of affectees;

(iii). The Proponent shall establish and maintain a 'Grievance Redressal System' (CGRS). The Grievance Redressal Committee, formulated under CGRS, headed by respective Deputy Commissioner and should have the representation of Affectees, EPA, C&W, Forest & Wildlife and Agriculture Departments;

(iv). To show the status of grievances and actions taken to redress them, the Proponent shall submit quarterly report to the EPA.

C. **State Environmental Quality Standards (SEQSs):**

(i). The Proponent shall ensure compliance to State Environmental Quality Standards (SEQSs);

(ii). The mechanized plants, machinery and other equipment must be fitted with noise abatement devices and should have the conformity to *SEQSs*;

(iii). The Proponent/Contractor shall ensure water sprinkling to suppress dust at all construction sites;

(iv). In case independent **Environment Specialist Companies (ISO-certified)** are to be hired as a compulsory arrangement to undertake measurements of different parameters. In order to ensure effective compliances of SEQSs; the findings of quality analysis and report of compliance to SEQSs should be shared with EPA AJK on regular basis during the construction phase of the project.

D. **Environmental Management Plan (EMP):**

(i). All mitigation measures, as suggested in the EIA Report and Environmental Management Plan (EMP), shall be strictly adhered to. This should be indicated or reported as a **"Commitment"**;

(ii). Institutional arrangements for implementation of **Environmental Management Plan (EMP)** may be finalized well before the commencement of construction of project, so that an efficient & effective mechanism for environmental protection & management should be operative well on time.

E. **Jobs/Employment for Local People;**

(i). The Proponent will take a policy measure, and, thereunder, it shall be obligatory on Contractor to provide employment preferably to local people for all semi-skilled and unskilled jobs. Preference should also be given to local people for skilled jobs as well. Employment record for all positions shall be provided to EPA AJK on quarterly basis;

(ii). For labor and all other types of workforce, the Contractor shall ensure strict compliance to Labor Laws.

F. **Quarrying Sites & Spoil Dumps;**

Continuation Sheet

Azad Jammu & Kashmir
Environmental Protection Agency

(i). Given to the geology, topography, terrain and demography of project areas; pre-identified and EPA approved sites shall be used/utilized for quarrying purpose so that the issues like land degradation, soil erosion, sedimentation of water bodies and potential threats to human life & properties and public infrastructure could be avoided;

(ii). The Proponent shall bound the Contractor to strictly ensure dumping of spoil or excavated material on pre-identified and designated sites/places both at Weir as well as Power House sites; duly approved by EPA. In order to avert damage to vegetative cover, perennial & non-perennial drains, irrigation channels, communication routes and productive lands; the free roll-down of spoil on hill slopes shall be strictly prohibited. The dumping of spoil into water bodies like rivers or streams shall be considered a sheer violation of this Approval. During transportation of spoil, adequate measures must be in-placed to avoid littering of roads or dust emission, etc.;

(iii). The Proponent shall bound Contractor to take effective measures (installation of protection walls, Gabion walls, etc.) for land stabilization and prepared a comprehensive plantation plan at pre- identified dumping sites after land leveling with the consultation of Forest Department;

(iv). The Proponent shall bound the Contractor to prepare Site-Specific Environmental Management Plan (SSEMP). In order to ensure best environmental management during construction phase, besides quarrying sites and spoils dumps, the SSEMP preferably be developed for all construction related activities as well and be submitted to AJK-EPA well before undertaking these activities;

(v). The Proponent/Contractor shall strictly avoid OPEN SOURCE acquisition of aggregate or construction material from sites other than identified and approved by EPA.

G. Vibration Impact on Property:

(i). All public or private buildings within 200 M of the blasting site will be surveyed prior to start of blasting. The survey will be undertaken independently by the Owner's Engineer, the Proponent, or a Third Party and will be undertaken to determine the pre-Project conditions of the buildings structure including any pre-existing damages. The survey results will be used to settle any damage claims arising out of the blasting activities.

H. Project Sites Demarcation Plan;

(i) The Proponent should bound the Contractor to mark the project sites (Weir, Powerhouse, Labor Camp, PMU Staff Colony sites etc) with the consultation of Revenue Department before the commencement of construction work and install a fence wall around aforementioned sites to ensure the public privacy.

I. Construction Camps, Sewage & Waste Management;

(i). The Construction Camps shall be located/constructed at suitable distance from any settlement to avoid disturbance or intrusion into the privacy of local communities. Independent arrangements shall be made for sewage

Continuation Sheet

Azad Jammu & Kashmir
Environmental Protection Agency

disposal/treatment and solid waste. The sewage treatment facilities/septic tanks shall be constructed at a suitable place from any permanent or seasonal water source and should not be located/constructed in the areas where high ground water table exists;

(ii). For construction camps, instead putting the local resources under stress, independent arrangements should be made/laid for commodity services;

(iii). The waste, chemical and oil spill generated during construction activities should be managed scientifically to avert any damage to flora & fauna and overall ecology of the area, etc.

J. Traffic Management;

(i). The Proponent shall bound the Contractor to work out a proper Traffic Management Plan, during construction phase, while working near settlements, towns, schools and hospitals. An early warning or announcement system shall be in-placed well before the time to avoid traffic jams and inconvenience for commuters and residents nearby;

(ii). The timings for transportation of construction material, aggregate & spoil, movement of heavy machinery and equipment should be fixed and predetermined to avoid traffic jams, inconvenience for commuters and local community.

K. Installation of Crusher Plant;

(i). If necessary for the requirement of construction activities of the project, the crusher plant must installed 200 m away from the population with the consultation of EPA. The proponent shall follow the term and conditions for installation of Crusher Plant as an independent case as mentioned in environment protection Act 2000.

L. Community Investment Plan (CIP);

(i). For the socio-economic uplift of Project Area Community, the Proponent should consider and undertake some development interventions particularly for the up-gradation or improvement of existing health & education facilities, development of recreational sites, provision of safe drinking facilities and etc. In this respect, a CIP Plan shall be worked out and shared with EPA.

M. Provision of Conditional Environmental Approval to Contractor;

(i). The Proponent shall provide a copy of this Conditional Environmental Approval and EIA Report to the contractor for efficient & effective implementation of obligatory mitigation measures. A regular Training Program preferably be devised for workers, labor, and implementing& management staff of the Contractor to ensure effective compliance from them during construction activities.

N. Independent Environmental Monitoring Consultant (IEMC);

(i). Reporting implementation progress of EMP and Environmental Approval is considered as a crucial aspect of the project implementation. In order to ensure transparency and accuracy in reported data or facts, this is strongly advised that the Proponent should appoint an independent Environmental Monitoring

Continuation Sheet

Azad Jammu & Kashmir
Environmental Protection Agency

Consultant or Firm (IEMC), in consultation with EPA AJK. The role of IEMC shall be to monitor and report the impact of the project during construction on the socio-economic, ecological and physical environment;

(ii). The scope of the IEMC will include monitoring of the impact on quality and quantity of water resources (in particularly springs), impact of ground vibration, ambient air quality, ambient noise levels, road and traffic conditions and community safety, and socio-economic conditions including local employment. The IEMC shall prepare quarterly monitoring reports based on regular visits to the site and submit to EPA AJK on regular basis.

O. Environmental Audit;

(i). The Proponent shall be responsible to conduct the Environmental audit through 3rd party (certified Environmental experts company) at the end of construction phase.

P. General Conditions;

(i). The Proponent shall bound Contractor to select sites for installation of the asphalt/concrete mixing plant in consultation with EPA AJK. In this respect, special consideration shall be given to critical installations like school, hospitals, mosques, community hall, etc.;

(ii). The Proponent shall bound the Contractor to ensure efficient Occupational Health &Safety (OHS) measures in-placed for workers and labor throughout the construction period;

(iii). In the case, the articles of Archeological importance like artifacts, coins rock-arts and other archeological relics are discovered, the work at the site should immediately be stopped and the concerned department or agency should be consulted for the appropriate action;

(iv). The Proponent shall ensure all public utilities, such as water supply pipes, power/phone lines, Roads be not disturbed during any construction activity of the project. If removal of such installations is inevitable then alternative may be provided to the people of the area beforehand, in consultation with respective agencies under intimation to AJK EPA;

(v). The Proponent/contractor shall make sure the safety & security of wild animals and their habitats at the project site and in its environs with the prior consultation and strictly adhering to the guidelines of Wildlife Departments;

(vi). The proponent shall rehabilitate all sites to their natural conditions affected by temporary use during the construction phase.

6. The proponent shall be liable for the correctness and validity of the information furnished by the environmental consultant;

7. The Proponent shall be liable for compliance of regulations 13, 14, 17 &18 of IEE/EIA Regulations 2009, which enunciate the conditions for approval, confirmation of compliance, entry, inspection and monitoring of the proposed project;

8. The Proponent shall facilitate EPA team during inspections and monitoring of the Project etc;

Continuation Sheet

Azad Jammu & Kashmir
Environmental Protection Agency

9. The Proponent shall submit "Quarterly Monitoring Report (QMR)" in compliance to the Conditions of Environmental Approval imposed for the Construction of proposed Project;

10. Any change hereinafter in the approved project, shall be communicated to AJK-EPA and shall commence after obtaining the approval in respect thereof;

11. This approval does not absolve the proponent of the duty to obtain any other approval or clearance that may be required under any law in force or by any competent forum/court of law, etc.;

12. This Approval shall be valid for a period of three (03) years from the date of issuance under Regulation 16 of IEE/EIA Regulation, 2009;

13. The EPA AJK, in continuation or supersession of any of the Conditions mentioned herein before for the construction of **22MW Jagran-IV HPP**, may impose additional conditions as and when the situation may warrant so;

14. The proponent shall be bound by Regulation 13 (2) read-with Schedule VII of the Regulations to furnish an UNDERTAKING to the Agency in terms that the proponent solemnly affirms and declare that the proponent fully understands and accept conditions contained in the approval accorded by the AJK-EPA and undertake to design, construct and operate the project strictly in accordance with the said conditions and the EIA;

15. This approval shall stand null and void in case any of the conditions, mentioned hereinbefore, are not fully complied with;

16. This Approval may be considered for review or withdrawal at any stage, as per stipulated procedure, if deemed appropriate in the larger public interest.

EIA Tracking No. 136
Date: 02-08-2012

Muzaffarabad

(Adnan Khurshid)
Director General- EPA

Managing Director,
Power Development Organization,
Azad Govt. of the State of Jammu & Kashmir,
Muzaffarabad.

CC.-

1. ACS (Dev)/Secretary Environment,
2. Secretary PDO,
3. Secretary Forest, Wildlife & Fisheries,
4. Commissioner, Muzaffarabad Division, Muzaffarabad.
5. Director General, Private Power Cell/PDO, Muzaffarabad.
6. Deputy Commissioner, Neelum Valley.
7. Master File.

Azad Govt. of the State of Jammu & Kashmir.

AKLASC Building Complex, Bank Square, Chatter Domail, Muzaffarad AJ&K

SECTION - 11: COST ESTIMATES

11.1 General

This section provides review of the cost estimates presented in the Feasibility Study, 2010 and Third Party Validation Study, 2021 for the Jagran-IV Hydropower Project. The details are provided below:

11.2 Review of Feasibility Study, 2010

The cost estimates in the Feasibility Study, 2010 were based on unit and lump-sum prices applied to measured quantities of major work items for various components. The following method has been implied:

- Summary of overall project cost
- Detailed component-wise cost breakdown
- The estimates consider local component in Pak Rupees (PKR) and foreign component in US Dollars (USD) and total cost equivalent in Pak Rupees (PKR) based on the August 2010 exchange rate (1 USD = PKR 85.60).
- The quantities of major civil structures of the project based on the feasibility design and corresponding design drawings. The drawings are presented in Volume-II of this report.
- Materials and quantities required have been computed using the engineering design drawings consisting of plans and sections of all the components of the project drawn on exact topographic survey maps.
- The cost estimates include the following main plant components and cost elements:
  - Land acquisition and environmental mitigation cost;
  - Preliminary works including mobilisation cost and site infrastructure;
  - Civil works include weir and flushing outlet, power intake, sand trap, headrace pressure pipe, surge pipe, penstock and surface powerhouse and tailrace system.
  - Manufacturing of hydro-mechanical and electrical equipment;
  - Transportation cost;
  - Erection and commissioning cost;
  - Import duties;
  - Project administration;
  - Engineering and supervision costs;
  - Contingencies.
- The some of the unit rates for civil works have been estimated by updating the basic costs of labour, material and equipment and compared with that of similar size hydropower projects. The remaining unit and lump sum prices for civil works have been prepared after consulting and escalating the unit prices of a number of similar hydropower projects including Jinnah, Keyal, Lower Spat Gah, Madyan, Golen Gol and Neelum-Jhelum Hydropower Projects.

- The cost of hydro-mechanical and electrical equipment was based on in-house database of the Consultants.
- The following project costs have been estimated:
  - The cost of Environmental Impact Mitigation has been taken as US$ 344,626 which covers the temporary relocation cost and compensation paid to the private land owner for the loss trees, water supply provisions costs, cost of disposal of excavated material, and afforestation cost, etc.
  - The cost of Civil Works has been taken as US$ 16.194 Million which include road and preliminary works, diversion weir, headrace pressure pipe, surge pipe, penstock and surface powerhouse.
  - The cost of hydro-mechanical equipment has been taken US$ 4.48 million.
  - The cost of electrical equipment has been taken as US$ 4.475 million.
  - The cost of transmission from Jagran-IV to Jagran-I switch yard has been taken as US$ 0.5 million.
  - The cost of transportation including freight, shipment and insurance, etc of electro-mechanical equipment is taken as 4% of E&M equipment which has been estimated as US$ 0.378 million
  - The cost of erection, commission and testing of E&M equipment is taken as 10% of E&M equipment, which has been estimated as US$ 0.946 million.
  - The cost for engineering and supervision has been taken as 5% on civil and E&M works and estimated as US$ 1.265 million.
  - The cost of administration expenses during project execution has been taken as 5% on civil and E&M works and estimated as US$ 1.265 million.
  - The total duties at a rate of 5% of the imported equipment and material have been added to the estimates, which is US$ 0.381 million.
  - The contingencies cost has been made as 3% of total base cost, which is estimated as US $ 0.897 million.
  - The interest during construction has been estimated at a rate of 15.79% per annum for four (4) years of the construction period for local cost component and 4.64% as interest rate and 11% as exchange rate variation on foreign cost component. Based on above, the total estimated interest during construction cost is US$ 11.228 million.
  - The total project cost has been estimated as **PKR. 3,595.943 million,** which requires foreign exchange of 42.009 million in US$.

11.3 Review of Third party Validation Study, 2021

- The third Party Validation study has made several corrections in the BoQ.
- Pressure pipe thickness was taken as 8 mm for its entire length of about 3.0 Km. The pipe thickness has been reviewed and is taken as 10 mm to 26 mm. The unit rate for pressure pipe 2.4 m diameter is updated. Considering the market prices for size and type of equipment's, the cost of hydro mechanical and electrical equipment's has been updated.

- The **Table 11.1** is reproduced from the TPV, 2021 which gives the revised cost of USD 49 million:

Table 11-1: Component Wise Cost Updated July 2021 (TPV, 2021)

Sr. No.	Description	TPV Recommended	As per FS
		$US	$US
I	**Land Acquisition, Roads and Environment**	**0.378**	**0.347**
II	**Civil Works**		
1	Road and Preliminary Works	2.075	2.34
2	Weir	0.586	0.88
3	Power intake to De-sander	0.664	1.25
4	Headrace Pressure Pipe		6.44
5	Embedded Penstock Pipe	14.87	1.35
6	Surge Pipe		1.12
7	Powerhouse	0.918	2.16
8	Tailrace	0.376	0.43
	Sub Total II	**19.866**	**16.31**
III	**E&M Equipment**		
1	Hydro-Mechanical Equipment	3.640	4.51
2	Electrical Equipment	5.254	5.09
3	132 kV Transmission Line and Interconnection	0.750	0.50
	Sub Total II	**9.644**	**10.10**
	Sub Total II + III	**29.510**	**26.40**
IV	Transportation (4%)	0.386	0.40
V	Erection & Commissioning (10%)	0.964	1.01
VI	Engineering & Supervision (5%)	1.457	1.30
VII	Project Director and Staff Expenses (5%)	1.457	1.30
VIII	Import Charges (5% of E&M)	0.374	0.41
	Base Cost	34.147	30.83
	Contingencies (3%)	1.024	0.92
	Total Base Cost	**35.172**	**31.76**
	Interest During Construction	14.001	11.49
	Total Project Cost	**49.173**	**43.249**

The total costs are compared from the FS with price index of May 2010 (1 USD= 85 Rs.) and the present study with price Index July 2021 (1 USD= 158 Rs.)

11.4 MC Observation

- While the methodology followed acceptable engineering practices for that time, the base price level of August 2010 & July 2021 is now outdated.
- Since 2010 and 2021, the labour, fuel, cement, and steel prices have increased significantly, while the PKR/USD exchange rate has risen from ≈ PKR 158/USD in July 2021 to ≈ PKR 280/USD in November, 2025, therefore, all civil and electro-mechanical cost components must be re-escalated to 2025 price levels using the latest Pakistan Bureau of Statistics construction index, international E&M price trends, and NEPRA guidelines.
- The estimated quantities of all major civil structures need to be revalidated during the preparation of tender level design, while considering refined hydraulic and structural design parameters.
- Contingencies for both physical uncertainty and price variation were included, which aligns with standard practice.
- The provision for IDC needs to be revised as per the current situation.
- The environmental mitigation cost (USD 0.345 million) needs re-evaluation against present-day environmental and social safeguard requirements under ADB/IFC/NEPRA ESMS frameworks to include the following aspects:
  - Comprehensive Environmental and Social Management Plan (ESMP);
  - Resettlement Action Plan (RAP) and livelihood restoration;
  - Environmental monitoring and compliance audits; and
  - Long-term catchment management.

SECTION - 12: CONSTRUCTION PLANNING

The Chapter-12 of Feasibility study, 2010 and the "Tentative Implementation schedule" contained in Chapter-12 has been reviewed and the following observations are offered:

1. In the Feasibility Report, total 60-months have been allocated for the construction of the 22 MW Jagran HPP with the breakup as detailed below:

   - 12-months have been allocated for preliminary works such as approval of PC-1 and land acquisition. It is also stated that no construction activities shall be started before the approval of PC-1. Although not particularly mentioned in Feasibility report, however, the MC understand that above period also included the activities pertaining to review & up gradation of feasibility study reports and designs, preparation of tender documents, conducting the tendering process till the award of contract to the EPC contractor.
   - 2-months have been allocated for the contractor's mobilization and site installations, and
   - 46 months have been allocated for the construction supervision, testing and commissioning.

   However, as per the ToRs of the current consultancy contract agreement, the above timeline is reduced to 46-months with the following details:

   - **Phase 1 – Procurement:** 6-months have been allocated for the review and up gradation of feasibility study reports and designs, preparation of Bidding document, conducting the tendering process and award of contract to the EPC contractor. The MC shall also assist PDO, AJK in land acquisition, RAP, Environmental and Social mitigation measures and studies, finalization of all agreements and review of PC-1, if required.
   - **Phase 2 & 3 (Pre-construction Activities and EPC Construction)**: 40-months have been allocated for demarcation of project sites, contractor mobilization, site installations, design review, construction supervision, testing and commissioning.

   Comparing the above two schedules, it is noted that as per the current schedule the timeline for Phase-1 activities has been reduced from 12-months to 6-months. The reduced timeline of 6-month for Phase-1 activities seems to be unrealistic because it does not taking into account the sequence of different activities to be performed and time required for approvals.

   Nevertheless, it is proposed to complete the approval of revised PC-1 (if required) and land acquisition process before the award of the EPC contract, so that uncertainties and risks associated with the delays in the handing over of sites to the EPC contractor may be avoided. The following procedure may be proposed to complete the above activities.

   - Identify the potential land requirements based on the project layout as per approved tender design and urgently complete the land acquisition process.
   - Review the Project PC-1 based on the lowest quoted price of the substantially responsive and qualified bidder and approves the revised PC-1, if required.
   - Based on above review and proposed procedure, the allocated timeline of 6-months for Phase-1 may prolong by 3 to 4 months.

2. The Tentative Implementation schedule given in the Feasibility study, 2010 is based on major activities only which should be based on more detailed activities with realistic time frame. This implementation schedule should be prepared by the EPC Contractor based on

M/S Project or Prima Vera or some other well known planning tool. Planning should be based on CPM method.

3. As per the TORs of Consultant, Turnkey/EPC Contractor is to be procured for the Project henceforth; only tender level design and drawings will be prepared and incorporated in the Tender Documents.
4. Detail Design will be submitted by the selected Turnkey /EPC Contractor.
5. Defect Liability period has also not been discussed in the schedule.

SECTION - 13: ECONOMIC AND FINANCIAL ANALYSIS

13.1 Economic Analysis

Economic benefits have been considered on the basis of avoiding costs for establishing alternate thermal plant, considering generation from steam plant using furnace oil. This is the only scenario considered in the Feasibility study, 20210 for establishing economic viability of the project, ignoring the fact that a large part of thermal generation is from HSD or single/combined cycle gas plants. There is need is to re-do the analysis considering benefits on the basis of avoiding costs of HSD or Gas turbine as thermal plants as well.

The following observations need also to be taken into account:

1. While estimating the economic benefits, location of alternative plant (steam operative) has not been mentioned and it is said in the report that the plant will run in integrated mode with the National Grid. In another paragraph, it is mentioned that the proposed Lawi Project will supply power to the population of Chitral (there is no mention of integrating with the national grid). If this be the case, then the analysis is not realistic and needs to be redone, working out benefits as of a standalone alternative.
2. Long Run Marginal Cost (LRMC) of WAPDA for generating power need also to be worked out for economic analysis.
3. Optimization and NPV analysis need also to be made part of the economic analysis.

13.2 Financial Analysis

Financial analysis presented in the Feasibility study, 2010 is scanty. There is no scenario discussed for the funding arrangements except assuming that the funds are readily available.

The financial analysis also needs revision considering the following aspects:

1. Scenarios based on interest rate of 17.74% needs to be developed for testing financial viability of the project comparing the returns with prevailing interest rate being offered by the commercial banks in Pakistan.
2. Two-part loan scenario (local and foreign components) needs to be developed for a viable option.
3. Statements showing profit and loss accounts, balance sheet, amortization schedule etc. needs to be included in the financial analysis.

13.3 Tariff

No tariff is computed based on project costs, except escalating the existing tariff of WAPDA, it needs to be determined. It is pointed out that under the Power Policy 2002, two part tariff should be calculated which is missing in the report.

13.4 Other Parameters

The following aspects may also be included as part of the financial analysis:

a. Power Market analysis
b. Impact of delay in implementation
c. Employment analysis
d. Amortization Schedule

e. Payback Period
f. Breakeven Point

In general, the approach and methodology is acceptable and appreciable, except it needs revision and updating.

SECTION - 14: CONCLUSION AND RECOMMENDATIONS

14.1 Conclusions

1. The FS consultants have established plan and height control at the weir and powerhouse through terrestrial traverses and precise spirit leveling, referenced to UTM-43N on WGS-84. The ASTER stereo DEM (~10 m pixels, practical vertical accuracy on the order of 5–10 m) complemented by SPOT-5 imagery (2.5 m panchromatic, 10 m multispectral) have been used to cover the pressure pipeline area. The end product was a corridor-wide surface with 2 m contours, locally merged to the terrestrial survey at structure pads.

   The TPV consultants have carried out a dedicated topographic campaign spanning Shaal Nullah to the Jagran-I weir. Using digital total stations with EDM and auto-levels, the team has established permanent benchmarks and survey marks, executed closed traverses and differential levelling. The working reference frame remained UTM-43N on WGS-84. The deliverables included 1:1000 mapping with 1 m contours, longitudinal and cross-sections for river hydraulics alongside structure-scale mapping.

2. The FS consultants have calculated the catchment area of Jagran River at the proposed weir site as 214 Km^2. The TPV consultants have undertaken GIS study and proposed revised catchment area of 205 Km^2. The MC has also collected SRTM data of 30m x 30 m DEM and carried out watershed analysis with GIS technique and calculated the catchment area of weir and powerhouse sites respectively as 205 Km^2 and 216 Km^2 .

3. The Jagran River flow measured data is available for short time at the Thunian (1994-96) and Kundal Shahi (1982-84 & 1994-96) stations installed on Jagran River; however both the gauging stations are currently inoperative. Except to the above, no further climatic, river flow and sediment measurement data is available for the Jagran River. Therefore, the estimation of long term flows, design floods and sediment transport is to be made by using the long term measured data available from the surrounding stations e.g. Dudhnial, Nausehri and Muzaffarabad on Neelum River and Naran station on Kunhar River, etc.

4. The FS consultants have carried out correlation between 10 daily specific flows of Jagran River at Thunian station and Kunhar River at Naran station and estimated long term flows from 1960-00. The estimated mean annual flows at weir site vary from 9.8 m^3/s to 21.0 m^3/s with average value of 15.81 m^3/s. The TPV consultants have carried out correlation between daily specific flows of Jagran River at Thunian station and Neelum River at Nausehri station and estimated long term flows from 1991-15. The estimated mean annual flows at weir site vary from 4.9 m^3/s to 17.7 m^3/s with average value of 12.30 m^3/s.

5. The FS consultants have established design floods by statistical analysis. The annual maximum floods measured at Muzaffarabad station are transformed at the proposed weir site by catchment area ratio method. The various return period floods are then estimated by used the transformed floods by applying the Log Pearson Type-III method. Based on above analysis, weir design flood of 418 m^3/s is adopted. It is noted that FS consultants have not considered the flood 2010 in their flood studies. The TPV consultants have noted carried out any flood updation studies.

   In light of above, the MC has reviewed the flood studies of existing Jagran-I and under construction Jagran-II hydropower project which revealed that the Jagran-I hydropower project has adopted weir design flood of 1000 m^3/s and Jagran-II hydropower project has adopted design floods of 1078 m^3/s and 1253 m^3/s respectively for the design of weir and flood protection wall at the powerhouse site.

6. The FS consultants has used suspended sediment data at the Nausehri station (1991-2005) and calculated total annual sediment load of 01651 MST at the Jagran-IV weir site. The TPV consultants have not carried out any updated sediment studies. Since, the FS studies does not consider the flood 2010, therefore the MC has reviewed the detailed design sedimentation studies of Jagran-II hydropower project performed by the EPC contractor. In the later study, the updated suspended sediment data of Nausehri station (1991-2014) has been collected and calculated total annual sediment load of 0.6614 MST at the weir site of Jagran-II weir site. Adopting the Jagran-II sedimentation studies, the MC has calculated total annual sediment load of 0.4374 MST at the Jagran-IV weir site.

7. Based on information and data from boreholes, test pits, and geological mapping provided in the previous studies, it is confirmed that rock is not exposed at any of the proposed project sites. The weir would most likely be founded on overburden, as the thickness in this area appears to exceed 40 meters. The connecting channel and sedimentation basin locations are covered by the overburden material of composed of angular boulders, gravel, sand, and a significant amount of fines (ABGM) overlying the granitic gneiss. The buried pressure pipe will primarily rest on overburden and partially on granite gneiss rock. The surface area at the proposed powerhouse is covered by the overburden material composed of rounded boulders and gravel with a significant amount of fines (RBGM), probably overlying the granitic gneiss. Although the thickness of this overburden has not yet been determined through drilling, the powerhouse could likely be built on the granitic gneiss if the overburden is thin enough.

8. The available geological and geotechnical data from the FS and TPV studies do not seem to be sufficient to develop the tender level design and drawings of the Project. Several key inputs needed for the design of the foundations and other structural elements require additional and targeted investigations.

9. The Client and the MC experts performed a site reconnaissance visit from 15 to 19, October, 2025 to the Jagran-IV hydropower project area. During the site visit, it revealed that there exists an active right-abutment landslide at the TPV consultants proposed weir site. Similarly, the MC also witnessed that the proposed powerhouse site by FS consultants may face slope stability problems due to the necessary slope cutting for the powerhouse and penstock. The TPV consultants proposed powerhouse site was also found situated right at the mouth of a watershed valley. Therefore, considering the overall landslide activity in the valley and the specific characteristics of this watershed, mudflows or debris flows are highly likely.

10. The FS consultants proposed diversion arrangement comprises a 6 m-high RCC overflow weir (crest EL 2264 m) founded on alluvium, with energy dissipation by a roller bucket and downstream stone pitching. The overflow portion (24 m crest) conveys ~190 m^3/s, while a gated flushing/ under sluice section on the left bank conveys the balance of the 500-year design flood (total 419 m^3/s). The layout places the intake and flushing facilities on the left bank; construction sequencing diverts flow to the right bank via a dyke to construct the left-bank works in low-flow season. An 8 m deep cutoff wall is foreseen along the axis to control seepage/piping in the alluvium. Stop logs to be operated by gantry crane and under-sluices radial gates hydraulically operated for flushing out the weir have been proposed.

    The TPV consultants shifts the weir axis ~120 m downstream of the feasibility location to a hydraulically tighter cross-section which lifts scheme head and improves approach hydraulics to the intake.

11. The FS consultants proposed power intake is sized to pass Q = 18 m³/s into the connecting/approach channel with controlled head loss and minimized sediment entrance. The concept sets the gross intake area = 19.6 m², limits entrance velocity to ≈0.92 m/s at design flow and places the lower sill 3.40 m above the flushing bed to suppress bed-load entry. The intake is oriented at an angle to the main river to deflect sediment-rich core flow away from the opening and includes trash rack panels (round bars Ø10 mm at 10 mm spacing) with stop-log grooves and a maintenance platform at EL 2267.5 m for manual cleaning. The stoplogs and Inlet gates have also been proposed.

    The TPV has proposed revised design discharge 16 m³/s. The lateral intake remains on the left bank, co-optimized with the re-aligned approach channel so that near-rack velocities are uniform and vortex-free.

12. The FS consultants defines the conveyance immediately downstream of the intake—an approach/connecting reach that conditions flow toward the desilting arrangement while maintaining stable, uniform hydraulics and controllable head loss. Lining (RCC/masonry as specified in the report) is selected to resist abrasion and minimize seepage.

13. The FS consultants provides a two-chamber, rectangular sand trap sized for Q = 18 m³/s with target removal size d ≥ 0.25 mm. Each chamber is 56 m long and 7.0 m wide, with depth increasing from ~6.43 m to 8.11 m (mean flow area ≈ 50.88 m², mean v ≈ 0.177 m/s at 9 m³/s per chamber). Flushing is provided via trapezoidal channels (area ≈ 12 m², slope 3%) with a Ø1.5 m flushing pipe returning to the river. Hydraulic steelworks comprise two inlet gates 4.3 m × 3.2 m, two outlet gates 7.2 m × 3.8 m, and two 1.2 m × 1.2 m sand-flush gates, all oil-pressure operated with stainless steel sealing surfaces and remote indication.

    The TPV consultants have proposed target removal of sediment of 0.25 mm dia.

14. The FS consultants conceived a buried GRP low-pressure conduit that starts in a small trapezoidal drop tank immediately downstream of the sand trap and then conveys flow to the surge area. The alignment follows the left bank, laid in a trench with mild longitudinal grade; anchor blocks are provided at every change in direction. The scheme fixes ID ≈ 2.5 m, wall thickness ≈ 8 mm, design discharge = 18 m³/s, and a computed mean velocity ≈ 3.67 m/s over a total length ≈ 3,075 m.

    The TPV consultants favored an embedded steel pressure pipe (low-pressure reach) with design discharge of 16 m^3/s and 2.4 m dia over a tunnel for the site length and terrain, aligned along the left bank in a trench with proper bedding and haunch support. Diameters are selected to maintain an economic velocity band (commonly ~2.0–2.5 m/s) and a controlled steady head loss budget. Anchor/thrust blocks are provided where the soil mass cannot take hydraulic thrust.

15. The FS consultants has adopts a steel penstock from the surge pipe outlet down to the turbine inlet, laid mostly on terraces and supported on concrete saddles with anchor blocks at bends. The internal diameter is 2.50 m for Q = 18 m³/s, giving V ≈ 3.68 m/s over a ~180 m run; feasibility calculations assume a head loss ≈ 10.2 m for the design discharge. The scheme Provides a vertical surge pipe branching from the buried GRP headrace to moderate transients and stabilize water levels in the low-pressure conduit with a surge pipe internal diameter of 5.0 m and height ≈ 52 m.

    The TPV favors steel for the penstock in this medium-head, rugged setting, with options for header/branch layouts and synchronous bypass strategies to eliminate the requirement of surge pipe and to protect the cascade during trips.

16. The FS consultants have proposed that powerhouse would be R.C.C. Frame structure of size 35.4 m length and 10 m wide and 16.5 m high. As per Drawing No. JAG-PWR-003, the powerhouse structure consists of Steel Structure above Machine Hall Floor at EL. 2111.00 to Steel Frame Top at EL. 2118.00 and From Foundation at EL. 2101.5 to Machine Hall Floor EL. 2111.00 is RCC framed structure.

17. The FS consultants have proposed vertical Francis turbines with 3 units each of 6 MW and one unit of 4 MW. The TPV consultants have proposed horizontal layout of turbines with 3 units each of 6.67 MW and one unit of 2 MW.

18. The FS consultants have proposed four vertical shaft synchronous generators of having 7.06 MVA (for Three Main Units) capacity and 4.7 MVA (for One Auxiliary Unit) capacity and having generation voltage of 11kV. Two Unit Step-up transformers each of having capacity 10/13MVA with voltage ratio of 11/132kV and One circuit of transmission line having connected with existing Grid station (Kundal Shahi) via Jagran-I substation are also proposed.

19. The FS has adopted gross head of 169 m, design flow of 18 m^3/s, environmental flows of 0.3 m^3/s, head losses in range of 1.97 to 11.82 m, turbine / generator / transformers / combined efficiencies of 91%, 96% and 99% & 86.4% and calculated power potential of 22 MW with mean annual energy of 98.2 GWh and plant factor of 51.3.

    The TPV consultants conducted fresh topography, updated the river flow studies and proposed improved efficiencies. Based on above, considering the gross head of 169 m, net head of 158.4 m, design flow of 16 m3/s, 5% downtime, and turbine / generator / transformers / combined efficiencies of 92.5, 97% and 99% and 88.8%, they calculated the power potential of 22 MW with mean annual energy of 91.8 GWh and plant factor of 50.0.

    The MC has also carried out the preliminary level energy calculation considering the TPV adopted parameters and considering the one month downtime period and calculated the power potential of 22 MW with annual energy as 91.04 GWh and plant factor of 47.23%.

20. The FS consultants have appended IEE report in the Feasibility Study report, 2010. Subsequently, the IEE report was later comprehensively updated and integrated into the Environmental Impact Assessment (EIA) finalized in 2021. The AJK-EPA has issued a Conditional Environmental Approval (No Objection Certificate – NOC) on 2 August 2022, under Section 11 of the AJK Environmental Protection Act, 2000.

    The MC has observed that the validity of the conditional approval of the EIA has already been expired. Besides, the MC has also observed several gaps in documenting the social aspects of the project regarding the land requirements, project affected persons (PAPs), Households (PAHs), resettlement planning and compensation, quantification of livelihood losses, stakeholder engagement and consultations.

21. The FS consultants have conducted detailed costing studies. The quantities are estimated from the structures drawings. The unit rates are adopted by updating the unit rate analysis of labor, material and equipment as well as from similar projects. The adopted prices corresponds to August 2010 with prevailing exchange rate of 1 USD = PKR 85.60. The total project cost has been estimated as **PKR. 3,595.943 million,** which requires foreign exchange of 42.009 million in US$

22. The TPV has made correction to the some quantities. In FS, the pressure pipe thickness was taken as 8 mm for its entire length of about 3.0 Km. The TPV consultants has revised the pipe thickness which was taken as in the range of 10 mm to 26 mm. The unit rate for

pressure pipe of 2.4 m diameter was updated. Considering the market prices for size and type of equipment's, the cost of hydro mechanical and electrical equipment's was also updated. The price Index July 2021 with exchange rate of 1 USD= PKR 158 was adopted. Based on above, the TPV consultants has proposed the revised total project cost as 49.173 million in US$.

23. The FS consultants anticipated the total construction period of 60 months which include 12 months for the pre-construction / preliminary works and 48 months for the construction. However, as per the MC consultancy services agreement, the project duration has been reduced to 46 months which include 6 month for preconstruction activities and 40 months for EPC construction.

24. The FS consultants have conducted economic & financial analysis and calculated the FIRR as 14.26% and B/C Ratio as 1.89:1 and established the economic viability of the project. The consultants also found that project FIRR is above the interest with an attractive NPV.

14.2 Recommendations

14.2.1 Recommendation for Tender Level Design Studies

1. The topographic survey work carried out by FS consultants is no more reliable due to frequent landslides observed on either side of the banks, which has resulted changes in the river widening of the river. The flood of 2010 has also major impacts on topography. On the other, the survey map prepared of the TPV consultants with 1 m contour covers all the proposed structures of the project. Therefore TPV consultant's topographic survey is recommended for the planning of project layouts and preparation of the tender level design and drawings.

2. The long term estimated river flows by FS consultants is found based on outdated river flow data upto 2010, it has also used 10-daily data which introduces errors in the calculation. On the other hand, the TPV consultants has used the latest daily flow data and achieved relatively high R2 = 84.21 as compared to the Feasibility value of R = 832, therefore, TPV consultants estimated long term daily flows at the weir site are recommended for selecting the design discharge of plant, performing the power and energy calculations and preparation of tender level design and drawings.

3. The flood studies carried out by FS consultants are found outdated as no flood data of 2010 has been considered. Keeping in view the devastating damages to existing Jagran-I project during the flood 2010 event and to ensure the safe operation of the proposed structures of the project, the enhanced revised design flood of 954 m^3/s for the design of weir and 979 m^3/s for the design of powerhouse flood protection wall are recommended.

4. The relocating of the weir upstream from the TPV, 2021 position to bypass an active right-abutment landslide is recommended. The site chosen by the MC has relatively stable abutments.

5. The relocation of the proposed powerhouse site is recommended to avoid the anticipated slope stability problems due to the necessary slope cutting for the powerhouse and penstock associated with FS consultants proposed location and move down from the mouth of a watershed valley to avoid the most likely potential hazard of mudflows or debris flows associated with the TPV proposed location.

6. The available geological and geotechnical data from previous reports do not seem to be sufficient to develop the tender level design for the Project. Several key inputs needed for the design of the foundations and other structural elements require additional and targeted investigations. Therefore, the MC has already recommended and sent a request to the Client vide letter No. DHS / 31 / 168 Dated 20-10-2025 for additional investigation including ERT (Electrical Resistivity Tomography), SRT (Seismic Refraction Tomography) and Construction Material Testing to be performed on priority before weather conditions become unfavorable for further investigations. It is recommended that the Client performed the above emergency nature site investigations at the earliest.

14.2.2 Recommendation for Detailed Engineering Design Studies by EPC Contractor

1. It is recommended that the EPC contractor shall conduct the fresh topographic, bathymetric and LiDAR survey (along the route of the penstock pipe) by using the most updated available techniques at the detailed engineering design stage. This item will be included in the employer requirements of the EPC contractor.
2. It is recommended that the EPC contractor shall collect and purchase the latest available hydro meteorological data of climate, river flows and sediment of all relevant neighboring stations and update the hydrological data base and studies at the detailed engineering design stage. This item will be included in the employer requirements of the EPC contractor.
3. It is recommended that the EPC contractor shall establish an automatic weather and river flow measuring station with control room at the Jagran-IV power station at the preconstruction stage of the project. The proposed stations shall be equipment with all required sensors including the rainfall, temperature, humidity, etc as per requirement of the World Meteorological Organization (WMO) and Pakistan Meteorological Department (PMD). This item will be included in the employer requirements of the EPC contractor. The detailed specification shall be provided in the Bidding documents.
4. It is recommended that EPC contractor shall conduct detailed geological and geohazard mapping and drilling of bore holes. The details are provided elsewhere in this report. This item will be included in the employer requirements of the EPC contractor.

POWER DEVELOPMENT ORGANIZATION

Government of Azad Jammu & Kashmir

CONSULTANCY SERVICES FOR
THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF
22 MW JAGRAN-4 HYDROPOWER PROJECT

THIRD PARTY VALIDATION REPORT

(Draft)

July 12, 2021

Consultants

Documents / Report Control Form

Project Name	Consultancy Services for Third Party Validation of Feasibility Study and Design of 22 MW Jagran-4 Hydropower Project
Report Name	Draft Validation Report – Revision 0
Project Number	PDO/AJK 01
Report for	Power Development Organization AJK

PREPARATION, REVIEW AND AUTHORIZATION

Revision	Date	Prepared by	Reviewed by	Approved for Issue by
0-00	12.07.2021	Ghulam Mehdi, Muhamad Javed Raza, Kashif Anwer Alam, Syed Muzamil Ali & Ali Mehdi	Sher Khan, Sohail Anwer	Ghulam Mehdi

ISSUE REGISTER

Distribution List	Date issued	Number of Copies
Power Development Organization AJK	12.07.2021	2 Hard Copies Electronic

Submitted by:

M/s INTEGRATION environment & energy GmbH, Pakistan Engineering Services (Pvt.) Ltd. and Integration Energy (Pvt.) Ltd.

INTEGRATION Umwelt & Energie GmbH
Bahnhofstrasse 9 D 91322 Graefenberg
Email:ufrings@integration.org
Tel:+49 9192 9959-0
URL: http://www.integration.org

Pakistan Engineering Services (Pvt.) Ltd.
Building No. 7, Sector-B Street No. 12, Phase-V,
Commercial Area DHA Lahore
Tel: +92 (42) 37182502

Integration Energy (Pvt.) Ltd.
House # 13B, Street-34, Sector F-7/1, Islamabad
Email: skhan@integration.org
Tel: +92 (51) 831791

Disclaimer

This document is issued for the party which commissioned it and for specific purposes connected with the above-captioned Project only. It should not be relied upon by any other party or used for any other purpose.

We accept no responsibility for the consequences of this document being relied upon by any other party, or being used for any other purpose, or containing any error or omission which is due to an error or omission in data supplied to us by other parties.

Table of Contents

1 Introduction 1
1.1 Context of Review and Validation 1
1.2 Scope of Work 1
1.3 Objectives 1
1.4 Document Reviewed 1
2 Description of the Project 2
2.1 Location 2
2.2 Salient Features of the Project 5
2.3 Existing Hydro Structures 5
3 Hydrology 6
3.1 Catchment Area 6
3.2 River Flows 6
3.2.1 Updated Flow Analysis 8
3.3 Flow Duration Curve 12
3.4 Floods 13
3.5 Potential Climate Change Impacts 14
3.6 Conclusion 14
4 Sediment Transport 15
4.1 Conclusion 15
5 Geology 16
5.1 Regional Geology 16
5.2 Geo-Tectonic Setting and Sub-Division 16
5.3 Lithostratigraphy of Neelum Valley 17
5.4 Geology of the Project Area 17
5.5 Engineering Geology and Geotechnical 18
5.6 Construction Material 18
5.6.1 Coarse Aggregate 18
5.6.2 Fine Aggregate 18
5.6.3 Fill Material 19
5.6.4 Cement and Steel 19
5.7 Tectonic and Seismic Conditions of Project Area 19
5.8 Observations and Recommendation 19
5.8.1 Weir Site 19
5.8.2 Powerhouse Site 20
6 Power and Energy 20
6.1 Discharge for Power Generation 21
6.2 Operation Levels and Gross Head 21
6.3 Head Losses 21
6.4 Plant Performance Parameters 22
7 Main Design Criteria 22
7.1 Seismic Design 22
7.2 Flood Management 23
7.3 Standards 23
8 Feasibility Design Review 23
8.1 Project Layout 23
8.2 Weir and Intake 25
8.3 Approach Channel 26
8.4 Sand Trap 26
8.5 Penstock Pipe 26
8.6 Powerhouse 27
9 Selection of Type of Turbine & Auxiliary Equipment 27

9.1 Turbine 27
9.2 Inlet Valve 28
9.3 Cooling Water 28
9.4 Synchronous Bypass Valve 28
9.5 Synchronous Generator 29
9.6 MV Switch Gear 29
9.7 132 kV Interconnection and Grid Station 29
9.8 LV Installation 30
9.9 Transmission Line 30
9.10 Conclusion 30
10 Cascade Operation Impacts 31
11 Construction Costs 32
11.1 Review Approach and Methodology 32
11.2 Civil Works 33
11.2.1 Units Price Assessment 33
11.2.2 Costs of Civil Works 33
11.2.3 Indirect costs 34
11.2.4 Contingencies Allowance 35
11.2.5 Project Development Costs 35
13 Summary of Conclusions and Recommendations 36
14 Annexes 41
14.1 Topo Survey Report 42
14.2 Project Alternate New Layout Plan 53
14.3 Updated Detail Cost Estimates 63
14.4 Photo Gallery 71
14.5 Geotechnical Investigation Report (Drilling Company) 72

List of Tables

Table 1: GPS Coordinates of Jagran-4 HPP 2
Table 2: Summary of Jagran-4 Features 5
Table 3: Summary of Flow Duration Values 13
Table 4: Selected Units Prices 34

List of Figures

Figure 1: Location Map 3
Figure 2: Location Map Google Earth 4
Figure 3: Naran Thunian Correlation 9
Figure 4: Comparison of Observed and Extended Flows (Naran) 9
Figure 5: Estimated Yearly Flows of the Jagran River at Weir Site (Naran) 9
Figure 6: Nausehri Thunian Correlation 10
Figure 7: Comparison of Observed and Extended Flows (Nausehri) 11
Figure 8: Estimated Yearly Flows Jagran River at Weir Site (Nausehri) 12

Acronyms

AJK	Azad Jammu and Kashmir
AP	Asian Plate
CSR	Composite Schedule Rates
CT	Current Transformer
BoQs	Bill of Quantities
E&M	Electrotechnical equipment
FS	Feasibility Study
FHC	Fida Hussain Chaudhry
FDC	Flow Duration Curve
GWh	Gigawatt Hour
GRP	Glassfibre Reinforced Plastic Pipe
HPP	Hydro Power Project
HHC	Higher Himalayan Crystalline
HKS	Hazara-Kashmir Syntaxis
IS	Indus Sutures
kW	Kilo Watt
kV	Kilovolt
KA	Kohistan Arc
LH	Lesser Himalayan
MW	Mega Watt
MMT	Main Mantle Thrust
MCT	Main Central Thrust
MBT	Main Boundary Thrust
MFT	Main Frontal Thrust
MV	Medium Voltage
MS	Mild Steel
m^3/s	Meter cube per Second
NS	Northern Suture
NPS	Nanga Parbat Syntaxes
NTDC	National Transmission and Dispatch Company
O&M	Operation and Maintenance
PDO	Power Development Organization
PT	Potential Transformer
RPM	Revolutions Per Minute
SCADA	Supervisory Control and data Acquisition
SH	Sub-Himalayan
TPV	Third-Party Validation
TG	Turbine & Generator
US$	United State Dollar
WAPDA	Water and Power Development Authority

1 INTRODUCTION

1.1 Context of Review and Validation

The Feasibility Study (FS) of 22 MW Jagran-4 Hydro Power Project (HPP) was prepared by M/s Fida Hussain Chaudhry (FHC) Consulting Engineers in association with M/s Scott Wilson Limited of United Kingdom in October 2010. M/s INTEGRATION e&e, PES and Integration Energy (Consultant) was contracted (16.4.2021) by Power Development Organization (PDO) Azad Jammu and Kashmir (AJK)/Client to Review and Validate the FS report, conduct the Topo Survey and supervise the Geotechnical investigation contracted to a Drilling Company (Universal Drilling Engineers) by the Client.

1.2 Scope of Work

The scope of work is to review and validate the Feasibility Study prepared by FHC and recommend appropriate measures for consideration of PDO for development of the Project. The main works to be carried out by the Consultant are:

S-1: Review and Validation of FS prepared by FHC

S-2: Conduct Topo Survey

S-3: Supervise Geotechnical investigation to be carried out by Third Party

S-4: Prepare the validation report for consideration of the Client/PDO

1.3 Objectives

O 1: Identify the gaps in FS

O 2: Suggest appropriate recommendation for consideration of Client

O 3: Provide guidance to Third Party in Geotechnical Investigation

1.4 Document Reviewed

The consultant has reviewed the following documents:

- Feasibility study prepared by FHC
- Hydrological data of Jagran-1
- Project PC-I
- Revalidation Study by FHC
- Other relevant documents and feasibility studies of HPPs in the area
- Military Schedule Rate 2014 and AJK CSR 2010-21

2 DESCRIPTION OF THE PROJECT

The Jagran River is a right bank tributary of Neelum River located in the Neelum Valley, Azad Jammu, and Kashmir (AJK). Neelum River joins Jhelum River as its right tributary at Domel in Muzaffarabad.

The Jagran-4, HPP is identified on intermediate stretch of Jagran River upstream of existing 30 MW powerhouse Jagran-1. The identified project in upstream of HPP Jagran-1, 2 & 3 on Jagran River. The proposed project is virtually in Cascade to projects located in the downstream.

The Project Feasibility Study was prepared by M/s Fida Hussain Chaudry (FHC) Consulting Engineers in associated with M/s Scott Wilson Limited in October 2010. The capacity of the proposed project is determined as 22 MW. The same Consultant has revalidated the Feasibility Study in June 2020.

2.1 Location

The proposed HPP is located on the left bank of Jagran River upstream of HPP Jagran-1 near Thunian village. The Jagran River join Neelum River at Kundal Shahi village on Neelam Valley Road.

The proposed project area is sited about 18 Km from Kundal Shahi village. The distance of Jagran-4 HPP from Muzaffarabad is about 68 Km. It requires approximately 6 hours to travel from Muzaffarabad to the project site located near Thunian village. The proposed powerhouse is located at about 300 m upstream of the existing intake of HPP Jagran-1.

The GPS Coordinates of the projects main features are summarized in Table 1. The Location Map is given in Figure 1.

Table 1: GPS Coordinates of Jagran-4 HPP

Location	Latitude	Longitude
Powerhouse	34°-37'-48.37"	73°-46'-3.51"
Forebay	34°-39'-15.36"	73°-46'-10.89"
Intake	34°-39'-20.78"	73°-46'-8.62"

Figure 1: Location Map

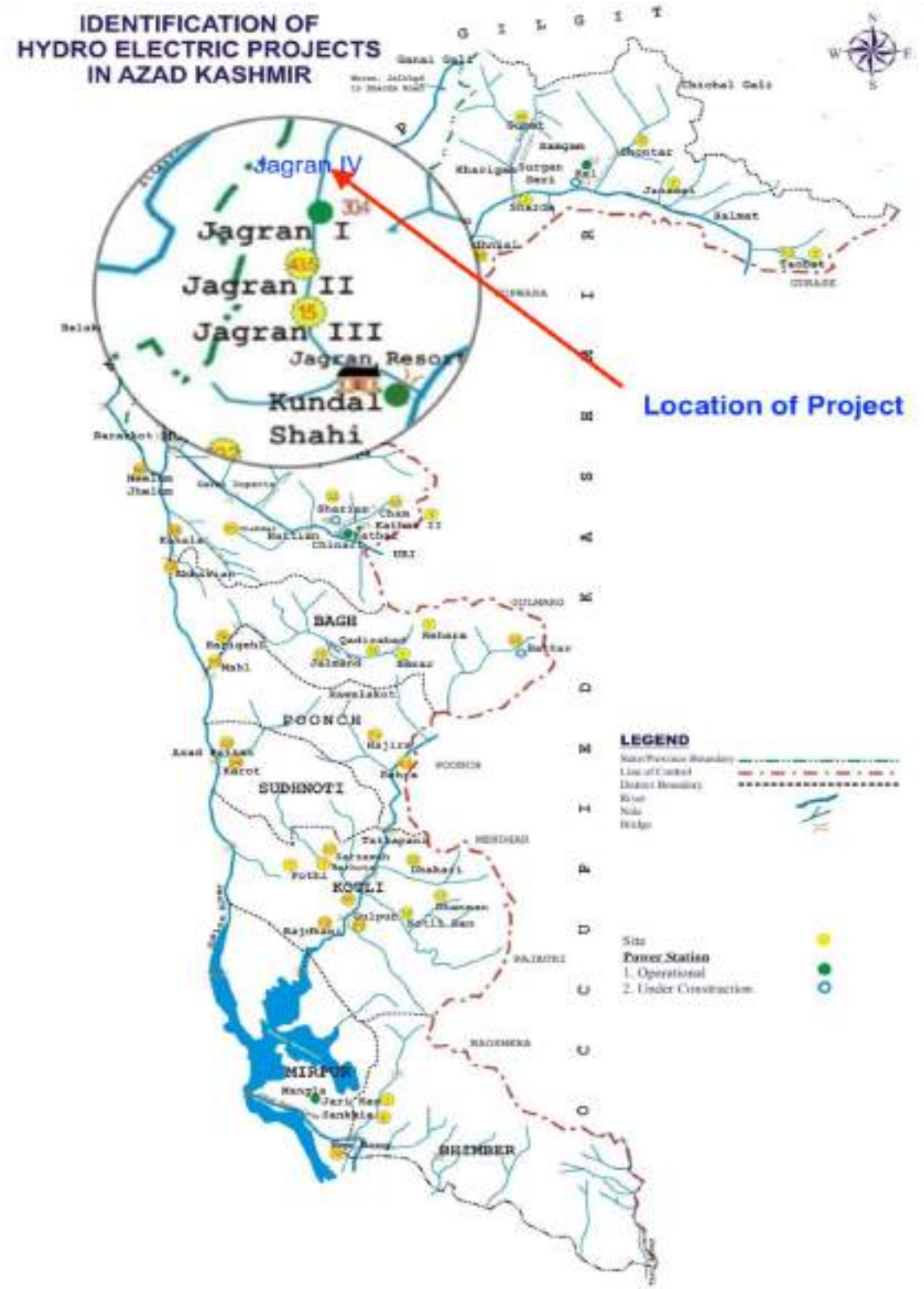


Figure 2: Location Map Google Earth

2.2 Salient Features of the Project

The salient features of the project in the FS have been reviewed by the Third-Party Validation (TPV) Consultant. Based on the new topo survey, and site visits of consultant's experts, these features have been updated for consideration during the detail design of the project. For comparison purposes it has been summarized in Table 2.

Table 2: Summary of Jagran-4 Features

Description	Project Features	
	Feasibility Study Report	TPV Consultant
Gross Head	156 m	169 m
Net Head	144.2 m	158.44 m
Total Design Flow	18 m^3/s	16 m^3/s
Design Flow per Unit	4.9 m^3/s for three units & 3.27 m^3/s for one unit	4.83 m^3/s for three units & 1.45 m^3/s for one unit
Turbines	Francis-Vertical,	Francis Horizontal recommended
Units	3x6MW & 1x4MW	3x6.67 MW & 1x2 MW
Efficiency of Turbine	91 %	92.5%
Efficiency of Generator	96 %	97 %
Firm Power	2.3 MW	1.25 MW
Total Energy Generation/annum	93.29 GWh	91.8 GWh
Plant Factor	51.25 %	50%
Weir	H=6 m L=24 m	Weir axis is proposed 120 m downstream of previous location and with change in weir location, dimensions may change
Connecting Channel	3.4x2.8 RCC and L=110 m	With change in weir location, dimensions may change
Sand Trap	2 (7mx56m)	To be changed according to 16 m^3/s design flow
Headrace Pipe	L= 3,075m, Dia 2.5 m	Pressure pipe is proposed with reduced length of 2,730 m
Surge Pipe	L= 52m, Dia = 5 m	Surge pipe is to be increased to 180 m or bypass surge relief valve to be installed with each turbine
Penstock	L = 180m, Dia = 2.5 m	This Pressure pipe penstock is not required.
Powerhouse	L=35.4m W10m	Powerhouse site is proposed 40 m upstream of previous location with orientation favoring outflow into Jagran River.
Tail Race	L=20 m	Will change according to new location
Generation Voltage	11 kV	11 kV
Power Dispatch	132 kV	132 kV
Project Cost	$US 43.249 million	$US 49.173 million

2.3 Existing Hydro Structures

The proposed 22 MW Jagran-4 HPP is upstream to the intake of 30.4 MW Jagran-1 HPP, which is currently operational. Downstream of Jagran-1 HPP, 48 MW Jagran-2 and 35 MW

Jagran-3 HPPs are currently under construction. These HPPs are being constructed in the series, however, in the construction planning, the cascade impacts and integration of their operational impacts in the design have not been considered.

3 HYDROLOGY

Hydrological and sediment transport studies play a pivotal role in the planning, design and execution of the hydropower projects. The hydrological analysis for a hydropower project essentially provides three main input parameters:

i) Water availability for power production by the project

ii) Flood magnitudes for safe design of the project structures

iii) Sediment simulation study

3.1 Catchment Area

- The catchment area of Jagran River up to the weir site is reported in the FS as 214 Km^2. It has been estimated by TPV Consultant as 205 Km^2 by using the GIS software. The lesser catchment reduces the flows by same ratio which is about 5%.
- The location of gauging stations used for the study and the associated watershed boundaries is to be indicated with a map as sound basis for the estimated flows and flood at weir and powerhouse site.
- The flows of Jagran River are generated with snow fall and rainfall in the catchment. Several glaciers are in its upper catchment above El. 4,000m. The intensive rainfall and snow results in high flows during summer months.
- The catchment of Jagran River experience snowfall in winter months and receive rainfall in summer months. The gauging station with term data and similar climatic conditions is required to be analyzed for realistic flows for this project.

3.2 River Flows

In the Feasibility study (2010), the estimation of flows for Jagran-4 HPP was made by developing a correlation between Thunian AJK (Jagran River) and Naran Hazara (Kunhar River) stations. The correlation so developed is acceptable considering the available flow data of nearby hydrological stations. The estimated flows need to be reviewed as the observed flow period is relatively short. Secondly the climatic condition of Kunhar River and Jagran River catchment are somewhat different. The flow data of another long term station would be useful to be analyzed.

- The flows of Naran station Kunhar River are found to be on lower side which is not matching with Jagran River flows. It could have been more beneficial if the additional data of some recent years be available from Jagran-I power station especially the low flows period.
- The observed flow data of Jagran River at Thunian and at Kundal Shahi is to be part of FS Report. The FS is submitted in the Year 2010. Additional flow data after Year 2000 needs to be incorporated. The extended flows are to be supported with precipitation data in the catchment.
- Jagran River is the major tributary of the Neelum River. In the feasibility study the regression analysis has been carried out between Jagran River at Thunian and Kunhar River at Naran. For establishing correlation between gauging stations, 10 daily data have been used that gives error in the estimated flows. It is recommended to use daily flow data for establishing correlation and extension of flows.
- Consistency test is not performed in the FS on the data to assess the data is homogenous or not. The flow duration curve (FDC) as given in the feasibility report is on monthly basis, which is to be developed on daily basis. The FDC of overall series is not given in the report only average, dry, and wet years are provided in the FS.
- The FS should include information on how gaps in the record have been filled. Most of the gauging station records have at least some gaps and the methods adopted for filling can affect the long-term variability of the data base.

Two years flow data of Thunian gauging stations for Jagran River (July 1994 to June 1996) has been used to extend the flows for Jagran-4 project with long term gauging station of Kunhar River at Naran. The selected station at Thunian is justified as a base station as it is close to Jagran-IV project. The selection of long-term gauging station at Nausehri or Naran depends on the comparison of specific flows for two stations with Thunian.

Figure 3.9 of FS indicates that specific flows of Thunian and Nausehri. Figure 3.17 of FS indicates that specific flows of Thunian and Naran. The specific flows of both stations i.e., Naran and Nausehri are low in summer moths and very similar in winter months as compared with that of Thunian. There is need to review flow analysis and extended flow series to be established with both long-term gauging stations for Jagran-4 project.

3.2.1 Updated Flow Analysis

The analysis of updated daily flow data of both Naran and Nausehri stations and its comparison with Thunian station have been carried out to ascertain the flow availability for Jagran-4 project. The daily flow data of both long-term gauging station is to be analyzed for extension of flows for Thunian gauging station.

Kunhar River at Naran was taken as long-term station for extension of flows at Thunian. The catchment of Kunhar upstream of Naran generate flows mainly due to snow melt and less with rainfall. Kunhar River downstream Naran has more similar climatic conditions as compared with upstream. A correlation using daily flows of Naran and Thunian has been developed and is indicated in Figure-3.

The comparison of specific flows of Thunian and Naran for the period July 1994 to June 1996 provide an equation $y = 0.017226954\ x^{1.12822869}$ with as R^2 value as 0.835, the correlation is shown in Figure-3. With this developed correlation i.e. the flows at weir site are estimated.

The observed and extended monthly flows at Thunian are compared in Figure-4. During winter months from November to February, observed and estimated flows are close, while from July to October, the extended values are less than the observed. This is due to fact that there is intensive monsoon impact on Jagran catchment. From March to May, the observed flows are less. The averages of observed and estimated flow values are 17.21 m^3/s and 16.26 m^3/s respectively which indicates that over all estimated flows from Nausehri are on lower side. Therefore extended flow series from Nausehri 1960-2009 can be relied on in the absence of additional flow data on Jagran River.

Figure 3: Naran Thunian Correlation

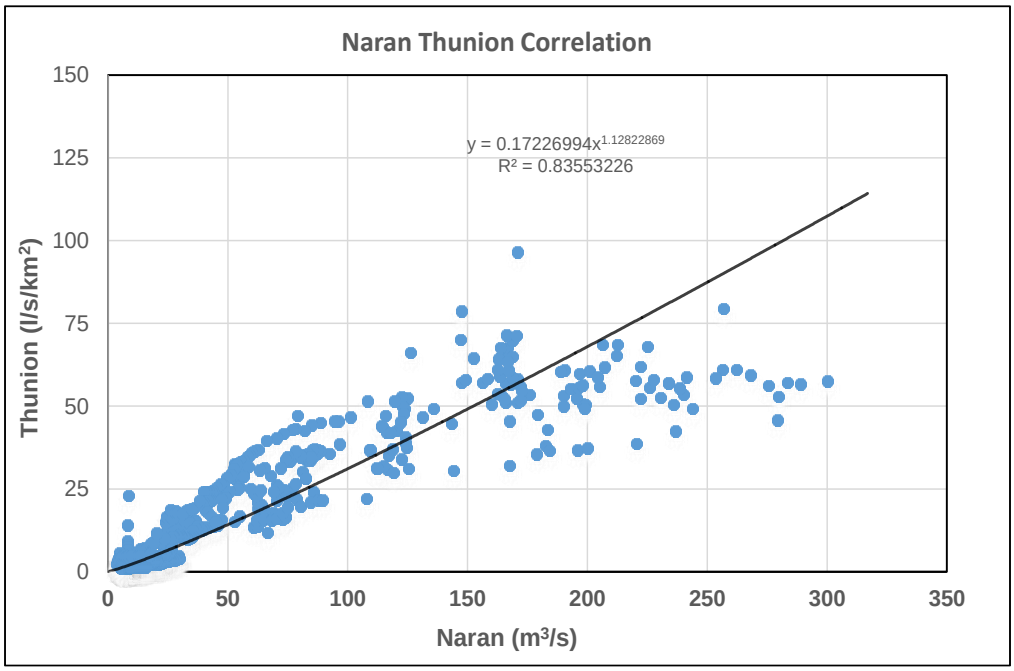
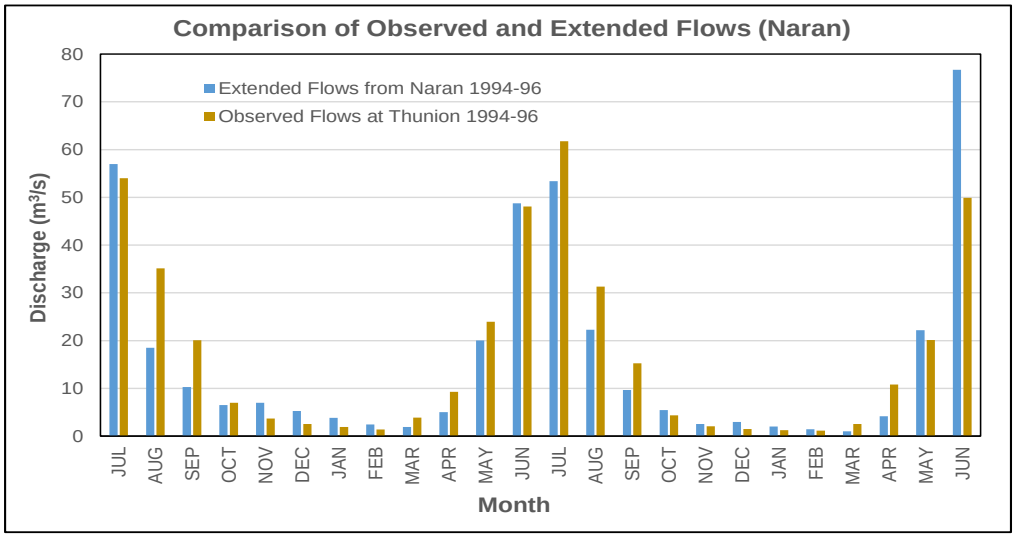
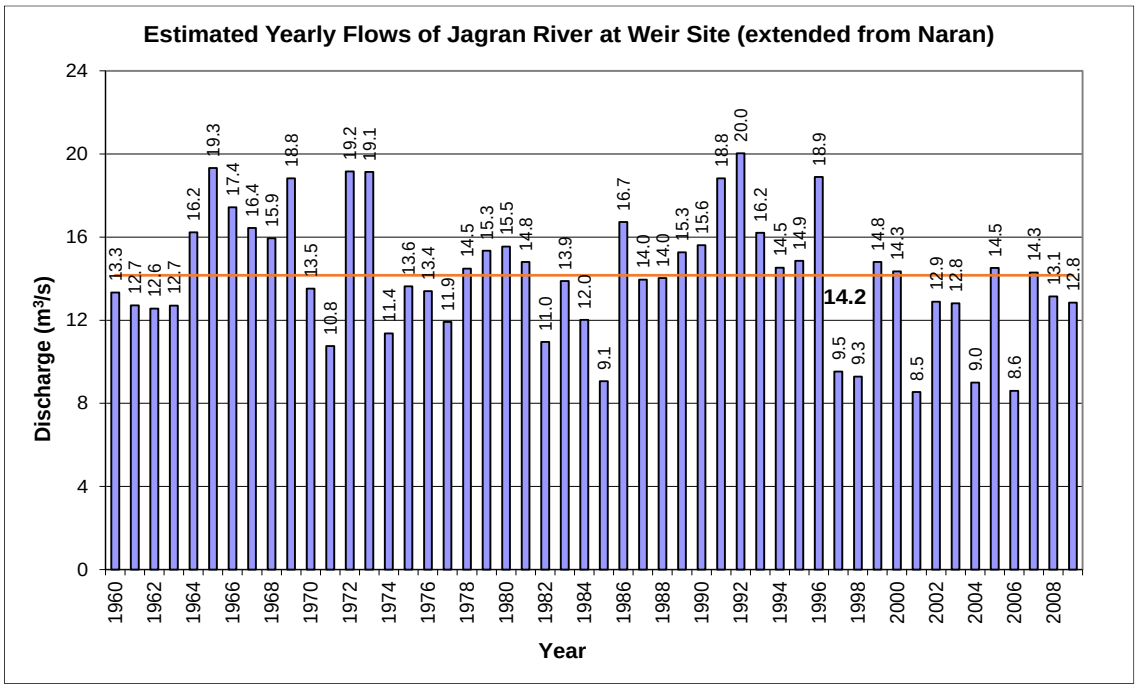


Figure 4: Comparison of Observed and Extended Flows (Naran)



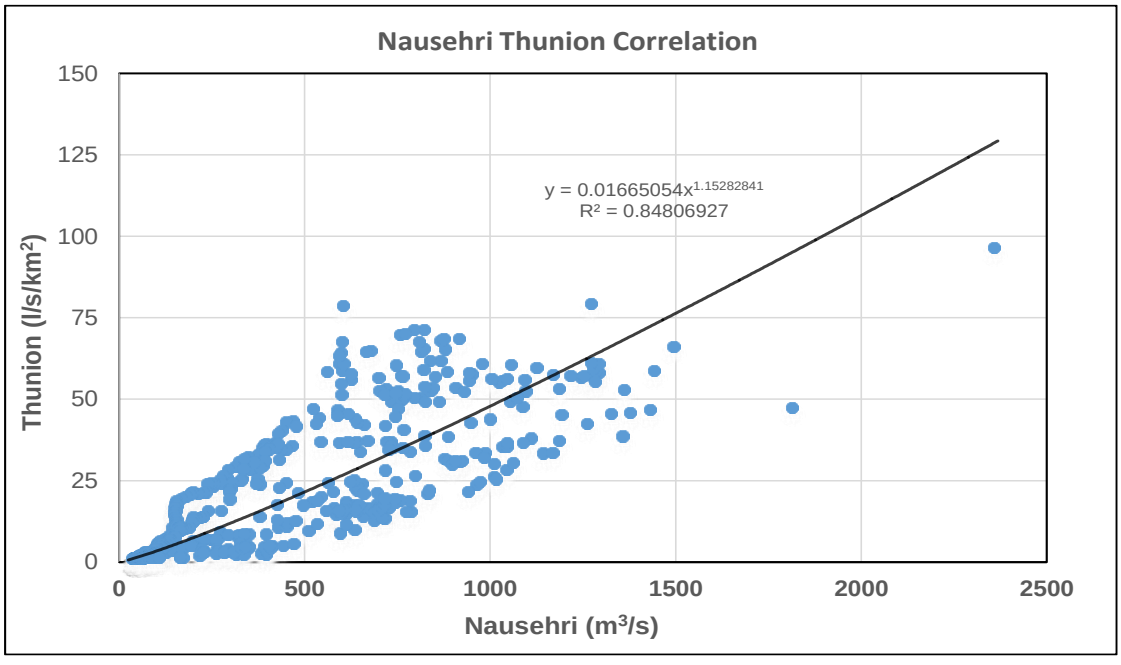
The extended yearly flows from Naran to Jagran-5 varies from 8.6 m^3/s to 21.0 m^3/s with average value of 12.3 m^3/s, the yearly flows are indicated in Figure 5. The mean annual flows estimated for Jagran-4 in FS was 15.59 m^3/s with variation from 10.2 to 21.5 m^3/s. The estimated flows in FS are considered optimistic and may provide over estimated energy. The updated flows from Naran are more rational.

Figure 5: Estimated Yearly Flows of the Jagran River at Weir Site (Naran)



Nausehri on Neelum River is the nearest gauging station to project area. The catchment characteristic of Thunion and Nuasehri station are similar except more snow melt in Neelum valley than Jagran River.

Figure 6: Nausehri Thunian Correlation

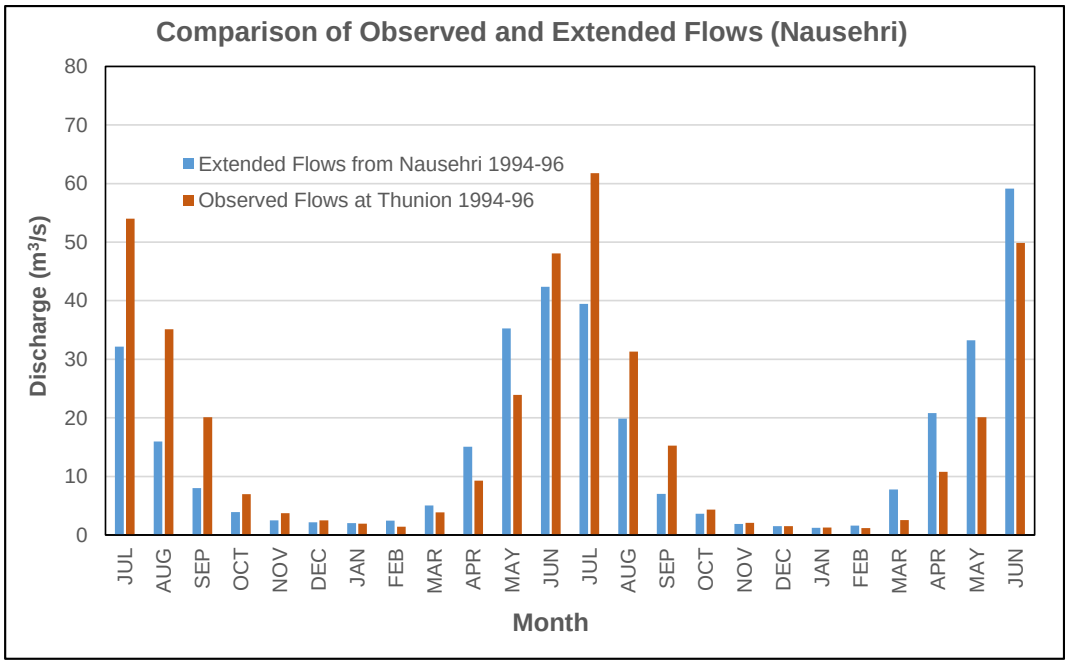


The comparison of specific flows of Thunian and Nausehri for the period July 1994 to June 1996 indicates that a good correlation can be established for extension of flows for Jagran-IV project as R^2 value is 0.848, the correlation is shown in Figure 7. With this developed

correlation i.e. $y = 0.01665054\ x^{1.15282841}$, the flows at weir site are estimated.

The observed and extended monthly flows at Thunian are compared in Figure-6. During winter months from November to February, observed and estimated flows are close, while from July to October estimated values are less than observed. This is since there is intensive monsoon impact on Jagran catchment. From March to May, the observed flows are less. It indicates less snow melt and rainfall in Jagran as compared with catchment of upper Neelum River. The average of observed and estimated flow values are 17.21 m^3/s and 15.71 m^3/s respectively that indicates the overall estimated flows from Nausehri are on lower side. Therefore, extended flow series from Nausehri 1991-2015 can be relied in in the absence of additional flow data on Jagran River.

Figure 7: Comparison of Observed and Extended Flows (Nausehri)

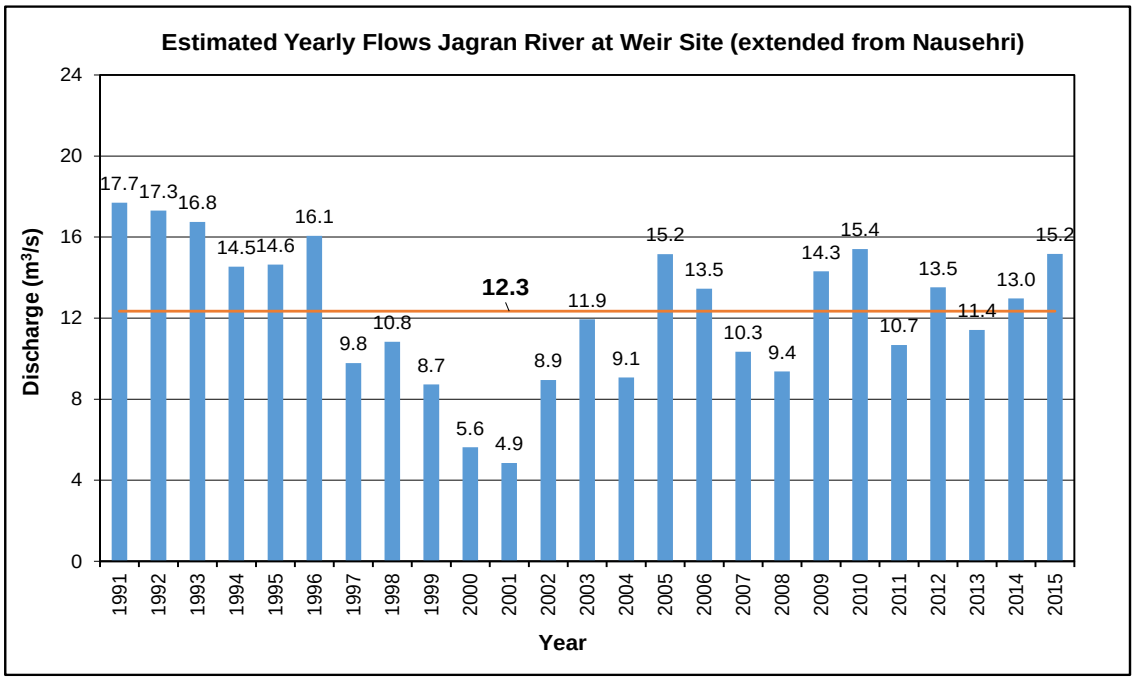


The extended yearly flows from Nausehri to Jagran-4 varies from 4.9 m^3/s to 17.7 m^3/s with average value of 12.3 m^3/s, the yearly flows are indicated in Figure-8. The mean annual flows estimated for Jagran-4 in FS was 15.59 m^3/s with variation from 10.2 to 21.5 m^3/s. The estimated flows in Feasibility Study are considered optimistic and may provide over estimated energy. The updated flows from Nausehri are more realistic.

Comparing with results of extended flows generated with flow series of Nausehri and Naran, the mean annual flows are 14.16 m^3/s (2087 mm/year) and 12.34 m^3/s (1819 mm/year) respectively. The mean annual rainfall at Balakot, Dudhnial and Muzaffarabad are 1,718 mm, 1,541 mm and 1,534 mm. The precipitation recorded at various stations around catchment of

Jagran does not support very high flow generation, therefore flows estimation with Nausehri flow data is recommended to be used.

Figure 8: Estimated Yearly Flows Jagran River at Weir Site (Nausehri)



3.3 Flow Duration Curve

The flow duration curves (FDC) are derived from the discharge data collected at Naran. Three (03) flow duration curves; dry, wet, and average years are prepared with 10 daily mean flow. It is recommended to use daily extended flows. The flow duration curve developed with 10 daily flows; the values are higher than one generated with daily flows. The mean annual flow 15.59 m^3/s is 20.5% higher than the updated mean annual flow of 12.39 m^3/s. The FDC Values are summarized in Table 3.

Table 3: Summary of Flow Duration Values

Time	Flow Duration Values (m^3/s)		
(%)	Nausehri	Naran	FS Jagran
0	183.98	168.84	101.46
5	40.17	55.01	58.03
10	32.48	42.49	44.58
15	27.46	32.39	35.98
20	23.40	24.67	27.50
25	18.87	18.75	20.69
30	15.12	14.26	16.81
35	12.20	10.98	13.54
40	9.93	8.17	10.78
45	7.91	6.16	8.03
50	6.18	4.99	5.99
55	4.90	4.18	4.93
60	3.99	3.55	4.21
65	3.28	3.18	3.50
70	2.80	2.87	3.07
75	2.45	2.60	2.68
80	2.17	2.34	2.37
85	1.85	2.13	2.15
90	1.57	1.88	1.93
95	1.21	1.35	1.59
100	0.62	0.20	0.55
Mean	**12.39**	**14.22**	**15.59**

The FDC values derived from Naran and Nausehri stations are compared with data of FS. The estimated values from Naran or Nausehri stations daily flows are relatively low as compared with that of FS. The flow duration data estimated from Naran station has extreme low flow values. Other flow duration values remain low except maximum peak value.

The flow duration values derived from Nausehri station are also lower than that of FS values.

3.4 Floods

- The FS has adopted a statistical approach to estimation of the design floods required for design. The flood data of Muzaffarabad is not given in the feasibility report and ratio method is not properly defined how to extend the data at the project site.
- With ratio method applied on the Muzaffarabad data to estimate the flood at project site provide the higher value of flood as given in the feasibility study. The PMF reported in the FS is underestimated without details in the FS.
- Single site flood frequency analysis is affected by a small number of large floods, especially if a three-parameter distribution such as the LPIII is adopted. The flood data should be screened to test for the presence of high outliers in the data and then

treated to reduce the effect of these on the distribution. The FS has taken this step but has allowed all high floods to be included at the position implied by the record length.

- The flood frequency analysis needs to be reviewed with observed data rather than on data transposed to the intake site. If the transposition induces a nonlinear error, the extrapolation can be erroneous. It is recommended to perform statistical analysis on the observed data and to transpose the results to avoid the extrapolation of errors introduced in the extrapolated sample.

Combining discharge data from different sources can be done by much more reliable methods, such as the index flood method, which would be recommended in the present case.

3.5 Potential Climate Change Impacts

Climate change is not considered in the present analyses in FS. The study of Huss and Hock (2018) do however show that the influences on glacier melt, and the related runoff discharge is particularly high in the Asian mountains. At first the runoff increases, what come with a reduction of the glacier mass. The runoff attends a peak before it decreases since the glacier mass cannot support the increasing runoff anymore. Whereas one could intuitively think that the attendance of this peak flow is to be awaited late in the century, their analysis shows that it can come rather soon, or has even been reached already in some case. There is thus a chance that climate change induces a decrease of the discharge at the project site. Therefore, to be complete, a specific study should be performed.

Other sources like publications from the World Bank support the possibility of a discharge decrease:

"*Upper Indus flows are strongly dependent on snow melt (22%) and glacial melt (41 percent). Climate change appears to be affecting rainfall, snowfall and glacier melt but in complex ways with no clear trends. No significant changes in river flows are projected before 2050. Under different climate change scenarios average flows either increase slightly or decrease slightly. Glacial melt is expected to increase but be offset by snowmelt reductions. A 20-28 percent reduction in ice volume is projected, mostly at lower elevations. The Indus has a greater share of glacial ice at higher elevation than other Himalayan basins, and although faster rates of warming are expected higher up, the absolute temperatures projected would not be enough to drive rapid melting there.*"

Nevertheless, such a decrease of the discharge should not affect the small discharges in the wintertime and therefore should not affect the power production of Jagran-4.

3.6 Conclusion

- The catchment area of Jagran River up to the weir site is reported in the FS (214 Km^2) is slightly higher as compared to the Validation of Consultant (205 Km^2).

- The mean annual flow estimated in the FS 15.59 m³/s is 20.5% higher than the updated mean annual flow of 12.39 m³/s. The estimated flows in FS are considered optimistic and may provide over estimated energy. The updated flows from Nausehri are more realistic.
- In the FS the design discharge 18 m³/sec is available for 28.7% of time however, in the TPV Validation discharge is available for about 26.1% of time.
- The recommended flood value is for the return period of 500 years, whereas usually flood value for a return period of 1,000 years is taken for the design of the weir to make the project resilient and to avoid damages due to the flood catastrophes and unforeseen climate change impacts. However, the return period of 500 years will also be OK, if appropriate flood protection measures are considered in the detail design.

4 SEDIMENT TRANSPORT

- No sediment measurements have been carried out in the past in Jagran River, neither for suspended load nor for bed load.
- The sediment load at the project site has been estimated from the Nausheri gauging station up to the year 2005, it should be updated. Sediment simulation study should also be carried out for Jagran-4 HPP before detail design, to estimate how much sediment will be deposited in front of weir and intake.

4.1 Conclusion

Considering that sustainable sediment management is one of the very important pre-requisites for reliable long-term operation of the plant following is suggested here:

It can be concluded that there is little sediment transport over a vast majority of flows during low flow months. However, the sediment issue becomes severe during high flow season and especially during single flood events and mass movement / monsoon season events. Therefore, for high flows a sediment/sand trap is considered as essential. The sediment trap shall be designed in such a way that during flushing of sediments the design discharge does not need to be reduced in order not to lose energy production. The sequence of flushing shall be analyzed as part of the basic design with typical high concentrations at that flow conditions. In case of extraordinary events, the power plant would need to be shut down to avoid damages at the intake, settling basin, and for the sake of life of the runners.

Furthermore, it can be learnt from the site visit, that the river gradient is quite steep, which is already an indication for a high likelihood for bed load transport during floods. This can also be confirmed from the river morphology, the existence of large boulders on the riverbed at the weir site, where large boulders are expected to be spilled over the structure. Based on this observation, adequate design measures would need to be considered.

The management of sediments also needs to be considered as part of the potential increased operation and maintenance costs, since dredging of depositions and regular repair works on the weir site are expected to be necessary due to the characteristics of the sediment transport in Jagran River.

The above-mentioned aspects are crucial for a smooth operation of the Project. The lessons learned from Jagran-1 shall be fully considered, such as design of the weir, intake, flushing gates and sediment trap and the experiences with potential abrasion effects on the turbine runners.

5 GEOLOGY

5.1 Regional Geology

The Neelum Valley is oriented NE-SW and constitute the northern flank of Neelum Valley between the locations of Tetwal and Kel. The Upper limit is delineated by the northern crest line separating Neelum Valley from Kaghan valley and northern areas. Neelum River is the lower boundary separating the valley from Indian Occupied Kashmir. The Project area is characterized by rugged topography and high relief where elevation range from 2260m at proposed weir site and 2120m at Power site about 1km upstream of Jagran-1 Intake Weir.

Lithological Unite of the Neelum Valley were collectively termed as The Sulkhala series, Dogra Slates and Tanawal (Wadia 1931; 1934). Ghazanfar et.al (1983) classified outcropping between Tetwal and Lawat comprising of psammitic-pelitic sequence as Tanol, whereas the pelitic-calcarious sequence found North of Lawat was included in Sharda Group instead of Salkhala Formation. Three different granitic batholiths were identified, two Southern ones were described to be Tertiary, while the Northern Kel granite was assigned as a Paleozoic age.

5.2 Geo-Tectonic Setting and Sub-Division

The major Himalayan tectonic units are well exposed along the relatively accessible Indus, Kaghan, Jhelum and Neelum valleys. They are the results of the collision between the Asian N and Indian S plates (Bossart et al; 1984; 1988; 1992. Along the river Hunza and Indus, five

principal fault zones can be recognized. The Northern suture (NS), the Main Mantle Thrust (MMT) or Indus Sutures (IS), the Main Central thrust (MCT), the Main Boundary Thrust (MBT) and the Main Frontal Thrust (MFT) (Tahirkheli, 1979; Trelaor et al 1989).

These fault zones trend E-W dividing the Himalayan organic belt in five main tectonic zones. The Asian Plate (AP), Kohistan Arc (KA), the Higher Himalayan Crystalline Unit (HHC), the Lesser Himalayan Unit (LHC) and the Sub-Himalayan Unit (SH).

The E-W trend of fault zones is disturbed locally by two tectonic semi-windows {Wadia 1931; Calkins et al., 1975}, the Nanga Parbat Syntaxes (NPS) and the Hazara-Kashmir syntaxis (HKS). The area connected these two syntaxes is still being affected by an exceptional rate of uplift reaching 7mm/year (Zeitler et al 1989. several of these tectonic units are encountered in an SW-NE traverse along the Neelum Valley.

The MBT which separate the SH from LHC lies near the Nauseri 40km NE of Muzaffarabad. Near the village Lawat 100 Km from Muzaffarabad on Neelum Valley Road, the MCT separates the LHC to the south from the HHC which extend north and east to the village Kel. These tectonic units share stratigraphic features but differ from there tectonic metamorphic evolution. Metamorphic grade and ductile deformation increase from the youngest and lower most unit (i.e. sub Himalayas) to the upper most unit (i.e. Higher Himalayas) (Bossart et al 1988 1992; Greco et al 1989 1993, Spencer 1993).

5.3 Lithostratigraphy of Neelum Valley

The crystalline rocks outcropping in the Neelum valley are subdivided into three major litho-stratagraphic units, the Precambrian Naril Group, the Precambrian Kundalshahi Group and the Upper Paleozoic to Mesozoic Surgan Group.

The Naril Group is the Pre-Himalayan basement, the Kundalshahi Group forms the Pre-Himalayan cover while the Surgan Group represents the Pre-Himalayan cover. All the above-mentioned groups are intruded by Meta-dolerite and Amphibolite collectively called Metabasite. All the litho-stratagraphic units occur both in the LHC and HHC and have undergone variable grade of metamorphism. The rocks forming the Naril Group, the Kundalshahi Group and Surgan Group were deformed and metamorphosed during the Tertiary Himalayan events.

5.4 Geology of the Project Area

At left and Right abutments of river, area is covered with the overburden containing large sub rounded, sub angular boulders, (ABGM, RBGM, and ABG, RBG) rock debris with sand of

Fluvial and colluvial material. Both abutments are thickly vegetated and cultivated small terraces.

The rock exposure is not available at suggested sites of Intake Weir, Water Conduit Path, Sand Trap, and Powerhouse locations.

Geological rock units exposed in Project area are metamorphic units Granitic Gneisses with igneous intrusion of Granite and Granodiorites are present at places but at reasonable height.

5.5 Engineering Geology and Geotechnical

As mentioned in above headings the project area is situated at such area where rock is not exposed at any proposed location of structures and missing the geotechnical data for evaluation. Only the location where rock can be examined is on the road near Jagran-1 intake Weir. Rock found in this area as per ISRM is very strong to extremely strong thickly bedded, slight to moderately weathered, closely jointed and fractured. In drilled Bore Holes and excavated test Pits, rock was not encountered. No Water Pressure Test could be performed to check the behavior of rock joints water intake. In the same way surface geological mapping data is missing in FS report.

5.6 Construction Material

Construction material required for various structures of the proposed Jagran-4 HPP is considered available in sufficient quantity. Boulders and gravel (ABGM) and (RBGM) type of material is found at the slopes and in the riverbed respectively.

With the completion of Geotechnical Investigation and Report, additional information will be available which shall be accounted for in the detail design stage of the proposed project.

5.6.1 Coarse Aggregate

Boulders and cobbles are available in huge quantity at both the upstream and downstream se boulders and gravel include granitic gneiss, phyllites and granite. Phyllites cannot be used as aggregates so these might be separated before crushing to the desired grading. • Maximum size of boulder is up to 8 x 7 x 6 m. These are generally very hard and may be crushed to the desired size for their use as coarse aggregate for concrete. The coarse aggregate is also found at the terraces. The riverbed mainly comprises of sub-rounded to rounded boulders and gravel with little amount of sand (RBG)

5.6.2 Fine Aggregate

Fine Aggregate (natural sand) is not available in the close vicinity of the project structures. Sand may be excavated from the terraces comprising of RBGM and ABGM type of materials.

It can also be produced from Jagran Riverbed during the low flow season. All the necessary tests shall be carried out on sand and other aggregates to ensure the durability and strength of concrete. 4.8.3 Building Stone Rock granitic gneiss is available for masonry works in the vicinity of the project area in sufficient quantity.

5.6.3 Fill Material

For protection measures along slopes and structures, fill material of almost every size is available from riverbed and from the adjacent terraces within a close vicinity of the project area. Boulders or angular stones can be picked up from riverbed and from hill side slopes respectively and used as per project specifications/requirements.

5.6.4 Cement and Steel

Cement and steel may not be available in sufficient quantity in Muzaffarabad as required for the construction of Jagran - 4 HPP. Therefore, these items will have to be procured from Rawalpindi or Khyber Pakhtunkhwa area. It is proposed that laboratory testing on representative sample be carried out to determine physical and mechanical characteristic of the available material.

5.7 Tectonic and Seismic Conditions of Project Area

Tectonically the project area is between two main faults MMT at Northern side and MCT at Southern side along with Pir Punjal Thrust. In Seismic Zoning Map of Pakistan According to Building codes of Pakistan BCP-2007 map the area lies in Zone-4 having severe earthquakes magnitude above 7 degree magnitude BCP-PGA >3.2m/sq. sec.

5.8 Observations and Recommendation

5.8.1 Weir Site

The following parameters were considered to select possible location for intake structures.

1- The riverbed should be rather narrow in order to avoid large structure; however some space should be available to take care of water during construction.

2- Rock outcrop should be present in the bank where intake and de-sanding basins are in order to avoid underground structure or deep excavation in loose material (slope debris, moraine deposits, alluvial deposits etc.)

3- Access to the site should be possible without excessive road work.

At left and Right abutments of river, area is covered with large sub rounded, sub angular boulders, (ABGM, RBGM, and ABG, RBG) rock debris with sand of Fluvial and colluvial material. Both abutments are thickly vegetated and cultivated small terraces.

It is observed that Weir site suggested in feasibility report, span of river is wide and at 150m upstream, a nullah of reasonable water potential is falling from left bank in river. One 36m bore hole has been recently drilled and rock wasn't encountered after new topographic survey newly suggested location for Weir site at downstream of previous location is more suitable as compared to previous location because at new location valley is comparatively narrow and there is no difference of geological features and material.

5.8.2 Powerhouse Site

The Powerhouse is suggested open in Riverbed approximately 300 m from Jagran-1 intake Weir. In the Riverbed area is covered with large sub rounded, sub angular boulders, (ABGM, RBGM, and ABG, RBG) rock debris with sand of Fluvial and colluvial material. At Left abutment rock is exposed road level but at Powerhouse location there is no visible exposure of rock.

The alternate location of Powerhouse proposed now is upstream of previously suggested location in the Feasibility Report which is closer to Intake Weir of Jagran-1 and is at a higher risk of flood damage during high flood season. The proposed location minimizes the possibility of damage due to flood in the peak season as it is in the maximum wide span of the riverbed where at end of slided material alluvial fan where the adverse effect of falling of slided material will also be less.

The Geotechnical Investigations report is attached at Annex 13.5.

6 POWER AND ENERGY

The topographic survey carried out by TPV Consultant indicates that the gross head from weir and powerhouse indicated is 170 m. Its comparison with Feasibility indicates that survey used in the FS was rather preliminary and found with less details. The detail topo survey carried out by consultant for validation of FS is more precise. With relocated weir axis 120 m downstream of previously proposed axis, the gross head for updated scheme is 169 m, 13 m more than as taken in the FS. **The Topo Survey report is attached at Annex 13.1.**

6.1 Discharge for Power Generation

The discharge for power generation is the discharge in the river minus the ecological discharge. Most of the time, the ecological discharge does not impact the energy production except in the winter months when flows in the river are lower than the design discharge.

The design discharge is assumed as 18.0 m³/s, available 28.7% time of the year in the FS. In FS, power and energy was calculated with monthly flows and environmental flows was taken as 0.3 m³/s. With net head of 156.0 m, an installed capacity of 22.0 MW was proposed. The Plant Factor with mean annual energy of 98.2 GWh was estimated as 51.25% without considering outage of the power plant. There is need to review the energy estimation with updated daily flows, net head and revised design discharge.

With updated estimated flows for Jagran-4 intake site, the flows are reduced than the flows estimated in FS. The design discharge of 18.0 m³/s is available 26.1% time of the year. The average discharge for plant production will be 8.53 m³/s and the ratio of average discharge to design discharge (8.53/18.0) is 0.474. This ratio needs to be improved to have a plant factor of about 50%. The design discharge may be selected with same duration of availability as taken in the FS. The design discharge of 16.0 m³/s in the updated estimated flow series is available for 28.6% time of the year. The average discharge for power generation would be 8.0 m³/s, for which the ratio of average to design discharge is 0.5. With reduced flow series, a design discharge of 16.0 m³/s would provide a plant factor as estimated in the FS.

6.2 Operation Levels and Gross Head

In the FS, normal head and tail water levels were taken as 2,264 m.a.s.l and 2,108 m.a.s.l respectively and the gross head was estimated as 156 m. With newly conducted topographic survey and relocated weir axis, the normal and minimum operation levels upstream of weir are assumed as 2,242.0 m.a.s.l and 2,241.0 m.a.s.l respectively. Minimum and normal tail water variation is from 2,073 m to 2,075 m. The gross head varies from 167 m to 169 m. Tail water levels are to be calculated with daily discharge in the river downstream of powerhouse. A rating curve at end sill of tailrace is to be established along with rating curve for Jagran River just downstream of tailrace.

6.3 Head Losses

With revised layout, pressure pipe length is reduced from 3,075 m (GRP) to 2,730 m (MS Pipe). The MS pipe diameter of 2.4 m has been considered for 16.0 m^3/s design discharge. There is connecting channel of 100 m length and a sand trap before pressure pipe. A friction coefficient of n = 0.015 $s/m^{1/3}$ for concrete lining and 0.011 $s/m^{1/3}$ have been applied to define

the head losses. In addition to friction losses, intake losses, entrance losses, exit losses and bend losses are also considered. With 10.56 m losses at design discharge, the net head is 158.44 m.

6.4 Plant Performance Parameters

In the FS, 3 vertical turbine unit of 6 MW and 1 vertical axis unit of 4 MW are proposed for the total discharge of 18.0 m^3/s. To generate power in low flow period, a smaller power unit is to be proposed and three (03) units of the size that can be transported to the site easily. The flows in Jagran River at proposed weir site remained less than 1 m^3/s for about 1.7% time of the year. For design discharge of 16.0 m^3/s to utilize low flows 1 m^3/s, one smaller unit of 2 MW capacity is recommended instead of 4 MW proposed in the FS.

The efficiency for turbine was used as 91%, for generator as 96% and for transformer as 99%. The combined efficiency is 86.4%. These needs to be improved as 92.5% for turbine, 97.0% for generator and 99% for transformer. The combined efficiency be thus taken as 88.8%.

Independent of the efficiencies of the electromechanical and electrical equipment, the power plant consumes some part of the energy produced to operate auxiliary equipment such as HVAC, drainage, or lighting. Generally, a percentage comprised between 0.5% and 1.0% is deducted from the produced energy to take these losses or other parasitic loads into account a percentage of 0.75% is assumed in the present review.

With design discharge of 16.0 m^3/s, the proposed capacity is 22.0 MW. The plant factor maximum power would be 50.38%. The net head as per revised survey and weir location and powerhouse tail water level is 158.4 m. An installed capacity of 22.0 MW can be recommended with mean annual energy of 96.6 GWh. With 5% outage, the annual energy to be delivered is 91.8 GWh.

7 Main Design Criteria

7.1 Seismic Design

The seismic design criteria indicated in the FS:

Horizontal Peak Ground Acceleration (PGA) for Maximum Credible Earthquake (MCE) as 0.68 g,

Design Base Earthquake (DBE) as 0.35 g,

Operating Basis Earthquake (OBE) as 0.26 g.

The vertical components recommended for this scheme are 2 / 3 of the corresponding horizontal component.

7.2 Flood Management

The recommended flood value is for the return period of 500 years, whereas usually flood value for a return period of 1,000 years is taken for the design of the weir to make the project resilient and to avoid damages due to the flood catastrophes. However, the return period of 500 years will also be OK, if appropriate flood protection measures are considered in the detail design.

7.3 Standards

Several standards and codes are mentioned in the FS including but not limited to the following:

- ICOLD Bulletin 72
- ASTM
- AISI
- IEC
- CMAA/FEM

8 FEASIBILITY DESIGN REVIEW

8.1 Project Layout

The Jagran-4 project area is located on the left bank of Jagran River about 18 km from its confluence with Neelum River at Kundal Shahi which is 68 km from Muzaffarabad city. The layout has been proposed on the left bank, along 3.6 km intermediate stretch of Jagran River. The weir has been proposed about 150 m downstream of confluence of Baihk Nullah on Jagran River near Shaal village. The powerhouse has been proposed about 300 m upstream of Jagran-1 weir intake.

The project layout comprised of diversion weir, power intake structure, embedded channel, sand trap, pressure pipe, surge pipe and surface powerhouse. In FS the design discharge is proposed as 18.0 m^3/s and with net head of 144.2 m, 22.0 MW installed capacity with four Vertical Francis units.

- The topographic survey carried out by TPV Consultant indicates that the gross head from powerhouse with relocated improved weir site is 169 m which is same taken in the FS. This indicates that survey used in the FS was rather preliminary, found with less detail and for planned layout, the gross/net head was underestimated.
- With relocated improved location of weir and powerhouse, the gross head is 158.4 m which is 14.2 m more than the one proposed in FS. **Details of alternative layout plan proposed by TPV Consultant is attached at Annex 13.2.**

- The design discharge has been reviewed as 16.0 m^3/s and with net head of 158.4 m, a powerhouse of 22 MW can be proposed. In the revised parameters of power generation, there is increase in net head, reduction in design discharge and plant capacity remain same as 22.0 MW with some improvement in equipment efficiencies as compared with proposed in the FS.
- Two alternatives project layouts were considered in the FS. Project layout with low pressure tunnel should have more net head as compared with pressure pipe as friction losses in pressure pipe are more than low pressure tunnel.
- Headrace tunnel if geological conditions allow is preferred over pressure pipe as head loss is less and surges can be absorbed in surge tank. With low design discharge and for a length of less than 3.0 Km, pressure pipe could be an economical option and easy to implement.
- The project layout involves surface structures like diversion weir, connecting channel, sand trap and powerhouse. The pressure pipe is preferred to be embedded to avoid from cold temperature in winter and from snow melt from uphill areas.
- The design discharge of 16.0 m^3/s is available for 28.6% time of the year to utilize the optimum potential of the river resource. Topography, geology, morphology, accessibility, and flow availability in the project support the proposed structures with their size from intake to powerhouse.
- The project sizing for 22 MW potential development with the size and type of structures and equipment is doable like existing Jagran-1 and under construction Jagran-2.
- The cascading impact of hydropower project on Jagran River is to be analyzed. How best the flood management, sediment sluicing, plant operation and maintenance can be made.
- The geological investigations, flow and sediment observations need to be carried out to improve the design basis and preparing the bidding documents before contract for project construction is awarded.
- Though the project area is in intensive snowfall area and alluvium deposits at, the configuration of potential development from weir to powerhouse with pressure pipe is considered appropriate. The refinement in weir and powerhouse location and pressure pipe alignment is required with detailed field investigations.

8.2 Weir and Intake

a) In the FS, the weir site is proposed at location where mild side slope and alluvium on both banks of River. For a diversion weir subjected to high flood and sediment load, there needs to be hard geological strata and steep side slope for abutment of concrete structure.

b) The weir site has been reviewed and the appropriate location is 150 m downstream of proposed axis is recommended. The relocated weir site has steep slope and hard strata on the left bank and river width is relatively narrow. The site is more suitable for river diversion and on the right bank and intake structure with under sluices on the left bank.

c) The stability analysis of weir structure including under sluices and power intake is to be carried out with data inferred from the geological investigation at weir site.

d) The FS report mentions that the foundation treatment will be made through traditional grouting. Considering the nature of the foundation, constituted with loose material and boulders, this technique is not adequate and will not reach the objectives.

e) The needs of a cut-off should be analyzed more in detail and considering the limited height of the weir, the necessity of such treatment should be confirmed by seepage and uplift pressure analysis. A possible alternative solution could consist just to foresee a deeper foundation or an extended U/S apron to increase the seepage path. The necessity of drainage and uplift pressure release under the energy dissipation basin should be also checked.

f) The estimation of sediment load is to be made with field observation. The sediment accumulation upstream of weir of existing Jagran-1 is to be analyzed to avoid the sediment accumulation upstream of weir.

g) The design of under sluices is to be made with the sediment load observation in Jagran valley. Jagran-1 weir site located being at most upper end would be affected severely with the flood passage and sediment load.

h) River diversion during construction of weir and under sluices to be based on Jagran River flood during last 20 years. The flood level in various years at Jagran-1 weir would be helpful in estimating the magnitude of flood that can be considered to design the river diversion scheme.

i) Two under sluices are proposed on the left bank adjacent to intake of power channel/conduit. The operation of Jagran-1 sluicing gates can provide the guideline for sizing, type, and number of gates.

j) The intake structure will operate under pressure more than 1/3rd of the year without energy dissipation, leading to overspill along the channel. The gantry crane should be used for the roller gates and the Stop logs.

8.3 Approach Channel

The power intake and connecting channel are to be relocated along with diversion weir at new axis. Sand trap is positioned as per topography and downstream of connecting channel. The headrace canal is approx. 100 m long concrete structure. The canal cross section is 3.4 m width and 2.8 m high. With a longitudinal slope of around 0.01 % and a conservative Manning coefficient of n = 0.016 the canal has the capacity to lead the design flow of more than 16 m³/s to sand trap. The canal has a 0.8 m freeboard. The water depth at full discharge capacity is 2.0 m leading to a flow velocity of 2.1 m/s, which is reasonable.

8.4 Sand Trap

Sand trap is to be relocated along with weir axis. A sand trap is designed for particles with a grain size larger or equal to 0.2 mm is foreseen before the pressure pipe. Sediment sampling of Jagran-1 weir site and sand entering headrace tunnel Jagran-1 can provide the sediment load and material sizing for design of sand trap basin. Flow velocity for sand shall not exceed 0.2 to0.3 m/s otherwise the sediments can be mobilized into pressure pipe again by bed load or even by suspension load.

8.5 Penstock Pipe

No analyses of the transient waves during powerhouse operation were found in the FS report. This need to be analyzed. The GRP pipe in such a rugged terrain without any previous precedence or experience of its use as Penstock of a medium head hydropower development does not seem to be recommendable.

There are several options of steel penstock selection summarized as under:

Option I. *Single header main penstock up to the powerhouse with surge pipe before the bifurcation point and four branches to feed water to each turbine.*

Option II. *Single header main penstock up to the powerhouse without surge pipe having appropriate thickness according to the hydraulic gradient to sustain the surge pressure due to water hammer at the time of full load rejection and four branches to fed water to each turbine.*

Option III. *Two header main penstocks up to the powerhouse bifurcated each in to two branches to feed water to two turbines by each main penstock with synchronous bypass surge relief valves with each turbine actuated by the governing system of the turbine.*

Option IV. *Single header main penstock up to the powerhouse without surge pipe four branches to feed water to each turbine with synchronous surge relief bypass valves with each turbine regulated by the governing mechanism of the turbine to mitigate surge pressure due to water hammer at the time of full load rejection and release of flow into the tailrace.*

These options need to be carefully analyzed at the detail design stage to reach out the most optimum solution from operational as well cost point of view.

The embedded pressure pipe alignment has been reviewed and adjusted to be safe from snow melt and avalanches from left bank. The reviewed alignment has been proposed close to valley road and it has downward slope eliminating sharp bends. The overall pressure pipe length has been reduced as compared with FS layout.

The hydraulic analysis of pressure pipe for various load conditions needs to be carried out at detail design stage to determine the diameter and thickness of the pipe.

Anchor blocks are to be carefully designed at the detail design stage for the forces acting at that specific point.

8.6 Powerhouse

The outflows from powerhouse are discharged into Jagran River. The powerhouse has been shifted 40 m upstream and oriented anti clockwise to be safer from high flood.

The flood level of Jagran River needs to be estimated with hydraulic modelling as to establish the safety of the proposed structures from intake to powerhouse.

Floods walls are recommended to be provided based on the hydraulic modelling to protect the powerhouse from 500-year return period flood volume.

9 SELECTION OF TYPE OF TURBINE & AUXILIARY EQUIPMENT

9.1 Turbine

For the proposed Jagran-4 site Francis turbine has rightly been selected for rated net head of 158.4 & design flow of 18 m^3/s. Now the proposed design flow is 16m^3/s whereas the minimum flow for 1.7% period is about 1m^3/s, therefore the number of units will remain four sets with three units 6.67 MW capacity & one unit 2 MW capacity. The orientation of the main E&M equipment has been kept vertical, which involve higher construction & maintenance cost.

The site of powerhouse is recommended to be located on a flat area having more space available where horizontal orientation of the main E&M equipment is possible. Therefore, the prospects of horizontal alignment of the T.G sets may be assessed during final and detail design of the project.

The speed of the T.G. set has been proposed 1,000 rpm in FS. According to the specific speed of the turbine having the net head & flow mentioned above the nearest rated speed comes between to be 750 & 1,000 rpm. This aspect may be investigated at detail design stage as lower speed having lesser vibration & lesser speed transients is better from operation point of view.

9.2 Inlet Valve

Butterfly Inlet Valve(s) have been selected in FS, which may be replaced with Spherical Valve(s) (ball valve) for the Francis turbine proposed for the project. Butterfly Valves are susceptible to high surge pressure at the time of full load rejection. The ball valves functions well without restriction of flow and pressure drop. In addition, the ball valves provide, tight seal at high pressure, while butterfly valves are prone to leakages at high pressure.

9.3 Cooling Water

The amount of cooling water has not been assessed and without knowing the required water flow the source of cooling water cannot be properly decided. In the proposed vertical E&M equipment cooling system for generator would also be a requirement as mentioned in the FS report. Cooling water has been proposed from the upstream of the header penstock pipe, which is normally done for smaller sized equipment where the water requirement use to be lesser. It is not appropriate to take higher amount of cooling water from the header penstock due to high pressure & the requirement of reduction in the pressure & proper sealing of the water feeding line. The requirement of cooling water needs to be assessed and provision of gravity cooling water supply arrangement from the river with stand by water supply source through lift pumps from the tail race may be made to ensure uninterrupted water supply to the cooling system.

9.4 Synchronous Bypass Valve

The Jagran-4 HPP is to be operated in cascade with other hydropower projects constructed or planned to be constructed on same river in series such as 30.4 MW Jagran-1 already in operation and the under construction 48 MW Jagran-2 & 35 MW Jagran-3 projects. The proposed model of back flow of water to the forebay & spilling into the river at the occasions of shut down will disrupt the continuity of flow in the river and operation of the downstream power stations will adversely be affected. Therefore, provision of synchronous bypass valves with each turbine simultaneously regulated by the governing mechanism of each turbine may be considered at the time of detail engineering design of the project. This will also mitigate the

issue of surge pressure in the penstock pipe due to part or full load rejection and the thickness of penstock can be reduced resulting decrease in cost of the penstock component.

9.5 Synchronous Generator

Vertical synchronous water-cooled generators are proposed in the FS. Horizontal air-cooled generators can be considered as space is available for a powerhouse building to accommodate 4 Nos. horizontally oriented T.G. sets. In this way cost saving can be done at the implementation stage besides easy access to each component for O&M. The E&M equipment to be designed having fly wheel of GD2 value to allow a safe closing time of the guide vanes with respect to the reflection time of the penstock, so that the surge pressure in penstock is not more than 25% as the penstock length to head ratio of the project is 12.3 in case no synchronous bypass relief valve is installed with each turbine.

The proposed insulation class F may be reviewed, and insulation class of F/H/F may be considered.

9.6 MV Switch Gear

The detail parameters of 11 kV MV switch gear such as withstand voltage, short circuit current, C.T. ratio, P.T. ratio, metering details etc. are not mentioned in the FS report. These data are recommended to be considered in a bankable FS report.

The detail specifications and sizes of 11 kV MV cables are also missing, which may be considered during detail design stage.

The synchronization system details and specifications are not mentioned in the FS report. The specifications and technical data of synchronization panel, D.C. panel and control panel are missing in the FS report, which is required to be incorporated.

SCADA & telecom as per WAPDA & NTDC standards design & specification has been referred in the report but the technical descriptions and relevant technical parameters/data in accordance with the project requirement neither mentioned in the report nor annexed with the report. These details must be either incorporated in the report or annexed.

9.7 132 kV Interconnection and Grid Station

The specification & technical data of 132 kV P.T, C.T., Surge Arrestor & DSES of 132 kV switch yard are not given in the FS report. These features must be considered in the detail design stage.

The capacity of two step up transformers proposed seems to be on lower side. Need to consider transformer capacity of 13/15 MVA. All technical data of the power transformer are not enlisted.

In the transformer protection section, the REF protection is missing. The protection system should be complete in all respect as per WAPDA standard and all the technical data needs to be incorporated in the detail design stage.

9.8 LV Installation

Two 630 kVA (1 MW) auxiliary transformers are proposed which seems to be on very higher side. The load assessment of auxiliary equipment, powerhouse lighting & HVAC system, switch yard lighting system, drainage/lift pump load etc. are missing in FS, which is required to be assessed and considered in the detail design stage.

The battery bank sizing mentioned in FS is not supported with the detail of requirement i.e. protection supply & D.C emergency supply.

No technical details of Fire Protection & Detection System are given. The protection system varies with respect to different installation e.g. for 11 kV switch gear AFFF and CO_2 extinguishers are used, in battery room smoke detectors are needed and so on. It is required to list up the FP&DS in accordance with the actual need of each unit.

9.9 Transmission Line

No technical details of 132 kV OHTL equipment is given in the FS report. It is required to list up complete technical specification & data of each transmission line accessories and materials and incorporated in the report.

9.10 Conclusion

a) The Electro-mechanical equipment & the auxiliary equipment sizing & design are required to be made precisely to achieve maximum energy output based on the topography & hydrology of the site.

b) Horizontally oriented 750 rpm speed Francis turbines are recommended

c) New penstock alignment following the roadside layout is recommended with synchronous bypass valves with each turbine simultaneously regulated by the turbine governing mechanism to ensure reduce surge due to water hammer & continuity of flow to the intake of next power station.

d) Ball valves may be used instead of butterfly valves to avoid pressure transients during opening & closing of the inlet valve.

e) In case of horizontally oriented E&M equipment brushless rotary excitation system may be considered.

f) List of tools & spares are required to be made part of the feasibility report.

g) All technical specifications & technical data of switch yard MV &HV equipment, 132 kV transmission line & auxiliary services are not incorporated in the feasibility report, which are needed to prepare the employer's requirement at the procurement stage.

10 CASCADE OPERATION IMPACTS

The proposed Jagran-4 HPP is planned at upstream of the existing 30.4 MW Jagran-1 HPP. In series to the Jagran-1, Jagran-2 & 3 are under implementation in the downstream on the same river. When operational, practically all these HPPs are to be operated in cascade mode, as the operation of these projects is dependent on operational status, and continuity of flow from the upstream HPP in series. The operational dependency will be more critical during low flow season.

It is common phenomenon that the discontinuity of flow causes at the time of tripping due to any fault current in the outgoing electrical circuits of power supply resulting load rejection and back flow of water towards forebay and spilling back into the river. This process of back flow and diversion of water via river course to the intake of the next power station take some time and the water supply to the downstream power station is interrupted, which is undesirable and causes destabilization of the entire power complex developed on the same river and connected to one grid.

Due to such operational issues in any of these HPPs in series, the required flow in the upstream if disturbed even for a short period of time, there will be power shut down or load rejection in all the downstream hydro power stations.

Almost all the HPPs completed, under implementation and/or planned on the Jagran River have design flows of less than Q_{30}. Surplus flow will be available for 30% period of a year, wherein 70% period of the year, except environmental flow the entire available flow would require to be diverted into the intakes towards the systems for optimal generation. The operational risks in these projects being developed on Jagarn River in cadscade are required to be considered in the planning and design stage otherwise the risk of unstable power generation will be very high at the operational stage.

Considering the above operational risks, the cascade impacts need to be studied and considered in the design. The Jagran-1 is already completed, while Jagran-2 & 3 are under implementation and Jagran-4 is at planning stage, however, it seems that in the design of all these projects the Cascade Impacts at operational stage have not been considered, therefore

it is recommended to consider this aspect in the projects under implementation (Jagran 2 & 3) and in planning (Jagran-IV) on Jagran River to avoid power supply interruptions and outages at operational stage.

It is also recommended to carry out analysis of generation versus flow for each HPP, so that the loading plan of each power station during lean flow period is known to each operator to maintain the load proportionate with the available flow in the river. Furthermore, a SCADA system shall be developed for monitoring and loading of each power station in accordance with the loading plan from a central load control & dispatch station.

11 CONSTRUCTION COSTS

11.1 Review Approach and Methodology

The review follows the methodology generally applied in HPPs, with a division between civil costs and equipment (mechanical, electrical, transmission lines and HSS). The construction costs are structured as follows:

- Civil Works
  - Direct Cost
  - Indirect Costs
- Hydraulic Steel Structures
- Mechanical and electrical equipment
- Switchyard and transmission

The direct costs of civil structures result from the estimation of quantities and the estimate of their unit price; the cost of equipment is derived from the Consultant's internal database reflecting the price level for equipment on the local and international market.

Some costs are directly linked with the developers/owners and should be borne independently from the contract form for the Owners Engineering or other issues. This is all the costs related to the activities required for the pre-development of the project until the contract award, the costs related to land acquisition, environmental and social costs, etc., as well as the costs required for the administrative follow up and the supervision of the works during the project implementation.

11.2 Civil Works

11.2.1 Units Price Assessment

The unit rates used for Civil works in FS are considered as market based, however these needs to be supported with rate analysis. Due to the project remote area, it is envisaged that the cost of construction material will be impacted through their availability in the country and through the transportation of them to the construction site.

For the present critical review, the unit prices for civil works were assessed from several projects mostly carried out in Pakistan, at different development stages from feasibility to execution, or directly from contractors active in the region. Although the projects cannot be named for confidentiality reason, the following indications are summarized as:

- Several corrections have been made in the BoQ presented in the FS to keep a constant exchange rate between Rs. and $US. After these corrections, the total amount of the costs reaches $US 49.173 million instead of $US 43.249 million in FS.
- Pressure pipe thickness was taken as 8 mm for its entire length of about 3.0 Km. The pipe thickness has been reviewed and is taken as 10 mm to 26 mm. The unit rate for pressure pipe 2.4 m diameter is updated.
- The cost of hydro mechanical and electrical equipment's needs to be revised/updated. Considering the market prices for such size and type of equipment's, the costs have been updated.

11.2.2 Costs of Civil Works

A bill of quantity was developed based on the elaborated feasibility drawings as well as, for some civil structures, based on models allowing to determine the main quantities of the major structural components required for the hydropower project, or some drawings or the quantities defined by the Consultants design experts. Hence, based on the available design, the volume of the main component/material is tentatively estimated, and their cost is determined.

The costs of diversion works have been realistically improved. The number of anchor block and BOQ are reviewed and included in the cost. When Synchronous surge Relief Valves and pressure pipe costs are included, the cost of penstock pipe will not be required. Similarly, the missing lateral overspill which should have been considered in the design are considered in the contingencies. The summary details of the main features are given in Table 3. **The details of costs is attached at Annex 13.3.**

Comparing the costs those found in the FS and after critical review (DD: due diligence.)

Table 4: Selected Units Prices

Sr. No.	Description	TPV Recommended	As per FS
		$US	$US
I	**Land Acquisition, Roads and Environment**	**0.378**	**0.347**
II	**Civil Works**		
1	Road and Preliminary Works	2.075	2.34
2	Weir	0.586	0.88
3	Power intake to De-sander	0.664	1.25
4	Headrace Pressure Pipe		6.44
5	Embedded Penstock Pipe	14.87	1.35
6	Surge Pipe		1.12
7	Powerhouse	0.918	2.16
8	Tailrace	0.376	0.43
	Sub Total II	**19.866**	**16.31**
III	**E&M Equipment**		
1	Hydro-Mechanical Equipment	3.640	4.51
2	Electrical Equipment	5.254	5.09
3	132 kV Transmission Line and Interconnection	0.750	0.50
	Sub Total II	**9.644**	**10.10**
	Sub Total II + III	**29.510**	**26.40**
IV	Transportation (4%)	0.386	0.40
V	Erection & Commissioning (10%)	0.964	1.01
VI	Engineering & Supervision (5%)	1.457	1.30
VII	Project Director and Staff Expenses (5%)	1.457	1.30
VIII	Import Charges (5% of E&M)	0.374	0.41
	Base Cost	34.147	30.83
	Contingencies (3%)	1.024	0.92
	Total Base Cost	**35.172**	**31.76**
	Interest During Construction	14.001	11.49
	Total Project Cost	**49.173**	**43.249**

The total costs is compared from the FS with price index of May 2010 (1 USD= 85 Rs.) and the present study with price Index July 2021 (1 USD= 158 Rs.)

11.2.3 Indirect costs

The indirect Civil costs are all the costs that are inherent to the site installation and operation during the construction works. It is common practice in this phase to consider preparation of the construction sites, camp installation, camp infrastructure and site administration as a percentage of the direct cost of the civil works. A percentage comprised between 7.5% and 15% is usually applied depending on the type of hydropower plant and its dimensions. In the

present case, 7.5% of the construction cost is assumed in the framework of this review and validation, considering that local contractors will participate in the construction.

11.2.4 Contingencies Allowance

Irrespective of the level of design, some elements of uncertainty always remain in the cost estimations of the hydropower plants, for which usually physical contingencies are included in the cost estimates to cover, for example, the following:

- Unforeseen construction items
- Errors or inaccuracies in the quantity calculations
- Unforeseen deviations from expected geological, topographical, or hydrological values.

Therefore, the application of a contingency allowance in order to take into account the prices and the quantity contingencies, as well as the level of technical development is highly recommended. The contingencies normally considered is 5% but in the FS are 3% of the construction cost (Civil works and E&M works), which may be reviewed.

11.2.5 Project Development Costs

In case the Project will be implemented under several contracts managed by the Owner or its Engineer, the costs borne by the Owner are increased for the technical and administrative development of the Project. The so-called development costs are:

- Environmental and Impact Assessment
- Engineering (Tender Design and Tender Documents)
- Owner's engineering
- Administration of the Owner

12 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The review of FS carried out by FHC shows that there are several gaps in assessment of hydrology, project layout, topographic survey, feasibility design, selection of weir intake, pressure pipe material, powerhouse sitting, selection of E&M equipment, BoQs, and cost estimates.

These gaps in the FS must require to be rectified before approval of project PC-1, so that tendering and implementation of the project will be accomplished without major design and cost revisions.

The consultants review findings and recommendations are summarized as following:

- The catchment is slightly underestimated (214 Km^2) instead it shall be considered as 205 Km^2.
- The design discharge in FS is overestimated as 18 m^3/s which is recommended to be considered as 16 m^3/s.
- The 500 years return period considered in the FS is conservative. While considering this period, appropriate flood protection measures are considered in the detail design.
- No sediment measurements have been carried out in the past in Jagran River, neither for suspended load nor for bed load. If not studied and considered at this stage, it will have serious impacts on Operation and Life of the proposed project. Therefore, sediment simulation study should be carried out and considered in the detail design and operation of the projects in series. Adequate design and operational measures should be considered to mitigate the sediment impacts.
- The findings and results of Geotechnical Investigation field and laboratory reports, which is currently under implementation should be considered in the tender and detail design of the project.
- The selection of project features, weir intake, sand trap, forebay, pressure pipe (GRP) and its alignment, powerhouse location in the FS needs to be reconsidered as following:

    - The proposed weir intake location recommended to be shifted 120 m downstream where river strata narrow with firm bed.

    - The sand trap is recommended to be designed such that it shall not hamper the operation (during de-sanding). The forebay shall be designed appropriately.

- The pressure pipe is proposed along hillside. Instead, it is recommended to lay it along the roadside which would be economical in construction and operation and little environmental impacts.

- GRP pressure pipe (L=3,075m) along hill side has been proposed in the FS. Instead, MS pipe (L=2,730m) along roadside is recommended, which is considered as more feasible and cost effective in construction and operation stage.

- In the new layout along roadside four options of pipe sizing have been recommended. The hydraulic analysis of pressure pipe along roadside for various load conditions shall be carried out at detail design stage to determine the diameter and thickness of the pipe.

- Vertical Francis turbines have been proposed in the FS, which is considered as cost intensive in construction of powerhouse, auxiliary structures and during O&M. Instead, Horizontal Francis turbines are recommended to be installed. In case of horizontally oriented E&M equipment brushless rotary excitation system shall be considered.

- In FS 6x4MW and 1x4MW Vertical Francis Turbine Units have been proposed in FS. Instead, it is recommended to consider 6.67MWx3 and 2 MWx1 Horizontal Units. The hydraulic analysis of pressure pipe for various load conditions needs to be carried out at detail design stage to determine the diameter and thickness of the pipe.

- Vertical oriented 1,000 rpm speed Francis Turbines have been recommended in the FS. Instead, horizontally oriented 750 rpm speed Francis turbines are recommended.

- Vertical synchronous water-cooled generators are proposed in the FS. Horizontal air-cooled generators can be considered as space is available for a powerhouse building to accommodate 4 Nos. horizontally oriented T.G. sets.

- Butterfly Inlet Valve(s) have been selected in FS. Instead, it is recommended to consider Spherical Valve(s) *(ball valves)*

- Cooling water is proposed from the penstock/pressure pipe. Instead, it is recommended to be arranged from independent source (gravity flow) and stand by lifting from the tail race.

- The detail specifications of 11 kV MV switch gear such as withstand voltage, short circuit current, C.T. ratio, P.T. ratio, metering details etc. are not mentioned in the FS report. It is recommended to be considered in the tender and detail design report.

- The detail specifications and sizes of 11 kV MV cables are not considered in FS. It is recommended to consider during detail design stage.

- The synchronization system details and specifications are not mentioned in the FS report. The specifications and technical data of synchronization panel, D.C. panel and control panel required to be considered.

- SCADA & telecom as per WAPDA & NTDC standards design & specification has been referred in the FS report and the technical descriptions and relevant technical parameters/data in accordance with the project requirement are not mentioned in the report. These details are recommended to be considered in the tender and detail design.

- The specification & technical data of 132 kV P.T, C.T., Surge Arrestor & DSES of 132 kV switch yard are not mentioned in the FS report. These features are recommended to be considered in the detail design stage.

- The capacity of two step up transformers proposed in FS are on lower side. This need to be considered with capacity of 13/15 MVA. Further in, REF protection is not mentioned. It is recommended to consider the protection system complete in all respect as per WAPDA standard and all the technical data to be incorporated in the detail design stage.

- Two 630 kVA (1 MW) auxiliary transformers are proposed in FS, which seems to be on very higher side. The load assessment of auxiliary equipment, powerhouse lighting & HVAC system, switch yard lighting system, drainage/lift pump load etc. are missing in FS, which is required to be assessed and considered in the detail design stage.

- The battery bank sizing mentioned in FS is not supported with the detail of requirement i.e., protection supply & D.C emergency supply. This need to be incorporated.

- No technical details of Fire Protection & Detection System are given in FS. The protection system varies with respect to different installation e.g. for 11 kV switch gear AFFF and CO_2 extinguishers are used, in battery room smoke detectors are needed. It is recommended to list up the FP&DS in accordance with the actual need of each unit.

- No technical details of 132 kV OHTL equipment is given in the FS report. It is recommended to list up complete technical specification & data of each transmission line accessories and materials and incorporated in the report.

- List of tools & spares are not mentioned in FS report. It needs to be included in tender and detail design stage.

- Technical specifications & technical data of switch yard MV &HV equipment, 132 kV transmission line & auxiliary services are not incorporated in the FS report which has a cost implication. It is recommended to consider these details to prepare the employer's requirement at the tendering stage.

- No mechanism has been proposed in FS for continuity of flow to ensure smooth operation of project in series downstream of Jagran-4. Therefore, it is recommended to provide synchronous bypass valves with each turbine simultaneously regulated by the governing mechanism of each turbine shall be considered for smooth operation of HPPs in the downstream.

- The project is to be run in cascade with the other HPPs in the same catchment, therefore cascade study for foolproof operation of these projects may be carried out. It is recommended to carry out analysis of generation versus flow for each HPP, so that the loading plan of each power station during lean flow period is known to each operator to maintain the load proportionate with the available flow in the river. Furthermore, a SCADA system is required be developed for monitoring and loading of each power station in accordance with the loading plan from a central load control & dispatch station.

- In site selection and placement of powerhouse, the impacts of highest floods and avalanches have not been critically considered. Therefore, it is recommended to shift the powerhouse slightly upstream (approx. 20m) from the proposed location to a safer

location. However, the proposed location and flood impacts, protection structures shall be carefully considered at the tender and detail design stage.

- Several corrections have been made in the BoQ presented in the FS to keep a constant exchange rate between Rs. and $US. After these corrections, the total amount of the costs reaches $US 49.173 million instead of $US 43.249 million in FS.

13 ANNEXES

13.1 Topo Survey Report

13.2 Proposed New Layout Plan

13.3 Updated Detail Cost Estimates

13.4 Photo Gallery

13.5 Geotechnical Investigations Report

13.1 Topo Survey Report

ANNEX-13.1

TOPOGRAPHY

July 2021

1. Table of Contents

13.1 TOPOGRAPHY 44
13.1.1 General 44
13.1.2 Purpose of Work 44
13.1.3 Scope of Work 44
13.1.3.1 Survey Methodology 44
13.1.3.2 Coordinate Systems 45
13.1.3.3 Traverse Survey 45
13.1.3.4 Levelling 45
13.1.4 Structural Survey 46
13.1.5 Description of Topo Maps Work 46
13.1.6 Benchmarks and Control Points 48
13.1.6.1 Primary Survey Control 48
13.1.6.2 Secondary Survey Control 49
13.1.6.3 Horizontal Control 50
13.1.6.4 Vertical Control 50
13.1.7 Topographic Survey 51
13.1.8 Survey Processing 51
13.1.8.1 Setting up a Surface Model 51
13.1.8.2 Triangulated Irregular Network“TIN” 52

2. List of Tables

Table 13.1: Configurations & Options of Total Station Leicia TS06 47
Table 13.2:Code List 51

3. List of Figures

Figure 13.1:Topographic surveying at Project Site Area 48
Figure 13.2:Steel rod fixed on Concrete monument, Survey Marker-9 48
Figure 13.3: Survey Area proposed powerhouse (upstream of Jagran-I weir) 50

13.1 TOPOGRAPHY

13.1.1 General

The topographic survey of the project area provides the basis for the project layout and planning of its structures and ancillaries. Except for the nominal permissible instrument errors, the accuracy of survey data is a primary objective.

13.1.2 Purpose of Work

The survey aimed to prepare the topographic mapping of the 22 MW hydropower project including basic site plan and the preparation of L-section & X-sections of Jagran River upstream and downstream of the proposed structures.

The topographic survey covers the concession area from Shaal Nullah to Jagran-I weir upstream of Gorial village. It was carried out by a team of experienced and professional surveyors under the supervision of professional field engineers using latest equipment (Digital Total Station, EDM, and Auto level Camera) and techniques. The extent and requirements of the survey were planned, scheduled and directed to meet the need of the geologist and the design engineers for the detailed design study. Mapping is used for project planning, preparation of construction material, quantity and construction cost estimates and preparation of the concept design documents. Furthermore, cross sections were taken from the Jagran River to allow estimation of water levels under various hydrological conditions.

13.1.3 Scope of Work

13.1.3.1 Survey Methodology

The survey included a number of at minimum 100 m to 600 m wide strips across the Jagran River route located 100 to 250 meters upstream & downstream of major structures from the Centreline of Jagran River on both sides. The position of all existing topographical features including roads, existing powerhouse, existing forebay, transmission line, houses/ settlements, boulders, existing wooden bridge, riverbank and water lines are marked. The horizontal and vertical information in Northing-Easting elevation form, showing the natural and artificial features by contour lines, the hills and mountain locations, rivers, farmlands, existing canals, existing or under construction structures, etc. (natural features) and buildings, utility location and other manmade features (artificial features).

The following main tasks have been included in the scope of work:

- Installation of permanent bench marks established at appropriate locations (major structure locations) with level
- Installation of thirteen survey marks
- Traverse connection and vertical control of all control points
- Generation of topographic sheets by using CAD/12D techniques
- Topographic survey in sufficient detail at the proposed area to support preparation of 1:1000 scale, 1 m contour interval maps
- Longitudinal profile of river upstream and downstream of weir
- L-section and X-section of intake canal, settling basin, forebay, penstock alignment, powerr house and tail race
- Upstream and downstream X-sections of proposed weir area.

13.1.3.2 Coordinate Systems

The Survey of Pakistan (SOP) Benchmarks were traceable in the nearby area (Jagran-I weir), and permanent benchmarks were established with reference to BM-A and BM-B in all project area.

13.1.3.3 Traverse Survey

The traverses survey was based on the following parameter:

(i) Horizontal angle measurement
  (a) Horizontal angles measured/observed by 2 rounds of angle on 2 different zero settings
  (b) The Total Station instrument used was capable for reading horizontal and vertical angles to at least 10 seconds fraction

(ii) Distance measurement
  Electronic Distance Meter (EDM) is used for distance measuring, which is accurate to at least 10 mm + 5 ppm x D;

(iii) Accuracy of primary traverse
  Linear mis-closure of the primary traverse is better than 1/10,000.

13.1.3.4 Levelling

Levelling was started from an existing Datum Benchmark (BM-A), primary control monument or a from secondary control point located close to another of these benchmarks, monuments or points. The levelling survey methodology applied is as follows:

(i) An automatic or digital level is used for fly levelling
(ii) Misclosure of leveling between existing benchmarks and primary control monuments is not exceed + 30 mm $\sqrt{D}$, where D is distance between existing benchmarks or Primary Control Monuments.

13.1.4 Structural Survey

The topographic survey was carried out for alignment/layout of structures as per TOR. The survey was conducted with the most modern and sophisticated Total Station. Computer Software "12D" has been used for plotting the surveys. Survey of Pakistan (SOP) Benchmarks has been used to establish the control points at suitable locations.

For major structures, suitable polygonal traverses were developed separately for the proposed structure sites. The polygons were divided into triangles and triangulation survey was carried out, starting with the base line as one of its sides.

After establishing the control points, data was acquired with the help of the digital total station. All-important land features like roads, tracks, nullahs, rivers, high flood levels and other man-made features were picked up according to their geographical position.

The topographic survey of main structures was carried out and mapped as follows:

- **Intake Area**

The diversion weir covering all appurtenant structures (head works, spillway etc.) with contour interval of 1 meter in a scale of 1:1,000 supported by sufficient numbers of X- (upstream and downstream) and L-sections as per site requirements.

- **Approach Canal**

Approach canal area at 1 m contour interval at a scale of 1:1,000 supported by sufficient numbers of L- and X-sections as per site requirements.

- **Forebay /Desilting Basin**

Detailed survey has been carried out for forebay cum peaking/desilting basin area, with contour interval of 1m at a scale of 1:1,000 supported along with L- and X-sections to ensure the most accurate position of the forebay /desilting.

- **Penstock**

Alignment of penstock with contour interval of 1 m in a scale of 1:1,000 supported by sufficient number of cross sections and long sections as per site requirements.

- **Powerhouse**

Survey of powerhouse area including tailrace canal with contour interval of 1 m in a scale of 1:1,000 supported by required cross sections and L-sections as per structure requirements.

Topographic survey maps of all sites are presented in the "Topographic Drawings" (Annex 3-I).

13.1.5 Description of Topo Maps Work

The topographic surveying was conducted by using Total Station of Leica TS 06 plus and Auto Level Sokkia-C30 Auto Level. The salient features of the equipment are summarized in Table 3.1.

Table 13.1: Configurations & Options of Total Station Leicia TS06

1” angular accuracy	
Enhanced measurement accuracy to prism	1.5 mm + 2 ppm
Reflector less measurement range	500 m included/1000 m option
Display with graphics and display illumination	Black & White high resolution
Full alpha-numerical keyboard with function keys	□
Second Keyboard	□
Keyboard illumination	–
Electronic Guide Light	□
USB Type A and mini B	□
Bluetooth® Wireless	□
SD Card	–
Imaging capability	–
Smart Station GNSS capability	–
Onboard software (package content)	Flex Field plus (advanced)

Source: Leica Geosystems

- Prism Mode
- Precision+ (1.5 mm + 2 ppm)
- Speed (1 second)
- Non-Prism Mode
- Precision (2 mm + 2 ppm).

Pinpoint EDM with coaxial, small laser pointer and measurement beam for accurate aiming and measuring was used.

Topographic maps have been prepared using advanced engineering software 12D. The maps contain planimetric features encountered during field surveys, including houses, roads (paved and unpaved), cultivated lands, vegetation, electric and telephone lines, trees and other built-up properties. Topographic features such as roads, tracks, spot elevations of water surfaces at the river as well as the high and low points at hill tops and depressions are shown on the maps to depict the relief of the area.

Figure 13.1:Topographic surveying at Project Site Area

Source: INTEGRATION

13.1.6 Benchmarks and Control Points

13.1.6.1 Primary Survey Control

Prior to the commencement of the topographic and level surveys, primary control points (Survey Marks) have been established along the full length of the section at nominal 1.0 km spacing and space at maximum intervals of 500 m and located in a way that minimum of two adjacent points are always inter-visible. A primary control survey was carried out to determine X and Y co-ordinates of the primary control points by traversing.

Figure 13.2:Steel rod fixed on Concrete monument, Survey Marker-9

Steel rod on road edge **BM with Steel Rod**

Source: INTEGRATION

13 survey marks were established (3 on stable big boulders/rocks with steel rods drilled in half meter and exposed 5 mm above the surface and 10 permanent concrete monument with

steel rod fixed), so that they will not be disturbed prior to the start of construction works to remain intact throughout the construction period.

Sufficient space was provided around each "Survey Mark" to enable survey instruments to be erected and operated. Each Survey Mark has been marked with its reference number. Description sheet for each Survey Mark is shown as under.

S. No	BM No.	Easting	Northing	Elevation	Location
1	BM-A	3271577.078	1164431.048	2066.835	At Jagran-I Weir.
2	BM-B	3271563.820	1164428.351	2066.82	At Jagran-I Weir.
3	BM-2	3271534.621	1164856.705	2113.659	Steel nail R/S road edge 60 m upstream from powerhouse area.
4	BM-3	3271479.910	1165138.947	2129.776	Steel nail R/S road edge.
5	BM-4	3271465.480	1165318.147	2144.954	Steel nail R/S road edge.
6	BM-5	3271468.704	1165495.575	2152.252	Steel nail R/S road edge.
7	BM-6	3271431.975	1165778.665	2160.597	Steel nail R/S road edge.
8	BM-7	3271411.990	1165978.255	2156.462	Steel nail R/S road edge.
9	Bm-8	3271513.745	1166857.819	2216.364	Steel nail R/S road edge.
10	BM-9	3271558.388	1167555.983	2257.887	Steel nail R/S road edge.
11	BM-10	3271586.557	1167395.689	2240.441	Steel nail R/S road edge.
12	BM-9A	3271518.235	1167810.001	2269.279	Steel rod drilled in big boulder near School, weir area.
13	BM-9B	3271494.954	1167857.226	2272.496	Steel rod drilled in boulder left bank, upstream of weir.
14	BM-9C	3271574.412	1167556.636	2264.777	Steel rod drilled in boulder, uphill side near BM-9.

13.1.6.2 Secondary Survey Control

The survey was carried out to determine X, Y and Z co-ordinates of secondary control points by traversing. Secondary control points were established to provide a suitable basis for the topographic survey along river and other sites. Survey monuments (benchmarks) were established near weir and powerhouse locations using total station & employing traversing

method. The benchmarks (BM) were protected through iron rods fixed in the competent ground (e.g. rocks & concrete monument). The secondary control points located in a way that minimum of two adjacent points is inter-visible. The points have been located to fully enclose the required area of topographic survey at sufficient distance from the proposed sites, so that it may not be disturbed during the construction.

13.1.6.3 Horizontal Control

Horizontal control started from BM-A established with the reference of Survey of Pakistan (SOP) . The Total Station has been used for distance measuring whose accuracy was at least 1.5 mm + 2.0 ppm X D; (2 ppm: 2 cm per 10 km, D: Measured Distance 5). Linear mis-closure of the primary traverse was best than 1/10,000.

Figure 13.3: **Survey Area proposed powerhouse (upstream of Jagran-I weir)**

Source: INTEGRATION

13.1.6.4 Vertical Control

The mean sea level (masl) was established with reference to BM-A. All necessary precautions and standard procedures which are applicable to this class of survey have been adopted. Vertical Control was also started from BMA (Established by PDO with reference of Survey of Pakistan) and fly levelling (using Sokkia Auto Level C30 Magnification “32 X”) and closed by DT Levelling by making a loop close to the Benchmarks. Mis-closure was found being not more than 3.8 cm which was also adjusted.

13.1.7 Topographic Survey

A plane topographic survey incorporating man-made features was carried out to prepare the topographic map on scale 1:1,000 by using the grid co-ordinates and heights of the established control points. Features for contouring were picked up at every change of slope and contour interval of 1 meter. The man-made features with their respective codes are compiled in Table 3.2.

Table 13.2:**Code List**

Description	Code
Road	R1, R2
Track	TRK
Tree	TRE
Building	BLD
Culvert	CVT
Electric Pole	EP
Telephone Pole	TP
Water Edge of river	NE
High Flood Level	HFL
Existing Channel	CH
Retaining Wall	RW
Plinth	PL
Water Course	WC
Bolder	BLDR
Traverse Point	BM
Survey Marker	SM
Wall	WALL
Spot Height	SH
Village	VI
Powerhouse	PH
Forebay	FB
Check Post	CHK

Source: Own compilation

13.1.8 Survey Processing

After collecting the data from the field, the data was stored in the memory card of the Total Station, which was then downloaded into laptop-computers. Survey codes were used to capture different field features in different layers in the computer model. After checking the data for survey accuracy and codes they were then used to prepare the required topographic maps. The survey maps were then further edited to prepare the required plans. The survey maps were again checked against known reference points with respect to their accuracy.

13.1.8.1 Setting up a Surface Model

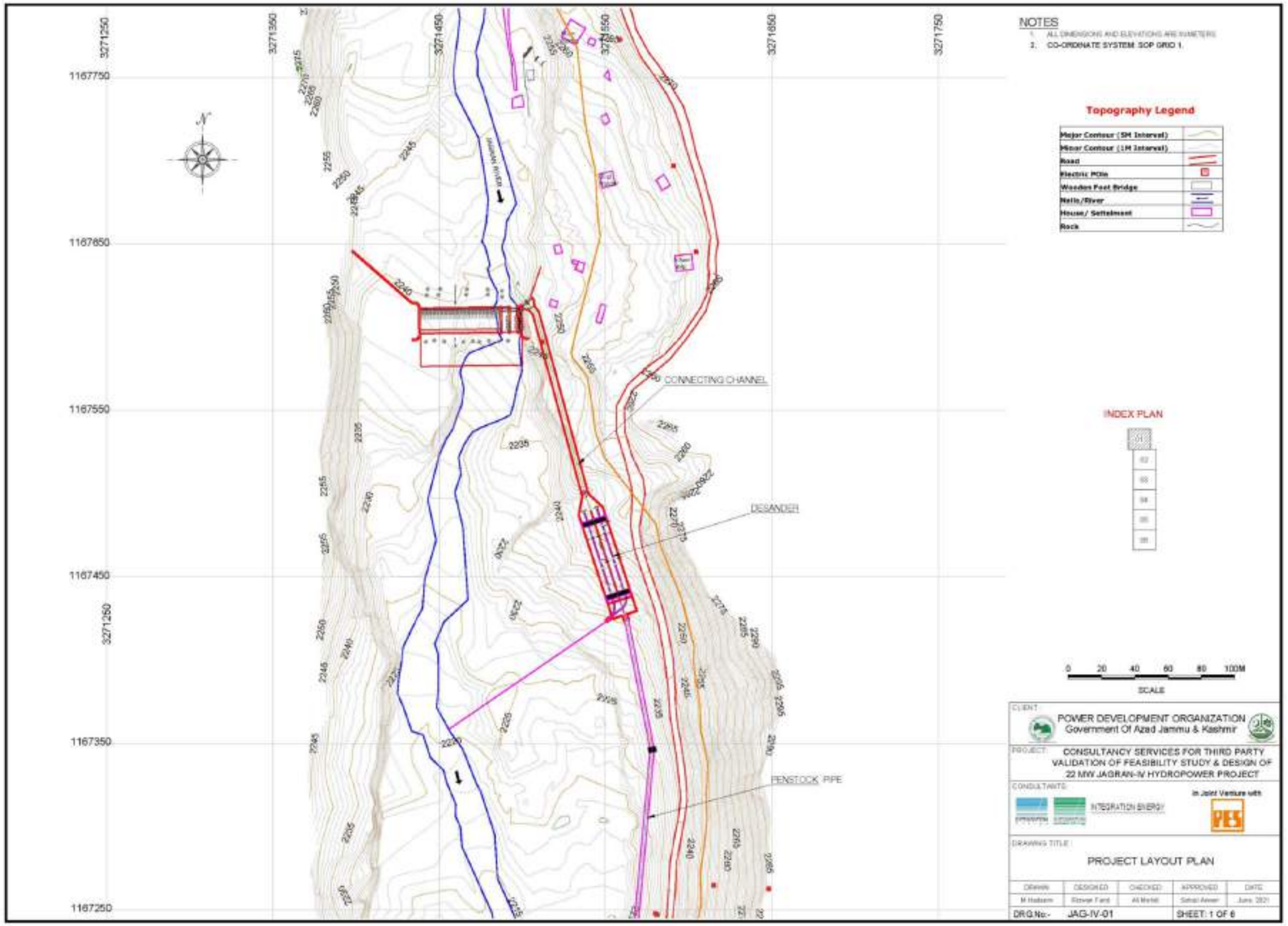
After setting the data a surface model is created. At first, properties which control the surface model itself were defined. In the next step the surface model was elaborated with parameters, such as description, minimum and maximum elevation range, and contour intervals, as specified for the model.

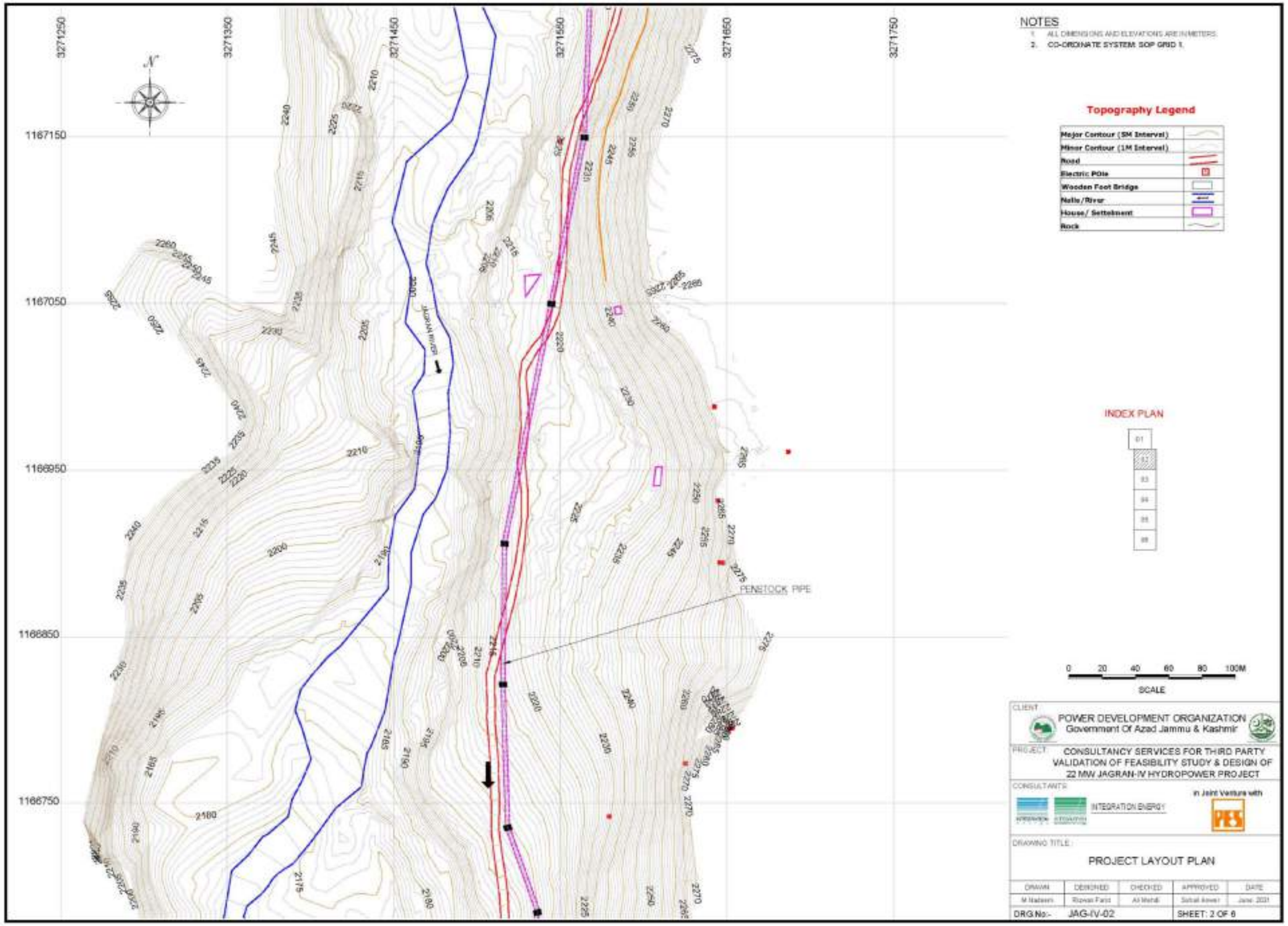
A boundary has been placed around the data set, so that surface modelling only triangulates the data within the boundary. This is useful when the site is not regularly shaped, and triangles are not created in an area due to lack of information. Furthermore, the boundary is placed in a 2-D or 3-D polyline (AutoCAD) to create a surface model and specify a boundary.

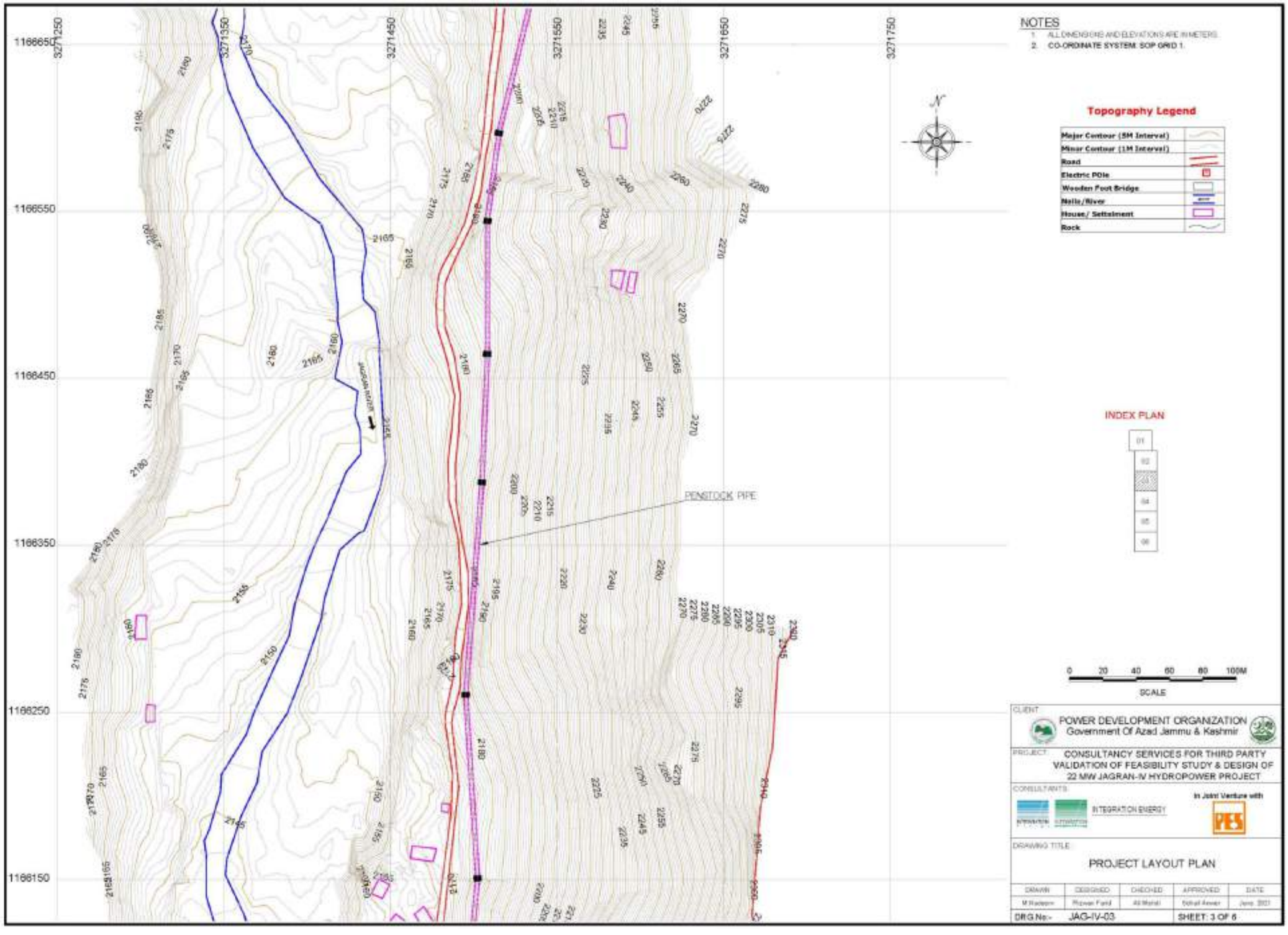
13.1.8.2 Triangulated Irregular Network"TIN"

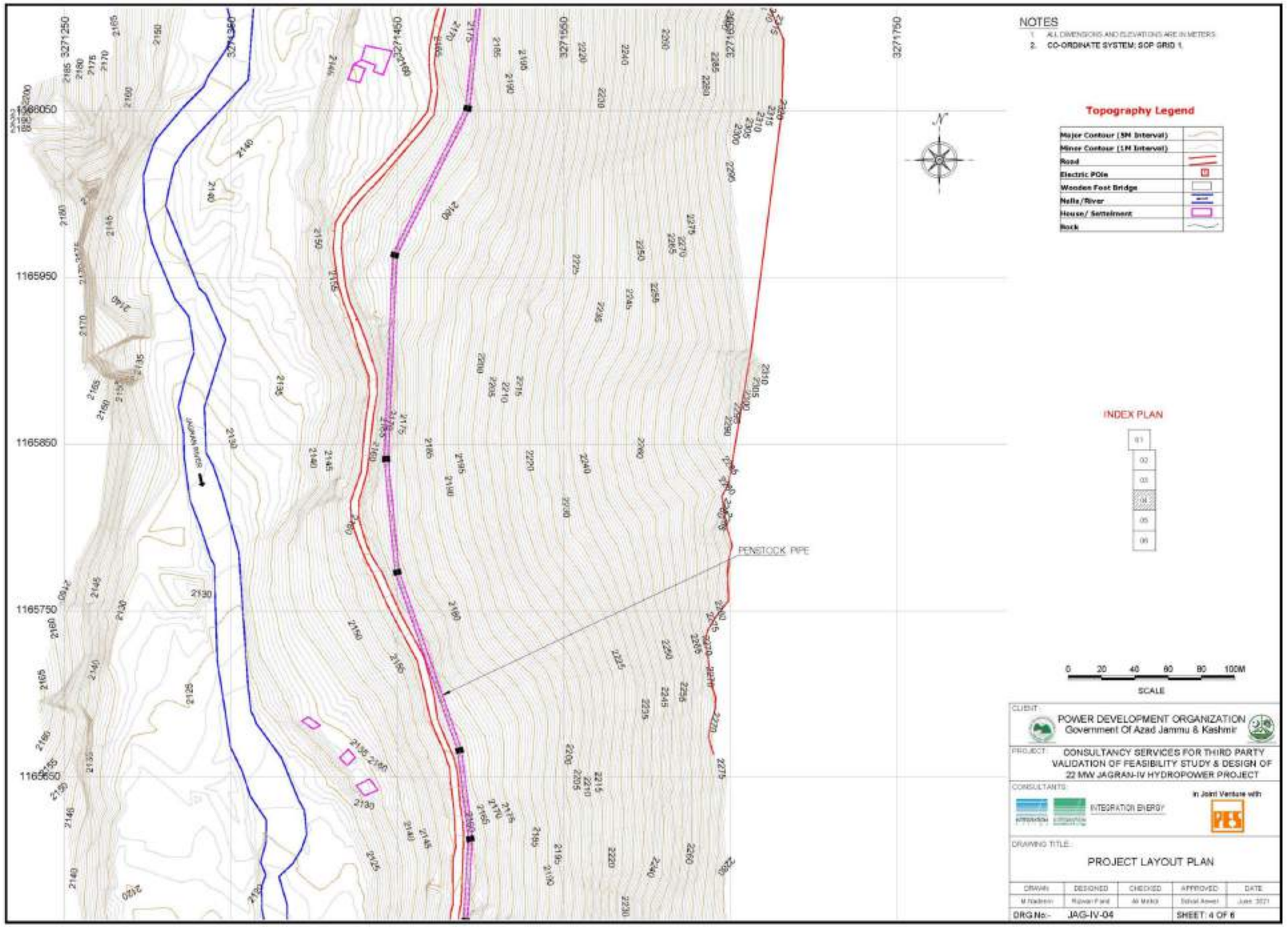
The triangulation process creates a network of triangles that finally makes up the surface model. The surface model information is contained in external files and is not part of the actual CAD graphic.

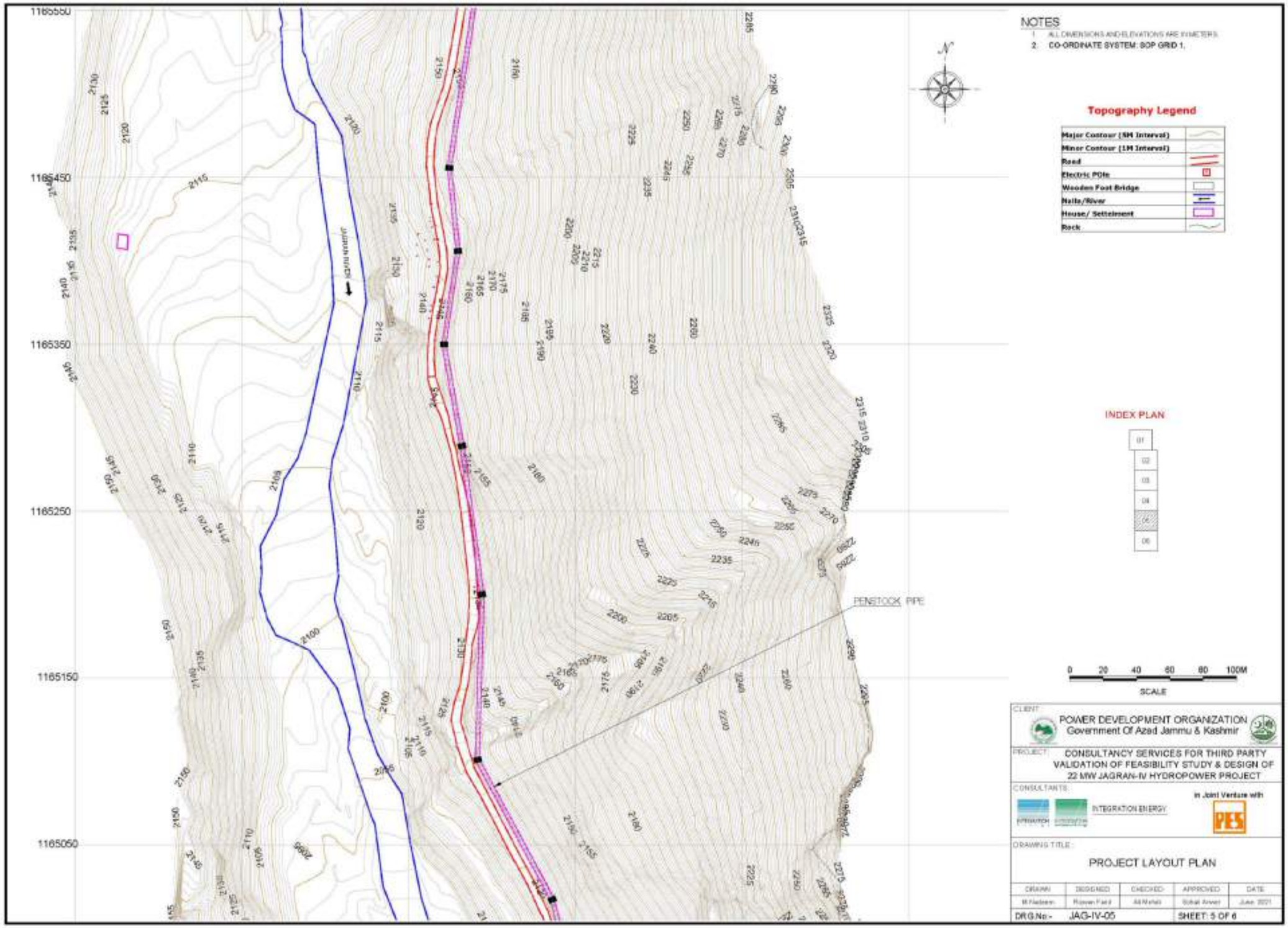
13.2 Project Alternate New Layout Plan

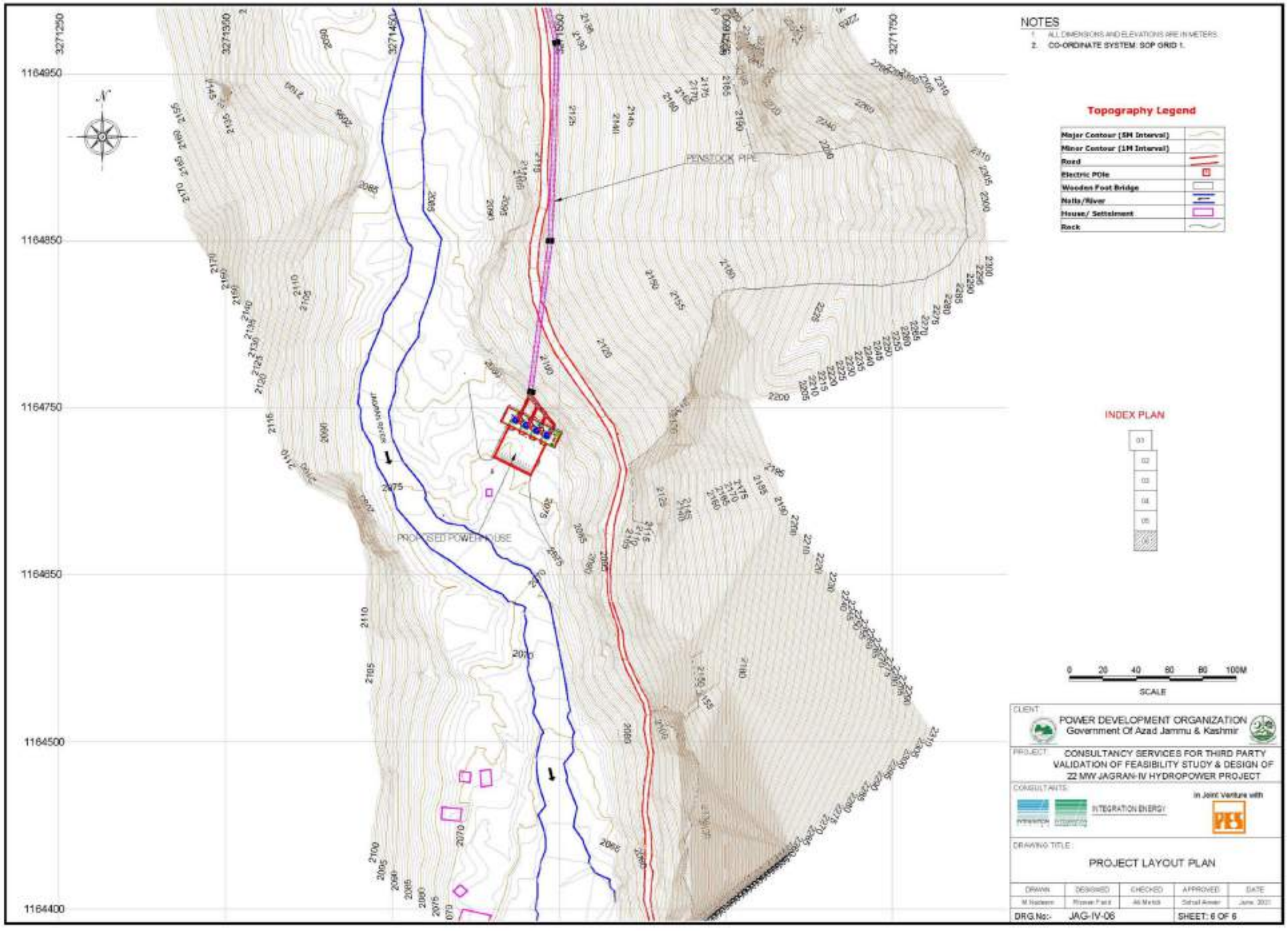


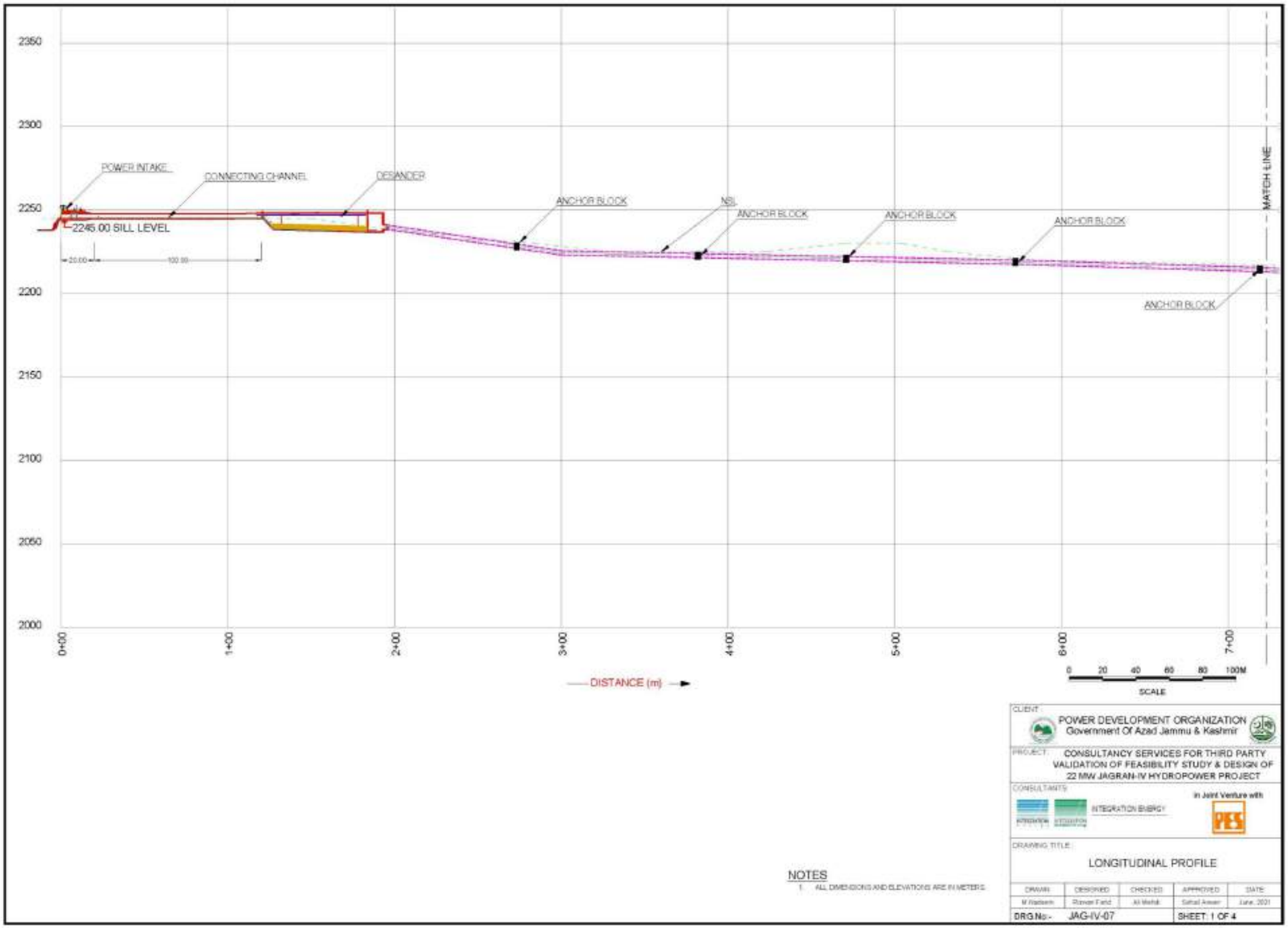

NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS.
2. CO-ORDINATE SYSTEM: SOP GRID 1.
Topography Legend
Major Contour (5M Interval)
Minor Contour (1M Interval)
Road
Electric POle
Wooden Foot Bridge
Nalla/River
House/ Settelment
Rock
INDEX PLAN
PENSTOCK PIPE
3271250
3271350
3271450
3271550
3271650
3271750
1167150
1167050
1166950
1166850
1166750
0 20 40 60 80 100M
SCALE
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
in Joint Venture with
INTEGRATION ENERGY
DRAWING TITLE
PROJECT LAYOUT PLAN
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG No:- JAG-IV-02
SHEET: 2 OF 6

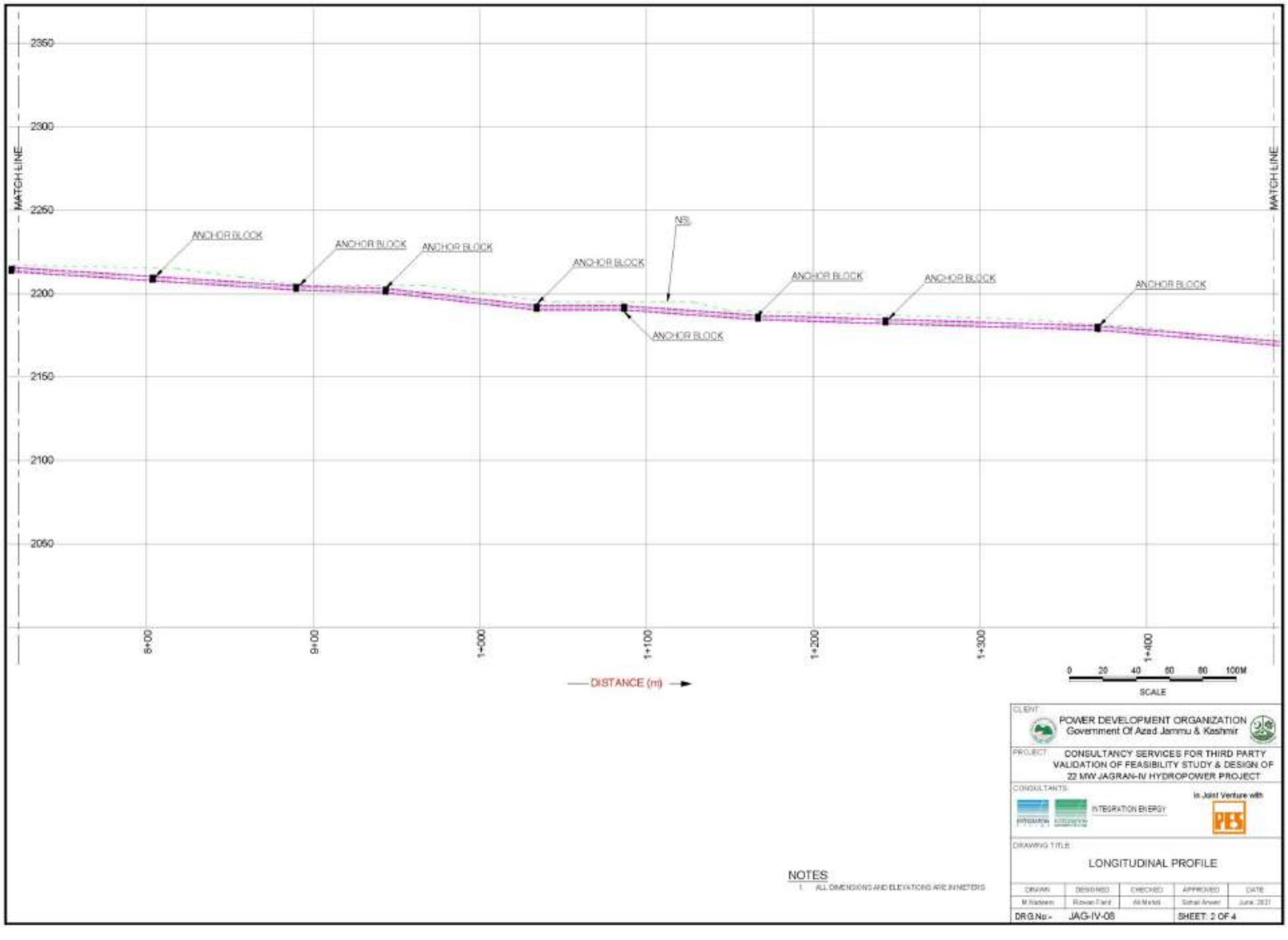

NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS.
2. CO-ORDINATE SYSTEM: SOP GRID 1.
Topography Legend
Major Contour (5M Interval)
Minor Contour (1M Interval)
Road
Electric POle
Wooden Foot Bridge
Nala/River
House/ Settelment
Rock
INDEX PLAN
PENSTOCK PIPE
0 20 40 60 80 100M
SCALE
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
In Joint Venture with
INTEGRATION ENERGY
DRAWING TITLE
PROJECT LAYOUT PLAN
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG No:- JAG-IV-03
SHEET: 3 OF 6

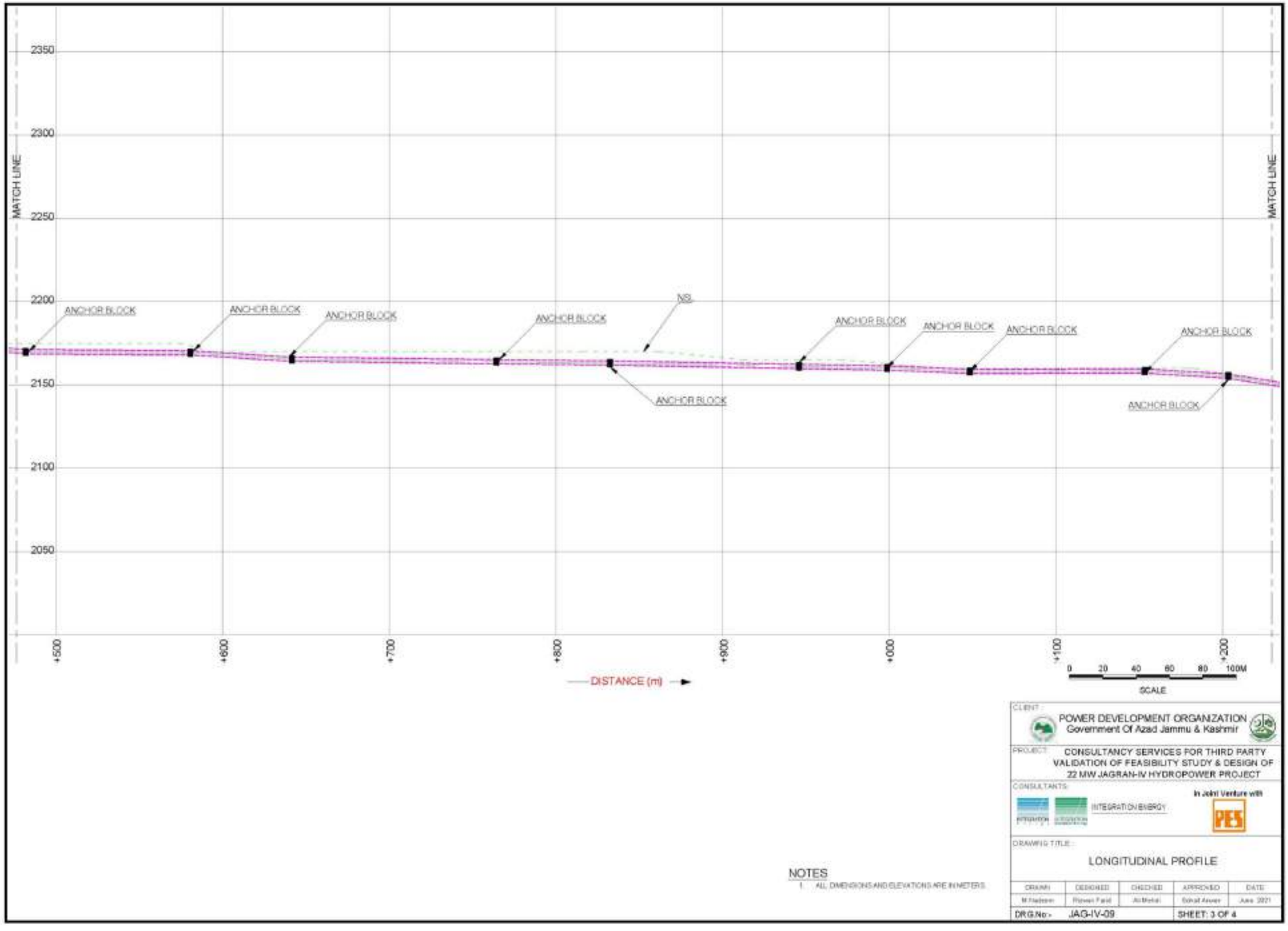

NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS
2. CO-ORDINATE SYSTEM: SCP GRID 1
Topography Legend
Major Contour (5M Interval)
Minor Contour (1M Interval)
Road
Electric POle
Wooden Foot Bridge
Nalla/River
House/ Settelment
Rock
INDEX PLAN
PENSTOCK PIPE
0 20 40 60 80 100M
SCALE
CLIENT:
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT:
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS:
In Joint Venture with
INTEGRATION ENERGY
DRAWING TITLE:
PROJECT LAYOUT PLAN
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG No:- JAG-IV-04
SHEET: 4 OF 6

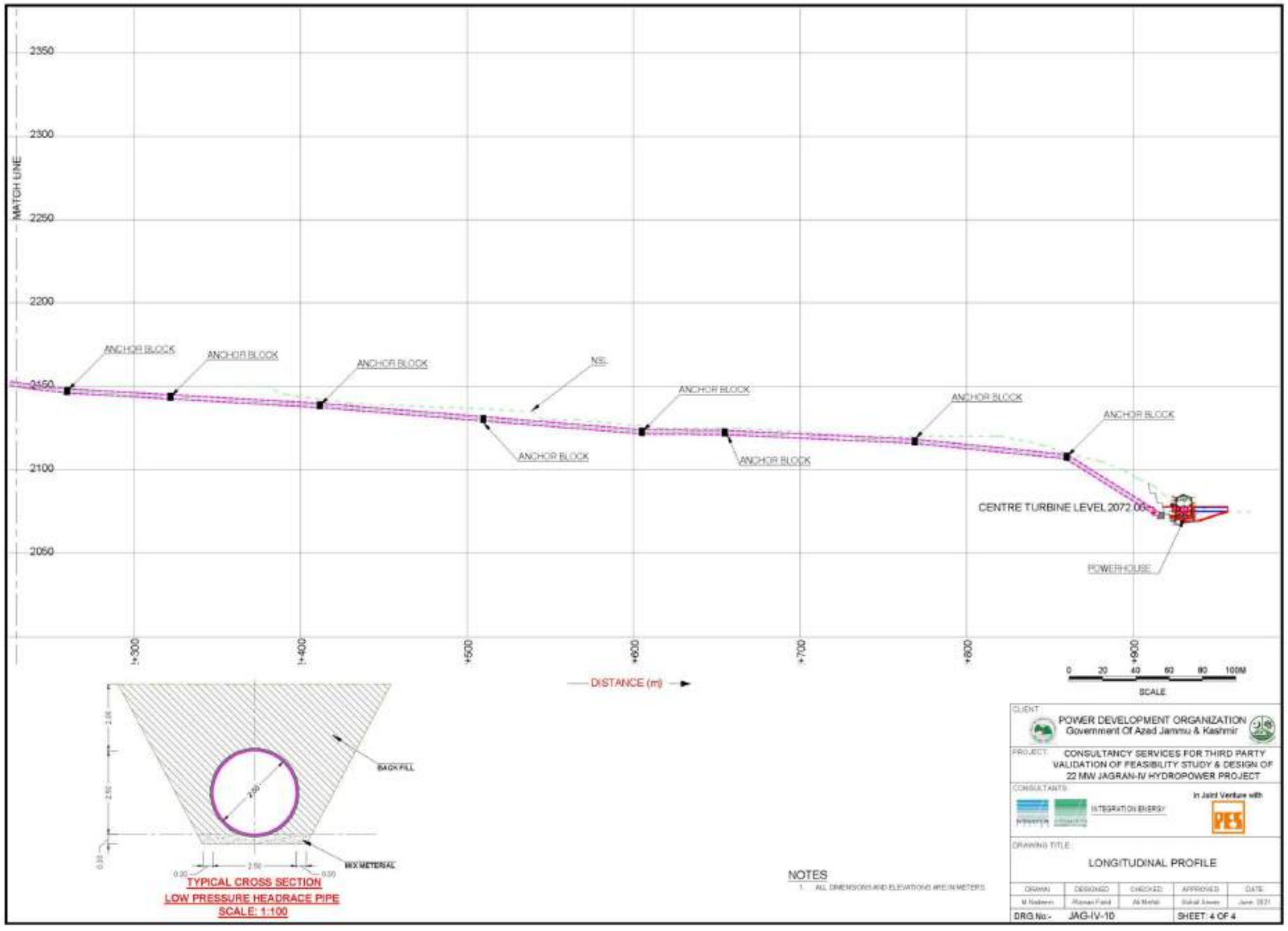

NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS.
2. CO-ORDINATE SYSTEM: SOP GRID 1.
Topography Legend
Major Contour (5M Interval)
Minor Contour (1M Interval)
Road
Electric POle
Wooden Foot Bridge
Nalla/River
House/ Settelment
Rock
INDEX PLAN
PENSTOCK PIPE
1165550
1165450
1165350
1165250
1165150
1165050
0 20 40 60 80 100M
SCALE
CLIENT:
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT:
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS:
in Joint Venture with
INTEGRATION ENERGY
PES
DRAWING TITLE:
PROJECT LAYOUT PLAN
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG.No:- JAG-IV-05
SHEET: 5 OF 6


NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS.
2. CO-ORDINATE SYSTEM: SOP GRID 1.
Topography Legend
Major Contour (5M Interval)
Minor Contour (1M Interval)
Road
Electric POle
Wooden Foot Bridge
Nalla/River
House/ Settelment
Rock
INDEX PLAN
PENSTOCK PIPE
PROPOSED POWER HOUSE
SCALE
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
in Joint Venture with
INTEGRATION ENERGY
DRAWING TITLE
PROJECT LAYOUT PLAN
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG.No:- JAG-IV-06
SHEET: 6 OF 6


2350
2300
2250
2200
2150
2100
2050
2000
POWER INTAKE
CONNECTING CHANNEL
DESANDER
ANCHOR BLOCK
NSL
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
MATCH LINE
2245.00 SILL LEVEL
20.00
100.00
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
DISTANCE (m)
0 20 40 60 80 100M
SCALE
NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
In Joint Venture with
DRAWING TITLE
LONGITUDINAL PROFILE
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
M Nadeem
Pervez Farid
Ali Mehdi
Sohail Anwar
June, 2021
DRG.No:- JAG-IV-07
SHEET: 1 OF 4


2350
2300
2250
2200
2150
2100
2050
MATCH LINE
MATCH LINE
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
NSL
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
0+00
0+00
1+000
1+100
1+200
1+300
1+400
DISTANCE (m)
0 20 40 60 80 100M
SCALE
NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
INTEGRATION ENERGY
in Joint Venture with
DRAWING TITLE
LONGITUDINAL PROFILE
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
M Nadeem
Rizwan Farid
Ali Mehdi
Sohail Anwer
June, 2021
DRG.No:- JAG-IV-08
SHEET: 2 OF 4


MATCH LINE
MATCH LINE
2350
2300
2250
2200
2150
2100
2050
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
NS
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
+500
+600
+700
+800
+900
+000
+100
+200
DISTANCE (m)
0 20 40 60 80 100M
SCALE
NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
In Joint Venture with
INTEGRATION ENERGY
DRAWING TITLE
LONGITUDINAL PROFILE
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG.No :- JAG-IV-09
SHEET: 3 OF 4


2350
2300
2250
2200
2150
2100
2050
MATCH LINE
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
NSL
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
ANCHOR BLOCK
CENTRE TURBINE LEVEL 2072.00
POWERHOUSE
0+300
0+400
0+500
0+600
0+700
0+800
0+900
DISTANCE (m)
0 20 40 60 80 100M
SCALE
BACK FILL
MIX METERIAL
TYPICAL CROSS SECTION
LOW PRESSURE HEADRACE PIPE
SCALE: 1:100
NOTES
1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS
CLIENT
POWER DEVELOPMENT ORGANIZATION
Government Of Azad Jammu & Kashmir
PROJECT
CONSULTANCY SERVICES FOR THIRD PARTY VALIDATION OF FEASIBILITY STUDY & DESIGN OF 22 MW JAGRAN-IV HYDROPOWER PROJECT
CONSULTANTS
In Joint Venture with
INTEGRATION ENERGY
DRAWING TITLE
LONGITUDINAL PROFILE
DRAWN
DESIGNED
CHECKED
APPROVED
DATE
DRG No:- JAG-IV-10
SHEET: 4 OF 4

13.3 Updated Detail Cost Estimates

JAGRAN-4 HYDROPOWER PROJECT

DETAILED COST ESTIMATION

(Price Index July 2021)

US$ 1.00 = Rs. 158.00

SR. NO.	DESCRIPTION	UNIT	QUANTITY	RATE (Rs.)	TOTAL (Rs.)	TOTAL (US $)
1	**LAND ACQUISITION, ROADS AND ENVIRONMENT**					
1.1	Land Acquisition Project Area	Acres	8	1500000	12,000,000	75,949
1.2	Land Acquisition Road	Acres	5	1500000	7,500,000	47,468
1.3	Other Environmental Impacts	L.S			10,000,000	63,291
1.4	Upgradation of Access Road (Jagran valley road)	m	4,000	3000	12,000,000	75,949
1.5	Road to Surge Area Near	m	1,000	5000	5,000,000	31,646
1.6	Bridge on Jagran River near Weir	m	35	200000	7,000,000	44,304
1.7	Bridge on Jagran River near Powerhouse	m	35	200000	7,000,000	44,304
1.8	Weir Site building and operators quarters	m^2	400	15000	6,000,000	37,975
1.9	Powerhouse Site building and Rest house	m^2	1,600	15000	24,000,000	151,899
	SUBTOTAL 1.1 - 1.9				**90,500,000**	**572,785**
1.10	Site Installation, Mobilization / Demobilization				275,125,284	1,741,299

1.11	Camp Facilities	m^2	1,200	12000.0	14,400,000	91,139
1.12	Depot Areas	m^2	1,500	5000.0	7,500,000	47,468
	SUBTOTAL 1.10 - 1.12				**297,025,284**	**1,879,907**
	SUBTOTAL 1				**387,525,284**	**2,452,692**
2	**WEIR WITH INTAKE**					
2.1	Diversion Works and Care of Water	L.S			16,000,000	101,266
2.2	Excavation (Overburden)	m^3	5,107	800	4,085,760	25,859
2.3	Excavation (Soft Rock)	m^3	1,277	1800	2,298,240	14,546
2.4	Backfill	m^3	1,596	400	638,400	4,041
2.5	Reinforced Concrete	m^3	2,124	13200	28,036,800	177,448
2.6	Mass Concrete	m^3	480	9500	4,560,000	28,861
2.7	Reinforcement 30 kg/m3	t	85	123000	10,450,080	66,140
2.8	Hard Concrete	m^3	384	10000	3,840,000	24,304
2.9	Sealing Foil	m^2	340	3300	1,122,000	7,101
2.10	Cut off	m^3	504	15000	7,560,000	47,848
2.11	Upstream Stone Apron	m^3	340	2600	884,000	5,595
2.12	Downstream Stone Apron	m^3	700	2600	1,820,000	11,519
	SUBTOTAL 2.1-2.12				**81,295,280**	**514,527**
2.13	**Hydraulic Steel Structures**					
2.13.1	Trash rack	kg	1,883	350	659,138	4,172

2.13.2	Vertical Lifting Gate	kg	5,580	500	2,790,000	17,658
2.13.3	Stoplogs	kg	3,000	350	1,050,000	6,646
2.13.4	Two Intake Gates	kg	4,200	450	1,890,000	11,962
2.13.5	Hoisting Equipment	L.S			468,000	2,962
	SUBTOTAL 2.13				**6,857,138**	**43,400**
	Add 5% for Minor Items				4,407,621	27,896
	SUBTOTAL 2				**92,560,038**	**585,823**
3	**POWER INTAKE WITH DESANDER**					
3.1	Excavation Intake Channel	m^2	7,840	800	6,272,000	39,696
3.2	Excavation Desander	m^3	20,736	800	16,588,800	104,992
3.3	Backfilling	m^3	5,715	400	2,286,080	14,469
3.4	Reinforced Concrete	m^3	3,647	13200	48,133,800	304,644
3.5	Reinforcement 40 kg/m^3	t	146	123000	17,940,780	113,549
3.6	Flushing pipe	m^3	180	13200	2,376,000	15,038
3.7	Outlet Structure Flushing pipe	L.S			960,000	6,076
	SUBTOTAL 3.1-3.7				**94,557,460**	**598,465**
3.8	**Hydraulic Steel Structures**					
3.8.1	Two Inlet Gates	kg	3,038	500	1,519,000	9,614
3.8.2	Two outlet Gates	kg	3,038	500	1,519,000	9,614
3.8.3	Sand Flushing Gate	kg	650	450	292,500	1,851

3.8.4	Fine Rack	kg	248	350	86,800	549
3.8.5	One Rack Cleaning Machine	L.S	1	1500000	1,500,000	9,494
3.8.6	Hoisting Equipment	L.S			483,050	3,057
	SUBTOTAL 3.8				**5,400,350**	**34,179**
	Add 5% for Minor Items				4,997,891	31,632
	SUBTOTAL 3				**104,955,701**	**664,277**
4	**EMBEDDED PENSTOCK**					
4.1	Excavation (Hard Rock)	m3	34,714	1662	57,694,934	365,158
4.2	Excavation (Soft Rock)	m3	138,857	579	80,397,995	508,848
4.3	Backfilling	m3	151,400	381	57,683,400	365,085
4.4	Concrete (Anchor Block)	m3	1,232	16276	20,050,242	126,900
4.5	Penstock Steel 10-26 mm thick	kg	3079268	650	2,001,524,200	12,667,875
4.6	Erection of Steel Penstock and Coating				20,000,000	126,582
	SUBTOTAL 4.1 to 4.6				**2,237,350,770**	**14,160,448**
	Add 5% for Minor Items				111,867,539	708,022
	SUBTOTAL 4				**2,349,218,309**	**14,868,470**
5	**POWERHOUSE**					
5.1	Powerhouse Surface					
5.1.1	Excavation (Hard Rock)	m^3	7,800	1662	12,963,600	82,048

5.1.2	Excavation (Soft Rock)	m^3	11,700	579	6,774,300	42,875
5.1.3	Backfilling	m^3	3,900	381	1,485,900	9,404
5.2	**Sub-Structure**					
5.2.1	Concrete	m^3	4,400	13200.0	58,080,000	367,595
5.2.2	Reinforcement 40 Kg/m^3	t	176	0.0	0	0
5.3	**Super-Structure**					
5.3.1	Concrete	m^3	3,780	13200.0	49,896,000	315,797
5.3.2	Reinforcement 60 Kg/m^3	t	227	0.0	0	0
5.3.3	Steel Truss	t	34	0.0	0	0
5.3.4	Wood Work	L.S			4,000,000	25,316
5.3.5	Powerhouse Finishing	L.S			5,000,000	31,646
	SUBTOTAL 5.1 to 5.3				**138,199,800**	**874,682**
	Add 5% for Minor Items				6,909,990	43,734
	SUBTOTAL 5				**145,109,790**	**918,416**
6	**TAILRACE CHANNEL**					
6.1	Excavation (Overburden)	m^3	2,000	1800.0	3,600,000	22,785
6.2	Back Filling	m^3	600	400.0	240,000	1,519
6.3	Concrete (Lining)	m^3	225	13200	2,970,000	18,797
6.4	Reinforcement 30 kg/m^3	t	7	0	0	0

6.5	Stone Placement	m^3	9,000	5530.0	49,770,000	315,000
	SUBTOTAL 6.1 to 6.5				**56,580,000**	**358,101**
	Add 5% for Minor Items				2,829,000	17,905
	SUBTOTAL 6				**59,409,000**	**376,006**
	TOTAL CIVIL WORKS (1-6)				**3,138,778,121**	**19,865,684**
7	**HYDROMECHANICAL EQUIPMENT**					
7.1	Turbines	No	4	60000000	240,000,000	1,518,987
7.2	Inlet Valve	No	4	10000000	40,000,000	253,165
7.3	Governor	No	4	10000000	40,000,000	253,165
7.4	Crane	No	1	12000000	12,000,000	75,949
7.5	Auxillary Equipment and spare parts	L.S			33,200,000	210,127
	SUBTOTAL 7.1 to 7.5				**365,200,000**	**2,311,392**
	Add 5% for Minor Items				18,260,000	115,570
	SUBTOTAL 7				**383,460,000**	**2,426,962**
8	**ELECTRICAL EQUIPMENT**					
8.1	**Generators and Transformers**					
8.1.1	Generators 3 x 7 MVA + 1 x 5 MVA	No	4	50000000	200,000,000	1,265,823
8.1.2	Unit Step-up Transformers 3 x 7 MVA + 1 x 5 MVA	No	4	35000000	140,000,000	886,076

8.1.3	Auxiliary Transformers 500 kVA	No	2	2500000	5,000,000	31,646
8.1.4	Surge relieve Bypass values (Actuvated by the governing mechanism of each turbine)	No	4	25,000,000	100,000,000	632,911
	SUBTOTAL 8.1				**445,000,000**	**2,816,456**
8.2	**Medium Voltage Equipments**					
8.2.1	400 V Switchgear	No	4	1600000	6,400,000	40,506
8.2.2	Auto Transfer Swtich and Bus Coupler	No	4	800000	3,200,000	20,253
8.2.3	11 kV Generator Circuit breakers	No	4	400000	1,600,000	10,127
8.2.4	11 kV Instrument Transformers	No	4	400000	1,600,000	10,127
8.2.5	11 kV Bus Bar	No	4	450000	1,800,000	11,392
	SUBTOTAL 8.2				**14,600,000**	**92,405**
8.3	**Low Voltage Switchgear**					
8.3.1	Low Voltage Switchgears & ATS	No	4	1000000	4,000,000	25,316
8.3.2	AC/DC Aux Supply Panels	No	4	800000	3,200,000	20,253
8.3.3	Static frequency Conveter (SFC)/UPS	No	4	500000	2,000,000	12,658
8.3.4	110 V DC Battery and Battery Charger	No	4	400000	1,600,000	10,127
	SUBTOTAL 8.3				**10,800,000**	**68,354**
8.4	**Lighting, and Diesel Generator**					
8.4.1	Indoor, Outdoor and Security lighting	L.S		1000000	1,000,000	6,329
8.4.2	100 kW Diesel Set	1		2000000	2,000,000	12,658
8.4.3	Earting System	1		2400000	2,400,000	15,190

	SUBTOTAL 8.4				**5,400,000**	**34,177**
8.5	**Miscellaneous Items**					
8.5.1	Fire Fighting System	L.S		4000000	4,000,000	25,316
8.5.2	Cooling System (Generator+Transformer)	L.S		5000000	5,000,000	31,646
	SUBTOTAL 8.5				**9,000,000**	**56,962**
8.6	**132 kV Switchyard**					
8.6.1	Circuit Breakers	No	6	3500000	21,000,000	132,911
8.6.2	Isolators	No	6	500000	3,000,000	18,987
8.6.3	Earthing Isolators	No	1	837000	837,000	5,297
8.6.4	Lighting Arrestors	No	1	3000000	3,000,000	18,987
8.6.5	Control and Relay Panels	No	4	2000000	8,000,000	50,633
8.6.6	Cables	No	4	1600000	6,400,000	40,506
	SUBTOTAL 8.6				**42,237,000**	**267,323**
	SUBTOTAL 8.1 to 8.6				**527,037,000**	**3,335,677**
	Add 5% for Minor Items				26,351,850	166,784
	SUBTOTAL 8.1-8.6				**553,388,850**	**3,502,461**
	TOTAL E&M WORKS				**936848850**	**5,929,423**

13.4 Photo Gallery

Traversing	Topographic Survey
Borehole Drilling (Weir)	Traversing

13.5 Geotechnical Investigation Report (Drilling Company)

AJK POWER DEVELOPMENT ORGANIZATION

JAGRAN-IV HYDROPOWER PROJECT

DISRTICT, NEELUM VALLEY, AJK

FIELD INVESTIGATION REPORT

(INTERIM REPORT)

UNIVERSAL DRILLING ENGINEERS

CONTENTS

1 GENERAL 1

2 SCOPE OF WORK 1

3 DRILLING OF BOREHOLES 1

3.1 Sampling 2

4 EXCAVATION OF TEST PITS 3

4.1 Sampling 3

5 CONSTRUCTION MATERIALS 4

6 IN-SITU TESTING 5

6.1 Permeability Tests 5

6.2 Standard Penetration Tests 5

6.1 Field Density Tests 6

7 SEISMIC REFRACTION SURVEY 7

APPENDICES

Appendix-A

Borehole and Test pit logs

Appendix-B

Permeability Test Interpretation Sheets

Appendix-C

Summary and Laboratory Test Result Sheets

Appendix-D

Photographs

1 GENERAL

The Azad Jammu & Kashmir Power Development Organization (AJK-PDO), hereinafter called as Client, is planning to execute Jagran-IV Hydropower Project in District Neelum Valley, AJK. For this purpose, AJK-PDO has planned to carry out geotechnical & soil investigations for the project. M/s Universal Drilling Engineers (UDE), have been entrusted with the execution of geotechnical and soil investigations for the proposed project on the basis of competitive bidding amongst the drilling contractors. M/s Integration are the project consultant for these investigations.

In order to ensure safe and economical deign of the project, proper assessment of geotechnical aspects of the project site is of utmost importance. For this purpose, geotechnical investigations program has been developed by the Consultants. The investigation program aimed at evaluation of subsurface conditions for the project components and investigations of construction materials.

This interim report provides description of the geotechnical activities carried out at the project site, the characteristics of subsurface materials, the details of field and laboratory tests. The field work was carried out under the fulltime supervision of site geologists/engineer of M/s Universal Drilling Engineers (UDE), Moreover, Client's representative was also present full time at site during the field work.

The field and laboratory work for these completed investigations were carried out from April 29, 2021 to July 06, 2021.

2 SCOPE OF WORK

Scope of work for geotechnical investigations was prepared by the Client, keeping in view the site conditions and project components, to fulfil the desired objectives. However, due to site conditions some minor adjustments had to be made in the planned Geotechnical Investigation Plan. The investigations carried out at site till now are summarized below;

- Drilling of Boreholes using hydraulic feed straight rotary drilling technique
- Excavation of Test pits
- In-situ testing
- Construction Materials
- Seismic Refraction Survey

3 DRILLING OF BOREHOLES

In order to collect the soil/ rock samples and perform in-situ tests, drilling of boreholes has been undertaken at the proposed location of project features. A total of 121 m of drilling has been completed till 10th July 2021 at the project site. Total of five (05) boreholes have been drilled at the proposed project components. One (01) borehole is under progress.

The drilling was carried out by using single tube core barrel with diamond bit of HQ size along with HW size diamond bit casing. During the drilling operations, when HW casing got stuck and no advancement was noticed, telescopic approach was adopted by using additional NQ diamond drilling bit and NW size casing inside the HW casing. This facilitated advancement of borehole.

The material/cuttings coming out of borehole during drilling process was carefully observed and placed in the core boxes. Sand samples, where encountered, were preserved in plastic bags and placed in core boxes along with its associated core barrel collected samples. Core extracted while drilling through boulder was also preserved in core boxes.

The finalized coordinates were recorded using hand held GPS for each borehole location provided by the Consultant at site and are summarized in the following Table-1

Table-1 Summary of Boreholes for Jagran-IV Hydropower Project

Sr. No.	Borehole No.	Location	Start Date	End Date	Northing	Easting	Drilling Depth (m)	Status
1	BH-1	Sand Trap 1	29-04-2021	04-05-2021	34°39'23.6"	73°46'10.6"	20	Completed
2	BH-2	Water Conduit alignment	29-04-2021	04-05-2021	34°39'23.6"	73°46'10.3"	20	Completed
3	BH-3	WL -2 Weir: Left Abutment	06-05-2021	07-06-2021	34°39'25.3"	73°46'9.4"	34	Completed
4	BH-4	Powerhouse (I)	22-06-2021	02-07-2021	34°37'48.3"	73°46'4.1"	32	Completed
5	BH-5	Powerhouse, Nullah Bed	29-06-2021	05-07-2021	34°37'48.2"	73°46'2.8"	15	Completed

6	BH-6	Powerhouse along Road Side	08-07-2021	-	34^{O}37'48.2"	73^{O}46'3.6"	5	In progress

A careful record of all the materials encountered and data of in-situ testing conducted in each borehole was maintained in the form of field borehole logs. The borehole logs are included in Appendix-A.

3.1 Sampling

Overburden material and boulder core samples were collected using single or double tube core barrels, depending upon the site conditions. All the samples were preserved in wooden core boxes with great care. The core boxes were labelled with project name, borehole designation, drilling depth, box number and date using black marker pen. Cores were placed in the boxes in the correct sequence, with increasing depth from left to right in the box and from the hinged side to the hasp side of the box.

4 EXCAVATION OF TEST PITS

For visual classification of foundation soils at shallow depths and to ascertain the depth of fill material, test pits were excavated using manual tools at the project site. The following table shows the details of excavated test pits at the project site. Excavation of remaining test pits is under progress.

Sr. No.	Test Pit No.	Location	Start Date	End Date	Depth (m)
1	TP-4	Pipe Line / Channel	07-07-2021	07-07-2021	3.0
2	TP-6	Pipe Line / Channel	06-07-2021	06-07-2021	3.0
3	TP-8	Pipe Line / Channel	28-06-2021	30-06-2021	3.0
4	TP-9	Pipe Line / Channel	20-06-2021	25-06-2021	3.0
5	TP-10	Pipe Line / Channel	24-06-2021	27-06-2021	3.0

Subsurface logs of excavated test pits were prepared after carefully observing the strata on the walls of the excavated pit. The test pit logs and field photographs are included in Appendix-A and Appendix-D respectively.

4.1 Sampling

Bulk and disturbed soil samples were collected from each test pit excavated at site and properly preserved, labelled to indicate the project name, project code, test pit designation and depth of sample.

5 CONSTRUCTION MATERIALS

In order to determine the availability of construction material, a source named as Shamkoli was investigated as per the instructions of the Consultant. Sampling was made for the quality evaluation of crush aggregates in the presence of Consultant's representative. Total eight sample bags were collected for the laboratory testing.

Untill now, these samples of coarse aggregate were transported to the testing laboratory facility of M/s Berkeley Associates (Pvt.) Ltd., Lahore for performance of tests as indicated by the Consultant. The following laboratory tests are completed and are appended in Appendix-C.

- Particle Size Analysis or Sieve Analysis (ASTM D – 422)
- Specific Gravity and Water Absorption Test (AASHTO T-85)
- Crushing Value Test (BS-812; Part 110)
- Ten Percent Fine Value Test (BS-812; Part 111)
- Los Angeles Abrasion Test (AASHTO T 96 and ASTM C131)
- Sulphates Content (BS 1377 Part 3)
- Chloride Content (BS 1377 Part 3)
- Flakiness & Elongation Index (BS-812; Part 105)

6 IN-SITU TESTING

The following in-situ tests have been carried out in the boreholes and test pits;

a. Permeability
b. Standard Penetration Tests
c. Field Density Tests

6.1 Permeability Tests

Permeability of overburden soils is being determined by means of permeability tests. The permeability tests are being conducted in drilled boreholes using constant head method. Summary of permeability test results have been provided in Table-4 and test interpretation sheets are attached in Appendix-B.

Table-4 Summary of Permeability Test Results

Sr. No.	Borehole No.	Location	Permeability Test No.	Test Depth (m)	Permeability (cm/sec)
1	BH-1	Sand Trap 1	1	10	7.40E-02
			2	20	1.23E-01
2	BH-2	Water Conduit alignment	1	5	9.59E-02
			2	15	1.06E-01
3	BH-3	WL -2 Weir: Left Abutment	1	5	3.70E-01
			2	10	2.64E+00
			3	15	8.35E-01
			4	20	1.58E-02
			5	25	1.53E-01
			6	30	1.68E-03
4	BH-4	Powerhouse (I)	1	7	5.62E-01
			2	14	1.30E-01
			3	16	5.81E-01
			4	21	3.78E-02
			5	23	1.91E+00
			6	28	2.64E+00
			7	32	6.36E-02
5	BH-5	Powerhouse, Nullah Bed	1	3	6.96E-01

6.2 Standard Penetration Tests

During these field investigations, Standard Penetration Test (SPT) was performed in the borehole at specified depth where feasible. A brief discussion of the in-situ test in boreholes is given as below.

For evaluating the consistency and compactness of the foundation soils, Standard Penetration Tests (SPTs) were performed in the borehole. A donut type hammer, weighing 63.5 kg, was used for the tests. The hammer was lifted and dropped manually through a manila rope using flywheel of drilling rig and pulley hanged to the tripod stand. Prior to performing each SPT, the loose material existing in the hole was properly washed.

6.1 Field Density Tests

In order to determine the in-situ compactness and density of sub-grade soils at shallow depth, Field Density Tests (F.D.Ts) were performed in all the test pits at various horizons. The tests were performed using sand replacement method in accordance with ASTM designated D 1556-86. The digitization of the results are under progress.

7 SEISMIC REFRACTION SURVEY

Geophysical surveys have been employed to obtain additional information on the depth of overburden, extent of moderately weathered rock and top of sound rocks at the specific location of various project features. These investigations are in progress and have been intended to supplement surface investigations of foundation conditions at the particular sites of project features.

APPENDIX-A

Borehole and Test pit logs

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-1
SHEET 1 OF 2

LOCATION: Sand Trap 1
DEPTH OF W.T: 11 m
FINAL DEPTH: 20 m

COORDS. E: 34°39'21.1" N: 73°46'10.6"
BORING STARTED ON: 29-04-2021
ENDED ON: 04-05-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: S. Ali Asghar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0									
	SPT-1	25		15			Greyish Brown to Dark Brownish Grey, Medium Dense, SILTY SAND trace Gravels.		
1.5									
	SPT-2	30		10					
3.0							OVERBURDEN: Whitish to Brownish Grey, Sandy Gravels, contain, pebbles & cobbles which are sub-rounded to sub-angular to different rocks, metasediments, phyllite & granite,		
				20					
4.5									
				30					
6.0									
				42					
7.5									
				30					
9.0	Permeability Test -1								
				32					
10.5									
				32					
12.0									
				30					
13.5									
				34					
15.0							(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-1
SHEET 2 OF 2

LOCATION: Sand Trap 1
DEPTH OF W.T: 11 m
FINAL DEPTH: 20 m

COORDS. E: 34°39'21.1" N: 73°46'10.6"
BORING STARTED ON: 29-04-2021
ENDED ON: 04-05-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: S. Ali Asghar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
15.0									
				20			OVERBURDEN: Whitish to Brownish Grey, Sandy Gravels, contain, pebbles & cobbles which are sub-rounded to sub-angular to different rocks, metasediments, phyllite & granite,		
16.5									
				20					
18.0									
				18					
19.0	Permeability Test -2								
				15					
20.0							(BOTTOM OF BOREHOLE)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-2
SHEET 1 OF 2

LOCATION: Water Conduit Alignment
DEPTH OF W.T: 8 m
FINAL DEPTH: 20 m

COORDS. E: 34°39'23.6" N: 73°46'10.3"
BORING STARTED ON: 29-04-2021
ENDED ON: 04-05-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Ihtisham-ul-Haq
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0									
	SPT-1	36		15			Greyish Grey, Dense, SANDY SILT trace Gravels		
1.5									
				38			OVERBURDEN: Greenish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, phyllite, quartzite, gneiss & granite,		
3.0									
				30					
4.5	Permeability Test -1 at 5m depth								
				48					
6.0									
				37					
7.5									
				30					
9.0									
				35					
10.5									
				35					
12.0									
				32					
13.5									
	Permeability Test - 2			45					
15.0							(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-2
SHEET 2 OF 2

LOCATION: Water Conduit Alignment
DEPTH OF W.T: 11 m
FINAL DEPTH: 20 m

COORDS. E: 34°39'23.6" N: 73°46'10.3"
BORING STARTED ON: 29-04-2021
ENDED ON: 04-05-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: S. Ali Asghar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
15.0									
				40			OVERBURDEN: Greenish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, phyllite, quartzite, gneiss & granite,		
16.5				65					
18.0				40					
19.0				32					
20.0							(BOTTOM OF BOREHOLE)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-3
SHEET 1 OF 4

LOCATION: WL-2 Wier: Left Abutment
DEPTH OF W.T: 10.5 m
FINAL DEPTH: 34 m

COORDS. E: 73°46'9.4" N: 34°39'25.3"
BORING STARTED ON: 06-05-2021
ENDED ON: 07-06-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0									
1				38			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, phyllite, metasediments, gneiss & granite,		
2				20					
3				31					
4				30					
5	Permeability Test -1			30					
6				45					
7				30					
8				30					
9				28					
10	Permeability Test -2			32					
							(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-3
SHEET 2 OF 4

LOCATION: WL-2 Wier: Left Abutment
DEPTH OF W.T: 10.5 m
FINAL DEPTH: 34 m

COORDS. E: 73°46'9.4" N: 34°39'25.3"
BORING STARTED ON: 06-05-2021
ENDED ON: 07-06-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
10									
11				36			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, phyllite, metasediments, gneiss & granite,		
12				52					
13				66					
14	Permeability Test -3			48					
15				45					
16				42					
17				42					
18				35					
19	Permeability Test -4			50					
20				36			(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-3
SHEET 3 OF 4
LOCATION: WL-2 Wier: Left Abutment
DEPTH OF W.T: 10.5 m
FINAL DEPTH: 34 m
COORDS. E: 73°46'9.4" N: 34°39'25.3"
BORING STARTED ON: 06-05-2021
ENDED ON: 07-06-2021
TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
20									
				42			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, phyllite, metasediments, gneiss & granite,		
21									
				25					
22									
				18					
23									
				58					
24	Permeability Test -5			30					
25									
				50					
26									
				42					
27									
				64					
28									
				40					
29	Permeability Test -6			72					
30							(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

BOREHOLE NO: BH-3 | SHEET 4 OF 4

LOCATION: WL-2 Wier: Left Abutment | DEPTH OF W.T: 10.5 m | FINAL DEPTH: 34 m

COORDS. E: 73°46'9.4" N: 34°39'25.3" | BORING STARTED ON: 06-05-2021 | ENDED ON: 07-06-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit) | LOGGED BY: Munawar | CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
30									
				35			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, phyllite, metasediments, gneiss & granite,		
31									
				30					
32									
				62					
33									
				50					
34							(BOTTOM OF BOREHOLE)		

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-4
SHEET 1 OF 4

LOCATION: Powerhouse (I)
DEPTH OF W.T: 18 m
FINAL DEPTH: 32 m

COORDS. E: 73°46'04.1" N: 34°37'48.3"
BORING STARTED ON: 22-06-2021
ENDED ON: 02-07-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0									
1				15			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, quartzite, phyllite, metasediments, granite gneiss.		
2				25					
3				25					
4				18					
5				35					
6				30					
7	Permeability Test -1			22					
8				25					
9				33					
10				25					

(CONTINUED)

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-4
SHEET 2 OF 4
LOCATION: Powerhose (I)
DEPTH OF W.T: 18 m
FINAL DEPTH: 32 m
COORDS. E: 73°46'04.1" N: 34°37'48.3"
BORING STARTED ON: 22-06-2021
ENDED ON: 02-07-2021
TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
10									
11				20			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, quartzite, phyllite, metasediments, granite gneiss.		
12				20					
13				30					
14				18					
15	Permeability Test -2			20					
16	Permeability Test -3			25					
17				18					
18				52					
19				20					
20				22					
							(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-4
SHEET 3 OF 4
LOCATION: Powerhouse (I)
DEPTH OF W.T: 18 m
FINAL DEPTH: 32 m
COORDS. E: 73°46'04.1" N: 34°37'48.3"
BORING STARTED ON: 22-06-2021
ENDED ON: 02-07-2021
TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
20	Permeability Test -4			22			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, quartzite, phyllite, metasediments, granite gneiss.		
21				26					
22	Permeability Test -5			22					
23				26					
24				26					
25				24					
26				24					
27	Permeability Test -6			18					
28				30					
29				43					
30							(CONTINUED)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

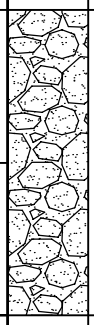
UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-4
SHEET 4 OF 4

LOCATION: Powerhose (I)
DEPTH OF W.T: 18 m
FINAL DEPTH: 32 m

COORDS. E: 73°46'04.1" N: 34°37'48.3"
BORING STARTED ON: 22-06-2021
ENDED ON: 02-07-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
30									
				26			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, quartzite, phyllite, metasediments, granite gneiss.		
31	Permeability Test -7			28					
32							(BOTTOM OF BOREHOLE)		

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

BOREHOLE NO: BH-5 | SHEET 1 OF 2

LOCATION: Power House - Nullah Bed | DEPTH OF W.T: 7 m | FINAL DEPTH: 15 m

COORDS. E: 73°46'02.8" N: 34°37'48.2" | BORING STARTED ON: 29-06-2021 | ENDED ON: 05-07-2021

TYPE OF DRILLING: Straight Rotary (Diamond Bit) | LOGGED BY: Munawar | CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0									
1				15			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, quartzite, phyllite, metasediments, granite gneiss.		
2				25					
3	Permeability Test -1			25					
4				18					
5				35					
6				30					
7				22					
8				25					
9				33					
10				25					

(CONTINUED)

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK
BOREHOLE NO: BH-5
SHEET 2 OF 2
LOCATION: Power House - Nullah Bed
DEPTH OF W.T: 7 m
FINAL DEPTH: 15 m
COORDS. E: 73°46'02.8" N: 34°37'48.2"
BORING STARTED ON: 29-06-2021
ENDED ON: 05-07-2021
TYPE OF DRILLING: Straight Rotary (Diamond Bit)
LOGGED BY: Munawar
CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	TEST TYPE / SAMPLES	OBSERVATION SPT-N VALUE	RUN NO.	SAMPLE LENGTH (cm)	R.Q.D. %	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
10									
11				20			OVERBURDEN: Greyish Grey to Whitish Grey, Gravels contain Pebbles & Cobbles which are sub-angular to sub-rounded of different rocks, quartzite, phyllite, metasediments, granite gneiss.		
12				20					
13				30					
14				18					
15				20					
16				25					
17				18					
18				52					
19				20					
20				22					

(CONTINUED)

CLIENT:
Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

LOCATION: Pipe Line / Channal

PIT DIMENSION: (2.0 x 2.5 x 3.0m)

TESTPIT NO: TP-4

DEPTH OF W.T: NIL

BORING STARTED ON: 07-07-2021

LOGGED BY: S. Ali Asghar

SHEET 1 OF 1

FINAL DEPTH: 3 m

ENDED ON: 07-07-2021

CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	DRILLING DETAILS	SAMPLES	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0.0	MANUALLY EXCAVATED TESTPIT	BULK SAMPLE / TEST (32kg)		OVERBURDEN: Dark Greyish to Grey, Silty Clayey Gravel, Gravels are angular to sub-angular having size 1" to 4".		
1.0				OVERBURDEN: Dark Greyish to Grey, Gravely Silty Clay, Gravels are 2" to 6"		
2.0				OVERBURDEN: Dark Greyish to Grey, Gravely Silty Clay, Gravels are 6" to 14"		
3.0				(BOTTOM OF TESTPIT)		
4.0						
5.0						

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

LOCATION: Pipe Line / Channal

PIT DIMENSION: (2.0 x 2.5 x 3.0m)

TESTPIT NO: TP-6

DEPTH OF W.T: NIL

BORING STARTED ON: 06-07-2021

LOGGED BY: S. Ali Asghar

SHEET 1 OF 1

FINAL DEPTH: 3 m

ENDED ON: 06-07-2021

CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	DRILLING DETAILS	SAMPLES	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0.0	MANUALLY EXCAVATED TESTPIT	BULK SAMPLE / TEST (32kg) FDT-1		OVERBURDEN: Dark Greyish to Grey, Clayey Sandy Gravel, Gravels are massive having size 6" to 40", Silts are in minor amounts.		
1.0				OVERBURDEN: Dark Greyish to Grey, Clayey Silty Gravel, Gravels are 6" to 20".		
2.0				OVERBURDEN: Greyish Grey, Sandy Silty Gravel, Gravels are 3" to 8", surface clay & vegetations are in minor amounts.		
3.0				(BOTTOM OF TESTPIT)		
4.0						
5.0						

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

LOCATION: Pipe Line / Channal

PIT DIMENSION: (2.0 x 2.5 x 3.0m)

TESTPIT NO: TP-8

DEPTH OF W.T: NIL

BORING STARTED ON: 28-06-2021

LOGGED BY: Munawar

SHEET 1 OF 1

FINAL DEPTH: 3 m

ENDED ON: 30-06-2021

CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	DRILLING DETAILS	SAMPLES	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0.0	MANUALLY EXCAVATED TESTPIT	BULK SAMPLE / TEST (32kg)		OVERBURDEN: Greyish Grey, Clayey Silty Gravels Contain Boulders of 6" to 18" which are angular to sub-angular.		
1.0						
1.7		FDT-1		OVERBURDEN: Dark Grayish to Grey, Clayey Gravely Silt, angular to sub-angular. Gravels are 3" to 12".		
2.0						
3.0				(BOTTOM OF TESTPIT)		
4.0						
5.0						

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

LOCATION: Pipe Line / Channal

PIT DIMENSION: (2.0 x 2.5 x 3.0m)

TESTPIT NO: TP-9

DEPTH OF W.T: NIL

BORING STARTED ON: 20-06-2021

LOGGED BY: Munawar

SHEET 1 OF 1

FINAL DEPTH: 3 m

ENDED ON: 25-06-2021

CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	DRILLING DETAILS	SAMPLES	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0.0	MANUALLY EXCAVATED TESTPIT	FDT-1		OVERBURDEN: Light Grey, Silty Gravels contain massive boulders, trace grass roots.		
0.5				OVERBURDEN: Greyish Grey, Silty Gravels contain boulders.		
1.0						
1.4				OVERBURDEN: Dark Grayish, Gravely Clayey Silt.		
2.0						
3.0				(BOTTOM OF TESTPIT)		
4.0						
5.0						

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

UNIVERSAL DRILLING ENGINEERS

PROJECT: Geotechnical & Soil Investigations for Jagran-IV Hydropower Project, District, Neelum Valley, AJK

LOCATION: Pipe Line / Channal

PIT DIMENSION: (2.0 x 2.5 x 3.0m)

TESTPIT NO: TP-10

DEPTH OF W.T: NIL

BORING STARTED ON: 24-06-2021

LOGGED BY: Munawar

SHEET 1 OF 1

FINAL DEPTH: 3 m

ENDED ON: 27-06-2021

CHECKED BY: Bilal

DEPTH, m BELOW E.G.L	DRILLING DETAILS	SAMPLES	LEGEND	DESCRIPTION OF MATERIAL	DEPTH, m	REMARKS
0.0	MANUALLY EXCAVATED TESTPIT	BULK SAMPLE / TEST (32kg) FDT-1		OVERBURDEN: Greyish Brown, Silty Clayey Gravels contain boulders of half to into feet, trace grass roots.		
1.5				OVERBURDEN: Greyish Brown, Clayey Silty Gravels contain boulders of 1' to 2'.		
3.0				(BOTTOM OF TESTPIT)		
4.0						
5.0						

CLIENT:

Azad Jammu & Kashmir Power Development Organization (AJK-PDO)

APPENDIX-B

Permeability Test Sheets

UNIVERSAL DRILLING ENGINEERS

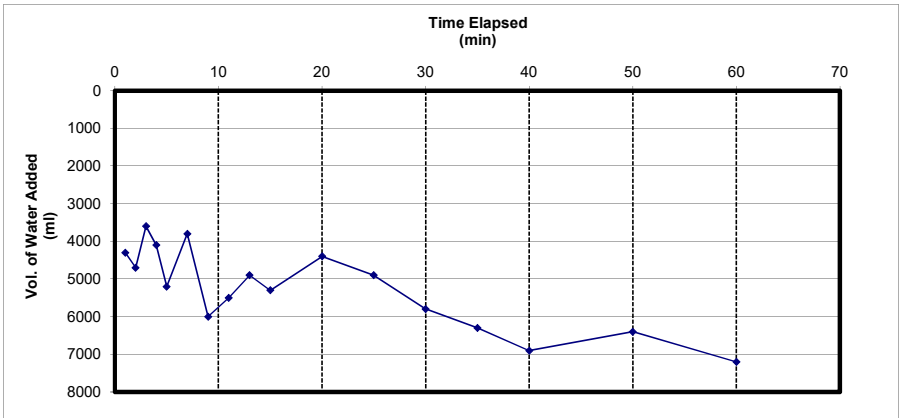
FIELD PERMEABILITY TES'

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-1
Test Number 1
Test Depth (m). 10
Test Date. 04/05/2021
Test Type Constant Head

Internal dia of casing = 10.1 cm

Depth of water table (cm) 1100 m

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	4300
2	1	2	4700
3	1	3	3600
4	1	4	4100
5	1	5	5200
6	2	7	3800
7	2	9	6000
8	2	11	5500
9	2	13	4900
10	2	15	5300
11	5	20	4400
12	5	25	4900
13	5	30	5800
14	5	35	6300
15	5	40	6900
16	10	50	6400
17	10	60	7200
	60	Σ	**89300**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	24.81	cm^3/sec
F =	27.775	cm
H_c =	12	cm
k =	**7.44E-02**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

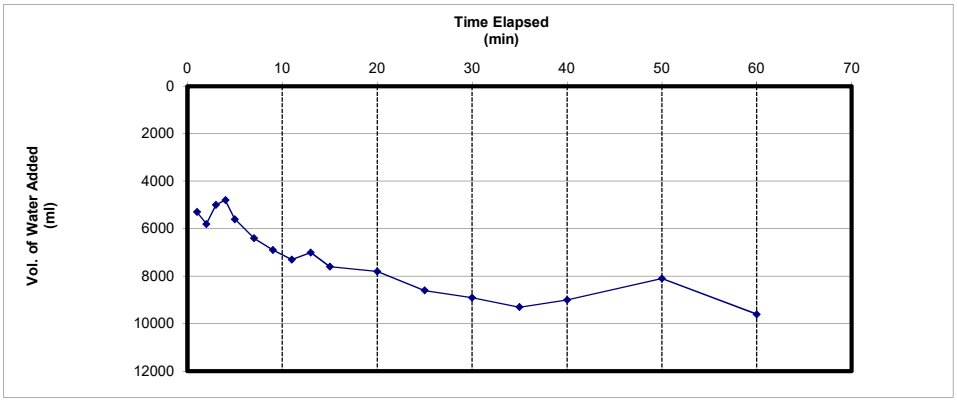
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-1
Test Number 2
Test Depth (m). 20
Test Date. 04/05/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm) 1100 cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	5300
2	1	2	5800
3	1	3	5000
4	1	4	4800
5	1	5	5600
6	2	7	6400
7	2	9	6900
8	2	11	7300
9	2	13	7000
10	2	15	7600
11	5	20	7800
12	5	25	8600
13	5	30	8900
14	5	35	9300
15	5	40	9000
16	10	50	8100
17	10	60	9600
	60	Σ	**123000**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	34.16667	cm^3/sec
F =	27.775	cm
H_c =	10	cm
k =	**1.23E-01**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

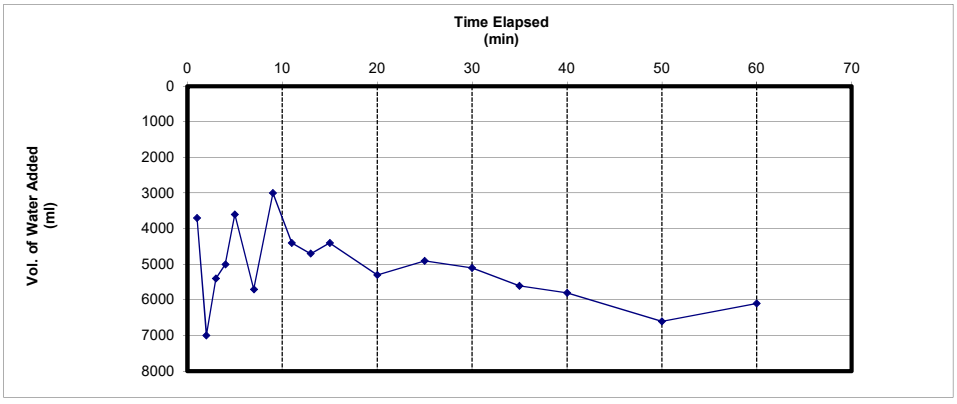
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-2
Test Number 1
Test Depth (m). 5
Test Date. 01/05/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm), nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	3700
2	1	2	7000
3	1	3	5400
4	1	4	5000
5	1	5	3600
6	2	7	5700
7	2	9	3000
8	2	11	4400
9	2	13	4700
10	2	15	4400
11	5	20	5300
12	5	25	4900
13	5	30	5100
14	5	35	5600
15	5	40	5800
16	10	50	6600
17	10	60	6100
	60	Σ	**86300**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

$Q =$ 23.97222 cm^3/sec
$F =$ 27.775 cm
$H_c =$ 9 cm

k = 9.59E-02 cm/sec

UNIVERSAL DRILLING ENGINEERS

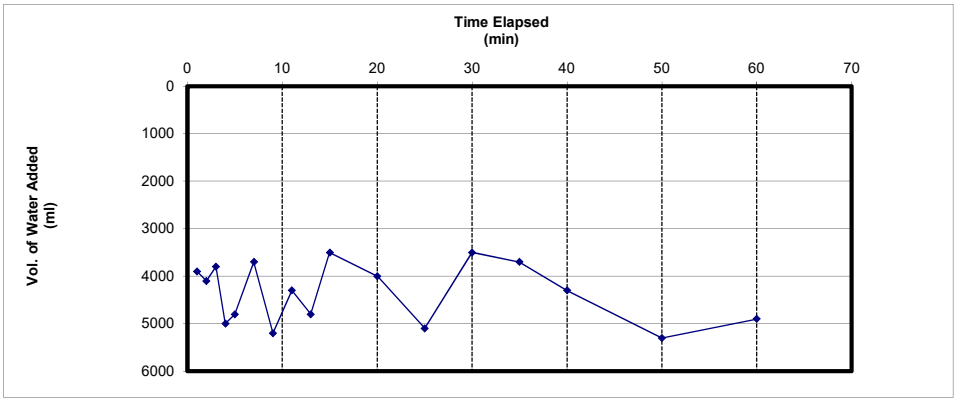
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-2
Test Number 2
Test Depth (m). 15
Test Date. 01/05/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm) 900 cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	3900
2	1	2	4100
3	1	3	3800
4	1	4	5000
5	1	5	4800
6	2	7	3700
7	2	9	5200
8	2	11	4300
9	2	13	4800
10	2	15	3500
11	5	20	4000
12	5	25	5100
13	5	30	3500
14	5	35	3700
15	5	40	4300
16	10	50	5300
17	10	60	4900
	60	Σ	**73900**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

$Q =$ 20.52778 cm^3/sec
$F =$ 27.775 cm
$H_c =$ 7 cm

k = 1.06E-01 cm/sec

UNIVERSAL DRILLING ENGINEERS

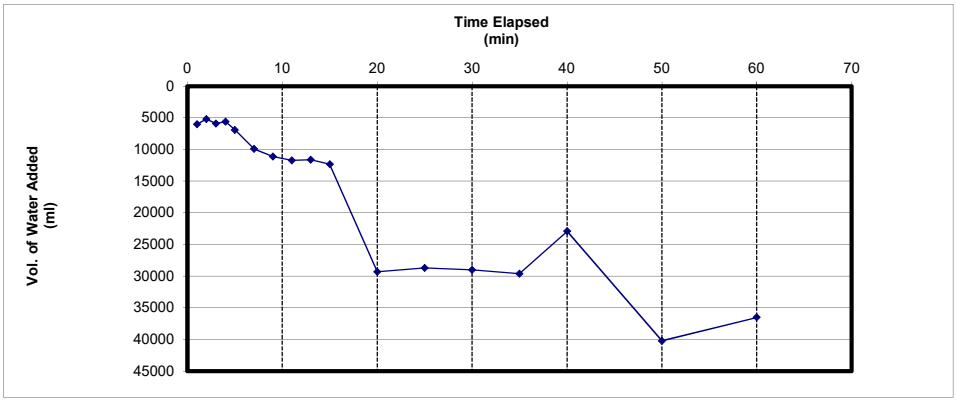
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-3
Test Number 1
Test Depth (m). 5
Test Date. 07/05/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm), nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	6000
2	1	2	5200
3	1	3	5900
4	1	4	5600
5	1	5	6900
6	2	7	9900
7	2	9	11100
8	2	11	11700
9	2	13	11600
10	2	15	12300
11	5	20	29300
12	5	25	28700
13	5	30	29000
14	5	35	29600
15	5	40	22900
16	10	50	40200
17	10	60	36500
	60	Σ	**302400**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	84.00000	cm^3/sec
F =	27.775	cm
H_c =	8	cm
k =	**3.78E-01**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

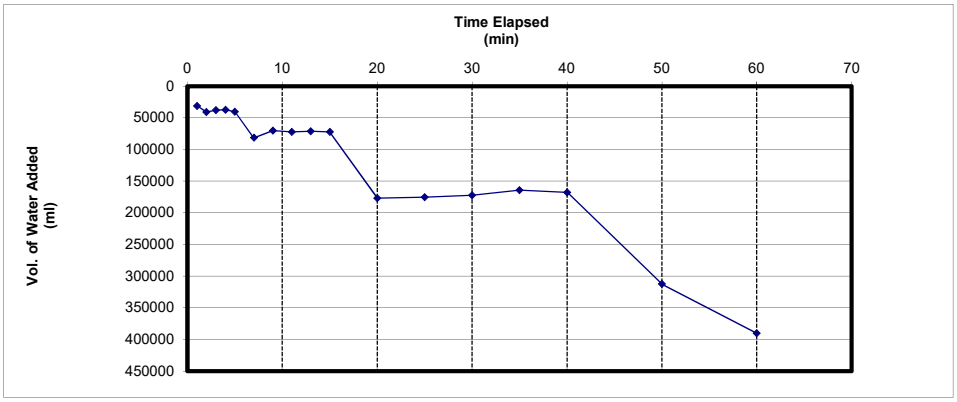
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-3
Test Number 2
Test Depth (m). 10
Test Date. 08/05/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	31000
2	1	2	41000
3	1	3	37600
4	1	4	37100
5	1	5	40500
6	2	7	81500
7	2	9	70200
8	2	11	72000
9	2	13	71000
10	2	15	72000
11	5	20	176900
12	5	25	175100
13	5	30	172000
14	5	35	163900
15	5	40	167800
16	10	50	312400
17	10	60	390000
	60	Σ	**2112000**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	586.667	cm^3/sec
F =	27.775	cm
H_c =	8	cm
k =	**2.64E+00**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

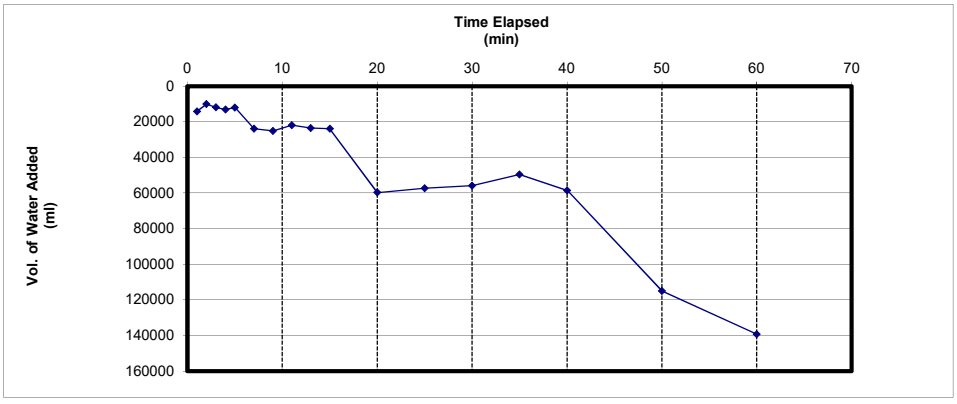
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-3
Test Number 3
Test Depth (m). 10
Test Date. 25/05/2021
Test Type Constant Head

Internal dia of casing : 10.8 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	14100
2	1	2	10100
3	1	3	11900
4	1	4	13100
5	1	5	12000
6	2	7	23800
7	2	9	25100
8	2	11	21900
9	2	13	23500
10	2	15	23900
11	5	20	59700
12	5	25	57200
13	5	30	55900
14	5	35	49500
15	5	40	58500
16	10	50	115000
17	10	60	139200
	60	Σ	**714400**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	198.444	cm^3/sec
F =	29.7	cm
H_c =	8	cm
k =	**8.35E-01**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

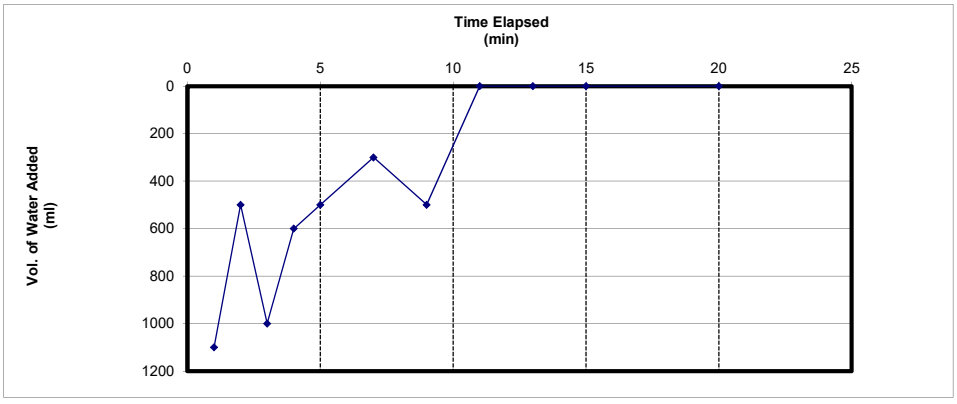
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-3
Test Number 4
Test Depth (m). 20
Test Date. 26/05/2021
Test Type Constant Head

Internal dia of casing : 10.8 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	1100
2	1	2	500
3	1	3	1000
4	1	4	600
5	1	5	500
6	2	7	300
7	2	9	500
8	2	11	0
9	2	13	0
10	2	15	0
11	5	20	0
12			
13			
14			
15			
16			
17			
	20	Σ	**4500**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	3.750	cm^3/sec
F =	29.7	cm
H_c =	8	cm
k =	**1.58E-02**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

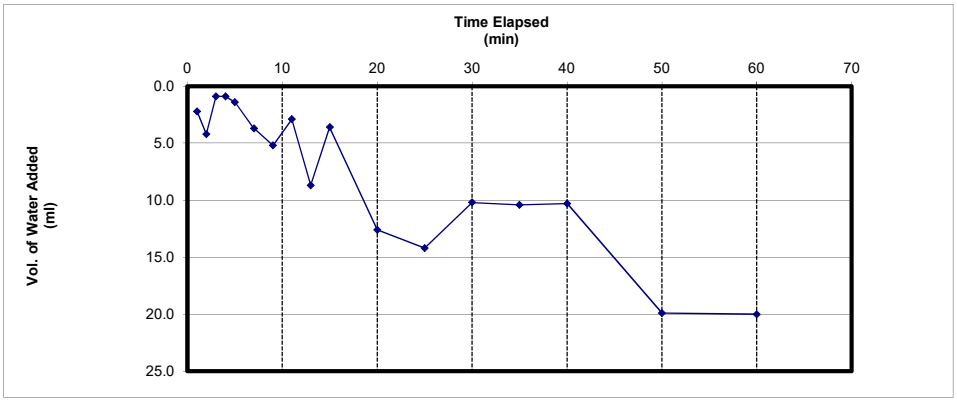
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-3
Test Number 5
Test Depth (m). 25
Test Date. 27/05/2021
Test Type Constant Head

Internal dia of casing : 10.8 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	2200
2	1	2	4200
3	1	3	900
4	1	4	900
5	1	5	1400
6	2	7	3700
7	2	9	5200
8	2	11	2900
9	2	13	8700
10	2	15	3600
11	5	20	12600
12	5	25	14200
13	5	30	10200
14	5	35	10400
15	5	40	10300
16	10	50	19900
17	10	60	20000
	60	Σ	**131300**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q = 36.47222 cm^3/sec
F = 29.7 cm
H_c = 8 cm

k = 1.54E-01 cm/sec

UNIVERSAL DRILLING ENGINEERS

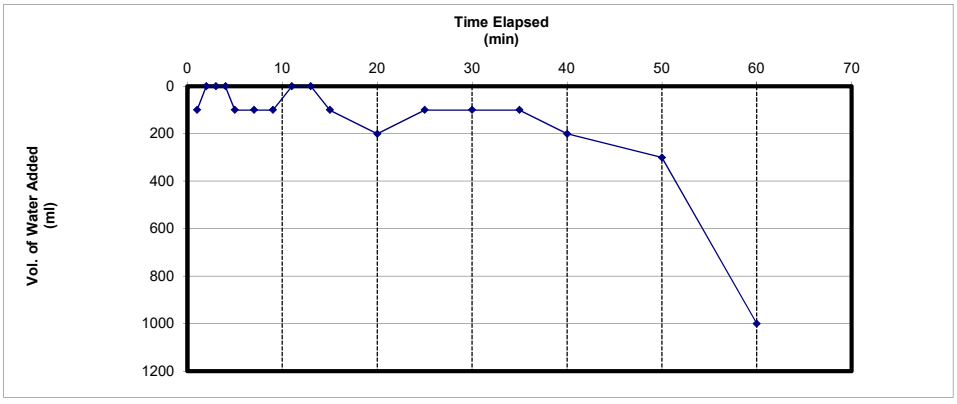
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-3
Test Number 6
Test Depth (m). 30
Test Date. 06/06/2021
Test Type Constant Head

Internal dia of casing : 7.5 cm

Depth of water table (cm), nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	100
2	1	2	0
3	1	3	0
4	1	4	0
5	1	5	100
6	2	7	100
7	2	9	100
8	2	11	0
9	2	13	0
10	2	15	100
11	5	20	200
12	5	25	100
13	5	30	100
14	5	35	100
15	5	40	200
16	10	50	300
17	10	60	1000
	60	Σ	**2500**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	0.69444	cm^3/sec
F =	20.625	cm
H_c =	20	cm
k =	**1.68E-03**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

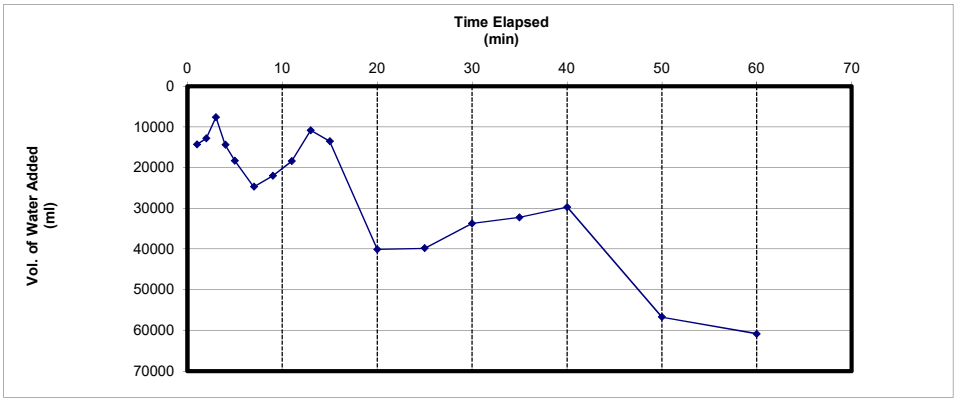
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 1
Test Depth (m). 7
Test Date. 24/06/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm), nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	14300
2	1	2	12800
3	1	3	7600
4	1	4	14400
5	1	5	18300
6	2	7	24700
7	2	9	22000
8	2	11	18400
9	2	13	10800
10	2	15	13500
11	5	20	40100
12	5	25	39800
13	5	30	33700
14	5	35	32200
15	5	40	29700
16	10	50	56700
17	10	60	60800
	60	Σ	**449800**



$$k = \frac{Q}{F \times H_c}$$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	124.94444	cm^3/sec
F =	27.775	cm
H_c =	8	cm
k =	**5.62E-01**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

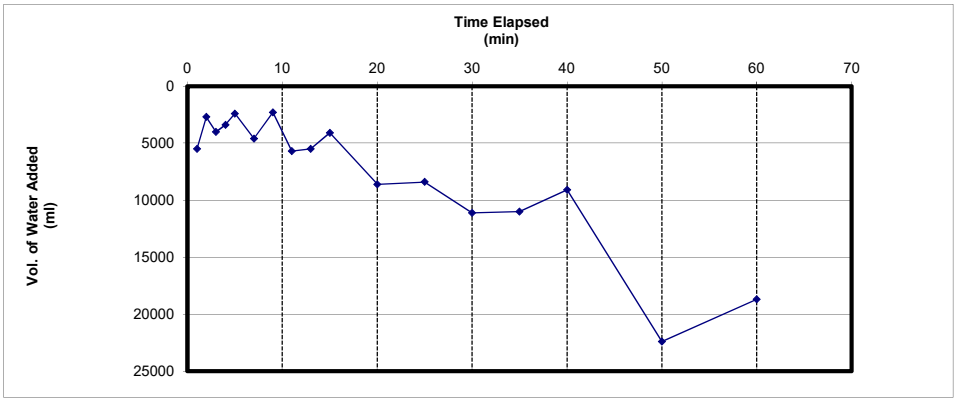
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 2
Test Depth (m). 14
Test Date. 26/06/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm), nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	5500
2	1	2	2700
3	1	3	4000
4	1	4	3400
5	1	5	2400
6	2	7	4600
7	2	9	2300
8	2	11	5700
9	2	13	5500
10	2	15	4100
11	5	20	8600
12	5	25	8400
13	5	30	11100
14	5	35	11000
15	5	40	9100
16	10	50	22400
17	10	60	18700
	60	Σ	**129500**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q = 35.97222 cm^3/sec
F = 27.775 cm
H_c = 10 cm

k = 1.30E-01 cm/sec

UNIVERSAL DRILLING ENGINEERS

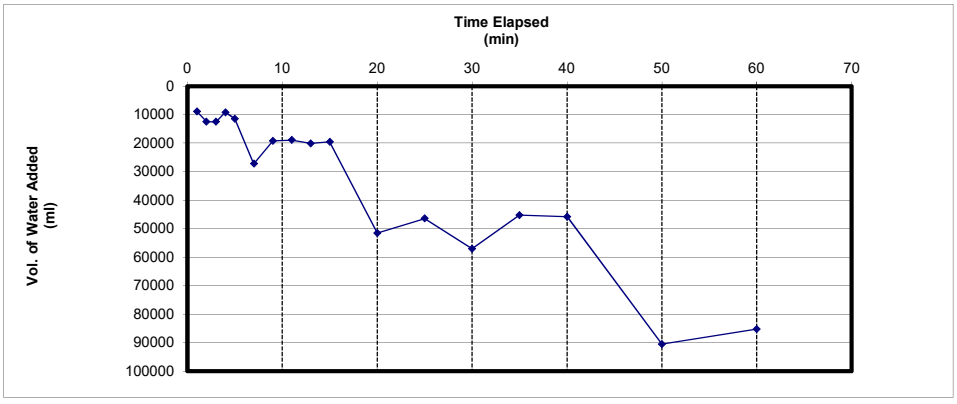
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 3
Test Depth (m). 16
Test Date. 27/06/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	8900
2	1	2	12400
3	1	3	12500
4	1	4	9200
5	1	5	11400
6	2	7	27200
7	2	9	19200
8	2	11	18900
9	2	13	20100
10	2	15	19500
11	5	20	51500
12	5	25	46400
13	5	30	57000
14	5	35	45200
15	5	40	45800
16	10	50	90500
17	10	60	85200
	60	Σ	**580900**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	161.36111	cm^3/sec
F =	27.775	cm
H_c =	10	cm
k =	**5.81E-01**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

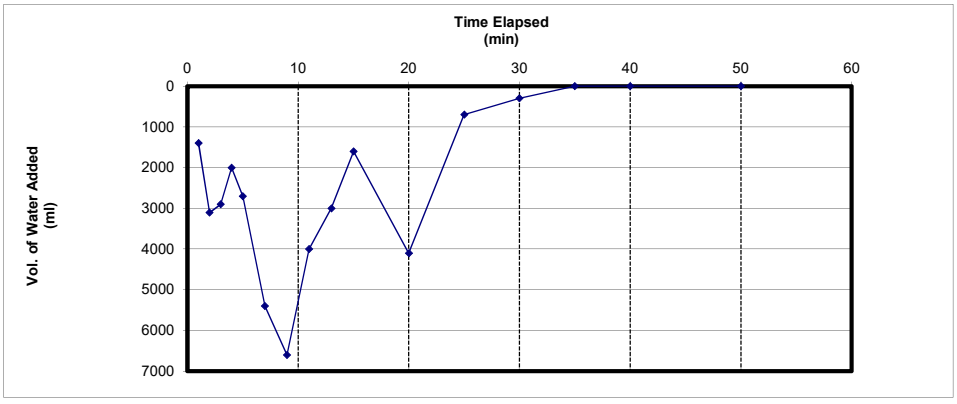
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 4
Test Depth (m). 21
Test Date. 29/06/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	1400
2	1	2	3100
3	1	3	2900
4	1	4	2000
5	1	5	2700
6	2	7	5400
7	2	9	6600
8	2	11	4000
9	2	13	3000
10	2	15	1600
11	5	20	4100
12	5	25	700
13	5	30	300
14	5	35	0
15	5	40	0
16	10	50	0
	50	Σ	**37800**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

$Q =$ 12.60 cm^3/sec
$F =$ 27.775 cm
$H_c =$ 12 cm

k = 3.78E-02 cm/sec

UNIVERSAL DRILLING ENGINEERS

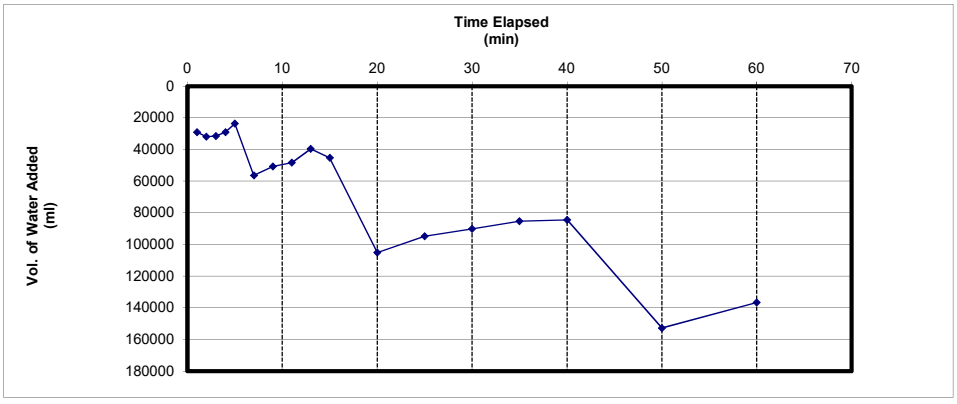
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 5
Test Depth (m). 23
Test Date. 30/06/2021
Test Type Constant Head

Internal dia of casing : 7.5 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	29000
2	1	2	31900
3	1	3	31400
4	1	4	29100
5	1	5	23600
6	2	7	56300
7	2	9	50700
8	2	11	48300
9	2	13	39500
10	2	15	45300
11	5	20	105000
12	5	25	94800
13	5	30	90100
14	5	35	85200
15	5	40	84400
16	10	50	152700
17	10	60	136600
	60	Σ	**1133900**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	314.97222	cm^3/sec
F =	20.625	cm
H_c =	8	cm
k =	**1.91E+00**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

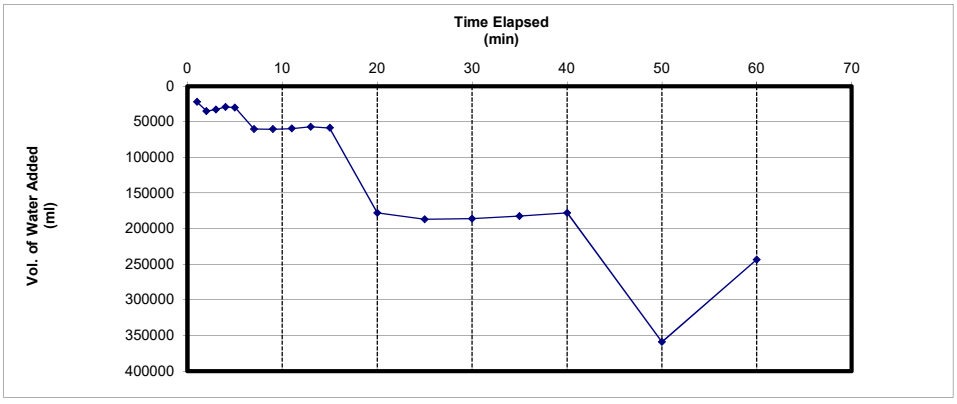
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 6
Test Depth (m). 28
Test Date. 01/07/2021
Test Type Constant Head

Internal dia of casing : 7.5 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	22000
2	1	2	35100
3	1	3	32800
4	1	4	29100
5	1	5	30100
6	2	7	59900
7	2	9	60300
8	2	11	59400
9	2	13	57000
10	2	15	58500
11	5	20	177900
12	5	25	186600
13	5	30	185900
14	5	35	182100
15	5	40	177700
16	10	50	358900
17	10	60	243500
	60	Σ	**1956800**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	543.56	cm^3/sec
F =	20.625	cm
H_c =	10	cm
k =	**2.64E+00**	**cm/sec**

UNIVERSAL DRILLING ENGINEERS

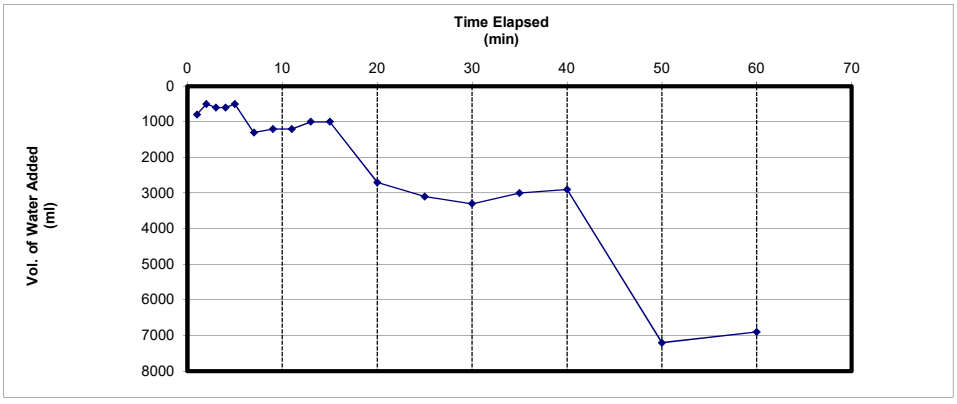
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-4
Test Number 7
Test Depth (m). 32
Test Date. 02/07/2021
Test Type Constant Head

Internal dia of casing : 7.5 cm

Depth of water table (cm), nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	800
2	1	2	500
3	1	3	600
4	1	4	600
5	1	5	500
6	2	7	1300
7	2	9	1200
8	2	11	1200
9	2	13	1000
10	2	15	1000
11	5	20	2700
12	5	25	3100
13	5	30	3300
14	5	35	3000
15	5	40	2900
16	10	50	7200
17	10	60	6900
	60	Σ	**37800**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

$Q =$ 10.50000 cm^3/sec
$F =$ 20.625 cm
$H_c =$ 8 cm

k = 6.36E-02 cm/sec

UNIVERSAL DRILLING ENGINEERS

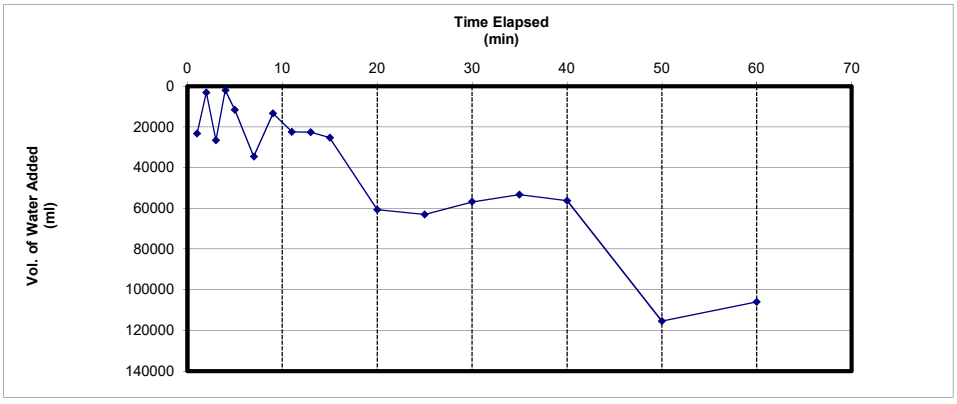
FIELD PERMEABILITY TEST

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK
Borehole No. BH-5
Test Number 1
Test Depth (m). 3
Test Date. 30/06/2021
Test Type Constant Head

Internal dia of casing : 10.1 cm

Depth of water table (cm) nill cm

Sr. No	Time Elapsed (min)	Commulative Time Elapsed (min)	Vol of Water Added (ml)
1	1	1	23300
2	1	2	3100
3	1	3	26600
4	1	4	2000
5	1	5	11600
6	2	7	34600
7	2	9	13400
8	2	11	22400
9	2	13	22600
10	2	15	25300
11	5	20	60700
12	5	25	63000
13	5	30	56800
14	5	35	53200
15	5	40	56300
16	10	50	115400
17	10	60	105900
	60	Σ	**696200**



$k = \frac{Q}{F \times H_c}$ REF: Page 285 Soil Mechanics by Lambe & Whitman 1969

Q =	193.38889	cm^3/sec
F =	27.775	cm
H_c =	10	cm
k =	**6.96E-01**	**cm/sec**

APPENDIX-C

Summary and Laboratory Test Result Sheets

TEST RESULTS OF COARSE CURSHED AGGREGATE MATERIAL

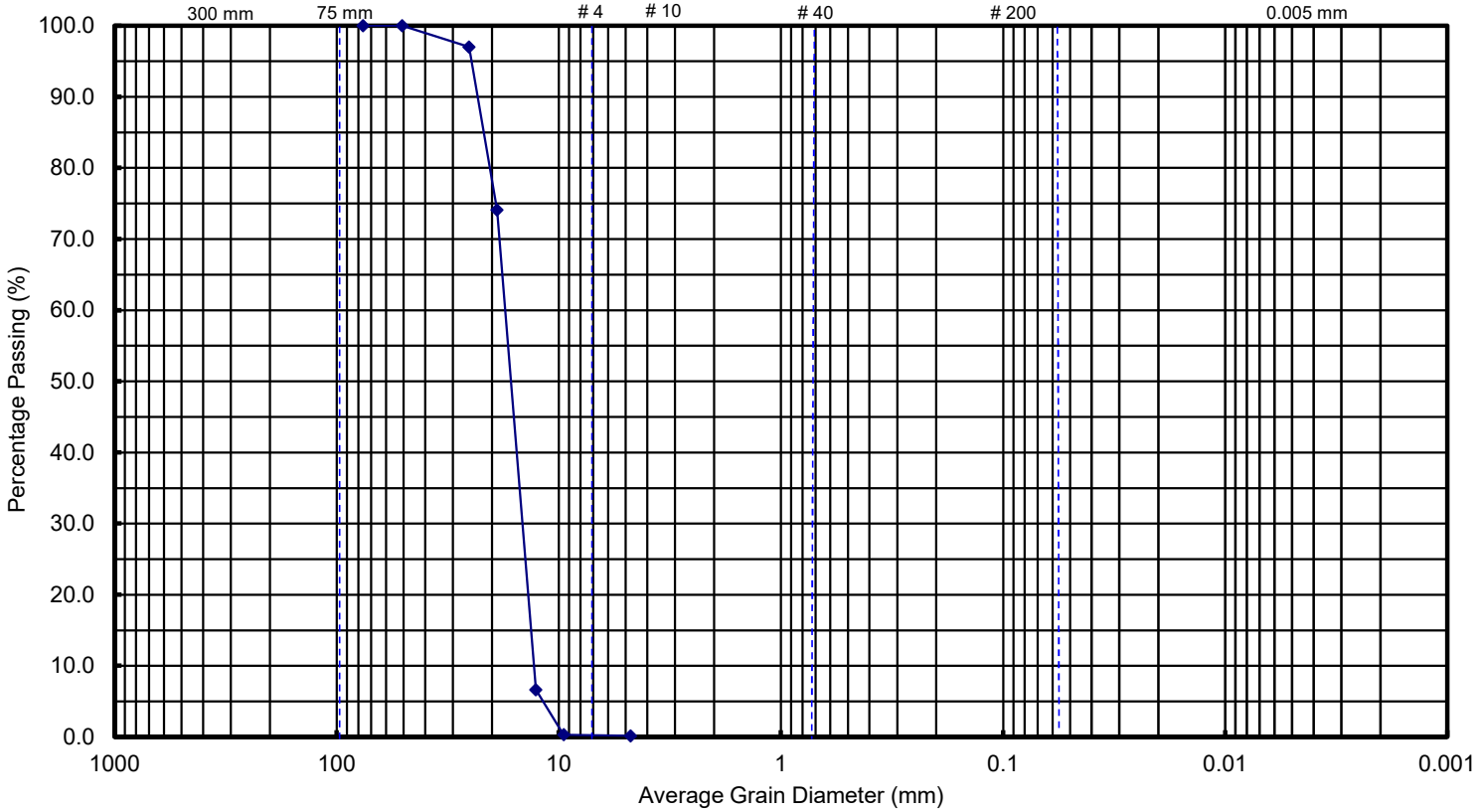
Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK

Location: Shamkoli **Ref: J-720**

Serial No.	Sample No.	Gradation %age Passing by weight								Specific Gravity	Water Absorption % age	Sulphate Content %	Chloride Content %	Los Angeles Abrasion Value % age	CRUSHING VALUE (ACV %)	Force Ten Percent Fines Value in kN (TFV)	Determinatic Shape
		2 ½"	2"	1 ½"	1"	3/4"	½"	3/8"	No.4								Elongation Index %
1	sample # 1	100.0	100.0	100.0	97.0	74.1	6.6	0.3	0.2	2.854	0.45	0.001	0.002		12.92	225	14.6
2	sample # 2	100.0	100.0	100.0	70.1	12.7	4.3	1.0	0.2	2.849	0.439				15.07		13.4
3	sample # 3	100.0	100.0	100.0	70.3	14.2	3.2	1.2	0.5	2.854	0.614			14.6	15.00		
4	sample # 5	100.0	100.0	100.0	100.0	82.1	17.4	1.8	0.2			0.000	0.001		12.85	227	13.1
5	sample # 7	100.0	100.0	100.0	100.0	55.7	13.3	1.3	0.5	2.903	0.397	0.000	0.002		12.31	234	
6	sample # 8									2.845	0.407		0.002	14.4			16.8

Grain Size Analysis (ASTM D422)

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	**Location:** Shamkoli	**Sample# 1**	**Lab Ref.** J-720



Seive Size. Inch/No.	Passing % age
3"	100.0
2"	100.0
1"	97.0
¾"	74.1
½"	6.6
⅜"	0.3
# 4	0.2
# 10	0.0
# 16	0.0
# 40	0.0
# 50	0.0
# 100	0.0
# 200	0.0

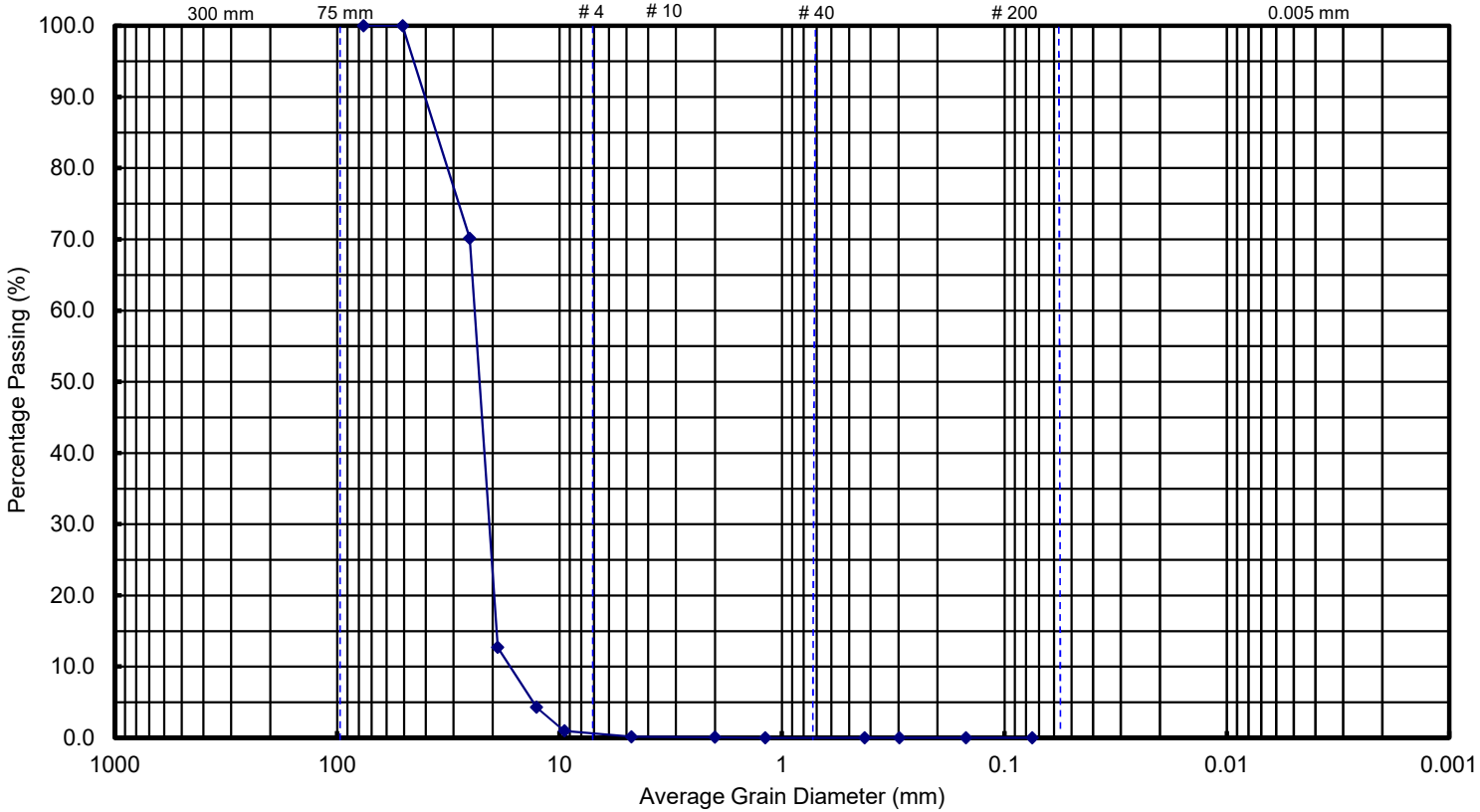
Gravel (%)=	99.83
Sand (%)=	0.17
Fines(%)=	0.00

Boulders	Cobbles	Gravel	Sand			Silt	Clay
			Coarse	Medium	Fine		

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

Grain Size Analysis (ASTM D422)

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	**Location:** Shamkoli	**Sample# 2**	**Lab Ref.** J-720



Seive Size. Inch/No.	Passing % age
3"	100.0
2"	100.0
1"	70.1
¾"	12.7
½"	4.3
⅜"	1.0
# 4	0.2
# 10	0.1
# 16	0.0
# 40	0.0
# 50	0.0
# 100	0.0
# 200	0.0

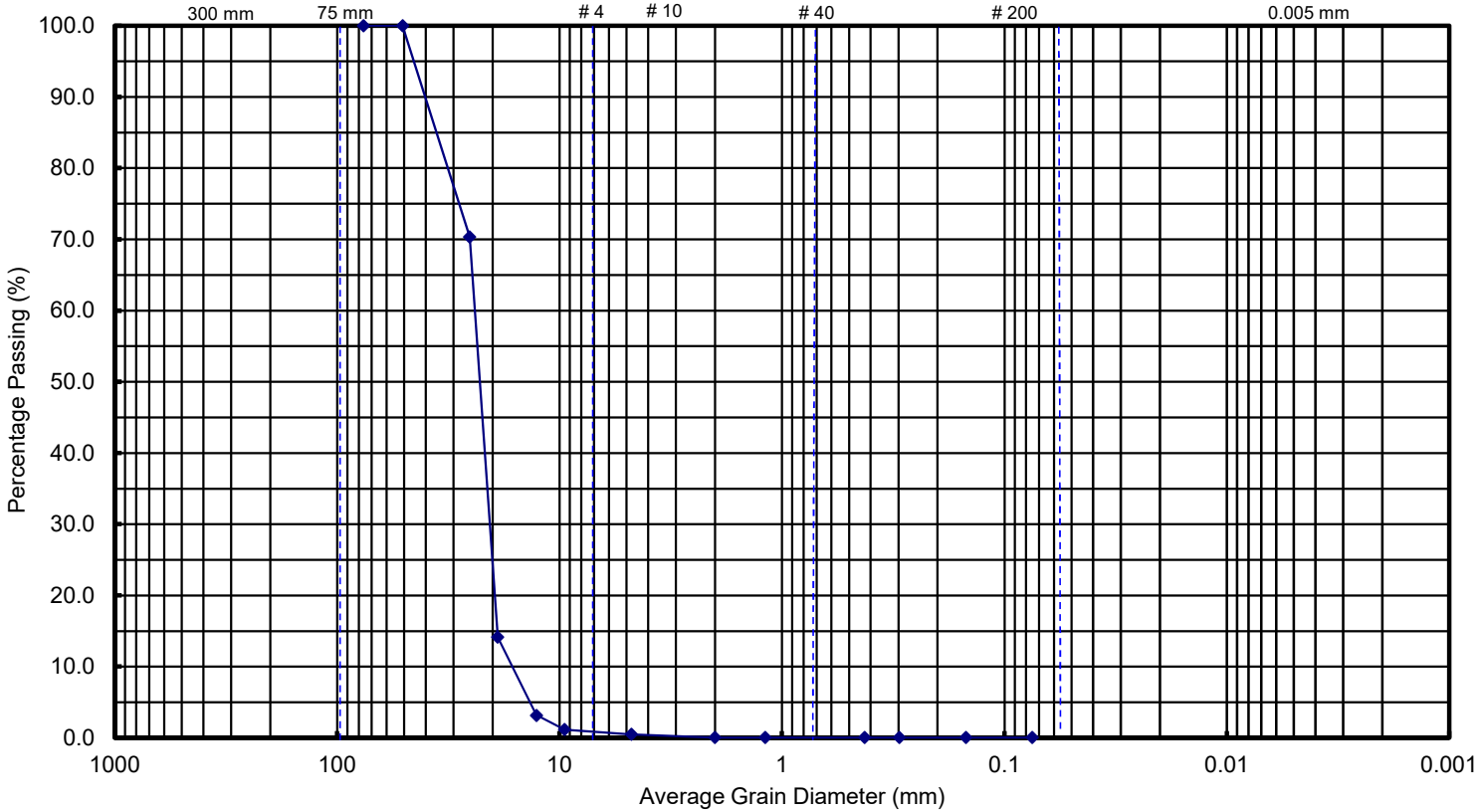
Gravel (%)=	99.83
Sand (%)=	0.16
Fines(%)=	0.01

Boulders	Cobbles	Gravel	Sand			Silt	Clay
			Coarse	Medium	Fine		

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

Grain Size Analysis (ASTM D422)

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	**Location:** **Shamkoli**	**Sample# 3**	**Lab Ref.** J-720



Seive Size. Inch/No.	Passing % age
3"	100.0
2"	100.0
1"	70.3
¾"	14.2
½"	3.2
⅜"	1.2
# 4	0.5
# 10	0.0
# 16	0.0
# 40	0.0
# 50	0.0
# 100	0.0
# 200	0.0

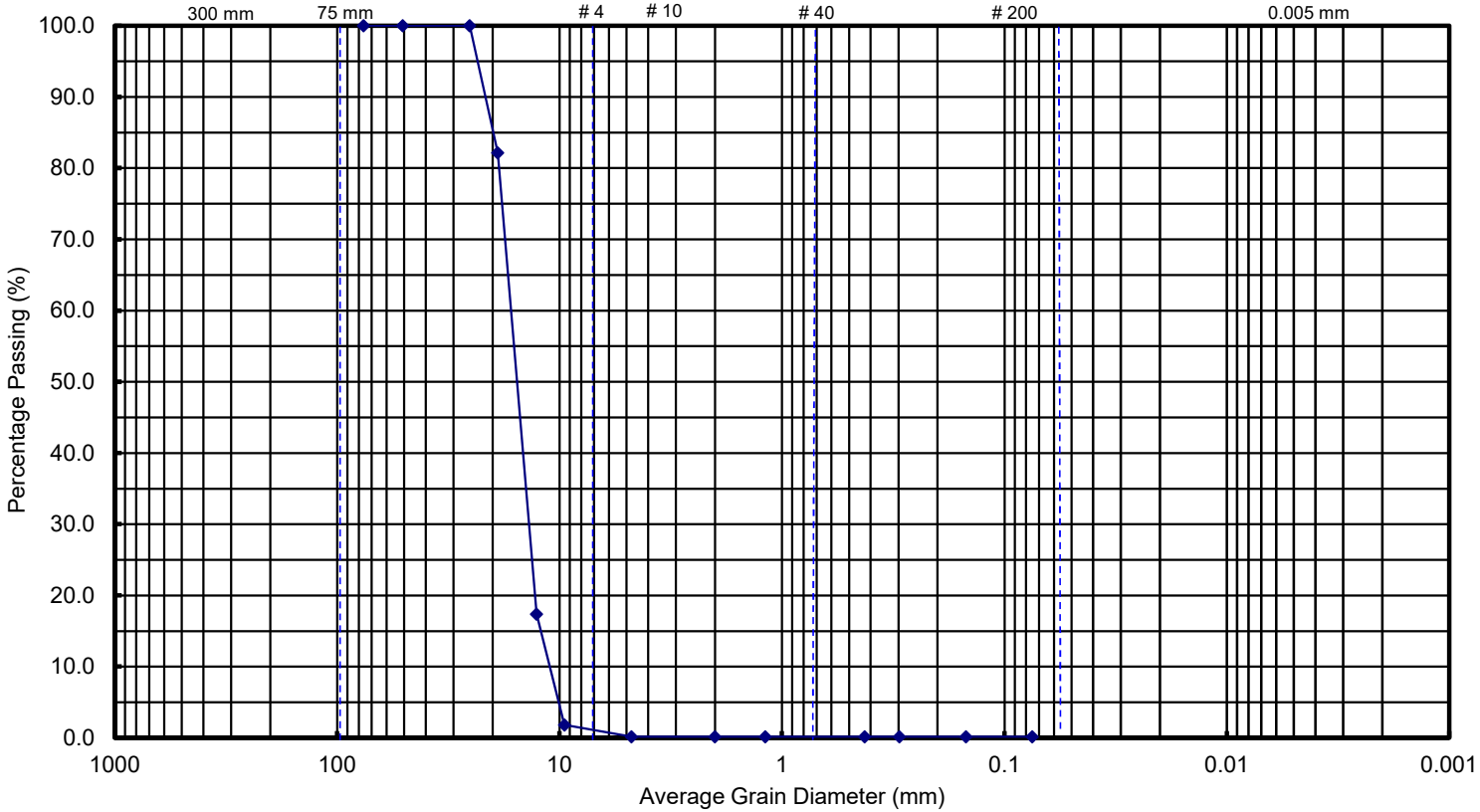
Gravel (%)=	99.50
Sand (%)=	0.46
Fines(%)=	0.04

Boulders	Cobbles	Gravel	Sand			Silt	Clay
			Coarse	Medium	Fine		

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

Grain Size Analysis (ASTM D422)

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	**Location:** Shamkoli	**Sample# 5**	**Lab Ref.** J-720



Seive Size. Inch/No.	Passing % age
3"	100.0
2"	100.0
1"	100.0
¾"	82.1
½"	17.4
⅜"	1.8
# 4	0.2
# 10	0.2
# 16	0.2
# 40	0.2
# 50	0.2
# 100	0.2
# 200	0.2

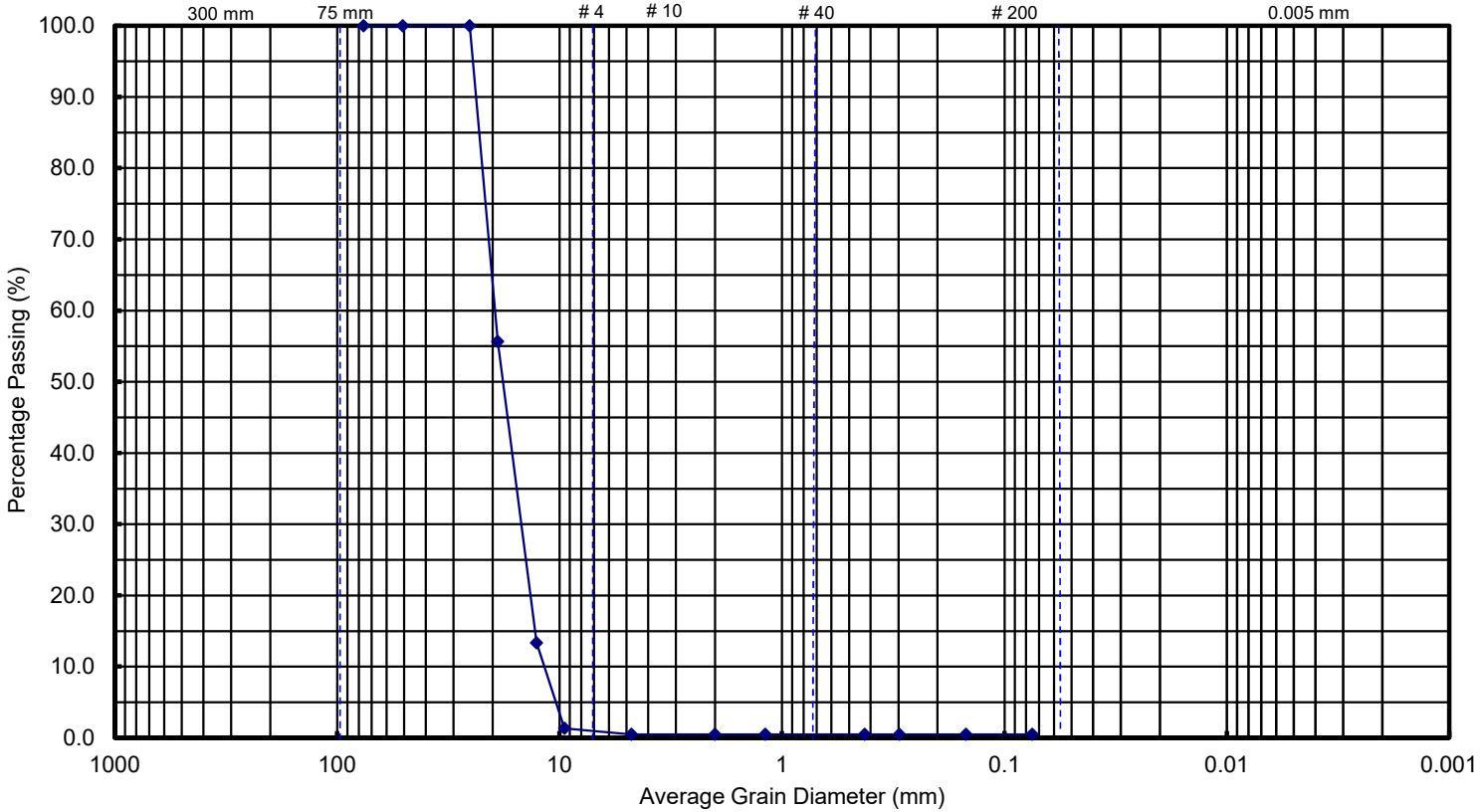
Gravel (%)=	99.83
Sand (%)=	0.00
Fines(%)=	0.17

Boulders	Cobbles	Gravel	Sand			Silt	Clay
			Coarse	Medium	Fine		

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

Grain Size Analysis (ASTM D422)

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	**Location:** **Shamkoli**	**Sample# 7**	**Lab Ref.** J-720



Seive Size. Inch/No.	Passing % age
3"	100.0
2"	100.0
1"	100.0
¾"	55.7
½"	13.3
⅜"	1.3
# 4	0.5
# 10	0.5
# 16	0.5
# 40	0.5
# 50	0.5
# 100	0.5
# 200	0.5

Gravel (%)=	99.50
Sand (%)=	0.00
Fines(%)=	0.50

Boulders	Cobbles	Gravel	Sand			Silt	Clay
			Coarse	Medium	Fine		

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE
AASHTO T-85

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 1, Crush Aggregate

Trial No	1	2	Average
Bulk Specific Gravity	2.857	2.850	2.854
Bulk SSD Specific Gravity	2.871	2.862	2.867
Apparent Specific Gravity	2.899	2.883	2.891
Water Absorption %	0.500	0.400	0.450

Tested by:	Checked by:
Sikandar Hayat	Muhammad Ajmal

SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE
AASHTO T-85

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 2, Crush Aggregate

Trial No	1	2	Average
Bulk Specific Gravity	2.849	2.849	2.849
Bulk SSD Specific Gravity	2.861	2.861	2.861
Apparent Specific Gravity	2.885	2.885	2.885
Water Absorption %	0.448	0.430	0.439

Tested by:	Checked by:
Sikandar Hayat	Muhammad Ajmal

SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE
AASHTO T-85

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 3, Crush Aggregate

Trial No	1	2	Average
Bulk Specific Gravity	2.855	2.852	2.854
Bulk SSD Specific Gravity	2.872	2.870	2.871
Apparent Specific Gravity	2.905	2.904	2.905
Water Absorption %	0.605	0.624	0.614

Tested by:	Checked by:
Sikandar Hayat	Muhammad Ajmal

SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE
AASHTO T-85

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 7, Crush Aggregate

Trial No	1	2	Average
Bulk Specific Gravity	2.905	2.902	2.903
Bulk SSD Specific Gravity	2.916	2.914	2.915
Apparent Specific Gravity	2.939	2.936	2.937
Water Absorption %	0.398	0.396	0.397

Tested by:	Checked by:
Sikandar Hayat	Muhammad Ajmal

SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE
AASHTO T-85

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 8, Crush Aggregate

Trial No	1	2	Average
Bulk Specific Gravity	2.844	2.845	2.845
Bulk SSD Specific Gravity	2.856	2.856	2.856
Apparent Specific Gravity	2.878	2.877	2.878
Water Absorption %	0.416	0.397	0.407

Tested by:	Checked by:
Sikandar Hayat	Muhammad Ajmal

TEST RESULTS OF AGGREGATE CRUSHING VALUE (ACV)

BS - 812; Part 110

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 1, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Load Applied	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2813	2450	363	400 kN/ 10 min	12.90	
2	14 mm-10 mm	2830	2464	366		12.93	
Average Crushing Value						**12.92 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

TEST RESULTS OF AGGREGATE CRUSHING VALUE (ACV)

BS - 812; Part 110

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 2, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Load Applied	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2863	2431	432	400 kN/ 10 min	15.09	
2	14 mm-10 mm	2870	2438	432		15.05	
Average Crushing Value						**15.07 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

TEST RESULTS OF AGGREGATE CRUSHING VALUE (ACV)

BS - 812; Part 110

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 3, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Load Applied	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2850	2420	430	400 kN/ 10 min	15.09	
2	14 mm-10 mm	2870	2442	428		14.91	
Average Crushing Value						**15.00 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

TEST RESULTS OF AGGREGATE CRUSHING VALUE (ACV)

BS - 812; Part 110

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 5, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Load Applied	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2814	2454	360	400 kN/ 10 min	12.79	
2	14 mm-10 mm	2820	2456	364		12.91	
Average Crushing Value						**12.85 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

TEST RESULTS OF AGGREGATE CRUSHING VALUE (ACV)

BS - 812; Part 110

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 7, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Load Applied	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2819	2474	345	400 kN/ 10 min	12.24	
2	14 mm-10 mm	2825	2475	350		12.39	
Average Crushing Value						**12.31 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

METHODS OF DETERMINATION OF PARTICAL SHAPE
TEST RESULT OF FLAKINESS & ELONGATION INDEX

BS - 812; Part 105

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK		
Location: Shamkoli	Sample # : 1, Crush Aggregate	

Elongation Index	14.6 %	**Flakiness Index**	3.2 %

Tested by: Sikandar	Checked by: Muhammad Ajmal

METHODS OF DETERMINATION OF PARTICAL SHAPE
TEST RESULT OF FLAKINESS & ELONGATION INDEX

BS - 812; Part 105

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK		
Location: Shamkoli	Sample # : 2, Crush Aggregate	

Elongation Index	13.4 %	**Flakiness Index**	3.2 %

Tested by: Sikandar	Checked by: Muhammad Ajmal

METHODS OF DETERMINATION OF PARTICAL SHAPE
TEST RESULT OF FLAKINESS & ELONGATION INDEX

BS - 812; Part 105

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK		
Location: Shamkoli	Sample # : 5, Crush Aggregate	

Elongation Index	13.1 %	**Flakiness Index**	3.0 %

Tested by: Sikandar	Checked by: Muhammad Ajmal

METHODS OF DETERMINATION OF PARTICAL SHAPE
TEST RESULT OF FLAKINESS & ELONGATION INDEX

BS - 812; Part 105

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK		
Location: Shamkoli	Sample # : 8, Crush Aggregate	

Elongation Index	16.8 %	**Flakiness Index**	4.2 %

Tested by: Sikandar	Checked by: Muhammad Ajmal

TEST RESULTS OF TEN PERCENT FINES VALUE (TFV)

BS - 812; Part 111

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 1, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Force TFV on Crushed Agg. 20 mm penetration (kN)	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2770	2560	210	227	7.58	
2	14 mm-10 mm	2790	2578	212	222	7.60	
Average Crushing Value					225	**7.59 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

TEST RESULTS OF TEN PERCENT FINES VALUE (TFV)

BS - 812; Part 111

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 5, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Force TFV on Crushed Agg. 20 mm penetration (kN)	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2790	2575	215	231	7.71	
2	14 mm-10 mm	2801	2584	217	222	7.75	
Average Crushing Value					227	**7.73 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

TEST RESULTS OF TEN PERCENT FINES VALUE (TFV)

BS - 812; Part 111

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK	
Location: Shamkoli	Sample # : 7, Crush Aggregate

Size Availability	14 mm-10 mm after crushing

Trial #	Size of Aggregate	Total wt. of Agg. Before test	Wt. of material retained on Sieve 2.36 mm	Wt. Of material passing seive 2.36 mm	Force TFV on Crushed Agg. 20 mm penetration (kN)	Crushing Value	Remarks
		gm	gm	gm		%	
1	14 mm-10 mm	2780	2565	215	236	7.73	
2	14 mm-10 mm	2760	2546	214	231	7.75	
Average Crushing Value					234	**7.74 %**	

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

AASHTO T 96 and ASTM C131

Los Angeles Abrasion Test

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK

Location: Shamkoli	Sample # : 3, Crush Aggregate

Sieve Size				Mass of indicated sizes (gms)				
				Grading				
Sr. No.	Passing	Retained on	Quantity (gm)	A	B	C	D	Grade of Sample
1	1 1/2 in.	1 in.		1250				
2	1 in.	3/4 in.		1250				
3	3/4 in.	1/2 in.	2500	1250	2500			
4	1/2 in.	3/8 in.	2500	1250	2500			
5	3/8 in.	¼"				2500		B
6	¼"	No. 4				2500		
7	No. 4	No. 8					5000	
Total			**5000**	5000	5000	5000	5000	
No. of Revolutions (r/500) 30 to 33 min				500	500	500	500	

Number of Spheres =11

Weight of sample before test	gm	5000 gm
Weight of sample retained on Sieve # 12 (before wash)	gm	4295 gm
Weight of sample retained on Sieve # 12 (after wash)	gm	4270 gm
Weight of sample passed through No. 12 Sieve	gm	730 gm
Percentage of wear		**14.60 %**

Tested by:	Checked by:
Sikandar Hayat	Muhammad Ajmal

AASHTO T 96 and ASTM C131
Los Angeles Abrasion Test

Project: JAGRAN-IV HYDROPOWER PROJECT DISRTICT, NEELUM VALLEY, AJK

Location: Shamkoli	Sample # 8 , Crush Aggregate

Sieve Size				Mass of indicated sizes (gms)				
				Grading				
Sr. No.	Passing	Retained on	Quantity (gm)	A	B	C	D	Grade of Sample
1	1 1/2 in.	1 in.		1250				
2	1 in.	3/4 in.		1250				
3	3/4 in.	1/2 in.	2500	1250	2500			
4	1/2 in.	3/8 in.	2500	1250	2500			
5	3/8 in.	¼"				2500		B
6	¼"	No. 4				2500		
7	No. 4	No. 8					5000	
Total			**5000**	5000	5000	5000	5000	
No. of Revolutions (r/500) 30 to 33 min				500	500	500	500	

Number of Spheres =11

Weight of sample before test	gm	5000 gm
Weight of sample retained on Sieve # 12 (before wash)	gm	4300 gm
Weight of sample retained on Sieve # 12 (after wash)	gm	4280 gm
Weight of sample passed through No. 12 Sieve	gm	720 gm
Percentage of wear		**14.40 %**

Tested by: Sikandar Hayat	Checked by: Muhammad Ajmal

APPENDIX-D

Photographs

Drilling of Boreholes using Straight Rotary Rig

Preservation of samples in wooden core boxes

Excavation of Test pits

TABLE OF CONTENTS

Page

ABBREVIATIONS

EXECUTIVE SUMMARY

SALIENT FEATURES

1 INTRODUCTION 1
1.1 PROJECT BACKGROUND 1
1.2 SCOPE OF CONSULTANCY SERVICES 3
1.3 PROJECT LOCATION - JAGRAN-IV HYDROPOWER PROJECT 4
1.4 ACCESSIBILITY TO THE PROJECT AREA 5
1.4.1 Route Distance 6
1.5 COMMUNICATION 6
1.6 ELECTRIC POWER SUPPLY 7
1.7 PREVIOUS STUDIES 7

2 TOPOGRAPHIC SURVEY 9
2.1 GENERAL 9
2.2 SCOPE OF WORK 9
2.3 TOPOGRAPHY OF NEELUM RIVER CATCHMENT 9
2.4 AVAILABLE TOPOGRAPHIC MAPS 10
2.5 DETAILED TOPOGRAPHIC SURVEY 10
2.5.1 Reference Grid 11
2.5.2 Bench Marks and Control Points 11
2.5.3 Horizontal Control 11
2.5.4 Vertical Control 12
2.6 LONGITUDINAL PROFILE OF JAGRAN RIVER 12
2.7 TOPOGRAPHY WITH SATELLITE IMAGES 12
2.8 PREPARATION OF CONTOUR MAPS 13
2.9 SOFTWARE 13

3 HYDROLOGY AND SEDIMENTATION 15
3.1 INTRODUCTION 15
3.2 DESCRIPTION OF THE CATCHMENT 15
3.3 CLIMATE 17
3.3.1 Temperature 18
3.3.2 Precipitation 19
3.4 HYDROLOGICAL STATIONS 21
3.4.1 Flow Record at Various Gauging Stations 22
3.4.1.1 Flows of Neelum River at Dudhnial and Nausehri Stations 23
3.5 ESTIMATION OF EXTENDED FLOWS AT THUNIAN & KUNDAL SHAHI 24
3.5.1 Muzaffarabad-Kundal Shahi & Thunian Correlation 24
3.5.2 Naran - Kundal Shahi Correlation 25
3.5.3 Naran - Thunian Correlation 29
3.5.4 Estimated and Observed Flows of Jagran River at Thunian 31

3.6 ESTIMATION OF FLOWS AT JAGRAN - IV WEIR SITE 32
3.7 FLOW DURATION CURVE 34
3.8 LOW FLOWS AT THE PROJECT 36
3.9 ESTIMATION OF FLOODS 36
3.9.1 Estimation of Floods by Gumble Frequency Analysis Method 37
3.9.2 Estimation of Floods by Log Pearson Type - III Method 38
3.9.3 Estimation of Floods by Rainfall Run-off Relationship 39
3.9.4 Floods Recommended at the Weir Site 40
3.10 SEDIMENT TRANSPORT STUDIES 41
3.10.1 Available Sediment Data 41
3.10.2 Sediment Load / Yield at Weir Site 41
3.10.3 Sediment Bed Load 42
3.10.4 Particle Size Distribution 42

4 GEOLOGICAL AND GEOTECHNICAL STUDIES 45
4.1 INTRODUCTION 45
4.2 GEOMORPHOLOGY 46
4.2.1 Topography 46
4.2.2 Hydrology 46
4.2.3 Drainage Pattern 46
4.2.4 Terraces 46
4.2.5 Talus Cone / Colluvial Material 46
4.3 REGIONAL GEOLOGY AND TECTONICS 47
4.3.1 General 47
4.3.2 Geo-Tectonic Setting of Neelum Valley 47
4.3.3 Geology and Lithostratigraphy of Neelum Valley 48
4.3.3.1 Naril Group 50
4.3.3.2 Kundal Shahi Group 50
4.3.3.3 Mansehra Granite (Cambrian - Ordovician) 51
4.3.3.4 Panjal - Traps Metabasites (Carboniferous - Triassic) . 51
4.3.3.5 The Surgun Group 51
4.3.3.6 Metamorphic Evolution 52
4.4 GEOLOGY OF THE PROJECT AREA 52
4.4.1 Lithological Units 52
4.4.1.1 Soil Units 52
4.4.1.2 Rock Units 53
4.5 GEOLOGICAL, GEOTECHNICAL INVESTIGATIONS AND THE SEISMIC STUDIES 54
4.5.1 Surface Geological Mapping 54
4.5.2 Drilling 59
4.5.3 Test Pits 59
4.5.4 Trenches 59
4.5.5 Seismic Refraction Survey 59
4.5.6 Laboratory Testing 60
4.6 SEISMICTY 61
4.6.1 General 61
4.6.2 Seismicity of the Region of Interest 61
4.6.3 Indus Kohistan Seismic Zone (IKSZ) & Associated Earthquakes . 62
4.6.4 Hazara Lower Seismic Zone (HLSZ) 62
4.6.5 Hazara Fault Zone and Associated Earthquakes 62
4.6.6 Kashmir - Balakot Earthquake of October 08, 2005 63

4.7 SEISMIC HAZARD ANALYSIS 64
4.7.1 Deterministic Seismic Hazard Analysis (DSHA) 65
4.7.2 Probabilistic Seismic Hazard Analysis (PSHA) 66
4.7.3 Seismic Hazard Analysis of the Project Area 67
4.8 CONSTRUCTION MATERIAL 67
4.8.1 Coarse Aggregate 68
4.8.2 Fine Aggregate (Sand) 68
4.8.3 Building Stone 68
4.8.4 Fill Material 68
4.8.5 Cement and Steel 68
4.9 PRELIMINARY FOUNDATION EVALUATION 69
4.9.1 Weir 69
4.9.2 Connecting Channel 70
4.9.3 Sandtrap / Desander 70
4.9.4 Pressure Pipe 70
4.9.5 Surge Pipe 71
4.9.6 Penstock 73
4.9.7 Surface Powerhouse 73
4.9.8 Tailrace Channel 73
4.10 ROCK MASS ASSESSMENT 73
4.10.1 Rock Structure Rating (RSR) 74
4.10.2 Geomechanics Classification or Rock Mass Rating System 76
4.10.3 Rock Tunneling Quality Index, Q 79
4.11 GLACIAL LAKE OUTBURST FLOOD (GLOF) 83
4.12 CONCLUSIONS 83
4.13 RECOMMENDATIONS 84

5 ALTERNATIVE PROJECT LAYOUT 85
5.1 GENERAL 85
5.2 TOPOGRAPHIC FEATURES 86
5.3 PROJECT LAYOUT ALTERNATES 86
5.3.1 Alternate Project Layout - I 87
5.3.2 Geological Aspects 88
5.3.2.1 Weir Site 88
5.3.2.2 Connecting Channel 88
5.3.2.3 Headrace Tunnel 88
5.3.2.4 Surge Shaft and Penstock 89
5.3.2.5 Powerhouse and Tailrace 89
5.3.2.6 Salient Features of Jagran - IV Alternative - I 89
5.3.3 Alternate Project Layout - II 90
5.3.4 Geological Aspects of Alternate - II 90
5.3.4.1 Weir Site 90
5.3.4.2 Headrace Pipe / Penstock 90
5.3.4.3 Powerhouse and Tailrace 91
5.3.4.4 Salient Features of Jagran-IV Alternative - II 91
5.4 COMPARISON OF ALTERNATIVE LAYOUTS 91
5.4.1 Gross Head and Power Potential 91
5.4.2 Project Layout 91
5.4.3 Snowfall and Landslides 92
5.4.4 Project Cost 92
5.5 SELECTED LAYOUT 92

6 PROJECT SIZING AND POWER POTENTIAL 93
6.1 GENERAL 93
6.2 HYDROLOGY 93
6.3 CAPACITY OPTIMISATION 94
6.3.1 Compensation Flows 94
6.3.2 Head Losses 95
6.3.2.1 Project Benefits 95
6.3.2.2 Cost Estimation 95
6.4 MARGINAL COST ANALYSIS 97
6.5 SELECTED CAPACITY 99
6.6 POWER AND ENERGY 100

7 CIVIL ENGINEERING DESIGN 107
7.1 GENERAL 107
7.2 DIVERSION WEIR 108
7.2.1 Design Considerations 109
7.2.2 Over Flow Section 109
7.2.3 Flushing Channel Section 111
7.2.4 Gates and Stop Logs 112
7.2.5 Gravel Scour 112
7.3 POWER INTAKE 112
7.4 CONNECTING CHANNEL 113
7.4.1 Reject Weir 114
7.5 DESANDER / SANDTRAP 114
7.5.1 Hydraulic Steel Structures 115
7.5.1.1 Inlet Gate 115
7.5.1.2 Outlet Gate 116
7.5.1.3 Sand Flushing Gates 116
7.6 HEADRACE PRESSURE PIPE 116
7.7 SURGE PIPE 117
7.8 PENSTOCK 119
7.8.1 Diameter of the Penstock Pipe 120
7.8.2 Thickness of Penstock Pipe Sheet 120
7.9 POWERHOUSE 121
7.10 TAILRACE 122

8 HYDRO MECHANICAL EQUIPMENT 123
8.1 GENERAL 123
8.2 MAIN DESIGN PARAMETERS 123
8.2.1 Discharge 123
8.2.2 Head Calculations 124
8.2.2.1 Head Water Level 124
8.2.2.2 Tail Water Level 124
8.2.2.3 Gross Head 124
8.2.2.4 Head Losses 124
8.2.2.5 Turbine Net Head 125
8.3 PLANT CAPACITY 125
8.4 TURBINE SELECTION CRITERIA 125
8.4.1 Number of Units 126
8.4.2 Efficient Water Use 127
8.4.3 Comparison of Alternatives 127
8.4.3.1 Space Limitation for Civil Structure 128
8.4.3.2 Transportation 128
8.4.3.3 Conclusions 129

8.5 TURBINE PARAMETERS 129
8.5.1 Sample Calculations 129
8.5.2 Specific Speed 130
8.5.3 Turbine Rotational Speed 130
8.5.4 Runner Discharge Diameter 131
8.5.5 Runaway Speed 131
8.6 TURBINE COMPONENTS 131
8.6.1 General 131
8.6.2 Turbine Structural Components 132
8.6.2.1 Runner 132
8.6.2.2 Guide Vanes and Operating Mechanism 133
8.6.2.3 Shaft Seal 133
8.6.2.4 Turbine Shaft 133
8.6.2.5 Spiral Casing 133
8.7 GOVERNOR SYSTEM 134
8.7.1 General 134
8.7.2 Governor Head 134
8.7.3 Oil Pressure System 135
8.8 INLET VALVE 135
8.9 POWERHOUSE CRANE 135
8.10 COOLING AND DEWATERING SYSTEM 136
8.10.1 Basic Requirements 136
8.10.2 Cooling Water System 137
8.10.3 Power Station Drainage System 137
8.11 HEATING, VENTILATION AND AIR CONDITIONING SYSTEM 137
8.11.1 General 137
8.11.2 General System Description 138
8.11.2.1 Machine Hall 138
8.11.2.2 Office and Control Room Building 139
8.11.2.3 Design Criteria 139
8.12 AUXILIARY SYSTEM 139
8.12.1 Workshop Equipment 139
8.12.2 Auxiliary Equipment 139
8.12.2.1 Oil Handling Equipment 140
8.12.2.2 Fire Fighting System 140
8.12.3 Maintenance Tools and Spares 140

9 ELECTRICAL EQUIPMENT 141
9.1 GENERAL 141
9.2 GENERATORS 141
9.2.1 General 141
9.2.2 Generator Protection 142
9.2.3 Excitation System 143
9.2.4 MV Switchgear 143
9.3 132 kV INTERCONNECTION AND GRID STATION 144
9.3.1 132 kV Interconnection 144
9.3.2 132 kV Grid Station 144
9.3.2.1 Power Transformer 145
9.3.2.2 Transformer Protection 145
9.3.2.3 Circuit Breakers 146

9.4 LV INSTALLATION 146
9.4.1 11/0.4 kV Switchgear 146
9.4.1.1 Low Voltage Auxiliary Switchgear 147
9.4.1.2 Motor Control Centers 147
9.4.2 Station Auxiliary Transformer 147
9.4.3 Black Start Diesel Generating Set 148
9.4.4 Battery and Battery Charger 148
9.5 ELECTRICAL AUXILIARIES 148
9.5.1 Lighting 148
9.5.2 Fire Detection and Protection System 149
9.6 TRANSMISSION LINE 149
9.6.1 Dispersal of Power 149
9.6.2 Transmission Line Route 149
9.6.3 Main Specifications of T/L Material 149
9.6.3.1 Transmission Line Towers 149
9.6.3.2 Conductor 149
9.6.3.3 Insulators 150
9.6.3.4 Shield Wire 150
9.6.3.5 Construction 150

10 INITIAL ENVIRONMENTAL EXAMINATION 151
10.1 INTRODUCTION 151
10.2 DESCRIPTION OF THE OBJECTIVES OF PROPOSAL 151
10.2.1 Land Use and Industrialisation 152
10.2.2 Regulatory Framework - Industrialisation 152
10.2.2.1 Deregulation of the Economy 152
10.2.2.2 Infrastructure Facilities 152
10.2.2.3 Incentives 152
10.2.3 Environmental Legal Framework 153
10.3 PAKISTAN ENVIRONMENTAL PROTECTION ACT (PEPA) 1997 153
10.4 GUIDELINES FOR ENVIRONMENTAL ASSESSMENT 153
10.5 GUIDELINES FOR PUBLIC CONSULTATION 154
10.6 DESCRIPTION OF EXISTING AND EXPECTED CONDITIONS 154
10.6.1 Existing (Baseline) Condition of the Biophysical and Socio-Economic Environment, Trends & Anticipated Future Environmental Conditions 154
10.6.2 Environmentally Sensitive Areas of Special or Unique Value 155
10.6.2.1 Physical Resources 155
10.6.2.2 Ecological Resources 156
10.7 ECOLOGICAL RESOURCES 156
10.7.1 Natural Flora 156
10.7.1.1 Overview 156
10.7.1.2 Forests 156
10.7.1.3 Medicinal Plants 157
10.7.1.4 Vegetation in the Weir Area 157
10.7`.1.5 Vegetation at Powerhouse Area 157
10.7.2 Natural Fauna 158
10.7.2.1 Mammals 158
10.7.2.2 Reptiles and Amphibians 158
10.7.2.3 Insects, Butterflies and Vectors 158
10.7.2.4 Birds and Fowl (Avifauna) Communities 158
10.7.2.5 Aquatic Ecology 159

10.8 PROTECTED AREAS 159
10.8.1 Overview 159
10.8.2 National Parks 160
10.8.3 Wildlife Parks 160
10.8.4 Wildlife Sanctuaries 160
10.8.5 Private Game Reserves 160
10.9 QUALITY OF LIFE 161
10.9.1 Socio-Economic Values 161
10.9.2 Existing Socio-Economic Conditions, Cultural and Aesthetic Values 161
10.10 BASELINE ENVIRONMENTAL DATA / STATUS 162
10.10.1 Noise 162
10.10.2 Ambient Gases 162
10.10.3 Particulate Matter 163
10.10.4 Water Quality 163
10.11 EVALUATION OF ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES 163
10.12 ENVIRONMENTAL IMPACTS 164
10.12.1 Impacts During Construction 164
10.12.1.1 Air Quality 164
10.12.1.2 Noise and Vibration 165
10.12.1.3 Soils 165
10.12.1.4 Waste 166
10.12.1.5 Construction Spoil 166
10.12.1.6 Use of Hazardous and Toxic Materials 167
10.12.1.7 Layout of Construction Camps, Workshops & Labour 167
10.12.1.8 Water Use / Quality 168
10.12.1.9 Impacts on Aquatic Life 168
10.12.2 Impacts During Operation 168
10.12.2.1 Air 168
10.12.2.2 Greenhouse Gases 169
10.12.2.3 Noise 169
10.12.2.4 Water Quality 169
10.12.2.5 Compensation Water 169
10.12.2.6 Impact on Microclimate 170
10.13 BIOLOGICAL IMPACTS 170
10.13.1 Biological Impacts During Construction 170
10.13.1.1 General Impacts on Flora 170
10.13.1.2 General Impacts on Fauna 171
10.14 SOCIO-ECONOMIC IMPACTS 172
10.14.1 Involuntary Resettlement of Project Affected People 172
10.14.2 Employment Generation During Construction Phase 172
10.14.3 Cultural Heritage and Archaeology 172
10.14.4 Recreation Activities 173
10.15 IMPACTS IDENTIFICATION FOR OPERATIONAL PHASE 173
10.15.1 Electricity Generation 173
10.15.2 Employment Generation During Operational Phase 173
10.15.3 Provision of Associated Facilities 173
10.15.4 Agricultural Impacts 174
10.15.5 Landscape and Visual Amenity 174

10.16 ENVIRONMENT AND SOCIAL MANAGEMENT AND MONITORING PLAN, ENVIRONMENTAL MITIGATION MEASURES & PROPOSED TRAINING 174
10.16.1 Introduction 174
10.16.2 Organisation and Implementation 175
10.16.3 Resettlement Action Plan (RAP) 176
10.16.3.1 Resettlement Principles and Objectives 176
10.17 PUBLIC CONSULTATIONS 176
10.18 CONCLUSION 177

11 COST ESTIMATES 178
11.1 INTRODUCTION 178
11.2 ESTIMATION OF QUANTITIES 178
11.3 UNIT RATES 179
11.4 ESTIMATION OF PROJECT COSTS 180
11.5 ENVIRONMENTAL IMPACT MITIGATION COST 181
11.6 CIVIL WORKS 181
11.7 ELECTRICAL AND MECHANICAL EQUIPMENT 182
11.8 TRANSPORTATION AND SHIPMENT 182
11.9 ERECTION, COMMISSION AND TESTING CHARGES 182
11.10 ENGINEERING AND SUPERVISION 182
11.11 PROJECT DIRECTOR ADMINISTRATION 183
11.12 IMPORT DUTIES 183
11.13 CONTINGENCIES 183
11.14 INTEREST DURING CONSTRUCTION 183
11.15 TOTAL PROJECT COST 183

12 CONSTRUCTION PLANNING 185
12.1 INTRODUCTION 185
12.2 CONSTRUCTION PLANNING 185
12.3 DESCRIPTION OF WORKS 186
12.3.1 Preliminary Works 186
12.3.2 Site Installation and Mobilisation 186
12.3.3 Construction of Camps 187
12.3.4 Diversion Weir 187
12.3.5 Power Intake, Connecting Channel and Sandtrap 188
12.3.6 Headrace Pressure Pipe 188
12.3.7 Surge Pipe 188
12.3.8 Penstock 188
12.3.9 Powerhouse and Tailrace Tunnel 189
12.3.10 Electro-Mechanical Equipment 189

13 FINANCIAL AND ECONOMIC ANALYSIS 190
13.1 INTRODUCTION 190
13.2 ECONOMIC ANALYSIS 191
13.2.1 Methodology 192
13.2.2 Thermal Power Plant Parameters 192
13.2.3 Fuel Cost 193
13.2.4 Operation and Maintenance (O&M) Cost 193
13.2.5 Service Life 194
13.2.6 Assumptions 194
13.2.6.1 Discount Rate 195
13.2.6.2 Standard Conversion Factor 195
13.2.6.3 Annual Energy Benefits 196
13.2.6.4 Project Economic Costs 196

13.2.7 Result of the Thermal Equivalent 196
13.3 FINANCIAL ANALYSIS 197
13.3.1 Capital Cost 197
13.3.2 Capital Structure 198
13.3.2.1 Local Currency Financing 198
13.3.2.2 Foreign Currency Financing 198
13.3.3 Results of the Financial Analysis 198
13.4 SENSITIVITY ANALYSIS 199
13.5 UNIT COSTS 200
13.6 CONCLUSIONS AND RECOMMENDATIONS 200

14 CONCLUSIONS AND RECOMMENDATIONS 201
14.1 CONCLUSIONS 201
14.2 RECOMMENDATIONS 202

PHOTOGRAPHS

LIST OF TABLES

Table - 1.1: Capacities & Location of Three Hydropower Projects as per TOR

Table - 2.1: Coordinates of Bench Marks / Control Points (Weir Area)
Table - 2.2: Coordinates of Bench Marks / Control Points (Powerhouse Area)

Table - 3.1: Long Term Climatic Stations in Jhelum River Basin
Table - 3.2: Hydrological Stations with Long Term Records
Table - 3.3: Specific Flows of Various Gauging Stations
Table - 3.4: Extended Mean Monthly Flows at Jagran River
Table - 3.5: Flow Duration Values for Average Year – Jagran River
Table - 3.6: Ratio of Specific Flow (l/s/km^2) of High Flow Period - Jagran River at Kundal Shahi and Neelum River at Muzaffarabad
Table - 3.7: Flood at Weir Site on Jagran River in Different Return Periods
Table - 3.8: Estimation of Flood with Log Pearson Method
Table - 3.9: Comparison of Flood Estimates
Table - 3.10: Particle Size Distribution Analysis at Nausehri (1991-1996)

Table - 4.1: Rock Units in the Neelum Valley (Nausehri to Kel)
Table - 4.2: Rock Units in the Region of Interest Surrounding the Proposed Project Area
Table - 4.3: Discontinuity Survey Data of Pressure Pipe Area of Jagran - IV HPP
Table - 4.4: Discontinuity Survey Data of Pipe Outlet Area of Jagran - IV HPP
Table - 4.5: Classifications of Rock Structure Rating
Table - 4.6: Rock Structure Rating System
Table - 4.7: Rock Mass Rating System (After Bieniawski 1989), Pipe Outlet Area
Table - 4.8: Classification of Individual Parameters used in the Tunneling Quality Index, Q (Pipe Outlet Area)

Table - 6.1: Jagran-IV Hydropower
Table - 6.2: Normal Cost Run-of-River Option
Table - 6.3: 10% Increased Cost Option
Table - 6.4: Reduced Flows Option

Table - 7.1: Water Level Profile
Table - 7.2: Hydraulic Calculation for Overflow Weir
Table - 7.3: Hydraulic Calculation for Undersluice
Table - 7.4: Hydraulic Calculation for Sandtrap
Table - 7.5: Hydraulic Calculation for Surge Pipe
Table - 7.6: Hydraulic Calculations for Penstock

Table - 8.1: Comparison of Basic Data
Table - 8.2: Comparison of Basic Data
Table - 8.3: Design Data for HVAC System

Table - 11.1: Major Quantities of Civil Works
Table - 11.2: Summary of Cost Estimate
Table - 11.3: Detailed Cost Estimation
Table - 11.4: Cash Flow

Table - 13.1: Economic Analysis
Table - 13.2: Financial Analysis
Table - 13.3: Sensitivity Analysis
Table - 13.4: Cost per KWH and KW

LIST OF FIGURES

Figure - 1.1: Location Map – Three (3) Hydropower Projects in AJ&K

Figure - 3.1: Catchment Area of Jagran River
Figure - 3.2: Mean Monthly Temperature at Muzaffarabad
Figure - 3.3: Mean Annual Temperature at Muzaffarabad
Figure - 3.4: Annual Precipitation at Muzaffarabad
Figure - 3.5: Mean Monthly Precipitation at Muzaffarabad
Figure - 3.6: Yearly Rainfall at Dudhnial
Figure - 3.7: Mean Monthly Rainfall at Dudhnial
Figure - 3.8: Location Map of Hydrological Stations
Figure - 3.9: Specific Flows - Neelum River at Nausehri and Jagran River at Kundal Shahi & Thunian
Figure - 3.10: Mean Annual Flows (m^3/s) - Neelum River at Muzaffarabad
Figure - 3.11: Specific Flows - Neelum River at Muzaffarabad and Jagran River at Kundal Shahi & Thunian
Figure - 3.12: Mean Annual Flow - Kunhar River at Naran 1960-2000
Figure - 3.13: Specific Flows - Kunhar River at Naran and Jagran River at Kundal Shahi 1982-84
Figure - 3.14: Specific Flows – Kunhar River at Naran and Jagran River at Kundal Shahi 1994-96
Figure - 3.15: Relationship between Specific Flows at Naran and Kundal Shahi for Summer Period
Figure - 3.16: Relationship between Specific Flows at Naran and Kundal Shahi for Winter Period
Figure - 3.17: Specific Flows - Kunhar River at Naran and Jagran River at Thunian 1994-96
Figure - 3.18: Relationship between Specific Flows at Naran and Thunian
Figure - 3.19: Estimated and Measured Flows of Jagran River at Thunian – 1995
Figure - 3.20: Mean Annual Flows - Jagran River at Thunian
Figure - 3.21: Mean Monthly Flows at Proposed Weir Site– Jagran River
Figure - 3.22: Mean Annual Flows at Weir Site - Jagran River
Figure - 3.23: Flow Duration Curve for Average Year – Jagran River
Figure - 3.24: Flow Duration Curve for Dry Year at Weir Site - Jagran River
Figure - 3.25: Flow Duration Curve for Wet Year at Weir Site – Jagran River
Figure - 3.26: Gumble Extreme Value Type-I (Method of Moments)
Figure - 3.27: Flood Estimation with Log Pearson Type-III Method
Figure - 3.28: Flood Hydrograph at proposed Jagran-IV Weir Site
Figure - 3.29: Sediment Rating Curve

Figure - 4.1: Principal Fault Zones in Northern Pakistan and AJ&K
Figure - 4.2: Tectonic Zones and Features in Northern Pakistan
Figure - 4.3: Geological Map of Neelum Valley
Figure - 4.4: Rose Diagram Showing Stereographic Projection of Joint Sets in Granitic Gneiss (Pipe Outlet Site)
Figure - 4.5: Rose Diagram Showing Location of Poles of Joint Sets in Granitic Gneiss (Pipe Outlet Site)
Figure - 4.6: Composite Pole Plot Showing Location of Joint Sets in Granitic Gneiss (Pipe Outlet Site)
Figure - 4.7: Rose Diagram Showing Stereographic Projection of Joint Sets in Granitic Gneiss (Pressure Pipe Site)

Figure - 4.8: Rose Diagram Showing Location of Poles of Joint Sets in Granitic Gneiss (Pressure Pipe Site)
Figure - 4.9: Composite Pole Plot Showing Location of Joint Sets in Granitic Gneiss (Pressure Pipe Site)

Figure - 6.1: Mean Monthly Flows at Weir Intake - Jagran - IV
Figure - 6.2: NPV Curve for Various Scenarios
Figure - 6.3: Cost/kWh Curve for Various Scenarios
Figure - 6.4: B/C Ratio Run-of-River - Base Case
Figure - 6.5: Estimated Mean Monthly Power
Figure - 6.6: Estimated Mean Monthly Energy

Figure - 8.1: Flow Duration Curve
Figure - 8.2: Mean Monthly Flows
Figure - 8.3: Application Ranges of Different Types of Water Turbine

Figure - 12.1: Implementation Schedule

ABBREVIATIONS

- AZAD JAMMU AND KASHMIR	AJ&K
- HYDRO ELECTRIC BOARD	HEB
- AIR HANDLING UNITS	AHUs
- ALKALI SILICA REACTION	ASR
- ALTERNATING CURRENT	AC
- AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS	AASHTO
- AMERICAN IRON AND STEEL INSTITUTE	AISI
- AMERICAN SOCIETY OF HEATING, REFRIGERATION	ASHRAE
- AND AIR CONDITIONING ENGINEERS	
- AMERICAN STANDARD FOR TESTING AND MATERIALS	ASTM
- AMPERE	A
- ANGULAR BOULDER GRAVEL MATERIAL WITH APPRECIABLE AMOUNT OF FINES	ABGM
- BENCH MARK	BM
- BENEFIT-COST RATIO	B/C
- COMPAGNIE FRANCAISE POUR LE DEVELOPPEMENT DE LA GEOTHERMIE ET DES ENERGIES NOUVELLES	CFG
- CONTROL POINT	CP
- CROSS LINKED POLYETHYLENE	XLPE
- CUBIC METER PER SECOND	m^3/s or cumec
- DEGREE CELSIUS	°C
- DETERMINISTIC SEISMIC HAZARD ANALYSIS	DSHA
- DIGITAL ELEVATION MODEL	DEM
- DIRECT CURRENT	DC
- DRAWING	Dwg
- ECONOMIC INTERNAL RATE OF RETURN	EIRR
- ELECTROMAGNETIC DISTANCE MEASUREMENT	EDM
- ENVIRONMENTAL AND SOCIAL MANAGEMENT AND MONITORING PLAN	ESMMP
- ENVIRONMENTAL MANAGEMENT PLAN	EMP
- ENVIRONMENTAL MANAGEMENT UNIT	EMU
- ENVIRONMENTAL PROTECTION AGENCY	EPA
- EUROPEAN MATERIAL HANDLING FEDERATION	FEM
- FINANCIAL INTERNAL RATE OF RETURN	FIRR
- FOREIGN COMPONENT	FC
- GENERAL TOPOGRAPHIC SHEET	GT Sheet
- GIGAWATT HOUR	GWh
- GLACIAL LAKE OUTBURST FLOOD	GLOF
- GLOBAL POSITIONING SYSTEM	GPS
- HAZARA KASHMIR ASYNTAXIS	HKS
- HAZARA LOWER SEISMIC ZONE	HLSZ
- HEATING, VENTILATION AND AIR CONDITIONING	HVAC
- HECTARE	ha
- HERTZ (Frequency)	Hz

-	HIMALAYAN FRONTAL THRUST	HFT
-	HYDRO POWER PROJECT	HPP
-	INDUS - KOHISTAN SEISMIC ZONE	IKSZ
-	INITIAL ENVIRONMENTAL EXAMINATION	IEE
-	INTEREST DURING CONSTRUCTION	IDC
-	INTERNATIONAL ELECTRO-TECHNICAL COMMISSION	IEC
-	JHELUM FAULT	JF
-	KARACHI INTER-BANK OFFERED RATE	KIBOR
-	KILO VOLT	kV
-	KILOMETER	km
-	KILOVOLT AMPERE	kVA
-	KILOWATT HOUR	kWh
-	LINE OF CONTROL	LoC
-	LITERS PER SECOND PER SQUARE KILOMETER	l / s / km^2
-	LITERS PER SECOND PER PERSON	l /s / person
-	LITERS PER SECOND PER SQUARE METER	l / s / m^2
-	LOCAL COMPONENT	LC
-	LONDON INTER-BANK OFFERED RATE	LIBOR
-	MAIN BOUNDARY THRUST	MBT
-	MAIN CHAKWAL THRUST	MCT
-	MAIN KARAKORRAM THURST	MKT
-	MAIN MANTLE THRUST	MMT
-	MAXIMUM CREDIBLE EARTHQUAKE	MCE
-	MAXIMUM DESIGN EARTHQUAKE	MDE
-	MEAN SEA LEVEL	msl
-	MEGAVOLT AMPERE	MVA
-	MEGAWATT	MW
-	METER ABOVE SEA LEVEL	m asl
-	METER PER SECOND	m/s
-	METER	m
-	MILLIMETER	mm
-	NATIONAL ELECTRIC POWER REGULATORY AUTHORITY	NEPRA
-	NATIONAL ENVIRONMENTAL QUALITY STANDARDS	NEQS
-	NET PRESENT VALUE	NPV
-	NET PRESENT WORTH	NPW
-	NITROGEN OXIDES	NOX
-	OIL NATURAL AIR FORCED	ONAF
-	OIL NATURAL AIR NATURAL	ONAN
-	OPERATING BASIC EARTHQUAKE	OBE
-	OPERATION AND MAINTENANCE	O&M
-	PAKISTANI RUPEES	Pak. Rs. / PKR
-	PARTS PER MILLION	ppm
-	PEAK GROUND ACCELERATION	PGA
-	PEAK GRUOND VELOCITY	PGV
-	PERCENT	%
-	PLAIN CEMENT CONCRETE	PCC
-	POLY VINYL CHLORIDE	PVC

- POWER LINE CARRIER	PLC
- PROBABLISTIC SESMIC HAZARD AHALYSIS	PSHA
- PROJECT AFFECTED PEOPLE	PAP
- REINFORCED CEMENT CONCRETE	RCC
- RESIDUAL FURNACE OIL	RFO
- REVOLUTION PER MINUTE	rpm
- ROCK MASS RATING	RMR
- ROCK QUALITY DESIGNATION	RQD
- ROCK STRUCTURE RATING	RSR
- ROUNDED BOULDER GRAVEL MATERIAL WITH APPRECIABLE AMOUNT OF FINES	RBGM
- SALT RANGE THRUST	SRT
- SANDSTONE	SS
- SHUTTLE RADAR TOPOGRAPHY MISSION	SRTM
- SILICON CONTROLLED RECTIFIER	SCR
- SOCIAL IMPACT ASSESMENT	SIA
- SQUARE KILOMETER	km2
- STANDARD BENCH MARK	SBM
- STANDARD CONVERSION FACTOR	SCF
- SULFUR HEXAFLOURIDE	SF6
- SULPHUR OXIDES	SOX
- SUPERVISORY CONTROL AND DATA ACQUISITION	SCADA
- SURFACE WATER HYDROLOGY PROJECT	SWHP
- SURVEY OF PAKISTAN	SOP
- TERMS OF REFERENCE	TOR
- THYRISTOR CONTROLLED RECTIFIER	TCR
- TRANSMISSION LINE	T/L
- UNITED STATES GEOLOGICAL SURVEY	USGS
- UNITED STATES DOLLAR	US $
- UNIVERSAL TRANSVERSE MERCATOR	UTM
- WATER AND POWER DEVELOPMENT AUTHORITY	WAPDA
- WATER AND POWER DEVELOPMENT AUTHORITY IN COLLABORATION WITH GERMAN AGENCY FOR TECHNICAL COOPERATION	WAPDA-GTZ
- WORLD GEODETIC SYSTEM	WGS
- ZANSKAR SHEAR ZONE	ZSZ

EXECUTIVE SUMMARY

1. PROJECT LOCATION

The proposed Jagran-IV Hydropower Project is identified on the intermediate stretch of Jagran River, near Thunian village, just upstream of intake of existing Jagran-I Hydropower Project in Azad State of Jammu and Kashmir. Jagran River is a right bank tributary of Neelum River located in the Neelum district with its confluence about 68 km North East of Muzaffarabad city.

The proposed project layout has been planned on the left bank of Jagran River with diversion weir, lateral intake, sandtrap, headrace pressure pipe, surge pipe, penstock, surface powerhouse and tailrace discharging back into Jagran River. The access road to weir, surge pipe and powerhouse sites would be improved.

The diversion weir is proposed 150 m downstream of confluence of Baihk nullah with Jagran River near Shaal village and the powerhouse would be located 200 m upstream of existing Jagran-I weir intake.

The coordinates and elevations of weir and powerhouse are listed below.

Site	Latitude	Longitude	Surface Elevation (m asl)
Weir	34°-39'-27"	73°-46'-09"	2258
Powerhouse	34°-37'-48"	73°-46'-09"	2120

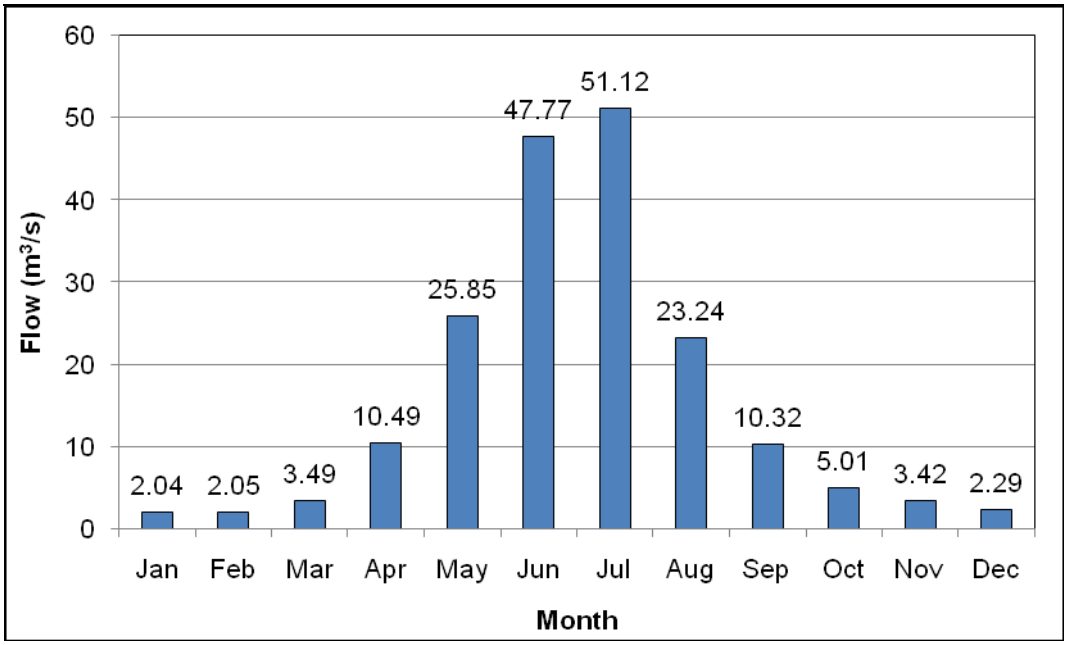
The project area is accessible from Muzaffarabad via main Neelum road up to Kundal Shahi village. The proposed weir site is accessible by an established jeepable track. Jagran valley becomes inaccessible during winter months due to snowfall. Construction of bridges over Jagran River will also be required for an access to the powerhouse area and handling of the plant and equipment.

2. HYDROLOGY AND SEDIMENTATION

The flows measured on Jagran River for short period correlated with long term gauging station of Kunhar River at Naran. With two years data of Jagran River at Thunian, empirical equations have been developed and used for estimation of flows for Jagran-IV Hydropower Project. The catchment areas at Naran, Kundal Shahi and Jagran-IV weir site are 1036 km^2, 430 km^2 and 214 km^2 respectively. A long term gauging station of Neelum River at Muzaffarabad was also checked but the correlation with smaller catchment like Thunian and Kundal Shahi was not as appropriate as with Naran.

A few years observations of Jagran River were carried out by HEB, during past years. The estimated and observed flows are matching and considered realistic, comparing specific flows at Kundal Shahi and Thunian on Jagran River.

The estimated mean monthly flows at Jagran-IV at the proposed weir site are graphically presented in the following Figure.



The mean monthly flows vary from 2.04 to 51.12 m^3/s with mean annual value of 15.59 m^3/s. The design flood for weir is taken as 419 m^3/s for a return period of 500 year.

Long term data available at nearest hydrological station Nausehri has been considered to assess the suspended and bed sediment load for Jagran-IV Hydropower Project by developing a relationship between flows and sediment concentration in ppm as given below.

$$Y=1.881X^{0.841}$$

where

Y = Sediment concentration (ppm)

X = Discharge (m^3/s)

The particle size distribution at the diversion site has also been estimated as stated below:

- Sand 13%
- Silt 64%
- Clay 23 %

3. TOPOGRAPHIC SURVEY

With the commencement of studies, control points and bench marks were established along the stretch of interest of Jagran River. A longitudinal profile survey of this stretch of river was carried out to estimate the head available for power generation. A detailed topographic survey has been carried out in the area of all important structures of the scheme.

The topographic survey has been carried out for weir area and surge to powerhouse area. A total area of about 46 hectares was surveyed by traversing with EDM. All the data was computerised and maps of appropriate scales with 2 m contour interval were developed.

4. GEOLOGY

The rock exposed in the proposed Jagran – IV HPP is metamorphic in origin; mainly comprised of granitic gneiss. The scheme with weir, connecting channel, sandtrap, pipe intake, pressure pipe, pipe outlet, surge pipe, penstock, surface powerhouse and tailrace has been recommended for further Geological and Geotechnical Studies.

Burried pressure pipe about 3075 m long shall rest mostly on overburden and partly on rock (granitic gneiss). Granite intrusions, pegmatites / quartz veins, basic dykes and sills are quite common in this region.

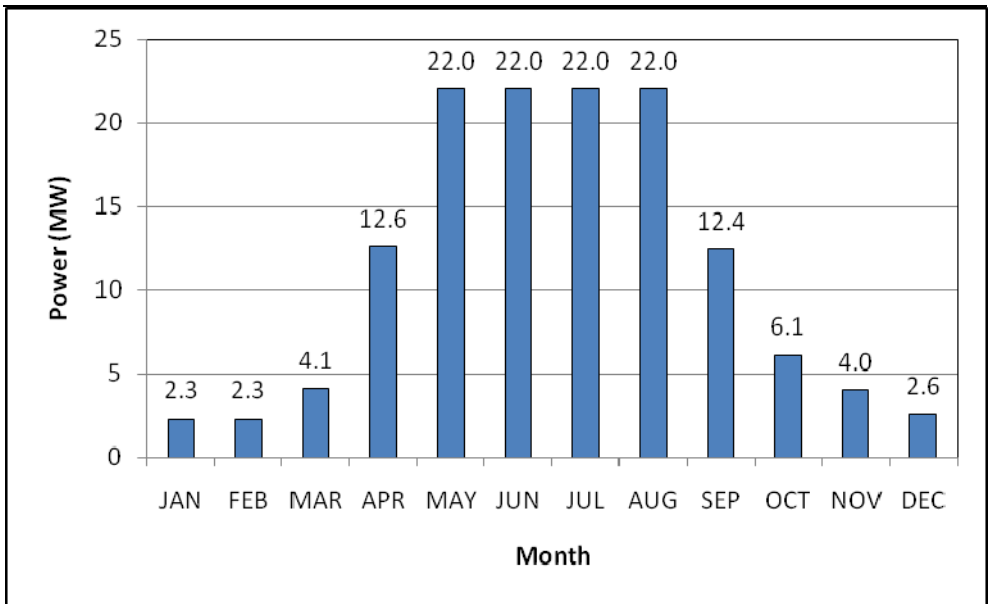
Surface powerhouse structure is proposed on alluvial material of considerable thickness comprising of rounded boulders and gravel with sand and appreciable amount of fines (RBGM).

The thickness of overburden is not yet known; but shall be confirmed through borehole drilling, by carrying out the seismic refraction survey or by excavating test pits.

5. PROJECT LAYOUT AND POWER POTENTIAL

The power and energy has been optimised considering the project benefits and cost. The project net benefits are maximum for a design discharge of 18 m^3/s. With the design discharge and net head of about 144.2 m, the installed capacity would be 22 MW and it would generate annual energy of 98.20 GWh with the plant factor of 51.25 %.

The estimated mean monthly power generation is graphically presented in the following Figure.



6. CIVIL STRUCTURES

The entire project layout is proposed to be located on the left bank of Jagran River. The weir is an ungated overflow structure with an undersluice for sediment flushing. The weir has been planned with the crest elevation at 2264 m asl about 18 km upstream of Jagran River confluence with Neelum River. A design discharge of 18 m^3/s would be diverted through lateral intake and pass through sandtrap, 3075 m low pressure headrace pipe and penstock to powerhouse. The flows will be discharged back into Jagran River. Headrace would be of GRP pipe.

The surge pipe would be located at the end of headrace pipe and before the start of embedded penstock. A 180 m long penstock with 2.5 m diameter would connect the surge pipe with surface powerhouse. The turbine axis is proposed at 2105 m asl. Tailrace would be 20 m long with outflows into Jagran River.

7. ELECTRO-MECHANICAL EQUIPMENT

Four vertical Francis turbines, three with a capacity of 6 MW and one with a capacity of 4 MW, have been proposed with the following parameters:

- Total Number of Units : 4
- Type of Turbine : Francis
- Design Head : 144.2 m
- Rated Speed : 1000 rpm

The powerhouse will be equipped with auxiliary mechanical equipment for the smooth operation as well as maintenance. Four generators, three of 7.06 MVA and one of 4.70 MVA have been proposed. Power factor would be 0.85 and generation will be at 11 kV. The generators will be synchronised at a common bus-bar feeding to two step-up transformers of 10 / 13 MVA capacity. The power would be transmitted through 132 kV lines to the existing Jagran – I Grid station.

8. PROJECT COST AND ECONOMIC / FINANCIAL VIABILITY

Based on the estimated quantities and updated unit rates the project cost including transportation, erection, engineering and supervision, project administration, import charges and interest during construction have been worked as PKR 3,595.943 million with the foreign exchange component of PKR 2,172.287 million. The cost for civil works has been estimated as PKR 1,386.209 million; whereas, the cost for electro-mechanical equipment is PKR 809.353 million. The price index has been taken as of August 2010 with the foreign currency exchange rate of 1 US$ = Rs. 85.6.

The estimated cost of the project would produce cheap energy with tariff of Rs. 6.080/kWh. This hydropower scheme is economically viable with EIRR and FIRR as 25.33% and 14.26% respectively and with B/C of 1.79 to meet the local area power demand and to connect it with the National grid at low rate tariff.

9. ENVIRONMENT

On the basis of field findings during Initial Environmental Examination (IEE) study, it can be concluded that the proposed Jagran-IV Hydropower Project will not have any significant adverse impacts on the local population or any segment of the environment, provided the mentioned recommendations and mitigation measures suggested in study are fully implemented during the construction stage and by the plant management in letter and spirit.

10. IMPLEMENTATION SCHEDULE

The implementation schedule comprises of preliminary works, i.e., approval of PC-I, land acquisition, access roads, etc. which shall be arranged by HEB. The preliminary works would be completed in about one (01) year; whereas, construction activities would span over a period of four (04) years.

The winter season in the project area is quite severe with snow fall. Some of construction activities like concreting shall not be possible during winter season. The main working season is from March to October each year.

SALIENT FEATURES OF JAGRAN - IV HYDROPOWER PROJECT

1 GENERAL

- Location — Proposed project location is about 86 km from Muzaffarabad city on Jagran River which is a right bank tributary of Neelum River

2 HYDROLOGY

- Catchment Area up to Weir Site — 214 km^2
- Mean Annual Flow — 15.59 m^3/s
- Design Discharge — 18 m^3/s
- Design Flood (500 year return period) — 419 m^3/s

3 TOPOGRAPHY

- Gross Head — 156 m
- Net Head — 144.2 m

4 CIVIL STRUCTURES

4.1 DIVERSION WEIR

- Type of Intake — Weir with Lateral Intake
- Height above River Bed — 6 m
- Length of the Crest — 24 m
- Crest Elevation — 2264.0 m asl
- Type of Energy Dissipater — Roller Bucket

4.2 CONNECTING CHANNEL

- Cross Section (Internal) — 3.4 m x 2.8 m, RCC
- Velocity — 2.2 m/s
- Length of the Channel — 110 m

4.3 SANDTRAP

- Number of Chambers — 2
- Clear Width of each Chamber — 7.0 m
- Length of Chamber — 56 m

4.4 HEADRACE LOW PRESSURE PIPE

- Length of Pipe — 3075 m
- Diameter of Pipe — 2.5 m
- Material — Galvanised Reinforced Pipe (GRP)

4.5 SURGE PIPE

- Diameter 5 m
- Length 52 m

4.6 PENSTOCK

- Diameter 2.5 m
- Length 180 m

4.7 POWERHOUSE

- Type Surface
- Length 35.4 m
- Width 10.0 m
- Tailrace Length 20.0 m

5 ELECTRO-MECHANICAL

- Type of Turbine Francis with Vertical Axis
- No. of Units Four (04) (3 x 6 MW and 1 x 4 MW)
- Installed Capacity 22 MW
- Annual Energy Generated 98.20 GWh
- Firm Power (95 % of time) 2.3 MW
- Plant Factor 51.25 %
- Generation Voltage 11 kV
- Voltage of Dispatch 132 kV

6 PROJECT COST AND ECONOMIC AND FINANCIAL VIABILITY

- Project Cost (With Trans.+IDC) US $ 42.009 million
- Foreign Components US $ 25.377 million
- Project Economical IRR 25.33%
- Project Financial IRR 14.26%
- Benefit / Cost Ratio 1.79
- Unit Cost (US cent / kWh) 7.103
- Unit Cost (Rs. / kWh) 6.080

7 CONSTRUCTION PERIOD

- Preliminary Works 1 Year
- Construction Period 4 Year

1 INTRODUCTION

1.1 PROJECT BACKGROUND

Neelum River is a right bank tributary of Jhelum River with its confluence at Domel in Muzaffarabad. Neelum River is fed by a network of major tributaries on its right bank along its stretch from Taobut to Muzaffarabad. These tributaries generally run in North to South direction with catchment areas ranging from 50 to 430 km^2. Gagai River, Baral River, Janawahi nullah, Surgan nullah, Changan nullah, Dowarian nullah, Chutiari nullah, Nagdar nullah and Jagran River are the major tributaries.

High specific discharge and steep gradient of the main river as well as that of its tributaries offer promising hydropower sites in the valley. A number of potential hydropower sites were identified on the lower part of the catchments of these tributaries; whereas, the sites on the upper catchment are yet to be identified and firmed up.

Hydro Electric Board (HEB) of Azad State of Jammu and Kashmir (AJ&K) has signed a Consultancy Agreement, in May 2009, with M/s Fida Hussain Chaudhary – FHC Consulting Engineers, Lahore in association with M/s Scott Wilson Limited of United Kingdom.

The scope of consultancy services includes the preparation of the feasibility study reports, detailed technical / engineering designs and tender documents for the three (3) high head, medium sized hydropower sites namely; Jagran-IV, Changan and Hariyola - Zaminabad.

The Consultants are also required to prepare the tender documents for the geotechnical / geological investigations and supervision of these works for the three schemes. Out of these three proposed project sites, two are located on the right bank tributaries of Neelum River in Neelum District and the third one, Hariyola - Zaminabad is located on Agar nullah, a left bank tributary of Jhelum River.

The location of all three schemes is shown in **Figure - 1.1**.

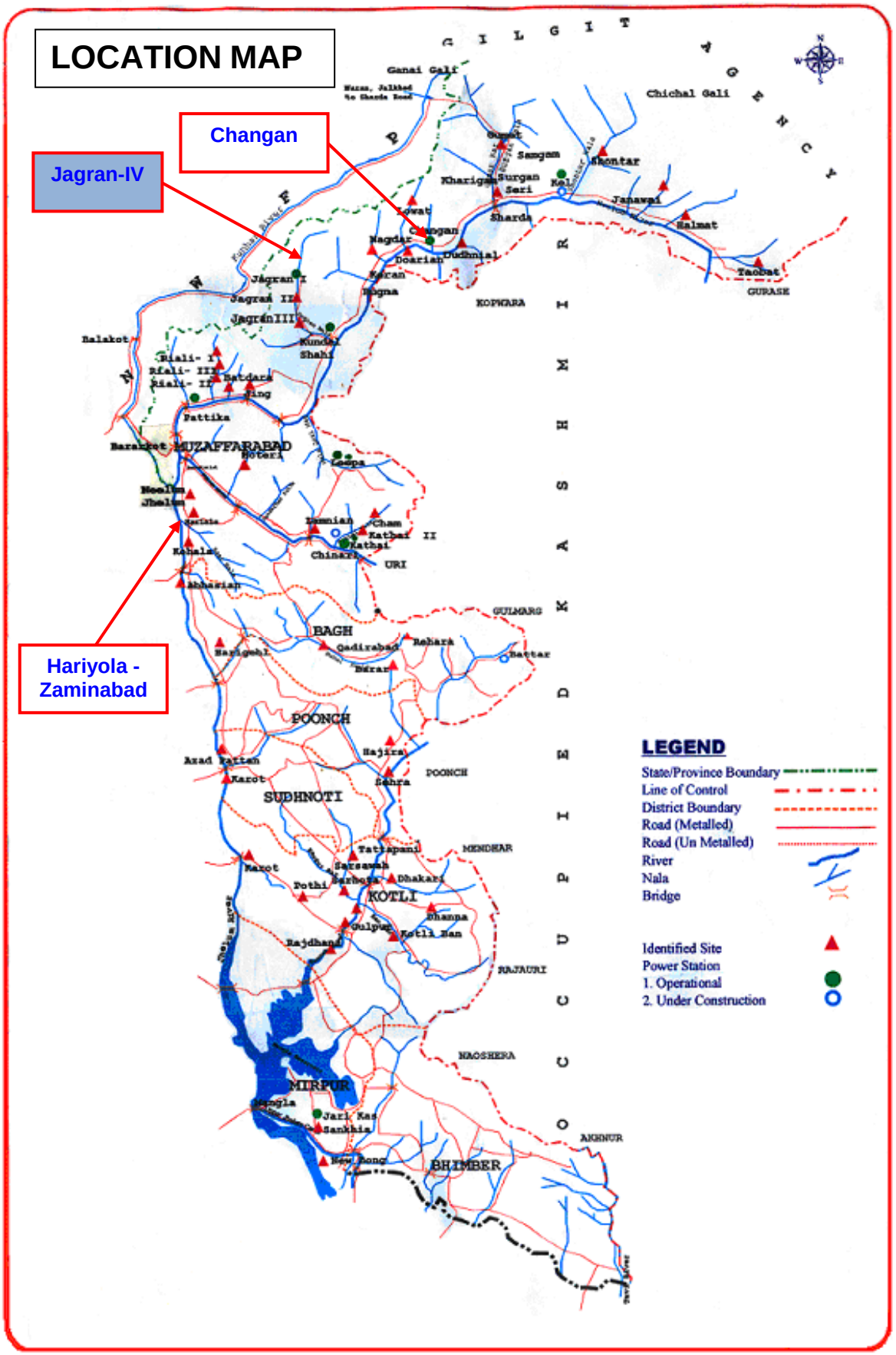


Figure - 1.1: Location Map – Three (3) Hydropower Projects in AJ&K

The two sites namely; Jagran - IV and Changan were identified by HEB; whereas, Hariyola - Zaminabad was identified in 1992 by WAPDA-GTZ as mentioned in the Terms of Reference (TOR).

During the preliminary site identification studies the name of the schemes, their preliminary estimated installed capacities and their approximate locations from Muzaffarabad as given in TOR are as under:

Table - 1.1: Capacities & Locations of Three Hydropower Projects as per TOR

Sr. No.	Site	Estimated Capacity as per TOR	Distance from Capital
1	Jagran - IV	6.0 to 8.0 MW	85 km NE
2	Changan	5.4 MW	105 km NE
3	Hariyola - Zaminabad	12.4 MW	30 km SW

1.2 SCOPE OF CONSULTANCY SERVICES

The objective of the present assignment of the Consultants is to study the previously identified site in detail and to firm up the installed capacity, proposed layout and development plans in order to optimally harness the power potential of perennial flow of the river.

The development of this site would add to the installed generation capacity from the indigenous hydro resources of AJ&K, which to some extent would add to the National Grid system.

As per the Terms of Reference, the Consultants have to accomplish the following main tasks during the studies.

- Review of the existing data and reports;
- Carry out topographic survey, geological mapping and other fieldwork to investigate the physical and geological environment of potential site;
- Hydrological, sediment and power potential studies;
- Preparation of sub-surface investigations tender documents for HEB and supervision of the investigation works;
- Development of alternative layout plans of the scheme;
- Selection of the optimal configuration of the components of the scheme;
- Power dispersal / transmission system plan;
- Undertake environmental and social impact assessment;

- Preparation of realistic cost estimates and evaluate the economic and financial performance;
- Preparation of implementation programme;
- Preparation of detailed and comprehensive Feasibility Study Report, Detailed Design / Drawings and Tender Documents.

The Client has made it mandatory for the Consultants to carry out the activities and to complete the assigned tasks in three phases, as mentioned below;

- Phase-I: Preparation of Feasibility Report
- Phase-II: Preparation of Detailed Engineering Design
- Phase-III: Preparation of Tender Documents

1.3 PROJECT LOCATION - JAGRAN-IV HYDROPOWER PROJECT

Jagran-IV project area is located on the left bank of Jagran River about 18 km from its confluence with Neelum River at Kundal Shahi. Kundal Shahi is a main village on Neelum valley road located about 68 km from Muzaffarabad.

The travel time from Muzaffarabad to Jagran River at Kundal Shahi is about 4 hours and 1 ½ hours is required from Kundal Shahi to the proposed diversion weir. The powerhouse has been identified just about 0.20 km upstream of existing intake of Jagran - I.

The project location is shown in **Dwg. No. 1-1** and accessibility to the project area is shown in **Dwg. No. 1-2**.

The coordinates of weir and powerhouse site are listed below:

Site	Latitude	Longitude	Elevation (m asl)
Weir	34°-39'-27"	73°-46'-09"	2258
Powerhouse	34°-37'-48"	73°-46'-09"	2120

Jagran River descends from the mountainous peaks at El. 5030, 5021 and 4858 m asl. The catchment of Jagran River borders with Mahandar nullah on its west, Naran and Dadar on the north, and Nagdar nullah on the east. Along its length, it has a few tributaries on either bank. The elevation at its confluence with Neelum River is about 1330 m asl.

The average gradient of Jagran River is about 5.5%. Generally, the ground slopes on either bank of nullah are very steep.

Upstream of the Thunian forest rest house, the valley formed by Jagran River starts its gradual widening with a relatively less steep river slope. The mountainous slopes on both banks of the river are relatively far apart as compared to the slopes downstream of existing Jagran-I power station, where the river flows in a deep gorge.

1.4 ACCESSIBILITY TO THE PROJECT AREA

The main road runs along the right bank of Neelum River from Nausehri up to Kundal Shahi. The Line of Control (LOC) is quite close to main road at Tithwal on the way to Jagran valley. The road from Kundal Shahi leads inside the Jagran valley.

The existing Jagran-I Hydropower Project is located about 10 to 12 km from Kundal Shahi and the proposed Jagran-IV Hydropower Project is located just upstream of Jagran-I. The roads from Kutton to Jagran-I are rough and run at a higher elevation. The road comes to lower elevation near intake structure of Jagran-I and it remains at lower elevation in the proposed scheme area of Jagran-IV.

Transportation between Islamabad and Muzaffarabad is possible by buses and trucks throughout the year. The road distance from Islamabad to Muzaffarabad via Murree and Kohala is 154 km.

The road distance from Islamabad to Murree is 74 km and the road is wide, metalled and in very good condition. From Murree to Muzaffarabad, the road distance is about 80 km. From Islamabad to Muzaffarabad, a good condition car or jeep takes about 3½ hours. Buses and trucks also travel at this high elevation road through Murree city. The road in Murree and Kohala areas has a number of sharp bends.

There is another route from Islamabad to Muzaffarabad via Abbottabad and Mansehra. The road is metalled and all types of vehicles can operate throughout the year. This route is relatively longer and passes over low height areas as compared with that of via Murree and Kohala.

However, in case of snowfall or the severe weather conditions, Abbottabad – Mansehra route is used.

1.4.1 Route Distance

- **Karachi Docks to Rawalpindi**

  The distance from Karachi to Lahore to Rawalpindi via National Highway is 1520 km.

- **Karachi to Islamabad (Motorway Entrance)**

  The distance from Karachi to Lahore to Islamabad via Motorway up to junction of GT road with Islamabad road is1625 km.

  The transportation via Motorway, although 105 km longer, is recommended due to better road conditions as compared to route by National Highway.

- **Rawalpindi / Islamabad to Muzaffarabad Road**

  There are many sharp turns on this route in mountainous area of Murree and Kohala.

  The distance via this route from Islamabad National Highway road crossing to Muzaffarabad is 154 km.

- **Islamabad to Muzaffarabad via Abbottabad and Mansehra**

  The distance via this route from Islamabad to Muzaffarabad is 182 km.

  The condition of the road from Garhi Habibullah crossing with Mansehra Balakot road is not good. There are many sharp turns at entry to Muzaffarabad, and in Muzaffarabad the road passes through busy trade centres. These obstacles may be faced by the loaded ten wheelers on way to Muzaffarabad.

- **Muzaffarabad to Kundal Shahi in Neelum Valley**

  The distance from Muzaffarabad to Kundal Shahi is 68 km.

  The road condition from Muzaffarabad to Nausehri is generally quite poor. The road from Muzaffarabad to Authmuqam is being widened and the construction works are in progress.

1.5 COMMUNICATION

Muzaffarabad city, being central place of AJ&K has good communication services. There are postal and telegraph facilities. Telephone services for main places of AJ&K, main towns / cities of down country and internet services are available. Pakistan Television (PTV) and other regional channels can be seen.

As regards communication services, the district of Neelum with Headquarter at Authmuqam has postal and telephone services. The city is connected with international direct dialing system.

Neelum valley is considered as remote area with respect to level of communication and accessibility. For transportation of the heavy equipment, railway broad gauge track from Karachi to Rawalpindi (1500 km) can be considered.

The remaining 215 km up to Kundal Shahi can be travelled on the Rawalpindi - Muzaffarabad road and then in Neelum valley to project area on truckable metalled road.

1.6 ELECTRIC POWER SUPPLY

The electric power is supplied from nearby power stations at Kundal Shahi and Jagran-I. There is no other existing power station on Jagran River that can provide electric power for the valley. Considering the population located on either banks of Jagran River, the area needs to be connected with the power station through the National Grid.

1.7 PREVIOUS STUDIES

As stated earlier, Jagran-IV is one of the hydropower sites identified by AJ&K HEB. Those studies were of identification level without much site investigations like the hydrologic observations, field survey and geological investigations, etc.

The Consultants planned the present project layout of Jagran-IV Hydropower Project after detailed studies in order to achieve the following objectives:

- The project layout comprising technically feasible diversion weir and powerhouse location;
- The proposed project to be optimised to transmit surplus power to main load centers of AJ&K;
- The project layout need to be economical, feasible and financially viable;
- The project structures must be placed at safe location;

All necessary field data has been collected and presented in this report.

For the comparison purpose, the salient features of proposed Jagran-IV Hydropower Project as compared to the previous studies by HEB are as hereunder:

Parameter	As per previous study	As per present study by the Consultant
Gross Head	110-130 m	156.0 m
Net Head	100-120 m	144.2 m
Design Discharge	8 m^3/s	18 m^3/s
Installed Capacity	6-8 MW	22 MW
Length of Headrace Tunnel / Pipe	4260 m	3075 m
Length of Penstock	Not Mentioned	180 m
Average Energy (April – September)	34.29 GWh	82.55 GWh
Average Energy (October – March)	17.96 GWh	15.65 GWh
Yearly Average Energy	52.25 GWh	98.20 GWh

2 TOPOGRAPHIC SURVEY

2.1 GENERAL

The availability of accurate survey data and maps in the digital format is a pre-requisite for project studies like planning and design of scheme. Therefore, the Consultants carried out the field topographic survey in the areas of interest to collect required field survey data in the digital format and then processed the same with appropriate survey software for producing the computer aided maps.

2.2 SCOPE OF WORK

The scope of survey work comprised of:

- Establishment of survey bench marks and control points network in the project area;
- Survey of longitudinal profile of Jagran River for the stretch involved in the proposed scheme;
- Detailed topographic survey by observing horizontal and vertical survey data of random spots in the area;
- Production of survey maps on different scales to the requirements of project.

2.3 TOPOGRAPHY OF NEELUM RIVER CATCHMENT

Neelum River has a number of small to medium size nullahs joining from either side. Neelum River rises on the south-west side of Deosai plain with a number of peaks like Kaobai Gali 5666 m asl, Betagah 4668 m asl, Burzil pass 4199 m asl and Shalamar 4764 m asl. In the initial portion Minimarg nullah is joined by right bank tributary Burzil nullah to from it as Kishen Ganga River and Potalwan nullah is its left bank tributary in Indian held Kashmir. Kishen Ganga River becomes Neelum River as it enters into Azad Jammu and Kashmir, 5 km upstream of Taobut.

From Taobut to Kel, the right bank tributaries of Neelum River are Gagai River, Falowai nullah, Janawahi nullah and Baral River and the left bank tributaries are Hant-i-Naushahra and Mastil nullahs.

Further, from Kel to Nausehri, left bank tributaries are Lashdat nullah, Dudhnial nullah, Keran nullah, Kaiban nullah, and Katha Qazi Nag and right bank tributaries are Gamot nullah, Changan nullah, Dowarian nullah, Chutiari nullah, Nagdar nullah and Jagran River.

Further on, from Nausehri to Muzaffarabad, Pankot nullah is left tributary and Jhing da Katha, Bheriwala Katha and Ghoriwala Katha are the right bank tributaries.

The main stream of Neelum River from Taobut to Dudhnial flows with average bed gradient of 6 m / km. From Dudhnial to Nausehri, Neelum River flows with an average bed gradient of 13 m / km. From Nausehri to Muzaffarabad, the average bed gradient of Neelum River is 7.5 m / km.

2.4 AVAILABLE TOPOGRAPHIC MAPS

The topographic maps from Survey of Pakistan (SOP) are the basis for initiating the preliminary studies of project layouts.

The following Survey of Pakistan General Topographic (GT) sheets covering areas of the Consultants' assignment were arranged:

- Scale 1:250,000 43-F
- Scale 1:50,000 43-F/14

2.5 DETAILED TOPOGRAPHIC SURVEY

Topographic survey of Jagran-IV Hydropower Project was carried out for the whole project area. Suitable polygonal traverses were developed individually at proposed intake and powerhouse site area. The polygon was divided into triangles and triangulation was carried out starting with the one having baseline as one of its sides. The detailed topographic survey at the site was carried out using Sokkia Total Station.

Leveling was carried out using Auto Level having least count of 0.001 m and the elevations at all the polygonal traverse points were determined. The topographic sheets were used for the marking of different alternatives, placement of component structures and alignments.

For the geological investigation of powerhouse and intake area mainly for rock overburden contact, plain table maps at scale 1:2,500 and at scale 1:1,000 were developed using the same polygonal traverse points and results of leveling.

To obtain fine working details and to facilitate placement of diversion weir, intake, sandtrap, low pressure headrace pipe, penstock and powerhouse of the proposed project an area of about 111 hectares has been mapped on scale 1:1,000 with contour interval of 2 m.

Accurate and up to date spatial information is a pre-requisite for planning and designing of any project to be implemented on ground. Traditional techniques of surveying assisted with modern mapping techniques for quick, economical and up to date information has been used.

The density of positional readings in project area satisfied level data interpolations to 2 m contour interval at scale 1:1,000. The estimated survey area at weir and powerhouse sites is 28 and 18 hectares.

2.5.1 Reference Grid

In order to start topographic field survey work, the reference grid of SOP is required to be connected. But there is no standard bench mark established by SOP in the vicinity of the proposed project areas and surroundings. The ground survey has been carried out with reference to established control points to prepare the topographic features of Jagran-IV Hydropower Project.

2.5.2 Bench Marks and Control Points

Standard bench marks (BMs) have been established along the river stretch where Jagran-IV hydropower scheme is proposed. These bench marks are located with precise leveling and traversing. Horizontal and vertical control of the project network has been achieved through these bench marks.

The control points have been established to cover the area of powerhouse and weir site along the stretch of the river on which scheme has been proposed.

The ground control points have been established in the field with total station (Sokkia 630-RK, Sokkia 530-RK and Sokkia 510) having the following native accuracy of the receiver:

- Horizontal 2 mm + 2 ppm
- Vertical 2 mm + 2 ppm

A list of permanent bench marks / control points is presented in **Table - 2.1 and Table - 2.2**.

2.5.3 Horizontal Control

This has been done through a combination of conventional triangulation and the Electromagnetic Distance Measurement (EDM) traversing. All survey work was conducted by having digital display infrared beam total station. The triangulation network consists of well balanced quadrilaterals or center point polygons and well balanced triangles.

The EDM traversing was in the closed loop form and all traversing lines were measured two ways and mean value was used, provided two measurements agree to 1:10,000. Horizontal angle measurement with maximum spread of 20 seconds has been used in computations.

2.5.4 Vertical Control

The mean sea level (msl) of SOP has been taken as reference for the project site. Standard bench marks were established in the project area through double check leveling, using precise leveling instruments. All necessary precautions and standard procedures which are applicable to this class of survey have been adopted.

2.6 LONGITUDINAL PROFILE OF JAGRAN RIVER

The longitudinal profile survey has been carried out by the Consultants for potential stretch of Jagran River. Ground control points have been established near main structure sites. The developed profile indicates that there is a drop of approximately 206 m in about 3.75 km length of the river. The average river gradient is about 5.5%.

2.7 TOPOGRAPHY WITH SATELLITE IMAGES

The area along the headrace pipe alignment is inaccessible and it is difficult to carry out the ground survey. The maps of this area have been developed with the help of satellite images. Digital Elevation Model (DEM) generated from the stereo pair of the ASTER satellite images has been used to prepare the topography of headrace pipe alignment area.

Terrestrial survey carried out for weir and powerhouse areas have been used as a basis for improving the precision of DEM. Topography developed with DEM is very well connected with ground survey for weir and powerhouse areas.

The following satellite data and DEM have been used:

- SPOT-5 data 2.5 m resolution
- Aster Digital Elevation Model resolution 10 m x 10 m, vertical accuracy 5 to 10 m, horizontal accuracy 5 to 15 m

SPOT-5 images have also been procured for both weir and powerhouse area and along the pipe alignment. An overview map and digital elevation data, low resolution of the project area was generated and made available for developing the alternative project layouts.

2.8 PREPARATION OF CONTOUR MAPS

A background image was processed based on the SPOT-5 (2.5 m) resolution data. The SPOT-5 satellite image provides the multi-spectral data at four (4) spectral bands in the optical and near infrared range (0.45 µm to 2.35 µm) with a resolution of 10 m, and a panchromatic channel with a nominal pixel spacing of 2.5 m.

Further, to provide the colour images with improved quality, the multi-spectral bands were merged with the panchromatic band by means of pan-sharpening using the HIS technique. The two multispectral-pansharpened band combinations were generated and saved in a common Raster format (GEOTIFF).

The DEM was generated with the stereo pair of the Aster satellite images of 10 m pixel spacing. The DEM was developed in UTM-43, WGS-84 Ellipsoid, and local datum WGS-84. Elevation contour lines have been calculated and stored as ESRI Shape files.

The acquisition of ASTER images with 15 m resolution was also made covering the project area. The specific areas for the weir and powerhouse were defined for acquisition of medium resolution stereo standard satellite images. The processing of high resolution satellite images, including ortho-rectification using DEM and image acquisition parameters has been carried out.

The topographic maps of the area surveyed have been developed with contour interval of 2 m. For weir, powerhouse and headrace pipe areas, ground survey conducted has been connected with contours developed with DEM.

2.9 SOFTWARE

The following softwares have been used for image processing and GIS database development.

- Imagine 9.1
- ArcGIS 9.2
- AutoCAD 2009

Table - 2.1: Coordinates of Bench Marks / Control Points

Jagran - IV Hydropower Project, Weir Area

Sr. No.	Station	Easting (m)	Northing (m)	Elevation (m asl)
1	J 1	3271476.000	1167509.000	1150.000
2	J 2	3271457.488	1167728.646	2160.805
3	J 3	3271513.517	1167206.515	2124.082
4	J 4	3217481.280	1167431.860	2124.499
5	J 5	3271483.510	1167805.227	2174.269
6	J 6	3271469.255	1167640.282	2157.171
7	J 7	3271452.160	1167927.476	2180.942

Table - 2.2: Coordinates of Bench Marks / Control Points

Jagran - IV Hydropower Project, Powerhouse Area

Sr. No.	Station	Easting (m)	Northing (m)	Elevation (m asl)
1	BM1	3271624.543	1164389.266	1972.179
2	BM2	3271603.819	1164474.413	1973.734
3	J 14	3271577.041	1164822.101	2026.158
4	J 15	3271547.246	1164738.527	1997.189
5	J 16	3271547.268	1164738.545	1997.126

3 HYDROLOGY AND SEDIMENTATION

3.1 INTRODUCTION

The project area is located near Kutton village about 85 km from Muzaffarabad in the Neelum River valley. The project site is upstream of the existing Jagran - I Hydropower Project on the Jagran River.

Jagran River is a right bank tributary of Neelum River. The river confluence with Neelum River is at Kundal Shahi village which is about 68 km from Muzaffarabad. The approximate travel time from Muzaffarabad to Kundal Shahi village is about 4½ hours. The main road runs along the right bank of Neelum River via Nausehri up to Taobut.

The road from Kundal Shahi village leads to Kutton village and onwards, a rough jeepable track suitable for 4 x 4, leads to project area into the Jagran valley.

3.2 DESCRIPTION OF THE CATCHMENT

The river descends from the mountain peaks at elevations of 5030.70 and 5021.00 m asl. The river along its length has a few tributaries joining the main stream from either bank. The elevation at its confluence with Neelum River is 1330 m asl. The average gradient of Jagran River in the project area is about 5.5 %.

Generally, the ground slopes on either bank of river are very steep. Catchment area of the river at its confluence with Neelum River is about 430 km^2 and up to weir intake, it is 214 km^2.

The catchment area of Jagran River is illustrated in **Figure - 3.1**.

Kutton village is located on the right bank and Thunian village is located on the left bank of Jagran River. The valley is populated on either bank at the higher elevations, where the terraces are available. Along the river, the valley supports clustered and scattered population on both the banks.

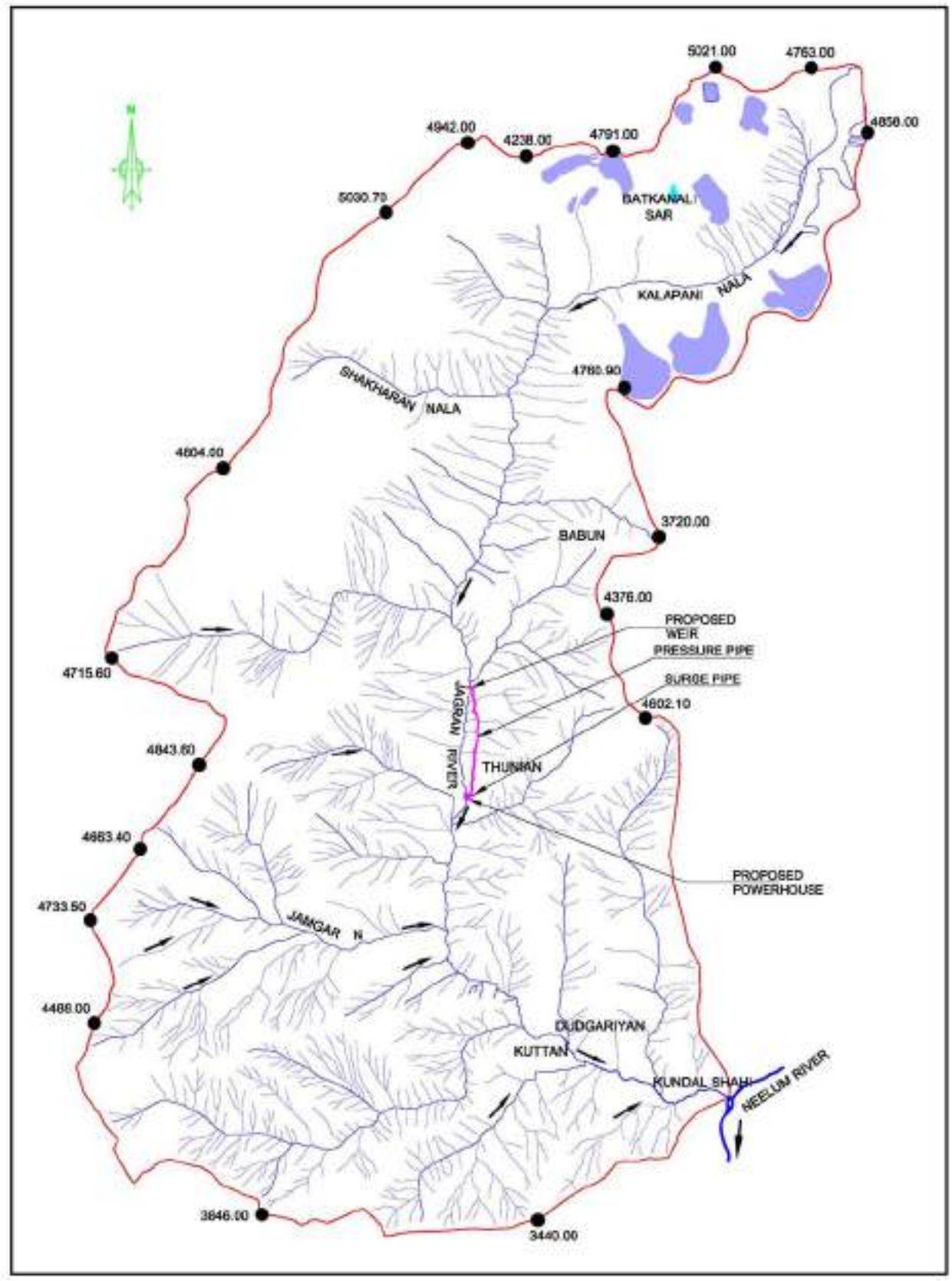


Figure - 3.1: Catchment Area of Jagran River

The entire left bank of the river in the project area was viewed and it is considered that the left bank is more suitable for proposing the project layout with low pressure pipe and surface powerhouse.

3.3 CLIMATE

The climate of the catchment is characterised by very cold snowy winter and relatively pleasant summer. The high areas of the catchment are permanently clad with snow and glaciers. Forest cover in the area extends up to an elevation of about 3700 m (12,000 ft).

The climatic data in Neelum valley is very scarce. One station in Neelum valley with limited climate record is at Dudhnial. The nearest station to project area with long term record is located at Muzaffarabad and Naran.

The list of Climatological stations in the region is presented in **Table - 3.1**.

Table - 3.1: Long Term Climatic Stations in Jhelum River Basin

Station	Mean Annual Rainfall (mm)
Balakot	1718
Garhi Dopatta	1602
Dudhnial	1541
Muzaffarabad	1534
Bagh	1415
Sehr Kakota	1386
Rawalakot	1375
Kotli	1255
Palandri	1230
Mangla Dam	1221
Rehman Bridge	1132
Naran	1118
Kallar	945
Jhangi	921

Source : SWHP, WAPDA

The above table provides the mean annual rainfall data at various stations in Jhelum River catchment. Dudhnial and Muzaffarabad are two stations which represent the rainfall pattern in lower part of Neelum valley. The snowfall at higher elevation is not included in the rainfall data.

3.3.1 Temperature

The one meteorological station with long record of temperature is located at Muzaffarabad, at a distance of about 85 km from the project area. The data has been collected from the Pakistan Meteorological Department in order to get the maximum and minimum temperatures on monthly and yearly basis.

The mean monthly temperature at Muzaffarabad varies from 9.2° C in January to 28.6° C in June and July, and the average yearly temperature varies from 18° C to 24° C. Mean monthly temperature is graphically indicated in **Figure - 3.2**; whereas, the mean annual temperatures are shown in the following **Figure - 3.3**.

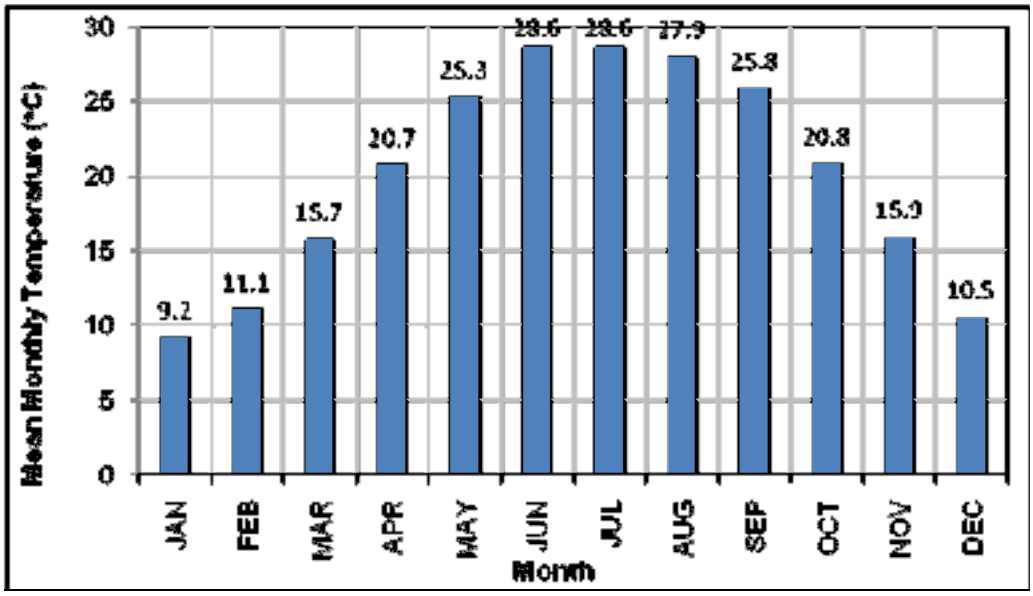


Figure - 3.2: Mean Monthly Temperature at Muzaffarabad

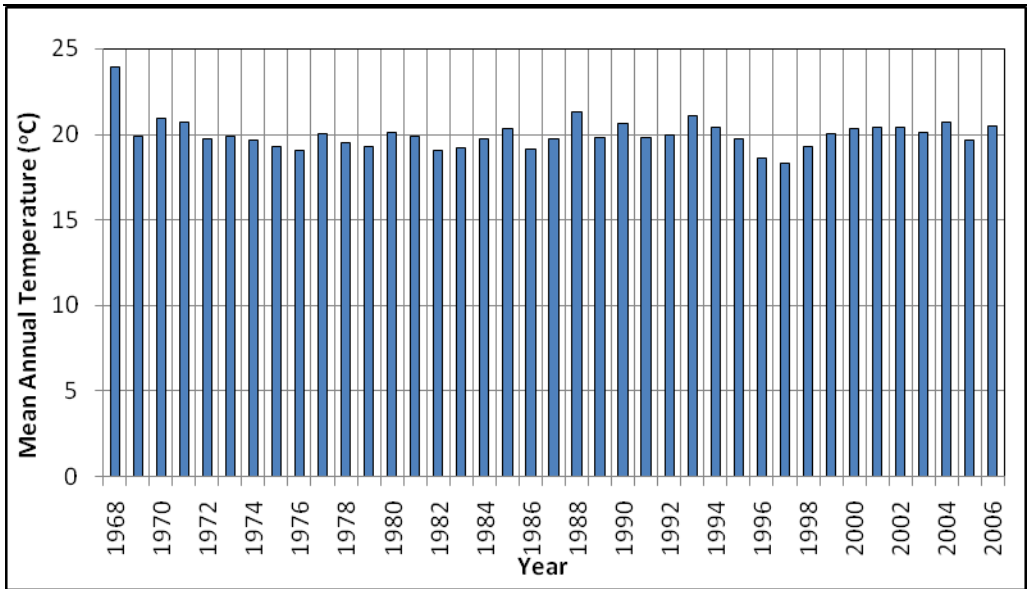


Figure - 3.3: Mean Annual Temperature at Muzaffarabad

January is the coldest month at the project site, when the temperature drops to several degrees below zero. The highest temperatures are experienced in the month of June.

3.3.2 Precipitation

Precipitation data of Muzaffarabad station was collected from Pakistan Meteorological Department in order to get maximum, minimum and average precipitation on monthly and yearly basis. Mean annual precipitation at Muzaffarabad (1955-2004) is shown in the following **Figure - 3.4**.

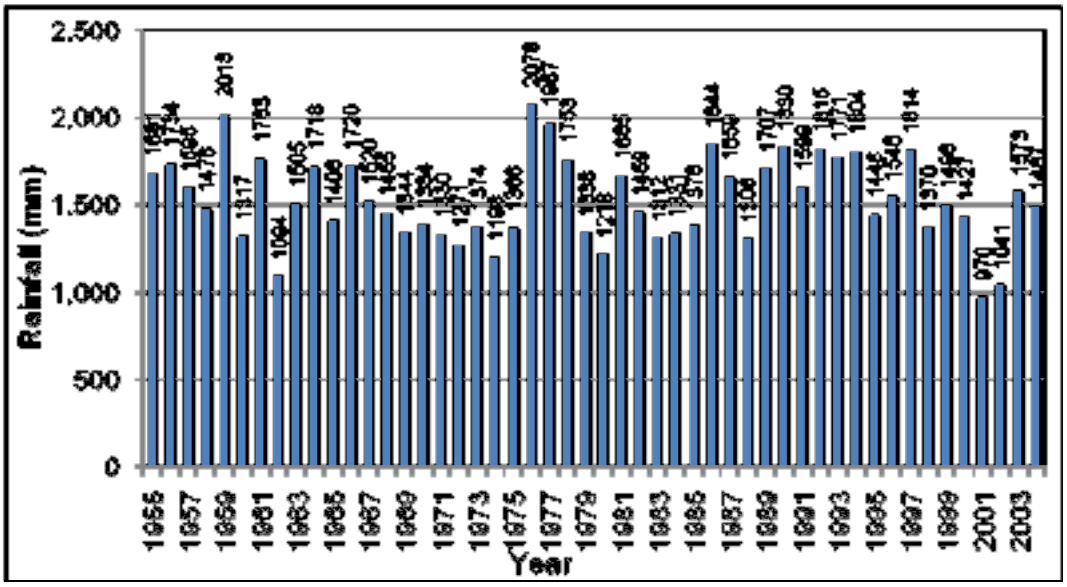


Figure - 3.4: Annual Precipitation at Muzaffarabad

Mean Annual rainfall varies from 970 mm in 2001 to 2078 mm in 1976. The average of mean annual rainfall is 1534 mm over a period from 1955 to 2004. The monthly rainfall varies from 40 mm in November to 328 mm in July.

The mean monthly rainfall is presented in **Figure - 3.5**.

From November to May, during the winter period the precipitation is mainly brought by the western disturbances. The precipitation during this part of the year is approximately 690 mm.

During summer period, i.e., from June to October, the precipitation in the catchment is induced by the monsoon rainfall and averages to about 844 mm.

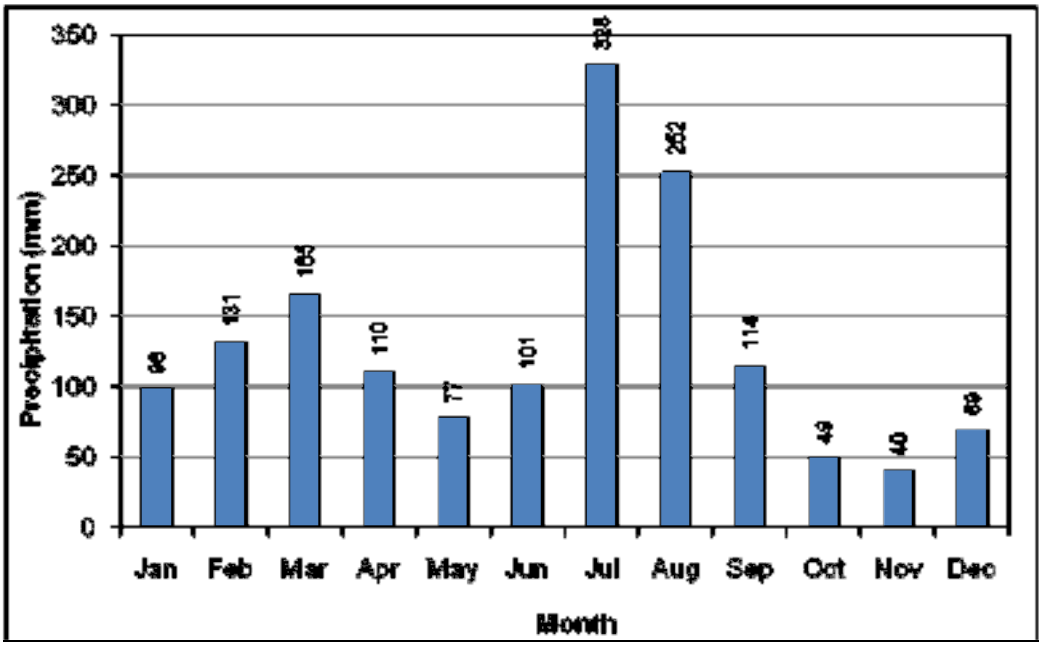


Figure - 3.5: Mean Monthly Precipitation at Muzaffarabad

For some years, rainfall data at Dudhnial is available from Surface Water Hydrology, WAPDA. The annual variation of rainfall is indicated in **Figure - 3.6**. The mean monthly rainfall at Dudhnial is shown in **Figure - 3.7**. The rainfall at Dudhnial is comparatively lesser than that of at Muzaffarabad, because there is more snowfall at Dudhnial. The overall precipitation at Dudhnial is more than that of at Muzaffarabad. As there is no snowfall gauging station in upper part of Neelum valley, the rainfall data at Dudhnial is not true representation of total precipitation at Dudhnial.

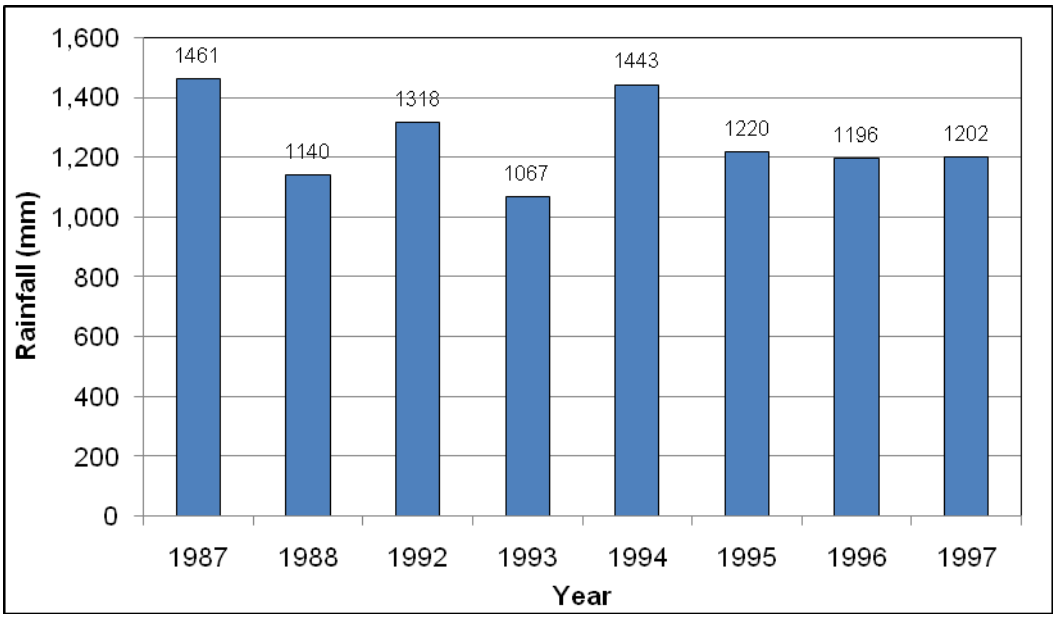


Figure - 3.6: Yearly Rainfall at Dudhnial

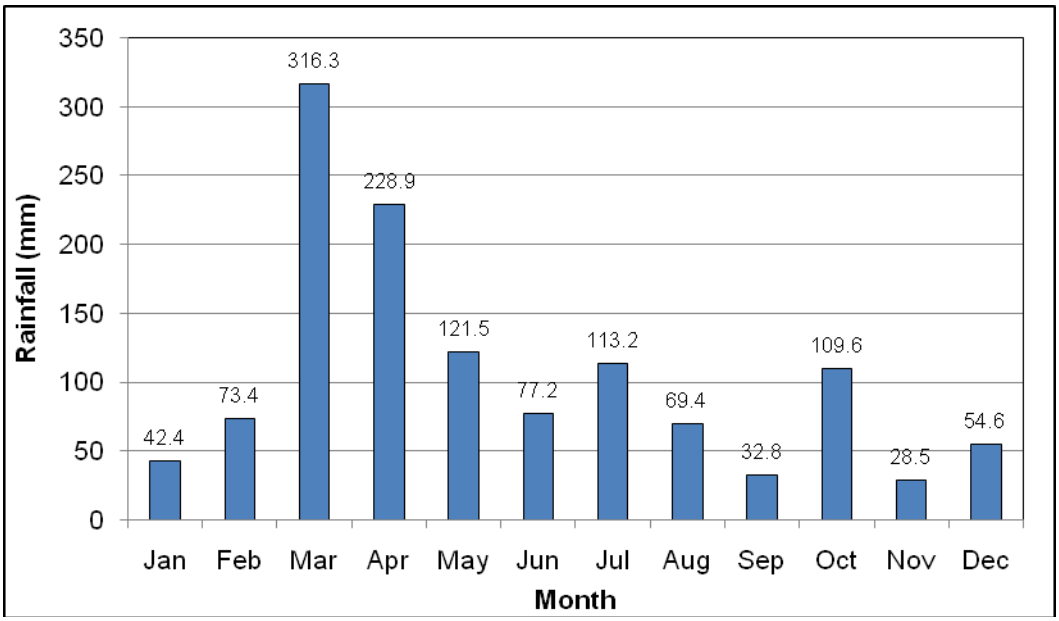


Figure - 3.7: Mean Monthly Rainfall at Dudhnial

3.4 HYDROLOGICAL STATIONS

In previous years during July 1994 to June 1996 and September 1982 to August 1984, discharge measurements were performed on the Jagran River by the AJ&K Hydro Electric Board in collaboration with French Consultants.

The discharge measurements at these locations of Jagran River provide the basis for the estimation of flows. This data needs to be correlated with long term gauging station to prepare a flow series for estimation of power and energy.

The location map of the gauging stations in northern part of Pakistan is presented in **Figure - 3.8**. The list of gauging stations with period of record is mentioned in **Table - 3.2**.

Table - 3.2: Hydrological Stations with Long Term Records

Station / River	Location		Elevation (m asl)	Area (km²)	Period of Record
	Latitude	Longitude			
Muzaffarabad	34°22’	73°28’	670	7278	1963-2006
Nausehri	34°23’	73°43’	1030	6809	1990-00
Dudhnial	34°42’	74° 7’	1823	4905	1980-92
Naran	35°27’	75°25’	2341	1036	1960-2000
Thunian*	35°35’30”	75°18’50”	2150	219	July 94 to June 96
Kundal Shahi*	35°27’22	75°18’40	1360	430	July 94 to June 96 Sep 82 to Aug 84
Taobut*	35°35’30”	75°8’20”	2250	275	Jan 92 to June 95

*Short term Record.

Flow measurements have been recorded by the Surface Water Hydrology Project on a few stations located on the main Neelum River. This includes Muzaffarabad, Dudhnial and Nausehri stations on Neelum River. Naran station is located on Kunhar River where a long term daily flow data is available.

The flows of Jagran River have been taken from the report Jagran-II Feasibility Study published in March 1999. On Gagai nullah, the flow measurements have been observed by Surface Water Hydrology Project, WAPDA and the daily flow record is available for two years.

Jagran River at Thunian is the nearest station to the proposed project area, where daily flow record is available for two years and also the Jagran River at Kundal Shahi is another station on Jagran River, at the confluence of the river with Neelum River where four (4) years daily flow record is available. Neelum River at Muzaffarabad and Kunhar River at Naran stations have the longest period of recorded data.

At Dudhnial climatic station, only rainfall data for a few years is available and there is no record of snow fall near the project area, therefore flows in Jagran River can not be estimated using limited rainfall data. The daily flow data of Jagran River at Thunian or at Kundal Shahi is important for flow estimation at Jagran River in addition to limited data observation in the project area.

3.4.1 Flow Record at Various Gauging Stations

The long term flows are required at the diversion site to design the proposed project. Daily flows at the proposed weir site have been calculated to estimate the water availability at the project by using different approaches.

The specific flows of various gauging stations in the region are presented in **Table - 3.3**.

Table - 3.3: Specific Flows of Various Gauging Stations

Sr. No.	Station	Period of Record	Mean Annual Flows (m^3/s)	Specific Flows ($l/sec/km^2$)
1	Muzaffarabad	1963-2006	337.6	46.2
2	Naran	1960-2000	48.0	46.3
3	Dudhnial	1980-92	259.2	52.8
4	Nausehri	1990-2000	306.0	44.9
5	Kundal Shahi	1982-84 & 1994-96	27.0	62.8
6	Thunian	1994-96	17.26	78.8
7	Gagai	1992-95	19.35	70.4

The above table indicates that two long term stations at Muzaffarabad and Naran have same specific flows of 46 l/sec/km^2. Although Dudhnial and Nausehri stations on Neelum River have less period of record; however, these stations also have specific flows in the same range.

Jagran River at Thunian is the closest gauging station to the project area and also the Jagran River at Kundal Shahi. Thunian station is preferred over Kundal Shahi station as it is very close to the weir site as compared to the Kundal Shahi station. Therefore, the flows record at Thunian is important to be used for estimation of flows at proposed weir site of Jagran - IV Hydropower Project.

3.4.1.1 Flows of Neelum River at Dudhnial and Nausehri Stations

There are three (03) hydrological stations located on the Neelum River, at Muzaffarabad (1963 - 2006), Nausehri (1990 - 2000) and Dudhnial (1980 - 1992). The proposed project area lies in between the Nausehri and Dudhnial stations.

A study has been made to estimates the flows at Thunian and Kundal Shahi by using historical flows of these stations. A comparison was made between the flows at Nausehri and Dudhnial with the flows at Thunian and Kundal Shahi by using the discharge data of the same period. It was observed that the trend of flows is similar in winter period and specific flows of Thunian and Kundal Shahi are higher than Nausehri in summer period as presented in **Figure - 3.9**.

The flow record at Dudhnial and Nausehri stations is comparatively less as compared with that at Muzaffarabad station. Therefore, Muzaffarabad station is preferred over these stations.

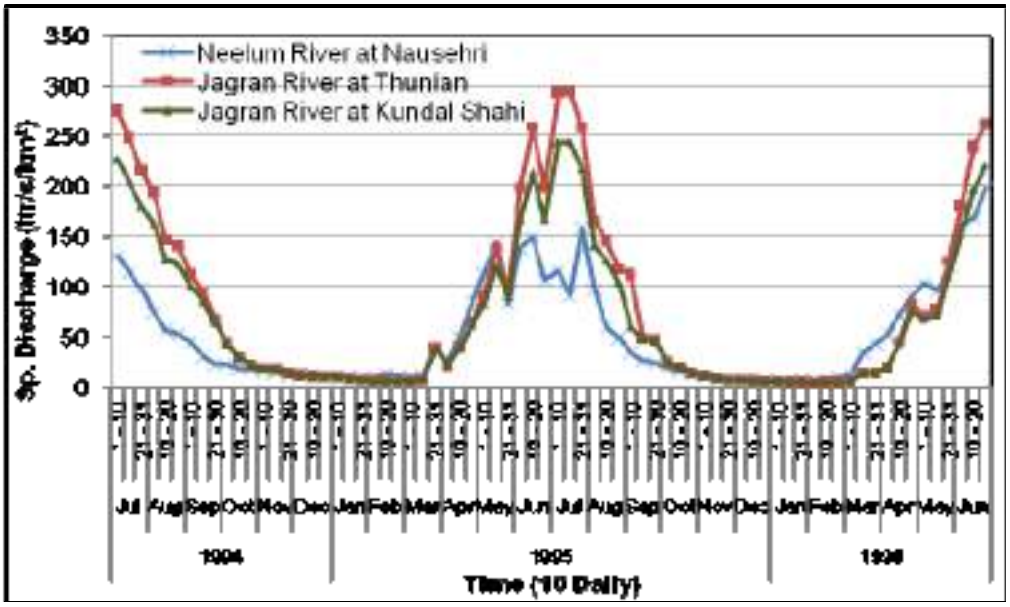


Figure - 3.9: Specific Flows - Neelum River at Nausehri and Jagran River at Kundal Shahi and Thunian

3.5 ESTIMATION OF EXTENDED FLOWS AT THUNIAN & KUNDAL SHAHI

The methodology for estimation of flows at Jagran River is first to have an extended series of the flows at a station where some years of flow record is available. Near to Jagran River, daily flow record of few years is available at Kundal Shahi and Thunian on Jagran River.

Thunian Station is very close to the diversion weir site where the estimation of flows is required for the project. With two year long daily flows, Thunian station has been preferred to be used as a reference station for estimating the flows at weir site on Jagran River as Thunian station is very close to the weir site in comparison to Kundal Shahi Station.

The Kundal Shahi Station is also considered in the estimation of flows as it has four years long daily flow data. The flows at these stations would be extended by establishing a correlation with the long term gauging station either Neelum River at Muzaffarabad or Kunhar River at Naran.

3.5.1 Muzaffarabad-Kundal Shahi & Thunian Correlation

Historic data of daily flows for Neelum River at Muzaffarabad is available from 1963 to 2006. The catchment area of Neelum River at Muzaffarabad is 7278 km^2.

For the recorded period, the average annual flow of Neelum River at Muzaffarabad is 337.6 m^3/s. The mean annual flows for Neelum River at Muzaffarabad are presented in **Figure - 3.10**.

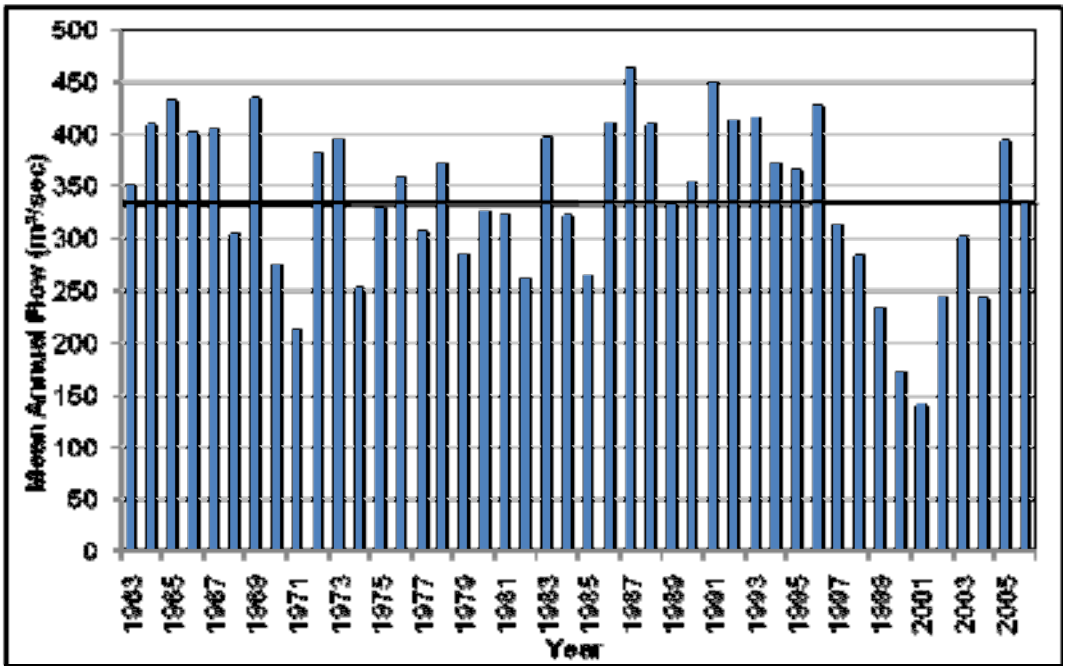


Figure - 3.10: Mean Annual Flows (m^3/s) - Neelum River at Muzaffarabad

Muzaffarabad station has been preferred over Dudhnial and Nausehri stations due to longer period of record for extension of flows of Jagran River at Thunian and Kundal Shahi.

The comparison of specific flows of Neelum and Jagran River is given in the **Figure - 3.11**.

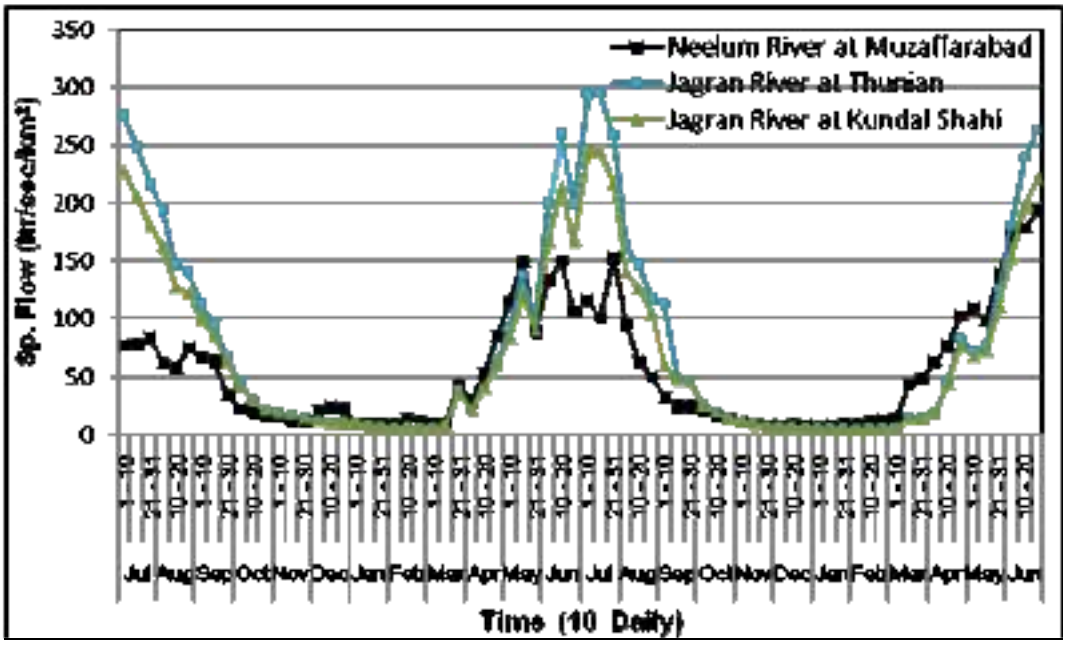


Figure - 3.11: Specific Flows - Neelum River at Muzaffarabad and Jagran River at Kundal Shahi and Thunian

The comparison indicates that Jagran River during summer months has the higher specific flows than Neelum River at Muzaffarabad. Neelum River has some equal or higher specific flows during the winter months than Jagran River at Kundal Shahi.

The above graph also indicates that the trend of specific flows is similar in winter and there is need to check the similarity of trend of Kunhar River at Naran with Jagran River at Thunian and Kundal Shahi.

3.5.2 Naran - Kundal Shahi Correlation

The catchment area of Kunhar River at Naran is 1036 km^2, while Jagran at Kundal Shahi has catchment area of 430 km^2. The catchment ratio of Kundal Shahi to Naran is higher as compared to Kundal Shahi to Muzaffarabad.

With the relatively smaller catchment, the climatic conditions for Naran are uniform as compared with large catchment of Neelum River at Muzaffarabad.

The flow record of Jagran River at Kundal Shahi is from September 1982 to August 1984 and from July 1994 to June 1996, which has been used for establishing the correlation.

Naran station has a long record of daily flow data. In this study, flow data from 1960 to 2000 has been used.

At Naran station, the average annual flow (1960-2000) is 48.0 m^3/s. The annual flow ranges from 32 to 63 m^3/s as presented in **Figure - 3.12**.

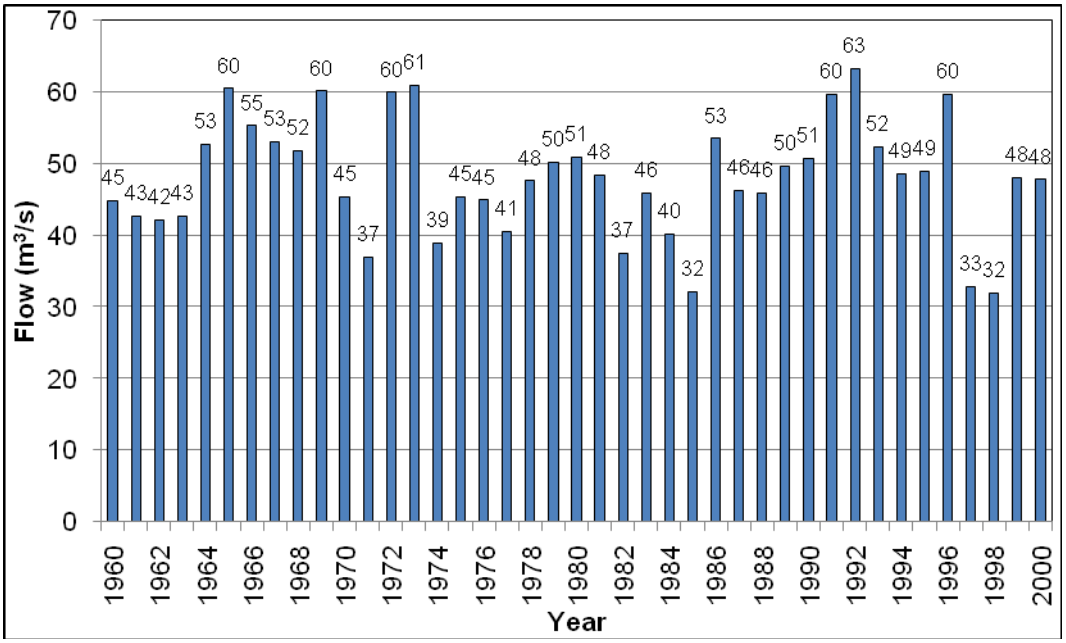


Figure - 3.12: Mean Annual Flow - Kunhar River at Naran 1960-2000

The specific flows of Naran and Kundal Shahi during the September 1982 to August 1984 were plotted as shown in **Figure - 3.13**.

The flow trend during low flow months is similar and it differs during high flow season. Kundal Shahi with smaller catchment has higher specific flows during summer month as compared with that of Naran.

The specific flows at Kundal Shahi become less during winter months as compared with Naran.

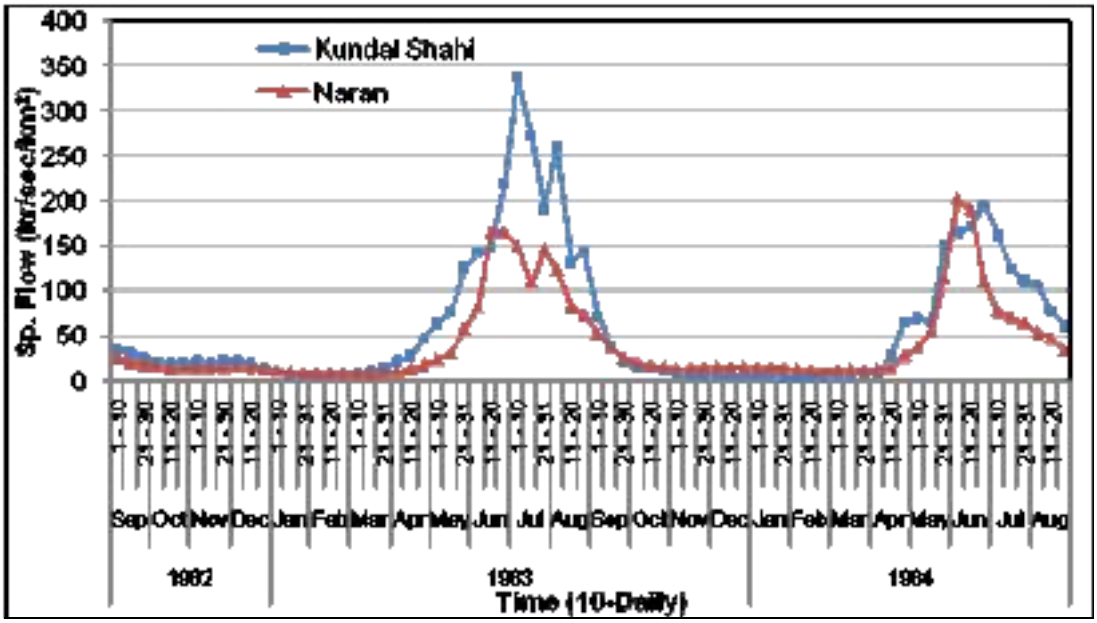


Figure - 3.13: Specific Flows - Kunhar River at Naran and Jagran River at Kundal Shahi 1982-84

For the period, July 1994 to June 1996, specific flows are plotted and the graph is presented in **Figure - 3.14**. During 1994-96, the difference of specific flows in summer months is less as compared with 1982-84.

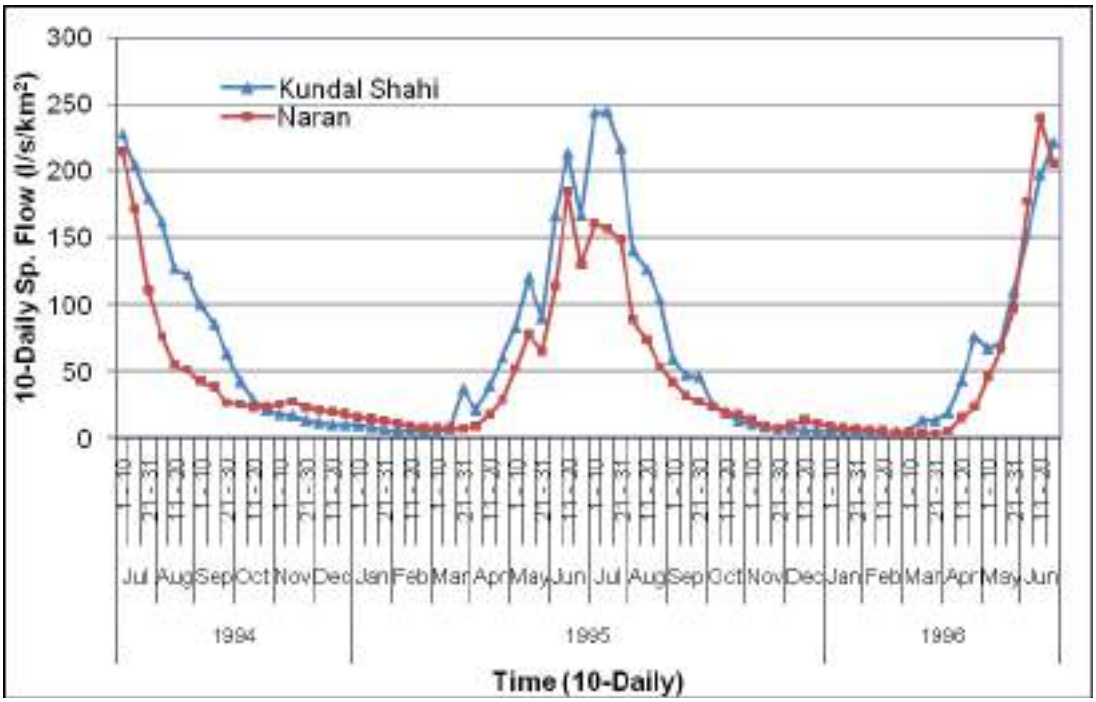


Figure - 3.14: Specific Flows – Kunhar River at Naran and Jagran River at Kundal Shahi 1994-96

The above graph indicates the pattern of specific flows is more similar as compared to the pattern of period 1982-84.

For correlation, the specific flows of Kunhar River at Naran and Jagran River at Kundal Shahi gauging stations have been plotted and are presented in **Figure - 3.15**.

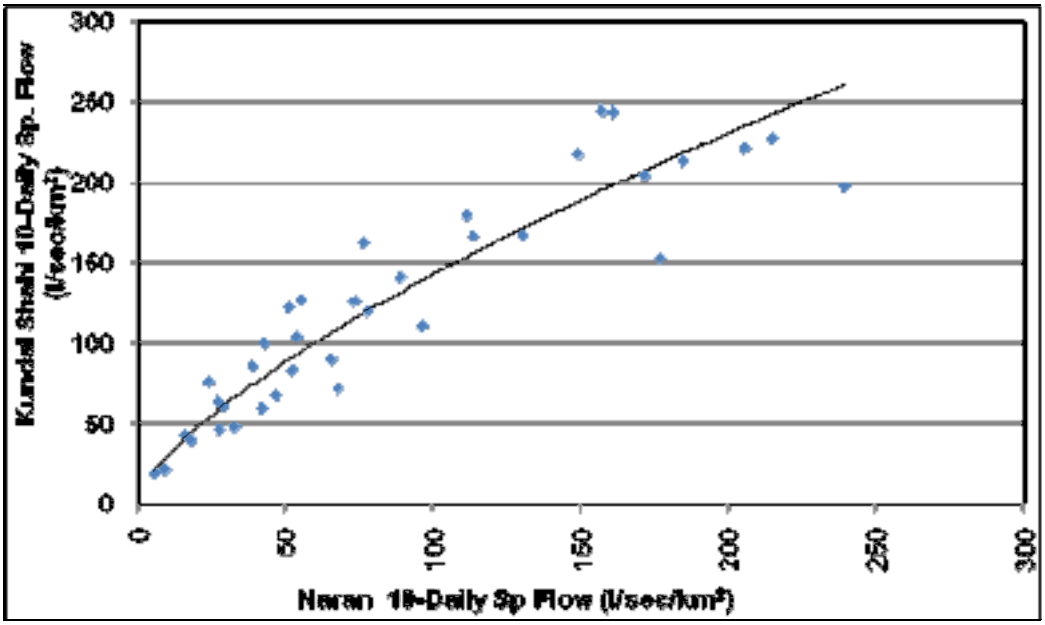


Figure - 3.15: Relationship between Specific Flows at Naran and Kundal Shahi for Summer Period

The regression analysis was carried out which shows R^2 value of 0.904. The data in the summer months are closely oriented along the trendline.

The equation from the trend curve thus obtained is:

$$y = 5.801X^{0.6947}$$

Putting the specific flows of Kunhar River at Naran (x) in the above equation will give the specific flow of the Jagran River at Kundal Shahi (y) for the same period. The above relation has been applied to Naran flow data and it was found that the estimated flow values in summer months have better correlation.

In order to assess the low flows with better accuracy for a smaller catchment, the same data has been used to have another trend line equation.

The relationship is plotted and is indicated in **Figure - 3.16**.

The equation from the rating curve thus obtained is:

$$y = 0.6601X^{1.1629}$$

Putting the specific flows of Kunhar River at Naran (x) in the above equation will give the specific flow of the Jagran River at Kundal Shahi (y) for the same period.

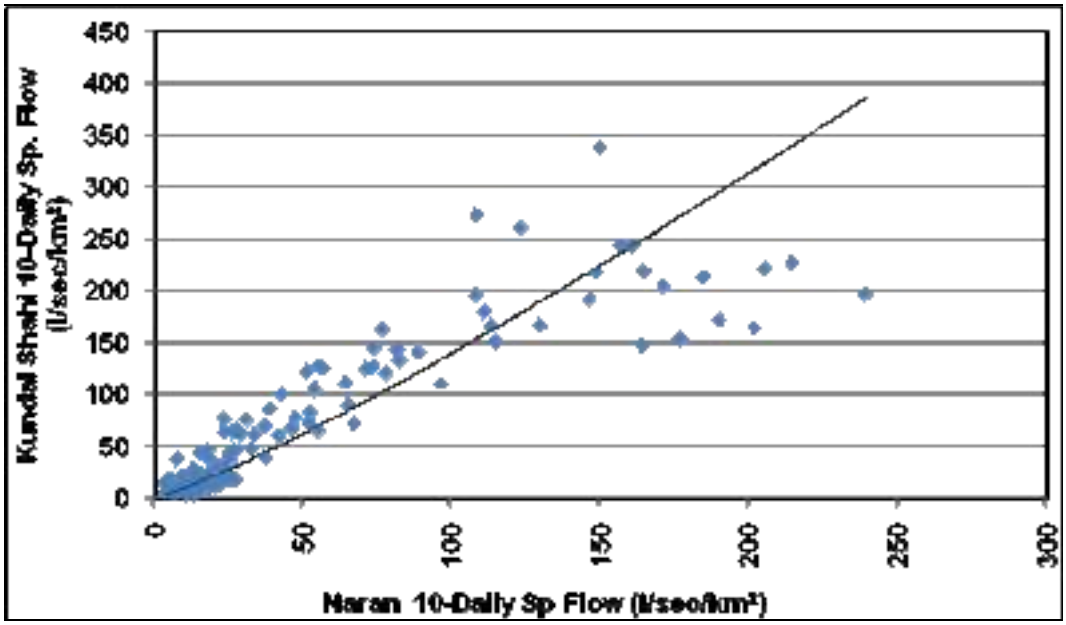


Figure - 3.16: Relationship between Specific Flows at Naran and Kundal Shahi for Winter Period

As the Jagran River at Thunian is the closest station where a few years flow record is available, so Thunian is also to be checked for its correlation with long term gauging station, i.e., Kunhar River at Naran.

3.5.3 Naran - Thunian Correlation

Jagran at Thunian has catchment area of 219 km^2. The flow record of Jagran River at Thunian is from July 1994 to June 1996, which has been used for establishing the correlation. Naran station has a long record of daily flow data. In this study, flow data from 1960 to 2000 has been used.

The specific flows of Naran and Thunian during the July 1994 to June 1996 were plotted as shown in **Figure - 3.17**. It can be observed that the flow trend during low flow months is similar.

Thunian with smaller catchment has higher specific flows during summer month as compared with that of Naran. The specific flows at Thunian during winter months are in same range as that of Naran.

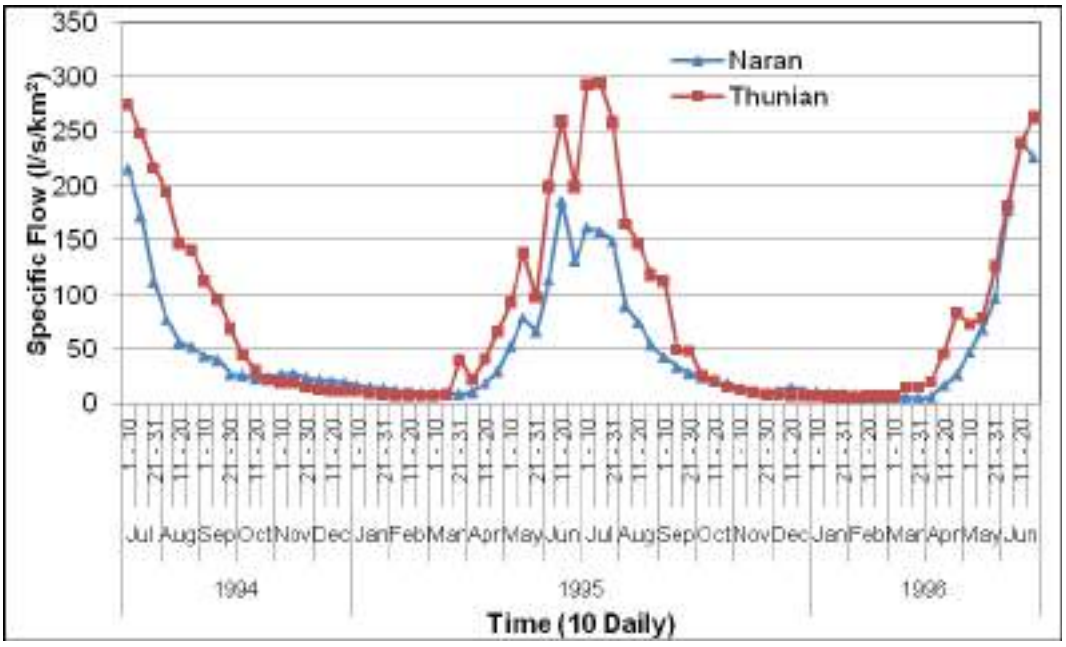


Figure - 3.17: Specific Flows - Kunhar River at Naran and Jagran River at Thunian 1994-96

During 1994-96, the difference of specific flows in summer months is less as compared with 1982-84.

For correlation, the specific flows of Kunhar River at Naran and Jagran River at Thunian gauging stations have been plotted and are presented in **Figure - 3.18**.

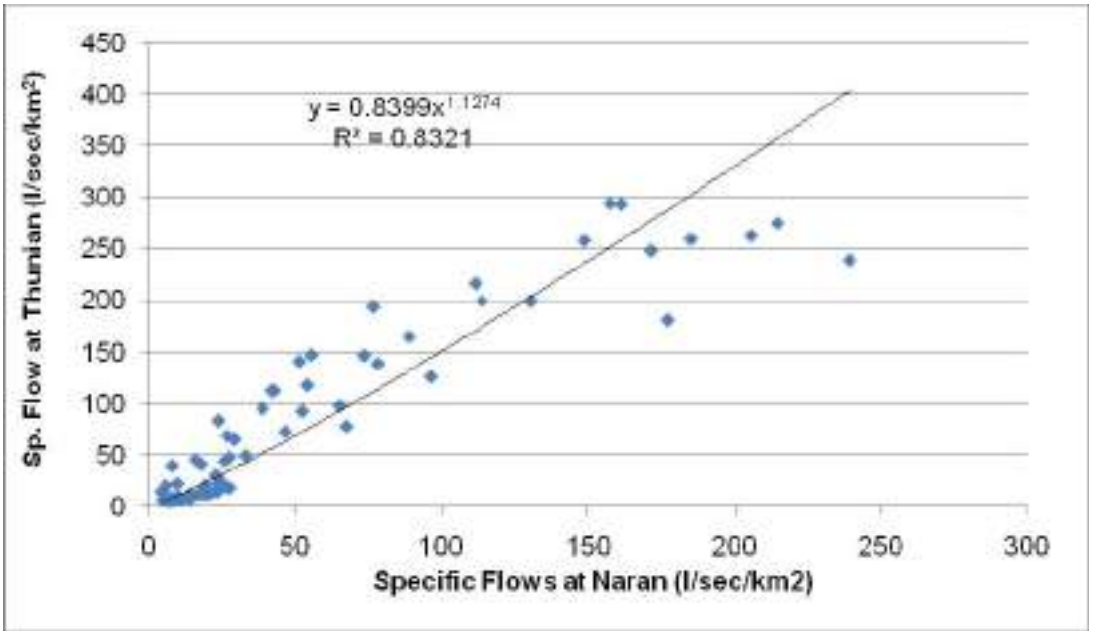


Figure - 3.18: Relationship between Specific Flows at Naran and Thunian

The regression analysis was carried out which shows R^2 value of 0.8321. The data is closely oriented along the trendline.

The equation from the trend curve thus obtained is:

$$y = 0.8399X^{1.1274}$$

Putting the specific flows of Kunhar River at Naran (x) in the above equation will give the specific flow of the Jagran River at Thunian (y) for the same period. The above relation has been applied to Naran flow data and it was found that the estimated flow values are realistic.

3.5.4 Estimated and Observed Flows of Jagran River at Thunian

Thunian station on Jagran River is the closest station to the proposed weir site, so for the estimation of flows at the weir site, Thunian station is preferred over Kundal Shahi station, therefore, the above developed relationships have been used for the estimation of ten (10) daily flows.

The comparison of monthly measured and estimated flows for the year 1995 is shown in **Figure - 3.19**. The estimated flows in the summer months are comparatively less than the actual observed flows. The estimated mean annual flow during 1995 is 15.81 m^3/s against the observed flow of 16.74 m^3/s.

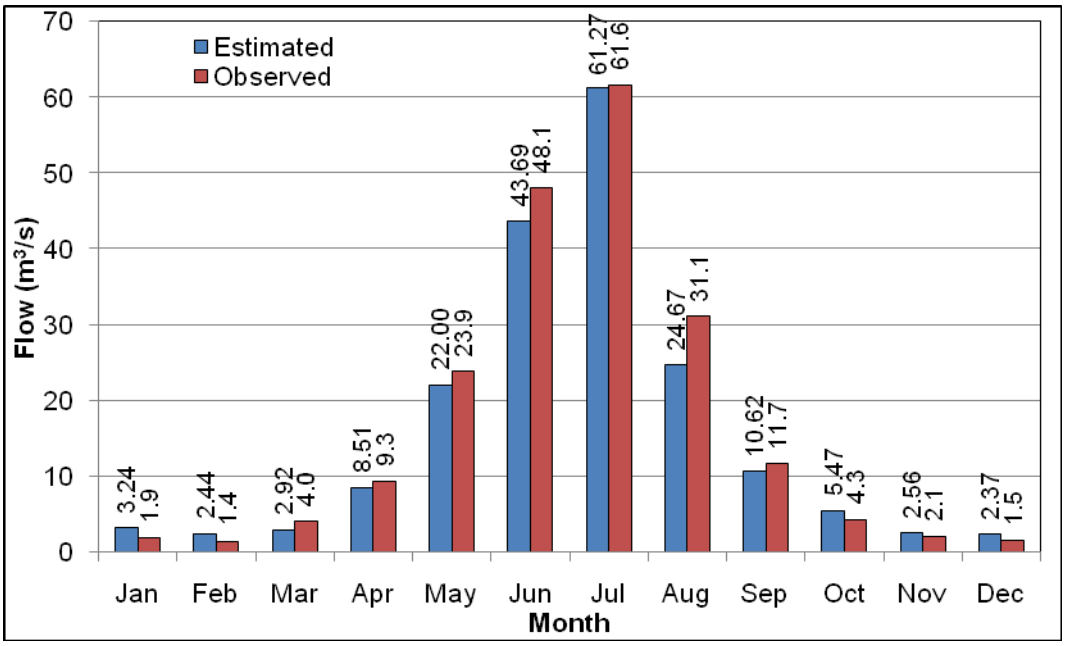


Figure - 3.19: Estimated and Measured Flows of Jagran River at Thunian - 1995

The estimated mean annual flow series at Thunian is presented in the **Figure - 3.20**.

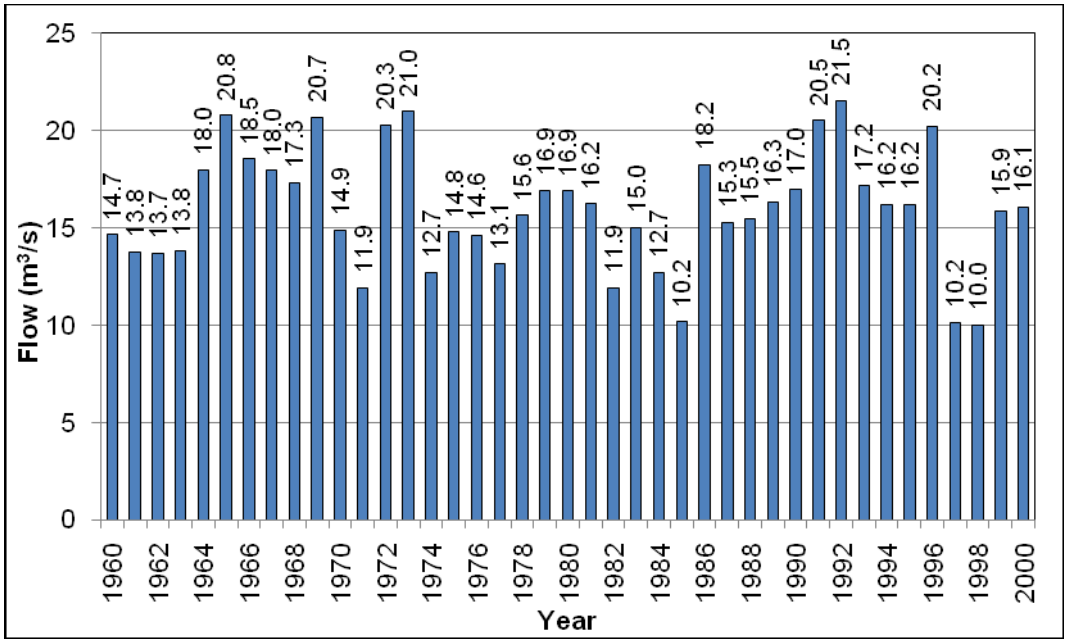


Figure - 3.20: Mean Annual Flows - Jagran River at Thunian

3.6 ESTIMATION OF FLOWS AT JAGRAN - IV WEIR SITE

For transposition of flows from Naran to Jagran - IV weir site, the relationship of Naran and Thunian has been used. The specific flows at Naran have been used for estimating specific flows at Jagran - IV. The developed relationship has been used for flows at Jagran – IV weir site.

The monthly flows at proposed weir site on Jagran River are graphically presented in **Figure - 3.21** and also given in **Table - 3.4**.

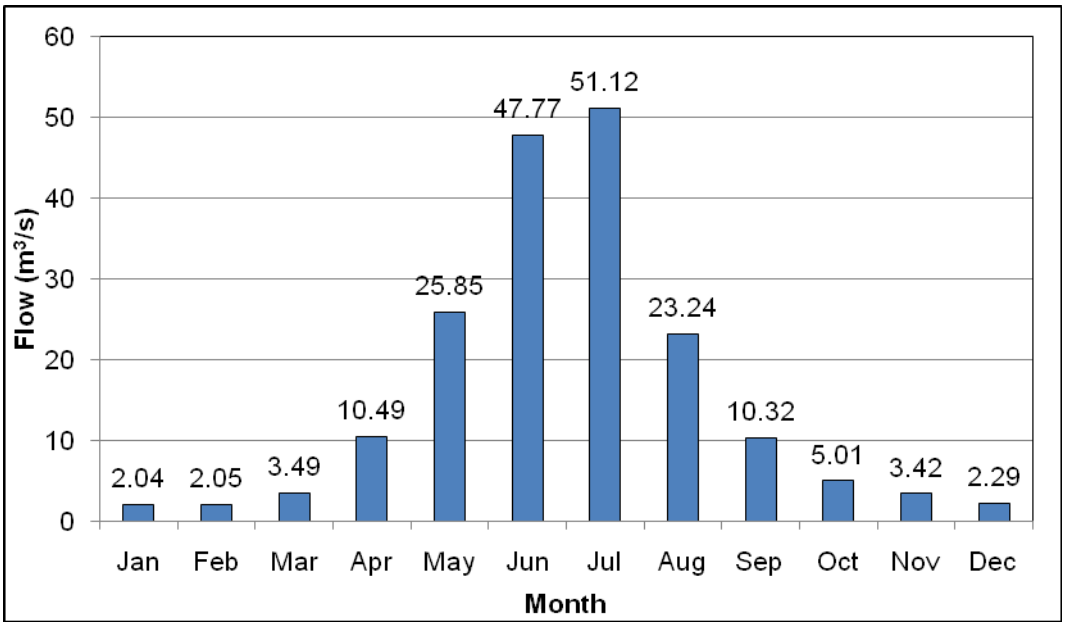


Figure - 3.21: Mean Monthly Flows at Proposed Weir Site– Jagran River

Table - 3.4: Extended Mean Monthly Flows at Jagran River

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960	2.93	3.10	6.03	9.37	20.15	38.20	50.36	21.66	10.31	4.43	3.11	2.22
1961	2.23	2.72	3.72	6.09	12.67	40.37	50.71	21.39	11.78	4.83	2.85	2.24
1962	2.50	2.09	2.89	8.69	17.02	37.41	49.41	22.06	9.63	4.16	2.67	2.02
1963	1.81	1.80	3.63	9.11	18.07	42.51	45.24	21.87	8.74	3.97	3.01	2.41
1964	1.66	1.61	3.71	9.36	25.00	41.74	70.86	33.48	13.03	5.17	2.95	2.02
1965	1.95	2.24	2.90	4.35	20.82	66.82	88.76	31.53	13.52	5.58	3.20	1.94
1966	1.78	1.84	3.19	9.25	18.04	73.55	57.07	28.85	13.52	5.38	3.02	1.86
1967	1.82	1.95	3.88	9.26	22.27	51.35	69.03	30.07	10.97	5.41	2.90	1.65
1968	1.45	1.90	3.63	10.59	18.49	55.13	58.98	29.85	11.92	5.19	3.59	2.51
1969	2.48	2.79	6.43	13.43	26.66	58.64	77.39	32.25	10.30	5.28	4.26	2.47
1970	2.46	3.08	4.60	16.87	35.44	41.70	29.57	19.41	10.86	4.83	3.30	2.18
1971	2.13	2.14	5.47	16.76	26.97	35.04	22.10	15.22	6.74	2.95	2.30	1.72
1972	1.75	2.35	4.50	7.86	23.62	83.89	66.00	24.96	11.53	5.17	3.77	2.48
1973	2.68	3.24	5.33	23.89	46.56	72.77	51.56	19.29	10.69	4.71	2.95	2.02
1974	2.10	2.24	5.27	13.25	19.78	32.10	42.27	16.81	6.75	3.80	2.63	1.72
1975	1.79	2.07	3.73	8.63	33.38	43.01	38.59	21.76	10.43	4.41	3.27	2.27
1976	2.17	2.32	3.58	7.60	26.22	36.56	48.38	22.64	10.69	5.06	3.62	2.73
1977	2.43	2.45	4.56	13.17	21.46	35.99	40.09	15.32	8.38	4.36	3.51	2.23
1978	2.20	2.06	3.43	12.22	30.69	54.23	42.72	18.33	6.71	4.40	3.75	2.54
1979	2.36	1.78	5.55	15.06	17.86	51.11	64.48	20.63	8.91	4.43	3.07	3.14
1980	2.68	2.23	3.58	16.24	30.79	56.36	46.98	18.74	8.76	5.41	3.09	3.16
1981	2.22	1.57	2.32	15.24	49.11	45.34	40.67	18.37	5.74	4.10	2.57	2.95
1982	1.72	1.31	3.52	7.02	15.23	35.90	41.21	16.77	6.38	3.79	3.66	2.97
1983	2.10	2.22	3.29	6.02	11.82	41.78	52.30	33.05	12.14	4.56	3.52	3.09
1984	3.03	2.92	4.57	8.06	23.87	52.10	25.23	14.58	7.80	3.26	2.23	1.54
1985	1.59	1.92	3.66	12.98	19.13	22.39	25.64	16.74	6.46	4.46	2.66	1.61
1986	1.57	1.89	2.73	8.07	19.83	53.13	73.74	30.58	11.70	5.19	3.16	2.08
1987	1.97	2.26	3.49	6.96	15.45	35.93	53.71	34.43	14.90	5.22	3.22	1.66
1988	1.21	1.13	2.04	18.40	34.20	47.82	48.56	14.83	6.30	3.12	2.37	1.55
1989	1.70	2.05	4.42	9.21	24.24	58.33	44.20	26.09	10.23	5.54	3.52	2.03
1990	1.87	1.57	2.56	7.91	53.65	45.42	44.19	20.79	11.27	4.43	3.97	1.31
1991	0.83	0.62	0.99	12.24	22.53	59.10	71.61	43.07	16.26	6.20	4.44	2.64
1992	2.22	2.15	3.73	6.04	23.20	64.14	75.53	34.96	23.66	9.19	4.84	2.83
1993	2.25	2.27	1.74	4.26	30.72	57.71	56.16	18.45	9.70	9.98	5.36	2.66
1994	2.22	2.18	2.49	13.73	23.03	30.70	66.12	20.46	11.33	6.50	6.99	4.23
1995	3.24	2.44	2.92	8.51	22.00	43.69	61.27	24.67	10.62	5.47	2.56	2.37
1996	1.70	1.43	1.54	7.06	23.99	68.75	69.13	37.36	12.06	6.46	4.68	2.84
1997	2.04	2.26	2.55	3.84	13.51	33.97	34.87	11.72	5.92	4.11	2.95	1.42
1998	0.85	0.64	0.76	1.71	15.68	25.09	40.18	16.57	7.10	3.87	3.00	2.05
1999	1.77	1.35	1.27	10.58	54.56	53.61	29.46	12.85	9.51	5.16	3.86	1.97
2000	1.59	1.92	2.92	20.98	52.08	35.01	31.60	20.27	9.69	5.92	3.97	2.40

The estimated mean annual flow at weir site of Jagran – IV Hydropower Project is 15.81 m^3/s and specific flow is estimated as 72.84 $l/s/km^2$. The annual flows at weir site vary from 9.8 to 21 m^3/s. The annual flow series at proposed weir site is graphically presented in **Figure - 3.22**.

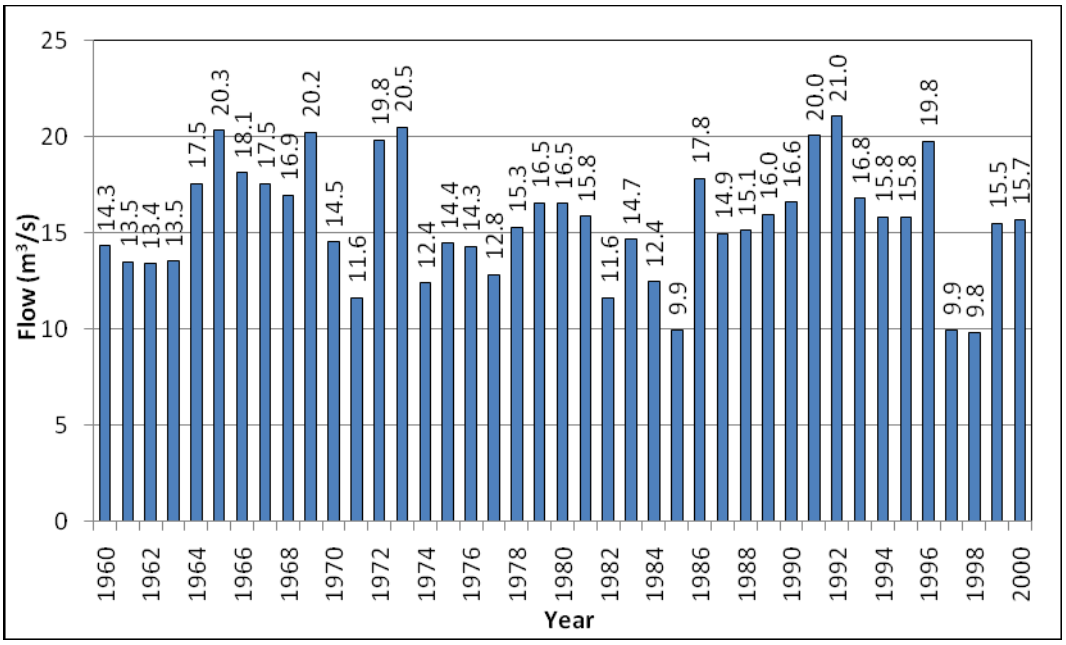


Figure - 3.22: Mean Annual Flows at Weir Site– Jagran River

3.7 FLOW DURATION CURVE

With the estimated series of flows, flow duration curves for average year, dry year and wet year at proposed weir site were drawn and are presented in **Figure - 3.23 to Figure - 3.25**.

The flow duration values for average year are listed in **Table - 3.5**.

Table - 3.5: Flow Duration Values for Average Year – Jagran River

Time (%)	Flow (m^3/sec)	Time (%)	Flow (m^3/sec)
0.1	101.46	55	4.93
5	58.03	60	4.21
10	44.58	65	3.50
15	35.98	70	3.07
20	27.50	75	2.68
25	20.69	80	2.34
30	16.81	85	2.15
35	13.54	90	1.93
40	10.78	95	1.59
45	8.03	100	0.55
50	5.99	**Mean**	**15.59**

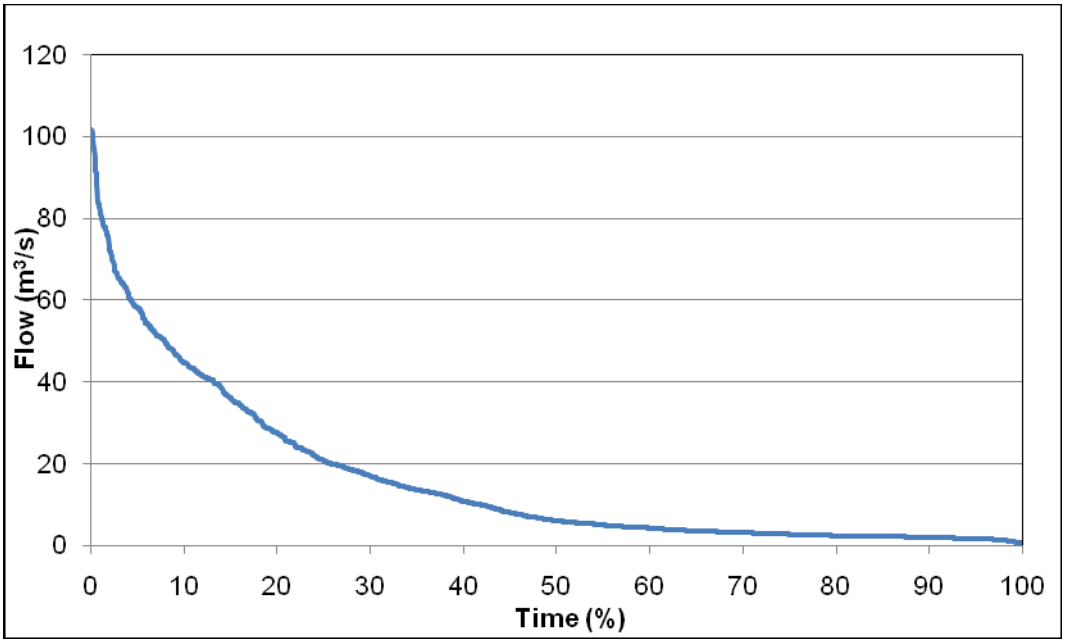


Figure - 3.23: Flow Duration Curve for Average Year – Jagran River

The mean annual flow in average year is 15.59 m^3/s and the design discharge of 18 m^3/s is available for about 28.7 % time of the year for the proposed project.

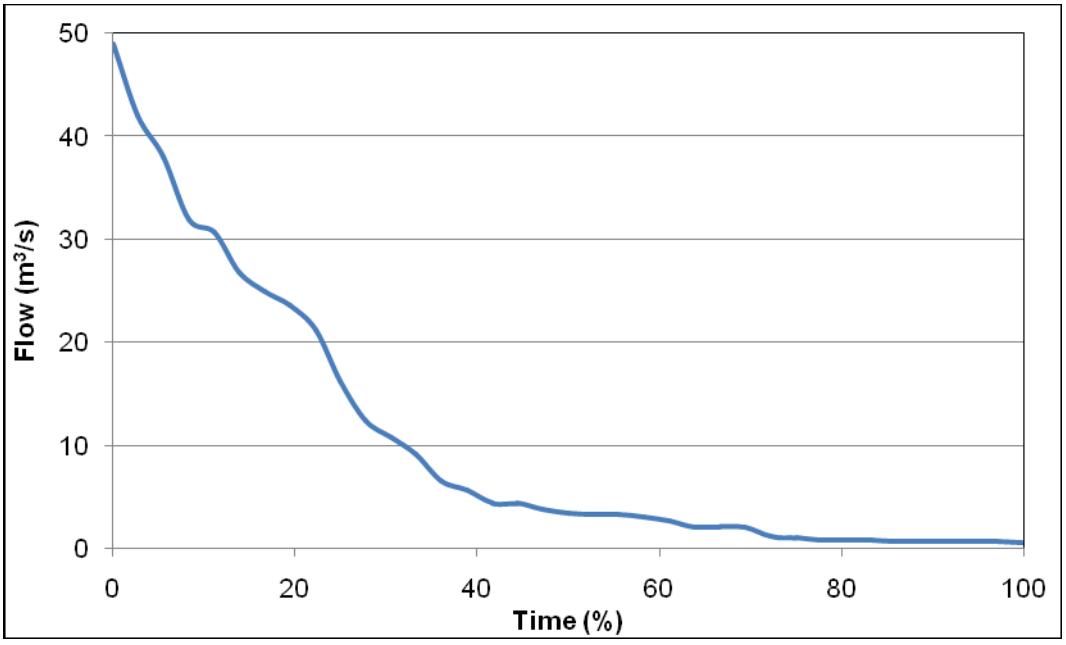


Figure - 3.24: Flow Duration Curve for Dry Year at Weir Site - Jagran River

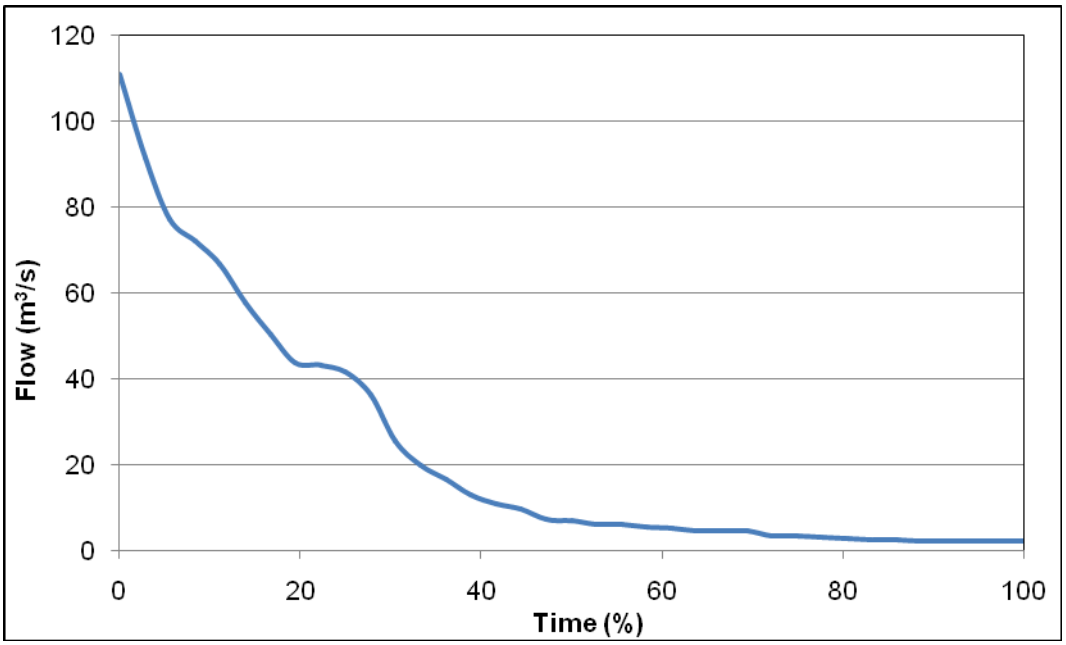


Figure - 3.25: Flow Duration Curve for Wet Year at Weir Site – Jagran River

3.8 LOW FLOWS AT THE PROJECT

The availability of flows at the proposed Jagran - IV Hydropower Project has been shown in the flow duration curve, as presented in the **Figure - 3.23**, and the values are also given in the **Table - 3.5**.

The flow duration curve reflects that the low flow period, i.e., less than 2 m^3/s flow is available 90% of time, while the designed discharge, i.e., 18 m^3/s is available 28.7 % of the time.

3.9 ESTIMATION OF FLOODS

For the estimation of flood, a study was made by comparing specific flows of Jagran River at Kundal Shahi with that of Neelum River at Muzaffarabad selecting the same period, i.e., (1983-1984) of available data at Jagran River at Kundal Shahi as shown in **Table - 3.6**.

It was observed that specific flows of river have almost double increasing trend during high flow period, i.e., July and August as reflected from **Table - 3.6**.

Therefore, floods achieved in different return periods from different methods have been enhanced in the light of this study.

Table - 3.6: Ratio of Specific Flow (l/s/km^2) of High Flow Period - Jagran River at Kundal Shahi and Neelum River at Muzaffarabad

Years	Months	Ratio
1983	Jul	2.4
	Aug	2
1984	Jul	1.9
	Aug	1.6
	Average	**1.975**

3.9.1 Estimation of Floods by Gumble Frequency Analysis Method

As explained above, discharge data at the project area is limited and for flood study instantaneous peaks are required, which are not available; therefore, in order to estimate the floods of different return periods at Jagran River, instantaneous peak discharges of Muzaffarabad hydrological station were obtained and Gumble distribution frequency analysis was applied.

The floods obtained in different return periods at Muzaffarabad were used to achieve floods at proposed weir site on Jagran River by applying catchment area relationship and are presented in **Table - 3.7** and shown in **Figure - 3.26**.

Table - 3.7: Flood at Weir Site on Jagran River in Different Return Periods

T-Year Return Period	95% Confidence Interval	
	Upper Limit	Lower Limit
2	77.7	55.3
5	125.3	82.3
10	158.0	98.9
20	189.7	114.5
50	230.9	134.6
100	261.8	149.6
500	333.3	184.1
1000	364.1	198.9

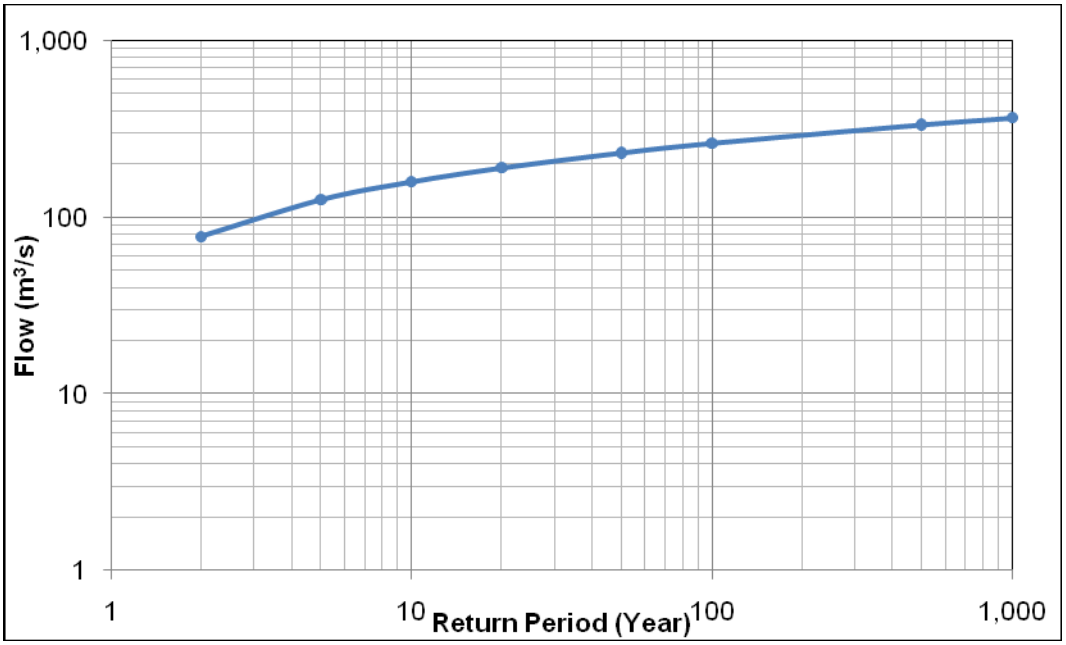


Figure - 3.26: Gumble Extreme Value Type-I (Method of Moments)

3.9.2 Estimation of Floods by Log Pearson Type - III Method

Log Pearson Type-III Method was also applied to analyse the peak discharges of Muzaffarabad hydrological station to achieve floods for the different return periods. The floods for different return periods at the Jagran – IV weir site were obtained from the calculated floods at Muzaffarabad by applying catchment area relationship.

The results are given in **Table - 3.8** and shown in **Figure - 3.27**.

Table - 3.8: Estimation of Flood with Log Pearson Method

Return Period, Tr (Years)	T-Year Flood for Jagran-IV
2	86.6
5	117.0
10	142.7
25	182.8
50	218.7
100	260.6
200	320.0
500	418.6
1000	479.1

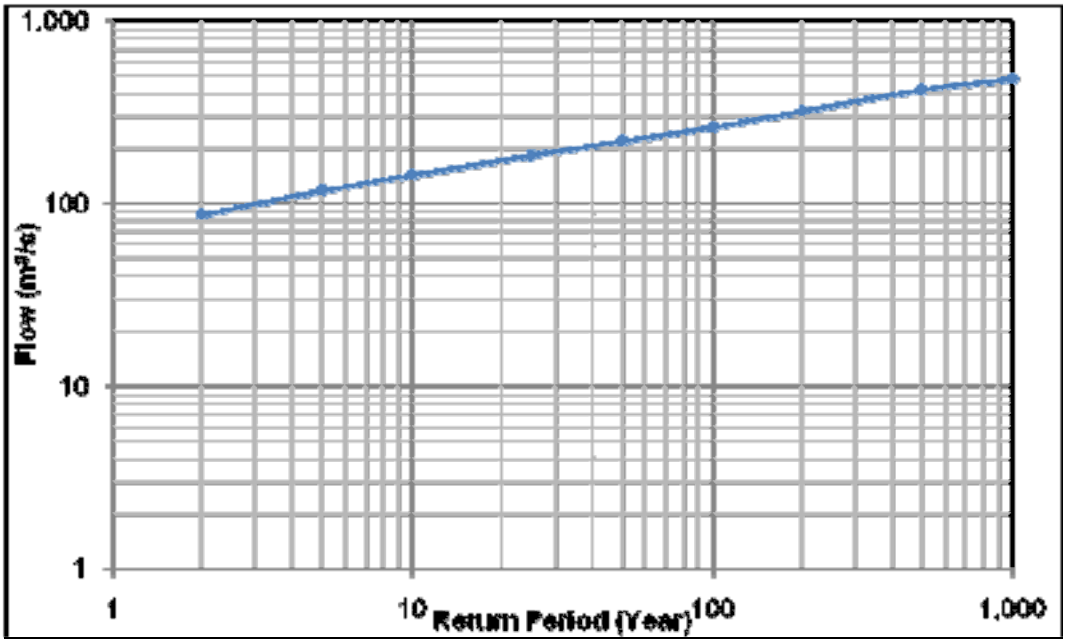


Figure - 3.27: Flood Estimation with Log Pearson Type-III Method

3.9.3 Estimation of Floods by Rainfall Run-off Relationship

In addition to the snow melt, rainfall is one of the major inputs producing run-off in the river. There is no climatological station in the project area. The available rainfall record is at Muzaffarabad, Nausehri, Dudhnial and Naran climatological stations.

Consultants in recent study of Azad Pattan Hydropower Project have carried out a comprehensive study of whole Jhelum River Catchment to determine the Probable Maximum Precipitation (PMP). The Jhelum catchment was divided into a number of sub-basins and PMP had been worked out for each of the sub-basins and iso-hytel maps were drawn.

Based on the study, the PMP for the Jagran River catchment worked out to be 90 mm (3.54 inches) for 24 hour storm. PMP value of 90 mm was used for the derivation of Probable Maximum Flood (PMF) with a critical rainfall distribution of 24 hours precipitation as the procedure given in Flood Estimation Manual, by Halcrow in 1986.

For the direct runoff generated from the PMP calculations, SCS Curve Number 85 was used for the 214 km^2 catchment area of Jagran River at proposed weir site and flood hydrograph was worked out.

Utilising the above procedure flood hydrographs from PMP is shown in **Figure - 3.28** and peak flood estimated was 748.1 m^3/s.

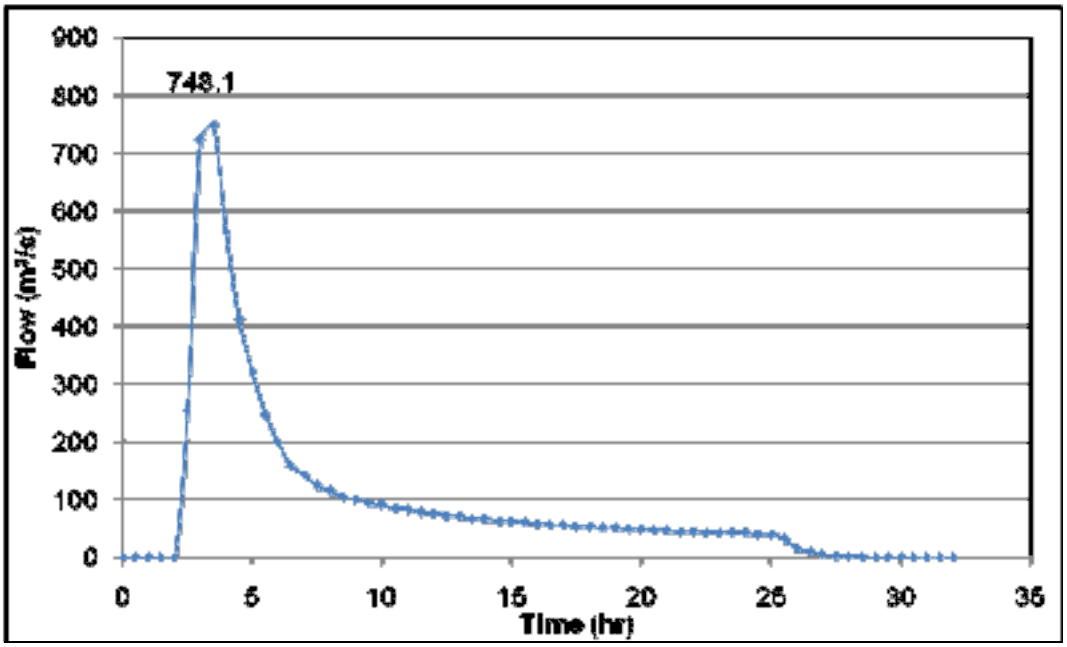


Figure - 3.28: Flood Hydrograph at proposed Jagran-IV Weir Site

3.9.4 Floods Recommended at the Weir Site

Flood values for different return periods achieved by applying Gumble distribution method, log Pearson Type - III method and Probable Maximum Flood from PMP have been considered for recommendation of floods at the weir site of river.

The values of floods are given in the following **Table - 3.9** for comparison purpose. It is recommended that the flood value of 419 m^3/s against 500 years return period as given in the table may be considered for further use in the project studies.

Table - 3.9: Comparison of Flood Estimates

Return Period	Floods using Gumble MOM (m^3/s)	Floods using Log Pearson Type-III Method (m^3/s)
2	77.7	86.6
5	125.3	117.0
10	158.0	142.7
20	189.7	182.8
50	230.9	218.7
100	261.8	260.6
500	333.3	418.6
1000	364.1	479.1
PMF		748.1

3.10 SEDIMENT TRANSPORT STUDIES

3.10.1 Available Sediment Data

No sediment sampling measurements were carried out at the proposed weir site of Jagran River. However, the long term data of recorded sediments is available at Nausehri hydrological station which is located on the main river and is about thirty (30) km downstream of confluence of Jagran River and Neelum River.

In addition to this, the sediment data is also available at different locations, i.e., Dudhnial and Muzaffarabad hydrological stations. As Nausehri station is the nearest downstream station of the Jagran River; therefore, sediment transport data of this station has been considered to estimate suspended and bed load at weir site of Jagran River.

The relationship achieved between flows and sediment concentration in ppm from the above data has been applied to get suspended sediment load at Jagran River.

3.10.2 Sediment Load / Yield at Weir Site

As explained above sediment data at weir site of Jagran River is not available, therefore the data of Nausehri hydrological station has been considered to obtain the sediment load being the nearest downstream station.

A sediment rating curve as shown in **Figure - 3.29** has been drawn at Nausehri with the available sediment data, (1991-2005).

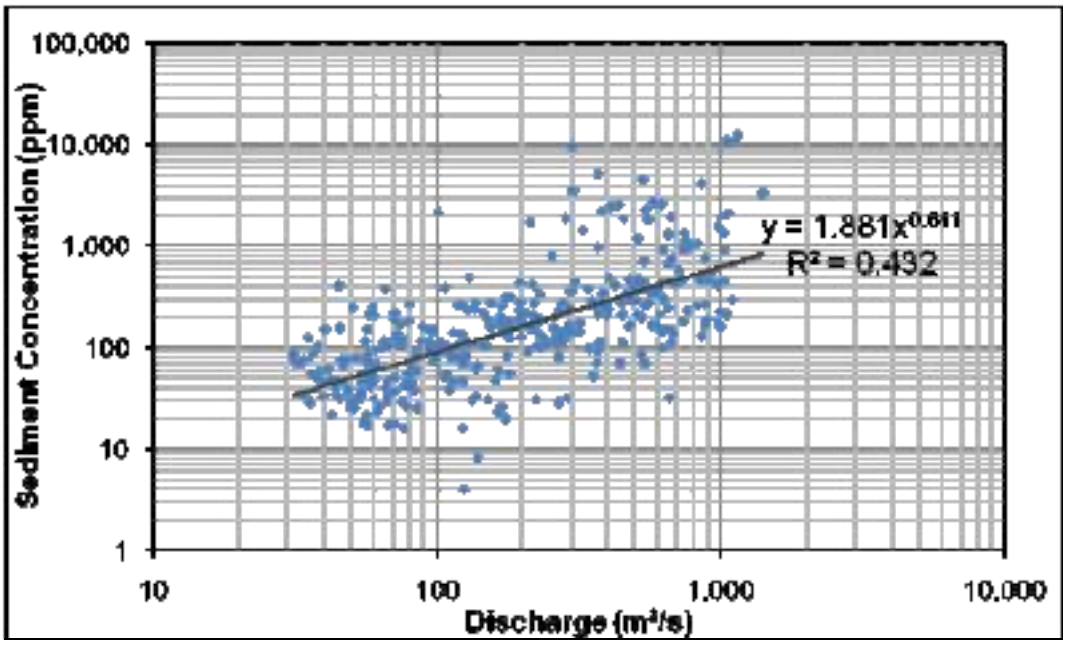


Figure - 3.29: Sediment Rating Curve

The relationship between discharge and sediment concentration as shown in the above figure is as under:

$$Y=1.881X^{0.841}$$

Where

Y= sediment concentration (ppm)

X=Flow (m^3/s)

By applying the above relationship, the sediment concentration against measured flows can be calculated. Sediment load at the weir site on Jagran River was calculated from the available sediment data and the detail is as under:

Average flow (1991-2005) at Nausehri = 289.2 m^3/s

Average ppm (1991-2005) at Nausehri = 436

Suspended Sediment Load at Nausehri = 12017 Tons/day

Suspended Annual Sediment Load at Nausehri = 4.38 M ST

Therefore, the Annual Sediment Load at Weir Site = 0.1376 M ST

3.10.3 Sediment Bed Load

Sediment bed load is usually taken as 20% of the suspended load. Therefore, the suspended bed load is 0.0275 M ST. In this way the total sediment yield is 0.1651 M ST.

3.10.4 Particle Size Distribution

As the Sediment data at weir site on Jagran River is not available; therefore the data of Nausehri hydrological station being the nearest downstream station has been considered to examine the particle size distribution at the project as presented in **Table - 3.10**.

The average percentage values are as hereunder:

- Sand 13%
- Silt 64%
- Clay 23 %

From above it can be assessed that at the project site sand exists in a little quantity while silt and clay exists comparatively in excess amount.

Table - 3.10: Particle Size Distribution Analysis at Nausehri (1991-1996)

Year	Date	Sand %	Silt%	Clay%
1992	02.01.92	1	59	40
	08.01.92	54	34	12
	16.01.92	9	82	9
	19.01.92	4	43	53
	26.01.92	11	37	52
	08.02.92	2	44	54
	15.02.92	3	79	18
	20.02.92	15	59	26
	28.02.92	3	70	27
	01.03.92	1	60	39
	08.03.92	4	75	21
	10.03.92	6	77	17
	17.03.92	14	41	45
	25.03.92	11	42	47
	02.04.92	12	78	10
	10.04.92	19	30	51
	08.05.92	15	61	24
	15.05.92	10	80	10
	21.05.92	1	62	37
	10.06.92	4	86	10
	16.06.92	6	83	11
	23.06.92	5	84	11
	01.07.92	5	78	17
	16.07.92	9	75	16
	23.07.92	16	40	44
	25.07.92	2	80	18
	28.07.92	4	81	15
	30.07.92	17	65	18
	02.08.92	15	57	28
	06.08.92	8	81	11
	21.10.92	3	79	18
1993	18.02.93	3	73	24
	28.02.93	4	64	32
	05.03.93	15	68	17
	10.03.93	27	67	6
	03.04.93	3	77	20
	21.04.93	3	83	14
	21.05.93	6	76	18
	30.05.93	20	58	22
	09.06.93	34	43	23
	21.06.93	12	67	21
	28.06.93	10	61	29
	09.07.93	19	63	18
	13.07.93	22	56	22
	17.07.93	5	83	12
	18.08.93	12	78	10
	26.08.93	27	62	11
	07.09.93	15	61	24

Year	Date	Sand %	Silt%	Clay%
	11.09.93	10	80	10
	12.09.93	20	49	31
	16.09.93	4	86	10
	30.09.93	6	83	11
	04.10.93	5	84	11
	07.10.93	5	78	17
	16.10.93	9	75	16
	08.11.93	26	54	20
	01.12.93	2	80	18
	11.12.93	4	81	15
	17.12.93	4	82	14
1994	30.03.94	22	44	34
	07.05.94	23	66	11
	20.05.94	15	68	17
	08.06.94	2	88	10
	23.07.94	4	71	25
	10.08.94	7	73	20
	08.09.94	22	64	14
	26.09.94	11	58	31
	14.10.94	9	63	28
	28.10.94	8	74	18
	18.11.94	8	48	44
	28.11.94	28	47	25
	11.12.94	7	66	27
1995	29.04.95	28	53	19
	05.05.95	11	65	24
	08.06.95	45	40	15
	11.07.95	37	43	20
	25.07.95	12	60	28
	02.08.95	6	72	22
	12.08.95	58	36	6
	19.08.95	21	61	18
	05.09.95	26	61	13
	12.09.95	2	53	45
	19.09.95	9	56	35
	26.09.95	4	62	34
	12.10.95	6	66	28
	14.10.95	7	67	26
	18.10.95	4	47	49
1996	07.04.96	10	75	15
	16.04.96	52	41	7
	23.04.96	24	61	15
	23.05.96	24	55	21
	03.06.96	25	60	15
	11.06.96	49	40	11
	13.08.96	17	48	35
	Average	**13.45**	**64.11**	**22.45**
		Sand%	Silt%	Clay%

4 GEOLOGICAL AND GEOTECHNICAL STUDIES

4.1 INTRODUCTION

The proposed Jagran - IV Hydropower Project has been identified on the Jagran River in Azad Jammu and Kashmir (AJ&K). The Jagran River is one of the right bank tributaries of Neelum River. Its confluence with Neelum River is located at Kundal Shahi about 68 km upstream from Muzaffarabad.

The proposed weir site of the project is located across Jagran River at about 17 km upstream of its confluence with Neelum River and the powerhouse site is located on left bank of Jagran River about 200 m upstream of weir intake of already constructed Jagran - I Hydropower Project.

On the basis of surface geological mapping, field observations and also the initial rock mass assessment; the scheme with diversion weir, connecting channel, desander / sandtrap, pipe intake, buried pressure pipe, pipe outlet, surge pipe, penstock, surface powerhouse and tailrace has been recommended for further detailed geological and geotechnical studies.

The pressure pipe about 3075 m long shall rest partly on overburden and partly on rock (granitic gneiss). Granitic gneiss is the predominant rock type in the proposed project area. Granitic intrusions, pegmatite / quartz veins, basic dykes and sills which are quite common in this region, are likely to encounter during excavation.

Surface powerhouse structure is proposed on the overburden of considerable thickness of angular boulders and gravel with sand and appreciable amount of fines (ABGM). The thickness of overburden shall be confirmed either through drilling and / or by conducting seismic refraction survey.

The engineering geological and structural mapping has been carried out at the weir site, intake structure, sandtrap, pipe intake and outlet, surge pipe, penstock alignment and powerhouse areas to establish the geological conditions at all the component structures of the scheme.

For these engineering structures, the geological mapping has been carried out on the topographic maps especially prepared for this purpose on scale 1:1,000; presented in this report on scale 1:2,000, and by using the satellite imageries with overlying DEM (Digital Elevation Model).

This report is based mainly on the field observations and surface geological mapping carried out in the proposed project area, for the evaluation of the geotechnical parameters. These shall have to be further reformed upon the availability of drilling and laboratory test data.

A detailed geotechnical site investigation programme including the drilling, test pitting, trenching, geophysical survey, etc. has been prepared by the Consultants.

4.2 GEOMORPHOLOGY

4.2.1 Topography

Jagran River is the right bank tributary of Neelum River. The Jagran River descends from an elevation of about 5030.70 m asl to 1350 m asl at its confluence with Neelum River. The average gradient of river is about 5.5 %.

The slopes are mostly covered with thick vegetation and at many locations have enough places to support the accumulation of angular boulders and gravel along with soil cover.

4.2.2 Hydrology

Jagran River has about 214 km^2 of catchment area at the proposed weir site of Jagran - IV Hydropower Project. The mean monthly flow ranges between 2.04 to 51.12 m^3/sec. The design discharge for the scheme is considered to be 18 m^3/sec.

4.2.3 Drainage Pattern

The general drainage pattern in the vicinity of Jagran River is the combination of dendritic and trellis patterns, though at places radial pattern in loose overburden material has also been observed.

4.2.4 Terraces

The terraces are well stratified and their fragments range from clay, silt and sand to gravel, cobble and boulder (ABGM). These boulder, gravel and cobbles are angular to sub-rounded, loose to semi consolidated. These are present at different elevations throughout the valley in general and within the project area in particular.

4.2.5 Talus Cone / Colluvial Material

Loose scree along the hill slopes is widespread in the area. These scree deposits conceal at many places the surface geological information such as the geological structural details and lithological contacts underneath. The colluvial material is moronic in origin brought about by avalanches in different episodes.

4.3 REGIONAL GEOLOGY AND TECTONICS

4.3.1 General

The intercontinental collision between the Eurasian and Indian plates has resulted in intense deformation with complex folding involving strike-slip and thrust faulting and crustal thickening expressed as a series of thrust faults accompanied by a continental subduction process.

The major regional thrust faults, related to the intercontinental collision include Main Karakorram Thrust (MKT), Main Mantle Thrust (MMT), Main Boundary Thrust (MBT), Panjal Thrust (PT), Main Central Thrust (MCT), Himalayan Frontal Thrust (HFT) and Salt Range Thrust (SRT). The planes of these faults run nearly parallel to the collision boundary.

On the basis of these regional thrust faults related to intercontinental collision, five major fault zones have been recognised in Northern Pakistan including AJ&K as indicated in **Figure - 4.1**. These fault zones include the Northern Suture Zone (NSZ) or MKT, the MMT or Indus Suture Zone (ISZ), MCT, MBT, HFT and SRT.

These fault zones generally trend E-W, dividing the Himalayan orogenic belt in the five main tectonic zones. The Asian Plate, the Kohistan Island Arc (KIA), the Higher Himalayan Crystalline Unit (HHC), the Lesser Himalayan Crystalline Unit (LHC) and the Sub-Himalayan Unit (SH).

4.3.2 Geo-Tectonic Setting of Neelum Valley

The major Himalayan tectonic units are well exposed along the relatively accessible Neelum valley. These tectonic units are the result of collision between the Eurasian (N) and Indian (S) plates. The various tectonic zones and features in Northern Pakistan including AJ&K are shown in **Figure - 4.2**.

As can be seen from this figure, the Neelum valley and the proposed project area lie in the Himalayan Crystalline, Schuppen Zone which is a sub-division of the Karakorram - Himalaya Crystalline and Thrust Zone, and is delineated by MMT in the North and Panjal Thrust in the South.

The East-West trend of the fault zones is disturbed locally by two the tectonic semis - windows, the Nanga Parbat Syntaxis (NPS) and the Hazara - Kashmir Syntaxis (HKS). The area connecting these two syntaxes including Jagran - IV Hydropower Project area is being affected by an exceptional rate of uplift; presently, reaching 7 mm/year.

Many of these tectonic units are encountered in a SW - NE traverse along the Neelum valley. The MBT which separates the SH from the LHC lies near the bridge of Nausehri, about 40 km NE of Muzaffarabad.

Near the village of Luat, approximately 100 km from Muzaffarabad on Neelum valley road, the MCT separates the LHC to the south from the HHC, which extends north and east to the village of Kel. These tectonic units share the same stratigraphic features, but differ in their tectono-metamorphic evolution.

The deformation history of the Neelum valley rocks is strongly related to the plate tectonic model describing the progressive convergence of the Indian and Eurasian Plates, and with the described metamorphic evolution.

In Pakistan the first manifestation of the N-S convergence between the two plates was the southward to south-eastward over thrusting (more than 150 km) of the Kohistan Island Arc over northern margin of the Indian continent along the MMT.

The early thrusting probably occurred between the Cretaceous and the Eocene at the latest. During the same period, rocks of the Neelum valley suffered compressive and shearing stress associated with the progressive development of the Himalayan metamorphism.

Metamorphic grade and ductile deformation increase from the youngest and lower most unit, i.e., Sub-Himalayas; to the oldest and upper most unit, i.e., Higher Himalayas.

4.3.3 Geology and Lithostratigraphy of Neelum Valley

The Geological Map of the Neelum valley is shown in **Figure - 4.3**. As can be seen from this figure, the metamorphic crystalline rocks outcropping in the valley constitute the cover as well as the basement. The crystalline rocks outcropping in the Neelum valley mainly belong to Salkhala series of Precambrian age with younger igneous Intrusions at places.

The lithostratigraphic units, present in Neelum Valley from Nauseri to Kel include the Precambrian Naril Group, the Precambrian - Cambrian Kundal Shahi Group, Upper Paleozoic to Mesozoic Surgun Group, Cambrian - Ordovician Manshera Granite and Carboniferous - Triassic Panjal Traps Metabasites, as presented in **Figure - 4.3**.

The rocks outcropping in Neelum valley are described in the **Table - 4.1**.

Table - 4.1: Rock Units in the Neelum Valley (Nausehri to Kel)

COVER	BASEMENT
Surgun Group (Upper Paleozoic - Mesozoic): **Unit C:** Paragneiss, quartzites and minor metaconglomerates with minor levels of amphibolites. Garnet, staurolite-bearing micaschists, garnet-bearing micaschists with minor levels of amphibolites. **Unit B:** Calcschists with minor levels of marble and amphibolite. Marbles, white marbles, yellowish marbles, alternance of white marbles and quartzites with minor levels of amphibolites. **Unit A:** Paragneiss, schists and impure quartzites with minor marble and amphibolites levels. **Panjal Traps Metabasites (Carboniferous - Triassic)** Metabasites, amphibolites with relics of doleritic texture and pillow lava structures	**Mansehra Granite (Cambrian - Ordovician):** Two micas, garnet-bearing metagranites and gneiss. **Kundal Shahi Group (Precambrian - Cambrian):** Kattha unit comprising Impure quartzites and metapsammites with minor metaconglomerate levels. Kuttar unit comprising alternance of metapelites and metapsammites with minor marble levels. **Naril Group (Precambrian):** Gneissic complex with relics of granulitic textures and minor levels of metabasites and marbles.

However, the rocks outcropping in the region of interest and surrounding the Jagran - IV Hydropower Project area are described in the following **Table - 4.2** and also in the **Figure - 4.3**.

Table - 4.2: Rock Units in the Region of Interest Surrounding the Proposed Project Area

BASEMENT
Mansehra Granite (Cambrian - Ordovician): Two micas, garnet-bearing metagranites and gneiss. **Kundal Shahi Group (Precambrian - Cambrian):** Kattha unit comprising Impure quartzites and metapsammites with minor metaconglomerate levels. Kuttar unit comprising alternance of metapelites and metapsammites with minor marble levels.

The details of the rock units outcropping in the Neelum valley from Nausehri to Kel are given below:

- Naril Group : Pre - Himalayan Basement
- Kundal Shahi Group : Pre - Himalayan Cover
- Panjal - traps Metabasites : (Carboniferous - Triassic)
- Mansehra Granite : (Cambrian - Ordovician)
- Surgun Group : Himalayan Cover

All the above mentioned groups are intruded at places by meta-dolerites and amphibolites, collectively called metabasites. All the lithostratigraphic units occur both in the LHC and HHC and have undergone variable grade of metamorphism.

4.3.3.1 Naril Group

The granulitic gneisses of the Precambrian Naril Group mainly outcrop in two separated areas, i.e., north of the Richmohri Fault (RF) and east of the Gumot Shear Zone as shown in **Figure - 4.3**. These gneisses are acid granulitic whitish banded rocks containing quartz, feldspar, garnet and biotite. The contact between the Naril and Kundal Shahi groups is sharp and is interpreted as an old unconformity folded during the strong Himalayan deformation.

The Naril group has been intruded by dolerites now metamorphosed to amphibolites. In certain cases the amphibolites grade into eclogites. The granulitic gneisses of the Naril Group are intruded by the Mansehra type leucogranites of Cambrian age.

4.3.3.2 Kundal Shahi Group

The metasediments of the Kundal Shahi Group (Precambrian - Cambrian) outcrop at three locations, i.e., south of the MCT, north of the MCT and in the Chatthewala Naril area.

The schists are fine-grained and sometimes phyllitic. The mineral assemblage includes biotite, white mica, quartz, garnet, chlorite and epidote.

Quartzites have preserved numerous sedimentary structures such as ripple marks, graded bedding, cross - bedding, etc. Basic dykes cross - cut the stratification throughout the three units. The mineral assemblage comprises pyroxene, plagioclase and rarely the olivine. The basic dykes are converted to foliated amphibolites.

The Kundal Shahi meta-sedimentary sequence outcropping north of the MCT shows the same lithostratigraphic features as described south of MCT. However, only the grade of metamorphic assemblage is higher.

The Kundal Shahi Group is subdivided into two units, i.e., Kattha Unit and Kuttar Unit. The Kattha Unit is composed of impure quartzites and metapsammites with minor metaconglomerate levels. The Kuttar Unit comprises alternance of metapelites and metapsammites with minor marble levels.

In Chatthewala, Naril and Tarli Domel areas the Kundal Shahi Group shows higher grades of metamorphism.

Kundal Shahi Group of the Pre-Cambrian Salkhala Series may be correlated with with the Hazara Formation defined on the eastern side of the Hazara Kashmir Syntaxis.

4.3.3.3 Mansehra Granite (Cambrian - Ordovician)

It contains selices of megnatic texture and assemblages composed of primary potash feldspar, plagioclase, quartz, biotite and muscovite.

4.3.3.4 Panjal - Traps Metabasites (Carboniferous - Triassic)

This formation consist of greenish grey to dark grey slates, phyllites, whitish quartzite and sandstone, bedded green and purple volcanic traps intermixed in various proportions at different localities in Neelum Valley near Nauseri. It is out cropped throughout pirpanjal ranges. It has faulted lower contact with Murree formation, called Main Boundary Thrust (MBT). Its upper contact with Salkhala formation is also faulted called Panjal Thrust (PT). The age of this formation is carboniferous to Triassic.

4.3.3.5 The Surgun Group

In the Neelum valley, the Surgun Group (Upper Paleozoic - Mesozoic) outcrops in three separated areas including Nausehri area, the area between the villages of Luat and Shardi, and north of Naril valley.

The geology of the Nausehri area is complicated by the imbrications of several tectonic slices along the Panjal Thrust and minor related thrusts. The rocks between the MBT and the Panjal Thrust can be correlated with the Surgun Group.

It is a succession of clastic rocks, pyrite bearing graphitic phyllites, sericite - chlorite bearing schists and rare metaconglomerates, volcanic rocks and carbonatic rocks.

The Surgun Group is divided into three units as shown in the **Figure - 4.3** and **Table - 4.1**. The description of each rock type constituting these three units has also been given there. The central portion of the Neelum valley is mainly occupied by this Surgun Group.

4.3.3.6 Metamorphic Evolution

Rocks forming the Naril Group, the Kundal Shahi Group and Surgun Group were deformed and metamorphosed during the Tertiary Himalayan events.

- The first metamorphic event is marked by the occurrence of chloritoid, quartz and white mica-bearing assemblages preserved as trails in the core of zoned garnets in the mica - schists of the Surgun Group.
- The second metamorphic event is characterised by eclogite facies in the medium grade HHC.
- The third metamorphic event developed under conditions of decompression associated with a decrease of temperature.

4.4 GEOLOGY OF THE PROJECT AREA

The intake area includes weir, connecting channel, sandtrap and pipe intake, flushing pipe, and cofferdams located upstream and downstream of weir.

The outlet area includes the surge pipe, penstock, surface powerhouse, tailrace and switchyard areas.

The surface geological mapping covering the project area has been carried out by the Consultants on the topographic sheets at scale 1:1,000, by using Total Station. Soil and rock units are marked on these maps. Structural discontinuities joints and foliation trends are also marked on these maps.

The maps and sections produced in this report prepared on appropriate scales are presented in **Dwg. No. 4-1 to 4-11**. The various lithological units occupying the project area as observed from the surface geological map are described in the sub-sections hereunder.

4.4.1 Lithological Units

4.4.1.1 Soil Units

The recent deposits are the most widespread soil units in the proposed project area, covering the bedrock and valley slopes with variable thicknesses ranging about 5 to 15 m. Terrace deposits include mixtures of clay, silt, sand with gravel and boulders in various proportions.

- **ABGM**: Most of the slopes are covered by material comprising angular boulders, gravel with sand and appreciable amount of fines. These materials are mostly of talus and glacial origin brought about by avalanches. The maximum size of boulders is up to 8 x 7 x 6 m.

- **RBGM**: It consists of the alluvial material having rounded to sub-rounded, loose to semi consolidated boulders and gravel with sand and appreciable amount of fines. These are found upstream of the proposed weir site in the form of terraces as well as in the proposed powerhouse area and in the river bed.

- **ABG**: Overburden material comprising mainly of the large sized angular / sub-angular boulders and gravel with the minor amount of fines. These are found at the base of slopes.

- **RBG**: Alluvial material deposited by streams is composed of rounded to sub-rounded boulders and gravel with little amount of sand. These are loose and highly permeable and mostly found in river bed.

4.4.1.2 Rock Units

Metamorphic rock unit, granitic gneiss is exposed in the project area. Igneous intrusions of granites and granodiorites are exposed at places. The description of rock units exposed within the project area is described in the following sections.

- **Gneiss**: It is dirty white to whitish grey on weathered surface. Light colored bands alternate with dark bands exists on fresh surface. The flaky minerals represent preferred orientation. The rock is medium to coarse grained, hard and sparsely jointed. Numerous granitic veins can be seen intruding the adjacent rocks.

  Small pegmatitic dykes are found within the gneissosed granite. Its mineralogical formation consists of the granular aggregate quartz, feldspar, muscovite, biotite, and also accessory tourmaline, garnet, magnetite and apatite. Gneiss has less mica, more quartz and high strength.

- **Granite**: It is light grey to brownish. The fresh exposures of the rock show whitish grey colour. However, close examination shows brownish black biotite specks in whitish grey background. At some places black tourmaline is also found in the granite.

4.5 GEOLOGICAL, GEOTECHNICAL INVESTIGATIONS AND THE SEISMIC STUDIES

After carrying out the desk study and reconnaissance visit, a comprehensive geological and geotechnical investigations programme was planned. This included the detailed field topographic survey of the selected sites for various engineering structures of the proposed Jagran - IV Hydropower Project, surface geological mapping, study of joints and discontinuities in rocks exposed in the project area, seismic refraction survey covering the weir site and powerhouse areas, drilling of boreholes at the selected sites and excavation of test pits and trenches from where the construction material could be procured, followed by laboratory testing and interpretation of results. The geotechnical investigations programme is not started yet; therefore, the data obtained on completion of the various activities would be incorporated at later stage in detail design of the project. For confirming the design basis of important structures, the proposed investigations need to be completed at an early date.

The important aspects and information obtained at this stage are described and discussed in the following sections.

4.5.1 Surface Geological Mapping

Surface geological mapping covering all the components of proposed Jagran - IV Hydropower Project including the diversion weir, connecting channel, sandtrap, pressure pipe, surge pipe, penstock, surface powerhouse and tailrace areas have been carried out on scale 1:1,000 and presented in report on scale 1:2,000 as shown in the **Dwg. No. 4-1 to Dwg. No. 4-7**.

The geological sections at various locations have been prepared to interpret and identify the different soil and rock units under foundations of different component structures of proposed Jagran - IV Hydropower Project. The geological sections are presented in the **Dwg. No. 4-8** to **Dwg. No 4-11**. The general foliation trend with their dip along with the joint sets exposed at different proposed structures have been measured in the field and marked on the maps. Data on the rock discontinuities and joint sets have been collected during the surface geological mapping. The most important aspect of a discontinuity is its orientation given by its strike and dip. Two methods, i.e., rose diagram and stereographic projection of poles were employed for plotting the joint sets.

Further, the **Figures - 4.4**, **4.5** and **4.6** present the rose diagrams of the stereographic projection, location of poles and the composite pole-plot for joint sets observed in granitic gneiss found at pipe outlet area. The **Figures - 4.7**, **4.8** and **4.9** present the rose diagrams of the stereographic projection, location of poles and the composite pole-plot for joint sets observed in granitic gneiss found at pressure pipe area.

JAGRAN - IV HYDROPOWER PROJECT
ROSE DIAGRAMS FROM DISCONTINUITY DATA AT
PIPE OUTLET SITE

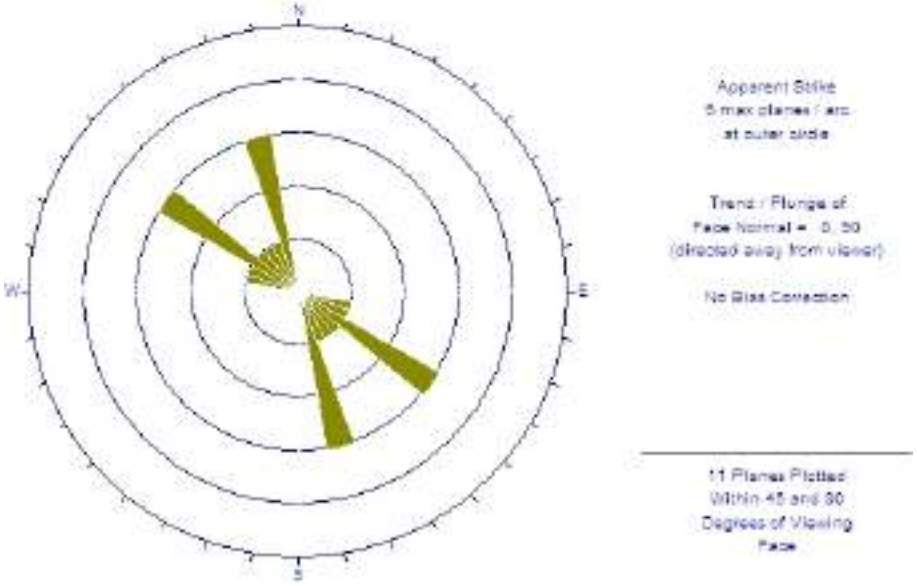


Figure - 4.4: Rose Diagram Showing Stereographic Projection of Joint Sets in Granitic Gneiss

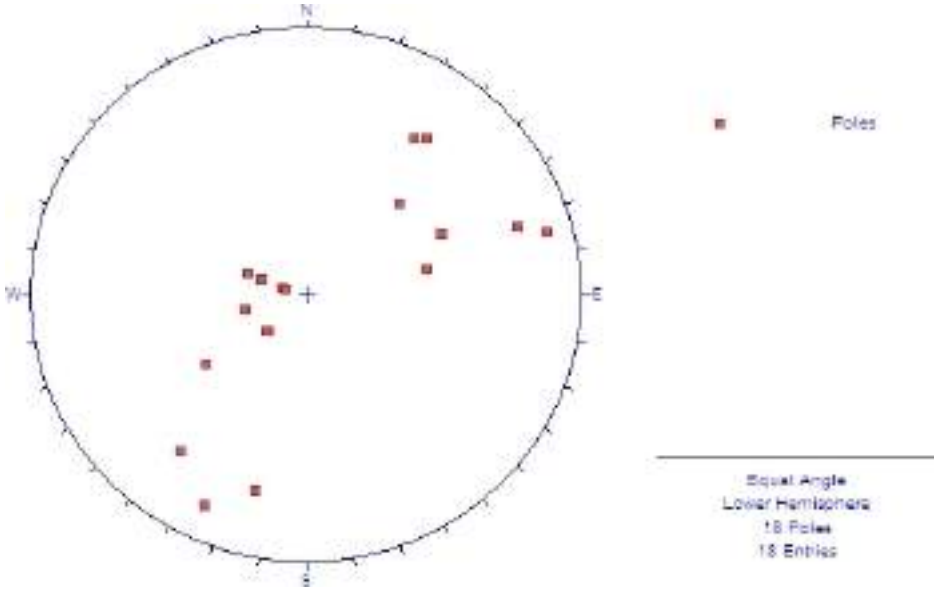


Figure - 4.5: Rose Diagram Showing Location of Poles of Joint Sets in Granitic Gneiss

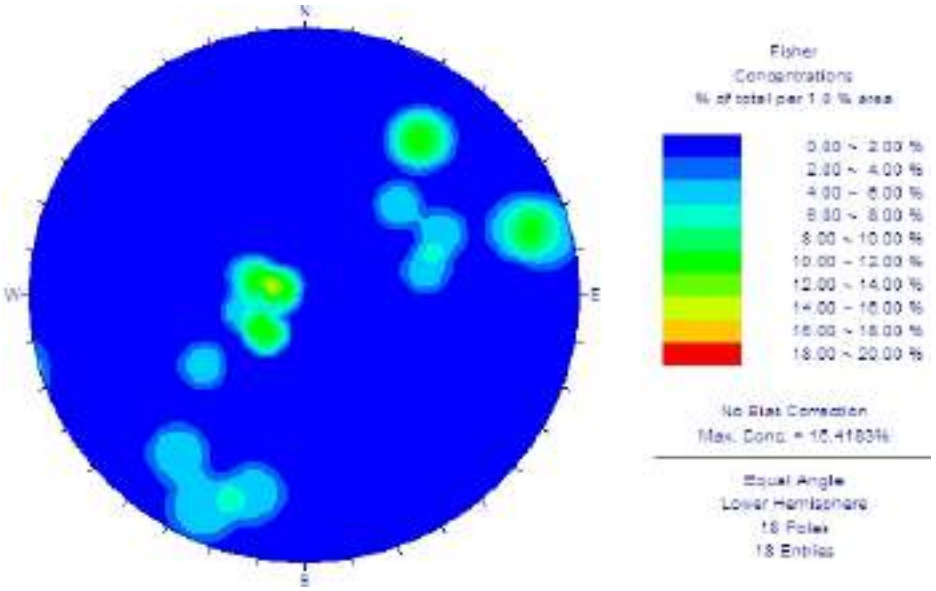


Figure - 4.6: Composite Pole Plot Showing Location of Joint Sets in Granitic Gneiss

JAGRAN - IV HYDROPOWER PROJECT
ROSE DIAGRAMS FROM DISCONTINUITY DATA AT
PRESSURE PIPE SITE

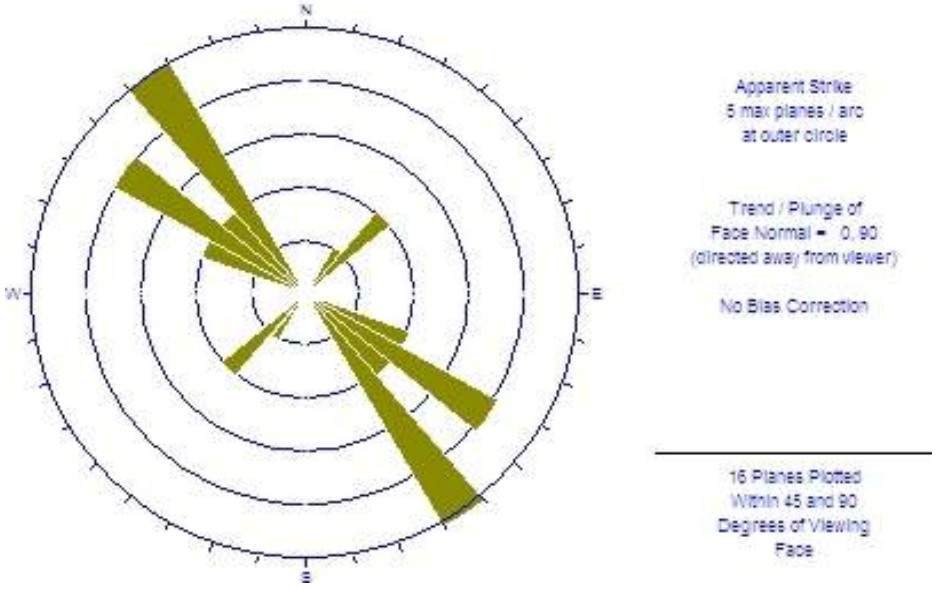


Figure - 4.7: Rose Diagram Showing Stereographic Projection of Joint Sets in Granitic Gneiss

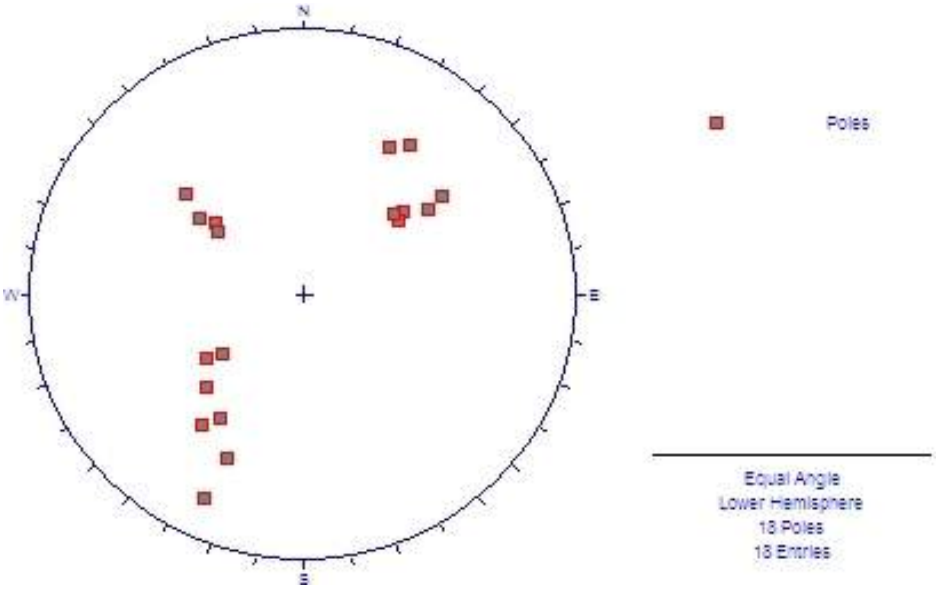


Figure - 4.8: Rose Diagram Showing Location of Poles of Joint Sets in Granitic Gneiss

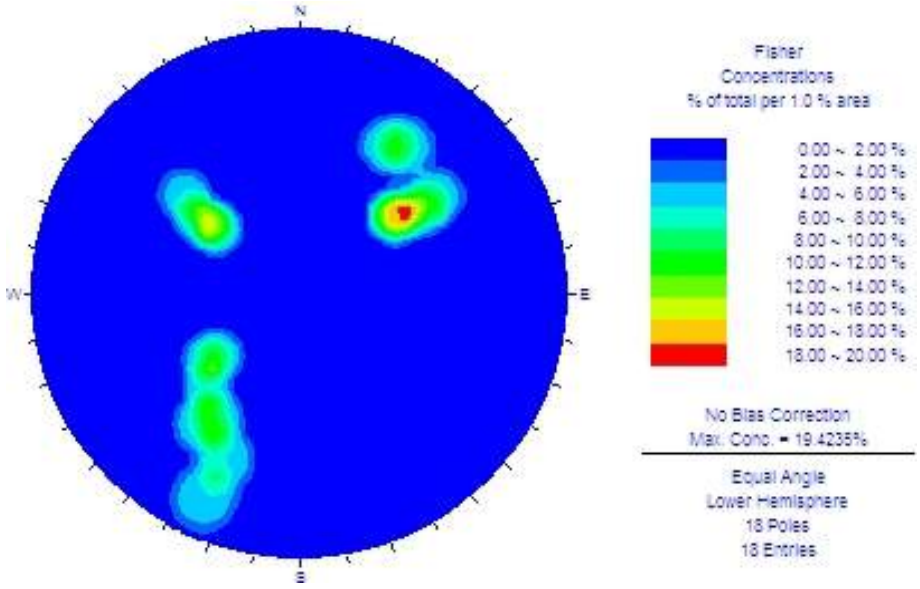


Figure - 4.9: Composite Pole Plot Showing Location of Joint Sets in Granitic Gneiss

A careful analysis of the overall results led to the following conclusions:

- Most of the discontinuities observed have a medium to steep dip angle.
- Three major and two minor discontinuity sets can be identified as under:

Major Sets

Strike	**Dip**
J_1 N 45° W	51° SW
J_2 N 35° W	75° NE
J_3 N 40° E	54° SE

Minor Sets

Strike	**Dip**
J_4 N 59° W	Vertical
J_5 N 17° E	13° SE

4.5.2 Drilling

Main objective of drilling is to determine the nature and engineering characteristic of soil / rock units encountered at each structure of the proposed Jagran - IV Hydropower Project and to observe the rock conditions at depth, to find out the different strata and determine depth to the bedrock, to perform the in - situ permeability / water pressure test (Lugeon test), to obtain the disturbed and undisturbed samples for laboratory testing.

The total proposed drilling to be accomplished for the sub - surface exploration programme is 290 meters in nine (9) boreholes.

4.5.3 Test Pits

A total of twelve (12) test pits (2x2x3 m) have been planned by the Consultants for their excavation in the overburden and at structures.

4.5.4 Trenches

A total of four (04) trenches have been planned by the Consultants for their excavation in the area of structures.

4.5.5 Seismic Refraction Survey

Seismic refraction survey, having a total profile length of about 500 meters, has been planned at weir and powerhouse site.

4.5.6 Laboratory Testing

The main objective of the rock / material testing is to determine the engineering characteristics of bedrock and overburden in order to analyse the samples and use their results to evaluate the geotechnical engineering design parameters for the detail design of the Project.

The laboratory tests to be performed on the disturbed and undisturbed samples obtained from the site exploratory works shall include:

- Natural Moisture Content
- Particle Size Distribution (Sieve Analysis / Hydrometer Test)
- Modified AASHTO Density
- Unconfined Compression
- Water Absorption in Fine and Coarse Aggregates
- Specific Gravity
- Point Load Tests
- Los Angeles Abrasion
- Elongation and Flakiness Index
- Chloride Content
- Sulphate Content of Soil and Surface Water
- Atterberg's Limits
- pH Value of Surface Water
- Alkali Silica Reaction (ASR)
- Modulus of Deformation
- Modulus of Elasticity
- Crushing Value Test
- Ten Percent Fine Value
- Petrographic Analysis

The number and type of tests, however, shall depend on the type of soil / rock and their engineering requirements.

4.6 SEISMICTY

4.6.1 General

Earthquakes are generally caused by the release of stresses within the earth crust. These stresses build up due to the crustal deformation resulting from the movement of tectonic plates and are released by movement along faults causing rupture of the rocks in the crust. Therefore, the occurrence of earthquakes is not merely a random phenomenon but is governed mainly by definite elastic and tectonic processes.

Seismic activity in the northern parts of Pakistan including AJ&K has been the source of a large number of destructive earthquakes and the epicenters are generally located along the plate margins. These earthquakes have originated from the sedimentary cover at shallow depths as well as from the deep basement rocks.

The Northern Areas of Pakistan including the Azad State of Jammu & Kashmir are therefore extensive zones of high seismicity and contain the several seismo-tectonic features generated by an integrated network of active faults.

4.6.2 Seismicity of the Region of Interest

As can be observed from the **Figure - 4.2** "Tectonic Zones and Features in Northern Pakistan and AJ&K", the area of interest lies in "Himalaya Crystalline Schuppen Zone" a part of Karakorram Himalaya Crystalline and Thrust Zone and is delineated MMT in the north and Panjal and MBT in the south. The Richmohri Fault (RF) lies close to the project area.

The other tectonic feature located near the project site is Neelum / Luat Barian Thrust. Evidently, the geo-tectonics of the whole region is related to the collision of the Indian tectonic plate with the Eurasian plate and subsequent formation process of the Himalayan ranges.

The above description clearly indicates that the project area is located in an area where the crustal deformation is an active process due to presence of some major active faults in the region.

The documented record of seismicity consists of mainly earthquake epicenters located on the basis of modern instrumental recordings. This seismic activity is the result of movement along various active faults in the region.

Thus it may be seen that the collision mountain ranges, where the active faults are common, are endowed with high seismicity, whereas the more stable Indus platform zone is characterised by relatively low seismicity.

In Northern Pakistan and Azad Jammu and Kashmir (AJ&K), including the proposed project area of Jagran - IV Hydropower in the Neelum valley, a telemeter seismic network which operated from 1973 to 1977 has recorded data from approximately 10,000 earthquakes covering the area between longitudes 69º and 75º and latitudes 30º 30' and 35º 30'.

This study shows that the northwestern margin of the Indian Plate north of the MBT comprises a zone of high seismicity, whereas the salt range and the Trans - Indus Range reflect moderate seismicity.

In the proposed project area region two main zones of high seismicity have been identified.

- the Indus – Kohistan Seismic zone (ISKZ)
- the Hazara Lower Seismic zone (HLSZ)

4.6.3 Indus Kohistan Seismic Zone (IKSZ) & Associated Earthquakes

The Indus Kohistan seismic zone has a NW - SE orientation and lies between the MMT and the Hazara – Kashmir syntaxis. It overlaps the crystalline nappes of Swat, Besham and Hazara and part of the Kohistan magmatic are along the MMT. The tectonic activity in this region was generated in 1974 Pattan earthquake. According to Seeber *et al* (1979), in this region most of the seismicity is associated with a 10 to 12 km deep, wedge shaped feature.

The seismic data shows that the upper surface conforms to a widespread seismic zone interpreted as a decollement zone along which the decollement of the sediments and met sediments are decoupled from the basement. Below the decoupling surface, fault plane solution indicates north-east and south - west dipping thrust faults.

4.6.4 Hazara Lower Seismic Zone (HLSZ)

The Hazara lower seismic zone is located about 60 km of ISKZ and runs parallel to it. Here the detachment zone forms a kind of divide, with a distinct overlying zone of shallow seismicity and a deeper seismic zone beneath it.

4.6.5 Hazara Fault Zone and Associated Earthquakes

The arctuate thrust and fold belts that form the northern border of the Indian shield are in general characterized by a strong vengeance in the direction of the convexity of the arc, towards the shield. Thus the Hazara fault, the structure in the Hazara arc that corresponds to the Himalayas main boundary fault, has been interpreted as a northward dipping thrust.

Seeber and Jacob (1977) suggested that the Hazara fault is directly connected to the HLSZ, forming a northward - dipping reverse fault continuous from the surface to the lower crust.

On February 14, 1977 a magnitude 5.2 (USGS) earthquake occurred in the Rawalpindi / Islamabad area. It was widely felt in the region and it caused considerable damage in the epicentral area near Nilore. The geometry of the rupture plane related to the Rawalpindi earthquake was determined by accurately locating about 50 aftershocks. The strike of this rupture plane is similar to the strike of the Hazara fault in the same area about (N 60° E) and if extrapolated to the surface, this plane would outcrop very near to the trace of the Hazara fault.

More geological and earthquake data are necessary to unravel the history and the present tectonic significance of the Hazara fault. An effort in this direction seems highly advisable considering the seismic risk associated with the major population, administrative and industrial centers growing in the vicinity of this fault.

4.6.6 Kashmir - Balakot Earthquake of October 08, 2005

A magnitude (Mw) 7.6 earthquake at 8:55 am on 8th October 2005 (USGS, 2005) caused extensive damage and killed in excess of 87,000 people in the Kashmir - Balakot regions of northern Pakistan. The most severely affected region was in the epicentral area around Muzaffarabad and in particular in a band about 10 km wide and about 60 km long.

To the north-east of the fault zone are the foothills of the Indus Kohistan. To the south - west of the fault trace are the Pir Panjal Ranges in the south and the valley of the Jhelum and Kaghan River adjacent to the Mansehra / Abbottabad Plateau in the west.

The geology of the area consists of several indurate sedimentary and metamorphic rock types forming the basement rock mass, which in the valley is overlain by more recent (Quaternary age) coarse fluvio - glacial gravels. At Muzaffarabad a shattered dolomite unit was observed on the up thrown side of the fault and could be traced for several kilometers from the distinctive white landslide scars (Cambrian Abbottabad Formation).

In the Jhelum River valley upstream of Muzaffarabad a sequence of siltstone and sandstone dipping in general southward direction forms the valley wall (scarp slope) of the Jhelum River valley on the down thrown or south western side of the fault.

In the Kaghan valley between Muzaffarabad and Balakot, Pelitic schist forms the local basement (Pre-Cambrian Hazara Formation).

First hand observations of fault rupture were made in the Neelum River valley 2 - 3 km north of Muzaffarabad. At this site ground rupture striking sub-parallel to the trend of river valley crossed a high terrace surface (about 20 m above river level). The terrace surface between the river and the rupture had been uplifted about 1 m relative to the terrace surface between the rupture and the adjacent hill slopes. The ground rupture could be traced for about 50 m.

At a number of places where the linear features traversed the rupture, no evidence for lateral offset could be seen (i.e., the movement on the fault plane was entirely dip slip with no detectable strike - slip component).

At an exposure on a steep terrace river where the ground rupture intersected the terrace edge at an oblique angle, the stratigraphic contact between shattered dolomite and the overlying recent coarse alluvial gravels was offset in the plane of the ground rupture.

On the terrace surface, the offset from the most recent event has been observed about 1 m. However, the dolomite / gravel contact was offset in the order of 2.5 m indicating that this fault has probably ruptured on at least two surfaces.

Further, the fact that the dolomite rock unit is present on both sides of the fault rupture indicates that this is probably not the primary fault plane, but a secondary rupture in the area where the fault zone in more complex.

The seismological and observed ground surface fault rupture data are consistent with the tectonic setting. The relative offset observed along the fault was up to the northeast and down to the southeast with no lateral offset. The provisional epicenter was located about 10 km to the northeast of the fault rupture.

This data is consistent with earthquake occurring on a reverse or thrust fault. Observance of fault rupture was surprising given that the earthquake was initially thought to have occurred on the MBT.

4.7 SEISMIC HAZARD ANALYSIS

The threat to human activities from earthquakes is significant to require the careful consideration in the design of structures and facilities. The goal of earthquake - resistant design is to produce a structure that can withstand a certain level of shaking without excessive damage.

The specification of design ground motion parameters is one of the most difficult and most important problems in geotechnical earthquake engineering. The Jagran - IV Hydropower Project area lies in the Neelum valley of AJ&K which is severely affected by tectonic activities in the past.

Careful seismic hazard analysis that involves the quantitative estimation of ground shaking hazards is of great importance even for small hydropower schemes proposed in seismically active zones.

The seismic hazards may be analysed deterministically, as when a particular earthquake scenario is assumed, or probabilistically in which uncertainties in earthquakes size, location and time of occurrence are explicitly considered.

4.7.1 Deterministic Seismic Hazard Analysis (DSHA)

A DSHA involves the development of a particular seismic scenario upon which a ground motion hazard evaluation is based. The scenario consists of the postulated occurrence of an earthquake of a specified size occurring at a specified location.

A typical DSHA can be described as a four step process consisting of

1. Identification and characterisation of all the earthquake sources capable of producing significant ground motion at a site. Source characterisation includes definition of each source's geometry and earthquake potential.
2. Selection of a source to site, the distance parameter for each source zone. In most DSHAs the shortest distance between the source zone and the site of interest is selected. The distance may be expressed as an epicentral distance or hypocentral distance, depending on the measure of distance of the predictive relationships used in the following step.
3. Selection of the controlling earthquake (i.e., the earthquake that is expected to produce the strongest level of shaking) generally expressed in terms of some ground motion parameters at the site. The controlling earthquake is described in terms of its size (usually expressed as magnitude) and distance from the site.
4. The hazard at the site is formally defined, usually in terms of the ground motion produced at the site by the controlling earthquake. Its characteristics are usually described by one or more ground motion parameters obtained from predictive relationships. Peak acceleration, peak velocity, and response spectrum ordinates are commonly used to characterize the seismic hazard.

However, it provides no information on the like hood of occurrence of the controlling earthquake, the like hood of it occurring where it is assumed to occur and the level of shaking that might be expected during a finite period of time.

DSHA involves subjective decision, particularly regarding earthquake potential that can require the combined expertise and opinion of seismologist, seismic geologists, engineers and risk analysts. The broad range of backgrounds and often divergent goals of such professionals can cause difficulty in reaching consensus on earthquake potential.

Over the years there have been many terms used to describe earthquake potential; amongst them the Maximum Credible Earthquake (MCE), Operating Basis Earthquake (OBE), and Maximum Design Earthquake (MDE). MCE is usually defined as the maximum earthquake that appears capable of occurring under the known tectonic framework.

4.7.2 Probabilistic Seismic Hazard Analysis (PSHA)

Probabilistic Seismic Hazard Analysis (PSHA) provides a framework in which uncertainties can be identified quantified, and combined in a rational manner to provide a more complete picture of the seismic hazard.

The PSHA can be described as a procedure of four steps.

1. The first step, identification and characterisation of earthquake sources, is identical to the first step of the DSHA, except that the probability distribution of potential rupture locations within the source must also be characterised. In most cases, uniform probability distributions are assigned to each source zone implying that earthquakes are equally likely to occur at any point within the source zone.
2. The seismicity or temporal distribution of earthquake recurrence must be characterised. A recurrence relationship may accommodate the maximum size earthquake, as DSHAs often do.
3. The ground motion produced at the site by earthquakes of any possible point in each source zone must be determined with the use of predictive relationships.
4. The uncertainties in earthquake location, earthquake size, and ground motion parameter prediction are combined to obtain the probability that the ground motion parameter will be exceeded during a particular time period.

The proper performance of PSHA requires careful attention to the problem of source characterisation and ground motion parameter prediction and to the mechanics of the probability computations.

4.7.3 Seismic Hazard Analysis of the Project Area

The seismic design parameters for the Maximum Credible Earthquake (MCE) as safety level, Design Basis Earthquake (DBE) and the Operating Basis Design Earthquake (OBE) as serviceability level for Jagran - IV Hydropower Project have been worked out.

All earthquakes have been selected according to the established international standards, described in the ICOLD Bulletin 72. The analyses were performed with the computer programme EZ - FRISK version 7.37 from Risk Engineering (EZ -FRISK 2009). A summary of these parameters is described in the following paragraphs.

For the OBE, considerably lower values for the annual probability of exceedance are recommended in the ICOLD Bulletin 72 (ICOLD 1989), at least 1 / 145 years.

The selection of an annual probability of exceedance for the OBE level depends on the residual risk for damage and business interruption that the client is willing to take.

The OBE level is not safety-related as it is in the MCE case, but determines the functionality of the structure after an earthquake event. So the selection of the OBE level is a management decision, which can be taken by the utility. In this report, two possibilities are shown:

DBE level corresponding to an annual probability of exceedance of 1 / 475 is thus corresponding to the earthquake action on structures in modern seismic building codes such as Euro - code 8.

OBE level corresponding to an annual probability of exceedance of 1 / 145, thus accepting a higher residual risk compared to the DBE level.

The resulting value for the horizontal peak ground acceleration at Jagran - IV Hydropower Project site is 0.68 g for MCE. For DBE and OBE, values of 0.35 g and 0.26 g for annual probabilities of exceedance of 1 / 475 and 1 / 145 are recommended. The vertical components are taken as 2 / 3 of the corresponding horizontal components.

4.8 CONSTRUCTION MATERIAL

Construction material required for various structures of the proposed Jagran - IV Hydropower Project is considered available in sufficient quantity. Boulders and gravel (ABGM) and (RBGM) type of material is found at the slopes and in the river bed respectively. Two (02) test pits have been planned at borrow area.

4.8.1 Coarse Aggregate

- Boulders and cobbles are available in huge quantity at both the upstream and downstream sides of the Jagran I & IV weir site. The coarse aggregate is also found at the terraces. The river bed mainly comprises of sub-rounded to rounded boulders and gravel with little amount of sand (RBG). These boulders and gravel include granitic gneiss, phyllites and granite. Phyllites cannot be used as aggregates so these might be separated before crushing to the desired grading.
- Maximum size of boulder is up to 8 x 7 x 6 m. These are generally very hard and may be crushed to the desired size for their use as coarse aggregate for concrete.

4.8.2 Fine Aggregate (Sand)

Natural sand is not available in the close vicinity of the project structures. Sand may be excavated from the terraces comprising of RBGM and ABGM type of materials. It can also be produced from Jagran River bed during the low flow season. All the necessary tests shall be carried out on sand and other aggregates to ensure the durability and strength of concrete.

4.8.3 Building Stone

Rock granitic gneiss is available for masonry works in the vicinity of the project area in sufficient quantity.

4.8.4 Fill Material

For protection measures along slopes and structures, fill material of almost every size is available from river bed and from the adjacent terraces within a close vicinity of the project area. Boulders or angular stones can be picked up from river bed and from hill side slopes respectively and used as per project specifications / requirements.

4.8.5 Cement and Steel

Cement and steel may not be available in sufficient quantity in Muzaffarabad as required for the construction of Jagran - IV Hydropower Project. Therefore, these items will have to be procured from Rawalpindi or Khyber Pakhtunkhwa area.

It is proposed that laboratory testing on representative sample be carried out to determine physical and mechanical characteristic of the available material.

4.9 PRELIMINARY FOUNDATION EVALUATION

On the basis of surface geological mapping and field observation, preliminary foundation evaluation of various structures proposed for Jagran - IV Hydropower Project has been made.

These are individually described in the following sections.

4.9.1 Weir

The weir shall be constructed on Jagran River near the village of Shal. The surface geological mapping of weir site has been carried out on scale 1:1,000 and presented in this report on scale 1:2,000 as shown in **Dwg. No. 4-1**. . The valley is passing through its stage of maturity according to geo-morphological classification. The weir anticipated to be founded on overburden, as the thickness of overburden in this area appears to more than 20 meters.

Maximum size of boulder in this area is up to 8 x 7 x 6 m. The river bed comprise of medium to large sized boulders and gravel with little amount of sand (RBG) which is loose and looks highly permeable. A geological section along the weir axis is shown in **Dwg. No. 4-8**. As can be seen from the section, the bedrock under overburden is anticipated to be Granitic Gneiss. This will be confirmed through drilling and seismic refraction survey.

Geotechnical and soil investigation at the weir include drilling of three boreholes at the right bank, at middle and at the left bank of Jagran River. The objectives of drilling are to find the thickness of overburden in river, to examine type and nature of rock if encountered, to perform in-situ permeability test in overburden, water pressure test (Lugeon) in rock and to perform various laboratory tests on selected samples to determine the strength and deformation parameters.

The slopes are generally stable and making angle between 35° - 45° with horizontal on both abutments. A good quality of construction material is available upstream and downstream area of the proposed weir site. The material includes large sized boulders, gravel and sand.

The aggregate for concrete is available in ample quantity for the construction of a weir. Selected boulders and gravel may be crushed to obtain the required grading as per ASTM standards and specifications.

Seismic refraction survey shall be conducted along the proposed alignment of the weir site.

4.9.2 Connecting Channel

The surface geological mapping of connecting channel has been carried out on scale 1:1,000 and presented in report on scale 1:2,000 as shown in the **Dwg. No. 4-1**. The connecting channel is located at the left bank of the Jagran River. It is anticipated that the channel shall be excavated through overburden (ABGM) of moronic origin. One test pit and one trench have been proposed at connecting channel to examine the nature, type and thickness of material.

4.9.3 Sandtrap / Desander

The surface geological mapping of sand trap has been carried out on scale 1:1,000 and presented in report on scale 1:2,000 as shown in **Dwg. No. 4-1**. The surface area, of sandtrap is occupied by overburden consisting of angular boulders and gravel with sand and appreciable amount of fines (ABGM) overlying the granitic gneiss. The thickness of overburden is yet to be determined through drilling.

However, it is anticipated that the desander / sandtrap shall be founded on Granitic Gneiss. The sandtrap shall be excavated through bedrock and overburden (ABGM) which is loose to semi consolidated. Two test pits have been proposed at the sandtrap to examine the nature, type and thickness of the sub - surface area. The geological section along desander / sandtrap is shown in the **Dwg. No. 4-9**.

4.9.4 Pressure Pipe

The buried Pressure pipe having a length of about 3075 m shall rest mostly on overburden and partly on rock (granitic gneiss). Generally, the slopes along the pressure pipe alignment are considered to be stable. The surface geological mapping along pressure pipe has been marked on maps prepared from satellite imageries with overlying DEM (Digital Elevation Model) on scale 1:1,000 and presented in report on scale 1:2,000 as shown in **Dwg. No. 4-1 to Dwg. No. 4-6**.

One borehole has been recommended at the downstream end of sandtrap, i.e., pipe intake. Two (02) trenches and three (03) test pits have also been proposed along pressure pipe alignment to examine the nature and type of overburden.

Heavy snowfalls and snow avalanches are common in this area. It is, therefore, recommended that the whole length of pressure pipe alignment may be buried. The geological section along pressure pipe is shown in **Dwg. No. 4-10**.

Some of the joints measured at pressure pipe area during surface geological mapping are given in the **Table - 4.3**.

Table - 4.3: Discontinuity Survey Data of Pressure Pipe Area of Jagran - IV HPP

Station No	Strike	Strike (Azimuth)	Dip	Dip Sense	Options				Dip Direction (DD)	Remarks
					E-NW	E-SE	W-NE	W-SW		
JPP - 1	N 60 W	300	65	SW	-	-	-	210	210	Pressure Pipe Site in granitic gneiss
	N 55 W	305	68	SW	-	-	-	215	215	
	N 38 W	322	40	NE	-	-	52	-	52	
JPP - 2	N 35 W	325	58	SW	-	-	-	235	235	
	N 66 N	294	68	NE	-	-	24	-	24	
	N 40 E	40	45	SE	-	130	-	-	130	
JPP - 3	N 40 W	320	51	SW	-	-	-	230	230	
	N 53 W	307	63	NE	-	-	37	-	37	
	N 37 E	37	42	SE	-	127	-	-	127	
JPP - 4	N 38 W	322	48	SW	-	-	-	232	232	
	N 37 E	37	50	SE	-	127	-	-	127	
	N 34 W	326	46	NE	-	-	56	-	56	
JPP - 5	N 42 W	318	48	SW	-	-	-	228	228	
	N 65 W	295	80	NE	-	-	25	-	25	
	N 41 E	41	59	SE	-	131	-	-	131	
JPP - 6	N 36 W	324	64	SW	-	-	-	234	234	
	N 45 W	315	52	NE	-	-	45	-	45	
	N 57 W	303	58	NE	-	-	33	-	33	

4.9.5 Surge Pipe

As can be seen from the geological map, the Surge pipe shall rest on rock (Granitic Gneiss). The surface geological mapping of surge pipe has been carried out on scale 1:1,000 and presented in report on scale 1:2,000.

One borehole has been proposed in the area of surge pipe. The drilling results will tell the nature and behaviour of rock.

The geological section covering surge pipe, penstock and powerhouse areas is shown in **Dwg. No. 4-11**.

The surface geological map of surge pipe area is shown in **Dwg. No. 4-7**. Some of the joints measured during surface geological mapping are given in the **Table - 4.4**.

Table - 4.4: Discontinuity Survey Data of Pipe Outlet Area of Jagran - IV HPP

Station No	Strike	Strike (Azimuth)	Dip	Dip Sense	Options				Dip Direction (DD)	Remarks
					E-NW	E-SE	W-NE	W-SW		
JPO - 1	N 15 W	345	84	SW	-	-	-	255	255	Pipe Outlet area in granitic gneiss
	N 45 W	315	22	NE	-	-	45	-	45	
	N 35 W	325	48	NE	-	-	55	-	55	
JPO - 2	N 18 W	342	78	SW	-	-	-	252	252	
	N 17 E	17	10	SE	-	107	-	-	107	
	N 14 W	346	26	NE	-	-	76	-	76	
JPO - 3	N 12 W	348	48	SW	-	-	-	258	258	
	N 65 W	295	82	NE	-	-	25	-	25	
	N 20 E	20	19	SE	-	110	-	-	110	
JPO - 4	N 45 W	315	51	SW	-	-	-	225	225	
	N 52 W	308	73	NE	-	-	38	-	38	
	N 21 E	21	25	SE	-	111	-	-	111	
JPH - 5	N 56 W	304	70	SW	-	-	-	214	214	
	N 53 W	307	72	SW	-	-	-	217	217	
	N 44 W	316	22	NE	-	-	46	-	46	
JPH - 6	N 25 W	335	57	SW	-	-	-	245	245	
	N 76 W	284	74	NE	-	-	14	-	14	
	N 15 E	15	09	SE	-	105	-	-	105	

4.9.6 Penstock

Surface geological mapping of penstock alignment area has been carried on map having scale 1:1,000 and presented in report on scale 1:2,000. It is evident from the geological maps that the penstock will mostly rest over rock (granitic gneiss) and partly on overburden.

Three (03) test pits and one (01) trench have been planned along the penstock alignment to know the nature and type of overburden. The location of penstock is shown in **Dwg. No. 4-7**.

4.9.7 Surface Powerhouse

The surface area of Powerhouse is occupied by overburden consisting of rounded boulders and gravel with appreciable amount of fines (RBGM) overlying the granitic gneiss. The thickness of overburden is yet to be determined through drilling. However, it is anticipated that the Powerhouse shall be founded on Granitic Gneiss. One borehole has been proposed at powerhouse area to determine the nature, type, thickness of overburden and type of bedrock, if encountered.

Surface geological mapping of powerhouse area has been carried out on scale 1:1,000 (presented in report on scale 1:2,000) by using the plane table, total station, GPS and Brunton compass. The surface geological map of powerhouse area is shown in **Dwg. No. 4-7** and the section on **Dwg. No. 4-11.**

4.9.8 Tailrace Channel

Surface geological mapping of tailrace channel area has been carried on map having scale 1:1,000 and presented in report on scale 1:2,000 as shown in **Dwg. No. 4-7**. Tailrace proposed for the Jagran - IV Hydropower Project shall be excavated through overburden (RBGM). The out-coming water will be drained into the left bank of Jagran River.

4.10 ROCK MASS ASSESSMENT

At the feasibility stage of Jagran - IV Hydropower Project, when a little detailed information is available on the rock mass and its stress and hydrologic characteristics, the use of a rock mass classification scheme has been of considerable importance.

At its simplest, this has involved using the classification scheme as a check list to ensure that all the relevant information has been considered. At the other end, various other rock mass classification schemes have been used to build up a picture of the composition and characteristics of a rock mass to provide initial estimates of support requirements, and to provide estimates of the strength and deformation properties of the rock mass.

It is important to understand the limitations of rock mass classification schemes and their use does not replace some of the more elaborate design procedures. However, the use of these design procedure requires access to relatively detailed information on in - site stresses, rock mass properties and planned excavation sequence, none of which is available at an early stage of this project.

However, when this information becomes available, it has to be used for the rock mass classification schemes and updated in conjunction with site specific analyses based on the field information and surface geological mapping.

The following rock mass classification systems have been used for the various components:

- Rock Structure Rating (RSR).
- Geomechanic classification or Rock Mass Rating (RMR).
- Rock Tunneling Quality Index “Q” system.

4.10.1 Rock Structure Rating (RSR)

This system describes a quantitative method for describing the quality of a rock mass and for selecting appropriate support. Most of the case histories, used in the development of this system, were for relatively small tunnels supported by means of steel sets. In spite of this limitation, it is worth examining the RSR System in some detail since it demonstrates the logic involved in developing a quasi-quantitative rock mass classification system.

Basically, this classification involves the determination of three parameters as shown in **Table - 4.5**.

Table - 4.5: Classifications of Rock Structure Rating

Parameter “A”	General appraisal of geological structure on the basis of a) Rock type origin b) Rock hardness c) Geologic structure	
Parameter “B”	Geometry:	Effect of discontinuity pattern with respect to the direction of the tunnel drive
Parameter “C”		Effect of ground water inflow and joint conditions

The RSR values determined for different structures, i.e., pipe outlet areas are described in the **Table - 4.6**.

Pipe Outlet Area (Jagran - IV Hydropower Project)

Rock Mass Classification

Table - 4.6: Rock Structure Rating System

Rock: Granitic Gneiss

	Basic Rock Type							
	Hard	Medium	Soft	Decomposed		Geological Structures		
Igneous	1	2	3	4		Slightly	Moderately	Intensively
Metamorphic	1	**2**	3	4		Folded or	Folded or	Folded or
Sedimentary	2	3	4	4	Massive	Faulted	Faulted	Faulted
Type 1					30	22	15	9
Type 2					27	**20**	13	8
Type 3					24	18	12	7
Type 4					19	15	10	6

	Strike 1 to Axis Direction of Drive					Strike II to Axis Direction of Drive		
	Both	With Dip		Against Dip		Either Direction		
	Dip of Prominent Joints [a]					Dip of Prominent Joints		
Average Joint Spacing	Flat	Dipping	Vertical	Dipping	Vertical	Flat	Dipping	Vertical
1. Very closely jointed, < 2 in	9	11	13	10	12	9	9	7
2. Closely jointed, 2-6 in	13	16	19	15	17	14	14	11
3. Moderately jointed, 6-12 in	23	24	28	19	22	23	23	19
4. Moderate to blocky, 1-2 ft	30	32	36	**25**	28	30	28	24
5. Blocky to massive, 2-4 ft	36	38	40	33	35	36	24	28
6. Massive, > 4 ft	40	43	45	37	40	40	38	34

	Sum of Parameters A + B					
	13 - 44			45 - 75		
	Joint Condition [b]					
Anticipated water inflow pgm/1000 ft of tunnel	Good	Fair	Poor	Good	Fair	Poor
None	22	18	12	25	22	18
Slight, < 200 gpm	19	15	9	23	**19**	14
Moderate, 200-1000 gpm	15	22	7	21	16	12
Heavy, > 1000 gp	10	8	6	18	14	10

a. Dip: flat: 0-20$^{o;}$; dipping: 20-50^{o} ; and vertical: 50-90 ^{o}
b. Joint condition: good=tight or cemented: fair=slightly weathered or altered: poor=severely weathered, altered or open

A+B+C=20+25+19
RSR=64

All the three parameters have been used to evaluate the rating of each of these parameters to arrive at the RSR values (maximum RSR = 100).

The results are given below:

	Structure	RMR (A+B+C)
1	Pipe Outlet area (Granitic gneiss)	64 (20+25+19)

4.10.2 Geomechanics Classification or Rock Mass Rating (RMR) System

This system has been successively refined as more case records have been examined. Bieniawski (1989) has made significant changes in the rating assign to different parameters.

The following six parameters have been used to classify the rock mass at pipe outlet area of the proposed Jagran - IV Hydropower Project:

- Uniaxial compressive strength of rock material;
- Rock Quality Designation (RQD);
- Spacing of discontinuities;
- Condition of discontinuities;
- Groundwater conditions;
- Orientation of discontinuities.

The detailed description and rating for each of the six parameters are provided below. These ratings are summed to give a value of RMR. The RMR values determined for structure i.e. pipe outlet area is evaluated in the **Table - 4.7**.

Pipe Outlet Area (Jagran - IV Hydropower Project)

Rock Mass Classification

Table - 4.7: Rock Mass Rating System (After Bieniawski 1989)

Rock: Granitic Gneiss

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
Parameters			Range of Values						
1	Strength of intact rock material	Point load strength index	> 10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	> 250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	**12**	7	4	2	1	0
2	Drill Core Quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	> 25%		
	Rating		20	17	**13**	6	3		
3	Spacing of discontinuities		> 2m	0.6 - 2 m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	**15**	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5mm thick or Separation 1-5 mm Continuous	Soft gouge >5mm thick or Separation >5 mm Continuous		
	Rating		30	**25**	20	10	0		
5	Groundwater	Inflow per 10m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	<0.1	0.1 - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	**7**	4	0		

Table - 4.7: Rock Mass Rating System (After Bieniawski 1989) (Continued)

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)						
Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	**-5**	-25	-50	
C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS						
Ratings		100 ← 81	**80 ← 61**	60 ← 41	40 ← 21	< 21
Class number		I	II	III	IV	V
Description		Very good rock	**Good rock**	Fair rock	Poor rock	Very poor rock
D. MEANING OF ROCK CLASSES						
Class number		I	II	III	IV	V
Average stand-up time		20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)		> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)		> 45	**35 - 45**	25 - 35	15 - 25	< 15
E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY CONDITIONS						
Discontinuity length (persistence) Rating		< 1m 6	1 - 3 m 4	3 - 10 m 2	10 - 20 m 1	> 20 m 0
Separation (aperture) Rating		None 6	< 0.1 mm 5	0.1 - 1.0 mm 4	1 - 5 mm 1	> 5 mm 0
Roughness Rating		Very rough 6	Rough5	Slightly rough 3	Smooth 1	Slickensided 0
Infilling (gouge) Rating		None 6	Hard filling < 5mm 4	Hard filling > 5mm 2	Soft filling < 5mm 2	Soft filling > 5mm 0
Weathering Rating		Unweathered 6	Slightly weathered 5	Moderately weathered 3	Highly weathered 1	Decomposed 0
F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELING**						
Strike perpendicular to tunnel axis			Strike parallel to tunnel axis			
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°		Dip 45 - 90°		Dip 20 - 45°	
Very favourable	Favourable		Very unfavourable		Fair	
Drive against dip - Dip 45 - 90°	Drive against dip - Dip 20 - 45°		Dip 0 - 20 Irrespective of strike°			
Fair	Unfavourable		Fair			

* Some conditions are mutually exclusive. For example, if in filling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.
** Modified after Wickham et al (1972).

The RMR value determined for pipe outlet area is given as following:

Sr.		Value	Rating
1.	Point Load Index	10 Mpa	12
2.	Rock Quality Designation (RQD)	64	13
3.	Spacing of discontinuities	(0.6 - 2.0m)	15
4.	Condition of discontinuities		25
5.	Groundwater conditions	Wet	7
6.	Adjustment for joint Orientation		-5
			Total = 67

Rock mass class determined from the total rating (RMR = 67) ~ CLASS II (Good Rock).

RMR value of 67 places granitic gneiss under the rock mass class II described as Good Rock".

4.10.3 Rock Tunneling Quality Index, Q

On the basis of an evaluation of a large number of case histories of surface excavations, Barton et al (1974) of the Norwegian Geotechnical Institute proposed a Tunneling Quality Index (Q) for the determination of rock mass characteristics and tunnel support requirements.

The numerical value of the index Q varies on a logarithmic scale from 0.001 and is defined by:

$$Q = RQD/Jn \times Jr/Ja \times Jw/SRF$$

Where RQD is the Rock Quality Designation
Jn is the joint set number
Jr is the joint roughness number
Ja is the joint alteration number
Jw is the joint water reduction factor
SRF is the stress reduction factor

The **Table - 4.8** (After Barton et al 1974) gives the classification of individual parameters used to obtain the tunneling Quality Index (Q) for a rock mass.

As no core is available at the present moment, the Rock Quality Designation (RQD) values are not possible by the physical measurements. A formula developed by Palmstrom (1982) has been applied to workout RQD values, on the basis of discontinuity traces visible in the surface exposures. According to this relationship, RQD = 115 - 3.3 Jv; where Jv is the sum of the number of joints per unit length for all the joint (discontinuity) sets known as the volumetric joint count.

RQD values rock units exposed at pipe outlet area of Jagran - IV Hydropower Project have been work out separately.

Pipe Outlet Area (Jagran - IV Hydropower Project)

Rock Mass Classification

Table - 4.8: Classification of Individual Parameters used in the Tunneling Quality Index, Q

Rock: Granitic Gneiss

DESCRIPTION		VALUE	NOTES
1	**ROCK QUALITY DESIGNATION**	**RQD**	
A.	Very poor	0 - 25	1. Where *RQD* is reported or measured as 10 (including 0), a nominal value of 10 is used to evaluate Q.
B.	Poor	25 - 50	
C.	Fair	50 - 75	
D.	Good	**75 - 90**	2. *RQD* intervals of 5, i.e., 100, 95, 90 etc. are sufficiently accurate.
E.	Excellent	90 - 100	
2	**JOINT SET NUMBER**	J_n	
A.	Massive, no or few points	**0.5 - 1.0**	
B.	One joint set	2	
C.	One joint set plus random	3	
D.	Two joint sets	4	
E.	Two Joint sets plus random	6	
F.	Three joint sets	9	1. For intersections use (3.0 x J_n)
G.	Three joint sets plus random	12	
H.	Four or more joint sets, random, heavily jointed, 'sugar cube', etc.	15	2. For portals use (2.0 x J_n)
I.	Crushed rock, earthlike	20	
3	**JOINT ROUGHNESS NUMBER**	J_r	
	a. Rock wall contact		
	b. Rock wall contact before 10 cm shear		
A.	Discontinuous joints	4	
B.	Rough and irregular, undulating	**3**	
C.	Smooth undulating	2	
D.	Slickenside undulating	1.5	1. Add 1.0 if the mean spacing of the relevant joint set is greater than 3 m.
E.	Rough or irregular, planar	1.5	
F.	Smooth, planar	1.0	

Table - 4.8: Classification of Individual Parameters used in the Tunneling Quality Index, Q (Continued)

G.	Slickenside planar	0.5	2. J_r = 0.5 can be used for planar, slickenside joints having lineation, provided that the lineation are oriented for minimum strength.	
	c. No rock wall contact when sheared			
H.	Zones containing clay minerals thick enough to prevent rock wall contact	1.0 (nominal)		
I.	Sandy, gravely or crushed zone thick enough to prevent rock wall contact	1.0 (nominal)		
4	**JOINT ALTERNATION NUMBER**	J_a	ør degrees (approx.)	
	a. Rock wall contact			
A.	Tightly healed, hard, non-softening, impermeable filling	0.75		1. Values of ør, the residual friction angle, are intended as an approximate guide to the mineralogical properties of the alteration products, if present.
B.	Unaltered joint walls, surface staining only	**1.0**	25 – 35	
C.	Slightly altered joint wall, non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	2.0	25 – 30	
D.	Silty, or sandy-clay coatings, small clay-fraction (non-softening)	3.0	20 – 25	
E.	Softening or low-friction clay mineral coatings, i.e., kaolinite, mica. Also chlorite, talc, gypsum and graphite etc., and small quantities of swelling clays. (Discontinuous coatings, 1 – 2 mm or less).	4.0	8 – 16	
	b. rock wall contact before 10 cm shear			
F.	Sandy particles, clay-free, Disintegrating rock etc.	4.0	25 – 30	
G.	Strongly over-consolidated, non-softening clay mineral filling (continuous < 5mm thick)	6.0	16 – 24	
H.	Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick)	8.0	12 – 16	
I.	Swelling clay fillings, i.e. montmorillonite, (continuous < 5mm thick). Values of J_a depend on percent of swelling clay-size particles, and access to water.	8.0 – 12.0	6 – 12	
	c. No rock wall contact when sheared			
J.	Zones of brands of disintegrated or crushed	6.0		
K.	rock and clay (see G, H and J for clay	8.0		
L.	conditions)	8.0 – 12.0	6 – 24	
M.	Zones or bands of silty or sandy-clay, small clay fraction, non-softening	5.0		

Table - 4.8: Classification of Individual Parameters used in the Tunneling Quality Index, Q (Continued)

N.	Thick continuous zones or bands of clay	10.0 - 13.0		
O.	& R. (see G, H and J for clay conditions)	6.0 - 24.0		
5	**JOINT WATER REDUCTION**	***J_w***	approx. water pressure (kgf/cm^2)	
A.	Dry excavation or minor inflow i.e. < 5 l/m locality	**1.0**	< 1.0	
B.	Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C.	Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates, increase J_w if drainage installed.
D.	Large inflow or high pressure	0.33	2.5 - 10.0	
E.	Exceptionally high inflow or pressure at blasting, decaying with time.	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered.
F.	Exceptionally high inflow or pressure	0.1 - 0.05	> 10	
6	**STRESS REDUCTION FACTOR**		***SRF***	
	a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated			
A.	Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth.		10.0	1. Reduce these values of SRF by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation.
B.	Single weakness zones containing clay, or chemically distegrated rock (excavation depth < 50 m)		5.0	
C.	Single weakness zones containing clay, or chemically distegrated rock (excavation depth > 50 m)		**2.5**	
D.	Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)		7.5	
E.	Single shear zone in competent rock (clay free). (depth of excavation < 50 m)		5.0	
F.	Single shear zone in competent rock (clay free). (depth of excavation > 50 m)		2.5	
G.	Loose open joints, heavily jointed or 'sugar cube', (any depth)		5	
Tunneling Quality	Q	= RQD / Jn x Jr / Ja x Jw / SRF = 64/1 x 3/1 x 1/2.5 Q = 77		

Tunneling Quality Index (Q) worked out for the various structures of Jagran - IV Hydropower Project is given below:

Structure	Tunneling Quality Index (Q)
Pipe Outlet Area	77

4.11 GLACIAL LAKE OUTBURST FLOOD (GLOF)

Glacial lake outburst flood events in the higher Himalayas though rare, can be catastrophic when they occur. There are glaciers in the catchment area. Snow melt can create avalanches which do normally occur in this area.

4.12 CONCLUSIONS

Based on the geological and geotechnical studies carried out so far for the feasibility of the proposed Jagran - IV Hydropower Project, the following conclusions are given:

1. The major Himalayan tectonic units are well exposed along the relatively accessible Neelum valley. These are the result of collision between the Eurasian and Indian plates.

2. The rocks exposed in the project area are mainly of metamorphic origin comprising of granitic gneiss with igneous intrusions (mostly granites and granodiorites) at places.

3. The both abutments of weir shall be founded on overburden, comprising mainly of rounded boulders and gravel with sand and appreciable amount of fines (RBGM).

4. Sandtrap and connecting channel shall have to be excavated through overburden of moronic type. The buried pressure pipe shall rest mostly on overburden and partly on rock. The surge pipe shall rest on rock (granitic gneiss). The penstock pedestal shall rest mostly on rock (granitic gneiss) and partly on overburden. Surface powerhouse and tailrace shall be founded on overburden.

5. Based on preliminary rock mass assessment made from three classification systems, i.e., Rock Structure Rating (RSR), Rock Mass Rating (RMR) and Tunneling Quality Index (Q); it is concluded that the overall rock conditions appear to be fair to good for excavation.

6. A good quality of construction material is available in abundant quantity in the vicinity of all the proposed structures of the scheme. There is no natural sand deposit in the project area. Sand may be extracted from the terraces, produced by crushing granite / granitic gneiss or procured from Neelum River bed during low flow season.

7. Glacial Lake Outburst Flood (GLOF) events in the higher Himalayas though rare, can be catastrophic when they occur. There are glaciers in the catchment area. Snow melt can create avalanches which do normally occur in this area.

4.13 RECOMMENDATIONS

1. The overall geological conditions appear to be fair to good for excavation; however, at places shear zones, fractures, local brittle faults and other structural discontinuities and defects may create problems during excavation.

2. As heavy snowfalls in the project area and heavy avalanches are frequent in the area, so the whole length of the pressure pipe should be buried for safety point of view.

3. The granitic gneiss could be potentially suitable rock type for concrete aggregate but its potential reactivity Alkali-Silica Reaction (ASR) needs to be confirmed by tests. If granitic gneiss is found reactive then instead of Ordinary Portland Cement (OPC), low alkali cement would be recommended for concrete.

4. An assessment of surface slope stability in the vicinity of the construction sites is strongly recommended. If adverse conditions found then potential impact on the project should be staged.

5. Seismic Hazard Evaluation for Jagran - IV Hydropower Project suggests a Horizontal Peak Ground Acceleration (PGA) for Maximum Credible Earthquake (MCE) as 0.68 g, for Design Base Earthquake (DBE) as 0.35 g and for Operating Basis Earthquake (OBE) as 0.26 g for detailed design of project structures. The vertical components recommended for this scheme are 2 / 3 of the corresponding horizontal component.

5 ALTERNATIVE PROJECT LAYOUT

5.1 GENERAL

Jagran River is a right bank tributary of Neelum River, located about 68 km upstream of Muzaffarabad. Jagran River is medium size stream with cluster of population up to 25 km inside valley. Due to attractive stream gradient and abundant flows, Jagran River was planned to be developed in stages. Kundal Shahi power station of 2.0 MW was developed in lower 1 km stretch of Jagran River, while Jagran-I with installed capacity of 30.4 MW was developed in upper middle reach about 10 years ago.

The Jagran River stretch between existing Jagran-I and Kundal Shahi power station remained to be planned and developed as Jagran-II and Jagran-III Hydropower Projects.

A feasibility study of 43.5 MW Jagran-II Hydropower Project was prepared by French Consultants in year 1999. The feasibility study of Jagran-III Hydropower Project is being prepared in Private Sector. Jagran-IV Hydropower Project was identified by AJ&K HEB in three (03) km stretch just upstream of Jagran-I power station. The project was identified as to produce 6 to 8 MW with project layout as headrace tunnel, penstock and surface powerhouse on the left bank of Jagran River.

The Consultants have critically examined the project and reviewed the project layout conceived originally. Alternate project layouts have been prepared and compared. The project components, design discharge and installed capacity have been thoroughly checked keeping in view the climatic conditions, topography, geology, available flows and operation difficulties faced at Jagran-I Hydropower Project.

Jagran River is covered on General Topographic maps of Survey of Pakistan (SOP) Sheet No. 43-F/10, 43-F/13, and 43-F/14. About 3.5 km intermediate stretch of Jagran River, just upstream of intake of Jagran-I, was selected to be checked in the field for various alternatives of Jagran-IV Hydropower Project.

Jagran River has accessibility with jeepable road available up to the weir and powerhouse sites of the proposed Jagran-IV Hydropower Project. Considering morphology and geological conditions of Jagran valley, the left bank was considered to propose alternate layouts for Jagran-IV Hydropower Project.

5.2 TOPOGRAPHIC FEATURES

The catchment area of Jagran River with its confluence at Neelum River is estimated as about 430 km^2. Jagran River joins with Neelum River at about El. 1330 m asl. Due to perennial flows and steep gradient varying from 5 to 13%, Jagran River is attractive for harnessing enormous hydroelectric energy to meet future power demand of regional grid of AJ&K.

As two hydropower stations i.e. Jagran-I and Kundal Shahi hydropower stations are in operation for a decade or more, access to Jagran valley is well established and 132 kV transmission line from Jagran to Muzaffarabad is available, therefore potential stretch even upstream of Jagran-I is attractive to be studied. Jagran-IV layout has been identified with river gradient of 5.5%.

A number of streams join Jagran River in 25 km populated valley. With higher elevation in Jagran valley, snow fall is more, topographic conditions are difficult and geology in some areas is of poor nature. Jagran-IV project area is located in an area with river elevation from 2100 m asl to 2270 m asl. The area is generally problematic due to a number of avalanches on the right side of Jagran River. The left bank has better topographic conditions although geological conditions are not very good.

The diversion of Jagran River for Jagran-IV power station can be planned through a shortest water way and to optimally use the gross head of 156 m available just upstream of Jagran-I power station.

5.3 PROJECT LAYOUT ALTERNATES

With the selected stretch of Jagran River, alternate project layouts have been studied. Both banks have been checked in the field to have option for project layout on either bank. The right bank has a number of avalanches or glaciated area, therefore, for the project layouts the left bank was found suitable.

Topographic and geological conditions on the left bank of Jagran River were found better as compared with that of right bank to propose alternate project layouts. The location of surface powerhouse is suitable on the left bank of Jagran River, about 200 m upstream of existing weir of Jagran-I.

Considering the topography and geology on the left bank, two types of alternate layout have been conceived. The first option is to have low pressure headrace tunnel, surge tank penstock and surface powerhouse. In the second layout option, instead of low pressure tunnel, headrace pressure pipe mainly embedded, surge pipe, penstock and surface powerhouse have been considered.

The weir intake, connecting channel, sandtrap, forebay / surge location, penstock and surface powerhouse are same for two considered alternate layouts. The difference in two alternate layouts is the headrace tunnel in first option and low pressure pipe in the second option.

Both the project layouts are shown in **Dwg. No. 5-1 and Dwg. No. 5-2** and have been described in the following paragraphs.

5.3.1 Alternate Project Layout - I

The weir has been proposed about 150 m downstream of confluence of Baihk nullah with Jagran River near Shaal village. The powerhouse would be located about 200 m upstream of Jagran-I weir intake.

At the proposed weir site, there is enough space to accommodate intake structure, 110 m embedded channel, surface sandtrap in the area of Shaal village. About 3100 m long low pressure tunnel has been proposed on the left bank slope, where in the first about 300 m length sound rock is not expected to be found.

In the latter portion, surface geological conditions are very good for low pressure tunnel. The geological conditions for surge tank and embedded / surface penstock are favourable.

The estimated length of penstock is 320 m and to accommodate surface powerhouse, excavation of slope has to be made.

The coordinates of weir and powerhouse sites are listed below:

Site	Latitude	Longitude
Weir	34°-39'-27"	73°-46'-09"
Powerhouse	34°-37'-48"	73°-46'-09"

The weir crest has been proposed at El. 2264 m asl and the design discharge would be dropped back into Jagran River at El. 2108 m asl. The design discharge has been taken as 18.0 m^3/s for estimation of power and energy.

The geological aspects and salient features of Alternative-I are presented below.

5.3.2 Geological Aspects

The rocks exposed in the proposed Jagran - IV Hydropower Project area are metamorphic in origin; mainly comprising of granitic gneiss. This is generally massive, sparsely jointed, moderately weathered. Quartz veins are quite prominent in granitic gneiss. Foliation / lamination plane has strike about N 55° W with 50° to 60° dip towards SW.

5.3.2.1 Weir Site

Both the abutments of the weir shall be founded on rounded to sub-rounded boulders and gravel with sand and appreciable amount of fines (RBGM).

The boulders are quite large, loose to semi compact, with the maximum size being 8 x 7 x 6 m. The width of river is about 30 m. Sufficient space is available for locating the sandtrap at the left bank of the river.

5.3.2.2 Connecting Channel

Connecting channel shall be connected with the headrace tunnel at the left side of river. This channel shall be founded on ABGM type of material. Angular boulders and gravel (ABGM) are brought about by glaciers and contain heterogeneous type of material. The slopes are quite stable and covered with thick vegetation. The lower part of slope is covered with rounded to sub-rounded boulders and gravel with sand and appreciable amount of silt and clay (RBGM).

5.3.2.3 Headrace Tunnel

Headrace tunnel shall be excavated mainly through rocks of metamorphic origin comprising of granitic gneiss. At some places intrusion of igneous rocks are expected. The general trend of rocks exposed along the proposed tunnel alignment is N 60º W with foliation plane dipping from 50º to 55º SW.

Two sets of joint as measured during visit to the propose project site are given below:

- N 55º W / 68º SW
- N 44º W / 40º NE

It is considered that no major problem is expected during the tunnel excavation. Keeping in view the general behavior of metamorphic rocks, temporary and permanent supports shall be required in shear zones, fissures, factures, local fault zones and other structural discontinuities and defects. Seepage is also expected through joints, cavities and fissures.

5.3.2.4 Surge Shaft and Penstock

Surge shaft and penstock pedestals shall be founded on slopes making angles of 40° - 55° with the horizontal. These slopes are considered stable and covered with angular boulders and gravel with sand and appreciable amount of fines (ABGM). Thickness of overburden shall be determined through drilling or by excavating test pits.

The excavation of surge shaft shall be made through rocks comprising mainly of granitic gneiss. Further, granites and granodiorites may encounter as intrusive igneous rocks.

The overall rocks are moderately weathered and sparsely jointed. If the rock is not encountered at shallow depth then the foundations of penstock pedestals shall be made on material comprising of angular boulders and gravel with sand and the appreciable amount of fines (ABGM).

5.3.2.5 Powerhouse and Tailrace

It is envisaged to be located about 200 m upstream of Jagran - I weir, where sufficient space is available in shape of terraces at the left bank of the river. Top one meter cover of soil is comprised of silty clay with fine gravel, underlying by the rounded boulders and gravel with sand and appreciable amount of fines (RBGM).

Terraces at the higher elevation comprise mainly of loose to semi consolidated angular boulders and gravel with sand and appreciable amount of fines (ABGM).

As rock (granite gneiss) is exposed at the left bank of the river, it is suggested that foundation of powerhouse may be placed or cut through strata comprising of rounded boulders and gravel with sand and appreciable amount of fines. The maximum size of boulder is 8 x 7 x 6 m, in this particular area.

5.3.2.6 Salient Features of Jagran - IV Alternative - I

- Design Discharge = 18.0 m^3/s
- Gross Head = 156 m
- Design Capacity = 22.0 MW
- Mean Annual Energy = 98.20 GWh
- Plant Factor = 51.25 %
- Type of Intake = Weir with Lateral Intake
- Height of Weir above River Bed = 6 m

- Crest Length of Weir = 24 m
- Headrace Tunnel Length = 3100 m
- Diameter of Tunnel = 3.70 m
- Penstock = 320 m
- Penstock Diameter = 2.30 m
- Type of Powerhouse = Surface Powerhouse
- Number of Units = 4, Francis 1000 rpm
- Tailrace = 40 m

5.3.3 Alternate Project Layout - II

The weir and powerhouse sites are same as identified for Alternate-I. The project layout would comprise of headrace pressure pipe instead of low pressure tunnel.

About 3075 m long pipe partly embedded and partly open up to surge pipe would be laid. The flows of Jagran River would be diverted into 110 m connecting channel, sandtrap and then to the headrace pressure pipe.

The coordinates of weir and powerhouse sites are same as for Alternate-I.

Site	Latitude	Longitude
Weir	34°-39'-27"	73°-46'-09"
Powerhouse	34°-37'-48"	73°-46'-09"

The weir crest has been proposed at El. 2264 m asl and the design discharge would be dropped back into Jagran River at El. 2108 m asl. The design discharge has been taken as 18.0 m^3/s for estimation of power and energy.

The geological aspects and salient features of project layout Alternate-II are presented below.

5.3.4 Geological Aspects of Alternate - II

5.3.4.1 Weir Site

Same as for Alternate-I.

5.3.4.2 Headrace Pipe / Penstock

Same as for Alternate-I.

5.3.4.3 Powerhouse and Tailrace

Same as for Alternate-I.

5.3.4.4 Salient Features of Jagran-IV Alternative - II

- Design Discharge = 18.0 m^3/s
- Gross Head = 156 m
- Design Capacity = 22.0 MW
- Mean Annual Energy = 98.20 GWh
- Plant Factor = 51.25 %
- Type of Intake = Weir with Lateral Intake
- Height of Weir above River Bed = 6 m
- Crest Length of Weir = 24 m
- Headrace Pressure Pipe = 3075 m
- Pressure Pipe Diameter = 2.50 m
- Penstock = 180 m
- Penstock Diameter = 2.50 m
- Type of Powerhouse = Surface Powerhouse
- Number of Units = 4, Francis 1000 rpm
- Tailrace = 20 m

5.4 COMPARISON OF ALTERNATIVE LAYOUTS

5.4.1 Gross Head and Power Potential

The gross head for both Alternates is 156 m. The power potential for both alternates has been estimated as 22 MW.

5.4.2 Project Layout

Both Alternates have same weir, intake, sandtrap, and powerhouse sites. Alternate-I has headrace tunnel whereas Alternate-II has headrace low pressure pipe.

The project layout of Alternate-I comprise of surface as well as underground structures. The construction of 3.1 km long headrace tunnel is the main task for Alternate-I.

For Alternate-II, a 3.075 km long pressure pipe is relatively easy to construct. Topography for pressure pipe in later portion is steep but rock is available to support the pressure pipe.

Due to weak geological formation in about 35 % length for headrace tunnel, Alternate-I is considered difficult to be constructed as compared with the Alternate-II. Generally, Alternate-II is easy to build and to operate as compared to Alternate-II.

5.4.3 Snowfall and Landslides

The snowfall and landslides would affect the stability and operation of surface structures. Alternate-II has all embedded structures whereas Alternate-I has partial surface and partial underground structures.

5.4.4 Project Cost

The project costs for both alternates have been estimated. Alternate-I with headrace tunnel has a base cost of US$ 41.715 million whereas the base cost for Alternate-II is US$ 31.755 million. Alternate-I has about 31% more cost as compared with Alternate-II.

5.5 SELECTED LAYOUT

The project cost for the Alternate-II is less as compared with Alternate-I. For less project cost, the generation cost for Alternate-II is lower than that of Alternate-I.

The project layout for Alternate-II is easy to construct and can be managed in a shorter period as compared with Alternate-I. Due to lower cost, and relatively easy construction, Alternate-II is preferred over Alternate-I.

Project layout of Alternate-II as shown in the **Dwg. No. 5-2** is selected for optimisation, design of structures and investigations.

6 PROJECT SIZING AND POWER POTENTIAL

6.1 GENERAL

For the selected project location and project layout, project sizing have been carried out by considering various design discharges ranging from 10 m^3/s to 28 m^3/s with an interval of 2 m^3/s. The weir will provide a full supply level of 2264 m asl at intake. Approximately 3075 m long pressure pipe has been proposed for the selected project layout.

The discharge data near weir site shows that the mean monthly discharge varies from 2.04 m^3/s to 51.12 m^3/s. The capacity optimisation has been carried out by selecting various design discharges. The benefits and cost have been estimated for various design discharges and the plant has been optimised on the basis of marginal cost and average cost of generated unit. Sensitivity analyses concerning the hydrology and project cost has also been carried out for the selected plant capacity. The aim of project optimisation is to have an optimum capacity of the plant by utilising the full potential of the site. The project would be developed for its interconnection to National Grid. The project would be operated as run-of-river plant.

6.2 HYDROLOGY

The estimation of flows has been made by establishing a correlation with the other gauging stations in the area having similar catchment features. The estimated mean annual flow at weir site of Jagran-IV is 15.59 m^3/s. The estimated mean monthly flow for an average year is graphically presented in **Figure - 6.1**.

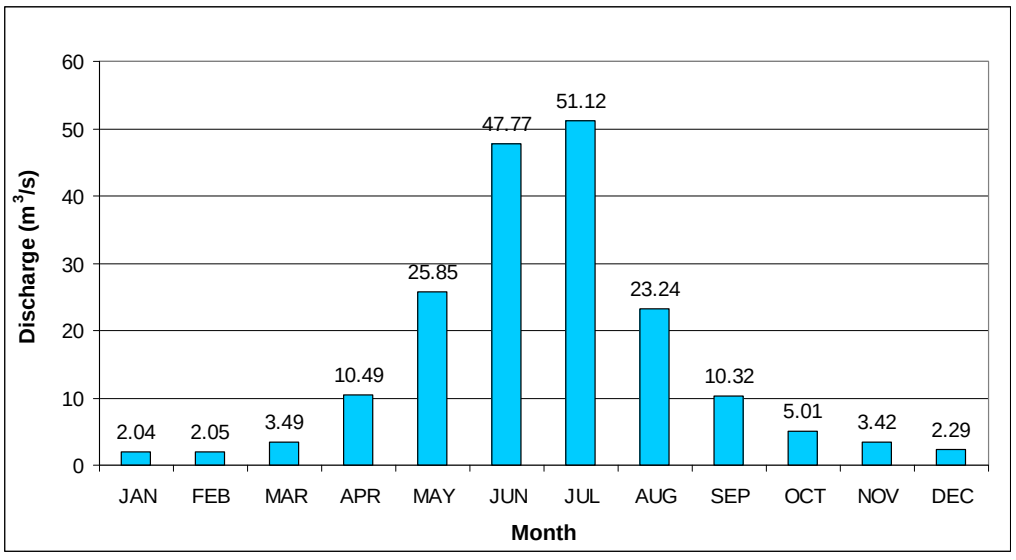


Figure - 6.1: Mean Monthly Flows at Weir Intake - Jagran - IV

The monthly flow varies from 2.04 to 51.12 m^3/s on average flow year basis. The design discharge range has been selected from the monthly flows range.

6.3 CAPACITY OPTIMISATION

The optimisation procedure involves first to estimate power and energy benefits for each design discharge of the hydropower project. The benefits for hydropower project are estimated from the cost of alternate source of equivalent energy production.

In this regard, the marginal cost parameters have been used which are derived from the tariffs offered to the power utilities. The benefits of the project consider the energy produced as well as to the firm capacity available. The optimum installed capacity is the one which maximises the difference between benefits and costs.

For the proposed Jagran-IV Hydropower Project, the daily discharge data indicates that a discharge of 10 m^3/s, 15 m^3/s, 20 m^3/s and 25 m^3/s are available for duration of 41.66%, 32.7%, 25.71% and 21.75% of the time respectively during the year.

For optimising the design discharge for power generation and energy estimation, a discharge range from 10 to 28 m^3/s has been considered to select the optimum design discharge. The optimum discharge would be the one at which generation cost, that is cost per kWh, is minimum and the NPV is maximum.

The power and energy has been estimated for each discharge range from 10 to 28 m^3/s. The gross head and net head are estimated from difference of head and tail water levels. The tail water fluctuations have also been considered. The reservoir level has been considered constant as 2264 m asl and tail water level is considered as 2108 m in Jagran - IV.

6.3.1 Compensation Flows

The power and energy are estimated on the basis of mean monthly discharges for average year. For sediment flushing, it has been assumed that power station may have to be shut down for a few hours during summer months.

A compensation flow from 0.30 m^3/s in winter six months and 0.60 m^3/s in summer months has been considered to be released from the weir as residual flows in Jagran River. The compensation flows would be released considering the downstream ecological and biological use and downstream water uses.

6.3.2 Head Losses

Head losses have been estimated based on the monthly flows through water ways. The losses from intake to turbine axis vary from 1.97 to 11.82 m. The losses are more in summer flows and are reduced to minimum in winter months.

The power and energy are estimated for the various design discharges and are presented as **Annexure 6-1.**

6.3.2.1 Project Benefits

Project benefits have been estimated equivalent to the cost of alternative gas turbine generation. The cost of not constructing gas power generation is taken as benefits to hydropower generation. Capacity and energy benefits for each design discharge have been estimated and added up to get the total benefits. The difference of benefits to cost of hydropower station for a particular discharge is compared with that of other discharges.

The Capacity Cost per kW in this case is US$ 80 and the corresponding Energy Costs per kWh peak and off peak in US cents for each month based on the recent alternate source of power and energy are as follows:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Peak	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98
Off-Peak.	7.98	7.62	7.25	6.63	6.24	5.95	5.70	5.70	5.95	6.63	6.63	7.26

The aim of the project sizing is to recommend a robust and stable solution for the so-called optimum installed capacity of the project. For the respective design discharges, monthly power, peak and off-peak energy have been estimated.

With the derived capacity and energy cost, total benefits for each design discharge have been estimated in a spread sheet. For each design discharge, net benefit and generated unit cost have been compared to get the optimum design discharge.

6.3.2.2 Cost Estimation

For the selected alternative, cost estimation has been carried out by a computer programme for various design discharges ranging from 10 m^3/s to 28 m^3/s with interval of 2 m^3/s. Data of various project components are inserted as input data for the computer programme. Unit rates of various civil works and E&M equipment are listed in separate file which is updated with price Index. The costing programme computer the dimensions of the structure for specific design discharge and gross head of the scheme.

The output of the programme provide the detailed cost estimates which includes the cost for civil works, E&M equipment, transportation, erection and commissioning. Further, the supervision charges, contingencies, import charges and owner cost have been added to prepare the project base cost.

Interest during construction and transmission line cost is added to the base cost for total project cost. The cost estimates have been made for each discharge scenario. Cost for transmission line of 132 kV from Jagran-IV to Jagran-I has also been considered. A comparison of cost estimates for various design discharges has been made and is presented in **Table - 6.1**.

Table - 6.1: Jagran-IV Hydropower Project - Comparison of Cost

Sr. No.	Discharge (m^3/s)	Cost (million US$)
1	10.0	23.338
2	12.0	25.251
3	14.0	27.322
4	16.0	29.562
5	18.0	31.987
6	20.0	34.609
7	22.0	37.447
8	24.0	40.518
9	26.0	43.841
10	28.0	47.436

A comparison of cost estimates for various design discharges has been made and is presented in **Table - 6.2 to Table - 6.4**.

Table - 6.2: Normal Cost Run-of-River Option

DESIGN DISCHARGE	CAPACITY	TOTAL ENERGY	PLANT FACTOR	TOTAL BENEFITS	TOTAL ANNUAL COST	COST/kWh	B / C	NPV
m^3/s	MW	GWh	(%)	million Rs.	million Rs.	million Rs.	-	million US$
10.0	12.2	69.93	65.3	434.43	353.92	5.061	1.118	7.269
12.0	14.7	77.15	60.0	475.80	382.68	4.960	1.133	8.408
14.0	17.1	84.37	56.3	517.17	413.78	4.905	1.139	9.335
16.0	19.6	91.59	53.4	558.54	447.42	4.885	1.137	10.034
18.0	22.0	98.20	51.3	599.91	483.80	4.897	1.129	10.484
20.0	24.5	106.02	49.5	641.39	523.15	4.934	1.117	10.677
22.0	26.9	112.55	47.8	678.88	565.71	5.026	1.093	10.219
24.0	29.3	117.81	45.8	709.26	611.74	5.193	1.056	8.806
26.0	31.8	121.39	43.6	729.59	661.53	5.450	1.004	6.145
28.0	34.2	124.97	41.7	749.92	715.39	5.725	0.955	3.118

Table - 6.3: 10% Increased Cost Option

DESIGN DISCHARGE	CAPACITY	TOTAL ENERGY	PLANT FACTOR	TOTAL BENEFITS	TOTAL ANNUAL COST	COST/kWh	B / C	NPV
m^3/s	MW	GWh	(%)	million Rs.	million Rs.	million Rs.	-	million US$
10.0	12.2	69.93	65.3	434.43	388.49	5.555	1.385	4.148
12.0	14.7	77.15	60.0	475.80	420.08	5.445	1.401	5.031
14.0	17.1	84.37	56.3	517.17	454.25	5.384	1.408	5.682
16.0	19.6	91.59	53.4	558.54	491.20	5.363	1.405	6.080
18.0	22.0	98.20	51.3	599.91	531.17	5.376	1.395	6.207
20.0	24.5	106.02	49.5	641.39	574.41	5.418	1.379	6.048
22.0	26.9	112.55	47.8	678.88	621.17	5.519	1.349	5.211
24.0	29.3	117.81	45.8	709.26	671.75	5.702	1.303	3.387
26.0	31.8	121.39	43.6	729.59	726.46	5.985	1.239	0.282
28.0	34.2	124.97	41.7	749.92	785.64	6.287	1.178	-3.226

Table - 6.4: Reduced Flows Option

DESIGN DISCHARGE	CAPACITY	TOTAL ENERGY	PLANT FACTOR	TOTAL BENEFITS	TOTAL ANNUAL COST	COST/kWh	B / C	NPV
m^3/s	MW	GWh	(%)	million Rs.	million Rs.	million Rs.	-	million US$
10.0	12.2	61.84	57.7	378.49	362.21	5.857	1.045	1.470
12.0	14.7	69.07	53.7	419.90	391.38	5.667	1.073	2.575
14.0	17.1	76.29	50.8	461.30	422.91	5.543	1.091	3.466
16.0	19.6	82.61	48.2	497.22	457.01	5.532	1.088	3.631
18.0	22.0	86.20	44.7	517.56	493.87	5.730	1.048	2.140
20.0	24.5	89.78	41.9	537.91	533.72	5.945	1.008	0.378
22.0	26.9	93.36	39.6	558.25	576.81	6.178	0.968	-1.676
24.0	29.4	96.95	37.7	578.60	623.40	6.430	0.928	-4.045
26.0	31.8	100.53	36.1	598.94	673.77	6.702	0.889	-6.757
28.0	34.3	104.11	34.7	619.29	728.24	6.995	0.850	-9.838

6.4 MARGINAL COST ANALYSIS

For the selected layout, benefits and costs have been calculated for the selected range of discharge of 10.0 m^3/s to 28.0 m^3/s for run-of-river, increased cost and reduced flows scenario.

The summary of analysis for three scenarios is presented in the **Table - 6.2 to Table - 6.4**.

Three parameters i.e. NPV, Cost / kWh and Benefit-Cost ratio have been checked for various discharges. NPV vs discharge curves are drawn for the three scenarios and presented in **Figure - 6.2**. It indicates that all three options have same trend, i.e., NPV first increases and then decreases with the increase in discharge. For the run-of-river option and increased cost scenarios, NPV is maximum at discharge of 20.0 m^3/s and for reduced flows; it is maximum at a discharge of 16.0 m^3/s.

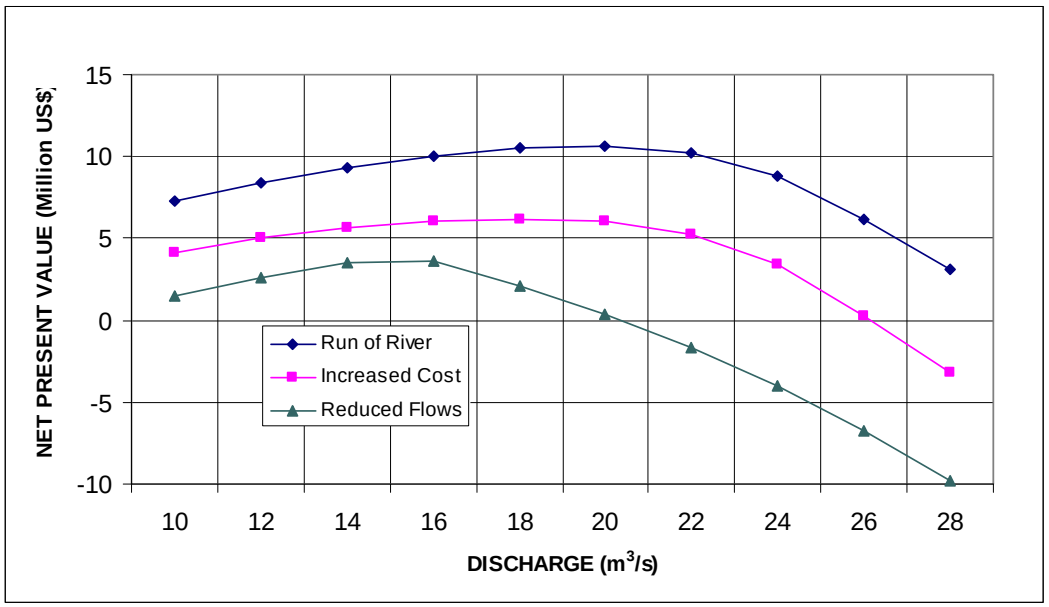


Figure - 6.2: NPV Curve for Various Scenarios

Similarly, the unit cost vs discharge curves are drawn for above mentioned three scenarios and are presented in **Figure - 6.3**.

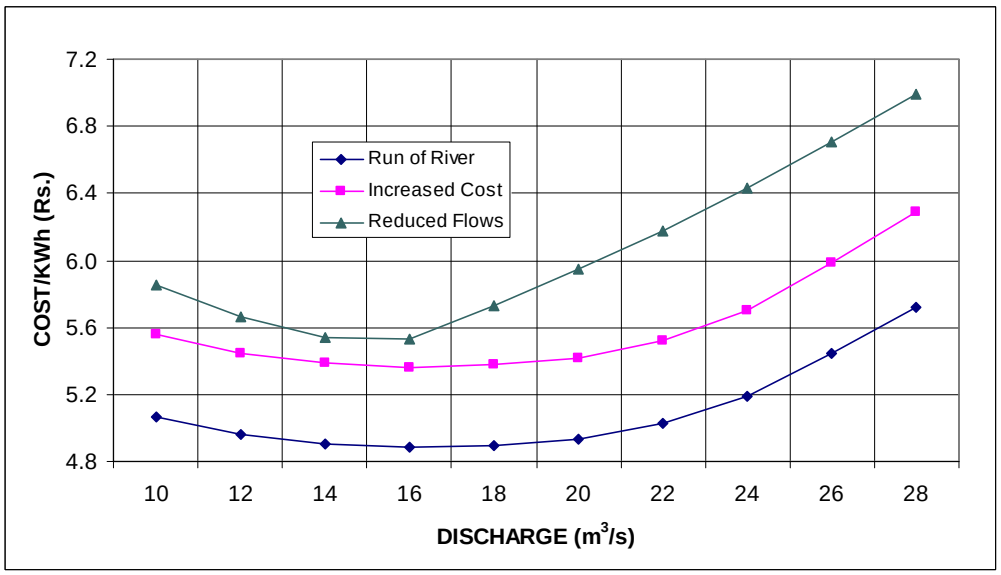


Figure - 6.3: Cost/kWh Curve for Various Scenarios

The graph indicates that unit cost for all three scenarios decreases to a minimum and then it increases again. The analysis for all three options indicates that unit cost is minimum for design discharge of 16.0 to 18.0 m^3/s.

Benefit cost ratio has also been checked for various discharges. The B/C ratio versus discharge curves are drawn for above mentioned three scenarios and is presented in **Figure - 6.4**.

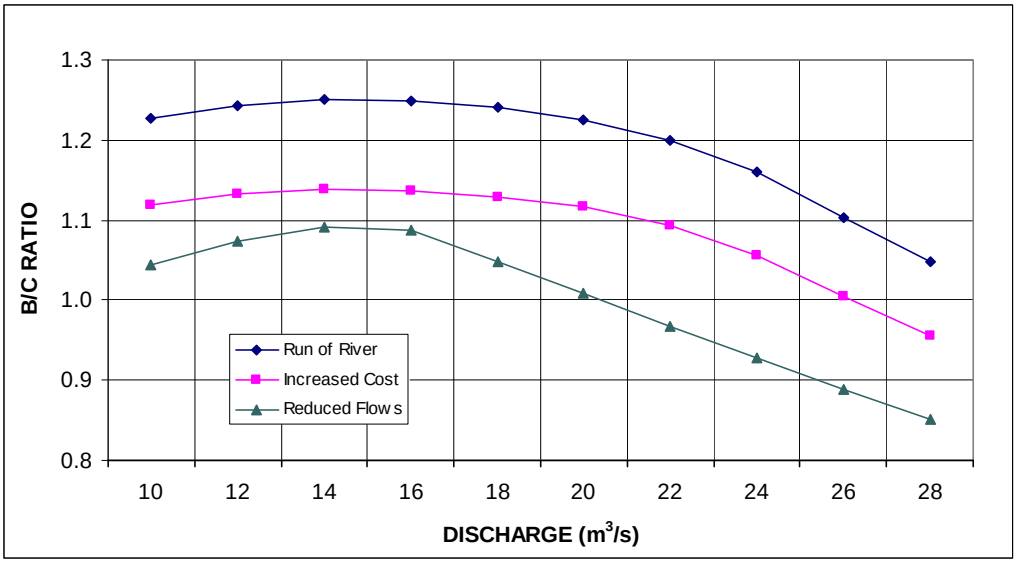


Figure - 6.4: B/C Ratio Run-of-River - Base Case

The graph indicates that B/C ratio increases to maximum and then it decreases for higher discharge. All three options indicates that B/C ratio have similar trend and is maximum at design discharge of 16.0 m^3/s and is close to maximum at discharge of 18.0 m^3/s.

6.5 SELECTED CAPACITY

The optimisation has been carried out for the three scenarios, i.e., run-of-river option, 10% increased cost and with the dry year reduced flows. Net present value, cost per kWh and B/C ratio has been considered in selecting the optimum capacity of the plant.

For base case 100% project cost and the run-of-river option, NPV and B/C ratio are maximum and unit cost is minimum at design discharge of 18.0 m^3/s.

Based on higher NPV for various scenarios, 18.0 m^3/s has been selected as optimum design discharge to determine the plant output and to dimension the various components of the project.

The design discharge of 18.0 m^3/s, available 28.7% time of the year would provide 22.0 MW power and 98.20 GWh of annual energy with the plant factor of 51.25%.

The change of mode of operation or increase in cost or change in flow pattern will naturally affect power and energy output and consequently the project benefit and unit cost scenario, but will not change the optimum design discharge.

6.6 POWER AND ENERGY

For the selected design discharge and gross head of 156 m, the power and energy have been estimated on the basis of monthly flows. The power station would be operated as run-of-river basis.

For the design discharge of 18.0 m^3/s and gross head of 156 m, the capacity would be 22 MW with the mean annual energy of 98.20 GWh. The plant factor is estimated as 51.25%.

The estimated mean monthly power is presented in **Figure - 6.5**.

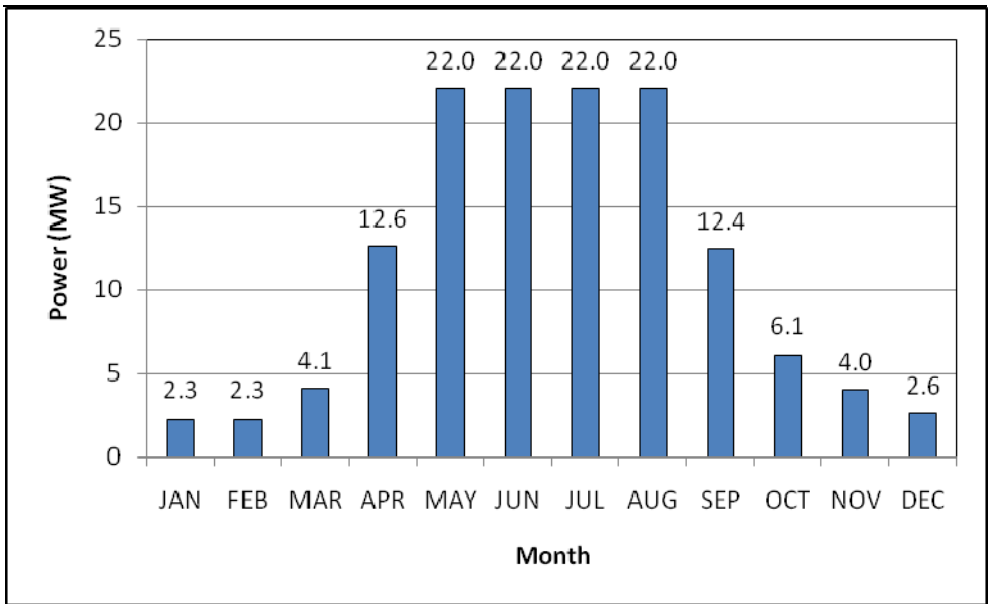


Figure - 6.5: Estimated Mean Monthly Power

From May to August, installed capacity of 22.0 MW would be available. The power would be reduced to 2.3 MW in January and February.

In the remaining months, the power would be between 2.6 MW to 22.0 MW.

The energy is directly proportional to the volume of water available for the power generation. The mean monthly energy generated has been estimated and is presented in **Figure - 6.6**.

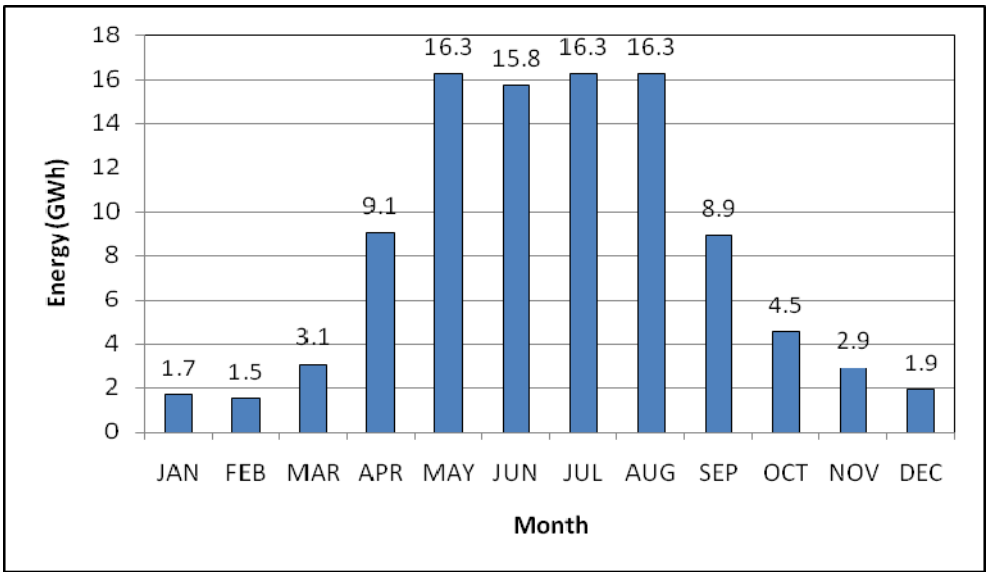


Figure - 6.6: Estimated Mean Monthly Energy

ESTIMATION OF POWER AND ENERGY

Q = 10.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	10.00	4.95	151.1	12.7	9.47
JUN	47.77	10.00	4.95	151.1	12.7	9.17
JUL	51.12	10.00	4.95	151.1	12.7	9.47
AUG	23.24	10.00	4.95	151.1	12.7	9.47
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
	15.59	6.34	3.53			**71.21**
					Plant Factor (%)	**63.85**

ESTIMATION OF POWER AND ENERGY

Q = 12.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	12.00	6.30	149.7	15.1	11.26
JUN	47.77	12.00	6.30	149.7	15.1	10.90
JUL	51.12	12.00	6.30	149.7	15.1	11.26
AUG	23.24	12.00	6.30	149.7	15.1	11.26
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
	15.59	7.01	3.98			**78.32**
					Plant Factor (%)	**59.06**

ESTIMATION OF POWER AND ENERGY

Q = 14.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	14.00	7.89	148.1	17.5	13.00
JUN	47.77	14.00	7.89	148.1	17.5	12.58
JUL	51.12	14.00	7.89	148.1	17.5	13.00
AUG	23.24	14.00	7.89	148.1	17.5	13.00
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
	15.59	7.68	4.51			**85.22**
					Plant Factor (%)	**55.67**

ESTIMATION OF POWER AND ENERGY

Q = 16.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	16.00	9.73	146.3	19.7	14.67
JUN	47.77	16.00	9.73	146.3	19.7	14.20
JUL	51.12	16.00	9.73	146.3	19.7	14.67
AUG	23.24	16.00	9.73	146.3	19.7	14.67
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
	15.59	8.34	5.12			**91.85**
					Plant Factor (%)	**53.16**

ESTIMATION OF POWER AND ENERGY

Q = 18.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	18.00	11.82	144.2	22.0	16.27
JUN	47.77	18.00	11.82	144.2	22.0	15.75
JUL	51.12	18.00	11.82	144.2	22.0	16.27
AUG	23.24	18.00	11.82	144.2	22.0	16.27
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
Mean	15.59	9.01	5.82			**98.20**
					Plant Factor (%)	**51.25**

ESTIMATION OF POWER AND ENERGY

Q = 20.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	20.00	14.15	141.8	23.9	17.79
JUN	47.77	20.00	14.15	141.8	23.9	17.22
JUL	51.12	20.00	14.15	141.8	23.9	17.79
AUG	23.24	20.00	14.15	141.8	23.9	17.79
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
Mean	15.59	9.68	6.60			**104.21**
					Plant Factor (%)	**49.75**

ESTIMATION OF POWER AND ENERGY

Q = 22.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	22.00	16.73	139.3	25.8	19.21
JUN	47.77	22.00	16.73	139.3	25.8	18.59
JUL	51.12	22.00	16.73	139.3	25.8	19.21
AUG	23.24	21.24	15.72	140.3	25.1	18.68
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
Mean	15.59	10.28	7.37			**109.33**
					Plant Factor (%)	**48.33**

ESTIMATION OF POWER AND ENERGY

Q = 24.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	23.85	19.33	136.7	27.5	20.44
JUN	47.77	24.00	19.55	136.4	27.6	19.87
JUL	51.12	24.00	19.55	136.4	27.6	20.53
AUG	23.24	21.24	15.72	140.3	25.1	18.68
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
Mean	15.59	10.77	8.06			**113.16**
					Plant Factor (%)	**46.80**

ESTIMATION OF POWER AND ENERGY

Q = 26.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	23.85	19.33	136.7	27.5	20.44
JUN	47.77	26.00	22.62	133.4	29.2	21.04
JUL	51.12	26.00	22.62	133.4	29.2	21.75
AUG	23.24	21.24	15.72	140.3	25.1	18.68
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
Mean	15.59	11.10	8.57			**115.54**
					Plant Factor (%)	**45.13**

ESTIMATION OF POWER AND ENERGY

Q = 28.0 m^3/s

Month	Discharge (m^3/s)		Head Loss	Net Head	Power	Energy
	River	Power	(m)	(m)	(MW)	(GWh)
JAN	2.04	1.74	1.97	154.0	2.3	1.68
FEB	2.05	1.75	1.97	154.0	2.3	1.53
MAR	3.49	3.19	2.19	153.8	4.1	3.08
APR	10.49	9.89	4.88	151.1	12.6	9.07
MAY	25.85	23.85	19.33	136.7	27.5	20.44
JUN	47.77	28.00	25.93	130.1	30.7	22.10
JUL	51.12	28.00	25.93	130.1	30.7	22.84
AUG	23.24	21.24	15.72	140.3	25.1	18.68
SEP	10.32	9.72	4.78	151.2	12.4	8.92
OCT	5.01	4.71	2.56	153.4	6.1	4.53
NOV	3.42	3.12	2.18	153.8	4.0	2.91
DEC	2.29	1.99	2.00	154.0	2.6	1.92
Mean	15.59	11.43	9.12			**117.69**
					Plant Factor (%)	**43.77**

7 CIVIL ENGINEERING DESIGN

7.1 GENERAL

The project layout of Jagran-IV Hydropower Project has been planned to utilise the optimum potential for generation of electric power. The mean annual flow of Jagran River has been estimated as 15.59 m^3/s and the bed gradient in 3.75 km stretch of Jagran River is about 5.5 %.

The design discharge has been optimised as 18.0 m^3/s to produce power generation of 22 MW by using a gross head of 156 m. The project would be operated as run-of-river and all structures have been designed at the optimum discharge of 18.0 m^3/s.

The project layout is presented in **Dwg. No. 7-1**.

The main project components are:

- Diversion weir with sediment sluice
- Power Intake with connecting channel
- Surface sandtrap with two (2) chambers
- Low pressure pipe of 3075 m length
- Surge pipe
- Embedded penstock of 180 m length
- Surface powerhouse fitted with Francis turbines (3 x 6 MW and 1 x 4 MW)
- Tailrace of 20 m length

As Line of Control is away from Thunian village, therefore most of structures have been proposed as surface but due to snow fall in the area during winter, embedded structures are preferred. The project can be developed to its optimum capacity of 22 MW to meet the power demand of AJ&K. The installed capacity will be available during summer months from May to August. In winter months, a minimum of 2.3 MW will be available during January and February.

The proposed unit of 4.0 MW will be capable of generating minimum power of 2.3 MW in low flow period. The power and energy of the optimum capacity can fully be utilised when the power station is connected with National Grid.

The water level profile at various structures is given in **Table - 7.1**.

Table - 7.1: Water Level Profile

No.	Location	Elevation (m asl)
1	Water level at intake	2264.00
2	Water level at sandtrap intake	2263.80
3	Water level at sandtrap outlet	2263.65
4	Water level at surge	2253.50
5	Penstock outlet	2252.90
6	Turbine shaft axis level	2105.0
7	Tailrace minimum water level	2108.00

Hydraulic design calculations of all the structures are provided in the **Table - 7.2 to Table - 7.6**.

The description of structure dimensions is provided in the following paragraphs:

7.2 DIVERSION WEIR

The weir is located about 150 m downstream of the confluence of Baihk nullah with Jagran River. At the proposed weir axis, the river bed level is 2258 m asl and the river in this stretch flows with average gradient of about 5.5 %. To divert the design discharge of 18.0 m^3/s first to connecting channel and then to low pressure pipe, a concrete weir of 6 m height above the river bed has been proposed. The intake structure has been designed to take the design discharge and excessive flow is spilled over the main weir down to river.

At the proposed weir axis, the river width is about 30 m. To accommodate a design flood of 419 m^3/s, the length of weir including the sluicing portion is 33 m.

During summer months from May to August, the water will flow over 24 m length of the weir. On the left side of the weir, a gated flushing section is provided to keep the intake free of sediment. The crest level of sluice is at 2258.00 m asl.

According to surface geological investigations of weir site, the structure will be founded on alluvial strata. This material has high leakage / seepage rate. To reduce the leakage / seepage up to desired level and also to control piping effect a cut - off wall up to 8 m depth along the weir axis has been foreseen.

7.2.1 Design Considerations

Following major design considerations have been adopted while designing the proposed weir for the proposed layout of Jagran-IV Hydropower Project:

- The diversion weir has been designed for 500 year return period flood.
- The crest elevation of weir has been fixed in consideration of power intake of connecting channel.
- The weir crest has been fixed in a manner so as to minimise the excavation and concrete work for the weir, and also to pass the design flood over the weir without much raised water level upstream of the weir.
- The location of weir has been selected in a way to have smooth and straight flow conditions at upstream and downstream of the weir structure.

The following design parameters have been adopted while making the calculations for the weir.

- Design flood of 500 years return period — 419 m^3/s
- Maximum height to pass 500 years flood — 2.57 m
- Weir crest length — 24 m
- Weir crest elevation over flow portion — 2264.0 m asl
- Weir crest elevation under sluice — 2258.0 m asl
- Roller bucket level — 2258.5 m asl

7.2.2 Over Flow Section

The over flow section of the weir has been proposed with 6 m height above river bed. The water is retained upstream of weir and the velocity is slow down. This section of the weir consists of a fixed weir with roller bucket at downstream end. The weir crest length is 24 m at an elevation 2264.0 m asl.

The spilling section is designed for a discharge of 190 m^3/s, and the under sluice would take the balance flood of 229 m^3/s. It is assumed that out of two under sluices, at least one could be operative along with over flow section.

The energy dissipation will be made by providing a roller bucket at the downstream side. The total length of weir structure including the roller bucket will be 24 m. Stone pitching has been proposed in about 20 m length downstream of the toe of roller bucket to avoid any scouring effect in downstream area. The abutment level will be 2267.0 m asl on upstream and 2264.0 m asl on downstream side. In the stone pitching area, embankment slopes will also be strengthened with stone pitching with sealing foil underneath.

The left bank portion of weir would be excavated first to construct flushing channel and power intake. This activity would be completed in low flow season and during that period the river would be diverted through right side. The diversion will be made with the help of diversion dyke.

The salient features of weir are as follows:

- River bed level at weir site — 2258.0 m asl
- Top level of weir — 2264.0 m asl
- Height of weir above river bed — 6.0 m
- Length of overflow weir crest — 24.0 m
- Foundation depth — 2.0 m
- Flood discharge — 419 m^3/s
- Flood for overflow section — 190 m^3/s
- Structural material — RCC

The design calculations of weir are presented in **Table - 7.2**. The weir plan and sections are shown in **Dwg. No. 7-6 and Dwg. No. 7-7**.

Table - 7.2: Hydraulic Calculation for Overflow Weir

Discharge	Q =	**190**	m^3/s
Crest Width (as per site conditions)	B =	**24**	m
Gravity	g =	9.81	m/s^2
Water Height over Weir from Formula : **$Q= 2/3\mu B (2g)^{0.5} h^{1.5}$**			
Height of Water above Crest	**h =**	**2.57**	m
Upstream Bed Level (as per site condition)		2258.00	m
Weir Crest Level (assumed to pass flood)		2264.00	m
Water Level at Flood (crest Elev.+h)		2266.57	m
Side Wall Level		2267.00	m

7.2.3 Flushing Channel Section

On the left side of the weir, two under sluice sections are provided to flush down the sediment into Jagran River. Along the river the flushing section varies from 2258.0 to 2256.0 m asl over a length of 14 m. The entire length of each flushing channel has a rectangular shape with clear width of 4.0 m. This arrangement has been made to increase the efficiency of the flushing section and to make sediment free area in front of power intake of the project.

The flushing section is equipped with two hydraulically operated radial gates for flushing of sediment. The gates will be 4.5 m high and 4.0 m wide. The gate must allow operation with full water pressure at the upstream side. The gate will be guided between the downstream guide rails and the upstream counter guide, where the machined seal sliding strips of stainless steel are provided.

Stop log grooves at upstream of vertical flushing gate have been provided to seal area during repair work of the gate. The wooden stop logs would be designed for lifting by a mobile crane. One grappling beam shall enable the placing and pick-up of the stop log.

The design calculations of undersluice are presented in **Table - 7.3**. The flushing channel section is shown in **Dwg. No. 7-8**.

Table - 7.3: Hydraulic Calculation for Undersluice

Maximum upstream Water Level		2266.0	m asl
Maximum downstream Water Level		2260.0	m asl
Upstream Bed Level		2258.0	m asl
Downstream Bed Level		2256.0	m asl
Design Discharge		229	m^3/s
Width of Undersluice		4.0	m
Height of Undersluice		4.0	m
CAPACITY OF UNDERSLUICE			
	$X = \{1/(1+fi+fo+fc+ffr)\}^{0.5}$		
where			
Coefficient for Intake Losses = fi		0.06	
Coefficient for Outlet Losses = fo		1	
Coefficient for change in Cross Section = fc		0.04	
Coefficient for Friction Losses = ffr			
Stickler's Coefficient = k		70	
	ffr =	0.21	
	X =	0.66	
	V = X (2gh)^0.5	7.18	m/s
	Q =	**229.0**	m^3/s

7.2.4 Gates and Stop Logs

There should be one set of wooden stop logs with a width of 4.2 m and height of 4.5 m with bottom pressure of 1 bar. The stop logs should be designed for lifting by a mobile crane. The sealing of the panels at the non-pressure side shall be provided with music-note type seals. All screws and sealing strips shall be of stainless steel. The stop logs are sub-divided horizontally in parts to reduce the weight to be lifted. One grappling beam shall enable the placing and pick-up of the stop logs.

The servomotor, mounted vertically on a support should allow the hoisting of the gate above the maximum water level. The weight should be increased, if necessary, by concrete to be filled in the lower part, in order to enable the sure closing without assistance of oil pressure.

7.2.5 Gravel Scour

On the left side of sediment sluice, a gravel sluice has been proposed to flush the sediments in front of the power intake. Between the main sediment sluice and the gravel sluice, there is a divide wall constructed mainly to keep the sediment free area in front of the power intake. The gravel scour will be equipped with 1 m x 1 m gate.

7.3 POWER INTAKE

The intake has been designed keeping in view to minimise the head losses at entrance and to avoid entering bed load and other floating debris in the connecting channel. The gross area of intake is 19.6 m^2. The lower sill level of intake is 3.40 m above the flushing bed to reduce bed load entry into the connecting channel.

The other components of the structure include trashrack and stop log grooves. The maximum velocity at the entrance of intake is 0.92 m/s at the design discharge of 18.0 m^3/s. The structure has been designed to divert the design flow towards the connecting channel. The direction of the flow has been set at an angle to the river flow to minimise the inflow of sediments.

The width of stop log gates to be provided is 3.7 m and height is 3.0 m. It will be roller gate with the bottom pressure of 1 bar. The gate must allow operation with full water pressure at the upstream side. It should be hydraulically operated by oil pressure and should be connected to the common oil pressure system. The guide rollers should be equipped with the self-lubricating bushings. The gate should be guided between the downstream lateral guide rails and the upstream counter guide, where the machined seal sliding strips of stainless steel are provided.

The bars of the rack have a circular shape with a diameter of 1.0 cm and the distance between two bars is 1.0 cm. Above the rack, there is a platform at elevation of 2267.5 m asl, which can be reached by means of iron steps. From this platform, the rack can be cleaned manually. The rack should be divided into panels of equal size, which will be connected by stiffening bars. The trash rack panels should be interchangeable and fixed by bolts made of stainless steel.

7.4 CONNECTING CHANNEL

Power channel is a rectangular RCC structure that off - takes from weir and flows at a slope of 1 in 700 along the left side of the river. It has been designed as an open channel. The channel has a maximum capacity of 18.0 m^3/s with 3.4 m width and 2.4 m water depth. The connecting channel has a length of 110 m up to the sandtrap. The connecting channel would take 20% additional discharge required for flushing of sandtrap.

The walls are vertical having internal height of 2.8 m and wall thickness is 0.5 m from top to bottom. The thickness of base is 0.5 m. The bed slope of power channel is 1:700 maintained over entire 110 m length of the channel. A 0.15 m thick PCC layer has been provided under the base of the channel to give the structure smooth surface and to transfer the load to the ground uniformly.

The salient features of the channel are as hereunder:

- Discharge 18.0 m^3/s
- Slope 1:700
- Length 110 m
- Bed Width 3.4 m
- Depth of Water 2.4 m
- Velocity 2.2 m/s
- Free Board 0.4 m

The parameters have been adopted to maintain non-silting and non-freezing velocity in the channel at design discharge as well as at minimum discharge.

Expansion joints will be provided to accommodate the expansion and contraction of concrete due to temperature variations; whereas, PVC construction joints are also provided as per requirement of the section.

7.4.1 Reject Weir

At connecting channel, upstream of the sandtrap, an over flow section is provided to drop the flows back into the river. The reject weir has a width of 10.0 m and it will spill all the excess flows from the connecting channel.

7.5 DESANDER / SANDTRAP

Sandtrap is provided to remove the suspended particles with diameter above 0.25 mm. For a design discharge of 18.0 m^3/s, two chambers have been provided. Each chamber has a length of 56 m and width of 7.0 m.

The total length is divided into the following reaches:

- Upstream Transition starting from Inlet Gate — 10 m
- Chamber length — 56 m
- No. of chambers — 2
- Maximum water depth — 6.43 to 8.11 m

The main elevations are as follows:

- Top of the sandtrap — 2265.00 m asl
- Bottom level of inlet gates — 2261.44 m asl
- Upstream elevation of bottom of chamber — 2257.41 m asl
- Downstream elevation of bottom of chamber — 2255.73 m asl
- Upstream elevation of bottom of flushing pipe — 2252.73 m asl

Table - 7.4: Hydraulic Calculation for Sandtrap

Mosonyi / Giesecke Zanke		**Units**
Q	18.0	m^3/s
Chambers	2	Nos.
Q / Chamber	9.0	m^3/s
d	0.25	mm
K (Stickler)	50.00	
Density	2.82	ton/m^3
Assume		
V	0.20	m/s
Assume width (**B**)	7.00	m
Depth (**H**)	6.43	m
Vs' = settling velocity in standing water	0.0320	m/s
Alphas α =0.132/√H	0.0572	m
Vs = settling velocity in flowing water	0.0205	m/s
Ls	46.83	m
Selected length	56.00	m

Checks		
Ls = 8*b =	56.00	m
H/B	0.92	
Vcr (Shields)	0.4186	m/s
Vcr (Camp)=0.44√d	0.2200	m/s
B	7.00	
b = (B-w) / 2	3.00	m
h	3.00	m
w	1.00	m
Slope	3.00	%
Depth at the end of slope	8.11	m
Mean area	50.88	m^2
Mean velocity	0.1769	m/s
Critical velocity	0.4186	m/s
Check:		
Mean Velocity < Critical Velocity		

The width of each chamber is 7.0 m and the water height is varying between 6.43 m at the beginning and 8.11 m at the end of the chamber. The wall thickness of the outer walls is 0.60 m.

The average net cross sectional area of each chamber is approximately 50.88 m^2, excluding the area for flushing. This corresponds to the average velocity of 0.1769 m/s for the discharge of 9.0 m^3/s. A grain size of 0.25 mm was selected as minimum diameter to be settled in the desander / sandtrap. The plan and sections of sandtrap are presented in **Dwg. No. 7-10**.

The flushing channels have a trapezoidal cross-section with an area of 12 m^2. The slope of these channels, which can be flushed by small vertical lifting gates, is 3 %. A sand-flushing pipe with a diameter of 1.5 m leads from sandtrap back to Jagran River.

7.5.1 Hydraulic Steel Structures

7.5.1.1 Inlet Gate

There would be two inlet gates, with 4.3 m width and 3.2 m height. The gates must allow operation with full water pressure at the upstream side. They should be hydraulically operated by oil pressure and should be connected to the common oil-pressure system with gravel flush gate. The guide rollers should be equipped with self-lubricating bushings.

The gates should be guided between the downstream lateral guide rails and the upstream counter guide, where the machined seal sliding strips of stainless steel are welded.

The servomotor, mounted vertically on a support should allow the hoisting of the gate above the maximum water level. The weight should be increased, if necessary by concrete to fill in the lower part in order to enable the sure closing without assistance of oil pressure.

7.5.1.2 Outlet Gate

At the end of flushing chamber, two outlet gates are required. Each gate width is 7.2 m and height is 3.8 m. The gates must allow operation with full water pressure at the upstream side. They should be hydraulically operated by oil pressure and should be connected to the common oil-pressure system placed in the station building. The guide rollers should be equipped with self-lubricating bushings. The gates should be guided between the downstream lateral guide rails and the upstream counter guide, where the machined seal sliding strips of stainless steel are welded.

The servomotor, mounted vertically on a support should allow the hoisting of the gates above the maximum water level. The weight should be increased, if necessary by concrete to fill in the lower part in order to enable the sure closing without assistance of oil pressure. Gates position switches must be provided for remote control.

7.5.1.3 Sand Flushing Gates

Two sand flushing gates will be required having width of 1.2 m and with a height of 1.2 m. The flushing gate shall be oil-pressure operated. One servomotor shall be vertically mounted in the centre of a support welded of plate steel. All parts coming into contact with sealing elements should be of stainless steel or stainless steel plated. The servomotor shall be connected to the common oil-pressure station of the inlet gates. The flushing gates should be locally controlled by hand. A remote indication of the position of the gate should be provided.

7.6 HEADRACE PRESSURE PIPE

At the downstream of sandtrap, there is trapezoidal shape tank in which water is dropped before it enters into the low pressure pipe. About 3075 m long pressure pipe has been proposed from sandtrap to surge area. The whole pipe would be embedded, placed in a trench excavated with mild slope on the left bank of Jagran valley.

Pressure pipe has been proposed with an internal diameter of 2.5 m and pipe thickness of 8 mm throughout its length. The material of headrace pressure pipe would be glass fiber reinforced plastic (GRP). At each turn of the alignment, anchor block would support the pressure pipe. The invert level of pipe at intake is 2254.0 m asl and it ends an elevation 2238.0 m asl near surge area. The design discharge of pressure pipe is 18 m^3/s and it will act as low pressure pipe.

The pressure pipe has been designed keeping in view the length of 3075 m, velocity and head losses in the pipe. The alignment of the pipe has been made keeping in view the topographical and geological conditions of the area.

The salient features of the headrace pressure pipe are as under:

- Discharge 18.00 m^3/s
- Length 3075 m
- Area 4.91 m^2
- Velocity 3.67 m/s

The longitudinal profile of the low pressure headrace pipe is presented in **Dwg. No. 7-2 to Dwg. No. 7-5** and cross section is shown in **Dwg. No. 7-14**.

7.7 SURGE PIPE

Surge pipe has been proposed to accommodate surges and will facilitate to maintain water level in headrace pipe. The surge pipe has been designed in connection with the hydraulic analysis as follows:

- The surge pipe branches at an elevation of 2238.0 m asl from the headrace pressure pipe.
- The surge pipe is of an internal diameter of 5.0 m and is of 52 m high.

The proposed layout of the surge pipe regarding the necessary surge volume, the highest and lowest surge levels are based on the most unfavourable conditions.

The design discharge is 18.0 m^3/s, when all four units are operating. A sudden shut down of all the turbines will generally be done by dissipating the jets with the deflectors which does not influence the continuous flow through the penstock.

The time needed for the subsequent closing of the turbine nozzles should be defined under the assumption, that the pressure rise in the pressure pipe should never exceed 10 % of the gross head. The oscillation in the surge pipe has to be considered when the time-stroke characteristic of the nozzles will be established. The final dimensioning of the surge pipe structures has to be optimised in detail design stage.

The preliminary data are:

- Closing time of the Nozzles: Tclno = 21 second
- Closing time of the Deflector: Tclde = 2 second
- Opening time of the Nozzles: T_{opno} = 19 second

However, to be on the safe side, a closing time of 13 second and an opening time of 12 second were used for the surge pipe calculation at the present stage.

Table - 7.5: Hydraulic Calculation for Surge Pipe

Flood level at dam, m	2264.0	**Low supply level at dam, m**	2263.0
Turbine rated head, m	154	Elevation at surge tank tee, m	2240.0
Design full load flow, m^3/s	18	Upstream conduit length, m	3075.0
Upstream Conduit Diameter, m	2.5	Avg. Manning friction coefficient	0.0091
Conduit Velocity m/s	3.67	Tank diameter, m	5.00
Elevation top of tank, m	2286.4	Elevation bottom of tank, m	2243.2
Tank height, top to bottom, m	43.20	Tank volume, m^3	848
Steel wt. in tank and legs, tons	55.57	Total ht. of tank, tee to roof, m	46.40
Acceleration n	0.010	Deceleration n	0.0086
Acceleration Head Loss, m.	9.47	Deceleration head loss, m	6.58
Acceleration c	0.704	Deceleration c	0.490
Tank Area, F m^2	14.72	Tank H/2 above tee. m	24.80
Acceleration		Deceleration	
N acc.	35.73	N dec.	24.84
K acc.	54.19	K dec.	23.12
y acc. = down surge m	9.83	Y dec. = upsurge m	28.48

The comparatively long acceleration time of the water mass in the headrace pipe resulting in a corresponding long oscillation period requires the observance of an intermediate time in the sequence of starting the turbines.

The preliminary calculation considering worst conditions leads to a necessary interval of about 200 sec before the next unit can be started. Any type of operation due to regulating conditions or due to timely peak operation with a change in discharge of less than 2.0 m^3/s with the above mentioned related closing or opening characteristics should be acceptable.

Considering a Thoma safety factor of 8.3 and the maximum and minimum water level respectively at the intake, the calculated surge levels are:

- Maximum Surge Level: 2286.4 m asl
- Minimum Surge Level: 2243.2 m asl

7.8 PENSTOCK

Penstock pipe is a pressurized water conduit that extends from the inlet valve to the surge pipe. Out of the available options, embedded / supported penstock pipe has been proposed for the project. The pipe line comprises of individual sections welded together at site.

Expansions joints shall be provided at regular intervals to counter longitudinal stresses caused by temperature difference and by hydrostatic and dynamic pressures.

The penstock shall be supported on concrete saddles. Individual pipe sections shall be 6 meters long to facilitate handling, transportation and site erection. The pipe section near the powerhouse is of smaller diameter but with a thicker shell.

The steel plates to be used for pipes shall be manufactured and tested in accordance with ASTM specifications pertaining to pressure vessel quality. The preferred method for pipe manufacture is spiral welding that has proven to be structurally sound and more economic.

The steel plates should be fully kilned and exhibit fine-grain characteristics in coil forms. Recommended steel grade is ASTM A516 grade 51 with a yield stress of 51000 psi.

From surge pipe to inlet to the turbine, penstock pipe would laid over terraces. The penstock diameter is 2.50 m and it would be placed as embedded pipe by excavating the terraces / rock. Anchor blocks would be provided at each turning angle. From surge pipe to powerhouse, there would be three (03) anchor blocks to withstand the forces.

The steel thickness would vary as per increase in the pressure. The estimated thickness of steel at top is 10 mm and it would increase to 15 mm at the bottom. The thickness of the pipe has been calculated after considering the water pressure over and above the gross head. A 15% pressure rise has been taken in the design calculations.

From surge pipe to powerhouse, the total length of penstock would be 180 m. The diameter would be 2.5 m for the designed discharge of 18.0 m^3/s. The velocity in pressure pipe will be 3.68 m/s and head loss from surge pipe to powerhouse will be 10.2 m for the design discharge of 18.0 m^3/s.

The longitudinal section and cross section of the pressure pipe are presented in **Dwg. No. 7-5 and Dwg. No. 7-14** respectively.

7.8.1 Diameter of the Penstock Pipe

The economic diameter of penstock pipes is a trade - off between costs and the acceptable losses. An optimum penstock diameter should minimise the sum of constructions costs, maintenance costs and the costs due to head losses, i.e., the power and energy that otherwise cannot be produced due to head losses. The practical approach is to use the empirical formulae derived on the basis of experience and practice.

The recommended diameter is 2.50 m from surge area to powerhouse inlet. Hydraulic calculation for penstock is presented in **Table - 7.6**.

Table - 7.6: Hydraulic Calculations for Penstock

Discharge (Q) (assume)	18.0	m^3/s
Stickler Value : (M)	90.00	
Slope of Energy Line : S	0.0031	
Penstock dia. (d)	2.50	m
Hydraulic Radius (d/4)	0.625	m
Area ($\pi d^2/4$)	4.91	m^2
Discharge (**$Q = M R^{0.667} S^{0.5} A$**)	18.05	m^3/s
Velocity	3.68	m/s

7.8.2 Thickness of Penstock Pipe Sheet

The thickness of MS steel sheets to be used in the manufacture of the pipes has been worked out on the basis of following:

Type of joint:	Welded	
Efficiency of joint:	90%	
Head from inlet to surge pipe:	30	m
Diameter	2.5	m
Max. Allowable stress in steel	1100	kg/cm^2
Now max stress in pipe P:	P = W x H	
Where:		
W = weight of water	1000	kg/m^3
H = head in meters	30	m
P=	1000 x 30	
Max stress in the pipe =	30000	kg/m^2
Max. Allowable stress =	1100	kg/cm^2
	11000000	kg / m^2
T = P x D / 2 x f x η		
=	(30000 x 2.5) / (2 x 11000000 x 0.9)	
	0.0038	m
	3.8	mm

The calculated sheet thickness is 3.8 mm, which needs to be enhanced with a factor of safety of about 25%. This gives a sheet thickness of 4.8% which can be rounded to 5 mm. Standard sheets MS Steel of Grade 51 are available in thickness of 4, 8, 10, 12 and 14 mm from Pakistan Steel Mills. A pipe thickness of 8 mm is recommended to be used.

The penstock pipes shall be fabricated by cutting plates of required sizes and welding them after rolling for required diameter.

7.9 POWERHOUSE

The powerhouse is placed as a surface structure on the lower left bank terraces of Jagran valley about 200 m upstream of intake for Jagran-I. The powerhouse area is accessible with existing jeepable track in Jagran valley.

The powerhouse would an R.C.C frame structure of size 35.4 m length and 10.0 m wide. The powerhouse building would be 16.5 high from foundation to roof top. The building would house four Francis turbine, 3 units of 6.0 MW and one unit of 4 MW.

The powerhouse would be placed at an elevation 2101.5 m asl by excavating the surface. For powerhouse foundation, the required space for powerhouse building and transformer has to be made. Machine Hall floor would be at an El. 2111.0 m asl and powerhouse top will be 2118.0 m asl.

Turbine axis level at 2105.0 m and tail water in the channel at powerhouse is 2108.0 m. The main hall would accommodate 4 Francis units, along with generators, fly wheel, switch cabinets and erection bay.

Place required for generator panel, auxiliaries etc. have also been considered. Control room relay protection, office, battery room, store and telecommunication will be accommodated in powerhouse building. An overhead gantry crane of capacity 20 tons has been provided for placing / replacing the heavy parts of machines.

The other important features of powerhouse are as under:

- Length 35.40 m
- Width 10.00 m
- Height 16.5 m
- Foundation Level 2101.5 m asl
- Turbine Axis Level 2105.0 m asl

7.10 TAILRACE

The outflow from powerhouse will be discharged into Jagran River through a tailrace channel. The tailrace has estimated length of 20 m. It is a rectangular concrete section with 24.0 m width and with varying height from 1.0 to 9.5 m.

About 0.8 m thick concrete bed slab would be laid to join the draft tube outlet to Jagran River. Tailrace will join Jagran River with varying water level from 2108.0 to 2111.0 m asl.

8 HYDRO MECHANICAL EQUIPMENT

8.1 GENERAL

This section describes the hydro mechanical equipment required for the Jagran-IV Hydropower Project. It includes the information about mechanical equipment directly related to generating units and for general services. It also covers the characteristics of these equipment and various other factors used to establish the size and configuration of such type of equipment. Jagran-IV project area is located on the left bank of Jagran River about 18 km from its confluence with Neelum River at Kundal Shahi.

Based on 18 m^3/sec design discharge and 156 m gross head, 22 MW power can be generated with four (4) turbo generating units. This medium sized scheme is proposed to be connected with national grid to meet the power demand. The mean annual energy would be 98.20 GWh.

8.2 MAIN DESIGN PARAMETERS

8.2.1 Discharge

A single value of flow has no significance. It is very necessary to know the flow regime, commonly represented by the Flow Duration Curve as shown in the **Figure - 8.1** below. In Jagran River mean monthly flow variation is from 2.04 m^3/sec to 51.12 m^3/sec. For the flow pattern against various months, the plant capacity has been optimized at design discharge of 18 m^3/sec that is available for 29.2 % of time.

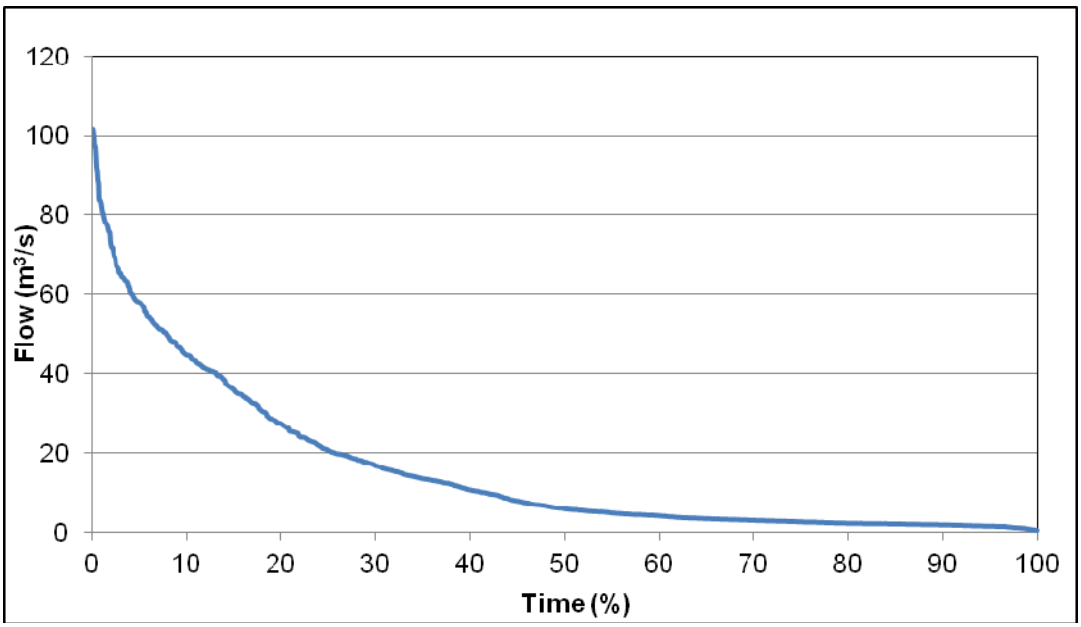


Figure - 8.1: Flow Duration Curve

The mean monthly flows are presented in **Figure - 8.2**

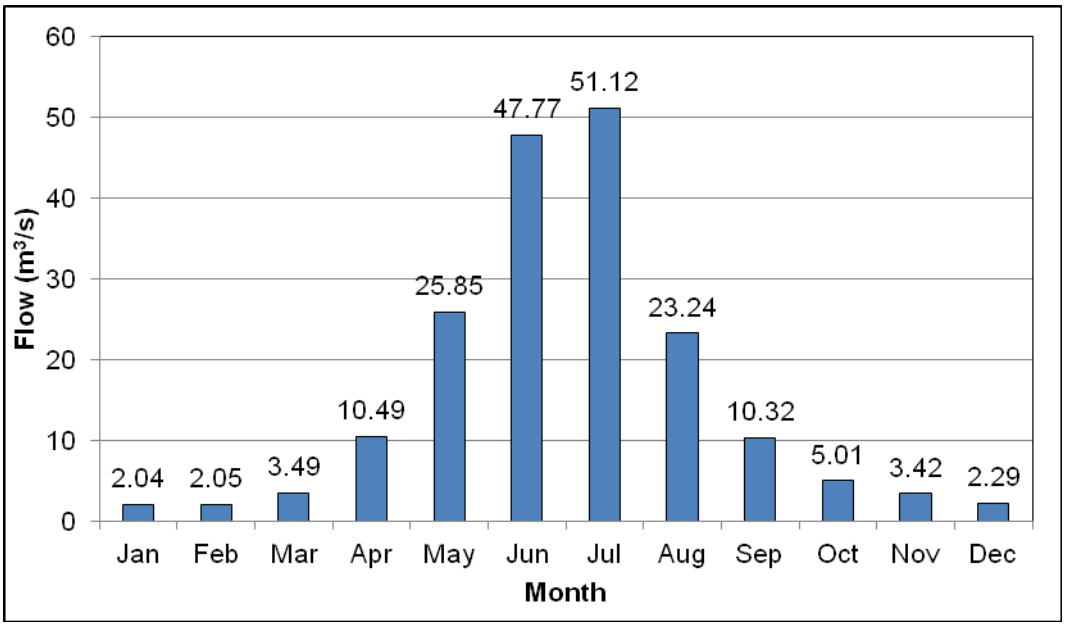


Figure - 8.2: Mean Monthly Flows

8.2.2 Head Calculations

8.2.2.1 Head Water Level

The maximum headwater level is 2264 m asl, while minimum head water level will be about 2263 m asl depending upon the flow pattern.

8.2.2.2 Tail Water Level

Since there is fluctuation of flow, thus tail water level will also be changing accordingly. Minimum tail water level has been recorded as 2108 m asl.

8.2.2.3 Gross Head

On the basis of above head water levels and turbine center line, the calculated gross head will be as follows:

- Maximum Gross Head: 156 m

8.2.2.4 Head Losses

Major head losses in the water ways are due to friction. Total length of headrace low pressure pipe is about 3075 m and proposed diameter is 2.5 m. Penstock is 180 m long and 2.5 m in diameter. Total head losses are 11.82 m WC.

8.2.2.5 Turbine Net Head

Considering the 11.82 m total head losses at rated flow of 18 m^3/sec, the net head variation with reference to available flows for generation will be as follows:

- Maximum Net Head = 154 m
- Minimum Net Head = 144.2 m
- Design Net Head = 144.2 m

8.3 PLANT CAPACITY

On the basis of selected rated discharge of 18 m^3/sec and rated net head of 144.2 m, the plant output capacity will be 22 MW and average energy available will be 98.20 GWh. The turbine centerlines will be 2.5 m and 4 m below the tail water level.

8.4 TURBINE SELECTION CRITERIA

The type, geometry and dimension of the turbine will be fundamentally conditioned by various criteria such as:

- Net Head
- Range of Discharges Through the Turbines
- Turbine Rotational Speed
- Sediment / Cavitation Problems
- Cost

Among the above criteria net head and discharge are the basic ones, while others support them.

As a first criterion for the selection of type of hydro turbine, is the head at which it is operated. In case of proposed Jagran-IV Hydropower Project, the rated effective net head will be 144.2 m. Francis type turbine is operate-able under this head condition.

However, for selecting the number of units the turbine rotational speed, shaft axis of turbine and available flow pattern will be considered.

The application ranges for different types of water turbines are presented in **Figure - 8.1**.

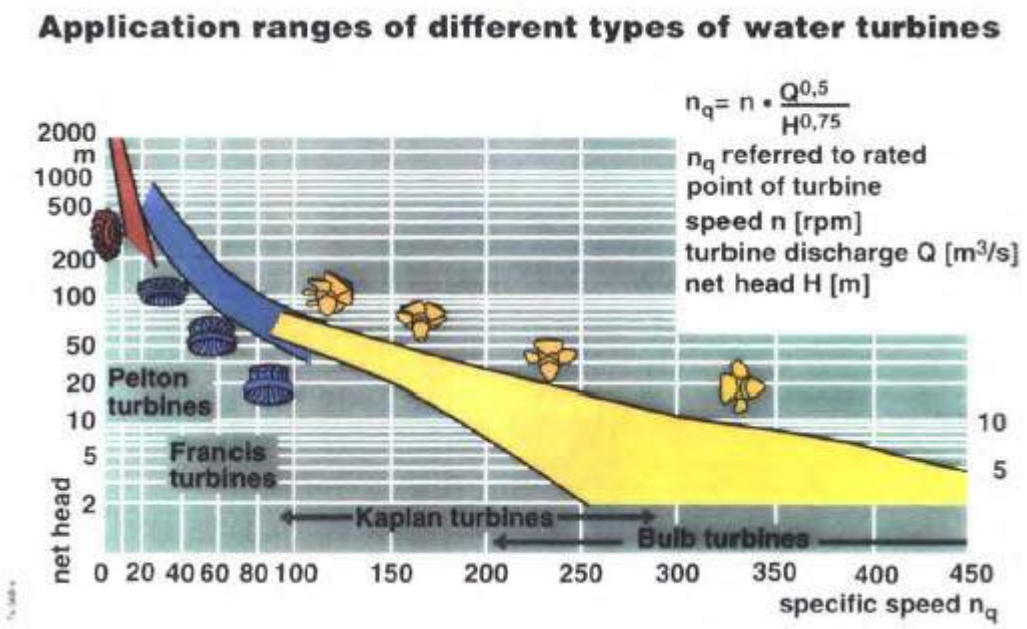


Figure - 8.3: Application Ranges of Different Types of Water Turbine

The proposed Jagran-IV Hydropower Project is a medium discharge and medium head scheme. Discharge in river varies from 2.04 m^3/s in January to 51.12 m^3/sec in July. The selected plant discharge of 18 m^3/s is available for 28.7 % of time. Since there is lot of variation of flow, thus keeping in view the flow pattern in various months and selected rated head, Francis turbine is more appropriate solution. The flow pattern also dictates higher number of units.

8.4.1 Number of Units

Normally it is most cost effective to have a minimum number of units at a given installation; however multiple units may be necessary due to various reasons. Thus for selecting number of units following factors have been considered.

- Efficient Water Use
- Getting Maximum Energy
- Space Limitation for Civil Structure
- Transportation Problems
- Maintenance View Point
- Cost Effectiveness

Based on above factors, four units have been selected for Jagran-IV Hydropower Project. Selection of the number of units has been discussed in the following paragraphs.

8.4.2 Efficient Water Use

Efficient use of available water and getting maximum energy from hydropower station is necessary to maximise the profitability. Selection of number of units plays a vital role to achieve this target. Three different alternatives having 3, 4 or 5 units for same installed capacity have been considered.

Number of units play vital role for selecting turbine rotational speed and minimum unit discharge. One major factor for evaluation of number of units is how the power station will anticipate in operation. This operational advantage will also contribute in the annual energy produced by the project. With more number of units, generation can be continued more efficiently for flows down to the minimum historic discharge, where as with less number of units this flexibility reduces.

8.4.3 Comparison of Alternatives

The following data as presented in **Table - 8.1** shows the comparison of basic data for the three alternatives.

Table - 8.1: Comparison of Basic Data

JAGRAN-IV HYDROPOWER PROJECT

Net Head: 144.2 m

Rated Flow: 18 m^3/sec

Number of Units	Nos.	3	4		5
Capacity (No. of Units x Power)		3 x 7.33	3 x 6	1 x 4	5 x 4.4
Unit Discharge	m^3/sec	6.0	4.91	3.27	3.6
Unit Orientation	Shaft axis	Vertical	Vertical	Vertical	Vertical
Rated Turbine Capacity at Shaft	MW	7.723	6.320	4.209	4.634
Plant Capacity	MW	22.0	22.0		22.0
Turbine Efficiency	%	91	91	91	91
Unit Combined Efficiency at Rated Discharge	%	86.49	86.49	86.49	86.49
Turbine Speed	rpm	1000	1000	1000	1000
Runaway Speed	rpm	1800	1800	1800	1800
Runner Diameter	m	0.713	0.71	0.73	0.725
Generator Rotor Weight	ton	17.815	15.173	11.845	11.372
Crane Capacity	ton	20	20		15
Minimum Submergence	M	- 8.04	- 4.00	- 2.50	- 3.22

8.4.3.1 Space Limitation for Civil Structure

Space limitation for the geological characteristics may dictate larger or smaller units and vertical or horizontal shaft orientation. The merits / demerits of horizontal / vertical orientation of turbine are given below.

Horizontal orientation is limited to smaller sized units up to 10 MW. Greater floor space is required for horizontal orientation installations; whereas, the lesser floor space or "footprint" is required for the vertical turbines as compared to horizontal turbines. However, the powerhouse will be taller and it may require greater powerhouse crane capacity.

In case of proposed Jagran-IV Hydropower Project, keeping in view the civil structure and the geological conditions, vertical axis turbines have been selected.

8.4.3.2 Transportation

The transportation of heavy construction and permanent equipment like (Turbine Runner, Generator Rotor, Stator and Transformers) to the site is a matter which needs careful attention.

In case of proposed Jagran-IV Hydropower Project, the transportation of light and heavy equipment from Karachi to the project area is possible in the following manner:

- By Air
- Entirely by Road
- By Rail to Rawalpindi and then by Road

Due to geographical location and costing, air transportation is not feasible while other two options are considerable and have their merits and demerits.

Entirely by road option requires more time and inconvenience to the other road users and also creates traffic problems. Thus by rail transportation from Karachi to Rawalpindi and then by road to the project site is more convenient, feasible and time saving. The initial study shows that the equipment weights of the considered alternatives are as presented in **Table - 8.2**.

Table - 8.2: Comparison of Basic Data

Components		**Alternative 01**	**Alternative 02**		**Alternative 03**
Number of Units		3	3	1	5
Generator Rotor	Tons	17.815	15.173	11.845	11.372

8.4.3.3 Conclusions

All the three alternatives have been considered at same turbine efficiency and same generator efficiency. The access road to powerhouse site compels to select the units with smaller outputs. Transportation of rotor may not be critical as it can be transported in parts and then assembled at site. The transportation of transformers without oil has been proposed.

The lesser number of units will have large output and thus larger weight of power transformers. Keeping in view the transport difficulties and cost of equipment, four (4) units have been selected for proposed Jagran-IV Hydropower Project.

8.5 TURBINE PARAMETERS

- Type of Turbine = Vertical Francis
- No. of Units = 04
- Plant Capacity P_{Total} = 22 MW
- Plant Discharge Q_{Total} = 18 m^3/s
- Unit Discharge Q_{Unit} =3.27 m^3/s & 4.91m^3/sec
- Min Unit Discharge Q_{Min} = 1.74 m^3/s
- Rated Net Head H_{Net} = 144.2 m
- Rated Generator Output P = 4 MW & 6 MW
- Rated Turbine Speed N = 1000 rpm
- Turbine Runaway Speed $N_{Runaway}$ = 1800 rpm
- Combined Unit Efficiency % = 86.49
- Runner Discharge Diameter D = 0.73 m & 0.71 m
- Minimum Submergence Hs = - 2.50 m & - 4.00 m

8.5.1 Sample Calculations

The type and dimensions of the Francis turbine can be easily determined from application guide prepared by manufacturers. The basic turbine calculations for the specific speed, turbine runner diameter etc. are as under:

- Specific Speed of the Turbine N_S
- Runner Discharge Diameter D_3
- Turbine Rotational Speed N

8.5.2 Specific Speed

As a general rule of thumb, the specific speed for a Francis turbine lies within the range of 105 ~ 257 rpm. However, it must be noted that the smaller specific speed machines are bulkier, and therefore, their transportation to the site may be problematic.

The physical size of the machine, therefore, is a critically important factor. The specific speed of a turbine is a useful index. At this speed, the unit operates at best possible efficiency under a unit head generating unit output power. The running speed of turbine is based on this basic value.

The specific speed of turbines has been worked on the basis of laws of similarity and is given by the formula:

$$N_{S\,(kW\text{-}m)} = N \times (P)^{0.5} / H^{1.25}$$

N_s: Specific speed of turbine (rpm)
P: Turbine shaft output (4209 kW & 6320 kW)
N: Running speed of turbine (rpm)
Q: Discharge per unit (3.97 m^3/sec & 4.91 m^3/sec)
H: Net design head (144.2 m)

Following basic formula for calculating the specific speed has been used:

$$N_{S\,(kW\text{-}m)} = 3470 / H_{Net}^{0.625}$$

For $H_{Net} = 144.2$ m

$N_{S\,(kW\text{-}m)}$ = 155 rpm which is within the range

8.5.3 Turbine Rotational Speed

Once the specific speed is calculated the turbine rotational speed can be calculated from the following equation:

$$N = N_S \times H_{Net}^{1.25} / P^{0.5}$$

Putting the known values in the above equation the rotational speed of 4 MW unit is calculated as 1193 rpm and the rotational speed of 6 MW unit is calculated as 981 rpm.

The nearest synchronous speed to 1193 rpm & 975 rpm is 1000 rpm, therefore 1000 rpm and 6 pole generating units have been selected.

8.5.4 Runner Discharge Diameter

The runner diameter, which is also known as runner discharge diameter is given by the equation:

$$D_3 = 84.5 * k_U * H_{Net}^{0.5} / N$$

Here k_U is the peripheral velocity of the runner. The peripheral velocity of runner is function of selected specific speed of turbine. The value of D_3 for proposed turbines operating at 1000 rpm comes out to be 0.73 m for 4 MW unit and 0.71 m for 6 MW unit.

8.5.5 Runaway Speed

The turbine speed remains constant due to regulating action of wicket gates under fluctuations of load. The speed shall, however, rapidly rise when the load is suddenly rejected. In such an event, the speed of the turbine shall rise to a maximum value, which is technically specified as runaway speed.

Under these conditions, the centrifugal forces may be as large as 4 - 6.75 times the forces at normal running speed.

The formula for runaway speed of a Francis turbine has been worked out from model tests as under:

$$N_{Runaway} = K \times N$$

Where K is a coefficient whose value varies from 1.8 to 2

With K = 1.8, the runaway speed of the turbines is about 1800 rpm. The recommended values of specific speed, runner diameter, rotational speed and runaway speed have been worked out from equations.

However, the actual physical sizes have been standardised by manufacturers and it is possible that some refinement and adjustments are made when the procurement order is finally placed.

8.6 TURBINE COMPONENTS

8.6.1 General

The type of turbine selected for the proposed Jagran-IV hydropower project is vertical axis Francis Turbine. This selection is based on the operating parameters which include available head, discharge, flow condition, location and operational behaviour of the plant.

Some other factors such as saving in civil work of machine hall, limited discharge and especially transportation are decisive factors for the selection of turbines.

The powerhouse will be equipped with four vertical axis Francis turbines. Rated power producing capacities will be 1x4 MW and 3x6 MW. Each turbine is connected via a butterfly valve to a common bifurcation joined with the penstock.

The butterfly valve shall be firmly connected to the penstock and inlet of the spiral casing of the turbine. Between the valve and the turbine spiral casing, a removable pipe with flange at both ends should be provided which is capable of bearing small axial movements.

8.6.2 Turbine Structural Components

The various turbine components are:

- Runner
- Guide Vane Mechanism
- Shaft
- Spiral Casing
- Embedded Parts
- Stay Ring
- Links and Levers
- Head Cover
- Bottom Ring
- Bearings
- Draft Tube

The details of some major components are described as hereunder.

8.6.2.1 Runner

Performance of turbine runner, in all hydraulic turbines, has great importance because of silty water and high sediments flow during flood season. Its design is subjected to special site conditions, available repair facilities and water quality of the stream.

The runner will be of 13:4 chrome nickel alloy steel. All field and shop welds will be stress relieved.

The turbine runner should be of the reaction type manufactured in die cast in one piece of stainless steel. The runner is designed and manufactured to operate at any load, head and speed within the limits given, as well as the runaway speed at maximum head without exceeding the allowable stresses and without undue cavitations and vibration.

The finished machined runner should be carefully statically balanced. A model of the turbine with the provided runner should be tested in the laboratory in order to verify the efficiency guaranties.

8.6.2.2 Guide Vanes and Operating Mechanism

The guide vanes are made of stainless steel and are operated by the two hydraulic cylinders, pressurised by the accumulator or the governor oil pressure system. The guide vane position is feedback as an electrical signal to the governor cubicle.

Guide vane shafts and all moving parts of the operating mechanism will run in self-lubricating, long life bushings. Guide vane shaft bushings will be protected against sand intrusion. Addition of the grease lubrication will be made to prevent the sediments from entering water.

8.6.2.3 Shaft Seal

Special packing will be adopted to minimise the water flow along the main shaft. Packing can easily be replaced merely by removing the water packing cover. The packing that ensures a high water sealing effect will be provided with a stainless steel sleeve for shaft protection. The sleeve that will be split into two halves could be readily replaceable.

8.6.2.4 Turbine Shaft

The turbine shaft should be designed for the maximum output of the turbine and making it operate without the harmful vibration and deformation at any speed up to the maximum runaway speed.

8.6.2.5 Spiral Casing

The spiral casing will be manufactured from steel plate sections as a welded construction. The number of sections will be suitably chosen so that the water may not abruptly change its flow direction. For transportation reasons, the steel plate sections should be welded at site. Necessary equipment for stress relieving and 100% X-Ray test of the welding will be provided at site.

The casing has to be embedded in the concrete, so it will be reinforced to transmit the forces to the foundation structure.

8.7 GOVERNOR SYSTEM

8.7.1 General

The governors will be of the electro hydraulic PID (Proportional, Integral, and Derivative) type. The latest designs incorporate digital technology, which allows easy adjustment of control parameters with diagnostics capabilities.

As such, PID type electro hydraulic governors with microcomputer control will be specified, and these will be equipped for joint as well as individual operation of the units. In this respect, these will be ideally suited for integration with the unit start / stop control equipment and with the project SCADA system.

The control should be possible, if:

- Locally at the governor for the control of individual components and for maintenance purposes.
- From the main control board for starting, synchronising, loading and stopping the unit.
- From the control room for supervising the function and operating the unit in connection with the main grid and for the local network.

For the control of the units the following conditions have to be considered:

- Flywheel effect of the governor control
- Generator GD^2
- Fly wheel to be added of GD^2
- The maximum pressure rise in the penstock in case of full load rejection shall not exceed 30% of the gross head.
- The maximum speed rise in case of full load rejection should not exceed 30% of the normal speed.
- The critical speed of the unit should be at least 10% higher than the runaway speed, which is estimated to be 1980 rpm.

8.7.2 Governor Head

Each electronic governor head to be assembled in the main control board of the power station shall be equipped with:

- Start and stop switches
- Quick shut down
- Speed setting
- Speed drop setting

All the necessary buttons, indicators, instruments and limit switches and the control equipment for the automatic start, synchronising and stopping sequence should be provided.

8.7.3 Oil Pressure System

Four hydraulic power pack / hydraulic oil system will provide the hydraulic power for the governors independently. The proposed oil pressure for governor system is 65 bars. The power pack shall have a continuously running motor coupled to a variable output pump and mounted on an oil reservoir. The governor accumulator system shall be the nitrogen closed system type will be capable of at least two (02) complete full-stroke movements. A separate hand pump system will also be required to enable start up without the AC power.

Two equal capacity AC-driven screw pumps, each of them sized for normal operation of the turbine with the pilot valves should be mounted on the sump tank. All the four oil-pressure systems should be interconnected in order to make possible an operation of each turbine - generator set with any of the remaining systems in emergency cases.

8.8 INLET VALVE

The inlet valves will be of the horizontal flow-through disc and trunnion; bronze seated tight - closure butterfly type. Each unit will be equipped with a butterfly valve diameter which is not less than the turbine inlet pipe diameter, with suitable extensions and coupling for connecting to the turbine inlet extension and to the penstock the valves will be closed during the longer stand-still periods of the turbines and in emergency cases against the full water flow. Before the valve is opened, the pressure upstream and downstream will be equalised via a bypass. The valve would be firmly flanged to the bifurcation at the upstream side.

The valves will be hydraulically operated using pressurised oil from the respective governor oil accumulator. The valve together with its bypass valve assembly, drain and blow-off valves, upstream and downstream connecting pipes will be designed to fit into the space available with proper regard to accessibility. The valve will be supported on concrete pedestals and secured by anchor bolts.

8.9 POWERHOUSE CRANE

An overhead motor operated bridge crane shall be provided to assemble and disassemble the heavy turbo generator components during the installation process and also during repair and maintenance of the powerhouse items. The lifting capacity of the overhead bridge crane is the maximum possible weight of a single piece of equipment to be lifted / moved by the crane.

Based on the previous experience, a 20 ton girder type overhead bridge crane has been proposed to be provided in the powerhouse. The lifting height of the hoists shall be determined by the height of the rotor or any other sub-assembly, which has greater height than the former.

The main crane hook shall be capable of lifting the highest component of the transport vehicle and both the main and auxiliary hooks shall be capable of reaching as far down as required to serve the inlet valve gallery. Crane hooks' approach distances normally vary from one manufacture to the other; however, shall be fixed either as per CMAA or FEM standards.

Access to the crane shall be provided through ladder located near to the entrance door. The rail section and size shall be finalised corresponding to the wheel load as per FEM or CMAA standards.

8.10 COOLING AND DEWATERING SYSTEM

The cooling water system is required for the generator surface coolers, thrust and guide bearings, turbine guide bearing, governor oil sump tank, ventilation equipment and the turbine shaft gland or seal. Water shall be taken from upstream of turbine inlet valve and fed to a common header through automatic strainers (cyclone filters), etc. and circulate to the generator surface coolers, thrust and guide bearing and turbine guide bearing of each unit. The warm water from coolers and heat exchangers will be drained to tailrace.

Provision of closed cooling water system is also planned to provide cooling water to the generating units in high sedimentation period or during the time when the water is severely contaminated.

In this regard, an elevated cooling water tank is proposed to make up the leakage through different areas of the cooling water system. The dewatering system is considered necessary to drain out the penstock, manifold, branches and the lowest part of the power station, waterway, etc.

8.10.1 Basic Requirements

All small cooling and drainage water pipes shall be of non-corrosive material as per AISI standards. These pipes shall be placed in the covered trenches or ducts. Embedded pipes shall pass straight through the concrete without any protection while pipes in free air on brackets or supports shall be insulated.

8.10.2 Cooling Water System

The cooling water system will be designed on the assumption that the water to the generating units is nearly free of heavy organic matter and is moderately sediment laden. The major amount of cooling water shall be taken from penstock just upstream of inlet valve. The cooling water shall be passed through the cyclone filters before routing to the coolers of turbine guide bearing, generator thrust bearing, generator surface coolers and coils of Air Handling Units (AHUs).

8.10.3 Power Station Drainage System

All drainage water from the power station shall be collected in a dewatering and drainage pit located at the inlet valves gallery floor and pumped out above the maximum tailrace level.

8.11 HEATING, VENTILATION AND AIR CONDITIONING SYSTEM

8.11.1 General

The proposed Jagran-IV powerhouse / power station is surface type and have opening for the natural ventilation. Main sources of heating load are electrical and mechanical equipment that give rise to indoor temperature. To maintain the indoor temperature at acceptable levels in accordance with the requirements of the occupants, electrical and mechanical equipment, Heating, Ventilating and Air Conditioning system has been recommended for Jagran-IV Hydropower Project.

The super structure of the plant shall be ventilated all the time and will not be cooled or heated except in cases where: -

- Temperatures are required to protect the plant equipment from freezing or excessive high temperature.
- Water condensation or moisture will cause damage to the equipment.

Heat exchangers will use the raw water to cool the air. The water will be pumped from the tailrace and cleaned by using twin strainers and filters up to required limit. The chillers and pumps shall be installed in modules for economical operation and to avoid complete failure of the system. The system is to be equipped with Automatic Controls for better and economical working.

The winter heating is normally not required as the equipment generates sufficient heat. However, in certain areas such as the administrative area and control room duct mounted electric resistance heaters will be used for the winter heating.

The current Handbook of Fundamentals from the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) should be used as reference for designing the HVAC system in the proposed power plant.

The system shall be designed for positive pressure within the plant to exclude inverse environmental intrusion. High velocity of air in the valley shall also be considered for the design calculations.

The design condition for minimum acceptable performance is established for the purpose of design calculations.

Therefore, an adequate HVAC system shall be designed with the following design data as presented in **Table - 8.3**.

Table - 8.3: Design Data for HVAC System

Outdoor design data	Summer	Max. 45 ^{o}C
	Winter	Min. –5 ^{o}C
Indoor design data, Admin. offices, computer, control room	Summer	About 24 ^{o}C
All other rooms		Max. 32 ^{o}C
Indoor design data, Admin. offices, computer, control room	Winter	About 22 ^{o}C
Workshop, corridors, toilets etc		Min. 15 ^{o}C in winter and Max. 32 ^{o}C in summer
All other rooms		Min + 5 ^{o}C
Ventilation Rates		
Supply air		Min. 2.5l/s/m^{2} floor area
Outside air		Min 5 % of supply air and/or 4.75l/s/person

8.11.2 General System Description

The HVAC system for the power station shall be designed during the final design phase. However, the following main outlines have been suggested.

8.11.2.1 Machine Hall

The machine hall of the power station shall have a forced ventilation system, using electrical heating of the circulating air during winter time and water based cooling during the hottest summer periods. Simple air circulation shall be ensured through axial flow fans installed at appropriate places at turbine floor.

8.11.2.2 Office and Control Room Building

The power station administrative and control building shall have a forced ventilation system, with equipment controlling the air temperature and the humidity. Toilets, kitchen, etc., shall have separate exhaust air systems.

8.11.2.3 Design Criteria

The HVAC system shall be designed by targeting the following objectives:

- To maintain the indoor temperature at a predetermined level.
- To provide the clean air to air - conditioned space by the filtration of re-circulated and outside (fresh) air.
- To pressurise the building so as to prevent the infiltration of uncontrolled outside air.
- To provide general winter heating in some areas such as control room, administration areas, workshops etc., by adding heat to the indoor environment.
- To recover heat dissipated by the equipment in winter, and to use it for space heating where possible.

8.12 AUXILIARY SYSTEM

8.12.1 Workshop Equipment

A central workshop with machinery comprising lathes, drilling, milling, welding machines and grinders shall be planned during design phase to perform dismantling; and erection of turbine and generator parts, as well as most other components related to the power plant and facilitate repair or renewal of components which do not need specialised skill or experience. This includes welding, drilling, turning, grinding, etc. and the repair of the power plant trucks and other vehicles, etc.

Electrical small tools, air driven tools and a mobile compressor of ample capacity shall also be proposed for heavy work. Additionally, the different sized hydraulic jacks, mobile dewatering pumps with hoses, slings, etc., as well as consumables shall also be proposed.

8.12.2 Auxiliary Equipment

This equipment includes oil handling and fire fighting equipment.

These are described hereunder in the following paragraphs.

8.12.2.1 Oil Handling Equipment

An oil handling system is proposed for the power station. The oil will be stored in ordinary drums and refilled after its purification. Besides equipment for taking oil samples, mobile pumps with pipes / hoses and filters as well as a mobile oil purifying unit which can be coupled into all oil systems including the transformers, during operation, shall be proposed during the design phase.

8.12.2.2 Fire Fighting System

In general, 6 kg hand held and 25 kg wheel-barrow mounted fire extinguishers shall be placed at appropriate locations in the power house building and at the intake area. In addition, the power station shall be provided with several hydrants with suitably sized fire hoses on each floor. The water for the fire hydrants shall be taken directly from upstream of inlet valves. A mobile foam unit may also be proposed.

For indoor and outdoor electrical equipment, an automatic foam based fire fighting system comprising of foam delivery pipe distribution ring system with specially designed spray nozzles, ionization detectors, flame & smoke detectors and integrated processor based control equipment for automatic operation is proposed. For step-up main transformers, high velocity foam dispensing system is proposed.

However for generators, Carbon Dioxide gas dispensing fire extinguishing automatic system may also be considered, if found appropriate, in detailed designing of the generators.

8.12.3 Maintenance Tools and Spares

Considering the remoteness of the project area from main cities, it is advisable to provide essential maintenance tools and spares to keep the machines in operation with minimum outage.

9 ELECTRICAL EQUIPMENT

9.1 GENERAL

The general layout of electrical equipment for Jagran - IV Hydropower Project is based on four (04) generating units each mechanically coupled with a Francis turbine. The rated capacity of the power generating units will be 6 MW for 3 units each and 4 MW for 1 unit. The turbine speed of 1000 rpm has been considered. The runaway speed of turbine will be 1800 rpm.

The proposed generator voltage will be 11 kV. Each generator will feed a common 11 kV bus-bar provided with complete synchronising system, protection relays and controls. This common bus-bar will feed two step-up 11 / 132 kV transformers each of rating 10 / 13 MVA for interconnection with existing Jagran - I hydropower plant by 132 kV transmission line. The single line diagram is shown in **Dwg. No. 9, Sheet No. 1 and Sheet No. 2**.

The description and general lay out of the generator, step-up transformers, transmission arrangement and auxiliary equipment are explained below.

9.2 GENERATORS

9.2.1 General

The generators are essentially three-phase synchronous, water-cooled, brushless machines mechanically coupled with Francis type turbines and a flywheel for smooth and stable running. The generators for this project have to be of a special design because of their high runaway speeds. The turbine speed is controlled by hydraulic governor regulating the water flow into the turbine.

The excitation system is proposed using independent uninterrupted power supply (UPS) of appropriate rating for each generator supplied from an independent excitation transformer. In case of failure of UPS, a *110 volts d.c. battery bank consisting of 92 numbers of 1.2 volts cells with adequate battery chargers shall automatically be available as back up.

The stator winding of each generator is star connected with brought out neutral solidly earthed. The remote temperature detectors are embedded in the stator winding to read out and record temperature levels at appropriate points.

The generators, excitation equipment and auxiliaries shall be designed, constructed and tested in accordance with IEC Standards. The generation terminal voltage will be 11 kV at 50 Hz frequency.

The main data of each generator is as under:

- Number of Units and Capacity** 3x6 MW + 1x4 MW
- Rated Power** 6 MW / 7.06 MVA & 4 MW / 4.70 MVA
- Rated Voltage 11 kV
- Rated Speed 1000 rpm
- Power Factor 0.85
- Rated Frequency 50 Hz
- Excitation Static UPS controlled with TCRs
- Cooling System Water Cooled
- Insulation Class F
- Stator Connection Y
- Generator Efficiency 96 %
- Applicable Standards IEC 34

* The voltage of the Battery Bank can be 110 V or 220 V according to the final control and protection schemes.

** The Capacity and Rated Power of generators is calculated considering 96% efficiency.

9.2.2 Generator Protection

For each generating unit, the following protection relays have been proposed and shown in the single line scheme **Dwg. No. 9. Sheet No. 3**.

- Over - Voltage relay
- Under - Voltage relay
- Under / Over frequency
- Thermal Overload relay for winding
- Overall differential relay
- Reverse power relay
- Negative phase sequence current relay
- Loss of excitation relay
- Generator differential relay
- Field over-current relay
- Stator earth fault relay
- Over current relay, etc

Solid State and/or composite state-of-the-art protection relays, keeping in view the NTDC approved standards and protocols for generation and transmission lines protection, shall be preferred.

9.2.3 Excitation System

Two types of excitation systems have been considered for the generator excitation namely:

- Static Excitation
- Rotary Excitation

Static Excitation by un-interrupted power supply (UPS), from independent Excitation Transformer is equipped with thyristor controlled rectifiers (TCR) and a battery bank of appropriate rating with additional battery charger units.

The static excitation has certain advantages such as quick in operation, with full reversible excitation voltage control and presents less maintenance.

The rotary type has the disadvantage that it involves brushes and slip rings causing certain losses and requires extensive maintenance.

For the Jagran - IV Hydropower Project, the static TCR excitation is proposed. Generator excitation system is shown in **Dwg. No. 9, Sheet No. 3.**

9.2.4 MV Switchgear

Each 11 kV generator supplies power to a common 11 kV bus-bar of appropriate rating and size through a synchronising generator breaker. Appropriate instrument transformers are installed for protection and measuring instruments and generator synchronisation on 11 kV bus as and when required.

- Installation — Indoor
- Nominal System Voltage — 11 kV
- Maximum Operating Voltage — 15 kV
- Rated Frequency — 50 Hz
- Current Rating — 630 A*

* The nominal current rating shall be finalised during the detailed design stage.

9.3 132 kV INTERCONNECTION AND GRID STATION

9.3.1 132 kV Interconnection

The Jagran - IV Hydropower Project shall be provided with one single circuit 132 kV transmission line for interconnection with Jagran - I Grid.

9.3.2 132 kV Grid Station

For the Jagran - IV Hydropower Project, different options of arrangements and layouts have been considered to step-up the generated voltage to transmission level.

Mainly the following two options have been discussed in detail:

- Each generator bay having its independent step-up 11 / 132 kV transformer. In this arrangement all generators shall be synchronised on a 132 kV common bus-bar.
- The other arrangement is to synchronise all generators on a common 11 kV bus-bar and two step-up 11 / 132 kV, 10 / 13 MVA power transformers will be used for inter-connection with national grid by a 132 kV transmission line through existing Jagran - I Hydropower Plant.

Both arrangements have their own advantages and disadvantages and possess different technical aspects. After detailed analysis, it is proposed to use the second of the above arrangements as illustrated in **Dwg. No. 9, Sheet No. 1** and **Sheet No. 2**.

At Jagran - IV HPP, a 132 kV transforming and switching station is proposed. This station will have two 11 / 132 kV step-up transformers, each of rating 10 / 13 MVA, oil natural and forced air cooled with on-load tap changers. Both transformers shall feed respective 132 kV bus-bars, having 132 kV circuit breaker as intertie, and an outgoing 132 kV transmission line, as illustrated in Dwg. No. 9, Sheet No 2.

132 kV outputs from two step-up transformers can be synchronised at 132 kV intertie circuit breaker whenever required. An adequate and perfect synchronising system will be provided with manual and automatic operation through synchronising check relays.

The other important components of proposed grid station at Jagran - IV will be bus-bars, line isolators, earthing switches, line circuit breaker, instrument transformers of appropriate rating and transformation ratio, lightning arresters, over head lightning shielding wire and underground earthing mesh for adequate safety of equipment and personnel.

132 kV outgoing transmission line will be provided with appropriate protection and line parameters measuring relays and instruments, SCADA and telecom as per WAPDA / NTDC standard design and specifications.

9.3.2.1 Power Transformer

The step-up transformers shall have the following typical characteristics:

- Number of Units 2
- Type Three-Phase, Step-up
- Installation Outdoor
- Duty Continuous
- Dielectric Mineral Oil
- Rated Power 10 / 13 MVA
- Nominal Frequency 50 Hz
- Rated Secondary Voltage 132 kV
- Rated Primary Voltage 11 kV
- Power Factor 0.85
- Voltage Control On Load, Tap changer (±5%)
- Impedance 7%
- Cooling ONAF
- Connection Ynd 11

9.3.2.2 Transformer Protection

In order to ensure reliable operation of the transformer, following obvious protections have been proposed:

- Oil level and temperature indicator (alarm & trip)
- Differential protection
- Over current protection and back up device
- Neutral point earth fault current relay
- Gas and temperature protections (alarm & trip).

9.3.2.3 Circuit Breakers

In the power plant there shall be mainly low voltage, medium voltage and high voltage circuit breakers installed at various places.

Low voltage breakers are air-break type with thermal and shunt trip characteristics and are mainly used for supply to motor control centers, station AC auxiliaries, battery chargers, heating, internal and external lighting, and other utilities.

The medium voltage 11 kV breakers are vacuum bottle or SF_6 gas insulated breakers. They are used as generator breakers (52GCB) installed between generators and 11 kV bus-bar. High voltage breakers, SF_6 insulated, are also used on High Voltage side of the step-up transformer and subsequently as 132 kV line breakers.

The 132 kV circuit breakers shall be of the following characteristics:

- Installation — Outdoor
- Nominal system voltage — 132 kV
- Maximum operating voltage — 145 kV
- Power frequency with stand voltage — 275 kV
- Lighting Impulse with stand Voltage — 650 kV
- Rated frequency — 50 Hz
- Current Rating — 800 A*
- Insulation — SF_6

The circuit breaker shall be provided with a power-driven, stored-energy mechanism for its operation.

* The nominal current rating shall be finalised during the detailed design stage.

9.4 LV INSTALLATION

9.4.1 11/0.4 kV Switchgear

It is proposed to use 11 / 0.4 kV switchgear at Jagran - IV Hydropower Project for station auxiliary supplies. Two identical auxiliary transformers of 630 kVA rating have been proposed. One transformer shall be capable to meet the complete energy requirements of the units and general auxiliaries of the project.

The switchgear shall be equipped with 11 / 0.4 kV circuit breakers; metal clad draw out type with all ancillary equipment. The arrangement of 11 / 0.4 kV switchgear is indicated in **Dwg. No. 9, Sheet No. 4**. Disconnecting switches and fuses or combined fuse-disconnecting switches shall be used for the outgoing feeders.

9.4.1.1 Low Voltage Auxiliary Switchgear

- Bus Bars — 3 Phases, neutral and ground
- Nominal Voltage — 11 / 0.4 kV
- Frequency — 50 Hz
- Nominal Current — 1250 A*
- Rated Short Circuit Withstand — 35 kA*, rms
- Auto Transfer Switch

* The nominal current rating and short circuit with stand current shall be finalised during detailed design stage.

9.4.1.2 Motor Control Centers

Motor Control Center with low voltage metal clad draw out switchgear with circuit breaker of appropriate rating feeding respective Direct-on-Line (DOL) or Star-Delta motor starters will be used for respective motor circuits. Each draw out unit will be provided with on / off push buttons, motor status indication lights (red, green and amber), circuit labels and measuring instruments like volt and amp meter. Each unit will be equipped with lock and key arrangement.

9.4.2 Station Auxiliary Transformer

The proposed power plant will be having two independent step-down unit transformers of 11 / 0.4 kV feeding low voltage common auxiliary bus-bar for station AC supplies as shown in the **Dwg. No. 9, Sheet No. 4**. Low voltage bus bar 1 and 2 shall be coupled through a low voltage tie-breaker operate able manually or on automatic functions of an Auto-transfer switch.

The power plant will be having battery charger to charge station battery bank for independent DC voltage for controls and protection circuits. However, a static inverter will also be installed to supply station auxiliaries with un-interruptible auxiliary supplies. Low voltage switchgear will be in-door.

The main characteristics of the auxiliary transformer are as follows:

- Rated Power 630 kVA
- Rated Frequency 50 Hz
- Cooling ONAN
- Rated Primary Voltage 11 kV
- Rated Secondary Voltage 0.4 kV
- Connection ΔYno

9.4.3 Black Start Diesel Generating Set

A diesel generator of 300 kVA capacity has been proposed for black start purpose. The generator set will provide emergency supply to power station in case of any forced or routine shut down. 300 kVA rating is sufficient to meet essential Black Start operations.

The interconnection of the diesel generating set is shown in the **Dwg. No. 9, Sheet No. 4.**

9.4.4 Battery and Battery Charger

DC battery shall be installed in the powerhouse for protection, controls, alarms tripping and indications. Two (02) battery banks of 110 V each are proposed. Each bank will have rating 500 AH, consisting of 92 x 1.2 V battery cells with independent battery chargers.

In normal conditions DC supply shall be obtained through an AC to DC converter and in case of failure of AC supply the DC battery shall be automatically brought in circuit. Lead acid battery shall be used for the above-mentioned installations. The battery bank will be equipped with its own battery charger.

9.5 ELECTRICAL AUXILIARIES

9.5.1 Lighting

The following lighting requirements for station service are foreseen:

- Normal lighting for working in normal conditions of comfort. This includes amenity lighting inside and outside the buildings.
- Emergency lighting is required and used when the power station is out of service due to any shut down under emergencies.
- Safety lighting to light up exits, entrances and operation / control areas.

9.5.2 Fire Detection and Protection System

Proper automatic fire detection and protection system shall be provided at the following locations of the power plant:

- Power plant hall.
- Control room, MV switchgear room and auxiliary equipment room of the power plant.
- Electrical gallery.
- Power transformers.
- LV Switchgear building, etc.

9.6 TRANSMISSION LINE

9.6.1 Dispersal of Power

Dispersal of power from proposed Jagran - IV power plant is recommended through 132 kV overhead Transmission Line (T/L) up to Jagran - I substation.

9.6.2 Transmission Line Route

The transmission line route has been proposed for the interconnection of the Jagran - IV power plant with Kundal Shahi grid station via Jagran - I HPP, as illustrated in **Dwg. No. 9-1**. The main criterion for route selection is that the line traverses as close to the existing access road as possible. It will help the transportation of material, line construction and its maintenance during operation.

9.6.3 Main Specifications of T/L Material

All material will be in accordance with the standard specifications of PEPCO / NTDC for 132 kV transmission lines.

9.6.3.1 Transmission Line Towers

“ZM-1”, “ZM-30” and “ZM-60” type of towers as per PEPCO / NTDC standard will be used for the transmission line.

9.6.3.2 Conductor

ACSR “Rail” conductor will be used.

9.6.3.3 Insulators

Fog type insulator disks will be used having strength of 100 kN on each phase string.

9.6.3.4 Shield Wire

Shield wire will be in accordance with ASTM - A 363 standard.

9.6.3.5 Construction

The construction of transmission line will be in accordance with the standard PEPCO / NTDC specifications for construction of transmission lines.

10 INITIAL ENVIRONMENTAL EXAMINATION

10.1 INTRODUCTION

The proposed Jagran - IV Hydropower Project is a run-of-river project located on Jagran River. Jagran River is a right bank tributary of Neelum River, having its confluence with Neelum River at Kundal Shahi about 68 km from Muzaffarabad.

The project has been identified on the intermediate stretch of about 4 km of the Jagran River The weir site is located upstream of Thunian village, about 18.0 km upstream of Jagran River confluence with the Neelum River and powerhouse is proposed about 200 m upstream of Jagran - I weir intake. The need for the project arises from the fast growing demand for electrical energy in Pakistan together with the increasing attraction of hydropower compared to thermal generation using fossil fuels.

10.2 DESCRIPTION OF THE OBJECTIVES OF PROPOSAL

Pakistan's Northern regions including the State of Azad Jammu and Kashmir (AJ&K) are abundantly blessed with hydropower resources. Presently, hydropower projects constitute around 6,500 MW of power as installed capacity and most of them are run and owned by WAPDA.

Inspite of the best efforts to develop hydropower projects, utilisation of the available hydroelectric potential is still on the lower side. According to the available information, about 11.7 % of the achievable potential has only been utilised so far.

Optimal utilisation of the country's hydroelectric potential has also been accorded priority in the future power development strategy according to which the Hydro Electric Board (HEB) of Azad Jammu and Kashmir has identified a number of potential sites attractive for their hydropower potential. In the same vein, one particular site is located on the Jagran River, about 86 km from Muzaffarabad.

The proposed Jagran - IV Hydropower Project shall be operated in compliance with the environmental standards by the World Bank (WB) in line with the Equator Principles as well as the National Environmental Quality Standards (NEQS) Pakistan.

According to the Pakistan Environmental Protection Act (PEPA); Section 12, no project can commence on ground unless No Objection Certificate (NOC) or Environmental Approval (EA) is obtained from the relevant Environmental Protection Agency (EPA).

In the present case, it is the EPA Government of Azad Jammu and Kashmir, Muzaffarabad; which has already adopted the Environmental Laws, Rules, Guidelines, and Regulations etc. of the Government of Pakistan. Therefore, all the requirements of this Act need to be fulfilled by the Client for the implementation of the project.

10.2.1 Land Use and Industrialisation

In the project area agriculture on small pieces of land in the form of terraces is common and over long stretches has no industry. However, the government policies for land use encourage industrialisation. Preparation of feasibility study report of the proposed Jagran - IV Hydropower Project is a clear proof of the policy of the Government of Azad Jammu and Kashmir for industrialisation.

10.2.2 Regulatory Framework - Industrialisation

The Government of Azad Jammu & Kashmir is facilitating investment, both local and foreign, in industrial sector. Liberalisation and industrialisation in the Azad State of Jammu and Kashmir (AJ&K), as a policy of the Government are well reflected from the initiatives as described in the following sections.

10.2.2.1 Deregulation of the Economy

Deregulation is the priority policy of the Government of the Azad State of Jammu and Kashmir, like the Government of Pakistan.

10.2.2.2 Infrastructure Facilities

In order to facilitate fast industrialisation, the basic infrastructure facilities like roads network, water and power supply, means of transportation and communications, etc. are being improved / developed speedily.

10.2.2.3 Incentives

In order to promote industrialisation, the following incentives are available equally to the investors:

- initial depreciation allowance (IDA),
- amortisation, and
- normal tax rates.

10.2.3 Environmental Legal Framework

The Government of Azad Jammu & Kashmir has been actively pursuing the cause of environmental protection.

The Government of AJ&K has adopted, though in infancy, the organisational structures and the rules, regulations, laws, NEQS, etc. of the Government of Pakistan for the protection of the environment and resource conservation. In Pakistan several laws exist for the protection of the environment and most of these are being adopted by the Govt. of AJ&K.

The Pakistan Environmental Protection Act (PEPA) 1997 provides the legal basis for the IEE / EIA studies being carried out in Azad Jammu and Kashmir.

10.3 PAKISTAN ENVIRONMENTAL PROTECTION ACT (PEPA) 1997

Amongst many other salient features the Act, PEPA 1997 empowers the EPA, Azad Jammu and Kashmir to:

- carry out the environmental assessment,
- identify categories of projects to which the Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) provisions will apply;
- develop guidelines for conducting IEE and / or EIA and procedures for the submission, review and approval of the same;
- develop environmental emission standards for parameters such as air, water and noise; and
- enforce the provisions of the PEPA through environmental protection orders and environmental tribunals headed by magistrates with wide-ranging powers, including the right to fine violators of the Act.

The EPA, Govt. of AJ&K is empowered to manage the environmental concerns and to implement all the environmental rules, regulations, laws, acts, etc.

10.4 GUIDELINES FOR ENVIRONMENTAL ASSESSMENT

The Pak - EPA published a set of environmental guidelines for conducting the environmental assessments and the environmental management of different types of development projects and these are also adopted by the EPA, AJ&K. The IEE / EIA reports are to be submitted to EPA for No Objection Certificate (NOC) and / or Environmental Approvals (EA).

10.5 GUIDELINES FOR PUBLIC CONSULTATION

These guidelines deal with the possible approaches to public consultation and techniques for designing an effective programme of consultation that reaches out to all the major stakeholders (also including the poor, women, building community, NGO, etc) and ensures that their concerns are incorporated in any impact assessment study.

10.6 DESCRIPTION OF EXISTING AND EXPECTED CONDITIONS

10.6.1 Existing (Baseline) Condition of the Biophysical and Socio-Economic Environment, Trends & Anticipated Future Environmental Conditions

As described earlier, the proposed project site is situated on the Jagran River a right bank tributary of Neelum River having the confluence with the Neelum River at Kundal Shahi village, about 68 km from Muzaffarabad. The weir site is proposed on Jagran River 150 m downstream of confluence of Baihk nullah with Jagran River near Shaal village, about 18 km from its confluence with Neelum River and powerhouse is proposed on left bank of Jagran River about 200 m upstream of Jagran - I weir intake. Agriculture on small pieces of land in the form of terraces is quite common. The project area over long stretches has no industry. The hydropower potential of the Jagran River will be used for power production.

The main road from Nausehri to Taobut runs along the right bank of Neelum River and the Line of Control (LoC) is close to the main road at Tithwal, Authmuqam and Keran village. The weir site can be accessed by rough track that branches off from Kundal Shahi from main road or on foot along the Jagran River. The rough road leads to Kutton and Thunian villages and proposed project sites.

The project area including weir and the powerhouse sites are surrounded by mountains which till the recent past were covered with dense forests and a variety of wildlife exists. In spite of the rapid deforestation, vegetation in the form of grasses and shrubs is quite dense.

Small scale irrigation on hill slopes is the major activity and source of livelihood of the people. Water from springs is used for all purposes including drinking, irrigation, domestic or other uses.

Human settlements are scattered all along the slopes and even on the top of the hills. Winding, unpaved, dangerous and unsafe hilly tracks add to the overall difficulty of the people living especially on hill slopes and on their tops.

By and large, majority of the people living in the area are very poor. They generally lead marginalised life style. Literacy rate, on the overall is very low due to poverty and non - availability of the adequate number of educational institutions. Health facilities are very sparse. People have to travel even up to Muzaffarabad for getting medical aid.

Electricity is not available in most of the human settlements and those who have it, are victim of long drawn out load shedding like in the rest of AJ&K and Pakistan. No industry exists in the area. Private transport in the form of buses, wagons, pick-ups and motorcycles is available to some extent. Private transport plying is also a source of income of some people. During very short period from usually June to September, tourism also becomes a source of earning of the people.

Centuries old traditions, customs and rituals are in practice. Women are restricted to petty household works. They have no say in the decision making.

The elderly people are well respected and they play major role in decision making. Marriages are generally arranged and are quite successful. The joint family system prevails. Print and electronic media are bringing change in the thinking levels and the same is now reflected in the day to day life of a common man's life.

With operation of the proposed project, it will provide job opportunities especially to the people of the area around the project site; Government will get large volumes of earnings in the form of taxes and duties on recurring basis. Poverty alleviation, to some extent, will be yet another benefit.

There is a serious shortage of power in the AJ&K. This project will help to add positively to the economy as well as fulfillment of domestic needs. The power supply from the project operations will help to bridge the crucially widening gap between power demand and supply.

Obviously, in case the project does not proceed further, there will not be any change in the existing status of the environment or a status quo will be maintained with regard to all environmental, social and economic factors.

10.6.2 Environmentally Sensitive Areas of Special or Unique Value

10.6.2.1 Physical Resources

The physical resources of the project area include topography, geology, soils, climate, water, etc. as described in previous chapters.

10.6.2.2 Ecological Resources

Fisheries and aquatic biology, biodiversity, forestry, wildlife, scientific institutions, socio-economic and cultural and other heritage are the major ecological resources.

10.7 ECOLOGICAL RESOURCES

Mainly a country's wilderness areas and scenic landscapes with their associated flora and fauna form natural capital of a country. Both collectively and within each level, the range or variety of the resources is referred to as the "Biological Diversity". The contribution of the "Natural Capital" is recognised at three distinct levels including genera, species, and community habitat and ecosystem.

The greater the number of genera, species and habitats and ecosystems present within the area, the greater is the Biodiversity. It is in this background that the ecology of the area is discussed hereunder.

10.7.1 Natural Flora

10.7.1.1 Overview

Natural flora of the Neelum district comprises of forests (mainly conifers), shrubs, herbs, forbs, grasses, ferns, mosses, lichens, medicinal plants, agricultural crops, vegetables, and cultivated fruit trees. The information below is about the valley as a whole supplemented by information on areas under weir site and powerhouse.

10.7.1.2 Forests

Different types of forests exist in the area of the two Divisions, i.e., Sharda and Keran of Neelum valley. These forests are:

- Moist Deodar Forests,
- Western Mixed Coniferous Forests,
- Kharsu Oak Forests,
- Moist Temperate Forests,
- Dry Oak Forests,
- Sub Alpine Forests,
- Sub Alpine Pastures,
- Moist Alpine Pastures.

Keran Division consists of Bandi Ashkot Range, Jagran Range and Keran Range.

Sharda Division has Sharda Range and Gureze Range.

The proposed Jagran - IV Hydropower Project site comes under the Keran Division and amongst the different types of the Forests in the valley; the Moist Deodar Forests and Western Mixed Coniferous Forests exist in the project area.

10.7.1.3 Medicinal Plants

A lot of medicinal plants are present in these forests which are of extreme importance. Amongst these, with local names, are Goldoof, Rattan Ju, Patrees, Kuth, Batwava, Chora Jari, Zakhm-e-hayat, Jogi Badshah, etc. An extensive growth of Mushrooms is also present in these forests at heights. Locally it is called “Gochhi” which is a very costly food item; collected and sold in the market of Islamabad and Rawalpindi.

10.7.1.4 Vegetation in the Weir Area

Vegetation in the project area has been studied by delineating the area into upper slopes and lower slopes up to the river bank. The forest on the upper slopes consists of mainly conifers such as Pinus Wallichiana (Kail / Biar), Piceae Smithiana (Kachal), Cederus Deodara (Paludar) and Abiespindrow (Fir / Rewar). Dominant shrubs include Zanthoxylum Alatum (Timer), Alunus Nitida (Sharol), Indigofera Gerardiana (Kainthi), Juniperus Communis (Bhentri) and Parrotia Jacquemontiana (Pesher).

The cultivated fruit trees in the weir site area include Prunus Armeniaca (Khobani / Apricot), Juglans Regia (Akhrot / Walnut), Prunus Persica (Arru / Peach) and Pyrus Malus (Apple).

10.7.1.5 Vegetation at Powerhouse Area

The powerhouse site falls under moist temperate climatic zone and is characterised by the scrub vegetation. The prominent plants species include Ficus Palmata (Phagwara), Accacia Modesta (Phulai), Olio Cuspidata (Kao), Morus Alba (Toot), Ailanthus Altissima (Drewa), and Robinia Pseudoacacia (Kikar). Few plants of Pinus Wallichiana and Populus Nigra (Sufaida) species were also found to be growing in the area. The shrubs in the powerhouse area include Indigofera Gerardiana (Kanthi) and Zanthoxylum Alatum (Timer).

A limited number of fruit trees also exist in the powerhouse area. Prominent trees are Juglans Regia (Akhrot / Walnet), Prunus Armeniaca (Khobani / Apricot), and Prunus Persica (Aru / Peach).

10.7.2 Natural Fauna

10.7.2.1 Mammals

The project area is rich in fauna, particularly small mammals in particular the rodents, long-tailed marmot and long-tailed mouse are of note. Himalayan monkeys and grey langur represent large mammals. It is generally considered that the wild mammals in the project area are mostly trespassers. The Macaca Mulatta (Monkey), Semnopithecus Entellus (Gray Langur) and Funambuius Pennanti (Himalayan Squirrel) are the most common mammals found in the vicinity of villages falling in the project area. Hemorrhagic Septicaemia (HS), Pneumonia, Eczema and Piroplasmosis (red water) are common diseases of buffalo / cattle. In addition, Enterotoxaemia and Anthrax infections are found in sheep and goat.

10.7.2.2 Reptiles and Amphibians

Rana Tigrana (Rain Frog), Trachydosaurus Rugosus (Stripped Lizard) and Uromastix Hard (Jungli Kirla) and a large variety of snakes (both poisonous and non-poisonous) have been reported both from the weir and powerhouse areas.

10.7.2.3 Insects, Butterflies and Vectors

Insect population include Chromatomyia horticola (Agromyzidae: Diptera), Caterpillars, Painted Bug, Bagrada Cruciferarum, (Pentatomidae: Hemiptera), Pieris brassicae and Leafminer, Cabbage semilooper and Plusia orichalcea (Noctuidae).

There are many varieties of butterflies in the project area; particularly during the summer months, in addition to praying mantis, bugs, cicadas, beetles, spiders, scorpions, glow-worms, centipedes, millipedes, snails, slugs and arrow worms. Further, the baseline survey indicated the absence of any vector borne diseases in the area.

10.7.2.4 Birds and Fowl (Avifauna) Communities

Of the four most important pheasants, the Kokies Pheasant are found more commonly then the Monal Pheasant. Reported varieties of other birds are also found in the valley such as the Long-legged Buzzard (Buteo Rufinus), Eurasian Woodcock (Scolopax Rusticola), Common Dipper (Cinclu Cinclus), Wren (Troglodytes Troglodytes), Little Forktail (Enicurus Scouleri), Common Tree Creeper (Certhia Familiaris), Alpine Yellow-billed Chough (Pyrrhocorax Graculus), Red Fronted Serin (Serinus Pusillus), Spectacled or Red-browed Finch (Callacanthis Burtoni) Common Rosefinch (Carpodacus Erythrinus), Eurasian Goldfinch, (Carduelis Carduelis), and White Winged Grosbeak (Mycerobas Carnipes).

Similarly, Monal Pheasant (Lophophorus Impejanus), Common Myna (Acridotheres Tritis), Western Horned Tragopan (Tragopan Melanocephalus), Kaleej Pheasant (Lophura Leucomelana Hamiltoni), House Sparrow (Passer Domesticus), Common Crow (Coturnix Coturnix) are common birds reported / observed in the area.

10.7.2.5 Aquatic Ecology

Fish and other aquatic organisms require snags, logs and rocks where they can shelter from predators and the current and can reproduce, to help them establish territories and to provide markers that help them navigate.

Aquatic plants are also very important for fish and other creatures in the stream; apart from providing food, their presence has a direct effect on the available oxygen in the water, which in turn can affect the type of fish and other animals living in the stream. Protruding snags provide roosting and preening sites for birds.

No aquatic life except green algae has been observed in Jagran River. The green algae were noted at all sites colonising on stones and other debris. No macro-invertebrates were observed at sites, but they were observed downstream near the confluence with Neelum River.

All the fish farms and hatcheries were damaged during the 2005 earthquake. Currently, only a few hatcheries were functioning under the AJ&K Fisheries Department which are damaged by the recent heavy flood in July 2010.

10.8 PROTECTED AREAS

10.8.1 Overview

Like Pakistan's current provincial and territorial legislation, only the following three protected area categories are already established in AJ&K:

- **National Parks**: To protect and conserve areas of exceptional geological, biological and cultural importance for educational, recreational and scientific uses.
- **Wildlife Sanctuaries**: To protect the species or groups of species of flora and fauna for breeding, and to protect them from extinction.
- **Game Reserves**: To protect flora and fauna for sustainable use.

10.8.2 National Parks

A National Park is an area owned by the government and set aside for protection and preservation of its outstanding scenery, flora and fauna in a natural state. It is accessible to the public for recreation, education and research activities, subject to such restrictions, as the Government may impose.

The construction of access roads, tourist facilities and other buildings in the National Park must not impair the park objectives. Forestry activities must also be controlled in the same way. AJ&K wildlife department is responsible for classifying the National Parks.

10.8.3 Wildlife Parks

Wildlife Park is an area owned by the Government and set aside for the rehabilitation of endangered wildlife species under semi natural conditions as well as for the education and recreation of the public.

The following acts are prohibited in a wildlife park:

- Hunting, killing or capturing of any wild species or firing any gun or any other fire arms.
- Polluting the water.
- Damaging or destruction of vegetation.

10.8.4 Wildlife Sanctuaries

A Wildlife Sanctuary is an area owned by the Government (set aside by notification in the official gazette) as an undisturbed breeding ground for the protection of wildlife. Public access to the sanctuary is prohibited. Exploitation of forest resources in a wildlife sanctuary is not permitted except for reducing the fire-hazards, epidemics, insect attacks or other natural calamities.

10.8.5 Private Game Reserves

Private game reserves are areas dedicated by landowners for the purpose of exclusively hunting wild animals within the reserve. Person other than the owner of the reserve are not permitted within the private game reserves without the owner's permission. The owner of a private game reserve is empowered to exercise, within the limits of his private game reserve, the same powers as a wildlife officer.

10.9 QUALITY OF LIFE

10.9.1 Socio-Economic Values

The average size of a typical rural family comprise of about Ten (10) persons including the older parents. Traditionally, the society is male dominated where the elders are placed at a higher level of esteem and authority. A handful of men are skilled in carpentry / woodwork, masonry and tailoring works. The growth of population is high as compared to the other urban areas of the state. This rapid increase in the population is putting enormous strains on the available natural resources; particularly, the forests which are shrinking in acreage at a faster rate.

More than a third of the national population lives below the poverty line. According to Earthquake Reconstruction and Rehabilitation Authority (ERRA) the income level per month per person in the affected area before the earthquake varied between about US$ 150 to 200 as compared to US$ 480 in the rest of the country.

Asian Development Bank (ADB) found that during 2000-01, 44% of the rural population in AJ&K was living under the poverty line of the daily equivalence to 2,550 caloric intake per adult.

The main source of income is agriculture which is mainly practiced by the male members. The family income comprises of a number of sources / activities. Farm size is usually very small where they grow seasonal crops especially the maize and potato which is main cash crop for the locals. Among other sources of income include cattle raring, poultry, trade, general menial labour, driving, milk selling, etc.

10.9.2 Existing Socio-Economic Conditions, Cultural and Aesthetic Values

- By and large, most of the people live under economic subsistence level.
- Agriculture on very limited scale is carried out. Wheat, maize and potato are the major crops. Agriculture alone cannot support the life.
- Job opportunities are extremely limited.
- Due to poverty level of education is low, however awareness about the importance of education is prevalent therefore the younger generation in large proportion visit schools.
- Due to poverty, lack of resources and education primitive life style prevails among majority of the people.
- After earthquake, universal design of houses built by Govt. of Pakistan and Foreign & local agencies has been adopted.

- Health care facilities are seriously lacking and inadequate.
- Spring water is mostly used as potable water and for all other practical purposes.
- Centuries old customs, traditions and rituals are in practice and dominant in almost every walk of life.
- Elders are respected and they play key role in decision making.
- Marriages are arranged and quite successful.
- The society is very conservative.
- People have strong bonds with the religion Islam.
- Recreational facilities are virtually not available and at the most they are restricted to only annual gatherings at the shrines of saints or at some places in the area.
- Means of transport include motorbikes, private wagons, buses and pickups.
- Print and electronic media has yet to play their role in all walks of life.
- Human settlements are found in the form of houses scattered here and there.
- People are quite coherent towards common cause.

10.10 BASELINE ENVIRONMENTAL DATA / STATUS

In order to assess the environmental quality status of the project area, on site environmental monitoring was carried and monitored at important sites of the project and data is described in the following sections.

10.10.1 Noise

According to the monitored data, noise levels range between 41.0 dB(A) to 52.5 dB(A) as against the maximum limiting value of 85.0 dB(A) set by the National Environmental Quality Standards (NEQS) Pakistan. It means that noise is not a problem in the area.

10.10.2 Ambient Gases

The monitored data for the ambient gases was observed in the proposed project area. From the monitored data, it is evident that concentration of the SOx, COx and NOx in the ambient air in the project area ranges below the detection limits of the instrument. The presence of these gases is considerably below the limiting values as set by the World Health Organisation (WHO).

10.10.3 Particulate Matter

The concentrations of particulate matter as measured in the ambient air of the project site range between 20.5 to 37.2 µg/m^3. These are far too below the WHO set limiting values.

10.10.4 Water Quality

In order to assess quality of water in the project area, two water samples were collected from the Jagran River. It is pertinent to note that all water samples are biologically (due to Coliform) contaminated.

For drinking purposes, most of the water is fetched from natural springs in large tumbler and stored for daily use. Each cluster of community lays claim on its own source of the natural spring. These springs are fed from the underground aquifers, whose source is the snow deposits.

10.11 EVALUATION OF ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

Evaluation of the likely adverse impacts of pollution from the project during construction and regular operation and mitigation measures to be adopted are detailed in the following paragraphs.

Agriculture on small pieces of land in the form of terraces is common. The project site over long stretches has no industry. The hydropower potential of the Jagran River will be used for power production. The project is surrounded by high mountains which are quite rich in vegetation.

Although due to extensive human interventions most of the worth mentioning wildlife has migrated to other parts of the valley where adequate habitat is available for them, yet during some parts of the year they use this site as passage for moving to other places.

On the overall basis, deforestation on massive scale has occurred in the project area and afforestation is lacking behind. The valley is one among the most beautiful sites of AJ&K and local and foreign tourists visit the area during summer.

Some people do menial work at Muzaffarabad and some other cities of the country, while animals, goats and sheep rearing is also done by some ethnic groups.

Further, some people run their own shops and a few others are engaged in running transport. Most of the people are poor and they lack facilities of education, health care and other basic facilities like electricity or piped water.

In view of the strict environmental management measures to be adopted during construction and operation of the plant, there will not be any adverse impacts on the population and environment around.

During the construction and operation phases of the project, some pollutants like effluent, gaseous emissions, particulate matter, solid wastes and noise will be generated. These can be likely impacts of pollutants, in case the environmental controls are not put in place.

Environmental management practices to be adopted will help to undo the adverse environmental impacts on all segments of the environment.

10.12 ENVIRONMENTAL IMPACTS

10.12.1 Impacts During Construction

10.12.1.1 Air Quality

The main impact on air quality during construction will be from increased airborne dust levels and vehicular emissions (primarily NO_x, SO_x and particulate matter) arising from construction machinery, rock blasting, foundation excavation, cement mixing, and road construction. The air quality impacts will however, be limited and confined to the construction sites i.e. Powerhouse, weir, sandtrap and embedded pipe etc.

Dust generation from vehicular movement and construction activities in the project area may affect vegetation / crops and animals and cause nuisance to local population in terms of lungs and eyes irritation and reduced visibility. Deposition of dust on plant leaves may impact photosynthetic activity and result in increased incidence of plant pests and diseases and reduced crop productivity. Sensitive receptors likely to be susceptible to air emissions are villages adjacent to the road as well as those near the weir site or powerhouse site.

Impacts associated with air quality during the construction phase are considered to be of be moderately negative significance, given the extent of the area to be affected, duration of construction, and presence of sensitive receptors.

The unpaved parts of the road leading to the construction sites and the construction sites will be regularly sprayed with water; at least twice a day during hot and dry period and the maintenance of vehicles will be properly managed and monitored. This will mitigate the problems.

10.12.1.2 Noise and Vibration

During the construction phase, the noise will generally be generated from vehicular movement, sand and aggregate processing, concrete mixing, excavation machinery, 'mucking out' of excavated material, construction noise and blasting. Noise levels in the construction area from machinery and vehicles should be as specified in the guidelines by the environmental protection agencies.

Construction activities will begin with the road enhancements to enable access to the powerhouse and weir sites, followed by other structures and low pressure pipe. Noise will be concentrated at powerhouse and weir sites; however, increased traffic to and from construction material sources and workers will result in noise impacts.

Impacts associated with construction noise are considered to be of moderate negative significance, considering the size and extent of the project area affected and within a predominately rural setting.

Mitigation measures for noise impacts on construction workers will include standard occupational health and safety practices such as ear protection and enforcement of exposure duration restrictions.

Blasting activity should be limited or restricted during night time, if noise levels are unacceptable for people living in the vicinity and to reduce impacts on wildlife.

Delayed Relays and low intensity dynamite should be used to minimize the noise and vibration.

10.12.1.3 Soils

Construction activities may have the following impacts on soils if mitigation measures are not adopted and enforced:

- Landscape value degradation.
- Erosion.
- Soil contamination.

Much of the land cover within the project area consists of steep slopes covered by shrubs and grasses and is prone to erosion due to medium textured soils (sandy loam / silt loam). Extensive grazing has exacerbated erosion issues within the area and additional causes of soil erosion should be avoided.

Potential negative impacts (without mitigation) on soils resulting from erosion, loss of topsoil and contamination are considered to be of moderate significance.

Disposal areas will be well marked and monitored so that appropriate procedures for disposal of different agents and waste materials are followed to minimise soil contamination.

All unpaved areas will be 'greened' by planting of trees and grasses to reduce erosion during the construction period.

Soil erosion due to road construction will be minimized by suitable road engineering techniques and road edge buffer re-planting.

All excavated rock and aggregate will be used in construction where possible, while the spoil will be deposited in an area with minimum landslide potential, multilayered and covered with soil, and planted with trees, shrubs and grasses.

Machine parking areas and roads should be paved to the extent possible.

10.12.1.4 Waste

Large volumes of waste are likely to be generated from the construction activities, construction camps, workshops and storage areas and include such things as waste oils, empty fuel tanks, lubricant tins, broken tools, cables, construction steel cuttings, scaffoldings, other discarded materials such as chemicals and paints and municipal solid waste. Depending on the nature of the waste there is a potential for material disposed of in open undesignated areas to be a source of smell and vector diseases. Waste streams generated from the project activities would be mainly localised and if disposed of properly, are unlikely to affect areas other than active project zone.

Impacts associated with waste generation (solid and liquid) and disposal is considered to be of minor magnitude considering localised extent and limited duration.

The leftover material should be collected and disposed off into the designated sites and also recycling of the material should be promoted like drum of fuel and lubricants should be returned to the companies for its recycling.

10.12.1.5 Construction Spoil

The major source of construction spoil is likely to be generated from the excavation of the diversion structure, intake foundations, etc. It is estimated that a large quantity of construction spoil will be generated from the excavation works. Potential negative impacts on the landscape and downstream sedimentation, resulting from inadequate spoil disposal and management, need to be mitigated through an ESMMP.

Negative impacts arising from the inappropriate spoil disposal during construction are considered to be of moderate magnitude.

The spoil would be dumped on the mild slopes near to the project site and subsequently these slopes would be covered with alluvial material so that plantation / greenery could be grown and the spoils become environmentally acceptable.

The soil and rock pits (quarry) will be filled and appropriately planted with trees, shrubs and grasses.

10.12.1.6 Use of Hazardous and Toxic Materials

Explosives shall have to be inducted into the project area, and without proper handling and management pose a safety risk to workers and residents alike.

Details of the hazardous and toxic materials to be used on site are not currently available and should be taken care during construction stage providing indicative quantities and the impacts arising from their use and disposal. The different materials need to be managed in different ways according to their potential environmental impacts.

Negative impacts arising from the inappropriate handling of hazardous and toxic material during construction are considered to be of moderate magnitude.

Mitigation measures including adequate monitoring and standard health and safety procedures will need to be included to avoid potential impacts.

10.12.1.7 Layout of Construction Camps, Workshops and Labour

Details on construction lay down areas and layout including workshop areas and number of labourers required is unknown at this stage. The impacts due to siting of construction camps will mainly include wastewater discharge, solid waste and traffic congestion (due to the movement of vehicles transporting work force to construction site and base camps). Such effects are considered to be localised.

However, the site specific impacts can only be predicted once siting of the construction areas is finalised at the construction stage.

The details of layout of construction camps, workshops and labour camps will be worked out by the contractor at project construction stage and impacts and mitigation measures will be taken care according to the regulations specified by the agencies.

10.12.1.8 Water Use / Quality

Water will be required for concreting works and also for washing/material preparation purposes. It is proposed that the Jagran River will be the main source of water, which will be pumped into settlement ponds/reservoirs to remove fine suspended particles (particularly during floods).

It is not known whether any restrictions will be applied to water extraction during low flow periods (construction activities will be constrained within winter/low flow periods due to access / weather). Currently, the data are not available on the estimated water use requirements for construction activities.

Presently, the sewage from all the major settlements along the Neelum River is being disposed off in septic tanks/soaking pits. A small quantity of sewage through seepage might be entering the river. Agriculture run-off is potential contributor to the river pollution; however, low inorganic concentrations are found due to limited use of inorganic fertilizers for growing of crops.

Impacts on water quality associated with construction camps during the construction phase are considered to be of minor significance as long as adequate mitigation measures are in place to prevent effluents entering the river.

10.12.1.9 Impacts on Aquatic Life

During construction activities the water in river will be channelised in a very short stretch of river. Impacts and mitigation measures on aquatic ecology and terrestrial fauna and flora within this zone are considered to be minor.

Construction impacts on aquatic life at weir site are considered to be negative and of minor magnitude.

10.12.2 Impacts During Operation

10.12.2.1 Air

During operation, air pollution is expected to be very limited, and the main sources will be from vehicle emissions / dust from maintenance traffic on unpaved roads and increased traffic due to movement of workforce. In addition, there may be some dust from construction quarries and sites before they are fully rehabilitated.

Impacts on air quality during operation are not considered to be significant.

Few mitigation measures such as proper vehicle tuning and road maintenance, etc. are available to limit influx of traffic movements resulting from improved road infrastructure.

10.12.2.2 Greenhouse Gases

In comparison to the other power production sources, such as the fossil fuels or nuclear, the hydropower produces relatively small or negligible amount of greenhouse gases which could contribute towards global warming.

Impacts on emissions of greenhouse gases are considered to be of a minor positive significance.

10.12.2.3 Noise

During operation the noise will mainly be generated in the powerhouse only through the operation of the electrical and mechanical equipment. Further, the increased access as a consequence of the road improvements may generate some additional traffic which could also impact on the existing noise levels in the project area. Therefore, appropriate noise reduction measures will be taken to reduce the generation of any noise levels.

Noise impacts during operational phase are considered to be of minor significance.

10.12.2.4 Water Quality

Changes in water quality are likely to occur within and downstream of the project area due to impoundment. Water quality impacts are likely to be a combination of physical, biological or chemical changes and the magnitude will depend to a large degree on the existing water quality, the water quality requirements for downstream users and the mitigation measures employed.

Key impacts on water quality will relate to existing sedimentation of the Jagran River and impacts resulting from sediment flushing of the weir and sandtrap.

In addition, the reduced flows within the Jagran River may limit dilution of contaminants entering the river course further decreasing water quality within the impounded length of the Jagran River.

The potential magnitude (taking into consideration extent, duration, likelihood and reversibility) of impacts resulting from changes to water quality are considered to be of moderate magnitude.

10.12.2.5 Compensation Water

According to site survey and interviews with the local people it was revealed that downstream section of the river, below the weir, there is very little human and aquatic life requiring water for its survival.

Therefore, under these circumstances there is small compulsion to discharge a definite quantity of compensation water which should be sufficient to sustain any activity and ensure survival of any aquatic life in the section of the Jagran River under discussion.

On the other hand, there is no hard and fast rule to be followed for the quantity of compensation water to be released through the section of the Jagran River except to assess the requirement of water in the section of the river.

Compensation flow has been estimated based on the average monthly flows to maintain the ecology of Jagran River The weir site has flow values which are about 90% of flows in Jagran River at its confluence with Neelum River. As the downstream small streams / tributaries joining Jagran River would provide about 10% of the flows at the Jagran River confluence with Neelum River, therefore, the residual flows are released downstream of the weir which are essentially required.

In winter months, i.e., from October to March, the compensation flows of 0.30 m^3/sec and during summer months, i.e., from April to September, it would be increased to at least 0.6 m^3/s.

These flows are in addition to the flows of streams / tributaries joining Jagran River downstream of the proposed weir. These flows are considered to be sufficient to support the downstream water usage. The monthly estimated flows at the weir site and diverted to powerhouse are indicated in **Section - 6** of the report.

10.12.2.6 Impact on Microclimate

Although the proposed Jagran - IV Hydropower Project will not create large reservoir, it might impact the humidity levels and cause a fall in temperature in the vicinity of the project area.

10.13 BIOLOGICAL IMPACTS

10.13.1 Biological Impacts During Construction

10.13.1.1 General Impacts on Flora

The extent of weir site to the reserve forest and other trees in powerhouse areas were estimated during field visit and an initial assessment of trees to be cut during project construction are very small in number. Overall, about 45 - 60 trees at the weir site and the powerhouse location will have to be felled.

Steep banks on either side of the river support mainly shrubs and grasses which in addition to trees identified will also be submerged by the project. The shrub and grass species affected are abundant in other areas. No endangered, threatened or vulnerable species in the project area exist.

The impacts of constructing labour camps, offices, borrow pits, quarries and new road will have to be established during construction stage and mitigation measures incorporated at proposed sites to limit vegetation clearance where possible.

The magnitude of impacts on flora during the construction phase is considered to be of major significance (potentially reduced to moderate should replanting strategies be implemented).

10.13.1.2 General Impacts on Fauna

Impacts to terrestrial fauna resulting from the project activities will be very negligible. However, physical clearance of the weir site and powerhouse site, and disturbance and degradation of habitats around the main construction sites resulting from increased worker population and improved access will impact.

Most of the faunal species identified within the baseline study are restricted to the reserve forest areas. Only a few reptile and amphibian species have been reported in the proposed project area and do not include any endangered, threatened or vulnerable species.

The faunal species that are only found within the area to be inundated which cannot migrate away from area will be lost and result in a moderate negative impact. Construction activities will disturb the migratory route of faunal species which use river crossings (i.e., suspension bridges) in the winter when the local inhabitants vacate their houses and migrate to lower elevations.

However, this will be a minor impact as the area of the reservoir is very limited. Animals could adopt alternate routes located upstream or downstream of the weir and powerhouse site. The increased human population in the project area due to the work force and labour in migration may exert a stress on the animal population through hunting / poaching, etc.

Construction activities will generate impacts of a moderate magnitude within the project area, in particular at the powerhouse, weir site, pressure pipe route and quarry areas.

Mitigation measures during vegetation clearance, blasting, creation of borrow pits and lay down areas should include site walkovers by a qualified ecologist to identify the presence of any vulnerable species before clearance activities are undertaken.

As a mitigation measure, the special corridors may be provided for easy movement of wild animals in the project area. Relocation of species should be considered where possible and viable.

Mitigation measures will need to be enforced through an ESMMP and contractually bind both contractors and their labourers from undertaking illegal poaching and any other hunting and fishing activities.

10.14 SOCIO-ECONOMIC IMPACTS

10.14.1 Involuntary Resettlement of Project Affected People

The proposed Jagran - IV Hydropower Project will require a few temporary resettlements of the people at the weir / intake site and powerhouse area. A Resettlement Action Plan (RAP) must be developed and implemented with the objective of ensuring that Project Affected People (PAP) improve or at least restore their livelihoods and standard of living.

The resettlement impacts are considered to be minor to moderate magnitude.

10.14.2 Employment Generation During Construction Phase

The construction phase is scheduled to take place over a few years. As most of the labour will be employed from the project area, the construction of the project will provide earning to the people of the area.

Employment generation impacts during the construction phase are considered to be positive impact of moderate magnitude.

10.14.3 Cultural Heritage and Archaeology

Although some changes in the social and cultural behaviour are expected due to the interaction of local population with the project staff from outside; however, the development of the project site is not likely to cause any adverse social impact at all. No place of religious or cultural veneration was sited during the field visits to the project area.

Impacts on cultural heritage and archaeology are considered to be negative and of moderate magnitude.

10.14.4 Recreation Activities

Neelum Valley is a renowned tourist destination and every year hundreds and thousands of tourists including foreigners visit the area, particularly during the summer season. The development of the proposed Jagran - IV scheme is likely to attract more tourists in the area and will increase the commercial and recreational activities.

Impact relating to recreation activities is considered to be positive and of moderate magnitude.

10.15 IMPACTS IDENTIFICATION FOR OPERATIONAL PHASE

10.15.1 Electricity Generation

The greatest benefit provided by the proposed Jagran - IV Hydropower Project will be the provision of electricity to population, expanding economic activities and increasing demand for energy. The Jagran - IV project is proposed to generate 22 MW installed capacity. Electricity is recognised as a necessary productive input contributing to a stable economy.

Electricity generation impacts are considered to be positive and of major magnitude.

10.15.2 Employment Generation During Operational Phase

During the project operations, a small number of people will get benefit from the employment opportunities thus created. The employees are considered to be a socio-economic receptor of medium sensitivity because they will have long term contracts providing fair remuneration on a regular basis.

Employment generation impacts during the operation phase are considered to be positive and of minor magnitude.

10.15.3 Provision of Associated Facilities

The project will require improved access roads, which will facilitate the local people to access the goods and markets and increased fish spawning in the area thereby improving the fishery opportunities. Both of these will contribute positively to the livelihood of people in the project area.

Local community members will benefit from these facilities. Moreover, education and health facilities will be enhanced due to project and these facilities will also be available for the local communities.

The impact of providing associated facilities is considered to be positive and of moderate magnitude.

10.15.4 Agricultural Impacts

It was noted / observed during the field visits and also through community consultations that the river is not used in the project area for the irrigation of large tracts of agricultural crops.

The impact of the proposed project on agricultural production is minor, although the operational phase is not expected to significantly adversely impact the agricultural activities.

10.15.5 Landscape and Visual Amenity

The Keran, Sharda and Neelum valleys are known for their outstanding natural beauty and landscape and it is a popular destination among tourists from both Pakistan and abroad. The area offers tourists opportunities generally for outdoor activities such as hiking and fishing.

During the construction, the related equipment and influx of people will temporarily affect the visual and landscape values of this relatively untouched area.

During the operation phase, the existence of the scheme may change the visual amenity at a particular place, impacting on the surrounding landscape and views.

10.16 ENVIRONMENT AND SOCIAL MANAGEMENT AND MONITORING PLAN (ESMMP), ENVIRONMENTAL MITIGATION MEASURES AND PROPOSED TRAINING

10.16.1 Introduction

For mitigation of the negative environmental impacts, a very strong Environmental Management Unit (EMU) should be created to ensure compliance with the ESMMP as legal requirement under the Pakistan Environmental Protection Act 1997.

The EMU will be headed by an individual responsible for the entire mitigation operations during construction phases and thereafter for implementation of the ESMMP during construction and operation phase also as regular feature. He will also be responsible to report on progress and the status of each rehabilitation conducted. Wherever required, he will be assisted by some expertise of the Forest Department, fisheries, Wildlife, etc., Government of AJ&K. It will be worthwhile to establish EMU right at the onset of the project.

The unit should employ suitable people and equip the unit with necessary equipment commensurate with the requirements of the project effective environmental management. All the staff of the EMU should be duly trained in the relevant fields of environment to be managed by them. Necessary budget on regular basis should be provided to keep the capabilities of this unit to effectively manage its all out responsibilities / activities.

A programme for monitoring of the water quality and aquatic life for pre-construction, construction and operation phases is given in the Environmental and Social Monitoring Plan (ESMP).

Environmental Protection training and awareness, and capacity building of institutions is important. This needs to be done at the earlier stages of the project execution.

10.16.2 Organisation and Implementation

The EMU will ensure implementation of the Environmental and Social Management Plan and the Environmental and Social Monitoring Plan during construction and Regular operation of the Project.

The EMU will:

- be responsible for the implementation and management of the ESMMP
- coordinate all environmental monitoring activities of the ESMMP.
- ensure that the ESMMP is updated periodically during the construction period.
- responsible for regular environmental, health and safety rounds in all construction areas.
- ensure that an independent environmental supervision consultant supervises and monitor environmental procedures.
- submit environmental and social monitoring reports (including physical data) to the EPA, Government of AJ&K on quarterly basis during construction and twice annually during operation.

Capacity Building includes training of EMU personnel and Forestry Department, Government of AJ&K in forest protection and management. Participation of representatives of the local communities in training workshop on environmental protection will be preferable.

10.16.3 Resettlement Action Plan (RAP)

The resettlement Action Plan provides a framework for addressing and reviewing compliance with the agreed rules, responsibilities and activities related to resettlement. The underlying assumption for the RAP is that efforts will be made to improve the livelihoods and standards of living for all projects affected persons or at least to restore them to pre-project levels.

10.16.3.1 Resettlement Principles and Objectives

The main involuntary resettlement principles and procedures that are applicable to the proposed Jagran - IV Hydropower Project are summarised below:

- Resettlement and land acquisition will be minimised as much as possible.
- Project Affected People (PAP) will be compensated or at least restored to pre-project levels.
- Land for Land is an easier and acceptable option for compensation in the case of loss of land. In the absence of replacement land, cash compensation for the property acquired will be paid at its replacement value in addition to any transaction costs.
- Each PAP is entitled to receive assistance to restore income and livelihood to a pre-project standard, and all vulnerable affected people are entitled for assistance to improve their income and livelihood.
- All PAPs will be informed and consulted on compensation and other entitlements, relocation programs and income restoration assistance.
- Compensation and income restoration programs will be carried out with equal consideration for women and men.
- PAPs social and cultural institution will be protected along with common property resources.
- The resettlement transition period will be minimised.

10.17 PUBLIC CONSULTATIONS

Public consultations were held with the people from the project area. They have welcomed the project and are of the view that the project will open up new avenues of job opportunities for the people of the project area. This will result in poverty alleviation to a reasonable extent.

Further, the people have clear perception that the installation of the hydropower project in the area is beneficial for the community especially and the area in general.

As far as the Social Impact Assessment (SIA) is concerned, the positive social impacts are dominant over hardly conceived any negative social impacts observed during the study. They correlate their positive attitude towards the plant with many socio-economic opportunities and benefits.

People also perceive the accelerated economic activity due to the business opportunities likely to emerge in the area. Directly or indirectly, many local people will get employment and business, e.g., shopkeepers, traders, suppliers, contractors, transporters, technicians, etc. They feel that the project and its related activities will provide a strong base for the social change.

10.18 CONCLUSION

On the basis of findings of this Initial Environmental and Social Impact Examination study, it is concluded that the proposed Jagran - IV Hydropower Project will not have any significant adverse impacts on the local population or any segment of environment provided the above mentioned recommendations and mitigation measures are fully implemented by the plant management in letter and spirit.

11 COST ESTIMATES

11.1 INTRODUCTION

The cost estimates used in this report are based on unit and lump sum prices applied to the quantities of major work items calculated for various components of Jagran-IV Hydropower Project. The Consultants have updated all relevant economic key parameters and have elaborated a detailed project unit cost data base.

The following estimates have been prepared;

- Summary of Costs
- Detailed Estimates of Cost

These cost estimates are based upon the price index of August 2010. The summary of cost estimates has been used for economic and financial analysis. This estimate considers local currency component in Pak Rupees, foreign currency component is US Dollars and total cost in equivalent Pak Rupees based on August 2010 exchange rate (1 US$ = Rs. 85.60).

11.2 ESTIMATION OF QUANTITIES

The Consultants have estimated the quantities of major civil structures of the project based on the feasibility design and corresponding design drawings. The drawings are presented in Volume-II of this report.

Materials and quantities required have been computed using the engineering design drawings consisting of plans and sections of all the components of the project on a scale of 1:500 and 1:1000, drawn on exact topographic survey maps.

For minor works provisions in terms of the miscellaneous items rates have been made. In accordance with common practice, the cost estimate is based on the concept of direct and indirect costs and provisions for unforeseen items and costs (contingencies).

The cost estimates include the following main plant components and cost elements:

- Land acquisition and environmental mitigation cost;
- Preliminary works including mobilisation cost and site infrastructure;
- Civil works include weir and flushing outlet, power intake, sandtrap, headrace pressure pipe, surge pipe, penstock and surface powerhouse and tailrace system;

- Manufacturing of hydro-mechanical and electrical equipment;
- Transportation cost;
- Erection and commissioning cost;
- Import duties;
- Project administration;
- Engineering and supervision costs;
- Contingencies.

The cost estimates for various works including Infrastructure development and site installations, civil, hydro-mechanical, electrical and transmission lines were prepared by multiplying unit rates with the relevant quantities of different structures. The cost estimate for environmental mitigation was prepared after collection of data during site visit and then estimated after evaluation.

Major portion of civil works cost estimates include concrete and earthwork calculations. For the major structures such as the diversion weir, connecting channel, sandtrap, pressure pipe, powerhouse and tailrace etc. the quantities of concrete and earthwork are presented in **Table - 11.1**.

11.3 UNIT RATES

The Consultants have estimated the unit rates for several items of civil works. Basic costs of labour, material and equipment have been updated to estimate unit costs and these unit rates are compared with that of similar size hydropower projects presently under development in Pakistan and AJ&K.

The unit and lump sum prices for civil works of Jagran-IV Hydropower Project have been prepared after consulting and escalating the unit prices of a number of similar hydropower projects under study or under construction. The similar projects include Jinnah, Keyal, Lower Spat Gah, Madyan, Golen Gol and Neelum-Jhelum Hydropower Projects.

Since the units rates presented in BOQ of the six (6) above projects refer to different reference dates, they were escalated to the level of August 2010 applying an appropriate inflation rate per annum on local and foreign currency rates and the corresponding currency exchange rate of the Central Bank of Pakistan.

Cost of hydro-mechanical and electrical equipment is based on in-house database of the Consultants.

There are a large number of hydropower project schemes under development in Pakistan. The cost estimates and unit rates derived from the tender documents and the Contractor's proposals of other hydropower projects of similar type and magnitude provide a reasonable orientation for the plausibility of the calculated unit rates.

However, the site, contract and other specific conditions may cause significant deviation in the unit rates for the same construction activity from one hydropower project to the other.

11.4 ESTIMATION OF PROJECT COSTS

The estimation of costs has been carried out by preceding the following steps in accordance with the requirements of a bankable feasibility study. In addition to the basic cost items of each civil structure in terms of their direct costs, the Consultants considered certain contingencies. These include both physical and price contingencies.

Physical contingencies result from the fact that the estimated quantity of certain items might have been under estimated. Additional minor items or quantities of components will ultimately be required which were based on the knowledge available at the particular planning level originally not included in the estimate.

Price contingencies are included to account for variation in prices, i.e. inflationary tendencies during the implementation period. Price contingencies are included in the total project cost for implementation.

Costs are presented by their local and foreign components for the individual unit rates and the overall cost of civil works and equipment. The composition of local and foreign cost component was derived from hydropower projects presently under development in Pakistan and AJ&K.

The direct costs of a hydropower project are commonly estimated separately for the following major components based on the major items / elements.

a) Civil works including hydraulic steel structures;

b) Hydro-mechanical; and

c) Electrical equipment.

The cost estimates form the basis of economic and financial evaluation of the project. It shall be prepared on the basis of representative unit rates for various construction activities and the respective quantities.

In order to comply with the requirements on accuracy of cost estimates, the Consultant adopted the following approach:

- Collected basic costs of material, fuel, consumables, labour, equipment etc. at factory and at site (cost of transportation);
- Calculated unit rates for relevant items of civil works for application to BOQ;
- Collected unit rates used in feasibility studies and tendering of hydropower projects of similar type and magnitude, escalated these unit rates to the reference data of the cost estimates;
- Compared, analysed and concluded on most appropriate unit rates for application.

11.5 ENVIRONMENTAL IMPACT MITIGATION COST

Major bases of mitigation cost are for the measures taken at pre-construction and construction stages. The main components covered under this item are temporary relocation cost and compensation paid to the private land owners, compensation for the loss to forest trees, water supply provision costs, costs for disposal of excavated material, channel lining cost and afforestation cost, etc.

The environmental mitigation cost has been estimated as US$ 344,626.

11.6 CIVIL WORKS

Civil works include road and preliminary works, diversion weir including intake, headrace pressure pipe, surge pipe, penstock and surface powerhouse and tailrace channel. The quantities for each structure have been estimated from drawings presented in Volume-II.

Cost of civil works includes all the civil engineering structures of proposed project including headrace pressure pipe, cofferdam, diversion weir, connecting channel, sandtrap, flushing outlet, surge pipe, penstock, powerhouse, switchyard, tailrace, etc. Due consideration has been given to the seasonal variation, inflation over years and distance from Muzaffarabad, etc. to have comparable prices as obtained from international contractor / different projects.

The cost of cement and steel is based on the prevailing market rates. Unit prices of aggregates based on the consideration that all the raw materials would either be available at site or from the quarry in the vicinity of the project area. The rate analysis for different items of works has been carried out on the basis of above consideration.

The cost for all civil works has been estimated as US$ 16.194 million. The detailed cost estimate has been presented in **Table - 11.3**.

11.7 ELECTRICAL AND MECHANICAL EQUIPMENT

The cost of turbines, generators and transformers were obtained from in-house database and experience of the Consultants to establish the costs of the equipment. The cost of electro-mechanical equipment would comprise of local and foreign components.

Some parts of the electro-mechanical equipment have been proposed in procurement of local components. The duties and taxes are also considered in firming up the cost.

The cost for hydro-mechanical equipment is US$ 4.480 million. The cost for electrical equipment is US$ 4.475 million.

The cost of transmission from Jagran-IV to Jagran-I switchyard has been estimated as US$ 0.5 million. In case, Off - Taker decides to construct its own transmission line then this cost will be deleted from the total cost because as per Energy Policy 2002 of Government of Pakistan, which is also to be followed by Government of AJ&K, transmission line is the subject of Off - Taker.

11.8 TRANSPORTATION AND SHIPMENT

Major electro-mechanical equipment including turbines and generators are to be imported. These materials are to be shipped from the country of its manufacturer and special arrangements for its inland transportation are to be made. The cost of freight, shipment and insurance, etc. from the country of manufacturer has been taken as 4% of E&M equipment, which is estimated as US$ 0.378 million.

11.9 ERECTION, COMMISSION AND TESTING CHARGES

About 10% of cost of the E&M equipment prices has been provided for erection, commission and testing of such equipment, which is estimated as US$ 0.946 million.

11.10 ENGINEERING AND SUPERVISION

This represents the cost of preparation of detailed construction drawings at tendering stage, pre-qualification of bidders, evaluation of tender / bids, review of contractor submittals, administration of the construction contract and measuring of work, etc. The cost for engineering and supervision has been taken as 5% on civil and E&M works and estimated as US$ 1.265 million.

11.11 PROJECT DIRECTOR ADMINISTRATION

5% of the project civil and E&M works cost has also been estimated for this purpose to meet the administration expenses during project execution, which is US$ 1.265 million.

11.12 IMPORT DUTIES

Import duties inclusive of custom duties have been calculated, based on Government of Pakistan import policy for 1993 and also energy policy 2002. This includes custom duties for each imported equipment and material. The total duties at a rate of 5% of the imported equipment and material have been added to the estimates, which is US$ 0.381 million.

11.13 CONTINGENCIES

An effort has been made for realistic project cost estimates. To cover some of the unforeseen that may occur over the period of construction, provision for contingencies has been made as 3% of total base cost, which includes local and foreign capital costs of civil works as well as of E&M equipment, etc. The total contingencies cost is estimated as US $ 0.897 million.

11.14 INTEREST DURING CONSTRUCTION

The interest during construction has been estimated at a rate of 15.79% per annum for four (4) years of the construction period for local cost component and 4.64% as interest rate and 11% as exchange rate variation on foreign cost component.

The total estimated interest during construction cost is US$ 11.228 million.

However, this cost is subject to adjustment on Commercial Operation Date (COD) of the project against the actual interest rates and drawn down amounts.

11.15 TOTAL PROJECT COST

Total project cost is estimated as PKR. 3,595.943 million which requires foreign exchange of PKR 2,172.287 million in US$. A brief summary of the cost is given in **Table - 11.2**. Detailed project cost estimates have been made and are provided in **Table - 11.3** and cash flow as required during construction period is presented in **Table - 11.4**.

Table - 11.1: Major Quantities of Civil Works

Sr. No.	MAJOR ITEMS	UNIT	QUANTITY
1	Excavation (ABGM)	m^3	112552
2	Excavation (Hard Rock)	m^3	76548
3	Excavation (Soft Rock)	m^3	57816
4	Backfill	m^3	24431
5	Reinforced Concrete	m^3	16331
6	Mass Concrete	m^3	480
7	Hard Concrete	m^3	384
8	P.C.C	m^3	2472
9	Stone Apron	m^3	9870
10	Reinforcement	t	676
11	Steel Lining - 8 to 15 mm thick	t	2079

12 CONSTRUCTION PLANNING

12.1 INTRODUCTION

The construction activities would mainly be spread over Jagran valley from weir to powerhouse site. The distance from weir to powerhouse site is about 3.1 km and elevation varies from 2264 m asl to 2108 m asl. Presently, there are not enough infrastructure in the project area like roads, residential buildings, market, hospital, etc.

Further, generally the working period is from March to November and the accessibility of project area from Muzaffarabad in winter three months is limited.

Materials, such as cement and steel have to be transported from down country. Aggregates, gravel and sand will be available within the working area in an economic distance of transportation.

Two camps will be constructed; one near powerhouse site and other near weir site. The access to project area is from Muzaffarabad, which is connected with a metalled road up to Kundal Shahi and by truckable road in Jagran valley.

12.2 CONSTRUCTION PLANNING

The proposed project implementation schedule spans over a period of 60 months, which include 48 months for construction activities and 12 months for pre-construction activities. This section deals with the critical factors, governing the pace of work. It will also cover the proposed construction techniques.

The construction planning for Jagran-IV Hydropower Project has been prepared. Construction of headrace pressure pipe and powerhouse are on the critical path. Keeping in view the following major factors:

- Manpower, equipment and skills of similar works are available with the contractor.
- Flood and low flow periods in Jagran valley.
- Severe weather conditions in winter months causing stoppage of concrete works from December to February.

The project area is located within high mountains of Jagran valley which is remote area and it remains under snow cover during winter months. Further, the access to project area is hindered due to landslides in rainy period. The project area is located near Shaal village which is about 86 km from Muzaffarabad. The weir and powerhouse sites are located about 18 km and 15 km respectively from Kundal Shahi.

The critical items required for construction process of the project has been studied in detail and accordingly the construction schedule has been framed, keeping in view the construction methods. The period of each activity has been estimated keeping in view the weather conditions, because some activities may have to be discontinued in severe weather such as surface civil works at the site may not be possible during very cold weather.

12.3 DESCRIPTION OF WORKS

The project layout includes a diversion weir and an intake structure, located on Jagran River at about 3.1 km upstream of intake of Jagran-I Hydropower Project. The project would involve a sandtrap, 3075 m long headrace pressure pipe, surge pipe, 180 m long penstock pipe, surface powerhouse and tailrace on the left bank of Jagran River.

The whole construction operation will be spread over a large area in Jagran valley, where the required camps, workshops, offices, processing plants and stores can be located near to the construction site.

The description is outlined for the various construction stages, required for the completion of different project components like; preliminary works, mobilisation, camps, diversion weir, sandtrap, headrace pressure pipe, surge pipe, penstock, powerhouse and tailrace, etc. in the following paragraphs.

12.3.1 Preliminary Works

Before the start of any construction activity, approval of PC-I Proforma by HEB from concerned authorities of AJ&K is a pre-requisite. Thereafter, the construction, improvement and extension of roads and construction of one bridge on Jagran River, needs to be completed for executing any work. The road along Jagran River also needs to be widened and improved. The road to surge area has to be built. These activities, including land acquisition, are to be completed by HEB.

12.3.2 Site Installation and Mobilisation

The first important stage in the construction planning is the site installation. It mainly deals with the mobilisation of all plant and equipment required for the various construction items, electric and water supplies to offices and equipment, erection of repair and maintenance workshops, stores for spare parts and materials, administration / planning office, concrete mixing and aggregate processing plants, steel yard, fuel storage stores, etc. The area for these items should be as close as possible to the construction sites and organised in such a way that no disturbance to the construction activities occurs.

12.3.3 Construction of Camps

The project consists of three major construction items such as:

- Diversion weir, power intake and sandtrap
- Headrace pressure pipe and surge pipe
- Penstock pipe, surface powerhouse and tailrace.

Since the Jagran-IV Hydropower Project would be spread over 3.1 km area, from weir intake to powerhouse, so two camps are necessary or there could be one major camp near weir area for the work force.

One camp may be placed on a relatively flat terrace near the weir site. This camp will fulfill all the basic necessities required for diversion weir, sandtrap and inlet portal of pressure pipe. After some months, it will be extended to meet the requirements for construction of other structures.

Another suitable location for site camp may be at powerhouse area near Jagran village. The camps should fulfill the requirements for construction of penstock, surge pipe, powerhouse, tailrace and other residential buildings. The camps have to be equipped and furnished with all necessary facilities such as workshops, stores, offices, mosque, accommodations for contractor's and consultant's personnel, hospital, recreation facilities, etc.

12.3.4 Diversion Weir

After construction of the first camp, works on diversion weir / intake structures shall be started. The work on diversion weir / intake will take about two summer seasons.

The construction of the weir should be carried out as follows:

First the Jagran River would be diverted to right bank by constructing a coffer dam to start the construction of left portion of weir, undersluice and sediment flushing channels on the left side of the weir. After completion of this left portion of weir, the river will be diverted to the left side to start the construction of remaining overflow portion of diversion weir.

A period of four months is available to carryout excavations and eight months for placement of concrete. The work on construction of weir will be stopped when flows in the river are high. Installation of the undersluice gates will also be completed up to June Year-2.

For the second stage of weir construction, the work on the weir will be re-started by Year -2 when the flows in the river drop down substantially. A coffer dam will be constructed in two months across the river and the river flows will be allowed to flow through the constructed under sluices structures.

12.3.5 Power Intake, Connecting Channel and Sandtrap

Power intake, connecting channel and sandtrap structures are located at left side downstream of the weir. It is proposed to initiate the work on these structures side by side with the works of the Stage-1 of the weir structure. The excavation work for connecting channel and sandtrap will be completed in four months. Afterwards these structures are to be completed in about seven months; the installation of gates will also be completed during this period.

12.3.6 Headrace Pressure Pipe

The headrace pressure pipe will be excavated from downstream end of sandtrap. The pressure pipe would be laid down in trench to be excavated with mild slope on the left bank of Jagran River. Along with excavation, base surface would be prepared and pedestal and anchor blocks would be constructed wherever necessary for alignment of pressure pipe.

The work on pressure pipe can be started simultaneously with the construction of weir. The excavation of trench, fabrication of pipe, anchor blocks and erection of pipe would take 24 months spread over three working seasons.

The headrace pipe may be on critical path, it has to be started as soon as area for inlet portal near sediment basin is ready for construction. This activity is expected to be completed in August Year-3.

12.3.7 Surge Pipe

The construction of surge pipe would be laid parallel to headrace pressure pipe. The intake for penstock and surge pipe connection with headrace pressure pipe would be made. The whole civil and mechanical works can be started independently.

12.3.8 Penstock

About 180 m long penstock has been proposed to connect surge pipe with powerhouse. The penstock would be laid as embedded pipe by excavating the natural surface and then covered with the excavated material. This activity would be made in parallel to powerhouse construction and it would take about 3 months for excavation for trench, 3 months for anchor blocks and 3 months for erection of penstock. The overall activity would take about 8 months from fabrication to erection.

12.3.9 Powerhouse and Tailrace Tunnel

The powerhouse is located on the left bank Jagran River just upstream of the intake for Jagran-I power station. The work on the excavation, rock blasting and formation of place for the powerhouse will take approximately 8 months. The construction of powerhouse building and tailrace can be started at any time a year head of project completion.

12.3.10 Electro-Mechanical Equipment

Manufacturing of electro-mechanical equipment will be started in the beginning of the first year of construction and will take approximately one and a half year.

Transportation from overseas and inland transportation of equipment will require about 9 months. Installation of the embedded parts will require 6 months for fixing. The erection of turbines and generators will take about 12 months.

The switchyard will be located near the powerhouse and it will take approximately six (6) months for its completion. Transmission line to Jagran-IV powerhouse to Jagran-I powerhouse would take about seven (7) months in the last year of construction.

A tentative implementation schedule for project containing all major activities is given in **Figure - 12.1**.

13 FINANCIAL AND ECONOMIC ANALYSIS

13.1 INTRODUCTION

The identified hydropower potential in AJ&K and rest of country mainly lies in far flung and remote rural regions which for some reasons, could not be brought up to the same level of socio-economic progress as that of the urban areas.

Due to lack of interest or resources to mitigate the situation, migration of people from under developed areas towards developed areas is on the rise and this pace is accelerating with the passage of time. The increasing trend has already put enormous strains on the resources of urban areas.

Notable socio - economic deficiencies in rural areas that compel the people to migrate to urban areas are:

- Absence of basic infrastructure and facilities like access roads, basic health units, education, electricity and other basic needs.
- Absence or lack of sufficient employment opportunities that meet the local needs.

Traditionally, the rural culture nurtures, promotes and sustains a large cadre of skilled workforce including masons, carpenters, electricians, plumbers and steel workers. This work force, however, either is un-utilised or remains under utilised due to the absence of opportunities.

One of the main advantages of setting up the hydropower project in such rural areas is the creation of opportunities for skilled, semi skilled or unskilled work force during construction as well as to tap the natural resources. Since, major component of capital cost is to be used for civil works, the local economy benefits with creation of employment and trading opportunities. The preparatory work for the project site includes setting up of access roads. This leads to opening up of the area even for promotion of tourism, if it has major tourism attraction.

The above described indirect socio-economic benefits due to a hydropower project are often not quantified in any development plan. The economic cost of these benefits over many years of plant's construction and operation; however, can significantly contribute towards stopping the migration trend.

In a public sector project development study, the detailed economic and financial analyses are performed so as to demonstrate that the proposed investment is an economic and optimal use of National Resources. The private developer's objective is financially motivated.

Notwithstanding this observation, it is appropriate to perform an economic analysis to demonstrate that development of the proposed Jagran-IV Hydropower Project would be an economic use of the National Resources if developed as a conventional public sector project.

This section presents the results of a public sector style economic and financial analysis in the form of an economic comparison of the Jagran-IV Hydropower Project with other alternative of thermal power plants.

13.2 ECONOMIC ANALYSIS

The purpose of the economic analysis of the project is to bring about a better allocation of resources, leading to enhanced incomes for investment or consumption. For a directly productive project where the output is sold in a relatively competitive environment, choices are made within the economy to ensure that projects selected for investment meet a minimum standard for resource generation and to weed out those projects that do not.

Pakistan is facing acute power shortage since 2005, which has gone up to 4,500 MW during peak hours. The main reason is non-development of any mega hydropower project in Pakistan after the completion of Ghazi Brotha Hydropower Project and completion of Thermal Power Plants pursuant to Energy Policy 1994.

Therefore, the country is in dire need of energy; especially, from the hydropower generating plants. The Thermal and Hydro mix has been reversed considerably over the last two decades.

Economic Analysis has been carried out in the above mentioned perspective and on the basis of economic benefits to the overall economy as a consequence of least cost optimal development of hydropower potential in the country. For this purpose, Hubco Narowal thermal power plant, which is in the process of development, has been selected as the representative project.

The feasibility aspects of project preparation and analysis deal with determining, whether a project is likely to contribute significantly to the development of the total economy and whether its contribution will be significant enough to justify the expenditure of the scare resources it would utilise.

The investment justification for current purposes depends on the returns generated and meeting the selected criteria of Economic Internal Rate of Return (EIRR) set by the Government of Pakistan and international funding agencies.

The Hubco Narowal power plant is being developed on the reciprocating engine technology. Its capital cost and tariff as allowed by NEPRA is almost same as allowed in the case of other Residual Furnace Oil (RFO) power plants on the Reciprocating Technology. Therefore, the benefits from the proposed Thermal Power Plant have been evaluated in terms of cost foregone for providing an equivalent generation.

13.2.1 Methodology

The analysis has been undertaken to establish the feasibility justification of the construction of the project. The standard methodology used by international funding agencies for appraising similar projects has been used for basic analysis.

The justification of the project has been assessed within the framework of efficiency criteria of public investment involved using Discounted Cash Flow Technique.

Project measures like Net Present Value (NPV), Benefit Cost Ratio (B/C), and project Internal Rate of Return (IRR) have been worked out to indicate the profitability of investment.

13.2.2 Thermal Power Plant Parameters

For carrying out a comparative analysis of hydropower station, an equivalent capacity which produces the same quantum of electricity has been taken. The capacity of hydro-electric plant in this case is 22 MW with annual energy generation of 98.2 GWh at 51.25% plant factor.

It will be pertinent to state that the facility which has an equivalent capacity cannot be a conventional steam power plant.

The alternate facility can either be diesel generating sets or gas turbines. The two technologies in small capacity range are available. In the present case of an equivalent thermal generation project, like Hubco Narowal Thermal Power Plant has been chosen to deliver same saleable energy to the grid for comparison purposes.

The capacity of Hubco Narowal diesel generator set has been proportionately taken as 22 MW. The diesel generators usually run for peaking hours only. The economic cost of a diesel generator set has been taken as Rs. 94.21 million /MW.

The unit cost analysis of Hubco Narowal Thermal Power Project is given hereunder:

Hubco Narowal Thermal Power Project

Unit Cost Analysis

Description	Amount	Unit
Gross Capacity	222	MW
Project Cost (in US$)	244.34	million US$
Project Cost (in Pak Rs.)	20,916	million Rs.
Project Cost per MW	94.21	million Rs./MW
Project Cost for 22 MW	2,072.71	million Rs.
Fuel Cost Component	4.7811	Rs./kWh
Var. O&M Charges	0.4454	Rs./kWh
Total Energy Charge	5.2265	Rs./kWh
Furnace Oil Price	23,247.07	M. Ton

Source: NEPRA Tariff Determination No. TRF-92/HUBCO/2008

13.2.3 Fuel Cost

The diesel generators will be run on Residual Furnace Oil (RFO). Fuel cost component per kWh is estimated as Rs. 4.7811. This cost has been approved by NEPRA vide Tariff Determination No. TRF-92/HUBCO/2008.

The Fuel Cost for generation of 98.20 GWh equivalent thermal energy has been estimated at Rs. 469.504 millions.

13.2.4 Operation and Maintenance (O&M) Cost

The variable O&M cost of a thermal facility generally has been taken as Rs. 0.4454 per kWh. This cost is also approved by NEPRA vide its Tariff Determination in the case of Hubco mentioned in the above paragraph.

The annual variable O&M Costs for the thermal power generation is Rs. 43.738 million.

13.2.5 Service Life

As compared with a hydropower station, which has useful economic life of more than 50 years, the thermal generation facilities have a comparatively lesser useful life (in the range of 20-30 years) with high cost of maintenance as compared to hydroelectric projects.

In no way it implies that after 20-30 years the machines become redundant. With timely maintenance, replacement and rehabilitation; the machine is kept in order to produce energy.

However, the rehabilitation cost of thermal power plant is considerably more than the hydropower plant to maintain the constant level of efficiency. Diesel generators have a lesser service life than conventional steam thermal power plant. However, 30 years useful life of hydroelectric power station has been assumed for comparison purposes.

13.2.6 Assumptions

The economic analysis is based on following input parameters and assumptions:

- All costs are taken at their estimated actual market prices at August 2010 constant price level. Price adjustments are not made by applying shadow price factors to correct the distortions in prices of the local inputs to reflect their true economic value.
- Application of shadow pricing would tend to favour the hydroelectric option, so any justification of the hydroelectric project excluding consideration of shadow pricing is considered conservative and robust.
- Exchange rate as prevailing in August 2010 has been taken as Rs. 85.6 per US Dollar. The price of crude oil has been continuously rising in the international market during the last few years. Presently, the crude oil is being traded at around US$ 60/BBL after touching the highest ever price of US$ 82/BBL.
- It is anticipated that the prices of crude oil will stay close to the present price level of US$ 60/BBL. However, for the Economic Analysis of Jagran-IV, a conservative furnace oil price of Rs. 23,247.07 per metric ton has been used (Ref: NEPRA Tariff Determination for Hubco Narowal Project).
- The furnace oil is inclusive of cost of fuel, freight, port handling and inland transportation charges and also a return of the oil marketing companies.

- The value of natural gas is artificially low in Pakistan. As gas is a depletable scarce resource and it will replace imported fuel in the local market, it is valued at par with the furnace oil.
- All amounts are expressed in real terms and no escalations are applied to any component including capital costs, O&M, fuel, etc.
- The economic value of the hydropower project is the anticipated total cost of delivering 98.20 GWh per year of electrical energy from an alternative thermal power plant to the National Grid System.
- The capital cost of alternative candidate thermal power plants is based on typical index US$/kW installed costs, adjusted to account for consumption in power station auxiliaries so that 22 MW is delivered to the grid net of auxiliary load.
- Thermal power plants generally exhibit lower reliability and higher forced outage rates and scheduled maintenance requirements compared to hydroelectric stations. As, forced outages and probability of outages during periods of peak demand and capacity shortfalls are difficult to predict, the commonly used adjustment factor of 1.15 applied to increase the installed capacity of thermal plant to equate it with hydel plant is not used.
- Capital costs are phased to match the implementation schedule of the project according to which the construction of the project would be completed by mid of the year 2016.
- The annual O&M Cost of the Jagran-IV Hydro Electric Project is taken as 1.5% of the Total Base Cost on the basis of O&M Cost approved by NEPRA in similar hydropower projects, i.e., Sukki Kinari Hydropower Project, etc. The O&M Cost will be escalated against changes in Dollar vs Rupees parity during the term of the project.

13.2.6.1 Discount Rate

Selection of an appropriate "Discount Rate" or "Cash Flow" analysis is a matter of considerable importance. In Pakistan, the marginal productivity of capital is believed to lie somewhere between 10 and 12 %. A discount Rate of 12% has also been assumed in the Economic Analysis.

13.2.6.2 Standard Conversion Factor

The Standard Conversion Factor (SCF) represents the ratio of prices of all goods within the economy with respective international prices. The SCF is mainly influenced by the trade policies of the Government.

It is approximated by the weighted average of import and export tariffs, with subsidies excluded. The weights used are based on the magnitude of imports and exports in the total trade during the recent years.

Rebates of the excise duties and sales tax are allowed on certain domestically produced goods used in the production of exports. Taxes on exports are levied on a range of items. Rebates of excise duties and sales tax are allowed on certain domestically produced goods used in the production of exports.

The value of SCF has been worked out as 0.90. However, this only takes into account the distortions to local prices of traded goods caused by tariffs. It may be noted that such factors as trade margins and labor input, particularly in non- tradable goods or services also tend to distort the ratio.

13.2.6.3 Annual Energy Benefits

The annual benefits attributed to the energy generation work out as below:

- Annual Energy Generation (GWh) 98.20
- Energy Tariff (Rs./kWh) 8.20
- Energy Revenue (Rs. million) 724.716

The average energy sale price in WAPDA project was Rs. 4.10 per kWh in the year 2007 as per 32nd WAPDA Annual Statistics Report, which has been escalated @8% per annum up to the year 2016. About 10% annual system losses have also been taken into account for the working of Energy Revenue.

13.2.6.4 Project Economic Costs

Project financial investment costs are estimated as Rs. 3,595.943 million including the interest during construction. These have been expressed in economic prices by applying various conversion factors and work out as Rs. 2,533.093 million and are phased over a period of four (4) years.

The annual recurring costs are estimated as Rs. 439.905 million for 20 years, and thereafter Rs. 35.959 million. The economic value of operation and maintenance costs has also been assumed as Rs. 25.331 million annually for comparison purposes.

13.2.7 Result of the Thermal Equivalent

Based on the above assumptions of an equivalent thermal generation facility against the proposed hydropower project, Economic Internal Rate of Return comes to 25.33% as given in **Table - 13.1**.

The measures like Net Present Worth (NPW), Benefit Cost Ratio (B/C) and project Economic Internal Rate of Return (EIRR) have been calculated to examine the economic feasibility of implementing the Project and the results are summarised below:

	Values at 12% (million Rs.)
Present Worth of Benefits	3,781.13
Present Worth of Costs	2,112.63
Net Present Worth	1,668.51
B/C Ratio	1.79 : 1
EIRR	25.33 %

A review of the results of economic analysis indicates that project is economically viable as it has a B/C ratio of 1.79 and an EIRR of 25.33%.

13.3 FINANCIAL ANALYSIS

The financial analysis of the proposed Jagran-IV Hydropower Project has been carried out in order to assess viability of the investment during the tenancy of useful life of the project, which is estimated as thirty (30) years. The analysis has incorporated a tariff, adequate to yield return on equity which is reasonable for the investors under the current market conditions.

Project installed generation capacity and power potential are computed based on peak and off-peak flow data. A plant design discharge of 18.0 m^3/s, and four turbines with a total plant installed capacity of 22 MW are selected. The annual energy generation is estimated at 98.20 GWh.

13.3.1 Capital Cost

Following is a brief summary of the total capital cost of the project. All figures are shown in million.

Description	**Local Component (PKR)**	**Foreign Component (PKR)**	**Total (PKR)**	**Total (US$)**
Base Cost	1,017.047	1,617.751	2,634.798	30.780
IDC	406.609	554.536	961.145	11.228
Total Capital Cost	1,423.657	2,172.287	3,595.943	42.009

13.3.2 Capital Structure

It is assumed that the project cost will be financed through Rupees Denominated Loan to meet the local cost of the project and US Dollar Denominated Foreign Currency Loan to meet the foreign currency cost. There is no Equity injected by the Govt. of Azad Jammu & Kashmir.

Brief assumptions relating to the local currency and foreign currency financing arrangements are given in the following sections.

13.3.2.1 Local Currency Financing

- The Interest Rate is 12.79%, which is Six Months KIBOR as on 5th August 2010.
- Spread is 300 bps keeping in view the existing market trend.
- Tenure is for 20 years and the payments will be made in 40 equal semi annual installments.
- Payment stream is worked out on the Amortisation basis.

13.3.2.2 Foreign Currency Financing

- The Interest Rate is 0.63894%, which is Six Months LIBOR as on 5th August 2010.
- Spread is 400 bps keeping in view the existing market trend and current risks associated to Pakistan.
- Tenure is for 20 years and the payments will be made in 40 equal semi - annual installments.
- Payment stream is worked out on Amortisation basis.
- Since, the foreign currency loan is for 20 years and dollar denominated; therefore, 11% Dollar vs Rupees exchange rate deprecation parity has been assumed to mitigate the impact of currency fluctuation.

13.3.3 Results of the Financial Analysis

The measures like Net Present Worth (NPW), Benefit Cost Ratio (B/C Ratio) and project Financial Internal Rate of Return (FIRR) have been calculated to examine the financial feasibility of implementing the project.

The streams of project benefits and costs are detailed in **Table - 13.2** and the results are summarised below:

	Values at 12% DR (million Rs.)
Present Worth of Benefits	5,521.36
Present Worth of Costs	2,928.83
Net Present Worth	2,592.52
B/C Ratio	1.89 : 1
FIRR	14.26%

The Financial Analysis indicates that the project has a B/C ratio of 1.89 and FIRR of 14.26%; is financially viable.

13.4 SENSITIVITY ANALYSIS

Sensitivity analysis has been carried out for following scenarios;

- Income/revenues decreased by 10%
- Project cost increase by 20%
- Income / revenues reduction by 10% and cost overrun by 20% both occurring simultaneously.

The Sensitivity Analysis is summarised below and the detail provided in **Table - 13.3**.

Sensitivity Assumptions	**EIRR%**
10 percent decrease in project Income	22.20
20 percent increase in project costs	20.15
Income / Revenues reduction by 10% and cost overrun by 20% both occurring simultaneously	17.63

A review of the results indicates that project is not sensitive to the assumptions made above. The investment in the project remains financially feasible even under the adverse condition of income / revenues reduction by 10% and the cost overrun by 20% both occurring simultaneously when the FIRR approached the discount rate of 12%.

13.5 UNIT COSTS

Unit cost refers to cost per unit of energy generated or cost per unit of installed capacity. Being a useful parameter, it indicates project financial efficiency at a glance. Cost of generation and installation per unit has been worked out for the Jagran-IV Hydropower Project as per PC-I practice used by WAPDA Power Planning Wing (Cost recovery in 20 years and levelised over 30 years).

The project generation cost per kWh inclusive of import charges and IDC for the useful life of the project and the cost per kW of installed capacity are shown in **Table - 13.4**.

As can be seen the project shows the levellised generation cost of Rs. 6.080 (7.103 US cents) at an interest rate of 15.79% and 4.64% for local and foreign currency costs over the useful life of the project. The cost per kW of installed capacity comes to Rs. 163,452 (US$ 1909).

13.6 CONCLUSIONS AND RECOMMENDATIONS

The unit cost of generation is attractive for developing the proposed Jagran-IV Hydropower Project. EIRR is very high indicating the economic viability of the project. The project FIRR is above the interest with an attractive NPV.

Important conclusions drawn from the economic and financial viability analysis are as follows:

- The addition of project to the local indigenous hydro resource shall replace equivalent thermal generation, whose unit cost of production is high, fluctuating widely and may rise in near future.
- The B/C ratio is 1.79 and EIRR is 25.33%.
- The successful completion of the project will turn into job opportunities and uplift in the socio-economic well being of the adjoining areas. This will result into increase in economic activities in the locality.

14 CONCLUSIONS AND RECOMMENDATIONS

Jagran-IV Hydropower Project has been studied to the feasibility level and following conclusions have been drawn and recommendations made:

14.1 CONCLUSIONS

1. Jagran River is one of the promising potential tributaries of Neelum River where cheap hydropower can be harnessed by planning and developing a number of medium size hydropower projects. Jagran-IV is one of the proposed schemes on this river. The hydro-geological, topographical, geological / geotechnical and other conditions are quite favourable.

2. The project is considered to be economically viable and financially feasible. The economic internal rate of return is 25.33% with the Benefit Cost Ratio (B/C) of 1.79. The financial internal rate of return is 14.26%. The unit cost per kWh is estimated as US cent 7.103.

3. Considering the project area topography, geological / geotechnical and weather conditions; the project has been planned on the intermediate 3.1 km stretch of Jagran River with project layout plan on the left bank of river.

4. The project layout involves 6 m high overflow weir with an undersluice, lateral intake, surface sandtrap, 3075 m long low pressure headrace pipe, surge pipe, 180 m long penstock, surface powerhouse and the tailrace. The structures and equipment have been planned for a design discharge of 18 m^3/s and the effective head of about 144.2 m.

5. The project has been optimised for an installed capacity of 22 MW which was estimated as 6 to 8 MW in the previous studies. The mean annual energy is estimated as 98.20 GWh with a plant factor of 51.25%.

6. The construction materials, especially, the aggregates are abundantly available near the proposed project site. Geotechnical investigations are to be carried out through third party contract. The results / data of the field investigations are to be utilised for the preparation of detailed design / drawings.

7. The powerhouse would be equipped with four vertical Francis turbines (3 x 6 MW and 1 x 4 MW), three generators of 6 MW / 7.06 MVA and one of 4 MW / 4.70 MVA, two step-up transformers of 11 / 132 kV, 10 / 13 MVA rating. The powerhouse would be connected through 132 kV line to the Jagran-I Hydropower Project Grid.

8. The cost estimates have been prepared considering the latest market rates and the estimated project quantities. The estimated project cost including the interest during construction is PKR 3,595.943 million involving the foreign exchange equivalent of PKR 2,172.287 million in US Dollars ($).

9. The proposed project is envisaged to be implemented in 4 years period and 1 year for approval of PC-I, land acquisition, access roads etc. to be arranged by HEB.

10. On the basis of field findings during the Initial Environment and Social Impact Examination study, it can be concluded that the proposed Jagran-IV Hydropower Project will not have any significant adverse impacts on the local population or any segment of environment provided the mentioned recommendations and mitigation measures suggested in study are fully implemented during construction and by the plant management in letter and spirit.

14.2 RECOMMENDATIONS

1. The project is economically viable and financially attractive and is recommended for its implementation.

2. The access road to weir site, surge area and powerhouse need to be upgraded and bridges are to be strengthened.

3. The proposed geotechnical investigation should be arranged through third party contract as soon as possible for the timely completion of detailed design and preparation of tender documents.

PHOTOGRAPHS

Photograph - 1: A view of Jagran River

Photograph - 2: Proposed Weir Site

Photograph - 3: Proposed Powerhouse Site

Photograph - 4: Reading being taken using Digital Total Station

Photograph - 5: Target Prism to take Reading of Different Points

Photograph - 6: Survey in progress using Digital Total Station at Powerhouse Site just u/s of Jagran - I Weir

Photograph - 7: Bench Mark at Jagran-I Weir Site

Photograph - 8: Staff Gauge at Thunian Installed in 1994 by HEB

Photograph - 9: Geological Mapping in Progress at Powerhouse Site

Photograph - 10: Geological Mapping in Progress at Proposed Weir Site

Photograph - 11: Water Quality being Check at Jagran-IV Weir Site

Photograph - 12: Water Sample Collected for Water Quality Testing in Laboratory