ARTISTIC HYDRO I (PVT) LTD.

Registered office : Plot 3/A, M.A.C.H.S Shahrah-e-Faisal, Karachi-75350 Pakistan
Phone : 92-21-38704711-14 Fax : 92-21-34321940 Email :energy@artisticmilliners.com

7004-AH1PL-NEPRA-000110A December 07, 2020

The Registrar
National Electric Power Regulatory Authority
NEPRA Tower, Attaturk Avenue (East)
G-5/1, Islamabad

SUBJECT: **APPLICATION FOR A GENERATION LICENSE FOR 62.606 MW HYDRO POWER PLANT TO BE LOCATED AT SAHIBABAD, DISTRICT UPPER DIR, PROVINCE OF KHYBER PAKHTUNKHWA**

Dear Sir,

I, Rafique Khanani, CFO/Company Secretary, being the duly authorized representative of Artistic Hydro I Private Limited by virtue of board resolution dated November 20, 2020, hereby apply to the National Electric Power Regulatory Authority for the grant of a Generation License to Artistic Hydro I (Private) Limited pursuant to section 15 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997.

I certify that the documents-in-support attached with this application are prepared and submitted in conformity with the provisions of the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, and undertake to abide by the terms and provisions of the above-said regulations. I further undertake and confirm that the information provided in the attached documents-in-support is true and correct to the best of my knowledge and belief.

A Cheque No. 13098804 dated December 03, 2020 of Bank AL Habib Limited amounting to PKR 429,971/- (Pakistani Rupees Four Hundred Twenty Nine Thousand Nine Hundred Seventy One Only) (net of WHT tax @8%), being the nonrefundable license application fee calculated in accordance with Schedule II to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations 1999 is also attached herewith.

Yours faithfully,

For and on behalf of **Artistic Hydro I (Private) Limited**

Artistic Hydro I (Pvt) Ltd

Rafique Khanani
CFO/Company Secretary

BACKGROUND TO GENERATION LICENSE APPLICATION

PROCESS OF ISSUANCE OF LETTER OF INTENT LEADING TO GENERATION LICENSE APPLICATION

a. Issuance of "Letter of Intent"

ARTISTIC HYDRO-I (PRIVATE) LIMITED (a company duly organized and existing under the laws of Pakistan, with its office located at Plot No. 3-A M.A.C.H.S main Shahra e Faisal, Karachi(the **Project Company**), was issued a LETTER OF INTENT by Pakhtunkhwa Energy Development Organization (PEDO), Govt. of Khyber Pakhtunkhwa (GOKP) on February 26, 2019 vide its letter No; 428-36/PEDO/DRE/AM/LOI (the **LOI**) to develop and establish an approximately 49 MW (now 62.606 MW) hydropower project to be located near Sahibabad, District Upper Dir (**Project**). The Project Company has also submitted a bank guarantee for an amount equal to US$ 49,000.

b. Submission of the Feasibility Study

Pursuant to the relevant provisions of the KP Hydropower Policy 2016 and the LOI, the Project Company completed the detailed technical and financial feasibility study for the Project and the Project Company submitted the same to PEDO, GOKP on August 24, 2020. A copy of Project Feasibility Study is attached hereto as ANNEXURE-07 for NEPRA's perusal.

c. Submission of Environmental Impact Assessment

The Project Company hired consultants, BAK Consulting Engineers Pakistan & DOLSAR Engineering Turkey, who completed the environmental impact assessment for the Project (the **Environmental Impact Assessment**) and the Project Company submitted the same to the KP Environmental Protection Agency (the **KP EPA**) on March 09, 2020.

d. Grid Interconnection Studies

The Project Company hired consultants, Power Planners International (Pvt.) Ltd, who used the updated transmission plan and load forecast from PESCO for the study, vide data permission letter no.GM (Dev)/4444-45 dated June 22, 2020.

A couple of options were investigated for the interconnection of this project. One possible interconnection scheme was to connect the plant to 132 kV Wari Grid but due to the unavailability of line bays at Wari, this scheme was dropped. Another possible option of interconnection was a 132 kV grid proposed by PESCO at Munda.

The possibility of connecting Artistic-I HPP to Munda 132 kV Grid Station via double circuit has been approved by PESCO through letter ref # CE (Dev) 5161-62 dated 22 July 2020 and attached as Annexure-09.

A Copy of Grid Interconnection Studies is attached hereto as ANNEXURE-08 for NEPRA's perusal.

e. Location of Project & Lease of Land

The Artistic-I Hydropower project is a run-of-the river project to be constructed on Panjkora River in district Upper Dir of Northern areas of Khyber Pakhtunkhwa province. The weir site is located near Darora village and about 6.7 km upstream of Sahibabad village. The powerhouse site is located about 3.5 km downstream of Sahibabad village. Both weir and power house sites are easily accessible through N-45 (Chakdara-Dir) Asphalt Road. Project coordinates are given below.

Location	Northing	Easting	NWL / TWL
Weir / Intake	35°05'52.77"	71°59'00.08"	1071.00 masl
Powerhouse	35°01'28.32"	72°00'40.77"	990.00 masl

The catchment of the Artistic-I HPP lies in the upper region of the Panjkora River, a tributary/ sub system of a Swat river basin and can be classified as a "high mountain catchment" which originates from glacier zone. Two major tributaries join at Chukiatan, just downstream of Dir town to form Panjkora River. On the way downstream it joins a number of small tributaries evacuating the discharge from different valleys. The stream flow patterns are followed by the seasonal change in temperatures. Glaciers are visible above altitude of 4000 amsl. The highest mountain peak ranges from 600 amsl up to 5750 amsl while river bed elevation at weir site is 1071amsl and tail water level at powerhouse site is approximately 990 amsl. Length of the Panjkora River up to the weir site is about 105 km. Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km and at powerhouse location is approximately 3235 sq.km.

Land shall be acquired through Government of KPK once the project is approved.

f. Brief Technical Synopsis of the Project

The Project has an estimated installed capacity of 62.606 MW_e with 1 small (unit-3) and 2 large (unit-1 and unit-2) turbines of the following characteristics.

Unit No	Rated Discharge (m^3/s)	Rated Net Head (m)	Capacity (MW_e)	Capacity (MW_m)
Unit-1	37.50	69.91	23.455	24.425
Unit-2	37.50	70.23	23.562	24.536
Unit-3	25.00	69.68	15.589	16.233
Total	**100.00**	-	**62.606**	**65.194**

There shall be a substation of 132 KV, which shall dispatch electricity as per Interconnection Grid Scheme, finalized by NTDC.

g. Tariff

Upon issuance of the Generation License and award of the Feasibility Stage tariff, the Project Company would finalise the EPC Contractor, apply for EPC Stage tariff, execute the Power Purchase Agreement with the Power Purchaser and aims to achieve Financial Close for the Project within 24 months of granting Letter of Support. The expected Commercial Operations Date of the Project is to be 48 month from the Financial Close.

Request for grant of a generation license

Based on the matters provided in Sections a, b, c, d, e, f and g above whereby the Project Company, on its part, has undertaken and completed all activities required for procurement of approvals of the relevant matters from various stakeholders, it is submitted that the requirements of the regulatory process for applying to NEPRA for grant of a generation license to the Project Company are complete.

Executive Summary

This application is for *Grant of Generation License* filed by *Artistic Hydro I (Pvt.) Ltd* (the "Project Company") for its 62.606 MW Hydropower Project (the "Project") is near Sahibabad, District Upper Dir, Pakistan.

Artistic Hydro I (Pvt.) Ltd is a local (Pakistani) organization having planned a 62.606 MW Artistic-I Hydropower Project near Sahibabad.

This application document is a package of information as per Section-5 of Article-3 of NEPRA Licensing (Application & Modification Procedure) Regulation, 1999 notified by National Electric Power Regulatory Authority (NEPRA).

The document is comprised of following Annexure:

Annexure – 01:	Prospectus
Annexure – 02:	Applicant Experience
Annexure – 03:	Board Resolution
Annexure – 04:	Certificate of Incorporation
Annexure – 05:	Article of Association
Annexure – 06:	Memorandum of Association
Annexure – 07:	Feasibility Study
Annexure – 08:	Grid Interconnection Study
Annexure – 09:	Approval of Grid Interconnection Study by PESCO
Annexure – 10:	CV of Senior Management
Annexure – 11:	Information for Schedule-I of License
Annexure – 12:	Information for Schedule-II of License

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Extract of resolutions passed unanimously by the board of directors of Artistic Hydro I (Private) Limited on November 20, 2020:

"RESOLVED THAT Artistic Hydro I Private Limited, a company incorporated under the laws of Pakistan with registration number 0128939 and having its registered office located at Plot 3/A, M.A.C.H.S., Main Shahra e Faisal, Gulshan Town, Karachi, (the **"Company"**) be and is hereby authorized to file Generation License Application (including any modification) for submission to the National Electric Power Regulatory Authority (**"NEPRA"**) in respect of its 62.606 MW Hydro Power Project to be located at Sahibabad, District Upper Dir, Province of Khyber Pakhtunkhwa, Pakistan (the **"Project"**) and in relation thereto, enter into and execute all required documents, make all filings and pay all applicable fees, in each case, of any nature whatsoever, as required."

"**FURTHER RESOLVED THAT** in respect of filing a Generation License Application (including any modification) for submission to NEPRA, Mr. Rafique Khanani, CFO/Company Secretary be and is hereby empowered and authorized for and on behalf of the Company to:

(i) review, execute, submit, and deliver the Generation License Application (including any modification) and any related documentation required by NEPRA including but not limited to filing, signing, presenting, modifying, amending or withdrawing the application and other documents, and responding to any queries of any nature whatsoever in respect thereof;

(ii) represent the Company in all negotiations, representations, presentations, hearings, proceedings, conferences and /or meetings of any nature whatsoever with any entity (including, but in no manner limited to NEPRA, any private parties, companies, partnerships, individuals, governmental and /or semi-governmental authorities and agencies, ministries, boards, departments, regulatory authorities and /or any other entity of any nature whatsoever);

(iii) appoint or nominate any one or more officers of the Company or any other person or persons, singly or jointly, in his sole and absolute discretion to communicate with, make presentations to and attend NEPRA hearings and to appear before NEPRA or any other relevant regulatory or governmental authority in any proceedings, hearings or representations pertaining to the Company or the Project;

(iv) do all such acts, matters and things as may be necessary for carrying out the aforesaid purposes and to give full effect to each of the matters approved in the above resolutions."

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"**AND FURTHER RESOLVED THAT** Mr. Rafique Khanani, CFO/Company Secretary, be and is hereby authorized to delegate all or any of the above powers in respect of the forgoing to any other officials of the Company he may deem appropriate.

Rafique Khanani
CFO/Company Secretary

IN WITNESS THEREOF, I hereunder set my hands as such Director and affixed the corporate seal of said company.

Yaqoob Ahmed
Director

PROSPECTUS

All stakeholders interested / effected persons and the general public are notified that the authority has admitted the application of Artistic Hydro I (Private) Limited for consideration of grant of generation license to finance, design, engineer, procure, construct, install, test, complete and commission a 62.606 MW hydropower generation facility to be located on Panjkora River near Sahibabad, District Upper Dir, Khyber Pakhtunkhwa. All stakeholders interested/ effected persons and the general public are invited to submit their comments for/or against the grant of license. The comments should be submitted to the registered office of National Electric Power Regulatory Authority within a period of 14 days from the date of this publication.

Brief of prospectus including salient features of Artistic Hydro I (Private) Limited is as under.

Applicant – Artistic Hydro I (Pvt.) Limited

The Project Company, being the applicant under this Generation License Application, is a private limited company incorporated under the laws of Pakistan and has been specifically established to undertake power generation business and activities in Pakistan.

The Project Company (following grant of a generation license and approval of the Project Company's reference generation tariff by NEPRA) proposes to design, engineer, construct, insure, commission, operate and maintain the Project constituting of a 62.606 MW power generation facility (the Facility) to be located on Panjkora River near Sahibabad, District Upper Dir, Province of Khyber Pakhtunkhwa, Pakistan (the Site).

Sponsor – Artistic Milliners (Pvt.) Limited

The primary sponsor financing the Project is Artistic Milliners (Private) Limited (which is one of the leading textile sector undertakings of Pakistan having a variety of business divisions e.g., spinning, weaving, denim, garments etc.).

Artistic Milliners group of companies was established in 1949, and is today one of Pakistan's leading business houses and one of the largest premium quality denim cloth and finished products mills in the country. The company is engaged in the manufacturing and trading of denim, garments and fabrics and has the distinct privilege of being one of the few mills that are completely export oriented.

The group has its roots in textile trading and has since expanded to become a complete vertically integrated textile set up with the aim of providing high-end customers with premium quality of denim fabrics and garments.

Today Artistic Milliners has total assets of over PKR 55 billion (US$ 344 million: 2019) with an annual turnover of over PKR 38 billion (US$ 237 million: 2019).

Renewable Power:

- Artistic Milliners has successfully commissioned a 49.3 MW Wind Power Project (Artistic Energy (Private) Limited) in Sindh while other 50 MW Wind Power Project (Artistic Wind Power (Private) Limited) is under construction.
- Artistic Milliners is developing a 50 MW Solar Park called Artistic Solar Energy (Private) Limited with Generation License awarded in April 2020.
- Artistic Milliners is also carrying out feasibility study of 55.032 MW Artistic-II Hydropower Project on Ushu River at Kalam, District Swat.

Environmental Impact

As per the requirements of Section 12 of Pakistan Environmental Protection Act (PEPA), 1997, Project Company has completed the Environmental Impact Assessment (**"EIA"**) report for the Project. Hydropower Project is a green energy Project and, therefore, there is no major long lasting social or environment impact foreseen. The Project is not likely to have any significant adverse environmental impacts, which could be irreversible or could affect sensitive eco-system, requires significant resettlement (except few small houses), or has an unprecedented impact. The Project Area does not fall under any sensitive, protected area. No threatened / Near-Threatened species of wildlife was recorded in the Project Area. There are no significant settlements in the project boundaries. Noise impacts will be less than 75 DB (A) which is within the range as per National Environmental Quality Standards (NEQs) of Pakistan.

Social Impact

The Sponsors of Project Company always regard corporate social responsibility as an important force in building a harmonious society. They also believe in paying full attention to human factors, exercising environmental protections and conservation, increasing employment, and helping build the community. Every year they support numerous educational, sporting, and charity programs designed to help a wide range of people. Operations of the Plant will provide job opportunities especially to the local people. Poverty alleviation, though at minor scale, will be another benefit besides meeting power shortage in Pakistan.

Proposed Investment

The Total Project Cost of US$ 236,841,074 (United States Dollars Two Hundred and Thirty-Six Million, Eight Hundred and Forty-one Thousand, Seventy Four) is to be financed in a debt to equity ratio of 80:20.

DEBT

With regards to debt financing for the Project, the Project Company will arrange 100% foreign financing from International DFIs etc.

EQUITY

Based on the Debt to Equity ratio of 80:20, the equity required to be injected by Artistic Milliners (the **Equity**), being the primary sponsor, amounts to USD 47.37 Million.

Salient Features of the Facility

Project Information

Since the issuance of the LOI, the Project Company conducted various studies to assess the feasibility of the Project. These studies *inter alia* included the Hydrology Study, geo technical investigation, topographic map, Environmental Impact Assessment and grid interconnection study. The complete feasibility study was submitted by the Project Company to Pakhtunkhwa Energy Development Organization (PEDO) and the Environmental Impact Assessment submitted to Environmental Protection Agency. Similarly, Grid Interconnection Study is completed on the basis of proposed interconnection scheme of 132kV double circuit line to 132kV Munda Grid and approved by PESCO on July 22,2020.

Project Site

The site proposed for the implementation of the Project has been selected by considering:

- Available discharge and gross head in the Panjkora river;
- Ecological conditions at the Site;
- Topographic conditions;
- Site accessibility; and
- Location of the grid with reference to the Site for interconnection.

The Site is located near Sahibabad, District Upper Dir, Khyber Pakhtunkhwa. The catchment of the Artistic-I HPP lies in the upper part of the Panjkora River, a main tributary of a Swat River basin and can be classified as a "high mountains catchment" which originates from glacier zone.

Two major tributaries join at Chukiatan, just downstream of Dir town to form Panjkora River. On the way downstream, it joins a number of small tributaries evacuating the discharge from different valleys. The stream flow patterns are followed by the seasonal change in temperatures. The highest mountain peak ranges from 5750 masl upto 6000.masl while river bed elevation at weir site is 1061.00 masl and river bed elevation at powerhouse site is at approximately 986.00 masl. Length of the Panjkora River up to the weir site is about 105 km. Slope of Panjkora River is about 0.034 but relatively flatter near weir axis i.e. about 0.0095.

Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km and at powerhouse location is approximately 3235 sq.km.

Land Description of the Project Site:

Coordinates of
Start of the Intake and Powerhouse of the Generation Facility/Hydel Power Plant of the Licensee

Site	Latitude	Longitude
Weir / Intake	35°05'52.77"	71°59'0.08"
Power House	35°01'28.32"	72°0'40.77"

Climate of Project Area

The weather of Project area is characterized by extreme winter and moderate summer. The monsoon penetrates into the project area but main mechanism of producing rainfall is due to western disturbance. Climate of the project area can be classified as cold and sub humid. As per available record of climate stations located in and around project area, indicates higher precipitation at higher altitude than at lower.

Topographical and Geological Conditions at Project Site

Topographical conditions:

The topography of the district is dominated by high mountains. The mountains in the western part of the district are covered with forests, while the eastern mountain range, Dir Kohistan, is barren. Dir Kohistan is the origin of the main river of Chitral i.e. Panjkora River. District head quarter, Upper Dir is connected with metal led or shingled roads to all Tehsil Headquarters. The district is totally mountainous, so, there is no railway and airport.

There are several settlements/villages outside the project boundaries (except few houses) in the vicinity of weir and powerhouse site. These settlements are on the right and left bank of the river. All these settlements are a cluster of houses at different places along the river.

There is no forest area at the project site. However, some non-fruit/farm trees are available at the project location.

Geological conditions:

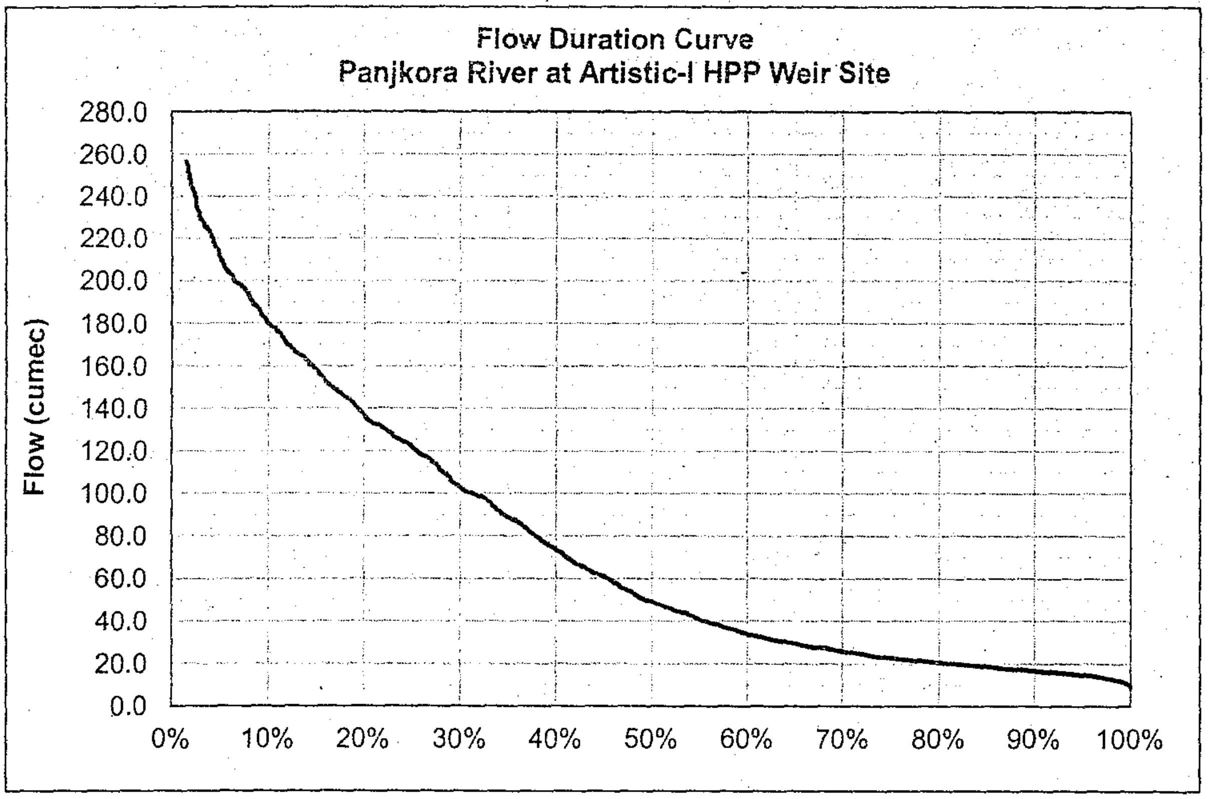
The bed rock is overlain by unconsolidated material of different nature throughout the project area. Valley of Panjkora River at the project area is 130-200 m wide. The river bed material consists of the gray, loose, sandy gravels, cobble with boulders generally of rounded to sub rounded and strong to very strong nature.

Besides the river and stream bed deposits, terraces comprised mainly of slope wash materials are present at the lower slopes and valley floor. The slope wash material has colluvial, fluvial and glacial origin based on the mechanism of downslope transportation and deposition. These are basically derived from the rock exposures present at higher elevation.

The rock units exposed in the project area belong to two formations Shandur Granodiorite Ksg (Early Paleocene) and Banded Amphibolite–Mzb (Middle Cretaceous). These intrusions vary in composition from granite (where lava was more acidic) to granodiorite to diorite (when lava is acidic to intermediate).

Hydrology:

Availability of flows at the proposed weir/intake site was checked using detailed flow duration curve analysis. A flow duration curve (FDC) shows relationship between magnitude and frequency of stream flows for a particular river basin at a particular location. FDC provides estimation of cumulative percentage of time that a given quantity of flow is equaled to or exceeded which helps in planning and capacity sizing of a power plant. Flow series generated at weir from available record of Panjkora River at Koto, Sharmai and Chakdara have been used for flow availability against different exceeding probabilities as summarized and shown in figure below.



Site Accessibility

Karachi seaport is expected to be used for loading and unloading of heavy equipment. It is connected to Peshawar through two existing major north-south links i.e. National Highway 55 called N-55 on the western bank of the Indus River and National Highway 5 called N-5 on the eastern bank. N-45 branches from N-5 in Nowshera located 30 km east from Peshawar and goes through Mardan, Chakdara and Dir along Swat and Panjkora River towards the north. The project site is located on N-45. The road is in good condition which make easy transportation of goods including heavy equipment from Peshawar to Sahibabad, District Upper Dir (Town near project site). The road network from Karachi to project location is shown in figure below.

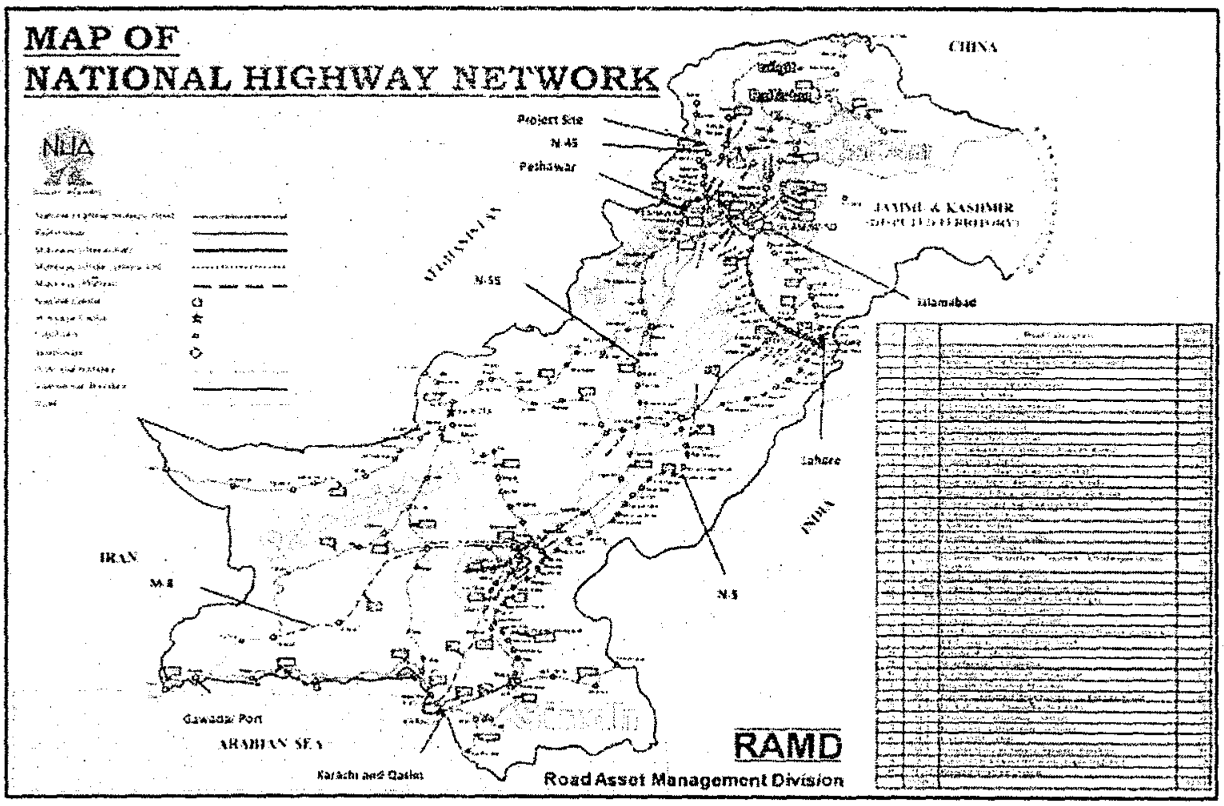


Figure 1 Map of National Highway Network

Availability of Semi-Skilled and Skilled Labor

There is a dearth of hydropower project specific skilled labor in the area, however unskilled and semi-skilled labor is available in the area and the Project will be a source of employment for these individuals. Training will be provided to the workers.

General Information

(i).	Name of Applicant/Company	Artistic Hydro I (Pvt.) Limited
(ii).	Registered/Business Office	Plot No. 3-A M.A.C.H.S Main Shahra e Faisal, Karachi
(iii).	Plant Location	Near Sahibabad, District Upper Dir
(iv).	Type of Generation Facility	Hydropower

Hydropower Capacity & Configuration

(i).	Hydropower Turbine Type,	Vertical Axis Francis
(ii).	Installed Electrical Capacity of Project (MW_e)	62.606 MW_e
(iii).	Installed Mechanical Capacity of Project (MW_m)	64.529 MW_m
(iii).	Number of Turbine Units/Size of each Unit (MW_e)	i. 1 x 23.455 MW_e (Unit-1) ii. 1 x 23.562 MW_e (Unit-2) iii. 1 x 15.589 MW_e (Unit-3)
(iv).	Plant Factor	55.71%
(v).	Debt to Equity Ratio	80:20
(vi).	Dispatch / Power Purchaser	Central Power Purchasing Agency (Guarantee) Limited

Francis Turbine Details

Types of turbine	Vertical Axis Francis	
	Large Units (Unit-1 & Unit-2)	Small Unit (Unit-3)
Number of Units	2 Nos.	1 Nos.
Mechanical Output at Rated Head & Discharge	Unit-1: 24.175 MW_m Unit-2: 24.286 MW_m	16.608 MW_m
Type	Francis, Vertical	Francis, Vertical
Rated Net Head	Unit-1: 69.910 m Unit-2: 70.230 m	69.697 m
Rated Discharge	37.50 m^3/sec	25.00 m^3/sec
Rotational Speed	300 rpm or as proposed by vendor	375 rpm or as proposed by vendor
Runaway Speed at Maximum Head	595 rpm and 607 rpm or as proposed by vendor	769 rpm or as proposed by vendor
Turbine Efficiency	94%	

Types of turbine	Vertical Axis Francis	
	Large Units (Unit-1 & Unit-2)	Small Unit (Unit-3)
Direction of Rotation	Clockwise	

Proposed Investment:

The total project cost is estimated at USD 236.841 million at 3.78 million USD per MW.

Expected Date of Financial Close:
Within 24 months of granting of Letter of Support
Expected COD:
48 months from the Financial Close

A049359

SECP

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

COMPANY REGISTRATION OFFICE, KARACHI

CERTIFICATE OF INCORPORATION

[Under section 16 of the Companies Act, 2017 (XIX of 2017)]

Corporate Universal Identification No. **0128939**

I hereby certify that **ARTISTIC HYDRO I (PRIVATE) LIMITED** is this day incorporated under the Companies Act, 2017 (XIX of 2017) and that the company is **limited by shares.**

Given under my hand at **Karachi** this **Twenty Second** day of **January, Two Thousand** and **Nineteen**

Incorporation fee Rs. **1,000/=**

(Muhammad Naeem Khan)
Additional Registrar/Incharge CRO

The Companies Act, 2017
Private Company Limited by Shares

ARTICLES OF ASSOCIATION
OF

ARTISTIC HYDRO I (PRIVATE) LIMITED

DEFINITIONS AND INTERPRETATIONS

1. In these Articles: unless there be something in the subject or context inconsistent therewith, words signifying the singular number only, shall include the plural and vice versa and words signifying males only shall extend to and include females and words signifying persons, shall apply mutatis mutandis to bodies corporate.

   (a) "Act" or "The Act" means the Companies Act, 2017

   (b) "Articles" means the Articles of Association as originally framed or as altered from time to time.

   (c) "Capital" shall mean the capital of the Company for the time being raised or authorised to be raised for the purpose of the Company.

   (d) "Company" means "ARTISTIC HYDRO I (PRIVATE) LIMITED"

   (e) "Dividend" includes bonus shares.

   (f) "Member" means the member of the Company within the meaning of the provisions of the Act.

   (g) "Month and year" shall mean the English calendar month and English calendar year respectively.

   (h) "Office" means the registered office of the Company for the time being.

   (i) "Register" means the register of members to be kept pursuant to the provisions of the Act.

   (j) "Section" means Section of the Act.

   (k) "Seal" in relation to a Company means the Common Seal or official seal of the Company.

   (l) "Shares" shall mean the shares in the capital of the Company.

2. Unless the context otherwise requires, words or expressions contained in these Articles shall have the same meaning as in this Act; and words importing the singular shall include the plural, and vice versa, and words importing the masculine gender shall include feminine, and words importing persons shall include bodies corporate.

PRIVATE COMPANY

3. The company is a Private Limited Company within the meaning of Clause (49) of Sub-section (1) of Section 2 and accordingly:

   (a) The right to transfer of shares in the company is restricted in the manner and to the extent provided herein.

Artistic Hydro

(b) The number of the members of the company (exclusive of the persons in the employment of the company) shall be limited to fifty, provided that for the purposes of this provision, where two or more persons hold one or more shares jointly in the company, they shall be treated as a single member.

(c) No invitation shall be issued to the public to subscribe for any shares, or debentures or redeemable capital of the company:

CAPITAL

4. The authorized share capital of the company is Rs. 100,000/- (Rupees One hundred thousand only) divided into 10,000 (ten thousand) Ordinary shares of Rs. 10/- (Rupees Ten only) each.

SHARES

5. In case of shares in the physical form, every person whose name is entered as a member in the register of members shall, without payment, be entitled to receive, within thirty days after allotment or within fifteen days of the application for registration of transfer, a certificate under the seal specifying the share or shares held by him and the amount paid up thereon:

   Provided that if the shares are in book entry form or in case of conversion of physical shares and other transferable securities into book-entry form, the company shall, within ten days after an application is made for the registration of the transfer of any shares or other securities to a central depository, register such transfer in the name of the central depository.

6. The company shall not be bound to issue more than one certificate in respect of a share or shares in the physical form, held jointly by several persons and delivery of a certificate for a share to one of several joint holders shall be sufficient delivery to all.

7. If a share certificate in physical form is defaced, lost or destroyed, it may be renewed on payment of such fee, if any, not exceeding one hundred rupees, and on such terms, if any, as to evidence and indemnity and payment of expenses incurred by the company in investigating title as the directors think fit.

8. Except to the extent and in the manner allowed by section 86, no part of the funds of the company shall be employed in the purchase of, or in loans upon the security of, the company's shares.

TRANSFER AND TRANSMISSION OF SHARES

9. The instrument of transfer of any share in physical form in the company shall be executed both by the transferor and transferee, and the transferor shall be deemed to remain holder of the share until the name of the transferee is entered in the register of members in respect thereof.

10. Shares in physical form in the company shall be transferred in the form prescribed by Table A in the First Schedule to the Act, or in any usual or common form which the directors shall approve.

TRANSMISSION OF SHARES

11. The executors, administrators, heirs, or nominees, as the case may be, of a deceased sole holder of a share shall be the only persons recognised by the company to deal with the share in accordance with the law. In the case of a share registered in the names of two or more holders, the survivors or survivor, or the executors or administrators of the deceased survivor, shall be the only persons recognised by the company to deal with the share in accordance with the law.

12. The shares or other securities of a deceased member shall be transferred on application duly supported by succession certificate or by lawful award, as the case may be, in favour of the successors to the extent of their interests and their names shall be entered to the register of members.

13. A person may on acquiring interest in a company as member, represented by shares, at any time after acquisition of such interest deposit with the company a nomination conferring on a person, being the relatives of the member, namely, a spouse, father, mother, brother, sister and son or daughter, the right to protect the interest of the legal heirs in the shares of the deceased in the event of his death, as a trustee and to facilitate the transfer of shares to the legal heirs of the deceased subject to succession to be determined under the Islamic law of inheritance and in case of non-Muslim members, as per their respective law.

14. The person nominated under these Articles shall, after the death of the member, be deemed as a member of company till the shares are transferred to the legal heirs and if the deceased was a director of the company, not being a listed company, the nominee shall also act as director of the company to protect the interest of the legal heirs.

15. A person to be deemed as a member under these Articles to a share by reason of the death or insolvency of the holder shall be entitled to the same dividends and other advantages to which he would be entitled if he were the registered holder of the share and exercise any right conferred by membership in relation to meetings of the company.

ALTERATION OF CAPITAL

16. The company may, by special resolution:

    (a) increase its authorised capital by such amount as it thinks expedient;

    (b) consolidate and divide the whole or any part of its share capital into shares of larger amount than its existing shares;

    (c) sub-divide its shares, or any of them, into shares of smaller amount than is fixed by the memorandum;

    (d) cancel shares which, at the date of the passing of the resolution in that behalf, have not been taken or agreed to be taken by any person, and diminish the amount of its share capital by the amount of the share so cancelled.

17. Subject to the provisions of the Act, all new shares shall at the first instance be offered to such persons as at the date of the offer are entitled to such issue in proportion, as nearly as the circumstances admit, to the amount of the existing shares to which they are entitled. The offer shall be made by letter of offer specifying the number of shares offered, and limiting a time within which the offer, if not accepted, will deem to be declined, and after the expiration of that time, or on the receipt of an intimation from the person to whom the offer is made that he declines to accept the shares offered, the directors may dispose of the same in such manner as they think most beneficial to the company. The directors may likewise so dispose of any new shares which (by reason of the ratio which the new shares

bear to shares held by persons entitled to an offer of new shares) cannot, in the opinion of the directors, be conveniently offered under this regulation.

18. The new shares shall be subject to the same provisions with reference to transfer, transmission and otherwise as the shares in the original share capital.

19. The company may, by special resolution:

(a) consolidate and divide its share capital into shares of larger amount than its existing shares;

(b) sub-divide its existing shares or any of them into shares of smaller amount than is fixed by the memorandum of association, subject, nevertheless, to the provisions of section 85;

(c) cancel any shares which, at the date of the passing of the resolution, have not been taken or agreed to be taken by any person.

20. The company may, by special resolution, reduce its share capital in any manner and with, and subject to confirmation by the Court and any incident authorised and consent required, by law.

GENERAL MEETINGS

21. A general meeting, to be called annual general meeting, shall be held, in accordance with the provisions of section 132, within sixteen months from the date of incorporation of the company and thereafter once at least in every year within a period of one hundred and twenty days following the close of its financial year.

22. All general meetings of a company other than the statutory meeting or an annual general meeting mentioned in sections 131 and 132 respectively shall be called extraordinary general meetings.

23. The directors may, whenever they think fit, call an extraordinary general meeting, and extraordinary general meetings shall also be called on such requisition, or in default, may be called by such requisitionists, as provided by section 133. If at any time there are not within Pakistan sufficient directors capable of acting to form a quorum, any director of the company may call an extraordinary general meeting in the same manner as nearly as possible as that in which meetings may be called by the directors.

24. The company may provide video-link facility to its members for attending general meeting at places other than the town in which general meeting is taking place after considering the geographical dispersal of its members:

NOTICE AND PROCEEDINGS OF GENERAL MEETINGS

25. Twenty-one days' notice at the least (exclusive of the day on which the notice is served or deemed to be served, but inclusive of the day for which notice is given) specifying the place, the day and the hour of meeting and, in case of special business, the general nature of that business, shall be given in manner provided by the Act for the general meeting, to such persons as are, under the Act or these Articles of the company, entitled to receive such notice from the company; but the accidental omission to give notice to, or the non-receipt of notice by, any member shall not invalidate the proceedings at any general meeting.

26. All the business transacted at a general meeting shall be deemed special other than the business stated in sub-section (2) of section 134 namely; the consideration of financial statements and the reports of the board and auditors, the declaration of any dividend, the election and appointment of directors in place of those retiring, and the appointment of the auditors and fixing of their remuneration.

27. No business shall be transacted at any general meeting unless a quorum of members is present at that time when the meeting proceeds to business. The quorum of the general meeting shall be governed as per the provisions of the Act and applicable to this company.

28. If within half an hour from the time appointed for the meeting a quorum is not present, the meeting, if called upon the requisition of members, shall be dissolved; in any other case, it shall stand adjourned to the same day in the next week at the same time and place, and, if at the adjourned meeting a quorum is not present within half an hour from the time appointed for the meeting, the members present, being not less than two, shall be a quorum.

29. The chairman of the board of directors if any shall preside as chairman at every general meeting of the company, but if there is no such chairman, or if at any meeting he is not present within fifteen minutes after the time appointed for the meeting, or is unwilling to act as chairman, any one of the directors present may be elected to be chairman, and if none of the directors is present, or willing to act as chairman, the members present shall choose one of their number to be chairman.

30. The chairman may, with the consent of any meeting at which a quorum is present (and shall if so directed by the meeting), adjourn the meeting from time to time but no business shall be transacted at any adjourned meeting other than the business left unfinished at the meeting from which the adjournment took place. When a meeting is adjourned for fifteen days or more, notice of the adjourned meeting shall be given as in the case of an original meeting. Save as aforesaid, it shall not be necessary to give any notice of an adjournment or of the business to be transacted at an adjourned meeting.

31. (1) At any general meeting a resolution put to the vote of the meeting shall be decided on a show of hands unless a poll is (before or on the declaration of the result of the show of hands) demanded. Unless a poll is so demanded, a declaration by the chairman that a resolution has, on a show of hands, been carried, or carried unanimously, or by a particular majority, or lost, and an entry to that effect in the book of the proceedings of the company shall be conclusive evidence of the fact, without proof of the number or proportion of the votes recorded in favour of, or against, that resolution.

(2) At any general meeting, the company shall transact such businesses as may be notified by the Commission, only through postal ballot.

32. A poll may be demanded only in accordance with the provisions of section 143.

33. If a poll is duly demanded, it shall be taken in accordance with the manner laid down in sections 144 and 145 and the result of the poll shall be deemed to be the resolution of the meeting at which the poll was demanded.

34. A poll demanded on the election of chairman or on a question of adjournment shall be taken at once.

35. In the case of an equality of votes, whether on a show of hands or on a poll, the chairman of the meeting at which the show of hands takes place, or at which the poll is demanded, shall have and exercise a second or casting vote.

36. Except for the businesses specified under sub-section (2) of section 134 to be conducted in the annual general meeting, the members may pass a resolution (ordinary or special) by circulation signed by all the members for the time being entitled to receive notice of a meeting. The resolution by circulation shall be deemed to be passed on the date of signing by the last of the signatory member to such resolution.

VOTES OF MEMBERS

37. Subject to any rights or restrictions for the time being attached to any class or classes of sshares, on a show of hands every member present in person shall have one vote except for election of directors in which case the provisions of section 159 shall apply. On a poll every member shall have voting rights as laid down in section 134.

38. In case of joint-holders, the vote of the senior who tenders a vote, whether in person or by proxy or through video-link shall be accepted to the exclusion of the votes of the other joint-holders; and for this purpose seniority shall be determined by the order in which the names stand in the register of members.

39. A member of unsound mind, or in respect of whom an order has been made by any court having jurisdiction in lunacy, may vote, whether on show of hands or on a poll or through video link, by his committee or other legal guardian, and any such committee or guardian may, on a poll, vote by proxy.

40. On a poll votes may be given either personally or through video-link, by proxy or through postal ballot:

Provided that nobody corporate shall vote by proxy as long as a resolution of its directors in accordance with the provisions of section 138 is in force.

41. (1) The instrument appointing a proxy shall be in writing under the hand of the appointer or of his attorney duly authorised in writing.

(2) The instrument appointing a proxy and the power-of-attorney or other authority (if any) under which it is signed, or a notarially certified copy of that power or authority, shall be deposited at the registered office of the company not less than forty-eight hours before the time for holding the meeting at which the person named in the instrument proposes to vote and in default the instrument of proxy shall not be treated as valid.

42. An instrument appointing a proxy may be in the form as per the provisions of the Act, or a form as near thereto as may be.

43. A vote given in accordance with the terms of an instrument of proxy shall be valid notwithstanding the previous death or insanity of the principal or revocation of the proxy or of the authority under which the proxy was executed, or the transfer of the share in respect of which the proxy is given, provided that no intimation in writing of such death, insanity, revocation or transfer as aforesaid shall have been received by the company at the office before the commencement of the meeting or adjourned meeting at which the proxy is used.

DIRECTORS

44. The following subscribers of the memorandum of association shall be the first directors of the company, so, however, that the number of directors shall not in any case be less than that specified in section 154 and they shall hold office until the election of directors in the first annual general meeting:

(a) Yaqoob Ahmed
(b) Muhammad Omer Ahmed
(c) Muhammad Murtaza Ahmed

45. The remuneration of the directors shall from time to time be determined by the company in general meeting subject to the provisions of the Act.

46. Save as provided in section 153, no person shall be appointed as a director unless he is a member of the company.

POWERS AND DUTIES OF DIRECTORS

47. The business of the company shall be managed by the directors, who may pay all expenses incurred in promoting and registering the company and may exercise all such powers of the company as are not by the Act or any statutory modification thereof for the time being in force, or by these Articles, required to be exercised by the company in general meeting, subject nevertheless to the provisions of the Act or to any regulations in these Articles, and such regulation being not inconsistent with the aforesaid provisions, as may be prescribed by the company in general meeting but no regulation made by the company in general meeting shall invalidate any prior act of the directors which would have been valid if that regulation had not been made.

48. The directors shall appoint a chief executive in accordance with the provisions of sections 186 and 187.

49. The amount for the time being remaining undischarged of moneys borrowed or raised by the directors for the purposes of the company (otherwise than by the issue of share capital) shall not at any time, without the sanction of the company in general meeting, exceed the issued share capital of the company.

50. The directors shall duly comply with the provisions of the Act, or any statutory modification thereof for the time being in force, and in particular with the provisions in regard to the registration of the particulars of mortgages, charges and pledge affecting the property of the company or created by it, to the keeping of a register of the directors, and to the sending to the registrar of an annual list of members, and a summary of particulars relating thereto and notice of any consolidation or increase of share capital, or sub-division of shares, and copies of special resolutions and a copy of the register of directors and notifications of any changes therein.

MINUTE BOOKS

51. The directors shall cause records to be kept and minutes to be made in book or books with regard to:

(a) all resolutions and proceedings of general meeting(s) and the meeting(s) of directors and Committee(s) of directors, and every member present at any general meeting and every director present at any meeting of directors or Committee of directors shall put his signature in a book to be kept for that purpose;

(b) recording the names of the persons present at each meeting of the directors and of any committee of the directors, and the general meeting; and

(c) all orders made by the directors and Committee(s) of directors:

Provided that all records related to proceedings through video-link shall be maintained in accordance with the relevant regulations specified by the Commission which shall be appropriately rendered into writing as part of the minute books according to the said regulations.

THE SEAL

52. The directors shall provide for the safe custody of the seal and the seal shall not be affixed to any instrument except by the authority of a resolution of the board of directors or by a committee of directors authorized in that behalf by the directors and in the presence of at least two directors and of the secretary or such other person as the directors may appoint for the purpose; and those two directors and secretary or other person as aforesaid shall sign every instrument to which the seal of the company is so affixed in their presence.

DISQUALIFICATION OF DIRECTORS

53. No person shall become the director of a company if he suffers from any of the disabilities or disqualifications mentioned in section 153 or disqualified or debarred from holding such office under any of the provisions of the Act as the case may be and, if already a director, shall cease to hold such office from the date he so becomes disqualified or disabled:

Provided, however, that no director shall vacate his office by reason only of his being a member of any company which has entered into contracts with, or done any work for, the company of which he is director, but such director shall not vote in respect of any such contract or work, and if he does so vote, his vote shall not be counted.

PROCEEDINGS OF DIRECTORS

54. The directors may meet together for the dispatch of business, adjourn and otherwise regulate their meetings, as they think fit. A director may, and the secretary on the requisition of a director shall, at any time, summon a meeting of directors. Notice sent to a director through email whether such director is in Pakistan or outside Pakistan shall be a valid notice.

55. The directors may elect a chairman of their meetings and determine the period for which he is to hold office; but, if no such chairman is elected, or if at any meeting the chairman is not present within ten minutes after the time appointed for holding the same or is unwilling to act as chairman, the directors present may choose one of their number to be chairman of the meeting.

56. At least one-third (1/3rd) of the total number of directors or two (2) directors whichever is higher, for the time being of the company, present personally or through video-link, shall constitute a quorum.

57. Save as otherwise expressly provided in the Act, every question at meetings of the board shall be determined by a majority of votes of the directors present in person or through video-link, each director having one vote. In case of an equality of votes or tie, the chairman shall have a casting vote in addition to his original vote as a director.

58. The directors may delegate any of their powers not required to be exercised in their meeting to committees consisting of such member or members of their body as they think fit; any committee so formed shall, in the exercise of the powers so delegated, conform to any restrictions that may be imposed on them by the directors.

59. (1) A committee may elect a chairman of its meetings; but, if no such chairman is elected, or if at any meeting the chairman is not present within ten minutes after the time appointed for holding the same or is unwilling to act as chairman, the members present may choose one of their number to be chairman of the meeting.

(2) A committee may meet and adjourn as it thinks proper. Questions arising at any meeting shall be determined by a majority of votes of the members present. In case of an equality of votes, the chairman shall have and exercise a second or casting vote.

60. All acts done by any meeting of the directors or of a committee of directors, or by any person acting as a director, shall, notwithstanding that it be afterwards discovered that there was some defect in the appointment of any such directors or persons acting as aforesaid, or that they or any of them were disqualified, be as valid as if every such person had been duly appointed and was qualified to be a director.

61. A copy of the draft minutes of meeting of the board of directors shall be furnished to every director within seven working days of the date of meeting.

62. A resolution in writing signed by all the directors for the time being entitled to receive notice of a meeting of the directors shall be as valid and effectual as if it had been passed at a meeting of the directors duly convened and held.

FILLING OF VACANCIES

63. At the first annual general meeting of the company, all the directors shall stand retired from office, and directors shall be elected in their place in accordance with section 159 for a term of three years.

64. A retiring director shall be eligible for re-election.

65. The directors shall comply with the provisions of sections 154 to 159 and sections 161, 162 and 167 relating to the election of directors and matters ancillary thereto.

66. Any casual vacancy occurring on the board of directors may be filled up by the directors, but the person so chosen shall be subject to retirement at the same time as if he had become a director on the day on which the director in whose place he is chosen was last elected as director.

67. The company may remove a director but only in accordance with the provisions of the Act.

DIVIDENDS AND RESERVE

68. The company in general meeting may declare dividends but no dividend shall exceed the amount recommended by the directors.

69. The directors may from time to time pay to the members such interim dividends as appear to the directors to be justified by the profits of the company.

70. Any dividend may be paid by a company either in cash or in kind only out of its profits. The payment of dividend in kind shall only be in the shape of shares of listed company held by the distributing company.

71. Dividend shall not be paid out of unrealized gain on investment property credited to profit and loss account.

72. Subject to the rights of persons (if any) entitled to shares with special rights as to dividends, all dividends shall be declared and paid according to the amounts paid on the shares.

73. (1) The directors may, before recommending any dividend, set aside out of the profits of the company such sums as they think proper as a reserve or reserves which shall, at the discretion of the directors, be applicable for meeting contingencies, or for equalizing dividends, or for any other purpose to which the profits of the company may be properly applied, and pending such application may, at the like discretion, either be employed in the business of company or be invested in such investments (other than shares of the company) as the directors may, subject to the provisions of the Act, from time to time think fit.

(2) The directors may carry forward any profits which they may think prudent not to distribute, without setting them aside as a reserve.

74. If several persons are registered as joint-holders of any share, any one of them may give effectual receipt for any dividend payable on the share.

75. (1) Notice of any dividend that may have been declared shall be given in manner hereinafter mentioned to the persons entitled to share therein.

(2) Any dividend declared by the company shall be paid to its registered shareholders or to their order. The dividend payable in cash may be paid by cheque or warrant or in any electronic mode to the shareholders entitled to the payment of the dividend, as per their direction.

76. The dividend shall be paid within the period laid down under the Act.

ACCOUNTS

77. The directors shall cause to be kept proper books of account as required under section [illegible].

78. The books of account shall be kept at the registered office of the company or at such other place as the directors shall think fit and shall be open to inspection by the directors during business hours.

79. The directors shall from time to time determine whether and to what extent and at what time and places and under what conditions or regulations the accounts and books or papers of the company or any of them shall be open to the inspection of members not being directors, and no member (not being a director) shall have any right of inspecting any account and book or papers of the company except as conferred by law or authorised by the directors or by the company in general meeting.

80. The directors shall as required by sections 223 and 226 cause to be prepared and to be laid before the company in general meeting the financial statements duly audited and reports as are referred to in those sections.

81. The financial statements and other reports referred to in these Articles shall be made out in every year and laid before the company in the annual general meeting in accordance with sections 132 and 223.

82. A copy of the financial statements and reports of directors and auditors shall, at least twenty-one days preceding the meeting, be sent to the persons entitled to receive notices of general meetings in the manner in which notices are to be given hereunder.

83. The directors shall in all respect comply with the provisions of sections 220 to 227.

84. Auditors shall be appointed and their duties regulated in accordance with sections 246 to 249.

NOTICES

85. (1) A notice may be given by the company to any member to his registered address or if he has no registered address in Pakistan to the address, if any, supplied by him to the company for the giving of notices to him against an acknowledgement or by post or courier service or through electronic means or in any other manner as may be specified by the Commission.

(2) Where a notice is sent by post, service of the notice shall be deemed to be effected by properly addressing, prepaying and posting a letter containing the notice and, unless the contrary is proved, to have been effected at the time at which the letter will be delivered in the ordinary course of post.

86. A notice may be given by the company to the joint-holders of a share by giving the notice to the joint-holder named first in the register in respect of the share.

87. A notice may be given by the company to the person entitled to a share in consequence of the death or insolvency of a member in the manner provided under the above regulations addressed to them by name, or by the title or representatives of the deceased, or assignees of the insolvent, or by any like description, at the address, supplied for the purpose by the person claiming to be so entitled.

88. Notice of every general meeting shall be given in the manner hereinbefore authorised to (a) every member of the company and also to (b) every person entitled to a share in consequence of the death or insolvency of a member, who but for his death or insolvency would be entitled to receive notice of the meeting, and (c) to the auditors of the company for the time being and every person who is entitled to receive notice of general meetings.

89. (1) In the case of members' voluntary winding up, with the sanction of a special resolution of the company, and, in the case of creditors' voluntary winding up, of a meeting of the creditors, the liquidator shall exercise any of the powers given by sub-section (1) of section 337 of the Act to a liquidator in a winding up by the Court including inter-alia divide amongst the members, in specie or kind, the whole or any part of the assets of the company, whether they consist of property of the same kind or not.

(2) For the purpose aforesaid, the liquidator may set such value as he deems fair upon any property to be divided as aforesaid and may determine how such division shall be carried out as between the members or different classes of members.

(3) The liquidator may, with the like sanction, vest the whole or any part of such assets in trustees upon such trusts for the benefit of the contributories as the liquidator, with the like sanction, thinks fit, but so that no member shall be compelled to accept any shares or other securities whereon there is any liability.

INDEMNITY

90. Every officer or agent for the time being of the company may be indemnified out of the assets of the company against any liability incurred by him in defending any proceedings, whether civil or criminal, arising out of his dealings in relation to the affairs of the company, except those brought by the company against him, in which judgment is given in his favour or in which he is acquitted, or in connection with any application under section 492 in which relief is granted to him by the Court.

We, the several persons, whose names and addresses and descriptions are subscribed below, are desirous of being formed into a company in pursuance of these articles of association and we respectively agree to take the number of shares in the capital of the company set opposite our respective names:

Name and surname (Present and former) in full (In block letters) / Fathers Name / Nationality / NIC #	Occupation	Residential Address in Full	Number of shares taken by each subscriber	Signature
MR. YAQOOB AHMED S/O. AHMED OMER PAKISTANI CNIC # 42201-4651073-5	BUSINESS	HOUSE NO. 35, STREET # 10, KHAYABAN-E-MUHAFIZ, PHASE VI, DHA, KARACHI	= 100 = (One hundred shares)	
MR. MUHAMMAD OMER AHMED S/O. YAQOOB AHMED PAKISTANI CNIC # 42201-4652023-5	BUSINESS	HOUSE NO. 35, STREET # 10, KHAYABAN-E-MUHAFIZ, PHASE VI, DHA, KARACHI	= 100 = (One hundred shares)	
MR. MUHAMMAD MURTAZA AHMED S/O. YAQOOB AHMED PAKISTANI CNIC # 42201-8075257-7	BUSINESS	HOUSE NO. 35, STREET # 10, KHAYABAN-E-MUHAFIZ, PHASE VI, DHA, KARACHI	= 100 = (One hundred shares)	
		TOTAL	= 300 = (Three hundred shares)	

Company Registration Office Karachi
Securities and Exchange Commission of Pakistan
SECP

Dated this 20th day of January, 2019

Certified
23/1/19

Artistic Hyd
Company

THE COMPANIES ACT, 2017

(PRIVATE COMPANY LIMITED BY SHARES)

MEMORANDUM

AND

ARTICLES OF ASSOCIATION

Of

ARTISTIC HYDRO I (PRIVATE) LIMITED

THE COMPANIES ACT, 2017

(PRIVATE COMPANY LIMITED BY SHARES)

MEMORANDUM OF ASSOCIATION

OF

ARTISTIC HYDRO I (PRIVATE) LIMITED

NAME

I. The name of the Company is Artistic Hydro I (Private) Limited.

REGISTERED OFFICE

II. The registered office of the Company will be situated in the Province of Sindh, Pakistan.

OBJECTS

III. (i) To carry on the business of power generation through Hydro power Plants, *thermal power plants and coal fire power plants, solar power plants, wind power plants* or any other means, operation and management of power generation projects anywhere in Pakistan or other countries of the world, and to develop, design, finance, engineer, negotiate, purchase properties etc. in regard to the development, installation, commissioning and operation of power projects.

(ii) Except for the businesses mentioned in sub-clause (iii) hereunder the company shall engage in all the lawful businesses and shall be authorized to take all necessary steps and actions in connection therewith and ancillary thereto.

(iii) Notwithstanding anything contained in the foregoing sub-clause of this clause nothing contained herein shall be construed as empowering the Company to undertake or indulge, directly or indirectly in the business of a Banking Company, Non-banking Finance Company (Mutual Fund, Leasing, Investment Company, Investment Advisor, Real Estate Investment Trust management company, Housing Finance Company, Venture Capital Company, Discounting Services, Microfinance or Microcredit business), Insurance Business, Modaraba management company, Stock Brokerage business, forex, real estate business, managing agency, business of providing the services of security guards or any other business restricted under any law for the time being in force or as may be specified by the Commission.

(iv) It is hereby undertaken that the company shall not:

(a) engage in any of the business mentioned in sub-clause (iii) above or any unlawful operation;

(b) launch multi-level marketing (MLM), Pyramid and Ponzi Schemes, or other related activities/businesses or any lottery business;

(c) engage in any of the permissible business unless the requisite approval, permission, consent or license is obtained from competent authority as may be required under any law for the time being in force.

We, the several persons, whose names and addresses and descriptions are subscribed below, are desirous of being formed into a company in pursuance of this Memorandum of Association and we respectively agree to take the number of shares in the capital of the company set opposite our respective names:

Name and surname (Present and former) in full (In block letters) / Fathers Name / Nationality / NIC #	Occupation	Residential Address in Full	Number of shares taken by each subscriber	Signature
MR. YAQOOB AHMED S/O. AHMED OMER PAKISTANI CNIC # 42201-4651073-5	BUSINESS	HOUSE NO. 35, STREET # 10, KHAYABAN-E-MUHAFIZ, PHASE VI, DHA, KARACHI	= 100 = (One hundred shares)	
MR. MUHAMMAD OMER AHMED S/O. YAQOOB AHMED PAKISTANI CNIC # 42201-4652023-5	BUSINESS	HOUSE NO. 35, STREET # 10, KHAYABAN-E-MUHAFIZ, PHASE VI, DHA, KARACHI	= 100 = (One hundred shares)	
MR. MUHAMMAD MURTAZA AHMED S/O. YAQOOB AHMED PAKISTANI CNIC # 42201-8075257-7	BUSINESS	HOUSE NO. 35, STREET # 10, KHAYABAN-E-MUHAFIZ, PHASE VI, DHA, KARACHI	= 100 = (One hundred shares)	
		TOTAL	= 300 = (Three hundred shares)	

Dated this 20th day of January, 2019

Certified to be True Copy
Joint Registrar
23/1/19

FREE OF COST COPY

Securities and Exchange Commission of Pakistan
Company Registration Office
Karachi
SECP

LIMITED LIABILITY OF MEMBERS

IV. The liability of the members is limited.

CAPITAL

V. The authorized capital of the Company is Rs. 100,000/- (Rupees One hundred thousand only) divided into 10,000 (Ten thousand) ordinary shares of Rs. 10/- (Rupees Ten only) each with powers to increase and reduce the capital of the Company and to divide the shares in the capital for the time being into several classes in accordance with the provisions of the Companies Act, 2017.

Company Registrar Karachi • Securities and Exchange Commission of Pakistan •

PESHAWAR ELECTRIC SUPPLY COMPANY
PROJECT MANAGEMENT UNIT PESCO PESHAWAR
Phone # 091-9211757, Fax # 091-9213018

No. CE (Dev) [illegible] Dated [illegible]/07/2020

Chief Commercial Officer
PESCO Peshawar.

Subject: **GRID INTERCONNECTION STUDIES OF APPROX. 63 MW HYDROPOWER PROJECT BY ARTISTIC MILLINERS (PVT) LTD. AT PANJKOR RIVER, DISTRICT UPPER DIR, KHYBER PAKHTUNKHWA**

Reference: (1) M/s Artistic letter No. AH-1/PESCO/0709-2020 dated 09.07.2020.
(2) This office letter No. 4444-45 dated 22.06.2020
(3) M/s Artistic letter No. Nil dated 20.01.2020.
(4) This office letter No. 308-9 dated 13.01.2020.
(5) M/s Artistic letter No. AH-1/PESCO/002-2020 dated 02.01.2020.

The revised Grid Interconnection Study Report / Cases of 63 MW Hydropower Project by Artistic Milliners (Pvt) Ltd. at Panjkor River, District Upper Dir, KPK received vide letter at S.No.1 referred above. The technical feasibility study has been analyzed for Load Flow, Contingency, Short Circuit and Stability analysis carried out for summer 2026. The following proposed interconnection scheme recommended by consultant is found feasible and technically approved.

"40 km 132 kV Double Circuit Transmission Line with Rail conductor from 63 MW Artistic-1 Hydropower Project switchyard to PESCO 132 kV Grid Station Munda (Jandol) Lower Dir."

However, technical approval of Grid Interconnection Study may not be considered as consent for purchase of Power. In case of any variation, the study may be revised and re-vetted from this office.

Chief Engineer (Development)
PMU PESCO Peshawar

Copy to:
1. General Manager Artistic Hydro-I (Pvt) Ltd Plot 3/A, M.A.C.H.S Shahrah -e-Faisal, Karachi.

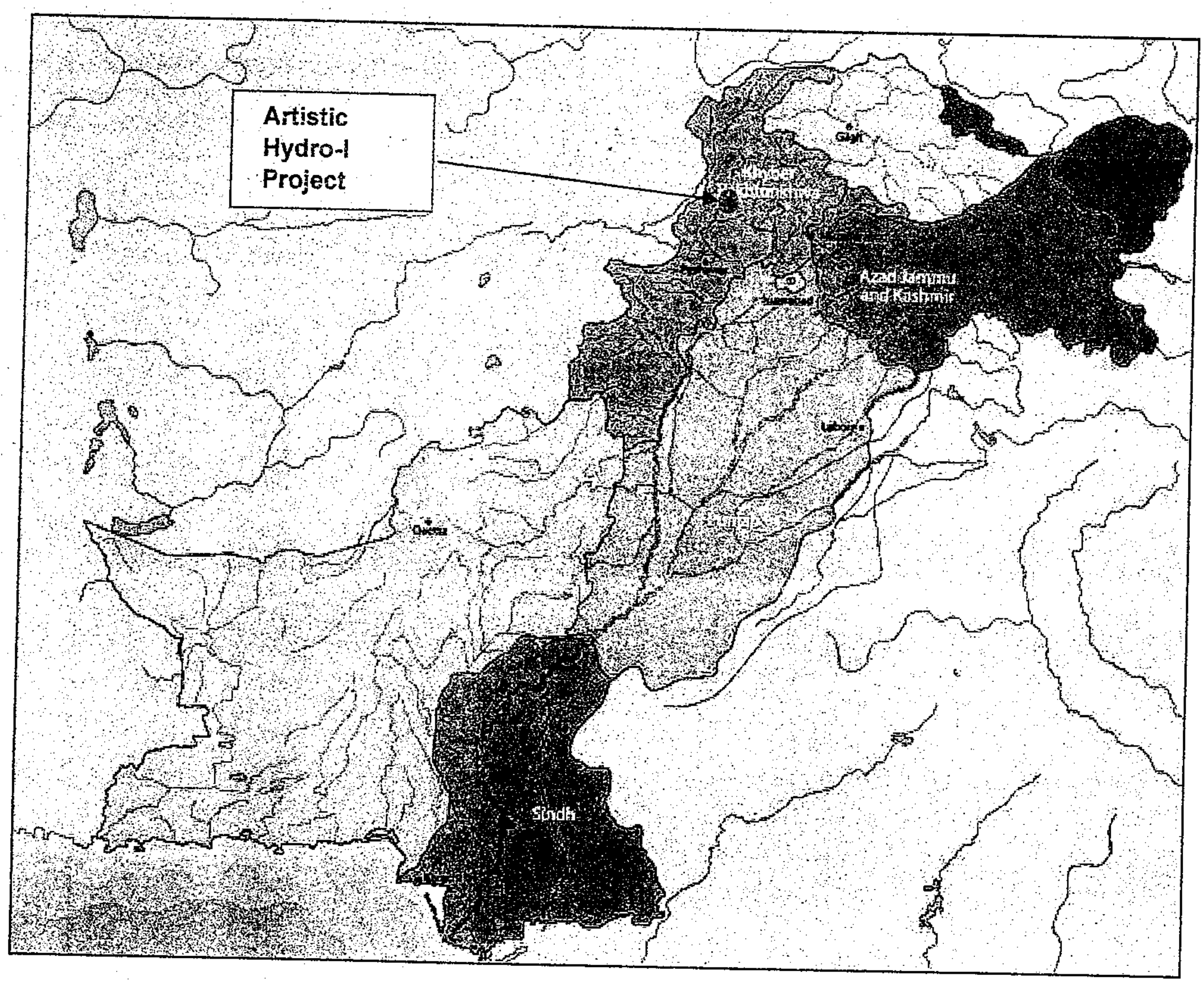
SCHEDULE-I

The Location, Size (i.e. Capacity in MW), Type of Technology, Interconnection Arrangements, Technical Limits, Technical/Functional Specifications and other details specific to the Generation Facilities of the Licensee are described in this Schedule.

Location of the

Generation Facility/Hydel Power Plant

of the Licensee



Location of the

Generation Facility/Hydel Power Plant

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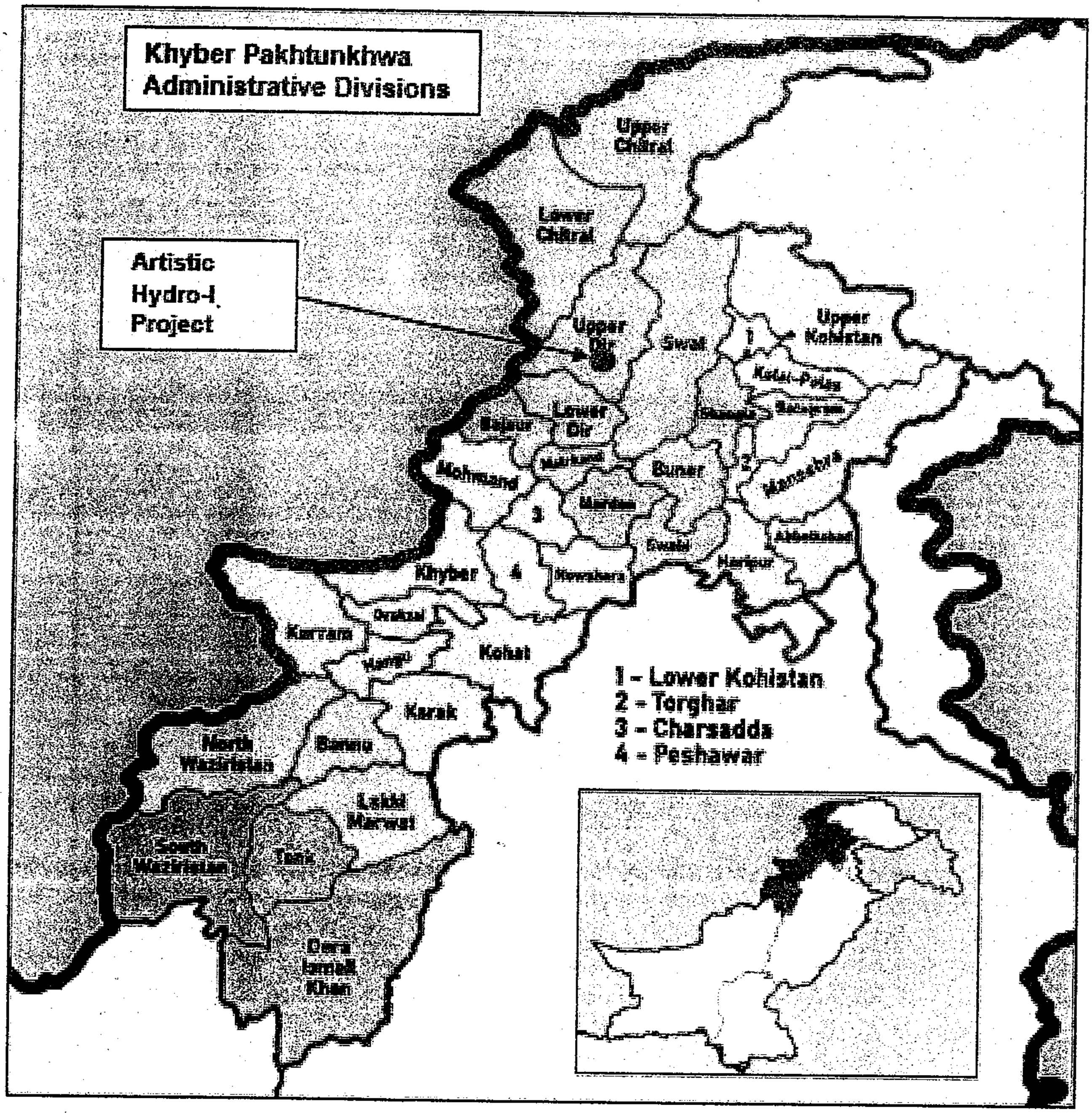
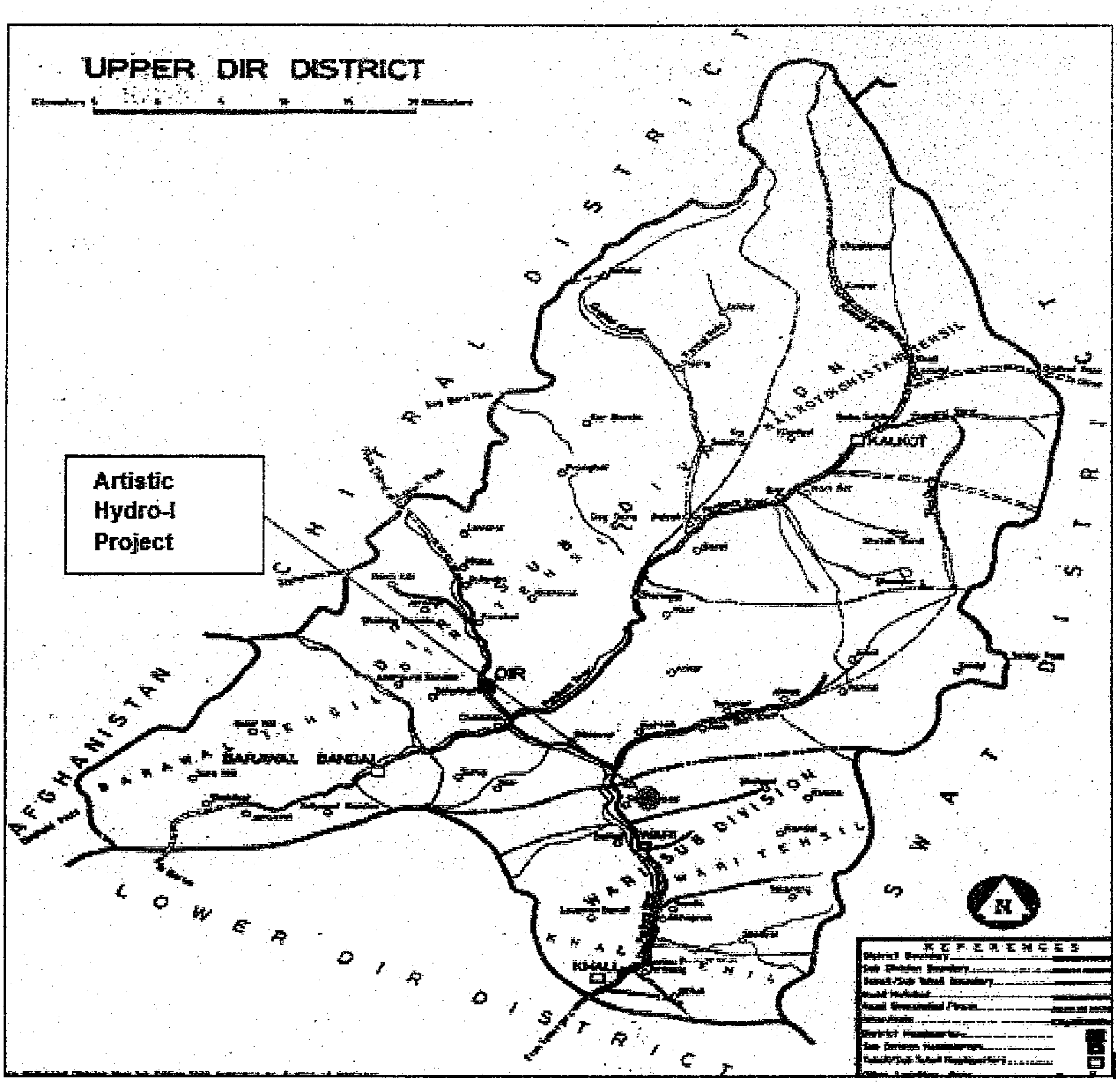


Location of the

Generation Facility/Hydel Power Plant

of the Licensee



Coordinates of
Start of the Intake and Powerhouse of the Generation Facility/Hydel Power Plant of the Licensee

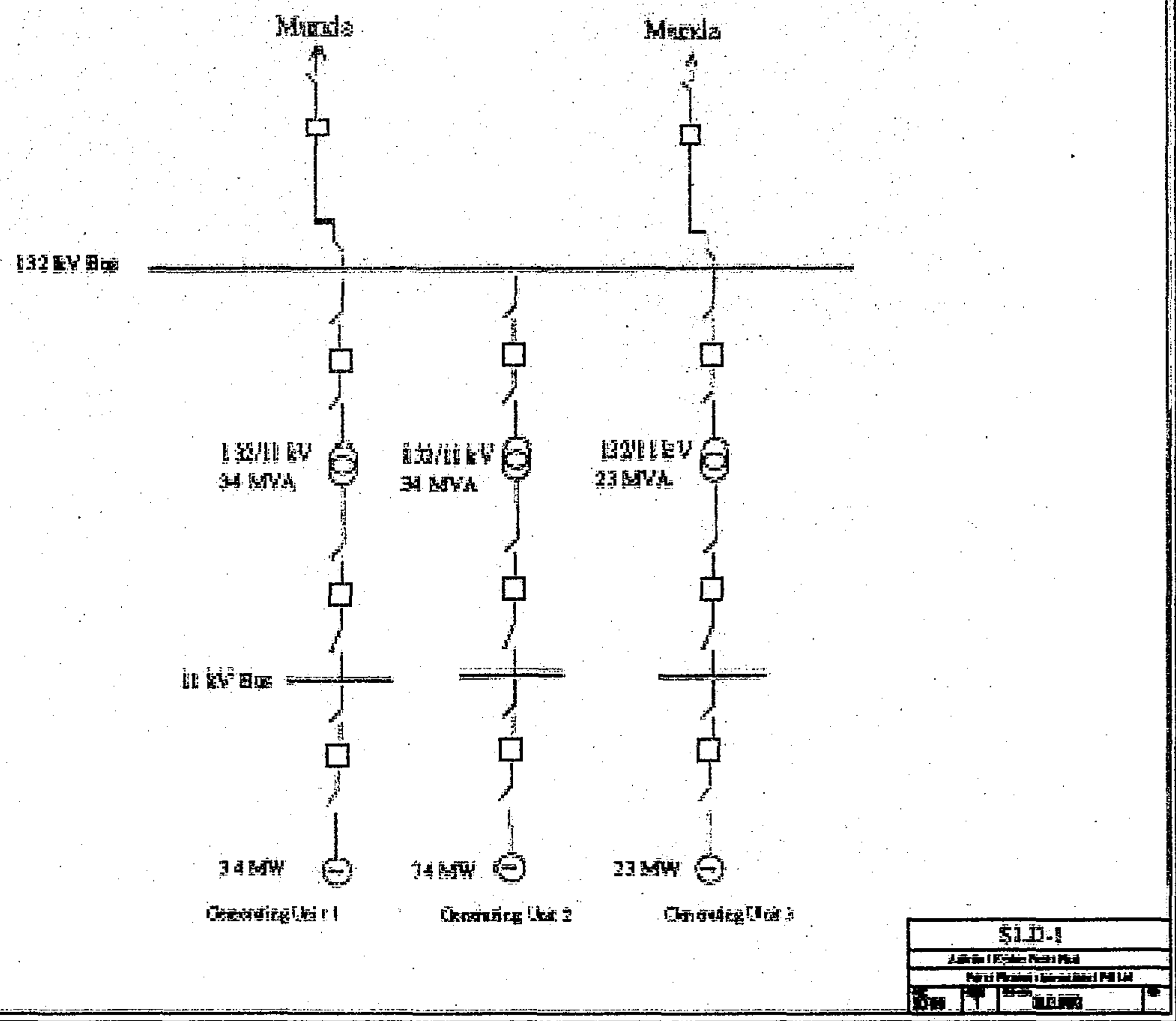
Site	Latitude	Longitude
Weir / Intake	35°05'52.77"	71°59'0.08"
Power House	35°01'28.32"	72°0'40.77"

Single line Diagram

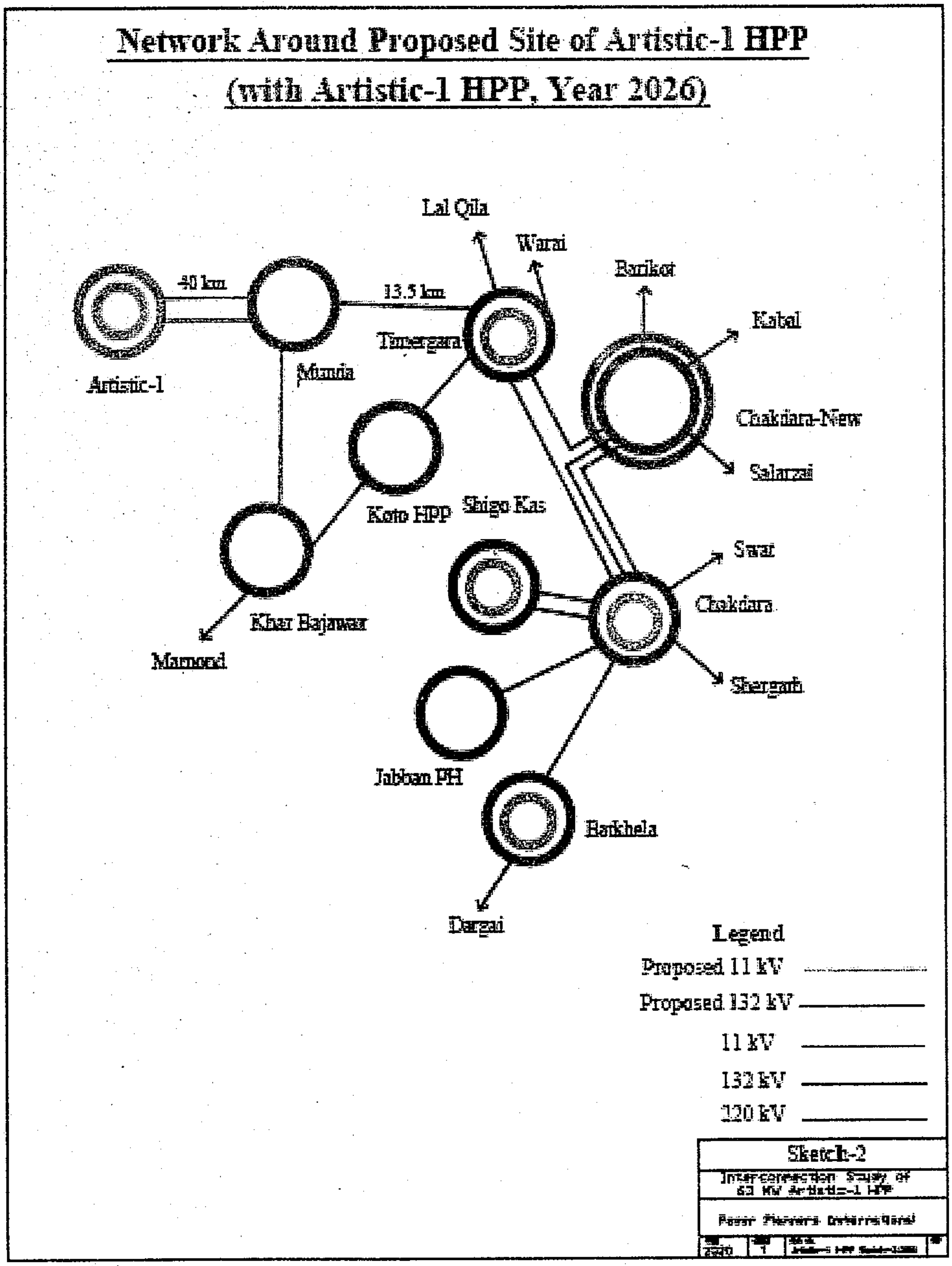
of the Generation Facility/Hydel Power Plant

of the Licensee

Single Line Diagram of 132/11 kV Busbar At Artistic-1 HPP



Schematic Diagram of the Interconnection Arrangement/Transmission Facility for Dispersal of Power from the Generation Facility/Hydel Power Plant of the Licensee



Interconnection Arrangement for
Dispersal of Electric Energy/Power from the Generation Facility/Hydel Power Plant of the Licensee

The electric power generated from the generation facility/Hydel Power Plant/Artistic-I Project of the Licensee shall be dispersed to the load center of PESCO.

(2). The proposed Interconnection Arrangements/Transmission Facilities for dispersal of power from generation facility/Hydel Power Plant of the Licensee will consist of the following: -

(a).40 Km 132 kV Double Circuit Transmission Line with Rail Conductor from 62.606 MW Artistic-1 HPP switchyard to PESCO 132 kV Grid Station Munda (Jandol) Lower Dir.

(3). Any change in the above Interconnection Arrangement/Transmission Facility duly agreed by Licensee and PESCO, shall be communicated to the Authority in due course of time.

Detail of

Generation Facility/Hydel Power Plant

of the Licensee

(A). General/Business Information

(i).	Name of the Entity/ Licensee	Artistic Hydro I (Pvt.) Ltd. Karachi, Pakistan
(ii).	Registered/Business Office of Entity/License	Plot 3/A, M.A.C.H.S Shahrah-e-Faisal, Karachi-75350 Pakistan

(B). Location & Type of Facility

(i).	Location	Near Sahibabad, District Upper Dir, Khyber Pakhtunkhwa, Pakistan
(ii).	UTM coordinates of weir	42 S, Easting = 771953.15 m Northing =3887983.19 m
(iii).	Hydropower type	Run-of-the-river
(iv).	River Name	Panjkora River

(C). Hydrology

(i).	Catchment Area	3100 km^2
(ii).	Normal Reservoir Level	1,071 masl
(iii).	Design Discharge for Power	100 m^3/s
(iv).	Selected Design Flood for Weir	3,208 m^3/s (100 year frequency)
(v).	Flood Discharge 100yr	3,208 m^3/s
(vi).	Flood Discharge 1000yr	5,011 m^3/s

(D). Diversion Weir

(i).	Type of Weir	Gated weir structure
(ii).	Width of approach canal	97 m

(iii).	Number of gates on spillway	8 Nos.
(iv).	Width of spillway gates	7.5 m
(v).	Height of spillway gates (from NWL to apex point)	8.5 m
(vi).	Freeboard of spillway gates	0.20 m
(vii).	Number of spillway piers	7 Nos.
(viii).	Width of spillway piers	3 m
(ix).	Width of the energy dissipating basin	82 m
(x).	Number of sluiceway gates	2 No.
(xi).	Width of sluiceway gates	4.5 m
(xii).	Height of sluiceway gates	5 m
(xiii).	Length of spillway section	82 m
(xiv).	Design Flood	100 year frequency
(xv).	Flood Discharge	3,208 m^3/s
(xvi).	Weir Height	10 m (NWL) from river bed
(xvii)	Size of Basin	82 m x 33 m (L x W)
(xviii)	Number of intake gates	4
(xix).	Size of Intake Gate	6.8 m x 5.0 m

(E). Box Channel Type-1

(i).	Type of Channel	Two-barrelled,Rectangular, Reinforced concrete
(ii).	Discharge capacity	110 m^3/s
(iii).	Dimensions of one barrel	5.90 m x 5.00 m (WxH)
(iv).	Freeboard	0.55 m
(v).	Total Length	617 m

(vi).	Velocity of water at full capacity	2.09 m/s
(vii).	Flow Depth	4.45 m
(viii).	Bed Slope	0.0004

(F). Free Flow Tunnel:

(i).	Type of internal cross section	D-shaped, reinforced concrete
(ii).	Diameter of internal cross section	7.10 m
(iii).	Diameter of excavation cross section	7.70 m
(iv).	Bottom slope of tunnel	0.0005
(v).	Length of tunnel	1,583 m
(vi).	Design Discharge	110 m^3/s
(vii).	Velocity	2.6 m/s

(G). Box Channel Type-1

(i).	Type of Channel	Two-barrelled, Rectangular, Reinforced concrete
(ii).	Discharge capacity	110 m^3/s
(iii).	Dimensions of one barrel	5.90 m x 5.00 m (WxH)
(iv).	Freeboard	0.55 m
(v).	Total Length	441 m
(vi).	Velocity of water at full capacity	2.09 m/s
(vii).	Flow Depth	4.45 m
(viii).	Bed Slope	0.0004

(H). Sand Trap

(i).	Type of Sand Trap	6 chambers
(ii).	Limit Particle Size	0.30mm

(iii).	Average Velocity in Chambers	0.266 m/s
(iv).	Length of Chamber	98 m
(v).	Bottom slope of sand trap	0.02
(vi).	Water depth at the beginning	6.5 m
(vii).	Water depth at the end	8.46 m
(viii).	Length of Upstream Transition	40 m
(ix).	Length of Downstream Transition	40 m
(x).	Free Board	0.96 m
(xi).	Size of Chamber at Start	B = 8 m , D = 7.46 m
(xii).	Size of Chamber at end	B = 8 m , D = 9.42 m
(xiii).	Inlet Gates	Six gates (4 m x 5.15 m)
(xiv).	Outlet Gates	Six gates (4 m x 5.15 m)
(xv).	Flushing Arrangement	Steel pipe (1.10 m dia) with sliding gate
(xvi).	Flushing Discharge	10.2 cumecs

(I). Box Channel Type-2

(i).	Type of Channel	Two-barrelled,Rectangular, Reinforced concrete
(ii).	Discharge capacity	100 cumecs
(iii).	Dimensions of one barrel	5.50 m x 5.00 m (WxH)
(iv).	Freeboard	0.54 m
(v).	Total Length	245 m
(vi).	Velocity of water at full capacity	2.04 m/s
(vii).	Flow Depth	4.46 m
(viii).	Bed Slope	0.0004

(J). Inlet Pond

(i).	Invert elevation at Start	1064.00 masl
(ii).	Invert elevation at tunnel inlet	1051.07 masl
(iii).	Normal Water level in inlet pond	1069.33 masl
(iv).	Freeboard	1.17 m
(v).	Minimum submergence provided	5.45 m
(vi).	Spillway section	Sharp crested weir
(vii).	Length of spillway section	60 m

(K). Power Tunnel

(i).	Type of Power Tunnel	Horseshoe, reinforced concrete
(ii).	Diameter of internal cross section	6.65 m
(iii).	Invert elevation of Tunnel	1051.07 masl
(iv).	Normal water level at inlet pond	1069.33 masl
(v).	Flow area	36.67 m^2
(vi).	Bottom slope of tunnel (between tunnel inlet and Kotkay Khwar)	0.001
(vii).	Bottom slope of tunnel (between Kotkay Khwar and valve chamber)	0.009
(viii).	Average flow velocity	2.73 m/s
(ix).	Length of tunnel	7,460 m
(x).	Bed level of tunnel at surge shaft	1021.32 m
(xi).	Frictional loss in tunnel (concrete lining)	6.984 m
(xii).	Frictional loss in tunnel (concrete + steel lining)	0.052 m

(L). Surge Shaft

(i).	Type of surge shaft	Circular shaft, reinforced concrete
(ii).	Maximum surge level	1,095.45 masl
(iii).	Minimum surge level	1,035.55 masl
(iv).	Diameter of surge shaft	17.30 m
(v).	Height of surge shaft	73 m(above tunnel crown)

(M). Penstock

(i).	Type of Penstock	Steel
(ii).	Invert level of penstock	1020.26 masl
(iii).	Length (until trifurcation)	50.50 m
(iv).	Diameter of penstock	5.05 m
(v).	Thickness of penstock	10 mm ~ 15 mm
(vi).	Design velocity of penstock	4.99 m/s
(vii).	Friction loss in transition from tunnel to penstock	0.011 m
(viii).	Friction loss in penstock	0.127 m
(ix).	Minor losses until trifurcation	0.435 m
(x).	Total loss until trifurcation	7.608 m
(xi).	Invert level of penstock at powerhouse	985.74 masl
(xii).	Trifurcation length	64.4 m
(xiii).	Diameter of Penstock (To Large Units)	3.1 m
(xiv).	Diameter of Penstock (To Small Unit)	2.5 m

(N). Power Facilities

(i).	Type of powerhouse	Surface powerhouse
(ii).	Size of powerhouse	45.65 m x 27.33 m
(iii).	Turbines	Vertical Francis
(iv).	Total installed capacity	62.606 MWe
(v).	Number of units	3 Nos. (2 Large + 1 Small)
(vi).	Average capacity of large units	23.508 MW_e
(vii).	Capacity of small unit	15.589 MW_e
(viii).	Design discharge of large units	37.50m^3/s(Units 1 and 2)
(ix).	Design discharge of small unit	25.00m^3/s(Unit 3)
(x).	Generator capacity of large unite (Unit-1 & Unit-2)	31 MVA
(xi).	Generator capacity of small unit (Unit-3)	20 MVA
(xii).	Gross Head	81 m
(xiii).	Net head for large unit-1	69.91 m
(xiv).	Net head for large unit-2	70.23 m
(xv).	Net head for small unit-3	69.68 m
(xvi).	Average annual energy	306.570 GWh
(xvii)	Plant factor	55.71%

(O). Tailrace Channel

(i).	Type of tailrace channel	Rectangular, Reinforced concrete
(ii).	Tail water level at design discharge (Q = 100 m^3/s)	990 masl

(iii).	Width of tailrace channel	25 m
(iv).	Slope of tailrace channel	2H:1V
(v).	Water depth just upstream of broad-crested sill at design discharge (Q = 100 m^3/s)	1.77 m
(vi).	Length of channel	17 m
(vii).	Free board between TWL and top elevation of tailrace side walls	5.75 m

(P). Other Information

(i).	COD of the generation facility/Hydel Power Plant	February 2028 (Expected)
(ii).	Expected minimum useful life of the generation facility from COD	60 years

SCHEDULE-II

The Total Installed Gross ISO Capacity (MW), De-Rated Capacity At Reference Site Conditions (MW), Auxiliary Consumption (MW) and the Net Capacity at Reference Site Conditions (MW) of the Generation Facility/Hydro Power Plant of Licensee is given in this Schedule

SCHEDULE-II

(1).	Total Installed Gross Capacity of the Generation Facility/Hydel Power Plant (24.175 +24.286 + 16.068) MW_m	64.529MW_m
(2).	Total De-Rated Capacity of the Generation Facility/Hydel Power Plant at Mean Site Conditions (24.175 +24.286 + 16.068) MW_m	64.529MW_m
(3).	Total De-Rated Capacity (Electrical) of theGeneration Facility/Hydel Power Plant at MeanSite Conditions (23.455 + 23.562 + 15.589) MW_e	62.606MW_e
(4).	Auxiliary Consumption of the GenerationFacility/Hydel Power Plant	0.4 MW
(5).	Net Capacity of the Generation Facility/HydelPower Plant at Mean Site Conditions	62.206 MW

Note

All the above figures are indicative as provided by the Licensee. The Net Delivered Energy available to Power Purchaser for dispatch will be determined through procedures contained in the Energy Purchase Agreement (EPA) or the Applicable Document(s).

ARTISTIC HYDRO I (PVT) LTD.

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7004-AH1PL-NEPRA-000112

January 11th, 2021

Director
Registrar Office,
National Electric Power Regulatory Authority (NEPRA),
Islamabad.

Subject: Replies to the Comments on Application of Artistic Hydro 1 (PVT) Limited for Grant of Generation Licence in Respect of 62.606 MW Hydropower Project, District Upper Dir

Dear Sir,

With reference to your official letter No: NEPRA/R/LAG-30/47759 dated December 31, 2020 where we have received the comments/observations made by the esteemed experts on the generation licence application letter for Artistic-I HPP dated December 7, 2020.

Our item wise reply/response for your perusal and kind consideration are;

S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
NEPRA(Ref: No. NEPRA/R/LAG-30/47759 dated December 31, 2020)		
A.	**General Comments:**	
i.	Certified true copy of Certificate of Incorporation (CoI) duly certified by SECP, as required pursuant 10 Regulation 3(5)(a)(i) of the Regulations.	True and Certified Copy of Certificate of Incorporation duly certified by SECP (attached).
ii.	Certified true copies of Memorandum and Articles of Association (MoA), duly certified by SECP, as required pursuant to Regulation 3(5)(a)(ii) of the Regulations.	True and Certified Copy of Memorandum and Articles of Association (MoA) duly certified by SECP (attached).
iii.	Certified true COPY of last filed Annual Return to the Registrar of Companies, duly certified by SECP, pursuant to Regulation	Attached

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		with the locals. Since this is a run-off river project therefore not much of resettlement is to be made however at powerhouse section, some part of the population will be resettled. During the public hearing, the concerns of all the stakeholders were heard and responded positively. Once the LOS is issued, then we shall be undertaking the process of land acquisition and resettlement.
x.	Consents as required pursuant to Regulation 3(6)(A)(c)(9) of the Regulations.	We have received all the consents in order for the issuance of Generation License. The relevant consents are the following: a) Forest b) Wildlife c) Fisheries d) PESCO e) etc
B.	**Technical Comments**	
xi.	Information regarding Peaking / base load operation as required pursuant to Regulation 3(6)(A)(c)(14) of the Regulations.	In the hydropower literature and practice, hydroelectric power plants are classified into two: i) base plant ii) peak plant according to their operation principles. As evident, peak plants are generally operated

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		during peak hours to contribute meeting the heavy load demands at these hours, whereas base plants are operated constantly during the whole day. So, hydraulic peak plants require considerable amount of stored water in the reservoir to be utilized in full capacity power generation at peak hours. This requirement is achieved by building dams to create reservoirs, which are capable of supplying the amount of water needed for full capacity operation of the power plant. Reservoirs provide the possibility of storing water during high flow times for onward utilization of this stored water during low flow times, for peak operation. However, Artistic-I HPP is not a dam and storage type project but a run of the river type project which comprises of only a 10 m high weir with approximately~455,780 m^3 of reservoir behind it. But, in order to operate Artistic-I HPP with full capacity (100 m^3/s) during, say, 5 hours peak time: $V_{peak} = 100 \times 60 \times 60 \times 5 = 1,800,000\ m^3$ of water is needed.

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		Consequently, the current reservoir volume of the project is not adequate for peak operation. Further, out of ~455,780 m^3 of reservoir water, only 319,050 m^3 can be used for such an operation since the bottom elevation of the intake structure is positioned at 1,064 masl to prevent entering of bed load or debris material into the water conveyance system. Another reason is, as mentioned in Section 8.1.10.1 of the draft feasibility report, the height of active volume in the inlet pond is only 3.62 m, which means that the water level in these structures or in the reservoir can be lowered maximum by 3.62 m considering the minimum operating discharge of the small unit.Otherwise it is impossible to operate the Francis type of turbine hydraulically and there is a severe risk of air entrance to the pressurized power tunnel. If air entrance into a pressurized system is allowed, then unrecoverable damages to the tunnel, penstock and E-M equipment is accepted in advance. As globally well known, run of the river hydropower schemes are of base plant types and cannot be operated as peak plants, mainly due to the lack of enough storage capacity, as stated

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		above. One possibility for a run of the river type scheme to be operated for peak demand may be the utilization of the active volume within the structures that operate under free flow conditions. The available volume in box channel type-1, which has 615 m length, two barrels each has 5.9 m width and 3.62 m active water depth is: $V_{channel-1} = 615 \times 11.8 \times 3.62 = 26{,}270\ m^3$ The available volume in free flow tunnel, which has 1,583 m length, 7.1 m diameter and 3.62 m active water depth and 25.70 m^2 wet area is: $V_{freeflowtunnel} = 1{,}583 \times 25.70 = 40{,}680\ m^3$ The available volume in sand trap, which has 6 chambers in98 m lengthand 3.62 m active water depthis: $V_{sand\ trap} = 98 \times 6 \times 3.62 \times 8 = 17{,}030\ m^3$

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		The available volume in box channel type-2, which has 245 m length, two barrels each has 5.5 m width and 4.46 m active water depth is: $V_{channel-2} = 245 \times 11 \times 3.62 = 9{,}750\ m^3$ Likewise, the active volume in the inlet pond, which has 144 m length and 11.50 m width is: $V_{inletpond} = 144 \times 11.50 \times 3.62 = 4{,}750\ m^3$ Also, the available water in the reservoir for peak operation was 319,050 m^3. Then the total of aforesaid volumes is approximately: $V_{total} = 26{,}270 + 40{,}680 + 17{,}030 + 9{,}750 + 4{,}750 + 319{,}050 = 417{,}530\ m^3$ As a result, during low flow seasons Artistic-I HPP can meet the peak demand only for: $417{,}530\ m^3 \div 100\ m^3/s = 4{,}175$ sec = **70 min** which is not sufficient and will result in emptying of the small reservoir and aforesaid upstream structures down to the minimum operation level.

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		In order to refill the system, say in the second ten days of February, when the divertible flow is 12.37 m^3/s: $t = 319{,}050\ m^3 \div 12.37\ m^3/s = 25{,}792$ sec = **7.16 his** required. The above issues clearly reflect thata run-of-river project like Artistic-I HPP cannot serve for peak operation. Constructing a dam on Panjkora River is not recommended as it will result in relocation of the current road extending to Upper Dirwhich is also of strategic importance. On the other hand, the area is very crowded and in case of dam construction, the land acquisition and resettlement in the reservoir will definitely pose a severe social problem. As a result, topographicaland environmental conditions are not favorable at these upper reaches of the Panjkora River for dam construction.

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
xii.	Plant characteristics (generation voltage, frequency, power factor, automatic generation control, ramping rate, control metering and instrumentation) as required pursuant to Regulation 3(6)(A)(c)(15) of the Regulations.	**Generation Voltage:** 11 kV **Frequency:** 50 Hz **Power Factor:** 0.85 (lagging) **Excitation:** Excitation system of the generators will be static, constant-voltage type with controlled thyristors. Main features and functions of the excitation system will include the followings: - Local, remote, manual and automatic control modes, - Automatic Voltage Regulator with manual control, - Reactive power/power factor control, - Joint control with equalizing of stator reactive currents, - Power system stabilizer, - Stator and rotor current limiter, - Excitation and impulse current limiter, - Under frequency control and limiter, - Under/over excitation limiter, - Voltage regulation within the specified limits at all permissible load conditions, - Voltage adjustment for synchronizing. **Automatic Generation Control:** The power plant is to be provided with a SCADA (Supervisory Control and Data Acquisition) system. This

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		system will include PLCs (Programmable Logic Controllers), monitors and hard discs for data display and data acquisition and distributed computer control systems with graphic display screens. Two PLCC (Power Line Carrier Communication) systems will be installed to interconnect 132 kV switchyard of this Power Plant to 132 kV Munda PESCO Substation. The PLC system will provide voice communication and Carrier Tele-Protection Channel (with 4 commands) with Munda Substation including Telephone Sets at all locations. The PLCC system shall communicate with NPCC/RCC Islamabad (The Satellite Communication system will be interim arrangement for communication with NPCC/RCC Islamabad until PLC System is in place and operative). Remote Satellite Telecommunication facilities between this Power Plant and RCC/NPCC, (Regional Control Centre / National Power Control Center) Islamabad will be installed. (*Kindly refer to Section 10.16.1 of the draft feasibility report*) **Ramping Rate:**NERC Disturbance Control Standard specifies that regulating and supplemental reserves must be able to reach their full capacity within 10 minutes, but since capacities may differ dramatically, this definition will not describe the feasible MW increase within

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		a minute. As per NERC standard, ramp up rate can be assumed 10% of the installed capacity of the planti.e. 6.26 MW/min (Although Artistic-1 HPP is run of river type project i.e., doesn't have storage water like dams), which means that the plant will be ready to operate with full capacity in 10 minutes.However, for run of river type schemes the precondition is the availability of sufficient water in the river. It means that in high flow season there is no problem for this but in low flow season the plant may also reach full capacity in 10 minutes but it cannot be kept working with full capacity for hours due to lack of water. As indicated above,after an hour, the plant has to be re-stopped, otherwise air enters into the pressure tunnel and causes unrecoverable damages not only to the water conveyance structures but also to the electromechanical machinery). **Control Metering and Instrumentation:**A reliable, secure and safe energy metering system for measuring and sale the electric power energy from CPPA/PESCO shall be provided according to WAPDA/NTDC specifications. The metering points to record the MWh and MVARh exchange between this power plant and National Grid System shall be shown in an appropriate diagram. Dedicated current and voltage

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S.No	Comments/Observations	Artistic Hydro I (Pvt) Ltd Replies / Response
		transformers shall be provided for metering as per NTDC Specs. Energy Meters shall be provided on 132 kV side of all Generator Transformers. The Metering System shall have a complete backup metering and shall be according to WAPDA/NTDC specifications
xiii.	Information regarding training and development as required pursuant to Regulation 3(6)(A)(c)(17) of the Regulation.	The scope of work will include all required studies, calculations, design, engineering, manufacturing, supply, submission of drawings and documents, shop and site testing, erection, adaptation to related equipment, commissioning and training services for the PLC, SCADA and its components. (*Kindly refer to Section 10.16.1 of the feasibility report*)

We hope that our above responses would be sufficient to satisfy the comments/observations made by the esteemed NEPRA. We would like to thank the NEPRA for their keen observations and critical review of the Generation Licence Application.

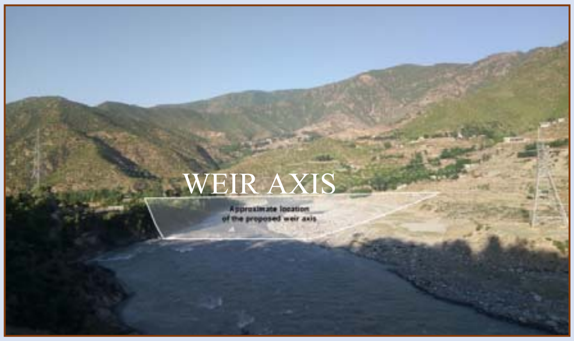
Thanking You,

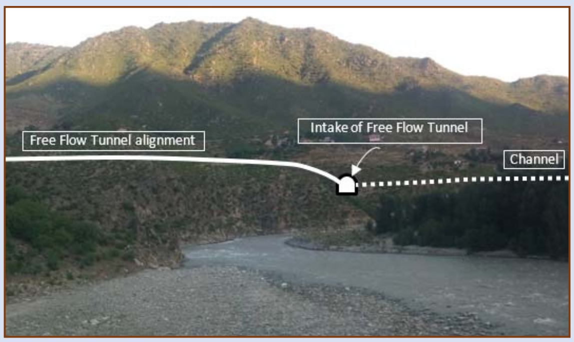
Yours Truly,
For & on behalf of **Artistic Hydro I (Pvt) Ltd.**

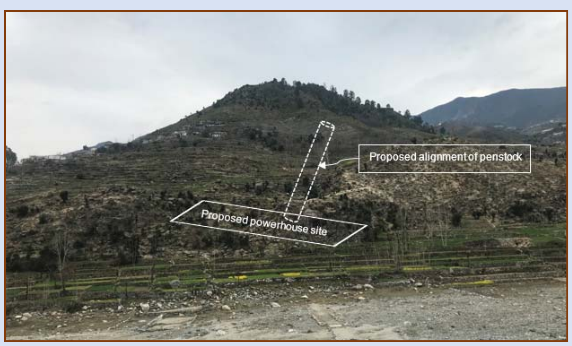
Rafique Khanani
CFO/Company Secretary

Artistic Hydro I (Pvt) Ltd.

ARTISTIC HYDRO I (Pvt.) Ltd.
KARACHI, PAKISTAN







ARTISTIC-I HYDROPOWER PROJECT

DRAFT

FEASIBILITY STUDY

VOLUME - I
(MAIN REPORT)

AUGUST 2020

ARTISTIC-I HYDROPOWER PROJECT CONSULTANTS

A Joint Venture of

BAK CONSULTING ENGINEERS, PAKISTAN & DOLSAR ENGINEERING TURKEY

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EXECUTIVE SUMMARY

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. INTRODUCTION

Hydropower potential in Khyber Pakhtunkhwa (KP) Provence especially in northern areas are very high and Pakhtunkhwa Energy Development Organization (PEDO) has been working on this dimension of development for the last three decades to achieve the self-sufficiency in the power sector, the organization is also encouraging public-private partnership and private investors. This effort has gained momentum in recent years. The present study is also an outcome of this effort of the PEDO.

Khyber Pakhtunkhwa has an estimated power potential of generating nearly 30,000 MW. The need for development of these immense hydropower potential in the province cannot be over-emphasized. While most of the hydro power projects under development are in public sector, the provincial government has embarked on a multi-pronged strategy for encouraging investment through Public, Private and Public Private Partnership sectors.

Raw hydropower sites identified by Pakhtunkhwa Energy Development Organization (PEDO) in Khyber Pakhtunkhwa Province need to be explored in detail. In this regard, PEDO under Government of Pakistan (GOP) policy, is encouraging the private investors, to develop infrastructure and hydropower projects in the province.

In view of the above, PEDO has entered into an agreement with M/s Artistic Milliners (Pvt) Ltd, Karachi to develop Artistic-I HPP Raw Site at Panjkora River, Sahibabad in District Upper Dir of northern part of Khyber Pakhtunkhwa Province, Pakistan.

2. TOPOGRAPHIC SURVEY

The Electronic Total Station (ETS), Automatic Level and Differential GPS (DGPS) were used for carrying out survey work for Artistic-I HPP. Survey control points for the project has been established by using latest survey equipment's. The first two control points S1 and S2 were established using hand held GPS. The remaining were then established by using total station. The coordinates of S1 & S2 are given in **Table 1;**

Table 1 : List of control points established using hand held GPS

S.NO	EASTING (m)	NORTHING (m)	LEVEL (m)
S1	772740.835	3885811.481	1060.155
S2	772807.960	3885302.014	1054.970

Traverse was carried out in a closed loop to established control in the area of interest starting from the survey control point S2. The traverse bearing and distances were observed in two directions (forward & backward) and mean was accordingly adopted. A closed traverse (polygonal, or loop traverse) was employed, consisting of a series of linked traverse lines where the terminal point closed at the starting point.

The vertical control was established with the help of auto level Nikon AS-2. The traverse was closed with double run.

The horizontal angles were measured on two zeroes i.e. four angle measurements were taken from each side. The average of these was used in the traverse computation that provided the spread of angles which was not more than 20” of arc.

A network of control points was established along the Timergara-Upper Dir road (N45) from powerhouse site to weir site. Bearing and distance observations were made two times on a single station from which mean value was calculated. The same process was repeated at every station. The mean value was converted to co-ordinate system.

In general, latest survey instruments i.e. Total Stations were used for field survey. Later on, field data was computer processed and various maps/ plans, profiles and cross sections were prepared and plotted at recommended/ required scales on A3 size paper. Eagle Point and Civil 3D software were used for processing of survey data while AutoCAD for drawing and plotting purposes.

The drawings produced on the basis of the survey has been used for planning and developing weir, box channel, sandtrap, tunnel alignment, powerhouse location and other associated structures.

3. HYDROLOGY AND SEDIMENTATION

The hydrological studies for Artistic-I Hydropower Project have been carried out. daily flow record of Panjkora River at Sharmai and Koto Gauge stations is available on the records of

Pakhtunkhwa Energy Development Organization (PEDO) for 14 years (2005-2018) & 13 years (2005-2017) respectively. While for the same river at Zulam Bridge gauge station records for the period of 8 years (1999-2006) are available on the record of Surface Water Hydrology (SWHP), WAPDA which is not sufficient to rely upon due to its availability for short periods. However, daily flow records of Swat River at Chakdara for the period of 55 years (1961 to 2015) are available on the records of Surface Water Hydrology (SWHP), WAPDA which can be used for the estimation of hydrological parameters for the Artistic-I Hydropower Project.

Mean 10-daily flow of Swat at Chakdara has been estimated 190.91 m^3/s, while for Panjkora at Koto it is just 87.81 m^3/s. 10-Daily flow of Swat River at Chakdara have been transposed to weir by mean 10-daily flow ratios at both gauging stations which is 0.46 instead of catchment area ratio of 0.54.10-Daily flow series of Swat at Chakdara from 1961 to 1998 have been generated from adjustment factor 0.46. From year 1999 onward, Panjkora at Zulam Bridge and Koto for 1999 to 2004 & 2005-17 have been transposed to weir by catchment area ratio. Flow series generated from long term historic record of Swat River at Chakdara including limited year data of Panjkora River at Zulam, Koto etc. are recommended for design and power estimation.

Availability of flows at the proposed weir/intake site was checked using detailed flow duration curve (FDC) analysis. FDC based on Chakdara Data is recommended for further use.

For design flood estimation, two approaches are adopted.

a) Regional Based Envelope Curves
b) Hydro-meteorological approach based of rainfall-Runoff

As rainfall-runoff based estimated lies in between the estimated flood from regional based estimate, it is recommended for design purpose. Furthermore, the rainfall-runoff estimated flood included rainfall data of Dir and physical parameter of watershed i.e. time lag and curve number.

For sedimentation study of the Artistic-I HPP, historical data of the sediment is available at the Chakdara gauge station at Swat River while sediment samples for short duration are available at Koto and Zulam Bridge at Panjkora River.

As per suspended sediment record of Panjkora River at Zulam Bridge “the average sediment concentration is about 0.885 % (by weight) or 8850 ppm. The suspended sediment concentration increases with the discharge. The observed minimum concentration is 16 ppm and the observed maximum concentration is 48700 ppm. At average discharge the suspended sediment consists of about 16 % sand, 65 % silt and 21 % clay. The unit weight of fresh deposits of this sediment is about 62 lbs per. cft.

As per Swat River at Chakdara Record, annual suspended sediment yield is 2.38 million short ton. The average sediment concentration is 0.042 % (by weight) or 420 ppm. The average annual sediment yield is 0.868 ac.ft. per sq. mile of drainage area. The computed maximum concentration is about 13,700 ppm while the observed maximum concentration is about 25700 and the minimum observed concentration is 2 ppm. Suspended sediment consists of approximately 8 % sand, 71 % silt and 21 % clay. Unit weight of fresh deposits shall be about 60 lbs per c.ft.

Estimated suspended sediment load is 1039 acre-ft per annum or 412 cubic meter per square kilometer. Including 20 % bed load total sediment load at weir is 1.54 million cubic meters (1248 acre-ft).

Apart from the historical available data, Artistic-I gauge station has been installed downstream of the weir location where water samples are collected twice a month. The samples were sent to the laboratory for the estimation of sediment content and gradation analysis.

4. GEOLOGY AND GEOTECHNICAL STUDY

The geological and tectonic setting of the project area has been conceived based on the available geological literature (GSP 1999) and supplemented by latest geological, structural and stratigraphic information recorded during field studies. At the important project components, engineering geological mapping was undertaken on base maps prepared by superimposing topographic data on free available satellite images. Geological contacts among soil and rock units were marked on the base maps together with the recording of information about the geological structures. The field geological maps have been finalized in GIS and/ or AutoCAD environment which have been used for onward geotechnical evaluation and design activities. Similarly, at important project locations, subsurface geological sections have been prepared based on the surface geological information and recorded structural geological features.

It has been assessed in the field that the reservoir area is situated in overburden materials and it is likely that slope wash material present along the right abutment may not be very good material for water tightness, and may require some treatment. However, along left abutment rock comprising granite/ granodiorite/ amphibolite is present that may be good material for water tightness. Generally, the slopes in the reservoir area are gentle and both in overburden and rock. The slopes may not require substantial treatment for the stability. However, minor treatment such as provision of rip rap (stone pitching) may help to stabilize the slopes at the problematic locations, if encountered any during excavation.

The Panjkora River in the weir site is flowing from northeast to southwest and the width of river bed at the weir axis is about 70m, whereas the valley is about 200m wide. The weir site area is occupied by both the rock outcrop at the left abutment and the overburden material (slope wash and old river bed material) at the right abutment. The river bed material is dominantly of cobbles and boulders of igneous and metamorphic origin with sandy matrix. The river bed material is loose at the top and relative density increases depth wise and appears to be good material for foundation of weir structure. However, it is pervious and will have seepage underneath the weir foundation. The left abutment comprises of rock slope which is nearly vertical slope consisting of banded amphibolite and granite/ granodiorite. The right abutment comprises unconsolidated materials of slope wash and ancient river bed material with vegetation. This material comprises gravels to boulders and occasional rock blocks embedded in sandy silty matrix.

Both the intake of the weir and channel will be on the unconsolidated slope wash material lying on the underlying valley floor of the river bed material. This material comprises mostly gravels and cobbles with occasional boulders embedded in sandy silty matrix. The foundation material appears to be good enough to bear the load of intake structure and box channel. Towards the intake of free flow tunnel, rock is likely to be at shallow depth (>10m) that gradually comes to surface near the intake of free flow tunnel. The material appears to be medium dense to dense and may be very dense at greater depth where river bed material is present.

The rock exposed along the free flow tunnel alignment is mainly granite/ granodiorite. However, thin exposures of amphibolite are also present near tunnel intake and outlets. The interpreted geological information shows that the following rock types shall be expected along the tunnel route.

- Banded Amphibolite: This rock unit is present at the intake and outlet locations of free flow tunnel with some intrusions of granite/ granodiorite along the tunnel route. The rock is blocky to very blocky having foliation trend in northeast-southwest direction dipping both in northwest and southeast directions at moderate to very steep angles. As per discontinuity surveys, the discontinuities are generally extremely close to wide spaced, very low to very high persistent with very tight to very wide apertures and generally smooth to rough having planar to undulating surfaces. As per surface condition and geotechnical investigation in the project area, water table is not likely to be present above the proposed stretch of the tunnel in this rock unit through the discontinuities intersecting the tunnel alignment. This rock unit is present from tunnel intake to 0+450m chainage of the tunnel alignment, where it makes its contact with the granite/ granodiorite of Shandur Granodiorite. From tunnel chainage 1+640m to onward, this rock unit reappears till the outlet of the free flow tunnel. This rock unit is present about 25% of the total tunnel length of free flow tunnel.

- Granodiorite/ Granite: This rock unit is present from 0+450m chainage along the tunnel route and extends up to the 1+640m tunnel chainage. This rock is blocky to very blocky having foliation trend in northeast-southwest direction dipping northwest at moderate to steep angles. As per discontinuity surveys, the discontinuities are extremely close to moderately spaced, very low to very high persistent with very tight to very wide apertures and generally have rough and undulating rock surfaces. The rock quality as per ISRM guidelines for intact rock classification is to be medium strong to strong. As per surface condition and geotechnical investigation in the project area, water table is not likely to be present above the proposed stretch of the tunnel in this rock unit through the discontinuities intersecting the tunnel alignment. This rock makes about 75% of the total rock mass along the free flow tunnel.

At the proposed bridge location near free flow tunnel, the valley floor is occupied by the unconsolidated deposits, slope wash materials making valley slopes and river bed alluvium making valley bed. The rock is present on higher elevations and is assessed to be at deeper depth (23m) in the valley center near proposed bridge location. The foundation of bridge is likely to be placed at the overburden material in form of open foundations or deep foundation i.e. pile foundations are to be provided to support the bridge structure. End bearing pile foundations may be preferred to transfer the bridge load on the underlying rock at the depth of 23 m.

Initial stretch of the box channel from free flow tunnel outlet to desander and desander to forebay will be mostly lying on the rock; banded amphibolite which is mostly exposed or under thin cover (2-3m) of slope wash material or vegetation. The overlying unconsolidated mass is mainly comprised of angular to subrounded gravels, cobbles and boulders embedded in fine silty sandy matrix.

The locations of the investigation points at sandtrap indicates the rock as massive to blocky and slightly weathered. The rock is fair for the foundation of sand trap. The rock will, however, require blasting for the placement of desander and the connecting box channel segments.

At the inlet pond location, the rock comprising amphibolite is present inform of mostly rock outcrop or under thin cover of overburden. The rock quality, as per ISRM guidelines for intact rock classification, is interpreted to be medium strong to strong.

At power tunnel intake, the rock quality, as per ISRM guidelines for intact rock classification, is interpreted to be medium strong to strong. The interpreted geological information shows that the following rock types shall be expected along the tunnel route.

- Dominantly Amphibolite with subordinate intrusions of granite/ granodiorite in places is present along the tunnel corridor. The surface geology has shown presence of slope wash terraces along the alignment of headrace tunnel; however, those are surficial deposits and rock is present along the tunnel alignment. This rock is massive to blocky generally and very blocky in places having foliation trend in northeast-southwest direction dipping mainly in northwest at moderate to steep angles. As per discontinuity surveys, the discontinuities are generally extremely close to moderately spaced, very low to very high persistent with tight to wide apertures and generally smooth to rough surfaces having planar to undulating/ stepped surface profiles. The rock quality as per ISRM's guidelines is interpreted from medium strong to strong generally. However, couple of discontinuity surveys (DS-13 & DS-16) along the left bank of Panjkora River indicated rock as extremely to highly weathered showing friable behavior. This type of rock was also indicated near discontinuity survey DS-11 location along the tunnel, because on this rock the conducting discontinuity survey was not possible. This type of rock is likely to intersect the tunnel alignment having cumulative thickness of 300-500m where intact rock strength may be very poor to poor as per ISRM's strength classification of intact rock. From all the discontinuity surveys, it is found that rock is more fractured and very blocky towards the powerhouse site while weir site rock is massive to blocky. Massive to blocky rock makes about 50% rock; very blocky makes about 33% rock and friable rock with shearing may have cumulative length of about 7% along the headrace tunnel.

- Granodiorite/ Granite: This rock unit is present from chainage 9+140m to 9+750 and from 10+280 to 10+315 along the tunnel route. These are massive bodies intruded in the country rock of banded amphibolite. This rock is very blocky having foliation trend in northeast-southwest direction dipping northwest and southeast owing to presence of consecutive syncline and anticline near powerhouse site. As per discontinuity surveys, the discontinuities are extremely close to widely spaced, low to very high persistent with tight to wide apertures and generally have rough and undulating rock surfaces. Localized shearing along the foliation are likely in this rock. Also, possibility of some limited reaches of extremely to highly weathered and friable rock is likely exhibiting very poor to poor intact rock strength. Intact strength of the rest of the rock mass is to be medium strong to strong as per ISRM guidelines for intact rock classification. This rock makes about 10% of the total rock mass along the tunnel.

At the adit tunnel, the outcome of the investigations indicates that the placement of the adit portal in rock will require about 30m cut toward the hill side that will involve mostly rock cutting. The height of the rock cut could be of the order of ~45m. As a guideline, the rock cut can be dressed at slope 1H:3-4V with the provision of about 4m wide bench after 10m bench height. The overburden slope can be stabilized at an angle of 1H:1V.

Along the cut and cover section, slope wash material comprising gravel, cobble and occasional boulders embedded in fine matrix is present on both banks of the slopes. The rock exposed at higher elevation of cut and cover section is comprised mainly of amphibolite. Generally, the rock mass quality determined by the discontinuity and borehole fall in fair category using RMR classification scheme which is reasonable to have the tunnel portals and providing a good foundation material for cut and cover section. To place the portals, the slope wash material will have to be removed and rock cutting will be required in amphibolite. At surge shaft outlet portal area, the rock is generally under thin cover of overburden and/ or vegetation with spot exposures. The slope cut for outlet portal may require adequate design of support for stabilization especially in slope wash material.

The subsurface conditions interpreted based on the geological mapping and conducted investigations indicate that the whole alignment will be in the rock overlain by the thin cover of overburden. The interpreted rock profile shows that the foundation of the penstock will be in rock which is a reasonably good material to provide the support to the penstock.

The surface powerhouse shall be placed mostly in rock and subordinately in overburden material on the right bank of Panjkora River at the slope toe. According to geological map, most of the valley floor is occupied by the unconsolidated deposits, slope wash materials making valley slopes and river bed alluvium at the valley floor. Generally, the unconsolidated deposits are heterogeneous and comprise angular to subangular rock fractions in silty sandy matrix in slope wash material while rounded to subrounded embedded in sandy matrix in river bed material. The slope wash material is underlain by old river bed material at the valley floor, which is medium dense to very dense as per depth variation. The rock comprising granite/ granodiorite is present along the lower stretch of penstock and at the proposed site of powerhouse.

At the proposed bridge location near powerhouse, the right abutment and valley floor is occupied by the unconsolidated deposits, and river bed alluvium making valley bed. The rock is present on higher elevations behind the right abutment slopes and at a depth of 25m at right abutment along the bridge axis. However, along left bank of river, the rock comprising granite / granodiorite is present after 2m fill material. The rock is sound for the foundation of bridge as found by the laboratory testing conducted on rock core samples to be medium strong to strong. The deep foundations comprising skin friction -end bearing piles shall be adopted to support the bridge at the right abutment and in the valley. However, the left abutment can be supported by the open foundation to be placed on granite rock after removing top weathered layer.

For aceess roads to the surge shaft and tunnel portals, the geology and rock conditions explored by the discontinuity surveys show a fair quality of rock having strike almost parallel slope face and moderately steep to steep dip into the face and towards the valley. The orientation of the foliation leads towards favorable conditions and no major slope failures are anticipated. However, minor rock falls as a result of intersection of foliation and other joint sets may induce localized slips and failures that need to be addressed. Most of the road's alignment will pass in the slope wash material that has reasonable strength in terms of CBR to act as subgrade material. However, the cut slopes in overburden material will be stabilized at 1H:1V~1.5V, while banked slopes at an angle of 1H:0.5V~0.75V. The rock cut slopes can be dressed at an angle of 1H:3-4V with the provision of benches of adequate width after definite height interval.

5. SEISMIC HAZARD ASSESSMENT

Seismic Hazard Evaluation of the Artistic-I Hydropower Project has been carried out by studying of the regional geological and tectonic information collected from available literature and maps, compilation of historical and instrumental earthquake data and analysis of the available earthquake record, identification and characterization of potential seismic sources in the project region and evaluation of seismic hazard in accordance with the current practices.

The Artistic-I Hydropower Project is located in the Kohistan Island Arc physiographic province, a seismically active region due to the continuing northward drifting of the Indian Plate and its subduction under the Eurasian Plate. The project region has been subjected to damaging earthquakes in the past. The major faults of the project region include, from north to south, the Main Karakoram Thrust (MKT), Kohistan Fault, Main Mantle Thrust (MMT), Panjal-Khairabad Thrust, Main Boundary Thrust (MBT) and Salt Range Thrust. The general trend of these faults is predominantly east-west with change in trend due to syntaxial bends.

The epicenters of three well-studied earthquakes of magnitude 5.9 or above have been recorded in Kohistan island arc east of the project area (Ambraseys, et al., 1975; Jackson & Yielding, 1983). These earthquakes are:

- Patan earthquake (28 December 1974); magnitude (Mb) 5.9; 90 km south of the site; close to the surface expression of MMT;
- Hamran earthquake (3 September 1972); magnitude (Mb) 6.3; 55 km northeast of the site; within the Kohistan Island Arc; and
- Darel earthquake (12 September 1981); magnitude (Mb) 6.1; 20 km northeast of the site; within the Kohistan Island Arc.

The conclusions and recommendations regarding study of seismotectonic setting of Artistic-I Hydropower Project and the resulting seismic design parameters are as follows:

a) The project is located in the Kohistan Island Arc which is sandwiched between Indian and the Eurasian tectonic plates and very active seismically.

b) A number of moderate sized earthquakes have been recorded in Kohistan Island Arc during the last 100 years.

c) A number of active faults are present around the project site.

d) The main seismotectonic features considered critical for the seismic hazard for the Project are as follows:

- Main Karakoram Thrust (MKT),
- Kohistan Fault,
- Main Mantle Thrust (MMT), and
- Shandur Fault

e) Both probabilistic and deterministic seismic hazard evaluations were made to determine the expected ground motions at the project site.

f) The recommended horizontal Peak Ground Acceleration (PGA) associated with Operating Basis Earthquake (OBE) for weir structure is 0.22g.

g) The recommended horizontal Peak Ground Acceleration (PGA) associated with Maximum Design Earthquake (MDE) for weir is 0.39g based on probabilistic analysis and 0.32g based on deterministic analysis, as the weir is categorized as Low Hazard Potential Hazard structure.

h) The recommended Design Basis Earthquake (DBE) for powerhouse and critical structures of headrace tunnel is 0.26g.

i) The recommended horizontal Peak Ground Acceleration (PGA) for all other project structures is 0.22g if resting on soil foundation and is 0.19g if placed on rock foundation or within rockmass.

j) Uniform hazard spectra for MDE, OBE and DBE associated ground motions are given for use in the seismic resistant design of the project structures.

k) It is recommended that in-situ shear wave velocity profile of the subsurface material at weir and powerhouse sites may be obtained for authenticating the assumption of V_{s30}.

l) For safety monitoring purpose Strong Motion Accelerographs may be installed at the Weir and Powerhouse sites.

6. PROJECT LAYOUT ALTERNATIVE & DESIGN OPTIMIZATION STUDIES

Layout alternative and design optimization studies have been carried out by the consultants to determine the best layout of the project as well as to optimize the dimensions of the structures belonging to this layout. Since, Artistic-I HPP is a run-off-river type project, water conveyance system between weir and powerhouse can be constructed both at the right or left bank of the river. On the other hand, since the project is at a raw site, alternative locations for weir and powerhouse can be studied according to topographical, environmental, social and in-situ geological conditions as well as to utilize the maximum head potential, considering the rights of other projects which are located upstream of Artistic-I Weir and downstream of Artistic-I HPP. Therefore, the Consultants developed technically possible layout alternatives, studied advantages and disadvantages of them to make comparisons, thus to present the best one to be studied further in detail. Selection of best layout was achieved by taking the same design discharge into account for all layout alternatives.

Following the determination of best layout, the dimensions and capacities of the structures comprised by this layout is optimized. The optimization procedure involves first to assume a range of possible design discharges on the basis on hydrological studies. Special consideration is given to compensation flows and lowest natural flows. Comparative costs and energy benefits were estimated and economic analyses were then conducted for each design discharge within the context of this study. The design discharge which has the annual maximum net benefit (difference of annual benefit and annual cost) was selected as the optimum one among others. As different diameter options for power tunnel, penstock and surge shaft were taken into account together with the design discharge alternatives, the optimization study also resulted in with the best dimensions of those structures. Furthermore, the optimum installed capacity has also been revealed which is the main aim of project sizing.

Four possible layout alternatives have been studied by the consultants. Alternative 2,3 & 4 are considered at the right bank of the river while alternative 1 is considered at the left bank of the river.

The weir site coordinates provided in the LoI are not appropriate due to the low elevation of existing asphalt road N-45 on the left bank as this road was over topped/flooded during 2010 flood at various location including this section of the road. Therefore, consultants identified three alternate project sites for the weir of Right-Side Alternatives which are discussed below. Alternative 2 Weir is identified about 250 m upstream of the weir site given in the letter of intent. Constructing Weir at this site will cause the submergence of few houses due to ponding of water on the upstream. Alternative 3 Weir is located about 705 m upstream of Alternative 2 weir, which will result in need of reconstruction of a mosque on the upstream. Finally, Alternative 4 Weir (W4) has been shifted upstream from its previous location to a new location which is about 2190 m upstream of Alternative 1 & Alternative 2 weir (W2 & W1). This alternative provides maximum head and hence maximum annual energy and revenue compared to all other downstream alternatives. This may involve resettlement of a few houses but that can be compensated.

The powerhouse location as provided in LoI was not suitable for left bank alternative due to presence of habitation nearby, which is therefore shifted downstream to a relatively suitable location. Furthermore, the tail water canal will cross the existing asphalt road and therefore bridge over the tailrace would be required. The powerhouse (Alternative 2, 3, 4) is seated in the relatively plan area to avoid excessive cutting and to minimize possible cost of excavation and having slightly milder environmental impacts. Power house level shall be fixed and optimized for different discharge levels in the river and tailrace level to get maximum energy from the design discharge. A surface power house is proposed for the Artistic-I Hydropower project. Switch yard and colony/residence for operational staff is proposed at a location in the vicinity of power house.

The Consultants after detailed discussions, analysis and comparison of all project layout alternatives, come to the conclusion that right bank Alternative 4 would be more practical and beneficial from construction, geological and geotechnical, power and energy production aspects. Alternative 4 would offer maximum power potential, annual energy and consequently annual revenue while having least diversion and construction problems.

For optimization of the selected layout alternative, the flow duration curve at Artistic-I Weir site has been revieved for seven discharges, namely Q = 80, 85, 90, 95, 100, 105 and 110 cumecs, which corresponds to 28% - 38% exceedance of flow duration, were selected to be included in the optimization study.

7 different design discharges together with 3 different power tunnel diameters and 3 different penstock diameters decided for each discharge; result in 7 x 3 x 3 = **63 alternatives** that are included in the optimization study for Artistic-I HPP.

Table 2: Best Options for Design Discharge Alternatives

Q_d (m^3/s)	Diameter of Free Flow Tunnel (m)	Diameter of Power Tunnel (m)	Diameter of Penstock (m)	Diameter of Surge Shaft (m)	Box Channel Width (m)	Box Channel Height (m)	Installed Capacity (MWe)	Average Energy Generation (GWh/year)	Marginal Net Benefit (PKR/year)
80	6.50	5.95	4.50	14.00	5.45	4.60	49.788	264.386	722,766,918
85	6.65	6.10	4.65	14.50	5.55	4.70	52.974	275.064	740,170,573
90	6.80	6.30	4.80	14.80	5.70	4.80	56.391	285.276	744,728,828
95	6.95	6.45	4.90	15.10	5.80	4.90	59.610	294.440	756,968,904
100	7.10	6.65	5.05	15.50	5.90	5.00	63.071	304.567	757,559,514
105	7.20	6.80	4.95	15.80	6.00	5.10	66.245	311.310	746,922,244
110	7.35	6.95	5.30	16.10	6.10	5.20	69.637	318.837	651,943,498

As can be seen from **Table 2**, by this detailed study, the design discharge, diameters of free flow tunnel, power tunnel, penstock and surge shaft, dimensions of box channel and consequently the installed capacity of the power plant, have been optimized at once.

7. DESIGN CONSIDERATIONS AND POWER POTENTIAL

From upstream to downstream, the Artistic-I project comprises of hydraulic structures such as weir, intake, box channels, free flow tunnel, sand trap, inlet pond, pressurized tunnel, surge tank, valve chamber, penstock and powerhouse. Following the determination of best layout, the dimensions and capacities of the structures comprised by this layout is optimized. The design discharge which has the annual maximum net benefit was selected as the optimum one among others. As different diameter options for power tunnel, penstock and surge shaft were taken into account together with the design discharge alternatives, the optimization study also resulted in with the best dimensions of those structures. Furthermore, the optimum installed capacity has also been revealed which is the main aim of project sizing.

The proposed characteristics as per optimization study and further feasibility studies for final dimensioning are as follows:

Box Channel Type-1:

Type of cross section	: Rectangular. Reinforced concrete
Flow regime	: Open channel, subcritical
Capacity	: 110 m^3/s
Bottom Slope	: 0.0004
Manning's "n" for concrete	: 0.014
Width	: 5.90 m
Water depth at full capacity	: 4.45 m
Freeboard	: 0.55 m
Height	: 5.00 m
Velocity of water at full capacity	: 2.09 m/s
Length of channel	: 617 m

Free Flow Tunnel:

Type of internal cross section	: D-shaped, reinforced concrete
Type of excavation cross section	: D-shaped
Diameter of internal cross section	: 7.10 m
Diameter of excavation cross section	: 8.20 m
Bottom slope of tunnel	: 0.0005
Length of tunnel	: 1,583 m

Power Tunnel:

Type of internal cross section	: Horseshoe, reinforced concrete
Type of excavation cross section	: D-shaped
Diameter of internal cross section	: 6.65 m
Diameter of excavation cross section	: 7.95 m
Bottom slope of tunnel (between tunnel inlet and Kotkay Khwar)	: 0.001
Bottom slope of tunnel (between Kotkay Khwar and valve chamber)	: 0.009

Length of tunnel	: 7,460 m
Surge Tank:	
Type of internal cross section	: Circular, reinforced concrete
Type of excavation cross section	: Circular
Diameter of internal cross section	: 17.30 m
Diameter of excavation cross section	: 20.20 m
Height of surge shaft	: 73 m (above tunnel crown)
Penstock:	
Length (until trifurcation)	: 50.50 m
Diameter	: 5.05 m
Pipe wall thickness	: 10 mm ~ 15 mm
After Valve Chamber	: Trifurcation
Diameter of Penstock (To Large Units)	: 3.1 m
Length of Penstock (Large Units)	: 64.40 m
Diameter of Penstock (To Small Unit)	: 2.5 m
Length of Penstock (To Small Unit)	: 64.40 m
Power House:	
Tailwater level	: 990.00 m
Gross head from Artistic-I Weir	: 81.00 m
Gross head from inlet pond	: 79.33 m
Net head (at design discharge)	: 70.23 m
Turbines	: 3 Nos. (2 Big + 1 Small)
Design discharge	: 100 m^3/s (2 x 37.50 + 1 x 25.00) m^3/s
Type of turbines	: Vertical Francis
Assumed rated efficiencies	: 0.94 x 0.98 x 0.99 (Trbn., Gen., Tr.)
Installed Capacity	: 62.606 MWe
Average Annual Energy Generation	: 306.570 GWh

The height of the structure is limited by the restriction of provision of maximum tail water level of Sharmai HPP upstream. A gated weir structure was designed for passing 1 in 100-year return flood discharge. To remove sediments and help spilling the flood discharge, two under sluices were designed between spillway and intake structure at right bank. The height of broad crested weir and radial gates mounted on this weir was selected as 1.50 m and 8.50 m, respectively. Thus, NWL of the project becomes 1,071.00 masl. The flood discharges at weir site with respect to different return periods were taken from Hydrology and Sedimentation Report, and given below:

Q_2 = 578 m^3/s Q_{10} = 1,586 m^3/s Q_{50} = 2,688 m^3/s

Q_{100} = 3,208 m^3/s Q_{500} = 4,445 m^3/s Q_{1000} = 5,011 m^3/s

The intake structure is envisaged at the right bank. The intake structure was located at right bank. The deflection angle between the longitudinal axes of intake and weir was selected as 50º.

Box Channel Type-1 connects the transition structure (just downstream of intake) to free flow tunnel and then transition structure (just downstream of free flow tunnel) to sand trap. Box Channel Type-1 has width of 5.90 m and height of 5.00 m. The design discharge of box channel type-1 is taken as 110 cumecs.

Free flow tunnel connects two box channels along the conveyance line to sand trap. The dimensions of the free flow tunnel were determined through optimization studies. While design discharge (110 cumecs) is carried by the tunnel, the water depth will be 6.23 m. The freeboard above this depth was taken as 0.87 m, thus the diameter and internal height is 7.10 m.

In order to settle down the suspended sediments in the water, sand trap is designed. Artistic-I HPP will be equipped with Francis turbines. In order to be on the safe side, the minimum particle size to be settled was assumed as 0.3 mm. Also, there will be a further settlement in the inlet pond structure, which has a large pond thus the water velocity reduces to ~0.59 m/s. The structure is placed at the end of the box channel Type-1. The width of each chamber and the bottom slope of the structure were selected as 8 m and 2%, respectively. Continuous flushing will be carried out for the Artistic 1 sand trap. The settled sediment at the bottom ditch of each chamber will accumulate to an inclined collector flushing canal with a bottom slope of 0.02, positioned perpendicular to the ditches in plan view, beneath the end sill of sand trap. The flushing canal will be controlled by a sliding gate, equipped at the left bank wall of the end sill block. An inclined 1.10 m diameter pipe will flush the settled sediment to Panjkora River. Hydraulic calculation shows that total flushing discharge is 10.2 cumecs.

Box channel Type-2 connects the sand trap to inlet pond. The design discharge of box channel type-2 is taken as 100 cumecs. Box channel type-2 has width of 5.50 m and height of 5.00 m.

The NWL of the inlet pond when total design discharge is passing through the upstream free flow conveyance system was taken as 1,069.33 m. To evacuate the flows coming from box channel in case of emergency shut downs at powerhouse, a side spillway of 5 m width is provided at the left bank of inlet pond.

Power tunnel outer (excavation) cross section is decided to be designed as “D-shaped” whereas the inner (concrete lining) cross section as “horseshoe” for the ease of construction and to save economy of the project. The diameter of power tunnel is selected as 6.65 m. The last 85 m length of tunnel is decided to be lined both with concrete and steel with circular cross section. The one stage diversion of Kotkay Khwar at the cut & cover segment of headrace tunnel will be maintained by an inverted syphon consists of two circular steel pipes with 2.20 m diameter.

A surge tank was designed with 17.30 m diameter and 73 m height above tunnel crown.

Following the tunnel exit, the circular steel lining is connected to the circular cross section of penstock by means of a steel transition pipe which has 9.30 m length. At the end of transition, a valve chamber is planned. The chamber will be equipped with a 5.05 m dimeter butterfly valve. The movable steel roof of the structure will allow for the maintenance of the valve, when required.

The alignment of penstock was determined according to the powerhouse location and the topography. The diameter of the penstock was selected as 5.05 m as per the optimization studies. Since the design discharge is 100 cumecs, the design velocity of penstock is 4.99 m/s. After trifurcation point three branch pipes (2 to large units and 1 to small unit) proceed to power plant.

Powerhouse is envisaged to be equipped with 3 vertical francis turbines. Two big turbines units will have design discharge of 37.5 cumecs while one small turbine unit will have design discharge of 25 cumecs.

The rated net heads, when all units are in operation, are accepted as 69.91 m for unit-1, 70.23 m for unit-2 and 69.68 m for unit-3. If the total design discharge 100 m^3/s is reached, then all three units are operated at full capacity.

8. MECHANICAL EQUIPMENT STUDIES

For the optimal use of the available hydropower potential, study was made of the hydrological data and other related parameters, the output of which was used to establish the type of turbine and number of units, for optimum output and trouble-free operation of the project.

The selection of turbine, along with its associated parts, and miscellaneous mechanical auxiliary systems, has been made for its optimum output with minimum losses. Two (2) large units of 24.230 MW_m and one (1) small unit 16.068 MW_m capacities (mechanical output of individual turbine at rated head and discharge) will be installed in the powerhouse. The generating units have been designed to work at 10% overload mechanically during the maximum flow season without developing any fatigue stresses in any moving part of the machine. It is pertinent to mention here that the installed capacity of the power plant is 62.606 MW_e, which is the maximum electrical output that can be generated when all units are in operation at the same time with their design discharges.

All mechanical equipment of the power plant, different auxiliaries systems, and their operating mechanism, are made at feasibility level of proven design. Emphasis may be laid on reliability, easy operation and maintenance, and procedure for dismantling and assembly of parts of the machine.

The material and design of the underwater parts of the turbines are selected such that it should work without exceeding permissible stresses under rated unit discharges of 2 x 37.50 m^3/s (large units), 25.00 m^3/s (small unit), and net rated heads of 69.910 m (Unit-1), 70.230 m (Unit-2) and 69.697 m (Unit-3-small unit) at runaway speeds (595 rpm for Unit-1, 607 rpm for Unit-2 and 769 rpm for Unit-3) of the machineries.

All the possible parameters are taken into accounts to minimize corrosion and sand abrasion to the possible extent on underwater parts of the turbine.

9. ELECTRICAL EQUIPMENT STUDIES

This section deals with the electrical equipment of Artistic-I Hydropower Project (62.606 MW). The feasibility level design aspects of the project including plant size, power plant equipment, generators, transformers, EHV, HV, MV and LV switchgear, power auxiliaries, batteries, control and monitoring, SCADA and Telecom System, have been developed and presented. The electrical equipment arrangement has been planned and laid out. It is proposed that all electrical equipment shall be designed, tested and supplied according to WAPDA/NTDC standards and specifications. Where WAPDA/NTDC standards and specifications are not available, International Standards such as IEC, BS, VDE, IEEE, ASTM, NFPA, ANSI etc. may be followed. Protective relays, PLC Communication System, Remote Satellite Communication with NPCC Islamabad and SCADA system manufactured and supplied from companies of West European origin which are proven to be reliable and compatible with NTDC/PESCO System are recommended.

- Two 23.5 MW, 0.85 lagging power factor, 50 Hz, 11 kV, vertical shaft, synchronous generators complete with control, monitoring, protection and auxiliary systems
- One 15.6 MW, 0.85 lagging power factor, 50 Hz, 11 kV, vertical shaft, synchronous generator complete with control, monitoring, protection and auxiliary systems
- Three static excitation systems with Automatic Voltage Regulators (AVR)
- Three non-segregated phases 11 kV Busduct (NSPB) systems between generators and neutral cubicles, generators and phase cubicles, phase cubicles and generator step-up transformers
- Three sets of 11 kV Generator Circuit Breakers (GCB) complete with all accessories
- Three sets of generator phase cubicles complete with all accessories
- Three sets of generator neutral earthing cubicle
- Two 25/31 MVA (11/132 kV), 3 Phase, ONAN/ONAF Transformers
- One 16/20 MVA, (11/132 kV) 3 Phase, ONAN/ONAF Transformer
- Two 630 kVA 11/0.4 kV Station Service Transformers
- Four 200 kVA 11/0.4 kV Transformers for Housing Colony (The quantity may vary as per detail design)
- One 315 kVA 11/0.4 kV Transformer for Spillway and Inlet Structures site
- One 125 kVA 11/0.4 kV Transformer for Sand Trap and Forebay Facilities site
- 11 kV (MV) Switchgears
- HV (132 kV) Air Insulated type Switchyard (AIS) and overhead line connection between step-up transformers and AIS

- LV AC auxiliary supply systems for the Powerhouse, AIS, Spillway and Inlet Structures site, Sand Trap and Forebay Facilities site
- Three emergency diesel generating units, one 400 kVA at the Powerhouse, one 315 kVA Generator at Spillway and Inlet Structures site, one 125 kVA Generator at Sand Trap and Forebay Facilities site.
- 110 V DC supply battery with charger and UPS systems for the Powerhouse and AIS.
- 48 V DC supply with charger for AIS, Spillway and Inlet Structures site, Sand Trap and Forebay Facilities site.
- Protection Relays systems for the Powerhouse and Switchyard and auxiliary equipment
- Supervisory Control and Data Acquisition (SCADA) system
- Local Control Systems for the Spillway and Inlet Structures site, the Sand Trap and Forebay Facilities site
- Power and control cable systems
- Earthing and Lightning Protection Systems
- Power and Control cable systems
- Lighting and small power installations
- 11 kV overhead transmission line from public network to the Spillway and Inlet Structures site, Sand Trap and Forebay Facilities site
- Electrical workshop
- Communication and Security systems
- Power Line Carrier Communication (PLCC) system
- Independent metering system

10. LOAD FLOW STUDIES

The possibility of connecting Artistic-I HPP to Munda 132 kV grid station via 40 km double circuit has been investigated in this report. Steady state analysis by load flow study reveals that the proposed scheme is adequate to evacuate the maximum power of 62.606 MW of the plant under normal conditions and no constraints are caused by interconnection of Artistic-I HPP in the 132 kV network of PSCO in the load flow scenarios of summer 2016. The proposed scheme of interconnection has been subjected to Load Flow, Short circuit and Dynamic Stability Analysis and found to be feasible for interconnection of Artistic-I HPP with the PESCO network.

11. ENVIRONMENTAL IMPACT ASSESSMENT

The estimated power potential of Artistic-I Hydropower Project is 62.606 MW which falls in schedule "II" of IEE/EIA Regulations 2000. Thus, the Environmental Impact Assessments (EIA) has been carried out keeping in view the instructions contained in the Khyber Pakhtunkhwa (KP) Environmental Protection Act 2014, IEE/EIA Regulations 2000 and Technical guidelines prepared by Pak EPA for Hydropower projects. These studies have identified alternative actions, mitigation activities, monitoring programme and other necessary aspects related to the social and environmental components of the project. They will be effectively incorporated into the Detailed Design and Implementation Process, which will help controlling environmental and social impacts to an acceptable level.

The proposed project is socio-environmentally friendly and sustainable. People agree with the proposed project but have the following reservations:

The electricity generated locally must be supplied to local population which has very little requirements; rest of the electricity may be utilized according to Government Policy. They agreed to provide their lands and property but needed full justice in entitlement matrix and demanded that compensation rates should be calculated on the existing market rates and payments should be made to the legitimate owners before commencement of project activities. They added that malpractices of all kinds must be checked and controlled by the responsible authorities and the process of estimation and payment should be transparent. Local population must be given preference in employment.

These studies have identified alternative actions, mitigation activities, monitoring programme and other necessary aspects related to the social and environmental components of the project. They will be effectively incorporated into the Detailed Design and Implementation Process, which will help controlling environmental and social impacts to an acceptable level.

12. TRANSPORTATION AND ACCESS ROADS

The Panjkora River is not a navigable river for shipment and the province has no port where large ship can be moored. Therefore, the heavy equipment such as turbines and generators needed for the project will be transported to the project site using inland transportation i.e.

road network or railway track. Karachi or Qasim Ports are expected for the unloading seaport of the heavy equipment such as turbines and generators due to the port facilities and the connection for the road network, etc. National Highway 5 and 45 (N-5 and N-45) to the project site are expected for the transportation route of the heavy equipment. The summary of the inland transportation is as follows.

National highway 5 (N-5) connected from Karachi and Qasim port to Peshawar passes through the western bank of the Indus River via the capital Islamabad and the main cities such as Rawalpindi, Lahore and Hyderabad. It is the main route for the inland transportation of the whole country which has the longest highway having 1,756 km length. The bulk of the commercial and industrial activity is concentrated along the N-5 corridor and 60 % of entire traffic of the country is carried. N-5 has sufficient width and grade to get heavy transportation vehicles through, except the road maintenance partly. At present, N-5 will be utilized for transportation.

National highway 55 (N-55) connected from Hyderabad to Peshawar passes through the eastern bank of the Indus River via Ratodero, Shikarpur, Dera Ismail Khan. N-55 is also available for the inland transportation from Karachi and Qasim Port to Peshawar. However, the road condition is poor compared with N-5. In addition, for the transportation from Gwadar port to Peshawar, the federal government has planed the construction of Motorway 8 (M-8) between Gwadar Port and Ratodero that is connected to N-55, which is 90% completed (FWO). After completion of the construction of M-8, the transportation of the heavy equipment from Gwadar Port would be available to pass through M-8 and N-55 to Peshawar.

From Peshawar to Sahibabad, District Upper Dir, N-45 as shown in Error! Reference source not found. is available for the transportation of the heavy equipment such as turbines and generators. N-45 branches from N-5 in Nowshera located 30 km east from Peshawar and goes through Mardan, Chakdara and Dir along Swat and Panjkora River towards the north.

N-45 leads from Nowshera to Chitral and is the most important traffic line for the transportation of the supplies to Chitral. The road is in good condition which make easy transportation of goods including heavy equipment from Peshawar to Dir (Town near project site).

The roads within the project area are narrow and un-unmetalled. In some places, there are sharp bends and steep grades. These roads will need surfacing and some other necessary improvements also, e.g. widening, improving of radius of curvatures and moderating the steep grades. For the new roads, a platform width of 6 m is designed with a 1 m wide ditch at cut side for water drainage. There is also stabilized material layer that is 20 cm thick designed as the superstructure of the road that helps bearing capacity at soil sections and corrects undulations and irregular surface shapes at rocky sections. The vertical slopes of the new roads are designed to be 10% maximum.

There are five major accesses which must be undertaken:

- Access to Weir Site
- Access to Free Flow Tunnel Exit Portal
- Access to Adit Tunnel
- Access to Kotkay Khwar Cut & Cover Segment
- Access to Power House, Valve Chamber and Surge Tank Sıte

13. CONSTRUCTION PLANNING & COST ESTIMATE

In order to complete the project in the shortest possible time, the construction schedule has been prepared so that the work can be taken up simultaneously on various activities independently at sites. The civil works will be taking about 36 months and erection of electromechanical works will take about 31 months. These works will start by the 4th month and 18th month respectively of the construction period. Accordingly, the first unit will be available for wet testing and commissioning at the end of 40th month of the beginning of 2nd year as per construction schedule.

It is anticipated that, the construction of the entire project will be completed in about 48 months period. The sequence, in which the construction of various components of the project will be taken up, has been shown in Figure-13.1(Annexure 13B) at the end of chapter–13.

The construction cost estimate of the Artistic-I Hydropower Project has been estimated and presented in this section. The total project construction cost of civil works has been estimated based on rates from recently completed hydropower projects in Khyber Pakhtunkhwa and Market Rate System (MRS 2020) while accommodating dolar disparity.

In the case of cost of E&M equipment, due considerations have been given to the rates from on-going similar projects, engineering judgment to review the prevailing local market rates of different items of works and Current International market trends. Equipment which can be manufactured in Pakistan has also been priced accordingly.

The summary of cost estimate of the Artistic-I HPP is presented in **Table 3**.

Table 3: Summary of Cost Estimate of the Artistic-I HPP

ARTISTIC-1 HYDROPOWER PROJECT						
SUMMARY OF COST ESTIMATE						
S. No.	Description	Local Currency (PKR)	Foreign Currency, (US$ = 160 PKR as on May 15, 2020)		Total Cost of Each Item (US$)	Total Cost of Each Item (PKR)
		Civil Works (PKR)	Hydraulic Steel (HS) Works (US$)	Electro-mechanical (E&M) (US$)		
1	Preliminary Works	330,620,400			2,066,378	330,620,400
2	Diversion Works	299,818,041			1,873,863	299,818,041
3	Weir	1,775,058,813	4,278,673		15,372,790	2,459,646,468
4	Fish Ladder	18,559,360			115,996	18,559,360
5	Intake	689,015,923	1,871,337		6,177,686	988,429,783
6	Box Channel (0+000 - 0+173)	373,479,764	117,593		2,451,842	392,294,642
7	Transition from Box Channel to Free Flow Tunnel (0+173 - 0+203)	51,504,956			321,906	51,504,956
8	Free Flow Tunnel	1,887,952,242			11,799,702	1,887,952,242
9	Transition from Free Flow Tunnel to Box Channel (1+786 - 1+840)	153,420,372			958,877	153,420,372
10	Box Channel from Free Flow Tunnel to Sandtrap (1+840 - 2+281)	584,179,874			3,651,124	584,179,874
11	Sandtrap	1,575,950,885	1,015,540		10,865,233	1,738,437,210
12	Box Channel from Sandtrap to Inlet Pond (2+466 - 2+711)	278,484,701			1,740,529	278,484,701
13	Inlet Pond	844,640,013	923,957		6,202,957	992,473,093
14	Power Tunnel	10,091,739,895			63,073,374	10,091,739,895
15	Kotkay Khwar	332,048,638			2,075,304	332,048,638
16	Surge Shaft	681,047,522			4,256,547	681,047,522
17	Valve Chamber	164,395,763	48,500		1,075,974	172,155,763
18	Penstock	243,595,724	2,419,995		3,942,468	630,794,898
19	Powerhouse and Tailrace	705,050,976	250,592	25,555,274	30,212,435	4,833,989,539
20	Access Roads and Bridges	559,410,041			3,496,313	559,410,041
21	Weir for Tablighi Markaz	16,703,036			104,394	16,703,036
22	Dumping Site Protection	505,740,602			3,160,879	505,740,602
	Sub total	**22,162,417,539**	**10,926,186**	**25,555,274**	**174,996,569**	**27,999,451,075**

		(US$)	(PKR)
A	Total Civil Works Cost	138,515,110	22,162,417,539
B	Total HS and E&M Works Cost	36,481,460	5,837,033,536
C	**Total Works Cost (A+B)**	**174,996,569**	**27,999,451,075**
D	Total Contingencies @ 3% on C	5,249,897	839,983,532
E	Transportation and Erection Charges of E&M Equipment @ 3% of B	1,094,444	175,111,006
F	**Total EPC Cost (C+D+E)**	**181,340,910**	**29,014,545,613**
G	Engineering Supervision of Civil and E&M Works @ 3.25% of F	5,893,580	942,972,732
H	Project Development Cost @ 3% of F	5,440,227	870,436,368
J	Environment & Resettlement Costs	10,658,093	1,705,294,847
K	Lenders Fees	3,372,574	539,611,840
L	Insurance during Construction @ 1.5% of F	2,720,114	435,218,184
M	Legal Costs @ 1.37% of F	2,489,340	398,294,400
N	Custom Duty @ 6.15% on E&M equipment	2,243,610	358,977,562
O	**Total Non EPC Cost (G+H+J+K+L+M+N)**	**32,817,537**	**5,250,805,934**
	Project Base Cost	**214,158,447**	**34,265,351,548**
P	Interest during Construction (IDC)	22,682,627	3,629,220,320
Q	**Total Project Cost (F+G+H+J+K+L+M+N+P)**	**236,841,074**	**37,894,571,868**

14. ECONOMIC & FINANCIAL ANALYSIS

In this chapter, four important aspects pertinent to the Project are discussed in detail. In first section the power market of the country, current situation of the installed generation capacity & actual generation, existing energy mix, key players of the power market and issues being encountered by the sector are discussed in detail. Government strategy and plans to meet the expected future demand and resolve the issues of the sector are also elaborated concisely.

In second part capital and operating costs are elaborated with consequent levelized tariff of the Project. Proposed capital structure and financing terms are explained and based on these inputs, financial statements for the 30 years Concession Period of the Project were prepared to calculate the key performance indicators. Key ratios of the Project are calculated keeping in view the profitability, liquidity, and solvency facets of the Project. Sensitivity analysis has been performed on key variables of the Project to demonstrate the impact of favourable and unfavourable adaptations in these variables.

In third part economic analysis of the Project is conducted using multi factor criteria i.e. need analysis of the Project, rationale for investment, least cost addition to existing power system and EIRR of the Project. Net benefit to power purchaser has been calculated in comparison to alternate thermal power project both on constant fuel prices and with inflation impacts. Key indicators like NPV, EIRR of the benefits and B/C ratios are calculated to quantify the advantages of the Project.

In fourth part, Project risks including commercial, political, environmental, and other risks during construction and operations phase have been discussed and mitigation measures available and proposed are discussed in detail.

Based on the results of these analysis, financial and economic model have exhibited optimistic conclusions for the development of the Project.

CHAPTER

1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Electrical energy produced from the water resources is a green power as it is non-polluting and renewable in nature. Hydropower development is necessary for countries like Pakistan, where the peaking shortages, both seasonal and daily in power generation are very high, which can only be met with hydropower projects developed for diurnal peaking in a run-of-the river or reservoir scheme.

The total installed capacity of the hydropower stations in the country is about 6700 MW, out of which 3850 MW is in Khyber Pakhtunkhwa Province, 1699 MW in Punjab, 1039 MW in Azad Jammu & Kashmir (AJK) and 117 MW in the Gilgit Baltistan.

Khyber Pakhtunkhwa has an estimated power potential of generating nearly 30,000 MW. The need for development of these immense hydropower potential in the province cannot be over-emphasized. While most of the hydro power projects under development are in public sector, the provincial government has embarked on a multi-pronged strategy for encouraging investment through Public, Private and Public Private Partnership sectors.

In view of the above, the Government of KP has decided to announce a new hydro power policy which offers enhanced incentives and simplified processing mechanism for setting up of power generation plants to bridge the demand supply gap in the minimum time through generation of affordable electricity. This Hydro Power Policy 2016 offers profitable business opportunity, modern engineering and technical processes, lower costs of doing business so that local and international investors may fully participate as partners in the development of hydro power projects.

Hydropower potential in Khyber Pakhtunkhwa (KP) Provence especially in northern areas are very high and Pakhtunkhwa Energy Development Organization (PEDO) has been working on this dimension of development for the last three decades to achieve the self-sufficiency in the power sector, the organization is also encouraging public-private partnership and private investors. This effort has gained momentum in recent years. The present study is also an outcome of this effort of the PEDO.

1.2 CONSULTANCY SERVICES

Raw hydropower sites identified by Pakhtunkhwa Energy Development Organization (PEDO) in Khyber Pakhtunkhwa Province need to be explored in detail. In this regard, PEDO under Government of Pakistan (GOP) policy, is encouraging the private investors, to develop infrastructure and hydropower projects in the province.

In view of the above, PEDO has entered into an agreement with M/s Artistic Milliners (Pvt) Ltd, Karachi to develop Artistic-I HPP Raw Site at Panjkora River, Sahibabad in District Upper Dir of northern part of Khyber Pakhtunkhwa Province, Pakistan.

M/s Artistic Milliners (Pvt) Ltd., Karachi has entered into an agreement with JV of M/s BAK Consulting Engineers, Peshawar and M/s DOLSAR Engineering Inc. Co. Turkey to provide consultancy services for carrying out Feasibility Study of Artistic-I HPP.

1.3 PREVIOUS STUDY

The Artistic-I Hydropower Project site is a raw site and therefore, no previous reports / data exist at present. However, informations were obtained from previous studies of projects done in areas located adjacent or at some distance from this raw site from the concerned departments i.e. PEDO, WAPDA etc. to be helpful for this study.

The data regarding the site have been collected and reviewed by a team of professionals and experts for its practicability and implementation and the requirement of topographic surveys and other field investigations required were determined.

Efforts has been initiated to collect reports/ literature regarding regional geological and tectonic maps and other reports on seismological aspects prepared by Geological Survey of Pakistan (GSP) and other relevant publications by the Department of Geology, University of Peshawar, Surface Water Hydrology Project WAPDA etc. The Consultants have also collected information and data from various departments relating to environmental and social parameters of the project areas.

1.4 PROJECT ACCESSIBILITY AND LOCATION

Artistic Hydro I (Pvt) Ltd. carried out the feasibility study of the 62.606 megawatt (MW) Artistic I Hydropower Project which is a run-of-river project and will be constructed on Panjkora river in district Upper Dir of Northern areas of Khyber Pakhtunkhwa province. The project proposed weir site is located near Darora village and about 6.7 km upstream of Sahibabad village. The proposed powerhouse of the project is located about 3.5 km downstream of Sahibabad village. Both weir and power house sites are easily accessible through N-45 (Chakdara-Dir) Asphalt Road. Coordinates of proposed weir and power house location are given in **Table 1-1.**

Table 1-1: Project Location Details

Location	Northing	Easting	River Bed Elevation
Weir / Intake	35°5'52.77"	71°59'0.08"	1061.00 masl
Power House	35°1'28.32"	72°0'40.77"	986.00 masl

The location of the Artistic-I Hydropower Project is shown in **Figure 1-1.**

Figure 1-1 Project Location Map

1.5 PROJECT DESCRIPTION

Artistic I Hydropower Project (62.606 MW) is a run-of-river project and will be constructed on Panjkora River in district Upper Dir of Northern areas of Khyber Pakhtunkhwa province. From upstream to downstream it comprises of the following structures;

- Weir, Undersluice and Intake
- Sandtrap
- Box Channel
- Free Flow Tunnel
- Inlet Pond
- Power Tunnel
- Adit Tunnel
- Surge Tank
- Valve Chamber
- Penstock
- Powerhouse
- Tailrace Canal
- Switchyard and Transmission Line
- Residential Colony
- Access Roads and Bridges
- Protection Works

The installed capacity at design discharge is estimated as 62.606 MW. The average annual energy generation of the project is estimated as 306.570 GWh.

1.6 PRESENT FEASIBILITY REPORT

Different Studies have been performed which are essential for the completion of Detailed Feasibility Report and are given below;

i.) Topographic survey of the whole project area with emphasis on details of the different project components such as access roads, main weir, box channel, sandtrap, free flow tunnel, headrace tunnel, tunnel portals, surge tank, penstock and powerhouse has been carried out. Important features of the site such as existing roads electric and telephone poles, houses, water courses, cultivated land and tress etc. were marked. The density of the observing points was considered for preparing a contour interval of 1 m.

ii.) Hydrological studies have been performed to calculate the design flood and optimization of discharge for Artistic-I Hydropower Project. At the project location, instantaneous flow data or precipitation data is not available for 30 years, therefore, flows were generated from the data available on the records of Surface Water Hydrology (SWHP), WAPDA for 55 years (1961 to 2015) of Swat River at Chakdara.

iii.) Historic suspended sediment and discharge observations are used to develop a sediment rating curve for the estimation of annual sediment inflow to the Artistic-I HPP weir site. In addition, regional analysis was also employed for comparison of sediment load estimated using sediment rating curve.

iv.) Geological and geotechnical investigations along with the engineering geological mapping of the project area with performance of discontinuity surveys for rock mass classification and characterization has been performed to develop geological / geotechnical models which are used for evaluation and design activities.

v.) Seismic Hazard Evaluation of the Artistic-I Hydropower Project has been carried out by studying of the regional geological and tectonic information collected from available literature and maps, compilation of historical and instrumental earthquake data and analysis of the available earthquake record, identification and characterization of potential seismic sources in the project region and evaluation of seismic hazard in accordance with the current practices.

vi.) Different possible layout alternatives have been studied by the consultants. The advantages and disadvantages of all the layout alternatives were compared in order to select the best alternative for further studies. The comparative costs and energy benefits were estimated and economic analyses were then conducted for different design discharges. The design discharge which has the annual maximum net benefit (difference of annual benefit and annual cost) was selected as the optimum one among others.

vii.) Mechanical equipment study has been performed based on the hydrological data and other related parameters, to establish the type of turbine and number of units, for optimum output and trouble-free operation of the project. The selection of turbine, along with its associated parts, and miscellaneous mechanical auxiliary systems, has been made for its optimum output with minimum losses. Two (2) units of 23.508 MW and One (1) unit 15.589 MW capacities (electrical output of turbine-generator-transformer at rated head and discharge) will be installed in the powerhouse.

viii.) The electrical equipment study has been performed for Artistic-I HPP based on a variety of factors, including economic, technical, environmental and operational consideration. The feasibility level design aspects of the project including plant size, power plant equipment, generators, transformers, EHV, HV, MV and LV switchgear, power auxiliaries, batteries, control and monitoring, SCADA and Telecom System, have been developed and presented.

ix.) Load flow study has been carried out considering switchyards and grid stations in nearby area. The study revealed that the possible option is to connect to the 132 kV grid proposed by PESCO at Munda. Artistic-I can be connected to Munda with a 40 km double circuit.

x.) The estimated power potential of Artistic-I Hydropower Project is 62.606 MW which falls in schedule "II" of IEE/EIA Regulations 2000. Thus, the Environmental Impact Assessments (EIA) has been carried out keeping in view the instructions contained in the Khyber Pakhtunkhwa (KP) Environmental Protection Act 2014, IEE/EIA Regulations 2000 and Technical guidelines prepared by Pak EPA for Hydropower projects. These studies have identified alternative actions, mitigation activities, monitoring programme and other necessary aspects related to the social and environmental components of the project. They will be effectively incorporated into the Detailed Design and Implementation Process, which will help controlling environmental and social impacts to an acceptable level.

xi.) Cost estimate and economic and financial analysis have been performed for the project in order to assess the project feasibility on the basis of EIRR and FIRR.

CHAPTER

2

POWER MARKET

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 2

POWER MARKET

2.1 COUNTRY PROFILE

Located in South Asia, Pakistan, officially the Islamic Republic of Pakistan (Urdu: Islami Jumhuriyah Pakistan), shares an Eastern border with India (2,912km), a North-Eastern border with the People's Republic of China (523km), a South Western border with Iran (909km) and a Western and Northern edge with Afghanistan (2,530km). The Arabian Sea is Pakistan's southern boundary with 1,064 km of coastline.

The name "Pakistan" means "Land of the Pure" in Sindhi, Urdu and Persian. It was coined in 1933 by Choudhary Rahmat Ali, who published it in the pamphlet "Now or Never". The name was coined from the names of five territories that were proposed as constituents of a separate country for the Muslims of British India. Officially, the nation was founded as the "Dominion of Pakistan" in 1947, and was renamed as the Islamic Republic of Pakistan in 1956.

The country has a total area of 796,096 km² and is nearly four times the size of the United Kingdom. From Gwadar Bay in south-eastern corner, the country extends more than 1,800 km to the Khunjerab Pass on China's border.

2.2 PAKISTAN ENERGY MARKET

2.2.1 INTRODUCTION

Electricity is the basic requirement of life and economy and most vital instrument of socioeconomic development of a country. Electricity has pivotal role in running machinery in factories and industrial units, for lighting our cities and powering our vehicles. Provision of electricity to all sectors of economy is a challenge for the government.

There has been an enormous increase in the demand of electricity as a result of industrial development and population growth, in comparison to enhancement in electricity production. Supply of electricity is, therefore, far less than the demand, resultantly crisis has emerged and load shedding has become a routine of the day.

2.2.2 HISTORY OF POWER DEVELOPMENT IN PAKISTAN

At the time of independence in 1947, Pakistan inherited about 60 MW of power generation capability for a population of 31.5 million, yielding 4.5 units per capita consumption. These were private sector owned power plants. However, the Government of Pakistan in 1952 by acquiring majority shareholding took control of the Karachi Electric Supply Company (KESC) engaged in generation, transmission and distribution of electric energy to the industrial, commercial, agricultural and residential consumers of the metropolitan city of Karachi and its suburbs.

In 1958, Water and Power Development Authority (WAPDA) was created as a semi-autonomous body for the purpose of coordinating and giving a unified direction to the development of in water and power sectors, which were previously being dealt with by the respective electricity and irrigation department of the provinces. In 1959, the generation capacity had increased to 119 MW and by that time the country had entered the phase of development, which required a dependable infrastructure, electricity being its most significant part. The task of power development was undertaken by WAPDA by executing a number of hydel and thermal generation projects, a transmission network and a distribution system, which could sustain the load of the rapid economic development.

After the first five years of its operation by 1964-65, the electricity generation capability rose to 636 MW. The task of accelerating the pace of power development picked up speed and by the year 1970, the generating capability rose from 636 MW to 1331 MW with installation of a number of thermal and hydropower units. In the year 1980 the system capacity touched 3,000 MW which rapidly rose to over 7,000 MW in 1990-91.

The rapid progress witnessed a new life to the social, technical and economic structures of the country. Mechanized agriculture started, industrialization picked up and general living standards improved. Due to fast economic development, the government could not keep momentum of development of power sector due to resource constraint. The government resources were limited and were not able to invest the required amount to power sector as it had responsibility for social sector as well more investment was needed. This resulted in heavy load shedding in 1990s.

2.2.3 INDUCTION OF PRIVATE SECTOR IN POWER GENERATION

In order to give enough impetus to the power sector, the government in 1985 declared the power sector as an industry and consequently power sector also became eligible for getting all the incentives that was available to industrial sector.

This did not prove successful and no private sector came forward for investment. In 1994 the government issued an investor friendly power policy that was very well received by national and international investors and more than the required amount of additional power generation capacity was committed by the government that caused power surplus situation.

The over commitment of additional power generation capacity was based on the presumption that economic growth will keep its momentum. But actually, it did not happen and economic growth slowed down that proved detrimental to the economy as the government had to pay capacity charges to the investors as per power policy and the agreement signed with the investors.

2.2.4 POWER POLICY

In order to eliminate power shortage/load shedding in the minimum possible time, the Government constituted an Energy Task Force in 1993 to devise a consolidated and comprehensive policy for revamping the energy sector. On the recommendations of the Energy Task Force, the Government announced a "Policy Framework and Package of Incentives for Private Sector Power Generation Projects" in March 1994 for a large-scale induction of private sector in power development and the terms for Independent Power Producer (IPPs) were standardized.

Under this policy, the government offered a fix levelized tariff of USD 0.0557/kWh to the prospective investors (USD 0.061/kWh average for 1-10 years) and a number of other incentives to attract foreign investment in the power sector.

The Power Policy 1994 helped in overcoming load shedding in the country. Rather, it resulted in surplus power as the actual load growth was much less than that projected and the projects were contracted beyond requirement. Moreover, the Policy attracted only thermal projects resulting in reversal of the hydro/thermal generation mix.

In order to provide one window facility to new investors in the power sector the Government of Pakistan (GoP) created a new organization, the Private Power and Infrastructure Board (PPIB), to negotiate agreements with sponsors and provide assistance in obtaining necessary government consents through a 'single window'. This power policy resulted in an enthusiastic response from the international investor community. The bulk supply tariff offered to the IPPs became a controversial issue as consumer tariffs had to be increased to meet the substantial financial commitments made for the IPP construction projects.

The 1994 power policy was only for a limited period and in 2002, the government issued a new policy (the 2002 Power Policy), which basically has the same structure and set of incentives as the 1994 policy but is broader in terms of its applicability.

The government's new power policy (2002) encourages solicited and unsolicited proposals for the establishment of new power plants. Unsolicited proposals allow investors to install a power plant at a location of their choice while solicited proposals give the government the opportunity to locate proposed power plants as it desires, generally, close to a load centre. However, the 2002 power policy could not bring same result due to one reason or the other.

2.2.5 Restructuring/ Unbundling of Power Wing of WAPDA

In the past there were two vertically integrated power supply companies operating in Pakistan, i.e. Water and Power Development Authority (WAPDA) and Karachi Electric Supply Corporation (KESC). WAPDA was responsible for supplying electricity to various sectors of the economy across the country apart from the greater metropolis of Karachi which is supplied by the KESC. However, with the passage of time and unprecedented expansion of WAPDA was witnessed thereby losing control of the government which resulted in in-efficiencies and governance issues. Therefore, the government decided to restructure the power wing of WAPDA. Under the restructuring plan all the power generation, transmission and distribution formations were made separate corporate entities leading to privatization. Accordingly, the power wing of WAPDA has been unbundled into ten Distribution and four Generation companies and one Transmission and Dispatch Company known as the National Transmission and Dispatch Company (NTDC).

These fourteen (14) corporate entities are:

→ **Ten (10) Distribution Companies (DISCOs) as under:**

- Lahore Electric Supply Company (LESCO)
- Gujranwala Electric Power Company (GEPCO)
- Faisalabad Electric Supply Company (FESCO)
- Islamabad Electric Supply Company (IESCO)
- Multan Electric Power Company (MEPCO)
- Peshawar Electric Power Company (PESCO)
- Hyderabad Electric Supply Company (HESCO)
- Quetta Electric Supply Company (QESCO)
- Tribal Electric Supply Company (TESCO)
- Sukkar Electric Power Company (SEPCO)

→ **Four (4) Thermal Power Generation Companies (GENCOs)**

- Southern Generation Power Company Limited (GENCO-1) head quarter at Jamshoro district Dadu near Hyderabad Sindh.
- Central Power Generation Company Limited (GENCO-2) head quarter at Guddu district Jacobabad Sindh.

- Northern Power Generation Company Limited (GENCO-3) headquarters at TPS Muzaffargarh district Muzaffargarh Punjab.
- Lakhra Power Generation Company Limited (GENCO-4) Headquarter at WAPDA House Lahore.

→ **One (1) National Transmission & Power Dispatch Company (NTDC).**

These un-bundled companies are being controlled by another newly created company called Pakistan Electric Power Company (PEPCO) working under the Ministry of Water & Power. The water wing of WAPDA was not touched and it remained responsible for controlling dams and hydro generation installed in the country in public and private sector.

The function of NTDC is to control national transmission & grid network and economical dispatch of hydro & thermal power generation by various companies connected through the national grid system. It is also responsible for development, operation and maintenance of National Grid system of the country (i.e. primary grid system).

2.2.6 Generation Capacity and Energy Mix

Oil, Gas, Hydropower and Nuclear Power are the sources of energy generation in Pakistan. While Hydro and Nuclear are used only for electricity generation with reference to energy, Oil and Gas are used to supply other areas also. Although Pakistan has one of the largest coal reserves in the world which remain under-utilized and their share in energy supply is insignificant at the moment.

Production of crude oil per day has increased to 86,533 barrels during 2013-14 from 76,277 barrels per day during the same period last year, showing an increase of 13.5 percent. During the same period the transport sector consumed 48.8% of the petroleum products, followed by power sector (42.7%), domestic (0.5%), industrial (6.1%), other government (1.7%), and agriculture (0.20%). The increase went on the next year (2014-15) to 94,493 barrels per day in the same rate as that of the previous year. The annual production of the crude oil has decreased during year 2015-16 to 31,652,000 barrels as compared to the previous year 2014-15 which was 34,490,000 barrels. While in the year 2016-17 an increased has been observed from 31,652,000 barrels to 32,269,000 barrels annually.

The average production of natural gas per day stood at 4,092 million cubic feet during July to March 2013-14, as compared to 4,126 million cubic feet over the same period last year, showing a decrease of 3.4%. The overall production of gas has decreased to 1,493,508 million cubic feet during July to March 2013-14 as compared to 1,505,841 million cubic feet daily in the same period in 2012-13, showing decrease of 0.8%. The daily production of natural gas has increased in the year 2015-16 as compared to 2014-15 from 4016 million cubic feet (mcf) to 4059 (mcf) respectively which was again decreased to 4032 (mcf) in the next year 2016-17.

Pakistan has large indigenous coal reserves estimated at over 186 billion tons which are sufficient to meet the energy requirements of the country on long-term basis. Apart from indigenous coal resources, there has been significant increase in import of coal as well due to commissioning of new power plants based on imported coal at Sahiwal and Port Qasim. However, domestic production of coal is expected to increase in the coming years with projects on Thar coal. During the period of 2016-17 the daily coal production was 10,883 tons as compared to 10,272 tons in the year 2015-16 showing an increase of about 5.46 percent.

Hydropower plants are considered one of the most capital-intensive projects and for a country like Pakistan, it is not possible to undertake such big projects without the financial support of international development agencies - a fact which brings in its own share of peculiarities and challenges.

During July - March FY2019, installed capacity of electricity reached 34,282 MW, which was 33,433 MW in corresponding period last year, thus, posting a growth of 2.5 percent. Although electricity generation varies due to availability of inputs and other constraints, the generation increased from 82,011 GWh to 84,680 GWh, posting a growth of 2.1 percent during July - March FY2019. Figure 2-1 gives the comparison of installed capacity (MW) and generation (GWh).

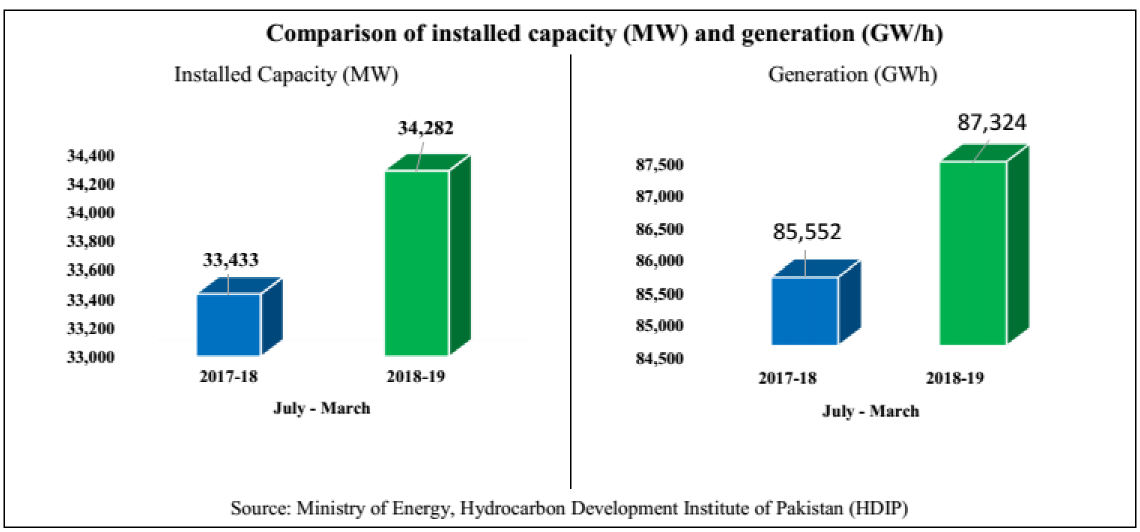

Figure 2-1 Comparison of Installed Capacity (MW) and Generation (GWh)

2.2.7 SHARE IN ELECTRICITY GENERATION

As far as the share of different sources of electricity generation is concerned, it can be observed that the share of hydro in electricity generation has decreased over the last few decades. Availability of water is also one of the main reason for reduced generation from hydel power plants. Currently, thermal has the largest share in electricity generation. Gas and Regasified Liquefied Natural Gas (RLNG) are other cheaper sources. RLNG tremendous growth in energy mix has helped supply the demand to various power plants (Bhikki, Haveli Bahadur Shah, Balloki, Halmore, Orient, Rousch, KAPCO, Saif and Sapphire) while, the remaining was supplied to fertilizer plants, industrial and transport sector.

As an alternate, the government showed commitment for electricity generation capacity through renewable energy sources. During July-March FY2019, there was an increase of 1 percent in share of renewables in electricity generation, and it is expected that the share will increase in coming yearsas well. The comparison of share of different sources of electricity generation is given in Figure **2-2**.

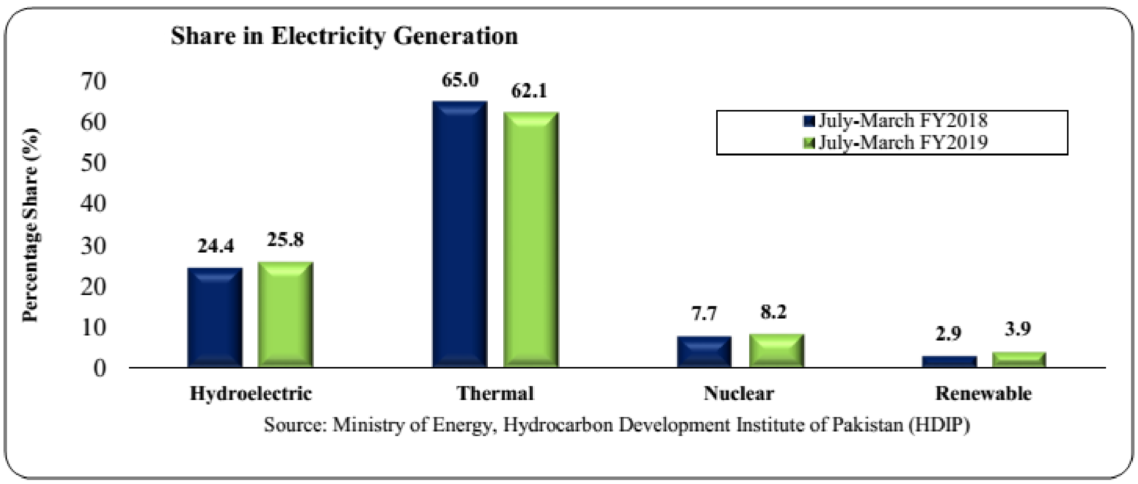

Figure 2-2 Share in Electricity Generation

2.2.8 ELECTRICITY CONSUMPTION

Regarding consumption pattern, there is no significant change in the consumption pattern of electricity. However, during July - March FY2019, the share of household and agriculture in electricity consumption has been decreasing which is indicating that people are trying to rationalize the usage due to increase in its tariff. The increase in the share of industry in electricity consumption is a positive sign showing revival of industry which was suffering earlier due to load shedding. The comparison between consumption patterns of electricity during July-March FY2019 with corresponding period last year is shown below in Figure 2-3.

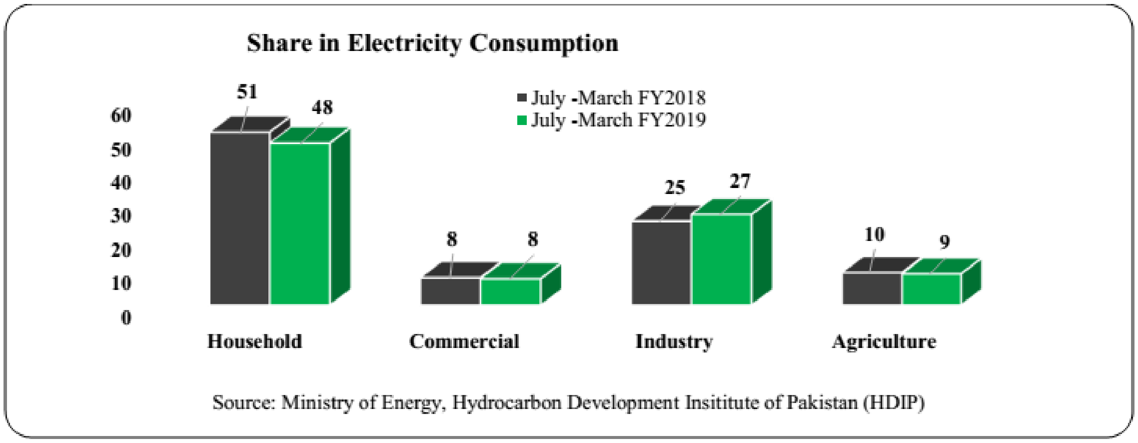

Figure 2-3 Share in the electricity consumption

2.2.9 POWER CRISIS

An increase in industrialization is accompanied by an increase in electricity demand. The nonavailability of natural resources for expansion of the power sector has widened the gap between demand and supply, which has resulted in excessive and frequent load shedding. The shortfall in supply could be the major cause for stunned growth in the industrial sector in Pakistan. At the moment industrial units are facing a dichotomous situation where market forces demand increased production, especially of consumer products, while the utility infrastructure fails to keep pace with this requirement. This dilemma is typical for organizations which see the potential for enhancing the market share of their products but are facing constraints in the reliability and supply of electricity.

The demand for electricity has continued to increase by out pacing the growth rate of the economy. A power shortage was likely to appear in 2006 which did and forced the utilities to go for load-shedding. Currently as per the “State of Industry Report 2018, NEPRA“ the shortfall has reduced to 374 MW for peak hours which has inturn reduced the load shedding throughout the country to a large extent. The same report predicts that by the end of June 2020, this shortfall will be overcomed and a surplus of 737 MW will be achieved.

The installed capacity does not fully contribute to energy production due to various factors like auxiliary consumption, impact of site reference conditions and seasonality effects on the renewables and large hydropower plants. After accounting for above factors, the capacity; known as the Generation Capability, is effectively used for meeting the electricity demand. The data about generation capability and future demand as reported by NTDC is shown in Table 2-1. It may be noted that in the years 2019 and 2020, the generation capability would just be close to the demand, whereas in subsequent years the capability would be more than the demand.

Table 2-1 Surplus/Deficit in Demand and Supply NTDC's System

Year ending 30th June	Installed Capacity (NTDC System) (MW)	Planned Generation Capability as per NTDC (MW)	NTDC's Projected Demand Growth Rate (%)	NTDC's Projected Demand during Peak Hours (MW)*	Surplus/ Deficit (MW)
2019	35,870	26,887	3.90	27,261	-374
2020	37,834	28,892	4.10	28,155	737
2021	42,078	31,184	3.80	29,325	1,859
2022	50,852	35,883	3.90	30,921	4,962
2023	54,532	37,786	3.90	31,953	5,833
2024	58,318	39,196	3.80	33,696	5,500
2025	60,183	37,935	3.90	35,422	2,513

* *NTDC develops the Demand Projections of Peak Demand only.*

- *Electricity Demand Forecast based on Regression Report (Period 2018-2040)*
- *Summary of Power Balance based on latest IGCEP 29 October, 2018*

Source: NTDC

2.2.10 STATUS OF THE HYDRO GENERATION

Hydropower makes a significant contribution to electricity generation in Pakistan, representing around 25% of capacity and 21% of generation. In 2017-18, hydro power capacity had a utilisation rate of 44% although this ranges widely during the year due to the seasonal nature of Pakistan's water resources.

The nation's hydro capacity has remained fairly constant over the last five years but is currently in focus as Pakistan makes major efforts to increase capacity.

"The NEPRA 2017 State of Industry Report" notes there is 13.6 GW of hydro capacity additions planned out to 2025. However, Pakistan's hydro plans extend much further than this. WAPDA's current hydro development pipeline lists 6.3 GW of projects under construction, 13.6 GW ready for construction, and a further 6.8 GW identified as projects 'for the future'. In addition, there are 6.1 GW of IPP hydro projects on the Private Power and Infrastructure Board's (PPIB) development list (Source: PPIB, Upcoming IPPs, August 2018).

The installed capacity of WAPDA Hydropower increased to 8,341 MW in FY 2017-18 as compared to 6,902 MW, recorded in FY 2016-17 owing to addition of 969 MW Neelum Jhelum HPP and one unit of Tarbela 4th Extension having capacity of 470 MW, whereas the 26,951 GWh generated in FY2017-18 shows a decrease of 4,140 GWh from the last year due to several reasons.With regards to the Hydel IPPs, they contributed 130 GWh more energy in the system during FY 2017-18 as compared to FY 2016-17 owing to addition of 147 MW Patrind HPP and 8 MW Marala HPP. The hydropower production pattern over the year shows a downward trend as compared to the historical trendsowing to seasonal variations and water flows. The availability and overall performance of major hydropower plants including Tarbela and Mangla remained satisfactory during the year FY 2017-18 (Source: The NEPRA 2018 State of Industry Report).

Installed power generation capacity of Pakistan as of June 30, 2018 stands at 36,010 MW, of which 33,126 MW is connected with NTDC system whereas 2,884 MW is connected with K-Electric Limited (KEL) system. Source wise installed capacity for the years 2016-17 and 2017-18 is shown in Table 2-2. It may be noted that close to 5,000 MW of thermal capacity was added in the PEPCO system during the period; an increase of 27% over the last year. About 1,600 MW of hydro-based capacity was also added in the system during the same period.

Table 2-2 Source Wise Installed Capacity by Type (MW)

As on 30th June	2017	2018	Variation	
			Capacity	%
A. PEPCO/NTDC SYSTEM				
A.1 HYDEL				
WAPDA Hydel	6,902	8,341	1,439	20.85
IPPs Hydel	214	372	158	73.83
TOTAL HYDEL	**7,116**	**8,713**	**1,597**	**22.44**
A.2 THERMAL				
GENCOs with PEPCO	5,897	5,637	-260	-4.41
IPPs	10,566	15,297	4,731	44.78
SPPs/CPPs	340	340	--	--
CHASNUPP (I, II, III & IV)	1,005	1,330	325	32.34
TOTAL THERMAL including Nuclear	**17,808**	**22,604**	**4,796**	**26.93**
A.3 RENEWABLE ENERGY (WIND, SOLAR AND BAGASSE)				
RE Power Plants connected with PEPCO	1,465	1,809	344	23.48
TOTAL PEPCO/NTDC	**26,389**	**33,126**	**6,737**	**25.53**
B. K-ELECTRIC SYSTEM				
KEL Own	1,874	2,294	420	22.41
IPPs Connected with KEL	252	366	114	45.24
SPPs/CPPs connected with KEL	87	87	0	0
KANUPP	137	137	0	0
TOTAL KEL	**2,350**	**2,884**	**534**	**22.72**
Total Installed Capacity of the Country	**28,739**	**36,010**	**7,271**	**25.30**

Source: NTDC/KEL

For future generation additions, the plans provided by NTDC last year, projected capacity additions of around 30,000 MW in NTDC system over next seven years, so that more than 62,000 MW of installed capacity would be expected by the year 2025. As reported in NEPRA State of Industry Report 2017, no renewable energy plants based on wind and solar were foreseen after 2021, which was contrary to the stated policy of the Federal Government (Source: The NEPRA 2018 State of Industry Report).

2.3 WHY TO INVEST IN POWER SECTOR IN PAKISTAN

Pakistan currently has 36.01 GW of installed capacity for electricity generation. Conventional thermal plants (oil, natural gas, coal) account for 66.71% of Pakistan's capacity, with hydroelectricity making up 24.20%, whereas nuclear and renewable (wind, solar and bagasse) make up the remaining 4.07% and 5.02%, respectively. The current supply, however, is unable to satisfy the electricity demand of the local market during peak hours resulting in an acute shortage of 374 MW. The NTDC estimates that by 2019, Pakistan's demand for electricity during peak hours will reach 27,261 MW and the country will have to increase its generating capacity to meet the increasing demand.

Major reasons for the energy crises include:

i. Lack of investment in power sector.
ii. Depleting gas reserves.
iii. Increasing reliance on foreign fuel based power generation sources.

In light of the prevailing circumstances, hydropower generation appears to be a viable and environmental friendly alternative for meeting Pakistan's growing electricity demands over the long-run. The development of hydropower generation projects could reduce dependence on oil based thermal power generation, increase diversity in Pakistan's electricity generation mix, and reduce greenhouse gas (GHG) emissions, all of which will contribute towards projecting a positive image of Pakistan within the international community. Also, the per kWh tariff for hydro power projects are comparatively lower than that of furnace oil projects.

Government of Pakistan is cognizant of the fact that they need to develop indigenous sources of energy to overcome the current energy crises to achieve sustainable development. Ministry of Water and Power, PPIB and AEDB and state energy departments are putting lot of efforts in progressing hydro energy in the country. The Government of Pakistan also acknowledges the above stated facts and Policy for Development of Renewable Energy 2006 offers many incentives for IPP developers because alternatives to further fuel imports for electricity generation are the use of domestic coal, or generation from hydro-electric or other renewable sources, such as wind, solar and hydropower; further supplemented by HPP policies issued under state energy departments. These options will assist in reducing Pakistan's reliance on imported oil, and resulting vulnerability to changes in global oil prices, and will in turn also have a positive effect on the current trade deficit and inflating import bill.

As with gas, securing future supplies of domestic coal would require significant spending on infrastructure. While Pakistan has domestic reserves of coal, it currently makes up a very small proportion of the country's total power generation. This is due, in part, to the fact that most of the reserves are located in the remote Thar Desert region. Exploiting the coal reserves would require significant upfront investment in local infrastructure (including provision of water supplies), development of mines, housing and related infrastructure, and investment in transmission lines, as a pre-requisite to any power plant development. Hydroelectric power already supplies almost 30% of the domestic electricity that is generated, and numerous sites for future investment exist and are solicited by federal and provincial agencies.

So, the GOP has identified hydro as one of the feasible renewable energy resources for power generation in the short and long term. The technology is already present in abundance in Pakistan, it has a globally proven track record, recognized commercial viability and an installed base of over 1055 GW around the globe (over 323 GW of which is installed in China and India alone), making the case for further development of hydro energy in Pakistan very strong.

The hydropower sector has been a crucial and core component of the energy mix since the inception of Pakistan. The total installed capacity of Pakistan's hydropower stations up till 2014 is about 6795 MW. Out of this total installed hydel generation capacity, the largest share is of KPK, with a total of 3767 MW. Moreover, there are 1698 MW in Punjab, and 1036 MW in Azad Kashmir. Thus this potential needs to be tapped on urgent basis.

Pursuant to the "Khyber Pakhtunkhwa Hydro Power Policy - 2016" the Pakhtunkhwa Energy Development Organization (PEDO) has entered into an agreement with M/s Artistic Milliners (Pvt) Ltd, Karachi to develop Artistic-I HPP at Panjkora River, Sahibabad in district Upper Dir.

The license for the said project was issued by Pakhtunkhwa Energy Development Organization (PEDO) in January 10, 2019. The project is an Independent Power Producer (IPP) project which is going to be constructed in district Upper Dir and is going to supply electricity to proposed 132 kV grid at Munda. Artistic-I HPP can be connected to Munda with a 40 km double circuit.

M/s Artistic Milliners (Pvt) Ltd., Karachi has entered into an agreement with JV of M/s BAK Consulting Engineers, Peshawar and M/s Dolsar Engineering Inc.Co. of Turkey to provide consultancy services for conducting Feasibility Study of Artistic-I 49 MW Raw Site at Panjkora River, Sahibabad in district Upper Dir. In this regard, an agreement was signed between M/s Artistic Milliners (Pvt) Ltd., Karachi and JV of M/s BAK Consulting Engineers, Peshawar and M/s Dolsar Engineering Inc. of Turkey on October 4, 2018 to carry out Feasibility Study of above site.

2.4 GLOBAL HYDRO ENERGY INDUSTRY

2.4.1 HYDRO ENERGY FUNDAMENTALS

Hydroelectric schemes are the largest contributor of electricity from renewable sources worldwide and it is estimated that 20% of the world's electricity is generated from such schemes. Hydro schemes may be classified as either 'impoundment' or 'run of river'.

The majority of large hydro stations are based around the use of a dam and impoundment reservoir. Impoundment schemes have an advantage over other renewable energy technologies in that using a dam or weir to store water in a reservoir means it can be used when it is needed most. Run of River schemes normally divert water from a river by the building of a diversionary weir which diverts water from a river into an intake which then passes through a generator and the water is returned some distance down the river.

Small run-of-the-river hydropower systems consist of these basic components:

- Water conveyance - channel or Tunnel, pipeline, or pressurized pipeline (penstock) that delivers the water.
- Turbine or waterwheel - transforms the energy of flowing water into rotational energy.
- Alternator or generator - transforms the rotational energy into electricity.
- Regulator - controls the generator.
- Wiring - delivers the electricity.

Hydro power is produced by simply using a body of moving water to turn a turbine. This is normally achieved by passing the water down a closed pipeline or through a closed culvert which then turns the turbine and the revolutions of the turbine convert mechanical energy through the generator into electricity.

Generation potential of a site is dependent on three overriding factors - the head, the flow of water available and the rainfall characteristics of the site. The head of water refers to the vertical distance from the intake at the top of the scheme and the floor level of the turbine at the bottom of the scheme.

Hydroelectric schemes can be divided into three basic categories:

- low head schemes, which could be built using a head of between 5 - 25 metres
- medium head schemes, which would be in the region of 25 - 50 metres
- high head schemes, which would be 50 metres and over and have been built up to heads of 300m and more.

The flow of water is normally expressed in cubic metres per second or litres per second and refers to the quantity of water used by the scheme to turn the turbine. Water availability must be accurately measured before calculations regarding cost, compensation water availability and the energy generation potential of a scheme can be calculated. High head schemes would normally be associated with an impoundment reservoir, impoundment can also be used for low head schemes. Hydro technology has been used for some 70 years for both large and small schemes and it is a credit to early turbine designers that even the most modern machinery has only increased in efficiency by a maximum of 3%. The machinery is therefore well understood and proven technology for generating electricity wherever there is sufficient flow in a river or burn. The type of scheme will determine the need to build a diversionary weir or a dam and reservoir.

2.4.2 DESCRIPTION OF HYDRO TURBINES

The waterwheel is the oldest hydropower system component. Waterwheels are still available, but they aren't very practical for generating electricity because of their slow speed and bulky structure. Turbines are more commonly used today to power small hydropower systems. The moving water strikes the turbine blades, much like a waterwheel, to spin a shaft. But turbines are more compact in relation to their energy output than waterwheels. They also have fewer gears and require less material for construction.

There are two general classes of turbines: impulse and reaction. Impulse turbines, which have the least complex design, are most commonly used for high head small hydro systems. They rely on the velocity of water to move the turbine wheel, which is called the runner. The most common types of impulse turbines include the Pelton wheel and the Turgo wheel.

The Pelton wheel uses the concept of jet force to create energy. Water is funneled into a pressurized pipeline with a narrow nozzle at one end. The water sprays out of the nozzle in a jet, striking the cupped buckets attached to the wheel. The impact of the jet spray on the curved buckets creates a force that rotates the wheel at high efficiency rates of 70 to 90 percent. Pelton wheel turbines are available in various sizes and operate best under low-flow and high-head conditions.

The Turgo impulse wheel is an upgraded version of the Pelton. It uses the same jet spray concept, but the Turgo jet, which is half the size of the Pelton, is angled so that the spray hits three buckets at once. As a result, the Turgo wheel moves twice as fast. It's also less bulky, needs few or no gears, and has a good reputation for trouble-free operations. The Turgo can operate under low-flow conditions but requires a medium or high head.

Reaction turbines, which are highly efficient, depend on pressure rather than velocity to produce energy. All blades of the reaction turbine maintain constant contact with the water. These turbines are often used in large-scale hydropower sites. Reaction turbines exploit the oncoming flow of water to generate hydrodynamic lift forces to propel the runner blades. They are distinguished from the impulse type by having a runner that always functions within a completely water-filled casing. Because of their complexity and high cost, they aren't usually used for micro hydro projects. An exception is the propeller turbine, which comes in many different designs and works much like a boat's propeller.

Propeller turbines have three to six usually fixed blades set at different angles aligned on the runner. The bulb, tubular, and Kaplan tubular are variations of the propeller turbine. The Kaplan turbine, which is a highly adaptable propeller system, can be used for micro hydro sites.

The Spiral Case Francis turbine is essentially a modified form of propeller turbine in which water flows radially inwards into the runner and is turned to emerge axially. For medium-head schemes, the runner is most commonly mounted in a spiral casing with internal adjustable guide and stay vanes.

2.4.3 GROWTH TRENDS OF HYDRO INDUSTRY[1]

In 2018, electricity generation from hydropower reached an estimated 4,200 terawatt hours (TWh), setting the highest ever contribution from a renewable energy source.

An estimated 21.8 gigawatts (GW) of hydropower capacity was put into operation last year, including nearly 2 GW of pumped storage, bringing the world's total installed capacity to 1,292 gigawatts (GW).

The East Asia and Pacific region once again held its position as the fastest growing last year, with 9.2 GW of hydropower installed capacity added. It was followed by South America (4.9 GW), South and Central Asia (4.0 GW), Europe (2.2 GW), Africa (1.0 GW) and North and Central America (0.6 GW).

Forty-eight countries added hydropower capacity in 2018. The countries with the highest individual increases in installed capacity were China (8.5 GW) and Brazil (3.7 GW). Among the top five were Pakistan (2.5 GW), Turkey (1.1 GW) and Angola (0.7 GW).

With Brazil reaching 104 GW in installed capacity, the South American nation has now overtaken the United States (103 GW) as the second largest country by hydropower capacity. The new installed capacity by region in given in Figure **2-4** and by country is given in the **Figure** 2-5.

[1] International Hydropower Association – 2019 Key Trends in Hydropower.

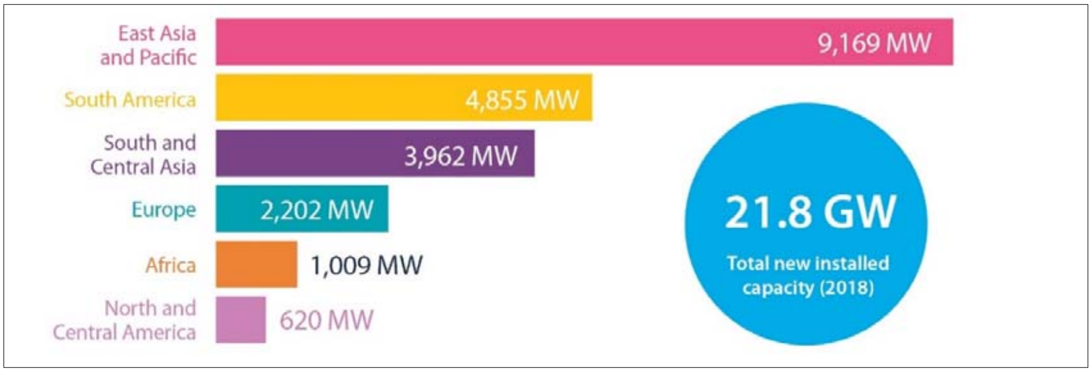

Figure 2-4 New Installed Capacity by Region in the year 2018.

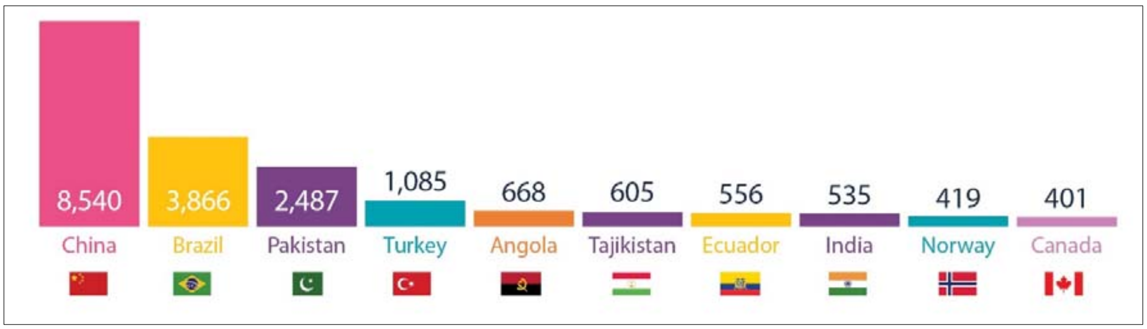

Figure 2-5 New Installed Capacity by Country in the year 2018.

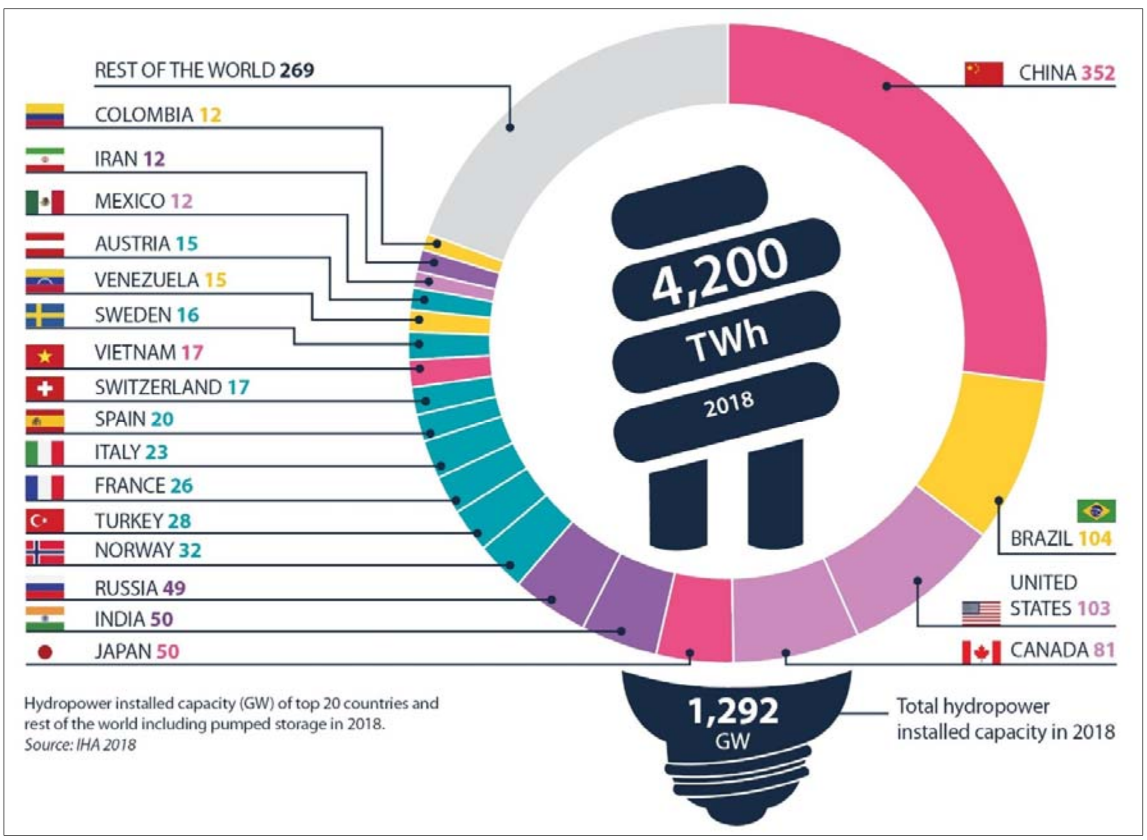

Figure 2-6 Distribution of Hydropower Generation Across the Globe (2018)

Globally, drivers for hydropower's strong showing include a general increase in demand not just for electricity, but also for particular qualities such as reliable, local, clean and affordable power. Looking forward, there remains significant undeveloped potential across all world regions, particularly in Asia, Africa and Latin America. Demand for electricity and other related reservoir services is also high in these areas, forming a strong foundation for continued growth in hydropower.

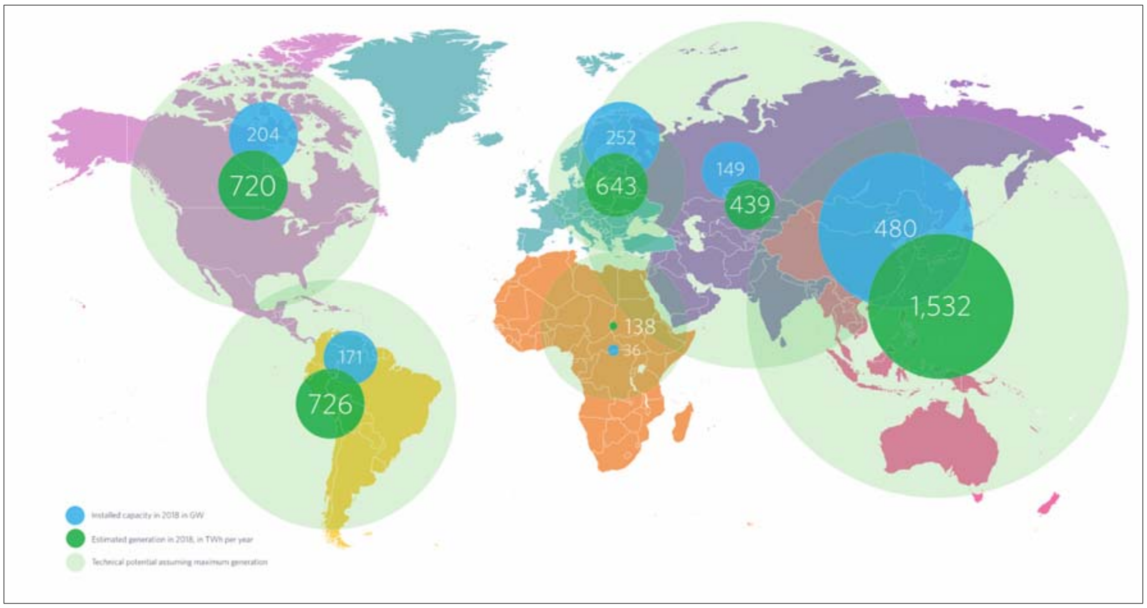

Figure 2-7 Comparison of Power Generation & Hydropower Potential Across the Globe

2.4.4 REGIONAL TRENDS IN BRIEF

2.4.4.1 NORTH AND CENTRAL AMERICA

Hydropower remains the dominant electricity source across North and Central America, although year-on-year growth in hydropower installed capacity is the lowest on a global scale. In 2018, 575 MW of conventional hydropower capacity was added in Canada, while the United States and Central America added a further 80 MW in 2018. Canada has four major hydropower projects under construction, which will add another 2,900 MW of capacity over the next five years.

2.4.4.2 SOUTH AMERICA

South America was the second fastest growing region, adding 4,855 MW in installed hydropower capacity in 2018. Brazil contributed 80 per cent of the region's added hydropower capacity and is the second fastest growing country in the world after China. Brazil has now overtaken the USA as the world's second largest country by installed hydropower capacity. Climate variability has increased the need for regional interconnections to import electricity from countries with growing surpluses like Bolivia, and diversify renewable energy sources in countries such as Argentina and Chile.

2.4.4.3 AFRICA

Africa has the highest percentage of untapped technical hydropower potential in the world. 1,009 MW was added in 2018, bringing total installed capacity to 36.3 GW. In 2018, Angola commissioned two more power generating units for the 2,070 MW Laúca hydropower station. Once fully operational in 2019, it will provide over 25 per cent of thecountry's electric installed capacity. Several modernisation projects were completed in 2018, including the 300 MW Kariba South Bank expansion project in Zimbabwe, the 32 MW Mwadingusha plant in the Democratic Republic of Congo and the 36 MW Nkula project in Malawi.

2.4.4.4 EUROPE

As variable renewables continue their rapid growth, hydropower is increasingly recognised in Europe for its flexible services to maintain secure, affordable and sustainable energy supply. Europe added an estimated 2.2 GW in 2018, including 384 MW of pumped storage, of installed capacity in 2018, bringing the total to 252 GW, including 57.4 GW pumped storage.Turkey led the region in new installed capacity additions, adding over 1 GW at greenfield sites. Austria added significant new and innovative pumped storage capacity to support wind and solar and overall system efficiency, including the 360 MW Obervermuntwerk-II project. Norway completed the 370 MW Lysebotn II project, which replaced its 210 MW predecessor. Iceland added 100 MW at the Búrfell II project, utilising existing infrastructure from Búrfell I.

2.4.4.5 SOUTH AND CENTRAL ASIA

Installed hydropower capacity in South and Central Asia grew by almost 4 GW in 2018, continuing the growth trajectory from 2017. India categorised large hydropower projects as renewable energy, which along with supporting measures, signifies a major step forward in national policy. Pakistan's installed hydropower capacity grew by over 25 per cent in 2018 alone, as large-scale projects came online boosting grid supply capacity. Tajikistan passed an important milestone with the construction of the Rogun hydropower project, as the first 600 MW unit entered into operation. Across Central Asia, there is growing interest in regional interconnections and power markets for hydropower development, including bilateral agreements signed between BBIN countries (Bhutan-Bangladesh-India-Nepal) in South Asia, and construction of the CASA 1000 cross-border transmission project. Modernisation programmes at large, older stations continued across Russia, Georgia and other Central Asian countries, with some rehabilitated units coming back into service in 2018.

2.4.4.6 EAST ASIA AND PACIFIC

East Asia and the Pacific again saw the highest annual increase in hydropower installed capacity in 2018. 9.2 GW was added last year, bringing total installed capacity across the region to over 480 GW. The region also accounted for over a third of the world's total hydropower generation. Over 90 per cent of the addedcapacity came from China, including 1.5 GW from pumped storage, which increased its total installed capacity to 352 GW. Significant activity took place in Myanmar where, after some delay, the government issued a notice to proceed for both the 1,050 MW Shweli 3 and the 60 MW Deeoke projects. Cambodia took an important step forward in achieving its energy goals with the commissioning of the 400 MW Lower Sesan II project, the country's largest hydropower project. Australia continued to progress with the development of several pumped storage projects, with Snowy Hydro's 2,000 MW 'Snowy 2.0' project receiving the green light to proceed in early 2019.Across the Pacific, in Fiji, the Solomon Islands and Samoa, a number of small hydropower projects are under active development.

2.5 HYDRO INDUSTRY IN PAKISTAN

2.5.1 CURRENT STATUS OF HPPS IN PAKISTAN[2]

The hydropower sector has been a crucial and core component of the energy mix since the inception of Pakistan. The total installed capacity of Pakistan's hydropower stations up till 2014 is about 6795 MW. Out of this total installed hydel generation capacity, the largest share is of KPK, with a total of 3767 MW. Moreover, there are 1698 MW in Punjab, and 1036 MW in Azad Kashmir. It is to be noted that the KPK has an even greater potential, Malakand-III is a project on Swat River with an 81 MW (WAPDA, 2013). Thus this potential needs to be tapped on urgent basis.

Straddling the Indus Valley, Pakistan is endowed with considerable water resources. According to Pakistan's Water and Power Development Authority (WAPDA), there is 60,000 MW of hydropower potential in the country, of which only 7,320 MW has been developed.

Pakistan's untapped hydropower potential largely lies in the mountainous north along the Indus River in the provinces of Gilgit-Baltistan and Khyber Pakhtunkhwa, as well as the Jhelum River in the provinces of Punjab and Azad Jammu and Kashmir.

[2] https://www.hydropower.org/country-profiles/pakistan

Pakistan is currently amid an energy crisis. Some 51 million Pakistanis lack access to electricity, while a further 90 million suffer from unreliable power supply and load-shedding on a daily basis, which is having a serious impact on the economy.

However, hydropower is poised for a resurgence and will play a significant role in addressing the power deficit, with some studies estimating the proportion of hydropower in the total electricity generation to increase to more than 40 per cent by 2030. A number of hydropower plants were completed or commissioned in 2016 including Ranolia (17 MW), Daral Khwar (37 MW) and Machai (2.6 MW), all located in the Khyber Pakhtunkhwa province.

Several micro hydropower projects were also installed as part of an initiative led by the government of Khyber Pakhtunkhwa, with the support of the Asian Development Bank, to install some 1,000 micro plants. Expected to have a total installed capacity of 100 MW, these micro projects are designed to support rural, off-grid communities by providing affordable and reliable electricity.

Numerous projects are currently under planning and construction in the private sector, overseen by the Private Power & Infrastructure Board, including Karot (720 MW), Suki (870 MW) and Kohala (1,124 MW). These projects are part of the China–Pakistan Economic Corridor (CPEC) – a collection of infrastructure projects supported by the Chinese Government to strengthen Pakistan’s economy and enhance the economic connectivity between both countries. The regulatory regime for private sector investors includes substantial incentives such as generous return on equity, tax concessions and hydrological risk cover.

Recently completed public sector projects overseen by WAPDA include Golen Gol (106 MW), Neelum-Jhelum (969 MW), Dasu (4,320 MW) and the fourth extension of the Tarbela plant that has lifted its installed capacity to 4,888 MW. The Tarbela Dam is the largest earth-filled dam in the world. The World Bank and the Asian Infrastructure Investment Bank have also announced USD 720 million in co-financing to help fund the fifth extension to the plant, which will add a further 1,140 MW in capacity.

2.5.1.1 Land Allocation by Government of KPK and PEDO

PEDO will provide support and facilitation to project sponsors in acquisition of land through local government of project area or PEDO may acquire land for the project concerned and lease to the project company on mutually agreed terms and conditions for the term of the project as per PEDO Hydropower Policy 2016.

2.5.2 TARIFF REGIME IN PAKISTAN

Due to their unique nature however, hydropower plants present a number of risks, which may be seen as hurdles by the prospective investors to invest in hydropower plants relative to investing in other forms of electricity generation. While recognizing cost uncertainty as a genuine problem, NEPRA in order to remove such ambiguities, has developed a mechanism ("Mechanism for Determination of Tariff for Hydropower Projects"), which provides for determination of tariff and subsequent adjustments at different stages of hydropower project development. In this respect three distinct stages have been identified when costs may differ. These costs are discussed below.

i. Feasibility Level Costs

Feasibility Study shall clearly include, among other relevant information, formulae based on which the Applicant have arrived at unit rates for various activities such as soil excavation, rock excavation, fill, underground excavation, reinforcement etc. Before determining a tariff, NEPRA will invite comments and consider recommendations of the respective province in which the proposed project is located, including comments on resettlement costs and where applicable land costs claimed by the Applicant for resettlement.

ii. EPC Level Costs

All the applicants possessing NEPRA's determined tariff on feasibility costs shall be required to file a tariff petition based on EPC Costs in terms of NEPRA Tariff Standards and Procedure Rules-1998, if they wish to seek revision in tariff on the basis of EPC. NEPRA will allow such adjustments, provided that the Project Company substantiates its costs to NEPRA's satisfaction preferably in the form of EPC contracts and/or in a form and manner as determined by NEPRA. While determining tariff; NEPRA may carry out detailed prudence of costs however, if the Applicant supports its petition by providing competitive bids from a number of reputable contractors, NEPRA may accept the lowest of bids without going in to detailed prudence exercise.

iii. Final Costs which shall be no later than the Commercial Operation Date (COD)

The COD stage determination is again subject to "Tariff Reopeners" such cost variation due to geology in the tunnel(s), civil works cost escalation, cost variation in hydraulic steel structure and M&E works, cost variation due to resettlement cost.

The Mechanism For Determination of Tariff for Hydropower Projects provides for NEPRA's tariff determination based on costs at feasibility study stage and then at EPC stage, adjustable at COD to reflect those changes which have been permitted in this mechanism.

2.5.2.1 NEGOTIATED TARIFF FOR HYDRO IPPS

The tariff regime for HPPs is split in two options; first being the 'Negotiated Tariff', which is applicable where the Project Company shall justify all expenses and financial position to NEPRA through a petition. NEPRA in return determines the project tariff on a "cost plus" basis.

2.5.2.2 UPFRONT TARIFF FOR HYDRO IPPS

NEPRA had announced the upfront tariff for Small HPPs which varies for low-head and high head projects; this tariff catered to Projects having capacity from 1 MW to 25 MW. However, this tariff expired in fall of 2016.

In this regime, the hydrological risk could be passed to the Power Purchaser if the Annual Plant Factor of 65% for low head projects and 50% by high head projects was met by Projects after allowing for auxiliary consumption at 1% on gross installed capacity.

In cases where hydrological risk is borne by the power purchaser, the company was to receive an assured minimum amount every month from the power purchaser to cover its fixed costs (fixed O&M, insurance, return on equity and debt servicing) in case the plant is available but sufficient water i.e. at least equal to the average historic hydrology for that particular month is not available to generate electricity. Payment on account of hydrological risk was to be made by the power purchaser, on the basis of benchmark monthly energy generation, based on the average historic hydrology for that particular month. Further, the tariff was to be limited to the extent of benchmark net annual energy generation of the project; while net annual energy generation supplied to the power purchaser in a year, in excess of the benchmark net annual energy generation was to be charged at 10% of the prevailing upfront tariff. The power purchaser before signing the Power Purchase Agreement was required to verify the month wise benchmark hydrology. Power producers opting to bear hydrology risk were allowed to sell all power at the prevailing upfront tariff.

In order to address the gap and the ever-increasing power shortage, there is a need to develop hydroelectric and other renewable energy resources to meet the expected demand of electricity.

In continuation of the above, a feasibility study of Artistic-I Hydropower Project is being conducted to meet the demand of affordable Hydro Electric Energy.

CHAPTER

3

TOPOGRAPHIC SURVEY

CHAPTER - 3

TOPOGRAPHIC SURVEY

3.1 GENERAL

Artistic-I HPP weir is located on Panjkora River near Darora village. The powerhouse site is located about 3.5 km downstream of Sahibabad village. Both weir and powerhouse site is easily accessible through N-45 (Chakdara-Upper Dir) asphalt road. The catchment area is estimated about 3100 km^2 at the weir location.

A credible topographic survey is one of the basic requirements for quality planning/design of a project. The Consultants, immediately after getting approval from Client, embarked upon to carry out topographic survey of the area as given in the project ToR.

This chapter will describe the detailed topographic survey carried out at the feasibility stage of the proposed Artistic-I Hydropower Project. Topographic survey is the foremost activity of the feasibility study of any hydropower project. The project area was visited and survey requirement were assessed keeping in view the suitable location of various components of the proposed scheme. The survey was carried out concentrating various options of project layout at appropriate scale, so that it would help in planning an optimum layout. This planning was essential because studies and investigations depend on the availability of accurate topographic maps of the area depicting all essential existing features. The consultants' survey activities are part of feasibility level design and will serve as basis of drawings to be prepared afterwards.

3.2 PROJECT SITE

Weir and powerhouse sites are easily accessible through N-45 (Chakdara-Dir) asphalt road. Project location map is attached as **Figure** 3-1**.** The coordinates of weir and powerhouse sites as per LoI are given as under:

Table 3-1 Project coordinates as per LoI

Location	Northing	Easting	Elevation
Weir / Intake	35°4'55.58"	71°59'32.33"	1046.94 masl
Power House	35°1'17.56"	72°0'58.83"	986.58 masl

The new project coordinates finalized by the consultants after site visits and mutual in-house discussions between experts are as under:

Table 3-2 Project coordinates finalized by consultants

Location	Northing	Easting	NWL / TWL
Weir / Intake	35°5'52.77"	71°59'0.08"	1071.00 masl
Power House	35°1'28.32"	72°0'40.77"	990.00 masl

The topography of the site area is mountainous with altitude varying between 970 amsl to 2,000 amsl. The tributaries on both sides of Panjkora River have steep slopes.

Figure 3-1 Project location map

The climate data of the project area shows that average of monthly mean maximum temperature varies between 32.3°C in the month of June to 12°C in the month of January, whereas monthly mean minimum temperature ranges between 18.6°C in July and -2.5°C in January.

The main features of the project are:

- Weir, under sluice and intake
- Box channel
- Free Flow Tunnel
- Sandtrap

- Power tunnel
- Adit tunnel
- Surge shaft
- Penstock
- Powerhouse
- Tailrace
- Switchyard
- Residential colony
- Access roads
- Bridges (2 Nos.)
- Protection works

3.3 MOBILIZATION

A credible topographic survey is one of the basic requirements for quality planning/design of a project. Survey teams, headed by Chief Surveyor, were constituted and mobilized on January 19, 2019 after getting approval from the client. The task given to team was to complete this most essential field activity on war footing basis before the rise of water level in the Panjkora River due to melting of snow in the upper portion of catchment area. Prior to making their move to the site, survey teams got associated themselves with the Client's requirements as per ToR of the project and planned their activities accordingly. The survey boundaries as per project requirements, marked on the google map, were provided to the Chief Surveyor to carry out the detailed topographic survey of various features of the project layout.

3.4 ADDITIONAL SURVEY

Survey team was remobilized to carry our additional survey to study shifting of the weir to utilize the maximum head available.

New location of Alternative 4 Weir (W4) was identified at site by shifting weir further upstream from its previous location. The coordinates of the newly located weir (W4) are given in the above **Table** 3-2. This alternative offers maximum head and hence maximum annual energy and revenue compared to all other downstream alternatives. This may involve resettlement of a few houses but that can be compensated.

3.5 SURVEY METHODOLOGY/CRITERIA

To prepare project layout and the feasibility level design of the project, following main tasks have been included in the survey scope of work:

- Installation of permanent survey control points;
- Processing of topographic survey digital data by using software.
- Generation of topographic sheets by using CAD/CAM techniques;
- Production of topographic survey drawings for different structures as per requirement of the project.
- Preparation of comprehensive survey report.

The project site office was established in the vicinity of Sahibabad town. Rented accommodation for bachelors is rarely available in such like localities while hotel facility is also not available in the nearby area. Traveling from Timergara or Upper Dir was time consuming during short sunshine duration. To achieve satisfactory progress, the teams somehow managed to hire a rented accommodation in the vicinity and completed the topographical activities. They were equipped with laptop computers for downloading and processing the survey data then and there for cross checking of their daily observation and data collected.

Latest technology/equipment were used and special care has been taken in establishment of survey control points for the project. Based on these established Bench Marks, additional survey control points have been established as per requirement of the area.

The aim was to survey the whole project area with emphasis on details of the different project components such as access road, main weir, box channel, sand trap, headrace tunnel portals, surge tank and pressure shaft, penstock and power house etc.

Important features of the site such as existing road/tracks, electric and telephone poles, houses, water courses, trees, cultivated land etc. were coded and marked. The density of the observing points was kept such that a contour map with 1 meter interval was prepared.

Universal Transverse Mercator (UTM) coordinate system has been adopted for the project. UTM was originally invented by Germans and then further developed by US Army Corps of Engineers. The Topographic survey maps and natural & man-made features can be easily transported to the latest version of Google Earth software.

The various steps taken to complete detailed topographic survey of the project are as under;

i. Mobilization
ii. Field visits
iii. Establishment of bench marks / control points
iv. Traversing
v. Precise leveling
vi. Detail topographic survey

vii. Preparation of survey drawing
viii. Field Check
ix. Preparation of Survey Report

3.6 SURVEY INSTRUMENTS

The Electronic Total Station (ETS), Automatic Level and Differential GPS (DGPS) were used for the survey. The specifications of the instruments used for the survey are as under;

3.6.1 ETS NIKON NIVO 2.M

Nikon's next generation total station is the Nivo™ Total Station. Nivo 2.M is supported with legendary Nikon high clarity optics, allowing clearer images in bright and low light conditions, making measurements easy and reducing eye stress.

Specifications

- High quality Nikon optics
- Intuitive powerful software
- Fast, accurate EDM
- Prism and reflectorless measurements
- Hot swappable batteries
- Compact, rugged, and lightweight
- Cable-free Bluetooth
- Optional laser plummet

3.6.2 ETS TOPCON GTM 3000

The Topcon GTM-3000 series are pulse laser total stations with a superior non-prism measurement capability. Making use of an updated optical system, the GTM-3000 Series incorporates special techniques to provide accurate, reliable and safe non-prism distance measurements.

Specifications

- Telescope Length: 150 millimeters
- Objective lens diameter: 45mm (EDM: 50mm)
- Magnification: 30 xs
- Image type: Erect
- Resolve power: 3"
- Min. Focus Distance: 1.3 meters

3.6.3 ETS SOKKIA 610 K

The instrument works on a unique pulse laser technology which allows measuring up to 450 m in reflector-less mode with complete safety and confidence.

Specifications

- IP66 Rating
- Ultra-Light 5.2kg Body
- Extra wide screen
- 1,600 m Prism Range
- 6″ Angle accuracy
- Comprehensive easy-to-use on-board system

3.6.4 DGPS TRIMBLE 5800

The Trimble 5800 GPS receiver provides reliability and simplicity for basic surveying tasks. The proven design of the Trimble 5800 performs under the toughest conditions.

Specifications

- Advanced Trimble Maxwell™ Custom survey GPS Chip
- High precision multiple correlators for L1 and L2 pseudo range measurements
- Unfiltered, unsmoothed pseudo range measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise L1 and L2 carrier phase measurements with <1 mm Precision in a 1 Hz bandwidth
- L1 and L2 Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- 24 Channels L1 C/A Code, L1/L2 full cycle carrier
- 2 additional channels for SBAS WAAS/EGNOS support
- 3-wire serial (7-pin Lemo) on Port 1. Full RS-232 serial on Port 2 (Dsub 9 pin)
- Fully Integrated, fully sealed internal 450 MHz receiver
- Fully integrated, fully sealed 2.4 GHz communications port (Bluetooth)
- External cell phone support for GSM/GPRS/CDPD modems for RTK and VRS operations
- Data storage on 2 MB internal memory: 55 hours of raw observables based on recording data from 6 satellites at 15 second intervals
- 1 Hz, 2 Hz, 5 Hz, and 10 Hz positioning
- CMR+, RTCM 2.1, RTCM 2.3, RTCM 3.0 Input and Output

- 16 NMEA outputs, GSOF and RT17 outputs

3.6.5 AUTOMATIC LEVEL NIKON AS-2

The automatic levels provide quick setup, easy sighting, and superior durability against vibration and shock, ensuring the increased productivity over an extra-long period of time.

Specification and Features:

- Precise measurements
- Waterproof
- High-power telescopes that help you make precise measurements even in the wettest conditions.
- Unique automatic air – dampened compensator to prevent magnetic Interference and an endless horizontal fine drive to ensure smooth, precise pointing and angular measurement.
- Auto levels are easy to set and easy to use.
- Can be attached to both flat and spherical head tripods.
- Mirror with a pent prism lets you view the circular bubble as an erect image during setup and sighting.

3.7 ESTABLISHMENT OF BENCHMARKS/ CONTROL POINTS

Establishment of control points is not only important for the survey work but also useful for the execution of the project at later stage. These control points should be on a firm ground and away from the places where it can be easily tampered. It is important to establish control points on permanent features i.e. existing structures, exposed rock, bridges, permanent protection bund etc. The monuments have been constructed of concrete and can be conveniently used during construction.

Figure 3-2 Control point/Bench mark

3.8 LEVEL CONTROL

3.8.1 MAIN BENCH MARK USED

Survey control points for the project has been established by using latest survey equipment's. The first two control points S1 and S2 were established using hand held GPS. The remaining were then established by using total station. The coordinates of S1 & S2 are as under;

Table 3-3 List of control points established using hand held GPS

S.NO	EASTING (m)	NORTHING (m)	LEVEL (masl)
S1	772740.835	3885811.481	1060.155
S2	772807.960	3885302.014	1054.970

Extra care has been taken in establishment of these permanent control points. The standard procedure, recommended for this kind of survey, was adopted. The leveling was carried out in pleasant hours to avoid errors. Additional survey control points have also been established as per requirement of the TOR and as per requirement of the area. These survey control points are then used to conduct the topographic survey of project area including locations of project structures. Before commencement of the detailed survey, all these control points were further refined by two-way leveling.

Survey control points with all the coordinates and levels are listed in the following table.

Table 3-4 List of benchmarks

ARTISTIC- I HPP				
LIST OF BENCHMARKS				
POINT ID.	**Easting**	**Northing**	**Elevation (masl)**	**Description**
S-1	772740.835	3885811.481	1060.155	
S-2	772807.960	3885302.014	1054.970	
A1-1	772707.111	3886453.215	1059.610	Concrete Monument
A1-2	772882.363	3886194.311	1057.629	Concrete Monument
A1-3	772781.749	3885976.735	1050.431	Concrete Monument
A1-4	774418.363	3880546.979	1027.832	Concrete Monument
A1-5	774487.433	3880400.010	1022.661	Concrete Monument
A1-6	774532.772	3880348.291	1019.386	Concrete Monument

3.8.2 TRAVERSE SURVEY

Traverse is a method in the field of surveying to establish control networks. Traverse networks involve placing survey stations along a line or path of travel and then using the previously surveyed points as a base for observing the next point.

Traverse was carried out in a closed loop to established control in the area of interest starting from the survey control point S2. The traverse bearing and distances were observed in two directions (forward & backward) and mean was accordingly adopted. A closed traverse (polygonal, or loop traverse) was employed, consisting of a series of linked traverse lines where the terminal point closed at the starting point.

The vertical control was established with the help of auto level Nikon AS-2. The traverse was closed with double run.

The horizontal angles were measured on two zeroes i.e. four angle measurements were taken from each side. The average of these was used in the traverse computation that provided the spread of angles which was not more than 20” of arc.

3.8.3 TRAVERSE POINTS

A network of control points was established along the Timergara-Upper Dir road (N45) from powerhouse site to weir site. Bearing and distance observations were made two times on a single station from which mean value was calculated. The same process was repeated at every station. The mean value was converted to co-ordinate system. The vertical control observations were made with level Nikon AS-2. This traverse was also closed. The detailed observation and calculation of the vertical and horizontal control is being reproduced in this chapter. This error was distributed over the traverse points and the adjusted values were obtained. The closing error of vertical coordinate was 3 mm which was distributed among the traverse points to obtain the final value.

3.8.4 TRAVERSE ACCURACY

A closing horizontal error of 20 mm was observed in the northing, similarly a closing error of 125 mm was observed in the easting. The achieved accuracy is about 1/457365.854.

The closing vertical error in the traverse was observed as 3 mm which is inside the allowable limits of ± 20 mm per km. The error is distributed in proportion to the cumulative easting and northing from the first station of the respective traverse.

3.8.5 HORIZONTAL CONTROL

A total of eight (8) survey control points have been established in the project area. The control points are concrete monuments with steel rods embedded in the center and flushed with the top surface. These steel pins are center punched with red paint. These control points are assigned the horizontal control values (northing, easting). All the control points have been established with the help of Total Station. It may be noted that the closing error for angular measurement was 5 sec. This error was distributed over the traverse points and the adjusted values were obtained.

3.8.6 VERTICAL CONTROL

The Second Order, Class-II survey allows an error of ± 20mm in a kilometer distance. This accuracy can be described as an accuracy of 1 in 50,000. The closing error in vertical measurements was within the acceptable limits.

3.9 TOPOGRAPHIC SURVEY

Topographic survey was carried out for marking the existing features, development of contour maps etc. Keeping in view the nature of diversity involved in the present survey requirements, the consultants used a combination of conventional and latest electronic / digitizing techniques to accomplish the assignment as desired.

Total station survey was done to collect data with feature codes through data loggers which was then processed and contour maps were prepared. Separate field sketches were also drawn at site to depict existing features of the land and built up details.

Topographic survey was carried out by observing appropriate density of spot heights, marking existing feature above ground, water edge, drains, protection works, bridge, houses, roads and other features. The survey data was recorded for the accurate representation of the land surface in the interval and scale desired to give a true picture of the existing features.

3.10 STRUCTURAL SURVEY

Topographic survey has been carried out for alignment/layout of structures as per TOR. The Consultants carried out the surveys with the most modern and sophisticated total stations. GPS has been used to establish the control points at suitable locations. Computer software "Eagle Point" has been used for plotting the survey data.

The following topographic surveys in the area of the main structures has been carried out and mapped as per the detail given below.

3.10.1 INTAKE AREA

Diversion weir with area of all appurtenant structures with contour interval of 1 m in a scale of 1:500 supported by sufficient number of cross section and long sections as per site requirements.

3.10.2 BOX CHANNEL ALIGNMENT

Connecting channel with 1 m contour interval at a scale of 1:500 supported by sufficient number of cross section and long sections as per site conditions.

3.10.3 SAND-TRAP

Sand-trap with 1 m contour interval at a scale of 1:500 supported by sufficient number of cross section and long sections as per site conditions.

3.10.4 HEADRACE TUNNEL

Survey of inlet and outlet portal of proposed tunnel alignment with contour interval of 1m in a scale of 1:500 supported by sufficient number of cross sections and long section as per site conditions.

3.10.5 SURGE TANK AND PRESSURE SHAFT

In location of surge chamber an alignment with contour interval of 1m in a scale of 1:500 supported by sufficient number of cross sections and long section as per site conditions.

3.10.6 PENSTOCK

Area with contour interval of 1m in a scale of 1:1000 supported by sufficient number of cross sections and long section as per site requirements.

3.10.7 POWER HOUSE

Area including tailrace canal with contour interval of 1m in a scale of 1:500 supported by sufficient number of cross sections and long sections as per site requirements.

3.10.8 ACCESS ROADS

Access road will be provided to all structures including weir, sand-trap, surge tank, penstock and powerhouse with contour interval of 5m at scale of 1:2000 supported by sufficient number of cross sections and long sections as per requirement.

3.10.9 RIVER CROSS SECTIONS

River cross sections 22 Nos. upstream of weir and 13 Nos. downstream of weir shall be taken at an interval of approximately 100 meters. 5 Nos. of cross sections upstream of powerhouse and 11 Nos. downstream of powerhouse at an interval of approximately 100 meters.

The topographical survey maps of all sites are presented in **Annexure 3B.**

3.11 PREPARATION OF SURVEY DRAWINGS

In general, latest survey instruments i.e. Total Stations were used for field survey. Later on, field data was computer processed and various maps/ plans, profiles and cross sections were prepared and plotted at recommended/ required scales on A3 size paper. Eagle Point and Civil 3D software were used for processing of survey data while AutoCAD for drawing and plotting purposes.

The drawings produced on the basis of the survey will be used for planning and developing weir, sediment excluder, tunnel alignment, powerhouse location and other associated structures.

3.12 UNITS OF MEASUREMENT

All dimensions and elevations in topographic surveys are in metric units and the angular measurements are in degrees, minutes and seconds

CHAPTER

4

HYDROLOGY AND SEDIMENTATION

LIST OF TABLES

LIST OF FIGURES

CHAPTER 4

HYDROLOGY & SEDIMENTATION

4.1 HYDROLOGICAL STUDIES

Hydrological studies are carried out as required for the design of a hydropower project, which include the determination of pattern and time of availability of river flows, flood magnitude for the determination of waterway, water level at weir/powerhouse sites and diversion arrangements. The hydrological series that represent variations in river flow available throughout the year, determines the power and energy production. Study of the nature and quantity of the sediments inflow into the river will be carried out to determine sediment deposition behavior in the project reach and its effect on the power plant components. Present study includes review of the available historic data, data collected during the study and its analysis.

4.1.1 CATCHMENT AREA

The catchment of the Artistic-I HPP lies in the upper part of the Panjkora River, a main tributary of a Swat River basin and can be classified as a “high mountains catchment” which originates from glacier zone. Two major tributaries join at Chukiatan, just downstream of Dir town to form Panjkora River. On the way downstream, it joins a number of small tributaries evacuating the discharge from different valleys. The stream flow patterns are followed by the seasonal change in temperatures. The highest mountain peak ranges from 5750 masl upto 6000 masl while river bed elevation at weir site is 1061.00 masl and river bed elevation at powerhouse site is at approximately 986.00 masl. Length of the Panjkora River up to the weir site is about 105 km. Slope of Panjkora River is about 0.034 but relatively flatter near weir axis i.e. about 0.0095.

Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km and at powerhouse location is approximately 3235 sq.km. Catchment area map and digital elevation model are shown in **Figure 4-1** to **Figure 4-3**.

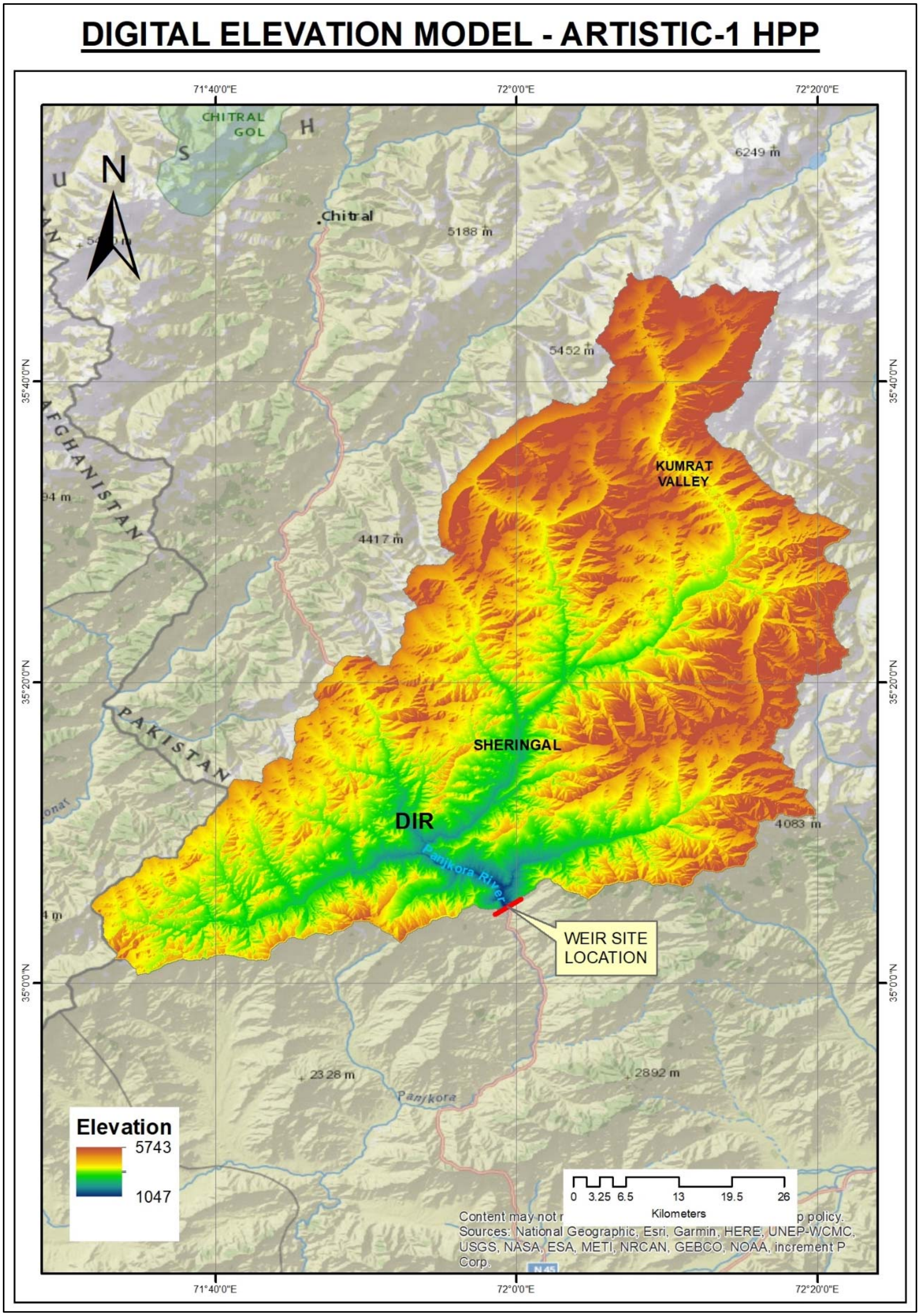

Figure 4-1: Digital Elevation Model of Artistic-I Hydropower Project

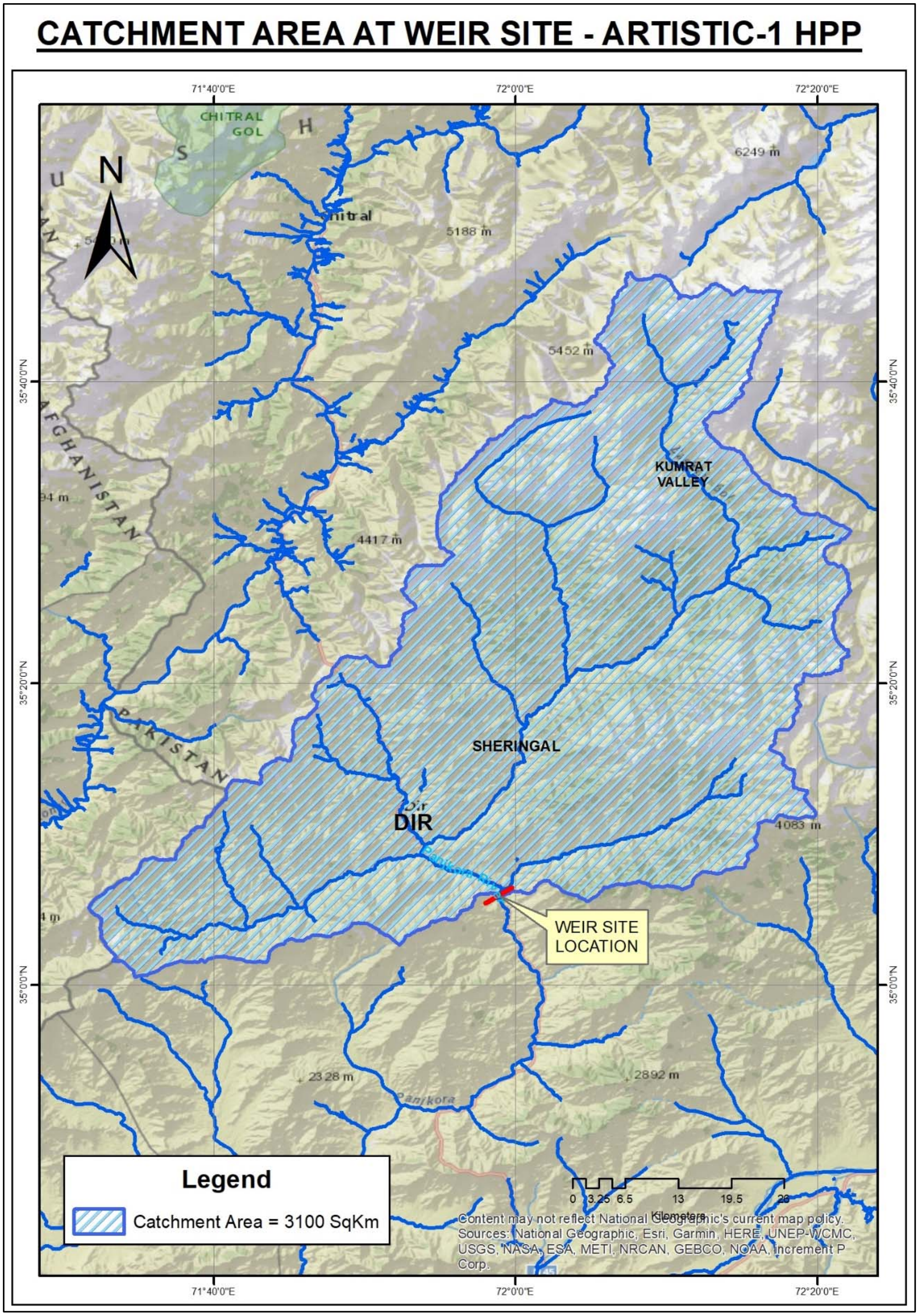

Figure 4-2: Catchment Area Map of Artistic-I Hydropower Project – At Weir Site

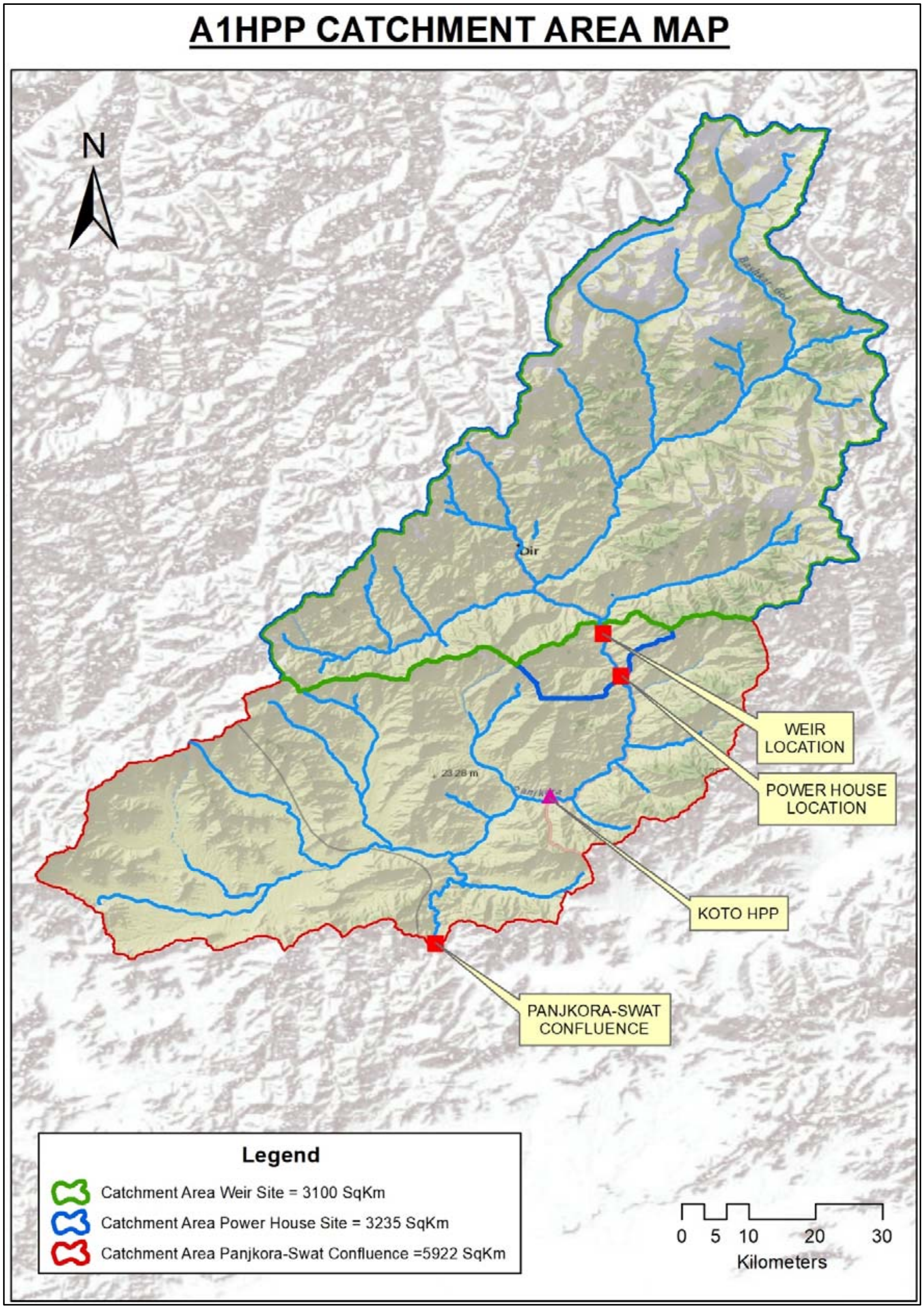

Figure 4-3: Catchment Area Map of Artistic-I Hydropower Project – Upto Weir, Powerhouse and Panjkora-Swat River Confluence

4.1.2 COLLECTION OF HYDRO-METEOROLOGICAL DATA

4.1.2.1 CLIMATE DATA

a) Daily rainfall data for Dir from 1970-2015.

b) Precipitation data of Lower Dir for period of 2010-2015.

c) Monthly data of rainfall for Chakdara and Amandara headwork.

d) Climate normal of Dir for period of 1981-2010 including rainfall, maximum temperature, minimum temperature, humidity & sunshine hour etc.

Mean monthly rainfall and temperature data of climate station at Dir are given in **Table** 4-1 and shown graphically in **Figure 4-4** and **Figure 4-5**.

Table 4-1: Mean Monthly Rainfall and Temperature: Dir

Month	Min Temp (°C)	Max Temp (°C)	Precipitation (1981-2010) (mm)
January	-2.5	12	112.5
February	-0.8	12.6	176
March	3.1	16.8	256.5
April	7.4	23	166
May	11.5	28.5	90.5
June	15.1	32.3	56.4
July	18.6	31.7	154.5
August	18.2	30.6	147.5
September	13.7	29.3	76
October	7.1	25.4	72.3
November	2.3	20.3	59.1
December	-1.1	14.6	79.9
Average	**7.7**	**23.1**	**Total 1447.2**

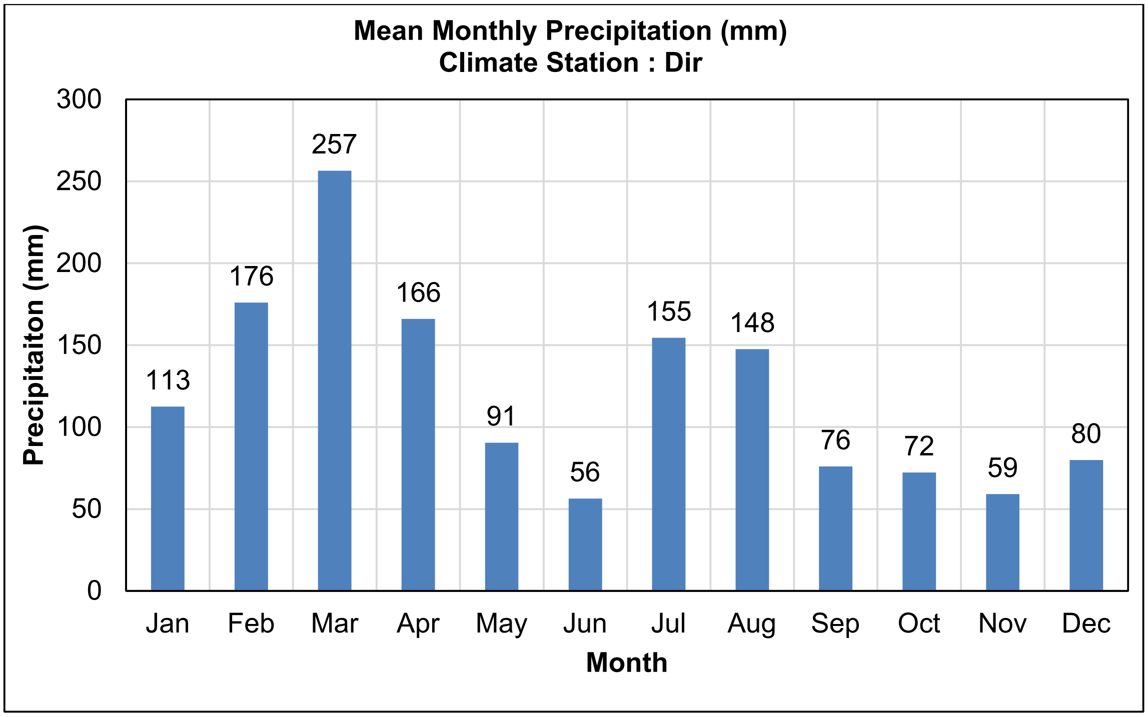

Figure 4-4: Mean Monthly Precipitation (mm) at Climate Station Dir

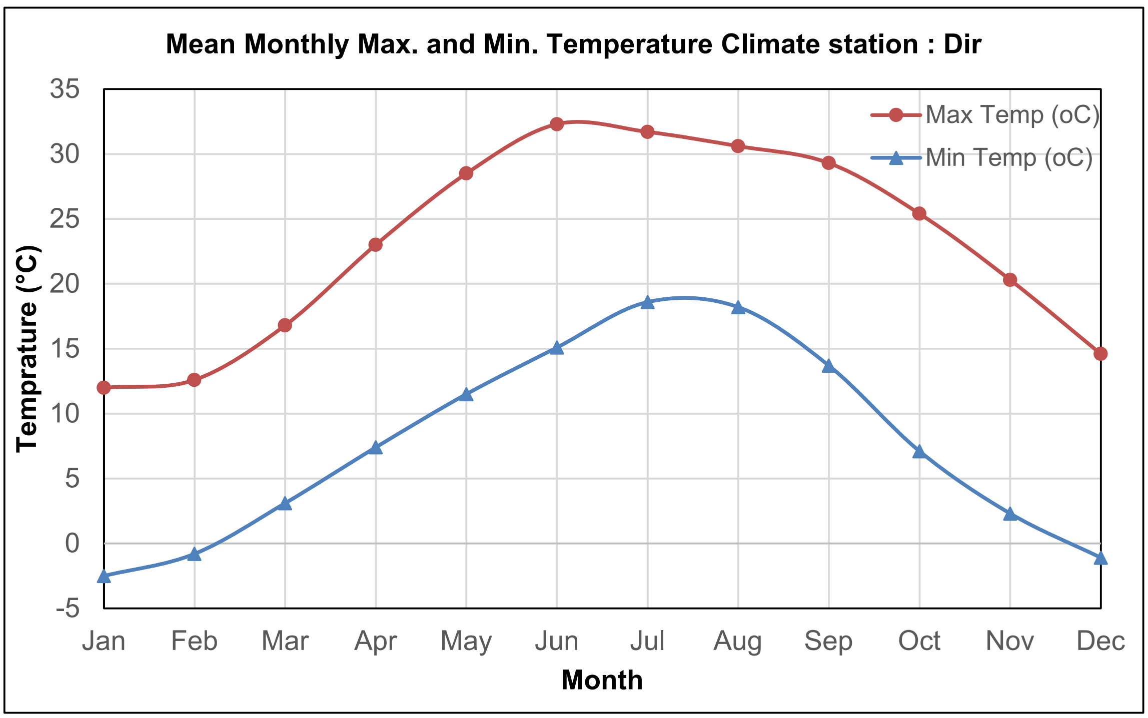

Figure 4-5: Mean Monthly Max. and Min. Temperature at Climate Station Dir

Table 4-2: Mean Monthly Rainfall for Different Climate Stations in and around Project Area (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dir	109	178	231	165	87	54	143	146	81	67	55	72	1388
Lower Dir	51	160	94	109	32	42	67	116	45	48	37	25	827
Zulam Bridge	83	98	90	69	37	27	85	119	44	10	18	21	699
Amandara Headwork	46	80	92	57	21	15	71	112	31	29	16	28	597
Malakand	47	75	85	58	50	20	64	92	33	30	24	31	610
Chakdara	62	86	111	79	46	10	110	113	46	21	24	54	762

Monthly rainfall data of different stations is given in the **"Annexure-A1, Volume-VII".**

Project area weather is characterized by extreme winter and moderate summer. The monsoon penetrates into the project area but main mechanism of producing rainfall is due to western disturbance. Climate of the project area can be classified as cold and sub humid. As per available record of climate stations located in and around project area, indicates higher precipitation at higher altitude than at lower as given in **Table 4-2.**

4.1.2.2 Hydrological Data

a) Daily flow data of Swat River at Chakdara (Maintained by Surface Water Hydrology SWHP, WAPDA) for period of 1961-2015.

b) Daily flow data of Panjkora River at Shigo Kas (Maintained by Pakhtunkhwa Energy Development Organization (PEDO) from 2009-2017.

c) Daily flow data of Panjkora River at Zulam Bridge (Maintained by Surface Water Hydrology SWHP, WAPDA) from 1999-2006.

d) Daily flow data of Panjkora River Downstream of Koto River (Maintained by Pakhtunkhwa Energy Development Organization (PEDO) for period of 2005-17.

e) Daily flow data of Panjkora River at Sharmai (Maintained by Pakhtunkhwa Energy Development Organization (PEDO) from 2005-2018

f) Daily flow data of Swat River at downstream of Mohmand Dam (Maintained by Surface Water Hydrology SWHP, WAPDA)

g) Suspended Sediment Data at Chakdara (1963-2015) and also for short duration at Koto and Zulam Bridge.

Figure 4-6 shows the location of the stream gauges. Mean 10-daily flow of Panjkora and Swat River at gauging stations are tabulated below in **Table 4-3** and shown graphically in

Figure 4-7 &

Figure 4-8 below. Historical 10-daily flow data is given in **“Annexure-A2, Volume-VII”.**

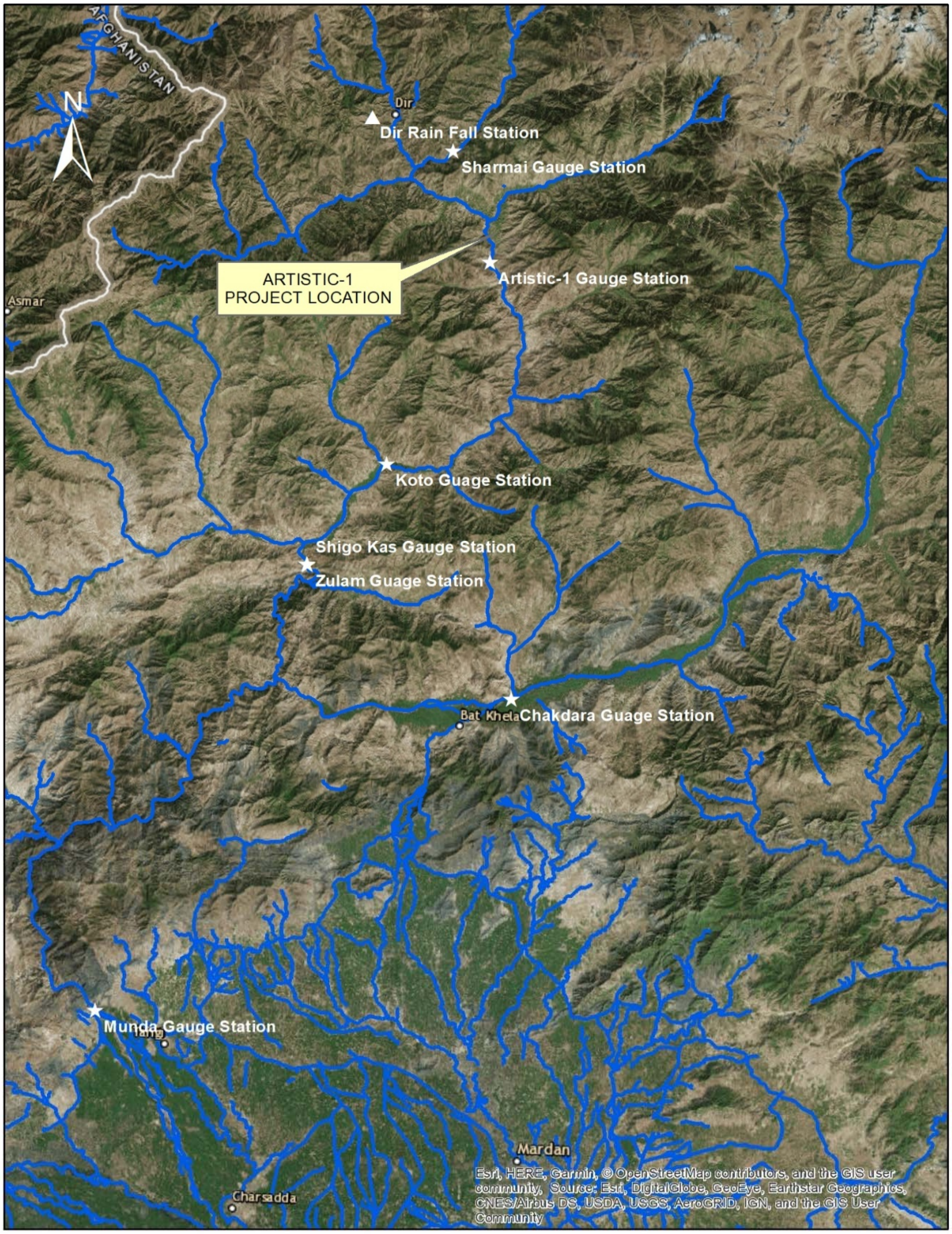

Figure 4-6: Stream Gauges Location near Artistic-I Hydropower Project

Table 4-3: Summary of Mean 10-Daily Flow (cumec) of Different Gauging Stations

Month	10 Daily	Panjkora at Sharmai	Panjkora at Koto	Panjkora at Zulam Bridge	Swat at Chakdara
Jan	I	11.33	25	29.4	50.24
	II	11.31	24.2	36.92	50.16
	III	11.48	23.9	33.93	52.64
Feb	I	13.61	31.4	37.18	57.49
	II	16.64	42.1	47.6	70.85
	III	18.83	52	59.8	73.38
Mar	I	22.63	63.3	67.72	91.97
	II	36.76	118.2	93.7	123.16
	III	53.21	127.6	138.35	155.85
Apr	I	70.14	174.1	147.87	173.65
	II	94.32	165.1	195.97	223.03
	III	101.15	173.4	206.48	259.59
May	I	123.85	188.4	203.57	282.43
	II	133.32	192.5	212.35	306.5
	III	128.89	176.4	179.59	340.95
Jun	I	128.8	170.8	170.72	393.94
	II	118.55	167.6	171.18	430.45
	III	122.11	161.3	157.22	457.41
Jul	I	104.58	147.1	126.78	448.61
	II	93.46	127.4	104.3	432.4
	III	86.3	142.6	112.3	397.26
Aug	I	79.14	121.6	101.67	359.62

Month	10 Daily	Panjkora at Sharmai	Panjkora at Koto	Panjkora at Zulam Bridge	Swat at Chakdara
	II	66.55	97.2	103.27	307.69
	III	50.73	72.1	79.15	245.94
Sep	I	40.59	69.7	69.92	189.16
	II	32.73	56.9	55.88	149.24
	III	26.32	44.3	71.18	115.25
Oct	I	22.88	38.7	75.63	95.82
	II	20.2	35	66.78	89.69
	III	18.54	33.3	47.09	78.28
Nov	I	19.68	35.5	46.88	69.86
	II	19.46	33.6	43.98	64.56
	III	15.36	25.5	37.53	59.98
Dec	I	14.08	25.2	35.02	66.04
	II	13.17	25.4	34.77	55.63
	III	12.11	24.5	97.23	54.61

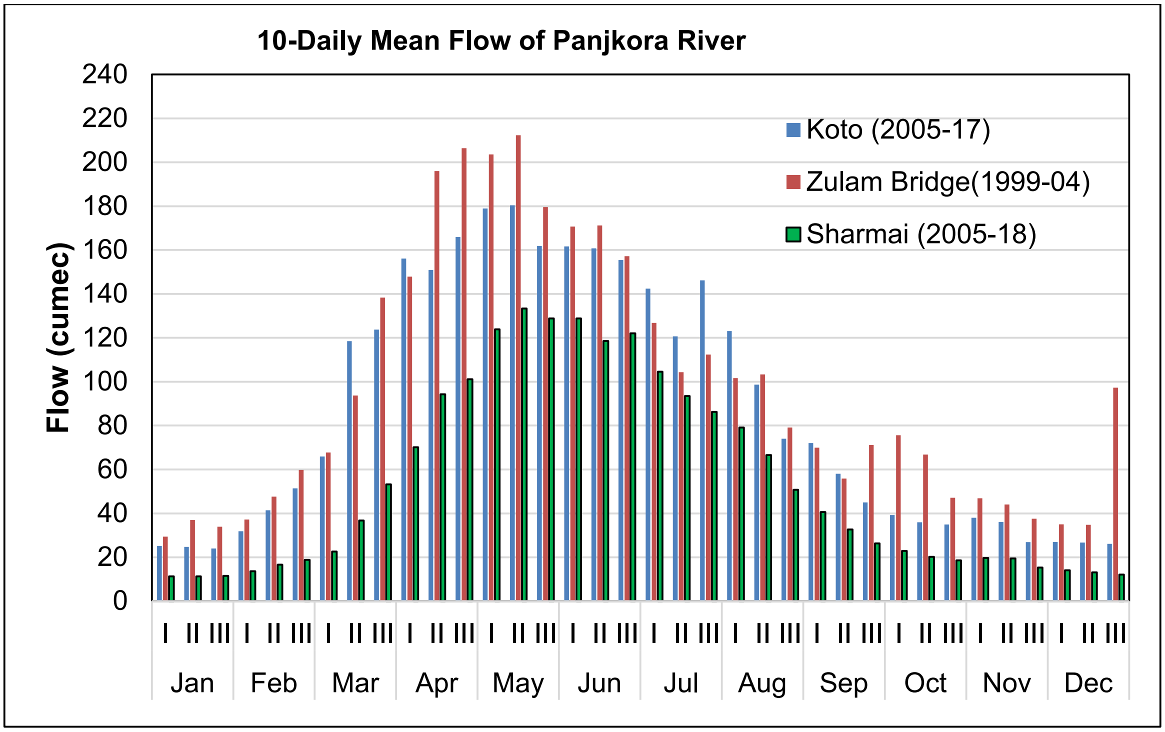

Figure 4-7: Average 10-Daily Flow of Panjkora River

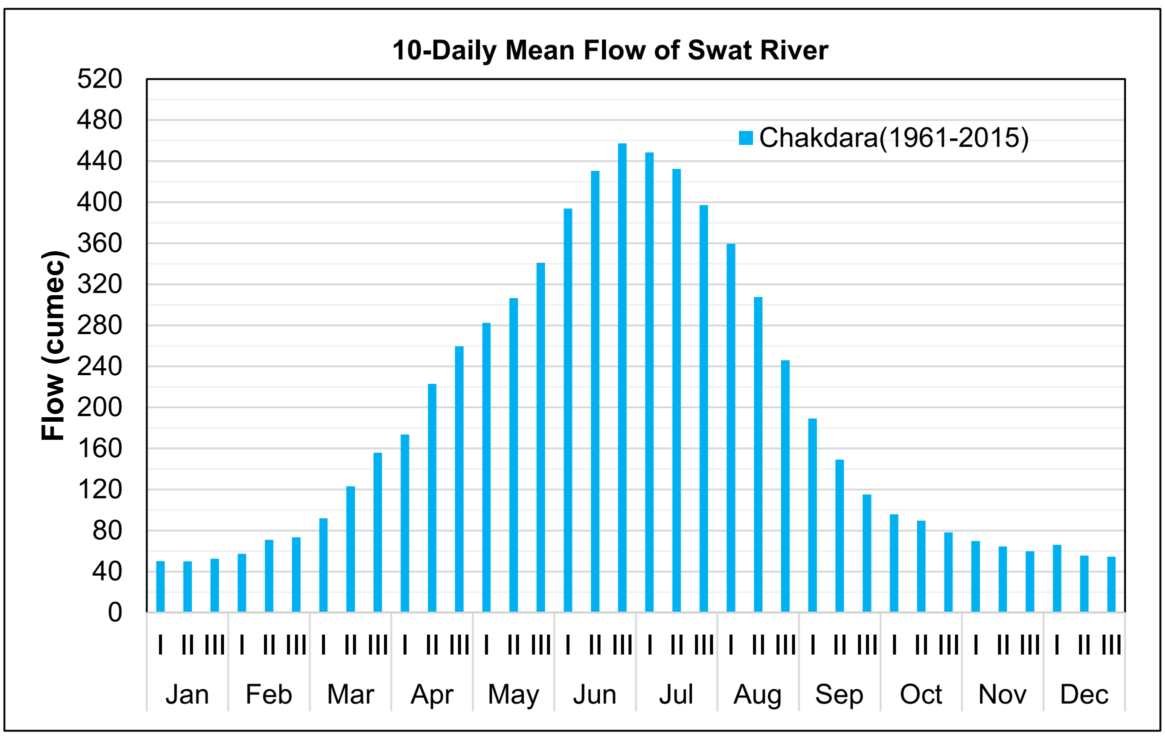

Figure 4-8: Average 10-Daily of Swat at Chakdara

4.1.3 GAUGING STATIONS UNDER THE PROJECT

Installation of stream gauge is one of the tasks as mentioned in the terms of reference. Four staged stream gauge was installed on January 29, 2019 approximately 4.3 km downstream of the proposed weir (W4) location on the right bank of river and about 40 m upstream of existing bridge of Sahibabad Village. The Google earth coordinates of the stream gauge location are 35° 04' 1.82'' N, 71° 59' 20.28'' E.

The stream flow measurements are being taken twice a month as per USGS standards using AA-type (vertical axis Gurley Current meter of USGS specification). For the stage reading of the gauge a local is hired on monthly basis to record the stream gauge three times a day.

- Morning at 8:00 am
- Noon at 12:00 pm
- Evening at 4:00 pm

The velocity observed at site was applied to the stream width and water depth to estimate the river flows. Measured flow at gauging station till date are tabulated below and detail calculations sheet is attached in **"Annexure-A6, Volume-VII".**

Table 4-4: Summary of Flow Measurement at Gauging Station

S. No.	Date	Discharge
1	January 29, 2019	14.097 cumecs
2	February 09,2019	18.041 cumecs
3	February 26, 2019	26.262 cumecs
4	March 9, 2019	38.278 cumecs
5	March 23, 2019	65.165 cumecs
6	April 7, 2019	173.593 cumecs
7	April 23, 2019	191.540 cumecs
8	May 5, 2019	129.823 cumecs
9	May 26, 2019	163.096 cumecs
10	June 09,2019	174.401 cumecs
11	June 25,2019	130.047cumecs
12	July 10,2019	169.635 cumecs
13	July 28, 2019	161.209 cumecs

Figure 4-9: Gauge Installation at Artistic-I HPP Site

Figure 4-10: Flow Measurements at Artistic-I HPP Site

Apart from the stream flows, suspended sediment samples are also collected using depth integrated suspended sediment sampler (D-49) and point sampler as per USGS standards. These suspended sediment samples are collected twice a month which will be sent to the laboratory for estimation of sediments contents.

Figure 4-11: Water Sampling at Artistic-I Site

4.1.4 WATER AVAILABILITY STUDIES

To estimate the water availability, a longer period of hydrological record must be available to rely upon. In case of Artistic-I Hydropower Project, daily flow record of Panjkora River at Sharmai and Koto Gauge stations is available on the records of Pakhtunkhwa Energy Development Organization (PEDO) for 14 years (2005-2018) & 13 years (2005-2017), respectively. While for the same river at Zulam Bridge gauge station records for the period of 8 years (1999-2006) are available on the record of Surface Water Hydrology (SWHP), WAPDA which is not sufficient to rely upon due to its availability for short periods. However, daily flow records of Swat River at Chakdara for the period of 55 years (1961 to 2015) are available on the records of Surface Water Hydrology (SWHP), WAPDA which can be used for the estimation of hydrological parameters for the Artistic-I Hydropower Project.

Mean 10-daily flow of Swat at Chakdara has been estimated 190.91 m^3/s, while for Panjkora at Koto it is just 87.81 m^3/s. 10-Daily flow of Swat River at Chakdara have been transposed to weir by mean 10-daily flow ratios at both gauging stations which is 0.46 instead of catchment area ratio of 0.54.10-Daily flow series of Swat at Chakdara from 1961 to 1998 have been generated from adjustment factor 0.46. From year 1999 onward, Panjkora at Zulam Bridge and Koto for 1999 to 2004 & 2005-17 have been transposed to weir by catchment area ratio. Generated flow series of Panjkora River at weir site is given in **"Annexure-A2, Volume-VII"** and mean 10-daily flow are tabulated below in **Table 4-5** and shown in **Figure 4-12** & **Figure 4-13**. Flow series generated from long term historic record of Swat River at Chakdara including limited year data of Panjkora River at Zulam, Koto etc. are recommended for design and power estimation.

Table 4-5: Estimated 10-Daily Flow of Panjkora River at Artistic-I HPP Weir Site

Month	10 Daily	Based on Chakdara Data (m^3/s)	Sharmai Data (m^3/s)	Koto Data (m^3/s)
Jan	I	18.7	19.6	22.3
	II	18.2	19.6	20.6
	III	19.6	19.9	20.4
Feb	I	21.3	23.6	26.8
	II	26.9	28.8	36
	III	29.8	32.6	44.4
Mar	I	38.1	39.2	54.1
	II	60.1	63.6	101

Month	10 Daily	Based on Chakdara Data (m^3/s)	Sharmai Data (m^3/s)	Koto Data (m^3/s)
	III	74.4	92.1	109
Apr	I	90.8	121.4	148.7
	II	106.3	163.3	141.1
	III	121.4	175.1	148.2
May	I	129.1	214.4	161
	II	135.1	230.8	164.4
	III	144.2	223.2	150.7
Jun	I	162.4	223	145.9
	II	173.8	205.3	143.2
	III	180	211.4	137.8
Jul	I	172.9	181.1	125.6
	II	165.1	161.8	108.8
	III	156.6	149.4	121.8
Aug	I	139.7	137	103.9
	II	116.7	115.2	83.1
	III	92.6	87.8	61.6
Sep	I	72.1	70.3	59.5
	II	55.9	56.7	48.6
	III	43	45.6	37.9
Oct	I	36.2	39.6	33.1
	II	33.5	35	29.9
	III	28.8	32.1	28.4
Nov	I	26.1	34.1	30.3
	II	24	33.7	28.7
	III	21.1	26.6	21.8
Dec	I	24.3	24.4	21.5
	II	20.2	22.8	21.7
	III	19.7	21	20.9
Period:		1961-2017	2005-18	2005-17

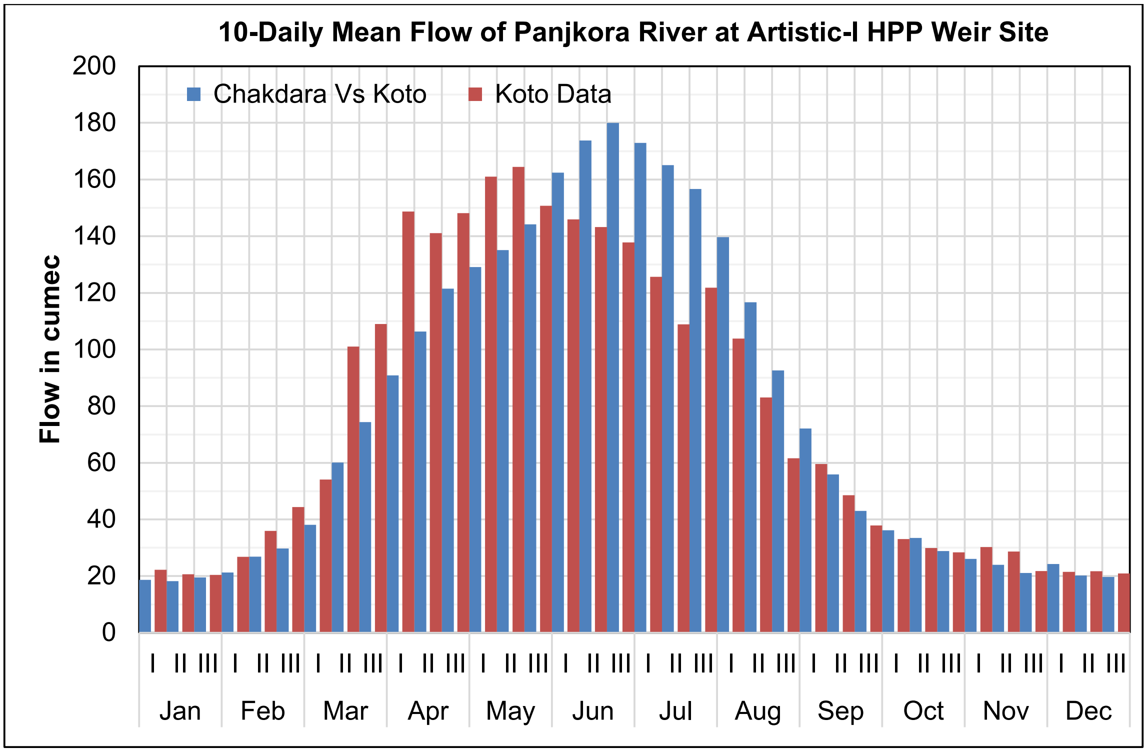

Figure 4-12: 10-Daily Mean Flow of Panjkora River at Artistic-I HPP Weir Site

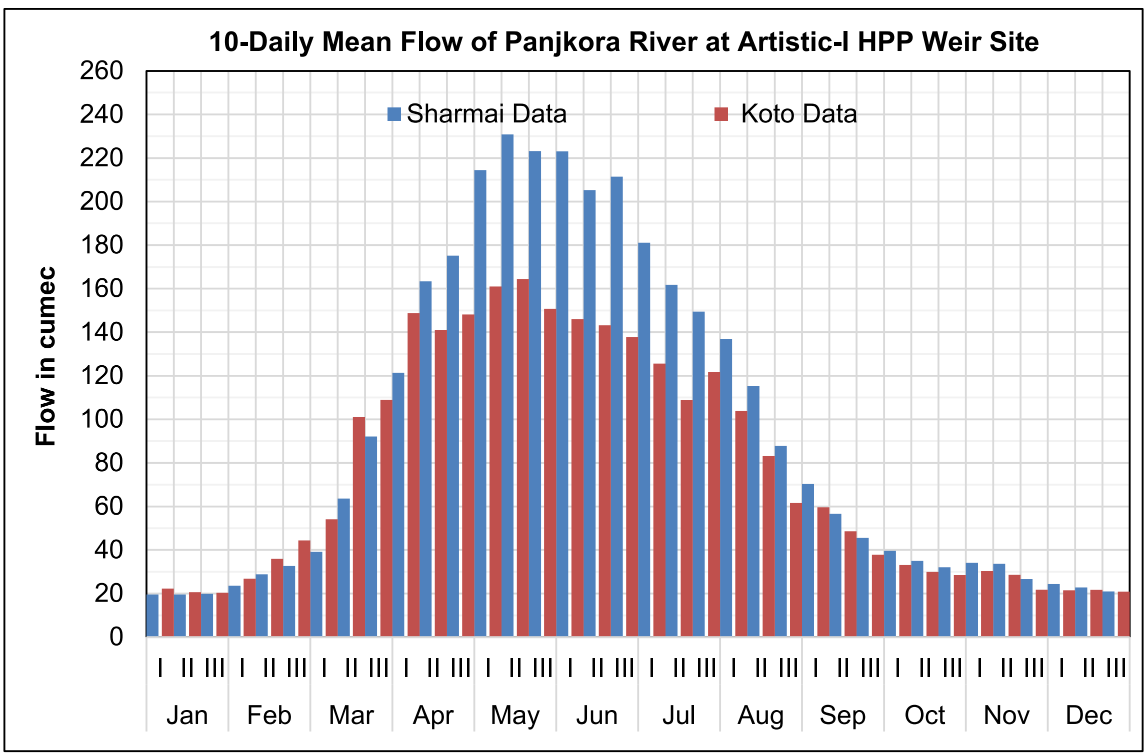

Figure 4-13: 10-Daily Mean Flow of Panjkora River at Artistic-I HPP Weir Site

4.1.5 FLOW DURATION CURVE

Availability of flows at the proposed weir/intake site was checked using detailed flow duration curve analysis. A flow duration curve (FDC) shows relationship between magnitude and frequency of stream flows for a particular river basin at a particular location. FDC provides estimation of cumulative percentage of time that a given quantity of flow is equaled to or exceeded which helps in planning and capacity sizing of a power plant. Flow series generated at weir from available record of Panjkora River at Koto, Sharmai and Chakdara have been used for flow availability against different exceeding probabilities as summarized and shown in figure below. FDC based on Chakdara Data is recommended for further use.

Table 4-6: Summary of Flow Availability Against Different Exceeding Probabilities

%	Based on Chakdara Data (m^3/s)	Sharmai Data (m^3/s)	Koto Data (m^3/s)
20.00%	138	165	132
22.50%	129	156	126
25.00%	121	145	120
27.50%	114	135	113
30.00%	**103**	**121**	**105**
32.50%	98	110	99
35.00%	89	98	90
37.50%	82	90	84
40.00%	74	83	77
45.00%	61	72	63
50.00%	**49**	**57**	**55**
55.00%	41	46	48
60.00%	34	40	41.5
65.00%	29	35	33
70.00%	26	30	30
75.00%	23	27	27
80.00%	20.5	24	23
85.00%	18.5	21	21
90.00%	16.8	19	17.5
95.00%	**15**	**16.5**	**14.8**
Period:	1961-17	2005-18	2005-17

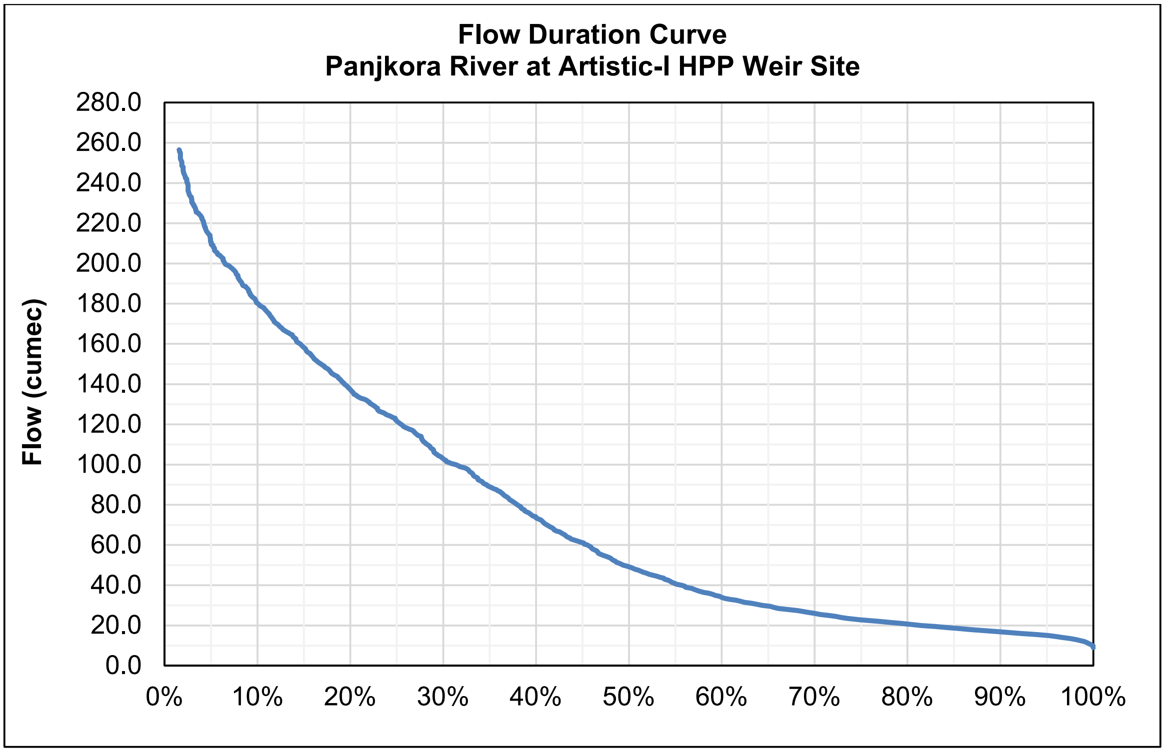

Figure 4-14: Flow Duration Curve of Panjkora River at Artistic-I HPP Weir Site

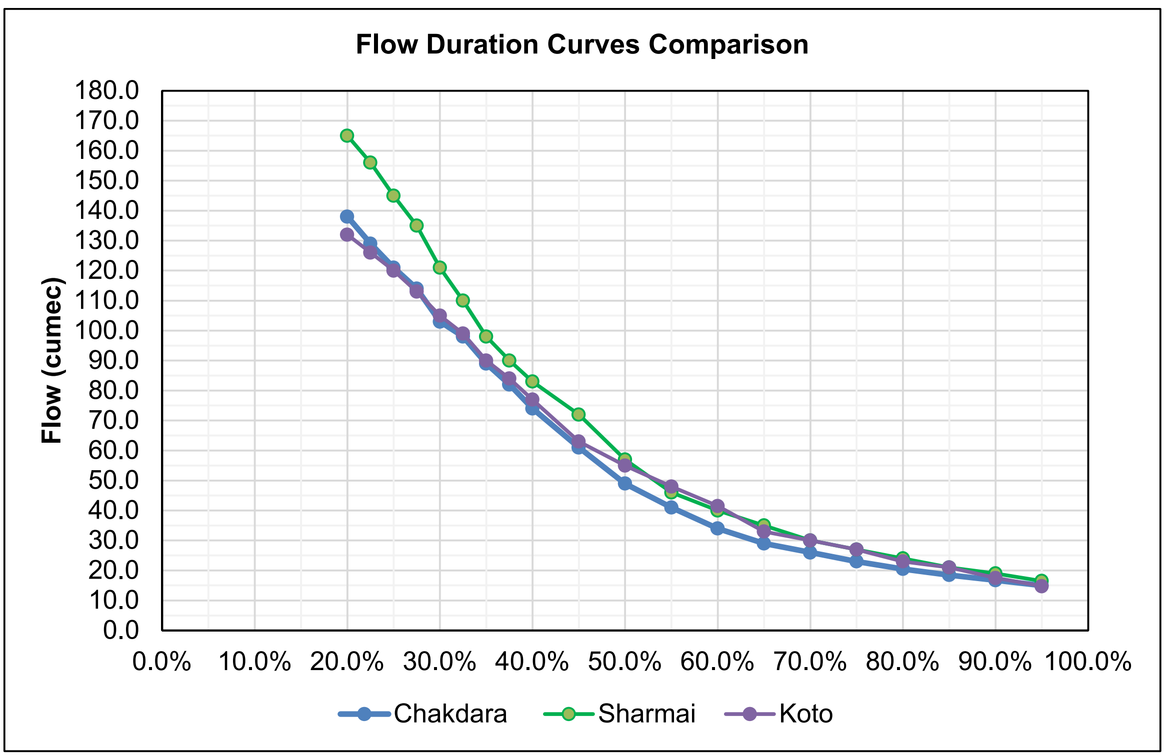

Figure 4-15: Flow Duration Curves of Panjkora River at Artistic-I HPP Weir Site

4.1.6 STAGE DISCHARGE RELATIONSHIP AT GAUGING STATION

Rating curves are mathematical functions relating measured flow and gauge record observed during the study period at gauging station. Gauge and measured flow are plotted and power curve is fitted as shown in **Figure 4-16**. Daily average gauges within project duration have been transferred into flow by power equation **"Annexure-A5, Volume-VII".**

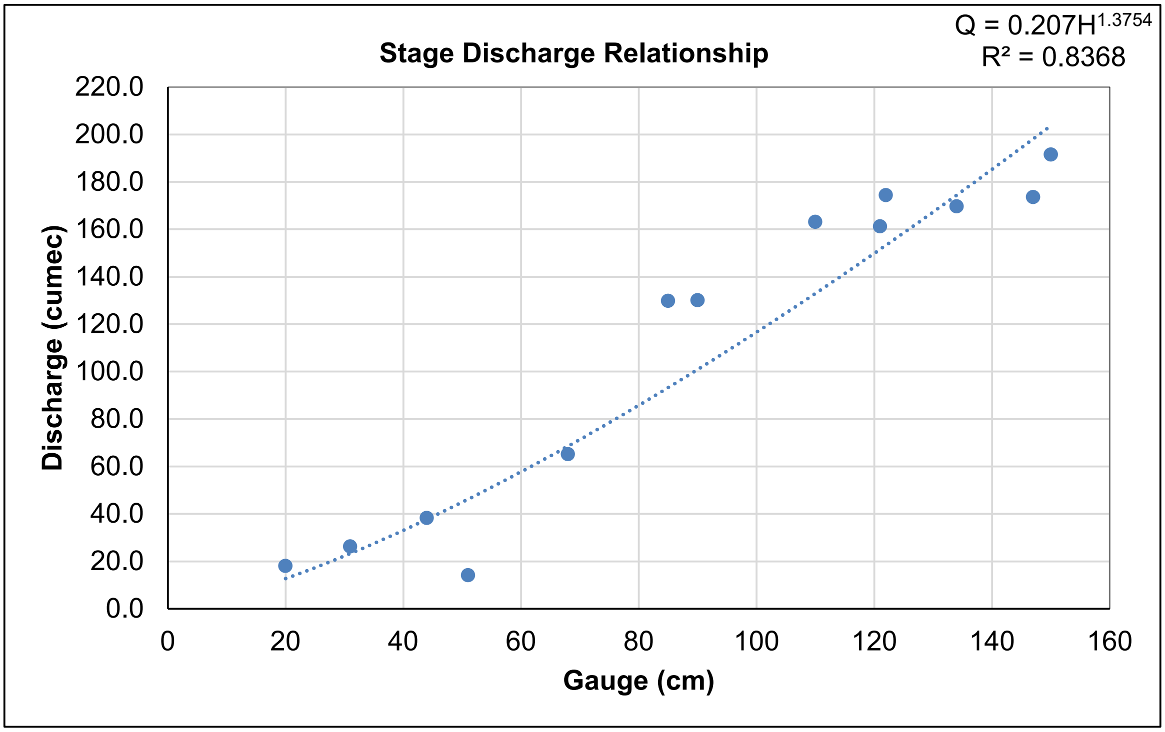

Figure 4-16: Stage Discharge Relationship

4.1.7 DESIGN FLOOD

Flood studies are carried out for planning and design as well as for checking the safety of hydraulic structures. To estimate the design flood at least thirty years of instantaneous flow data or precipitation data is normally required at the project location. In case of Artistic-I HPP, both does not exist and even further downstream at Koto and Zulam Bridge, the peak flood data do not exist.

For design flood estimation, two approaches are adopted.

a) Regional Based Envelope Curves
b) Hydro-meteorological approach based on rainfall-Runoff

Peak flood of other similar hydro-meteorological stations in the Regional enlisted below have been collected and compiled in excel. Flood frequency analysis of each gauging stations listed below are carried out and summary of results are tabulated below. Detail peak flood data is provided in **“Annexure-A3, Volume-VII”**.

Table 4-7: Regional Flood Peaks

Regional Flood Peaks(cumec)										
River	**Gauging station**	**years of Record**	**Period**	**Catchment Area**	**Return Period (yr)**					
				sq.km	**2**	**10**	**50**	**100**	**200**	**1000**
Siran	Phulra	43	1969-2012	1057	572	1127	1614	1820	2025	2500
Swat	Munda Dam Site	50	1960-2010	13650	1600	3010	4880	5900	7430	10670
Kunhar	Garhi HB	55	1960-2015	2383	566	1130	1625	1834	2042	2525
Ghorband	Korora	29	1975-2010	635	316	887	1387	1598	1809	2297
Swat	Chakdara	54	1961-2014	5770	881	2261	3471	3982	4492	5672
Regional Flood Peaks(cumec/sq.km)										
River	**Gauging station**	**years of Record**	**Period**	**Catchment Area**	**Return Period (yr)**					
				sq.km	**2**	**10**	**50**	**100**	**200**	**1000**
Siran	Phulra	43	1969-2012	1057	0.54	1.07	1.53	1.72	1.92	2.36
Swat	Munda Dam Site	50	1960-2010	13650	0.12	0.22	0.36	0.43	0.54	0.78
Kunhar	Garhi HB	55	1960-2015	2383	0.24	0.47	0.68	0.77	0.86	1.06
Ghorband	Korora	29	1975-2010	635	0.50	1.40	2.18	2.52	2.85	3.62
Swat	Chakdara	54	1961-2014	5770	0.15	0.39	0.60	0.69	0.78	0.98
Average specific flood (cumec per sq.km)					**0.309**	**0.710**	**1.070**	**1.226**	**1.389**	**1.761**
Weir- Flood estimation from average specific yield (cumec)				**3108**	**962**	**2206**	**3327**	**3811**	**4316**	**5474**
Weir - Flood from Envelop curves				**3108**	**736**	**1679**	**2523**	**2829**	**3459**	**4243**
Powerhouse- Flood estimation from average specific yield (cumec)				**3235**	**1001**	**2297**	**3463**	**3966**	**4493**	**5697**
Powerhouse - Flood from Envelop curves				**3235**	**750**	**1707**	**2567**	**2879**	**3527**	**4331**

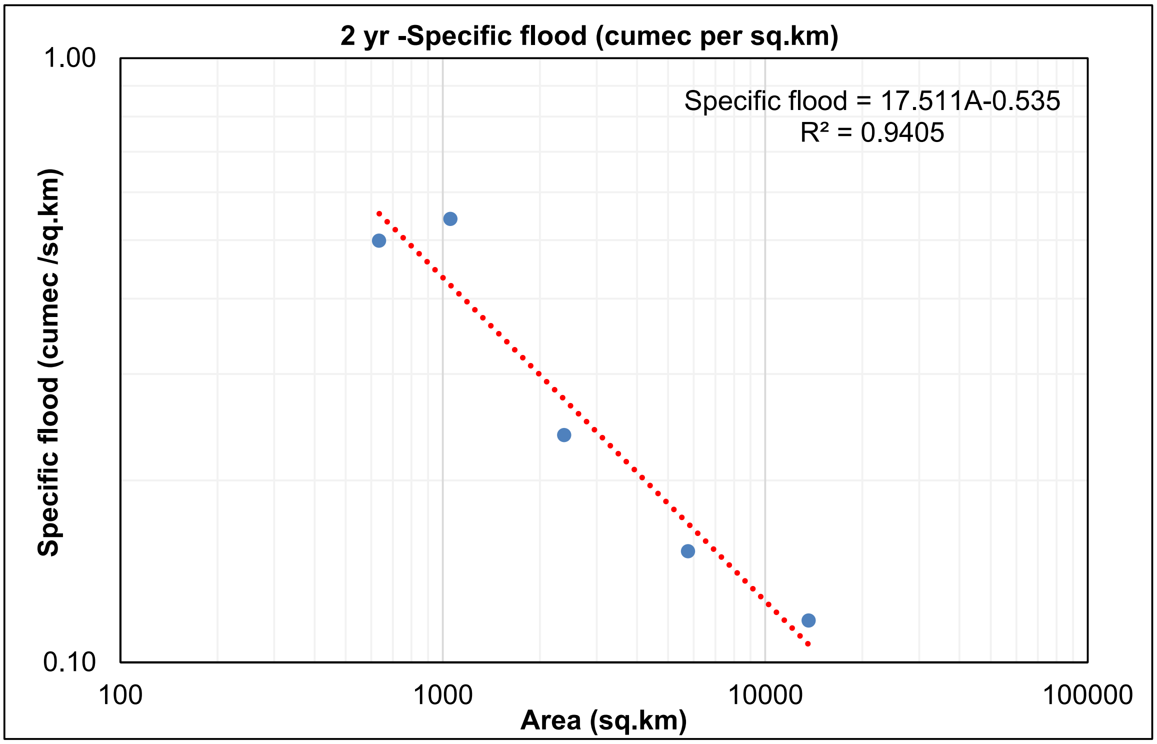

Figure 4-17: 2 yr -Specific flood

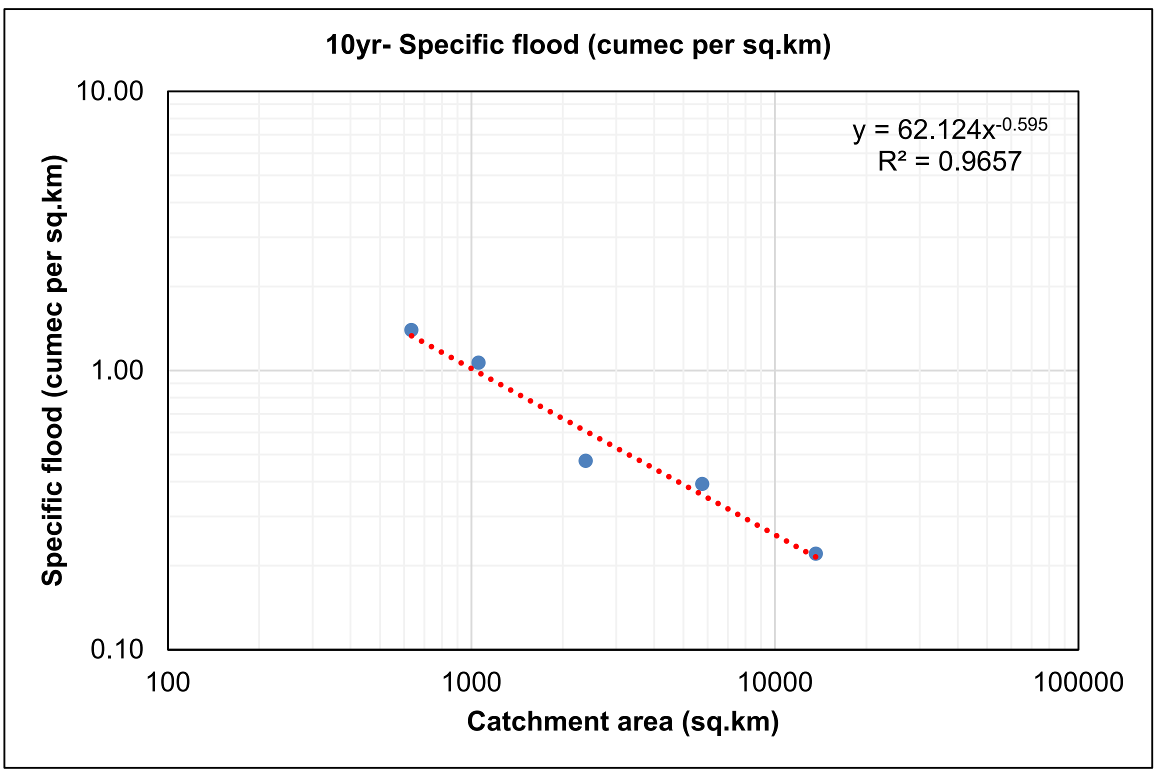

Figure 4-18: 10yr- Specific flood

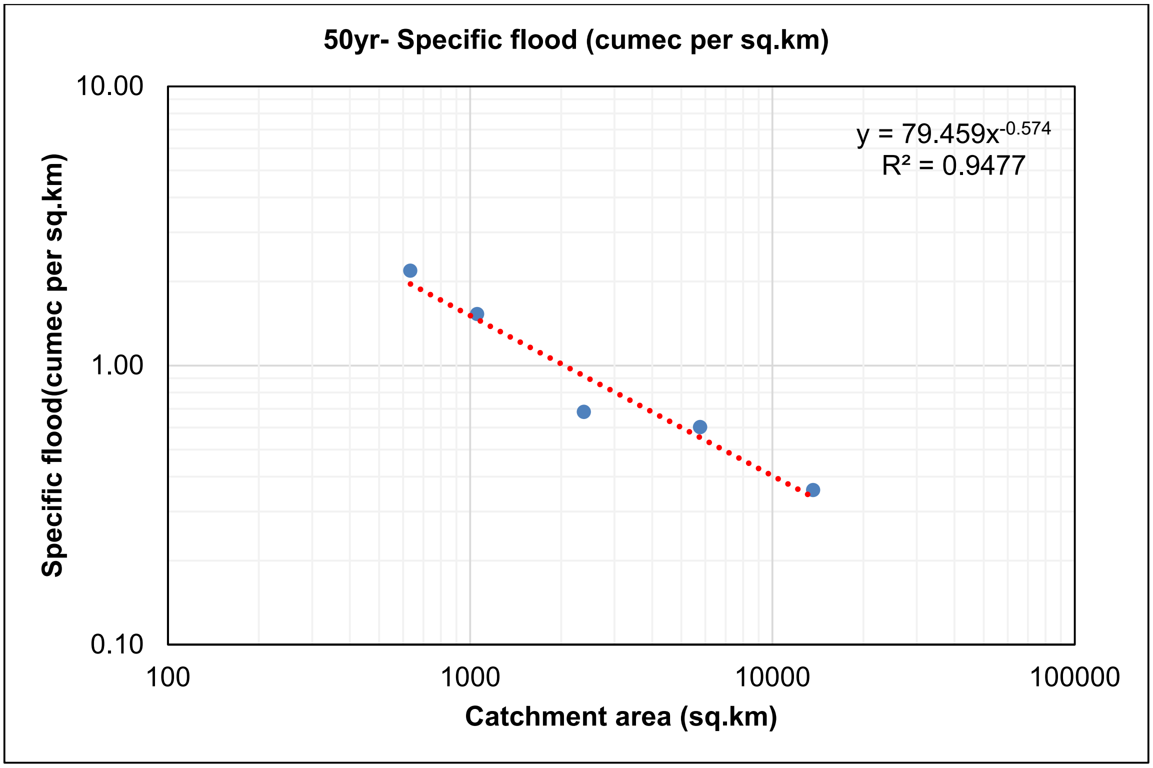

Figure 4-19: 50yr- Specific flood

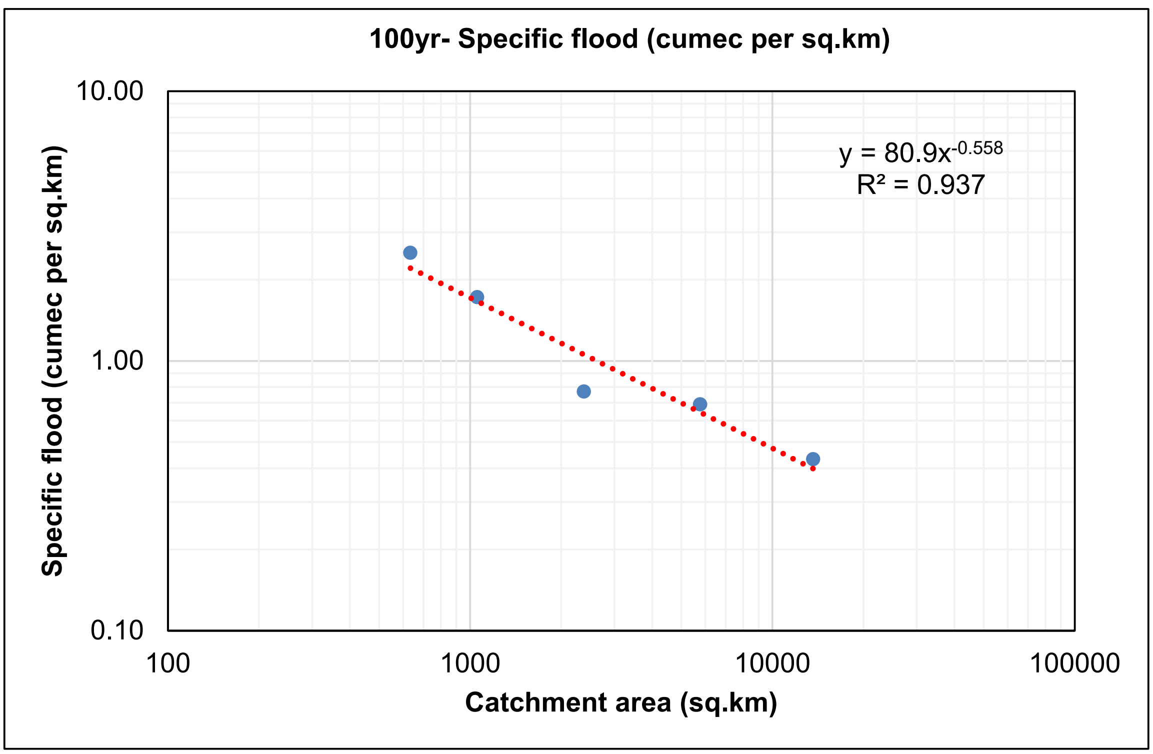

Figure 4-20: 100yr- Specific flood

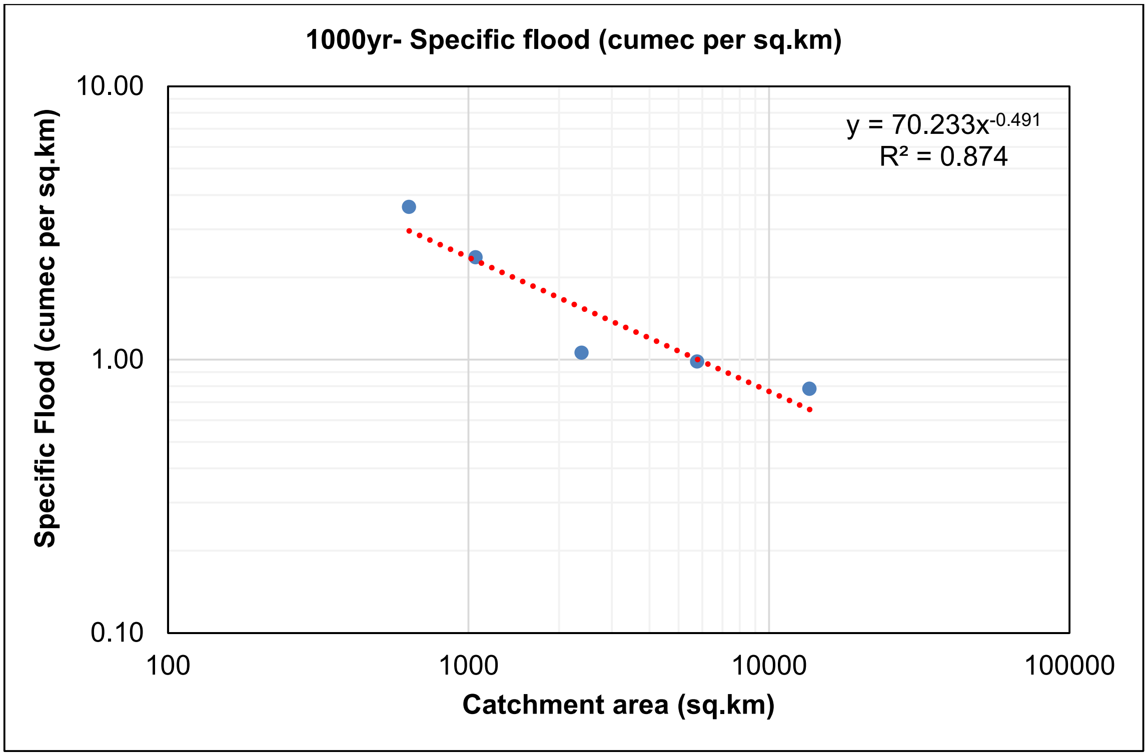

Figure 4-21: 1000yr- Specific flood

In hydro-meteorological approach, daily maximum rainfall data of climate station: Dir have been collected/compiled. Frequency analysis of the annual and flood season (April to September) have been carried out. Results of frequency analysis are tabulated below. Using unit hydrograph technique flood hydrographs for different return period are estimated.

Table 4-8: 1-Day Maximum Rainfall at Dir

	Annual	April to September
Year	Rainfall (mm)	Rainfall (mm)
1971	51	46.5
1972	80	79.8
1973	109	70.9
1974	57	51.9
1975	76	50.5
1976	59	59
1977	88	87.7
1978	118	74.1

	Annual	April to September
Year	**Rainfall (mm)**	**Rainfall (mm)**
1979	75	59.6
1980	95	94.5
1981	64	63.8
1982	74	49.1
1983	82	81.8
1984	92	48
1985	68	68
1986	102	70
1987	90	90
1988	78	59
1989	147	147
1990	68	60
1991	98	87
1992	98	52
1993	110	98
1994	95	95
1995	64	64
1996	57	57
1997	62	60
1998	65	65
1999	67	49
2000	53	45
2001	72	71.6
2002	66	27
2003	98	67
2004	166	45
2005	256	87

	Annual	April to September
Year	Rainfall (mm)	Rainfall (mm)
2006	80	80
2007	103	42
2008	76	76
2009	71	71
2010	149	149
2011	64	55
2012	49	28
2013	76	76
2014	84	46
2015	66	41
2016	98	64
2017	74	39

Table 4-9: Summary of Daily Maximum Rainfall (mm) Frequency Analysis Results

Return Period (Year)	Climate Station: Dir	
	Annual	April to September Rainfall (mm)
2	81	63
10	139	103
25	168	123
50	190	138
100	211	153
500	261	187
1000	282	202

Table 4-10: Design Flood (cumecs) from Rainfall-Runoff Model

Return Period (Year)	Maximum Rainfall (mm)	Weir	Powerhouse
		Flood (cumecs)	
2	63	578	602
10	103	1586	1651
25	123	2197	2287
50	138	2688	2798
100	153	3208	3339
500	187	4445	4627
1000	202	5011	5216

Table 4-11: Comparison of Design Flood (cumecs)

Approach	10	100	1000 year
Envelop Curve	1679	2829	4243
Rainfall-Runoff model	1586	3208	5011
Average regional flood yield	2206	3811	5474

As rainfall-runoff based estimated lies in between the estimated flood from regional based estimate, it is recommended for design purpose. Furthermore, the rainfall-runoff estimated flood included rainfall data of Dir and physical parameter of watershed i.e. time lag and curve number.

4.1.8 SEDIMENT INFLOW STUDIES

Sediment yields would be estimated using the sediment records of the relevant streams of the area. Historical data of the sediment is available at the Chakdara gauge station at Swat River while sediment samples for short duration are available at Koto and Zulam Bridge at Panjkora River. Detail data is provided in **"Annexure-A4, Volume-VII".**

As per suspended sediment record of Panjkora River at Zulam Bridge "the average sediment concentration is about 0.885 % (by weight) or 8850 ppm. The suspended sediment concentration increases with the discharge. The observed minimum concentration is 16 ppm and the observed maximum concentration is 48700 ppm. At average discharge the suspended sediment consists of about 16 % sand, 65 % silt and 21 % clay. The unit weight of fresh deposits of this sediment is about 62 lbs per. cft.

As per Swat River at Chakdara Record, annual suspended sediment yield is 2.38 million short ton. The average sediment concentration is 0.042 % (by weight) or 420 ppm. The average annual sediment yield is 0.868 ac.ft. per sq. mile of drainage area. The computed maximum concentration is about 13,700 ppm while the observed maximum concentration is about 25700 and the minimum observed concentration is 2 ppm. Suspended sediment consists of approximately 8 % sand, 71 % silt and 21 % clay. Unit weight of fresh deposits shall be about 60 lbs per c.ft.

Estimated suspended sediment load is 1039 acre-ft per annum or 412 cubic meter per square kilometer. Including 20 % bed load total sediment load at weir is 1.54 million cubic meters (1248 acre-ft).

Apart from the historical available data, Artistic-I gauge station has been installed the stream gauge downstream of the weir location where water samples are collected twice a month. The samples are sent to the laboratory for the estimation of sediment content and gradation analysis. Results are attached as **"Annexure-A7, Volume-VII".**

CHAPTER

5

GEOLOGY & GEOTECHNICAL INVESTIGATIONS AND CONSTRUCTION MATERIALS

CHAPTER 5

GEOLOGY & GEOTECHNICAL INVESTIGATIONS AND CONSTRUCTION MATERIALS

5.1 INTRODUCTION

This section presents the geological and geotechnical studies conducted as part of the feasibility study of the Artistic-I Hydropower Project. The studies comprise regional geological and tectonic frame work of the project area, detailed geological/ engineering geological studies, geotechnical & geophysical investigations and evaluation of the geotechnical parameters and assessment of the geotechnical conditions at important structures' locations together with the assessment of rock conditions along the tunnel and adit alignments. Also, a brief description of the construction materials has been given at the end of this section.

5.1.1 PROJECT INFORMATION

The Artistic-I project is proposed in Upper Dir District about 34 km from Timergara city. The weir is proposed on Panjkora River near Darora village while Powerhouse is proposed downstream of Sahibabad town along Peshawar- Dir road (drawing no. A1HP-FS-GE-GNL-DWG-200). The latitude and longitude of the weir site are 35°5'52.77" and 71°59'0.08" respectively. The Artistic-I Weir structure is proposed up to of 10 m height from River bed elevation. The River bed elevation is 1061 masl. Panjkora River is main river of the Dir valley that originates from Upper Dir catchment area. Both weir and powerhouse sites are along Peshawar- Dir road. Since the scheme is along the right bank, small foot or jeepable bridges are available to get to both sites. Two tunnels, free flow tunnel (about 1.6 Km long) and headrace tunnel (about 7.4 km long) have been proposed along with box channel. Desander is proposed between the free flow tunnel and the headrace tunnel (HRT). Another important structure along the HRT is cut and cover tunnel section that has been proposed along a deep cut stream day lighting the tunnel alignment. The surge shaft is proposed at the end of HRT near its outlet portal, which will be provided with surface penstock leading to surface powerhouse along the right bank of Panjkora River.

5.1.2 PREVIOUS STUDIES

No geological mapping of the proposed scheme was undertaken in the past. Only available studies are regarding the downstream scheme named Koto Hydropower Project. As part of the feasibility of the project, some geological studies have been undertaken. Since this scheme is downstream of the proposed Artistic-I Hydropower Project (A1HP), the available information is of no or little use. However, geological maps produced by the Geological Survey of Pakistan (GSP) were found helpful in perceiving regional geological setting.

Likewise, no geotechnical investigations including field investigations and laboratory testing were undertaken previously providing a basis for the detailed geotechnical investigations as part of the feasibility study.

5.1.3 PRESENT STUDIES

The present studies were aimed at preparing a detailed Feasibility Report of Artistic-I Hydropower Project (A1HP), based on sufficient surface and subsurface studies and investigations, comprising the followings;

5.1.3.1 GEOLOGICAL STUDIES

Regional geological studies based on the literature and field verification, detailed geological and engineering geological mapping, recording of structural information and characteristics, and execution of discontinuity surveys (DS) for rock characterization with necessary sampling at representative location for the identification of various rock units.

Geological studies were planned as part of the feasibility study of Artistic-I HP, in which, regional as well as engineering geological mapping was considered mandatory together with picking up rock structures' information through discontinuity surveys. These studies were to be used for onward rock characterization and classification for the design of various surface and underground structures. Engineering geological mapping at 1:2000 scale was conducted for weir, power channel and Intake structure for free flow and headrace tunnels, and for surge, tunnel outlet, penstock and powerhouse areas. Along the tunnels' routes, the mapping was conducted at scale 1:5000 and 1:4000. Besides geological mapping, 21 discontinuity surveys were conducted along with necessary geological sampling for the petrographic analyses to identify the rock units. The summaries of all the discontinuity surveys are attached as **Annexure B1, Volume VII** of the Feasibility Report and the locations of the discontinuity surveys are marked on the respective geological maps. The field data have been provided location wise in **Annexure B2, Volume VII**. The discontinuity surveys' data was plotted for stereographic projection using computer code DIPS (Rocscience) for the identification of the pronounced discontinuity sets. As part of geological mapping, petrographic analyses were undertaken in University of the Peshawar to identify the rock types. These rock types were used to finalize the geological units in the mapping. The results of the petrographic analyses are attached as **Annexure B3, Volume VII** of the Feasibility Report.

5.1.3.2 GEOTECHNICAL INVESTIGATIONS

Geotechnical investigations consisted of drilling of twenty-one (21) boreholes together with necessary in-situ testing and sampling, excavation of fifteen (15) test pits for foundation design and construction material evaluation. Necessary sampling and in-situ testing were conducted in all test pits. Laboratory testing programs were prepared, and laboratory testing was conducted on the selective and representative samples of soil and rock from boreholes and test pits and rock outcrops. Geotechnical investigations (field part) have been carried out by M/s Geo-consult Associates Lahore. The laboratory testing was undertaken in the geological and geotechnical laboratories of University of the Peshawar.

As part of the geotechnical investigations, geophysical investigations comprising seismic refraction surveys were also carried out at locations of important project components. The geophysical investigations were also carried out by M/s Geo-consult Associates Lahore.

All the geotechnical and geophysical data have been provided in the **Annexures B4-B8, Volume VII** of the Feasibility Report while details and interpretation of the field investigations and laboratory testing have been discussed in this report.

5.1.3.3 CONSTRUCTION MATERIAL STUDIES

The construction materials studies were aimed at to have assessment of the construction materials both available in the vicinity of the project area and those that have to be transported from other areas. These studies included the reconnaissance of the project area and adjoining areas together with geological mapping and excavation of test pits for the estimation of the available materials.

All the field geological and geotechnical investigations for Artistic-I Hydropower Project have been completed from October 2018 through to February 2020. The details of the studies and investigations are discussed in the following sections.

5.2 GEOLOGICAL MAPPING OF THE PROJECT AREA

The geological and tectonic setting of the project area has been conceived based on the available geological literature (GSP 2006) and supplemented by latest geological, structural and stratigraphic information recorded during field studies. At the important project components, engineering geological mapping was undertaken on base maps prepared by superimposing topographic data on free available satellite images. Geological contacts among soil and rock units were marked on the base maps together with the recording of information about the geological structures. The field geological maps have been finalized in GIS and/ or

AutoCAD environment to be used for onward geotechnical evaluation and design activities. Similarly, at important project locations, subsurface geological sections have been prepared based on the surface geological information and recorded structural geological features. The details of drawings prepared based on the geological mapping and interpretation are provided below. It should be noted that these drawings have also been updated on the basis of outcome of geotechnical and geophysical investigations. All the locations of investigation points and lines have also been provided on respective drawings.

A1HP-FS-GE-GNL-DWG-200	Project Layout Plan
A1HP-FS-GE-GNL-DWG-201	Regional Geological Map
A1HP-FS-GE-GNL-DWG-202	Physiographic Map of the Project Area
A1HP-FS-GE-GNL-DWG-203	Geological Map of the Project Area (2 Sheets)
A1HP-FS-GE-WR-DWG-204	Geological Map of the Weir, Intake and Box Channel
A1HP-FS-GE-WR-DWG-205	Geological Section along Weir Axis and Box Channel
A1HP-FS-GE-TNL-DWG-206	Geological Map of the Free Flow Tunnel
A1HP-FS-GE-TNL-DWG-207	Geological Section along Free Flow Tunnel
A1HP-FS-GE-ST-DWG-208	Geological Map of the Sand Trap and Box Channel
A1HP-FS-GE-ST-DWG-209	Geological Section along Sand Trap
A1HP-FS-GE-FB-DWG-210	Geological Map of the Box Channel, Inlet Pond and Intake of Headrace Tunnel
A1HP-FS-GE-FB-DWG-211	Geological Section along the Inlet Pond and Intake of Headrace Tunnel
A1HP-FS-GE-TNL-DWG-212	Geological Map and Section of Headrace Tunnel (4 Sheets)
A1HP-FS-GE-TNL-DWG-213	Geological Map and Section of Cut & Cover HRT Section at Kotkay Khwar
A1HP-FS-GE-TNL-DWG-214	Geological Map and Section of the Adit Tunnel
A1HP-FS-GE-PH-DWG-215	Geological Map of Powerhouse Facilities
A1HP-FS-GE-PH-DWG-216	Geological Section along the Powerhouse Facilities
A1HPP-FS-GEO-TNL-DWG-0500	Excavation Support Types for Free Flow Tunnel
A1HPP-FS-GEO-TNL-DWG-1100	Excavation Support Types for Headrace and Adit Tunnels
A1HPP-FS-GEO-SS-DWG-1300	Excavation Support Type for Surge Shaft

5.2.1 REGIONAL GEOLOGY AND TECTONICS AROUND PROJECT AREA

The tectonic setting of Northern Pakistan is characterized by the collision of Eurasian Plate in the North and Indian Plate in the South. This collision started in Late Eocene (50 Ma) and is still continuing in the region. The continuous subduction of the Indian plate under the Eurasian plate has given rise to the mega features such as Main Karakoram Thrust/ Fault (MKT/ MKF) in the North and Main Mantle Thrust (MMT) or Indian Suture in the South. The Kohistan Island Arc (KIA) occupies the area between these two mega features. The Himalayan orogeny in the form of northward movement and subduction of the Indian Plate has given rise to numerous other tectonic features like Hazara Thrust Fault System, Main Boundary Thrust (MBT), Main Frontal Thrust (MFT) / Riasi Thrust and the Kashmir Thrust.

The project area lies in the upper part of the Dir valley i.e. Dir Kohistan, which is a part of the "Kohistan island arc": This arc covers an area of about 36000 km^2 and is bounded by the geological units of Hazara, Diamir, Gilgit and Chitral. Evidence of the outpouring of lavas on a great scale can be seen by the presence of volcanic rocks forming two parallel arcs; one running along the northern margin of Kohistan and the other forming a bold and continuous outcrop in the vicinity of Kalam and extending south-westward towards Bajaur in Dir. Geomorphologically, Kohistan is characterized by rugged terrain and very high relief; the mountains have a general east - west trend.

According to the regional geological map after Jagoutz & Schmidt 2012 (**Figure 5.1**), the Kohistan arc is bordered by the Hindukush-Karakoram belt in the north.

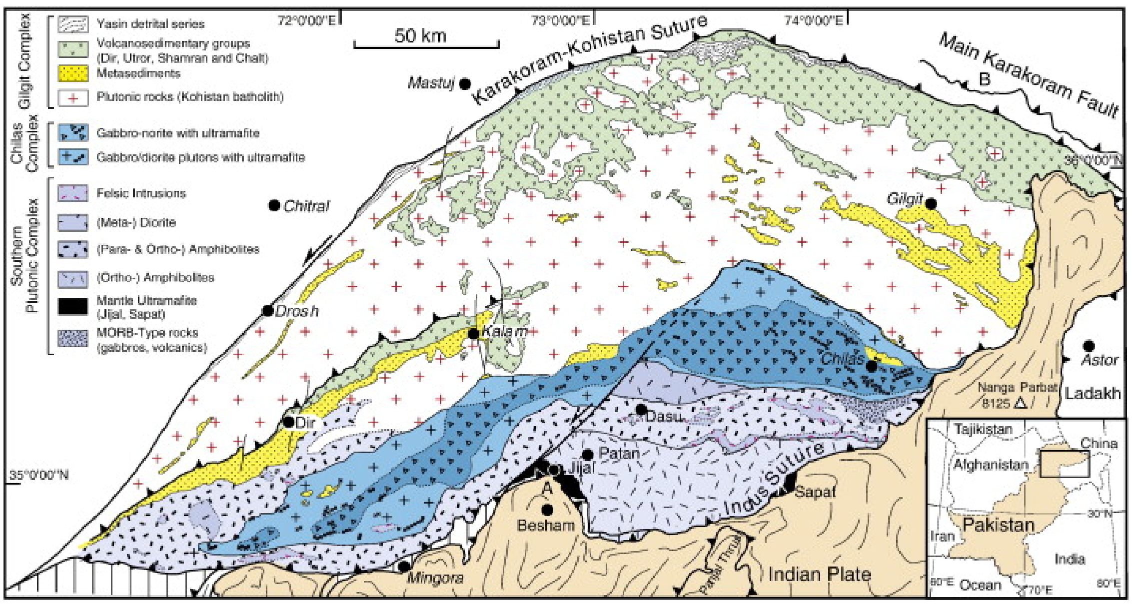

Figure 5.1: Geological map of the Kohistan arc (after Jagoutz & Schmidt 2012)

In this belt, the rocks are of Jurassic to Paleozoic age and consist of the Darkot-Karakoram metamorphic complex. In the east is the Nanga Parbat and on the south and south- east lies the Peshawar - Kashmir zone. The rocks bordering the Kohistan arc in this area belong mainly to the Pre-Cambrian Indian basement complex. The geology and rocks which are exposed in the Kohistan arc and the adjoining area can be briefly described as follows:

- Meta-sedimentary rocks of Mesozoic to Paleozoic age which lie in the eastern part.
- Kamila amphibolites and Mafic and ultramafic complex. These are Jurassic rocks which are located in the southern region.

- Chalt volcanics and the Yasin group in the northern part and Chilas complex in the southern part. These are Cretaceous to Jurassic rocks.
- Dir metasediments of Paleocene to late Cretaceous age which are found in the south-western part.
- Kohistan - Ladakh batholith and associated plutons of Miocene to Cretaceous age. These also contain smaller bodies of mafic Intrusive rocks with felsic associates of a much younger Tertiary age.
- Utror Volcanics are early Eocene to Paleocene rocks which are found in the western portion of the arc.
- Matiltan Granite of Miocene age rocks, shown in the map as plutonic rocks block, are present in the western portion of the arc.

5.2.1.1 STRATIGRAPHY AND LITHOLOGY

The regional geological setting around project area has been interpreted based on the geological maps of Dir and Nashnamal quadrangles, District Dir and Swat after Haq et al (2006), Geological survey sheets 38M/16 & 43A/4, at scale 1:50,000, published by Geological Survey of Pakistan (GSP). Composite map has been reproduced at scale 1:50,000 and provided as Drawing No. A1HP-FS-GE-GNL-DWG-201. The stratigraphy around the project area is summarized in the following table and is briefly described in the following sections. The distribution of these formations is shown on regional geological map attached as Drawing No. A1HP-FS-GE-GNL-DWG-201.

<table>
<tr><td rowspan="2">Quaternary</td><td colspan="2">Alluvial Deposits (Qal)</td></tr>
<tr><td colspan="2">Terrace Deposits (Qt)</td></tr>
<tr><td>Miocene</td><td colspan="2">Lawari Pluton (Tlp)</td></tr>
<tr><td>Late Eocene</td><td rowspan="3">Dir Group</td><td>Utror Volcanics (Tuv)</td></tr>
<tr><td rowspan="3">Paleocene to Early Eocene</td><td>Barawal Banda Slates/ Phyllites/ Schists (Tbp)</td></tr>
<tr><td>Barawal Banda Quartzite (Tbq)</td></tr>
<tr><td colspan="2">Shandur Granodiorite (Ksg)</td></tr>
<tr><td rowspan="3">Middle to Late Cretaceous</td><td colspan="2">Barawal Banda Meta-volcanics (Kbm)</td></tr>
<tr><td colspan="2">Deshai Diorite (Kdd)</td></tr>
<tr><td colspan="2">Banded Amphibolite (Mzb)</td></tr>
</table>

5.2.1.1.1 QUATERNARY DEPOSITS

- **Stream Deposits**

Stream deposits comprise gravels, cobbles and boulders with fine to coarse sand. The deposition is on-going process with the perennial and non-perennial streams. These cover the stream and river beds of active channels.

- **Alluvial deposits**

These are old river or stream deposits making terraces along the valley slopes. These deposits comprise gravels, cobbles and boulders embedded in silty sandy matrix. Most of the settlements are situated on these deposits. The top layer of these deposits comprises fine materials and therefore are being used for cultivation.

5.2.1.1.2 LAWARI PLUTON (TLP)

Lawari Pluton is of Miocene age and comprises light to dark grey, fine to medium grained granite, granodiorite and diorite with occasional pegmatite, quartz veins, aplite sills and dykes. These rocks are exposed in northwest of Dir town.

5.2.1.1.3 DIR GROUP ROCKS

Dir Group Rocks comprise Utror Volcanics (Tuv), Barawal Banda Slates/ Phyllites/ Schists (Tbp) Barawal Banda Quartzite (Tbq) and are believed to have Paleocene to early Eocene aged. The details of rock units are discussed in the following sections.

5.2.1.1.4 UTROR VOLCANICS (TUV)

Utror Volcanics were believed to be deposited in late Eocene. These are volcanic rocks comprising andesite, dacite, rhyolite with tuffs, agglomerate and pyroclasts. The color varies as grey, green, maroon red and at places white with fine to medium grained texture. Utror volcanic rocks are exposed in northeast of the Dir town making a slim belt that extends both northeastward and southwestward.

5.2.1.1.5 BARAWAL BANDA SLATES/ PHYLLITES/ SCHISTS (TBP)

Utror volcanics are underlain by Barawal Band metasediments comprising slates, phyllites and schists. Their age has been interpreted as early Eocene. The rock units in this formation comprise grey, green and maroon in color, thinly bedded, fine to very fine grained textured, interbedded with occasionally silty phyllites, schists and slates. Occasional beds of light grey thinly bedded limestone are also present at places. These rock units are exposed in the north and south of Dir town and extend both in northeast and southwest directions (Drawing No. A1HP-FS-GE-GNL-DWG-201).

5.2.1.1.6 BARAWAL BANDA QUARTZITE (TBQ)

Barawal Banda Quartzite is overlain by Barawal Banda metasediments (i.e. Slates, phyllites & schist). Its age is Paleocene and mainly comprises light to dark grey on fresh surface and brownish grey on weathered surface quartzite. It is found as thinly to thickly bedded with fine grained texture. Chert patches are also present in places. Quartzite is exposed south of the Dir town and north of the Darora village (Drawing No. A1HP-FS-GE-GNL-DWG-201). This has also extension in northeast and southwest directions.

5.2.1.1.7 SHANDUR GRANODIORITE (KSG)

Shandur Granodiorite consists of light grey to brownish in colour, medium grained, hard and massive granite and granodiorite present as plutons in the preexisting rocks. This formation is believed to have early Paleocene age. A massive unit is exposed along the Peshawar-Dir Road upstream of Darora village (Drawing No. A1HP-FS-GE-GNL-DWG-201). This also has massive exposures in the east and south east of the project area. Minor intrusions are laying also in the project area in Banded Amphibolite (MZb) both upstream side near Darora village and south of Sahibabad village. The rock is massive and hard. In the east of the project area, Shandur Gandodiorite has intrusions in the Massive Amphibolite (Mzm) as shown in Drawing No. A1HP-FS-GE-GNL-DWG-201.

5.2.1.1.8 BARAWAL BANDA META-VOLCANICS (KBM)

The Mesozoic (Late Cretaceous) rocks comprises of metamorphosed basaltic flows. These rocks are brownish and dark brown in colour and are not exposed in project vicinity. A thin belt of these rocks is present in the west of the project area (Drawing No. A1HP-FS-GE-GNL-DWG-201) extending northeast and southwest direction between Barawal Banda Slates, Phyllites & Schist (Tbp) and Barawal Banda Quartzite (Tbq).

5.2.1.1.9 DESHAI DIORITE (KDD)

Deshai Diorite comprises grey, greenish grey, medium to coarse grained diorite composed of plagioclase, hornblende, biotite with subordinate quartz, hornblended pegmatites and quartz veins. Deshai Diorite is exposed in the north of the Dir between Lowari Pluton (Tlp) in the west and Utror Volcanics (Tuv) in the east, and also in west- southwest of the project area with Banded Amphibolite (Mzb). No exposure of this rock is in vicinity of the project area (Drawing No. A1HP-FS-GE-GNL-DWG-201).

5.2.1.1.10 BANDED AMPHIBOLITE (MZB)

Banded Amphibolite is believed to be of Middle Cretaceous age and is underlain by Shandur Granodiorite in the project area and also by the Barawal Banda Quartzite (Tbq) and so on. It shows light to dark green color on fresh surface and is gray to brown on weathered surfaces. It is generally fine to medium grained, foliated and composed of plagioclase, hornblende and quartz minerals. In the project area, this is widely exposed rock formation, it is massive to foliated and crushed in places. Most of the project components will be placed on this rock unit.

5.2.1.1.11 MASSIVE AMPHIBOLITE (MZM)

Massive Amphibolite is believed to be of Late Cretaceous age and is underlain by Shandur Granodiorite and by Banded Amphibolite (Mzb) in the east of the project area. It shows dark gray to brownish gray on fresh surface and is brown on weathered surfaces. It is generally fine to medium grained, massive and composed of plagioclase, hornblende, epidote, biotite and minerals.

5.2.1.2 Regional Structures around Project Area

In and around project area, exposed rock units have generally northeast-southwest trend dipping into northwest. In the vicinity of the project area, a regional fault named as Shandur Thrust is present about 12-14km in the north of the project area (Drawing No. A1HP-FS-GE-GNL-DWG-201). This thrust fault has been marked by the Utror Volcanics (Tuv) group of rocks in southeast while by Kalam Quartz Diorite associated with meta sediments (Kkd) in the northwest. The fault is dipping towards the northwest and is directed northeast-southwest ward. In the geological map produced by GSP, the contact of Kalam Quartz Diorite and Utror Volcanics (Tuv) has also been shown as faulted. This thrust fault has also the same orientation as that of Shandur Thrust (Drawing No. A1HP-FS-GE-GNL-DWG-201). Both these faults are located about 12-14 km in the northwest of the project area and therefore may have little impact on the rock mass behavior.

About 2km downstream of the Sahibabad village near powerhouse site, a pronounced regional feature is anticline having trend in northeast-southwest. Further 3km downstream, a syncline has been interpreted by GSP that has curvy trend in northeast-southwest direction nearly parallel to anticline. Since all the rock units of Banded Amphibolite (Mzb) and Shandur Granodiorite (Ksg) follow the same trend, these are believed to have happened after Paleocene to early Eocene (The youngest age of Ksg)

Generally, foliation is well-developed throughout the project area from powerhouse to weir site. Mostly rock units have trend northeast-southwest dipping in the northwest at steep to very steep angles with localized variations in the dip directions. Two to three joint sets with random joints have been identified during recent field studies in addition to foliation. However, downstream of Sahibabad village near proposed powerhouse site, presence of consecutive anticline and syncline has resulted the variation of dip direction from northwest to southeast on the southern limb of the anticline and northern limb of syncline.

5.2.2 Project Area Geology

5.2.2.1 Project Area Physiography

The topography of study area is rugged hilly terrain with low to moderate relief with slope gradient in nullah bed is about 3 to 5%. Panjkora river flows southward in broad valley having mostly foot hill slopes that are rolling to moderate high. Behind the foothill slopes high and moderately steep to steep rock slopes are present resulting to moderate to high relief. A physiographic map of the Project area has been provided as drawing no. A1HP-FS-GE-GNL-DWG-202.

The bed rock is mostly exposed as thin exposures along the river while overburden material comprising mostly of slope wash and alluvial origin occupies the valley floor and lower slopes. Given the various episodes of the erosion of deposition, reasonable thickness of the overburden is expected in the valley floor. However, in places where rock exposures are present along the valley, depth to bed rock is believed to be less. Towards the slopes, terraces are present comprising overburden material and are under use of settlements and cultivation.

The river flow pattern is meandering resulting to bar deposits along both banks of the river. Immediately downstream of the proposed weir site, the river makes a nearly circular loop toward right bank and further downstream it makes bend towards left bank. Here average valley width is about ~200m. Further downstream, no significant meandering is present and valley gets narrow gradually to ~130m at the powerhouse site. Generally, the river flow is south to southeast ward. About 1km upstream of the weir, Panjkora River has its confluence with main left bank tributary named Ushirai Khwar. From this confluence to upstream, Panjkora River is aligned in northwest direction while Ushirai Khwar is flowing southwestward from northeastern hills that extend further northeastward to join Kalam valley hills.

5.2.2.2 STRATIGRAPHY AND LITHOLOGY

The composite geological map of the Project area is presented in drawing no. A1HP-FS-GE-GNL-DWG-203. The field studies have revealed that the Project area is occupied by both the unconsolidated overburden materials and the rock formations. These consist of the following;

5.2.2.2.1 OVERBURDEN

The bed rock is overlain by unconsolidated material of different nature throughout the project area. During engineering geological mapping, this overburden material has been mapped and named according to its origin and composition. The overburden found at various locations is of following types;

- **River bed alluvium**

Valley of Panjkora River at the project area is 130-200m wide. At the weir and powerhouse sites, it is around 200m wide, however, it narrows down to 130m near the powerhouse. The river bed material consists of the gray, loose, sandy gravels, cobble with boulders generally of rounded to sub rounded and strong to very strong nature (**Figure 5.2**). This material is of metamorphic and igneous origin. The sand present as matrix is fine to coarse grained and is micaceous in nature. The similar material is present in the entire length of the river in project area. However, proportions of the sand, gravels, cobbles, and boulders vary along the river. Immediate downstream of the weir site where river makes a loop, the left bank comprises mostly gravels and cobbles given the low river gradient. However, in downstream areas where river valley gets relatively narrow, boulders are also present (**Figure 5.3** & **Figure 5.4**).

- **Slope Wash Materials**

Besides the river and stream bed deposits, terraces comprised mainly of slope wash materials are present at the lower slopes and valley floor. It is interpreted that the low relief areas making banks of the river is basically the foot hills of the steep and high rock slopes present at about ~1km from river channel on either side. The ongoing erosion and deposition phenomenon from both sides resulted to development of wide terraces near the river banks. Later erosion has also exposed the rock close to river. The slope wash material has colluvial, fluvial and glacial origin based on the mechanism of downslope transportation and deposition. These are basically derived from the rock exposures present at higher elevation.

Generally, these deposits are heterogeneous and comprise angular to subangular rock fractions in silty sandy matrix where origin is colluvial or glacial (**Figure 5.5**). However, these comprise rounded to sub rounded rock fragments embedded in sandy matrix where their origin is alluvial. These normally possess thin to thick cover of silty/ clayey material and are under agriculture use. These materials are light gray to yellowish brown, firm to stiff, silty clay / clayey silt, overlying the material of varying size from gravel to boulders. These also comprise flood plains and old river deposits along the river banks at bit higher elevation indicating regression and transgression of the river.

- **Scree**

This material is situated on the hill slopes on higher elevation as loose angular rock fragments detached from the upslope hill faces and generally accumulated on slope faces. Often these extend towards the old terraces of river bed material forming colluvial cover. Scree is generally very loose to loose but having high degree of interlocking because of angularity. In the older scree deposits, the rock fragments have been stuffed with fines coming from up slopes and transformed to soil, that is currently covered by vegetation transforming to slope wash material in the project area. This material was not much witnessed in the project area; however, it is believed that at higher elevations adjacent to steep and high slopes scree accumulation will be present.

5.2.2.2.2 ROCK UNITS

The rock units exposed in the project area belong to two formations Shandur Granodiorite-Ksg (Early Paleocene) and Banded Amphibolite–Mzb (Middle Cretaceous). Banded Amphibolite is basically contrary rock that was deposited some time in Middle cretaceous while Granodiorites are intrusions in banded Amphibolite that deposited in early Paleocene. These intrusions vary in composition from granite (where lava was more acidic) to granodiorite to diorite (when lava is acidic to intermediate). The distribution of the rock units is shown in regional geological map (drawing no. A1HP-FS-GE-GNL-DWG-201) and Project Area Geological Map (drawing no. A1HP-FS-GE-GNL-DWG-203). During geological mapping, 21 rock samples were collected for petrographic analyses for the identification of the rocks. These samples were collected from the locations of the discontinuity surveys. The results of the petrographic analyses are provided in **Annexure B3, Volume VII** of the Feasibility Report, while identified rock types are presented in

Table 5-1**.** The characteristics of the rock units identified during field work and marked on the geological map (drawing no. A1HP-FS-GE-GNL-DWG-203) are described below.

- **Granodiorite/Granite**

Granodiorite/ Granite belong to Shandur Granodiorite which is of light grey to brownish in colour, medium grained, hard and massive granite and granodiorite present as plutons in the preexisting rocks. This formation is believed to have early Paleocene age. A massive unit is exposed along the Peshawar-Dir Road upstream of Darora village (drawing no. A2HP-FS-GE-GNL-DWG-201). A representative exposure of the granite/ granodiorite is shown in **Figure 5.6** near the proposed location of the cut & cover (or daylight) segment of the headrace tunnel. This also has massive exposures in the east and south east of the project area. Minor intrusions are laying also in the project area in Banded Amphibolite (MZb) both upstream side near Darora village and south of Sahibabad village. The rock is massive and shows pronounced foliation in places. Free flow tunnel alignment is likely to pass through this rock unit while alignment of headrace tunnel will have just a minor intrusion. The foliation as recorded in field is oriented in northeast-southwest direction while dipping in northwest near the proposed weir site and downstream area. However, its dip direction changes to southeast upstream of the weir site and near powerhouse leading to suggest the presence of the consecutive anticline and synclines (drawing no. A2HP-FS-GE-GNL-DWG-201 & 203).

- **Amphibolite**

Banded Amphibolite is present in the project area as contrary rock is believed to be of Middle Cretaceous age and is underlain by Shandur Granodiorite. It shows light to dark green color on fresh surface and is gray to brown on weathered surfaces. It is generally fine to medium grained, having bands of felsic and mafic minerals, foliated and composed of plagioclase, hornblende and quartz minerals. In the project area, this is widely exposed rock formation, it is massive (**Figure 5.7**) to foliated and sheared (**Figure 5.8**) in places. Most of the project components will be placed on this rock unit (drawing no. A1HP-FS-GE-GNL-DWG-203). This is major rock unit exposed along the alignment of headrace tunnel. These also have spot exposures and contacts with intruded granite/ granodiorite (**Figure 5.9**). The foliation as recorded in field is oriented in northeast-southwest direction while dipping in northwest near the proposed weir site and downstream area. However, its dip direction changes to southeast upstream of the weir site and near powerhouse leading to suggest the presence of the consecutive anticline and synclines (drawing no. A1HP-FS-GE-GNL-DWG-201 & 203).

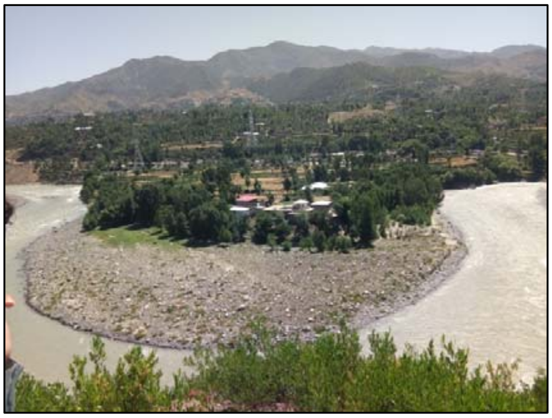

Figure 5.2: View of Panjkora River bed material in weir axis and downstream area.

Figure 5.3: Alluvial fan deposit near the sand trap, inlet pond and tunnel intake area.

Figure 5.4: Slope wash material at the right abutment of the weir.

Figure 5.5: View of massive amphibolite near the intake of the tunnel-2.

Figure 5.6: Rock outcrop of granite/ granodiorite along the free flow tunnel at discontinuity survey location DS-9.

Figure 5.7: Massive banded amphibolite outcrop near the Intake location of headrace tunnel along the right bank of Panjkora River.

Figure 5.8: Foliated/ Sheared Amphibolite outcrop along the road near cut & cover (or daylight) location at the right bank (DS-3 location) of right bank stream joining Panjkora River.

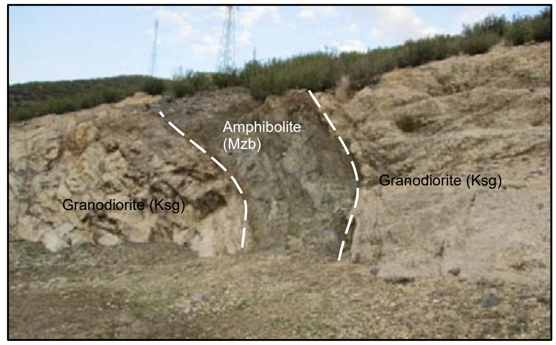

Figure 5.9: Contact between Granodiorite (Ksg) and Amphibolite (Mzb).

5.2.2.3 PROJECT AREA GEOLOGICAL STRUCTURES

The tectonic and structural features have been studied and picked up in the field. The orientation (strike and dip) of the individual beds have been picked-up and recorded to determine the overall structural trend of the rock units. The major joint sets and the discontinuity data have been picked up through window sampling technique. The orientation is observed to be same throughout the project area, trending in northeast-southwest and dipping in northwest ward mainly. However, at some places along the headrace tunnel alignment and powerhouse area, presence of consecutive anticline and syncline have resulted the variation of dip direction from northwest to southeast.

The rock units at certain places have been observed as sheared and fractured which may represent the presence of certain features like fault and shear zones (**Figure 5.8**). However, no direct evidence of faulting could be observed in the field. For the completeness of the study some shears have been assumed along the deep stream near the siphon structure and along the alignment of headrace tunnel.

5.2.2.4 DISCONTINUITY SURVEYS

The tectonic features and the joint system in the project area have been picked up through discontinuity surveys. The field data has been processed and interpreted to be used for rock characterization. The discontinuity parameters measured include;

- Orientation
- Spacing
- Persistence

- Aperture
- Roughness (Surface roughness, waviness & JRC- Joint roughness Coefficient)
- Joint Wall Strength/ Joint Compressive Strength (JCS) by Schmidt Rebound Hammer in terms of rebound values (Rn)
- Infilling materials
- Seepage, evidence of water flow
- Length of rock column above discontinuity

The major joint sets and the discontinuity data at various components of the Project (box channel, tunnel intake, along the headrace tunnel route and tunnel outlet areas) has been collected in the field through discontinuity surveys. A total of twenty-one (21) discontinuity surveys have been conducted together with recording spot readings in the project area. The locations of the discontinuity surveys have been marked on prepared geological map (drawing no. A1HP-FS-GE-GNL-DWG-203) and the details are summarized in

Table 5-1**.** The data has been summarized in **Annexure B2, Volume VII**. The summaries of the discontinuity data are provided in **Annexure B1, Volume VII** of the Feasibility Report showing stereo-net plots, representative photograph of rock outcrop, representative orientations of joint sets and their average spacing, persistence, aperture and other characteristics.

Table 5-1: Summary of conducted discontinuity surveys

Discontinuity No.	Coordinates		Sample No.	Identified Rock Type (Petrographic Analyses)	Bulk density (gram/cm^3)
	Longitude	Latitude			
DS-01	72° 0'27.53"E	35° 1'18.14"N	DS-01	Granite	2.09
DS-02	71°59'50.63"E	35° 2'2.64"N	DS-02	Foliated Amphibolite	2.41
DS-03	71°59'27.40"E	35° 2'28.40"N	DS-03	Foliated Amphibolite	3.01
DS-04	71°59'11.64"E	35° 3'37.18"N	DS-04	Amphibolite	2.49
DS-05	71°59'5.85"E	35° 3'48.55"N	DS-05	Alerted Amphibolite	2.65
DS-06	71°59'6.70"E	35° 4'21.90"N	DS-06	Massive Amphibolite	2.64
DS-07	71°59'23.23"E	35° 4'40.68"N	DS-07	Massive Amphibolite	2.67
DS-08	71°59'20.96"E	35° 4'58.75"N	DS-08	Massive Amphibolite	2.28
DS-09	71°59'1.85"E	35° 5'26.52"N	DS-09	Foliated Granite	2.30
DS-10	71°59'3.17"E	35° 2'46.70"N	DS-10	Massive Amphibolite	2.69
DS-11	71°59'46.94"E	35° 2'11.50"N	DS-11	Deformed Amphibolite	2.99
DS-12	71°59'47.92"E	35° 1'32.32"N	DS-12	Granite	2.66
DS-13	71°59'3.40"E	35° 5'34.60"N	DS-13	Foliated Granite	2.88
DS-14	71°59'8.80"E	35° 5'12.00"N	DS-14	Foliated Granite	2.36
DS-15	71°59'22.40"E	35° 5'8.30"N	DS-15	Massive Amphibolite	2.61

DS-16	71°59'10.00"E	35° 5'19.20"N	DS-16	Epidosite, altered Amphibolite	2.53
DS-17	71°58'47.77"E	35° 5'40.81"N	DS-17	Granite	2.89
DS-18	71°58'46.00"E	35° 5'45.48"N	DS-18	Amphibolite	3.01
DS-19	71°59'4.79"E	35° 5'52.52"N	DS-19	Amphibolite	2.94
DS-20	71°59'9.16"E	35° 5'56.37"N	DS-20	Granite	2.69
DS-21	71°58'57.22"E	35° 6'3.30"N	DS-21	Granite	2.66

Also, the details of the discontinuity parameters are provided in **Table** 5-2 comprising number and type of discontinuities, representative orientation and mean values of the spacing, persistence, aperture, roughness and Schmidt hammer rebound values, corresponding to each discontinuity survey.

Table 5-2: Details of Discontinuity Parameters

DS No.	Sr. No.	Discontinuity Type	Representative Orientation		Average Spacing (cm)	Average Persistence (m)	Average Aperture	Average Rebound No (Rn)	Joint Roughness Coefficient (JRC)
			Dip Direction	Dip			(mm)		
DS-1	1	Foliation	162	39	17.92	8.31	4.18	19.28	3.28
	2	Joint Set 1	336	50	33.64	1.20	1.12	25.70	3.35
	3	Joint Set 2	043	61	23.51	0.97	1.12	26.55	3.48
DS-2	1	Foliation	169	56	8.21	1.99	3.29	19.89	3.56
	2	Joint Set 1	339	37	13.95	1.47	2.95	20.34	2.43
	3	Joint Set 2	079	75	4.93	0.39	0.24	22.18	3.56
	4	Joint Set 3	198	51	7.23	1.51	0.94	20.00	3.95
DS-3	1	Foliation	162	37	6.70	6.45	8.72	19.60	2.43
	2	Joint Set 1	330	63	14.90	1.03	28.12	25.43	3.63
	3	Joint Set 2	022	51	12.92	1.16	2.92	16.36	2.88
DS-4	1	Foliation	336	65	9.46	0.69	2.93	27.13	3.68
	2	Joint Set 1	023	67	17.13	2.57	4.19	29.34	3.59
	3	Joint Set 2	078	82	17.25	3.50	3.75	26.50	3.41
	4	Joint Set 3	188	19	19.61	2.40	5.20	25.06	3.60
DS-5	1	Foliation	318	26	25.46	2.24	2.73	29.43	3.75
	2	Joint Set 1	155	71	26.11	1.77	1.14	29.88	3.48
	3	Joint Set 2	073	57	17.16	0.80	5.59	28.32	3.61
DS-6	1	Foliation	336	60	27.31	1.46	0.60	36.13	3.00
	2	Joint Set 1	046	74	26.41	12.79	20.62	31.29	3.00
	3	Joint Set 2	199	27	61.07	5.38	9.05	33.19	3.00
DS-7	1	Foliation	310	26	27.13	5.18	8.20	28.29	3.36
	2	Joint Set 1	142	67	58.76	2.83	5.57	21.64	3.57
	3	Joint Set 2	062	60	45.19	1.59	4.35	28.16	3.58
DS-8	1	Foliation	281	21	47.74	2.55	6.40	23.48	3.51
	2	Joint Set 1	109	60	10.54	0.67	2.09	34.54	3.45
	3	Joint Set 2	025	63	9.38	2.14	2.31	34.00	3.30
DS-9	1	Foliation	309	25	39.71	2.71	16.66	28.67	3.50
	2	Joint Set 1	139	58	33.68	1.10	7.24	29.93	3.44

DS No.	Sr. No.	Discontinuity Type	Representative Orientation		Average Spacing (cm)	Average Persistence (m)	Average Aperture	Average Rebound No (Rn)	Joint Roughness Coefficient (JRC)
			Dip Direction	Dip			(mm)		
	3	Joint Set 2	048	66	16.62	0.75	0.61	32.48	3.59
DS-10	1	Foliation	342	54	16.96	0.29	0.59	20.03	3.58
	2	Joint Set 1	052	41	9.15	1.60	1.89	21.90	3.68
	3	Joint Set 2	236	27	16.44	0.75	3.60	29.86	3.51
DS-11	1	Foliation	168	44	13.05	2.49	8.02	30.93	3.08
	2	Joint Set 1	333	40	13.60	0.40	0.98	31.85	4.00
	3	Joint Set 2	033	61	12.94	1.72	2.48	36.64	3.32
DS-12	1	Foliation	106	53	32.39	2.50	13.31	29.90	3.65
	2	Joint Set 1	047	60	29.29	0.70	1.00	30.47	3.58
	3	Joint Set 2	237	24	42.25	2.62	0.85	27.83	3.41
DS-13	1	Foliation	328	67	16.81	0.24	1.67	22.09	3.46
	2	Joint Set 1	051	52	14.75	0.17	1.14	23.22	3.64
	3	Joint Set 2	251	30	22.83	0.17	0.74	10.58	3.37
DS-14	1	Foliation	332	62	11.05	0.18	2.41	24.77	3.72
	2	Joint Set 1	119	40	12.18	0.23	1.60	18.53	3.58
	3	Joint Set 2	230	27	11.84	0.29	2.23	18.93	3.60
DS-15	1	Foliation	317	39	17.27	0.73	0.74	19.75	3.78
	2	Joint Set 1	064	46	28.82	0.91	2.88	17.03	3.71
	3	Joint Set 2	203	55	3.93	0.43	0.87	17.18	3.53
DS-16	1	Foliation	333	66	18.21	0.85	2.50	27.30	3.75
	2	Joint Set 1	071	43	28.35	0.68	0.66	32.35	3.64
	3	Joint Set 2	226	33	22.75	0.80	0.70	33.03	3.84
DS-17	1	Foliation	289	68	10.89	20.80	3.52	28.78	3.89
	2	Joint Set 1	018	69	20.00	8.14	2.00	28.12	4.00
	3	Joint Set 2	240	76	16.26	6.38	3.30	33.43	3.73
DS-18	1	Foliation	271	33	13.26	7.03	3.46	31.19	3.92
	2	Joint Set 1	056	52	9.33	3.44	3.66	34.11	3.55
	3	Joint Set 2	209	73	8.72	7.90	3.63	30.45	3.72
DS-19	1	Foliation	309	44	17.64	3.76	2.64	33.70	5.29
	2	Joint Set 1	157	61	17.60	5.92	3.40	30.20	6.70
	3	Joint Set 2	260	52	15.00	4.60	2.75	30.25	5.62
DS-20	1	Foliation	321	62	14.64	8.58	3.55	29.08	6.26
	2	Joint Set 1	113	72	11.20	6.60	3.35	30.90	8.70
	3	Joint Set 2	218	55	12.12	11.25	3.00	31.50	3.87
DS-21	1	Foliation	315	64	15.08	5.66	4.08	31.91	6.08
	2	Joint Set 1	144	70	23.57	9.28	4.42	28.85	8.00
	3	Joint Set 2	211	63	21.75	10.83	5.25	31.75	8.58

5.3 GEOTECHNICAL INVESTIGATIONS

The Artistic-I Hydropower Project site has been investigated through various means to the level of Feasibility Stage. These mainly include exploratory drilling, geophysical seismic profiling and the excavation of test pits. Besides, construction material investigations have also been carried out in the Project area and outside for the identification of potential sources of various construction Materials. The locations of the investigation's points are provided on the respective drawings and referred in each section. A brief of the completed works is given below;

5.3.1 EXPLORATORY DRILLING & INSITU TESTING

The Contractor M/s Geoconsult Associates, Lahore was engaged to undertake subsurface investigations comprising exploratory drilling, excavation of test pits, in-situ testing and sampling. A total of twenty-one (21) boreholes were proposed of cumulative lengths of about 646m. The contractor completed the drilling of twenty-one boreholes up to the maximum depth of 60m together with necessary sampling and in-situ testing at Artistic-I weir, tunnel intake, adit, powerhouse and bridge sites. Cumulatively 646m drilling was completed in which mostly drilling (412.4m) was in rock while 233.6m drilling in overburden material (**Table** 5.3).

Among the drilled holes; 3 holes were drilled at weir site up to maximum depth of 35m, 2 at the free flow tunnel with depths of 30m, and a hole of 30m for the adit tunnel, 5 bore holes along the abutments of proposed bridges near free flow tunnel and powerhouse area with the maximum depth of 30m, 5 holes along the surge shaft and powerhouse area with maximum depth of 60m by straight rotary drilling method, and remaining bore holes were along the other major components and along cut and cover section at Kotkay Khwar with maximum depth of 30m (**Table** 5.3). The locations of the boreholes are shown in drawing A1HP-FS-GE-WR-DWG-204 for weir site, in A1HP-FS-GE-TNL-DWG-206 for free flow tunnel, and in A1HP-FS-GE-ST-DWG-208 for sand trap area, in drawing A1HP-FS-GE-IP-DWG-210 for inlet pond and intake of headrace tunnel, in drawing A1HP-FS-GE-TNL-DWG-213 & 14 for cut & cover segment and along adit respectively, and in drawing A1HP-FS-GE-PH-DWG-216 for surge shaft, tunnel outlet and powerhouse area. The details of all boreholes are summarized in **Table** 5.3. In all holes, field permeability tests in overburden and water pressure tests in rock were conducted to have an assessment of permeability characteristics of the soil and rock units. Standard penetration tests (SPTs) were undertaken in the overburden soils to have estimation of relative density. In the overburden holes, disturbed sampling was undertaken by SPT sampler or by cutting, while rock coring was undertaken in the rock horizons to have continuous rock cores for onward logging and laboratory testing.

The field logs of all boreholes were prepared by an experienced geologist covering all aspects of geotechnical logging. These logs were checked and verified by principal engineering geologist/ geotechnical engineer. Core photographs of all core boxes of rock cored holes were taken for record with the demarcation of picked samples for the laboratory testing. The field logs were later finalized in view of the results of the in-situ testing and laboratory testing on selective soil and rock samples. The borehole logs, core photographs and results of in-situ tests are attached as **Annexure B4, Volume VII** of the feasibility report.

Table 5.3: Details of boreholes and undertaken insitu tests

BH No.	Location	Coordinates & Elevation (m)			Drilled depth (m)	Overburden Thickness (m)	Coring in Bed Rock (m)	DWT (m)	WPM	WPT	SPT
A1-BH-1	Weir left abutment	772014	3887936	1073	30	-	30	NE	-	5	-
A1-BH-2	Weir center	771973	3887986	1065	35	30	5	3.3	5	1	14
A1-BH-3	Weir right abutment	771928	3888039	1068	35	35	-	5.8	7	-	16
A1-BH-4	Intake of Free Flow Tunnel	771734	3887854	1087	25	1	24	NE	-	5	-
A1-BH-5	Outlet of Free Flow Tunnel	772021	3887118	1085	25	1	24	NE	-	4	-
A1-BH-6	Proposed Bridge near Free Flow Tunnel (Valley)	772245	3886793	1054	25	23	2	0.8	4	-	1
A1-BH-7	Proposed Bridge near Free Flow Tunnel (Left bank)	772277	3886813	1050	25	25	-	2	4	-	2
A1-BH-8	Sand Trap	772662	3886182	1069	30	3	27	NE	-	5	
A1-BH-9	Along Box Channel after Sand Trap	772549	3885752	1094	30	4	26	NE	-	5	-
A1-BH-10	Intake of Adit Tunnel	772290	3884010	1082	30	7	23	NE	1	3	5
A1-BH-11	Outlet of HRT at left bank of Kotkay Khwar	772859	3881969	1079	35	-	35	NE	-	6	-
A1-BH-12	Cut and Cover Section at Valley Center of Kotkay Khwar	772882	3881923	1056	30	7.1	22.9	7	1	4	7
A1-BH-13	Intake of HRT at Kotkay Khwar after Cut & Cover Section	772933	3881823	1072	30	7	23	NE	1	5	6
A1-BH-14	Surge Shaft	774506	3879714	1102	60	4	56	NE	-	11	1
A1-BH-15	Along HRT (between Surge shaft and outlet)	774558	3879751	1087	30	6	24	NE	-	5	5
A1-BH-16	Outlet of Headrace Tunnel	774616	3879800	1062	30	12	18	NE	2	5	7
A1-BH-17	Powerhouse	774746	3879911	998	30	4	26	NE	-	5	2
A1-BH-18	Tailrace channel	774776	3879937	992	30	15.5	14.5	2.2	2	3	7
A1-BH-19	Right abutment of bridge near powerhouse	774920	3879839	988	30	25	5	0.7	3	1	2
A1-BH-20	Left abutment of bridge near powerhouse	774989	3879891	989	30	2	28	NE	-	6	-
A1-BH-21	Left abutment of bridge near Free Flow Tunnel	772294	3886822	1055	21	21	-	5.5	4	-	-
Total					**646**	**233.6**	**412.4**	**-**	**34**	**79**	**75**

DWT- Depth to water table, PM-Permeability test in overburden, WPT- Water pressure test, SPT- Standard penetration test, NE- Not encountered,

5.3.2 TEST PITS EXCAVATION

The test pits were excavated both for the purpose of foundation material evaluation and for the construction material studies. Twelve (12) test pits were excavated up to a maximum depth of 3m; four at weir site, five at box channel, one at inlet pond, two at adit tunnel, two at pressure tunnel and three at powerhouse and penstock site. The locations of the test pits are shown in respective drawings and details are summarized in

Table 5.4. Test pits' logs were prepared by an experienced geologist in view of the encountered subsurface materials. Small samples from the test pits were taken for moisture content determination in the laboratory for calculation of dry densities. Disturbed soil samples were also taken for other classification testing in the Laboratory. The test pit logs were finalized in view of the laboratory tests results. Test pit logs and photographs are attached as **Annexure B5, Volume VII**.

Table 5.4: Details of test pits and undertaken in situ tests

BH No.	Location	Material	Coordinates (m)			Depth (m)	Collected Samples	FDT Depth (m)	FDT g/cm^3
A-1 TP-1	Weir upstream	RBM	3888026	772018	1063	2.0	CS-1	1.5	6.28
A-1 TP-2	Weir down stream	RBM	3887938	771922	1063	1.0	CS-1	-	-
A-1 TP-3	Weir channel alignment	SWM	3887953	771833	1066	3.0	CS-1	1.5	1.71
								3.0	1.85
A-1 TP-4	Tunnel alignment	SWM	3886407	772518	1072	3.0	CS-1	1.5	1.68
								3.0	1.98
A-1 TP-5	Tunnel alignment	SWM	3886227	772634	1072	1.5	CS-1	-	-
A-1 TP-6	Channel	SWM	3886117	772676	1078	3.0	CS-1	1.5	1.68
								3.0	1.90
A-1 TP-7	Channel	SWM	3886023	772631	1072	2.0	CS-1	1.5	2.06
A-1 TP-8	Fore Bay	SWM	3885881	772589	1075	3.0	CS-1	1.5	15.29
								3.0	18.23
A-1 TP-9	Kotkay Khwar	SWM	3881865	772912	1060	1.3	CS-1	-	-
A-1 TP-10	Tunnel	SWM	3879877	774703	1025	1.0	CS-1	-	-
A-1 TP-11	Powerhouse	RBM	3879948	774727	993	1.5	CS-1	-	-
A-1 TP-12	Powerhouse	SWM	3879900	774785	995	3.0	CS-1	1.5	1.79
								3.0	1.92

CS- Composite sample, RBM- River bed material, SWM- Slope wash material

5.3.3 GEOPHYSICAL INVESTIGATIONS

M/s Geoconsult Associates, Lahore were entrusted to undertake geophysical Investigations comprising seismic refraction surveys at Artistic-I Hydropower Project site. The locations of the profiles were marked and handed over to contractor before initiating the survey. The main objective was to explore the subsurface exploration, that is, the thickness of overburden or the depth to bed rock, at important project structures' locations. A total of 2230m length was explored comprising ten (10) seismic refraction profiles; two (2) at weir site, six (6) along tunnels and adit, and two (2) at powerhouse area. The location of the seismic profiles A1-SP-1 to A1-SP-10, are shown in respective drawings.

The details of the conducted seismic profiles are summarized in the following

Table 5.5 and interpreted subsurface sections are attached as **Annexure B6, Volume VII**.

Table 5.5: Details of conducted seismic profiles.

Sr. No	Profile Names	Profile Lengths (m)	Structure
1	A1 - SP-1	230	Powerhouse Site
2	A1 - SP-2	200	Powerhouse Site
3	A1 - SP-3	340	Kotkay Khwar (Cut & Cover Section of HRT)
4	A1 - SP-4	110	Kotkay Khwar (Cut & Cover Section of HRT)
5	A1 - SP-5	340	Kotkay Khwar (Cut & Cover Section of HRT)
6	A1 - SP-6	210	Adit
7	A1 - SP-7	150	Tunnel Alignment
8	A1 - SP-8	210	Tunnel Alignment
9	A1 - SP-9	210	Weir Site
10	A1 - SP-10	230	Weir Site
Total		**2230**	

5.3.4 LABORATORY TESTING

Geotechnical investigations cannot be considered complete without the necessary laboratory testing on the soil, rock and water samples. During current drilling campaign, significant laboratory testing including geotechnical testing and mineralogical testing was undertaken. After completion of the boreholes, laboratory testing programs for necessary testing for soil, rock and water samples. The proposed testing was aimed at to determine the physical, mechanical and mineralogical parameters that were considered necessary for the design of various project components and the usage of various materials as construction materials. After receiving the laboratory programs, the selected samples were picked up, labeled and transported to the Department of Civil Engineering and Department of Mining Engineering of University of Engineering and Technology, Peshawar, and Department of Geology, University of Peshawar. A summary of all the laboratory test results is attached as **Table 5.6** for boreholes' samples, **Table 5.7** for test pit samples, **Table 5.8** for construction materials' samples and **Table 5.8** for water samples. The test data sheets are attached as **Annexure B7** for boreholes' and **Annexure B8** for test pits' laboratory test results of **Volume VII** of the Feasibility Report.

The laboratory tests conducted on rock samples mainly include point load strength index, uniaxial, triaxial compressive strength tests together with the measurements of the elastic parameters such as elastic modulus and Poisson's ratio. Other tests include bulk and dry density, moisture content determination, porosity, water absorption and petrographic analysis. While soil samples were subjected to grain size analysis, limits, direct shear tests, etc. Since the soil was dominantly granular, no consolidation, unconfined compression or triaxial compression testing was undertaken.

In the construction material testing, mainly grain size analysis, compaction (modified proctor), California bearing ratio (CBR), bulk density, specific gravity, soundness, water absorption, flakiness and elongation index tests were undertaken.

In the chemical analysis of the water from boreholes, chloride and sulphate contents, total dissolved solids (TDS), and pH values were determined.

Table 5.6 :Summary of Laboratory Test Results of Boreholes' Samples

BH No.	Sample No.	Depth	Rock Type as per field inspection	Moisture Content	Density		Specific Gravity	Water Absorption	Point Load Index Strength	Poisson's Ratio	Young Modulus	Uniaxial Compressive Strength	Tri-Axial Testing		Rock type as per Petrographic analysis
					Bulk Density	Dry Density							Cohesion	Angle of Friction	
		(m)		(%)	g/cm³	g/cm³		(%)	(MPa)		(GPa)	(MPa)	(MPa)	(Degrees)	
A-1 BH-1	R1	13.7	Amphibolite	-	2.48	-	-	0.81	2.44	-	-	-	-	-	-
	R2	19.7	Amphibolite	-	2.43	-	-	-	3.14	-	-	-	-	-	-
	R3	22.0	Amphibolite	-	2.59	-	-	0.48	-	-	-	-	-	-	-
	R4	26.6	Amphibolite	0.54	-	2.56	-	-	1.91	-	-	45.81	-	-	Granitoid
A-1 BH-2	R1	31.3	Amphibolite	-	2.61	-	-	0.55	2.06	-	-	-	-	-	-
	R2	32.2	Amphibolite	0.22	2.72	2.71	-	-	-	-	-	36.16	-	-	-
A-1 BH-4	R1	6.0	Amphibolite	-	-	-	-	-	1.13	-	-	-	-	-	-
	R2	11.0	Amphibolite	0.69	-	2.57	-	0.70	1.03	-	-	24.71	-	-	-
	R3	16.7	Amphibolite	-	2.41	-	-	-	1.05	-	-	-	-	-	-
	R4	19.3	Amphibolite	0.45	2.89	2.74	-	0.36	1.38	0.34	4	33.15	9.98	30	Granodiorite
A-1 BH-5	R1	7.0	Granodiorite	-	2.820	-	2.78	0.45	2.81	-	-	57.01	-	-	-
	R2	10.0	Granodiorite	-	2.740	-	-	-	4.15	-	-	52.95	-	-	Granite (Foliated)
	R3	16.7	Granodiorite	-	2.833	-	2.81	0.82	5.64	0.35	9	66.31	-	-	-
	R4	22.2	Granodiorite	-	2.774	-	-	-	3.24	-	-	-	-	-	-
A-1 BH-8	R1	9.3	Granodiorite	-	2.658	-	2.84	0.18	8.66	-	-	-	-	-	-
	R2	20.0	Granodiorite	-	2.652	-	-	-	7.39	-	-	107.26	-	-	-
	R3	28.5	Granodiorite	-	2.659	-	0.00	0.00	6.71	-	-	95.78	-	-	Monzodiorite
A-1 BH-9	R1	10.0	Amphibolite	-	2.47	-	-	-	2.17	-	-	39.21	-	-	-
	R2	16.7	Amphibolite	-	2.64	-	-	-	2.86	-	-	-	-	-	Peridotite

BH No.	Sample No.	Depth	Rock Type as per field inspection	Moisture Content	Density		Specific Gravity	Water Absorption	Point Load Index Strength	Poisson's Ratio	Young Modulus	Uniaxial Compressive Strength	Tri-Axial Testing		Rock type as per Petrographic analysis
					Bulk Density	Dry Density							Cohesion	Angle of Friction	
		(m)		(%)	g/cm^3	g/cm^3		(%)	(MPa)		(GPa)	(MPa)	(MPa)	(Degrees)	
	R3	21.7	Amphibolite	-	2.34	-	-	0.28	-	-	-	36.3	-	-	-
	R4	28.1	Amphibolite	-	2.63	-	-		2.74	0.26	2.41	50.83	-	-	-
A-1 BH-10	R1	10.8	Amphibolite	-	2.50	-	-	-	1.13	-	-	-	-	-	-
	R2	13.3	Amphibolite	0.75	2.69	2.66	-	-	1.31	-	-	31.34	-	-	-
	R3	21.7	Amphibolite	-	2.62	-	-	-	1.26	-	-	-	-	-	Granitoid
	R4	28.7	Amphibolite	0.35	-	2.46	-	0.25	1.05	0.33	3.70	25.31	8.56	25	-
	R5	29.3	Amphibolite	-	2.66	-	-	-	1.76	-	-	-	11.36	33	-
A-1 BH-11	R1	6.5	Amphibolite	-	2.42	-	-	1.65	1.00	-	-	-	-	-	-
	R2	14.6	Amphibolite	-	2.60	-	-	-	0.63	-	-	-	-	-	-
	R3	19.8	Amphibolite	-	2.77	-	-	0.60	1.63	-	-	-	-	-	-
	R4	29.4	Amphibolite	0.00	2.30	2.28	-	-	2.84	-	-	68.11	-	-	-
	R5	34.2	Amphibolite	0.19	2.31	2.30	-	0.36	0.75	-	-	18.08	-	-	Amphibolite
A-1 BH-12	R1	11.4	Amphibolite	-	2.30	-	-	-	2.31	-	-	55.45	-	-	-
	R2	18.3	Amphibolite	-	2.74	-	-	-	1.88	-	-	45.2	-	-	-
	R3	29.3	Amphibolite	-	2.29	-	-	-	2.06	-	-	49.42	-	-	-
A-1 BH-13	R1	9.2	Amphibolite	-	2.29	-	-	-	1.58	-	-	-	-	-	-
	R2	15.1	Amphibolite	0.07	2.28	2.27	-	0.00	1.63	-	-	39.18	11.12	29	-
	R3	22.6	Amphibolite	-	2.60	-	-	0.48	2.46	0.29	2.78	59.07	-	-	-
	R4	29.2	Amphibolite	-	2.65	-	-	-	1.53	-	-	-	-	-	-
A-1 BH-14	R1	10.7	Granodiorite		2.908	-	3.084	0.20	4.59			71.63	-	-	-

BH No.	Sample No.	Depth	Rock Type as per field inspection	Moisture Content	Density		Specific Gravity	Water Absorption	Point Load Index Strength	Poisson's Ratio	Young Modulus	Uniaxial Compressive Strength	Tri-Axial Testing		Rock type as per Petrographic analysis
					Bulk Density	Dry Density							Cohesion	Angle of Friction	
		(m)		(%)	g/cm^3	g/cm^3		(%)	(MPa)		(GPa)	(MPa)	(MPa)	(Degrees)	
	R2	20.3	Granodiorite		3.193	-	-	-	5.46	0.35	10	74.4	-	-	-
	R3	30.5	Granodiorite		3.086	-	3.009	0.30	2.67			75.61	-	-	Amphibolite
	R4	41.0	Granodiorite	0.485	3.166	3.152	-	-	3.12			76.02	-	-	-
	R5	52.7	Granodiorite	-	3.225	-	-	-	14.34	0.36	10	61.4	-	-	-
	R6	54.0	Granodiorite	-	3.146	-	3.109	0.14	5.72	-	-	111.43	-	-	-
A-1 BH-15	R1	14.4	Granodiorite	-	2.681	-	-	-	3.36	-	-	47.52	-	-	Granite
	R2	20.7	Granodiorite	-	3.067	-	-	-	7.59	-	-	-	-	-	-
	R3	21.0	Granodiorite	-	3.094	-	-	-	4.75	-	-	-	-	-	Amphibolite
	R4	28.4	Granodiorite	-	3.072	-	-	-	5.25	-	-	-	-	-	-
	R5	29.1	Granodiorite	-	2.941	-	-	-	4.73	0.31	50	73.6	-	-	-
A-1 BH-16	R1	15.3	Granodiorite	0.93	2.37	2.36	-	0.56	2.56	-	-	61.48	-	-	Dacite
	R2	23.6	Granodiorite	-	2.74	-	-	-	1.73	-	-	-	-	-	-
	R3	27.5	Granodiorite	-	2.78	-	-	-	2.11	-	-	-	-	-	-
A-1 BH-17	R1	4.1	Granite	-	2.30	-	-	0.79	2.22	-	-	-	-	-	-
	R2	9.5	Granite	-	2.45	-	-	-	1.67	-	-	29.04	-	-	Granite
	R3	16.0	Granite	-	2.30	-	-	-	2.86	0.24	2.96	53.25	-	-	-
	R4	18.6	Granite	-	2.46	-	-	-	2.41	-	-	44.05	-	-	-
A-1 BH-18	R1	16.2	Granodiorite	-	2.52	-	-	-	1.33	-	-	31.94	-	-	-
	R2	19.3	Granodiorite	-	2.25	-	-	-	0.50	-	-	-	-	-	-
	R3	25.0	Granodiorite	-	2.46	-	-	0.51	1.23	-	-	29.53	-	-	-
A-1 BH-19	R1	28.6	Granodiorite	-	2.70	-	-	-	-	-	-	39.21	-	-	-

BH No.	Sample No.	Depth	Rock Type as per field inspection	Moisture Content	Density		Specific Gravity	Water Absorption	Point Load Index Strength	Poisson's Ratio	Young Modulus	Uniaxial Compressive Strength	Tri-Axial Testing		Rock type as per Petrographic analysis
					Bulk Density	Dry Density							Cohesion	Angle of Friction	
		(m)		(%)	g/cm³	g/cm³		(%)	(MPa)		(GPa)	(MPa)	(MPa)	(Degrees)	
	R2	29.7	Granodiorite	-	2.34	-	-	-	2.62	-	-	48.41	-	-	-
A-1 BH-20	R1	8.7	Granodiorite	0.00	2.52	2.51	-	-	2.29	-	-	54.85	-	-	Quartzite
	R2	9.4	Granodiorite	-	2.26	-	-	0.74	2.11	-	-	-	-	-	-
	R3	12.0	Granodiorite	-	2.42	-	-	-	1.51	-	-	36.16	-	-	-
	R4	14.4	Granodiorite	-	2.24	-	-	-	2.29	-	-	-	-	-	-

Table 5.7 : Summary of Laboratory Test Results of Test pits' Samples

TP No.	Sample No.	Depth	Particle Size Analysis (% passing)					Atterberg's Limits			NMC	Modified Proctor		Percentage Swell	California Bearing Ratio					Direct Shear Box		Petrography of Gravels
			Sieve Analysis			Hydrometer test		Liquid Limit	Plastic Limit	Plasti-city Index		MDD	OMC		Compaction at					Cohesion	Angle of Internal Friction	
		(m)	Gravel	Sand	Silt/ Clay	Silt	Clay	(%)	(%)		(%)	(lb/ft^3)	(%)	(%)	90 %	93 %	95 %	98 %	100 %	(PSF)	(Deg.)	
A1-TP-01	CS-1	2.0	77.6	21.6	0.8	-	-	-	-	-	6.28	-	-	-	-	-	-	-	-	8.0	39.9	Foliated Granite / Fine grained Granite / Amphibolite
A1-TP-02	CS-1	1.0	70.1	28.6	1.2	-	-	-	-	-	9.04	-	-	-	-	-	-	-	-	7.0	37.4	Amphibolite / Granite
A1-TP-03	CS-1	3.0	0.8	49.4	49.8	-	-	Non-Plastic			4.04	-	-	-	-	-	-	-	-	24.0	40.6	-
A1-TP-04	CS-1	3.0	58.2	23.9	18.0	18.0	0.00	25	21	4.0	4.42	132.9	7.2	0.66	10.9	14.4	17.2	22.7	27.2	276.0	36.6	-
A1-TP-05	CS-1	1.5	36.8	42.7	20.5	20.5	0.00	Non-Plastic			5.26	-	-	-	-	-	-	-	-	251.0	38.8	-
A1-TP-06	CS-1	3.0	48.8	20.6	30.6	30.6	0.00	30	20	10	8.53	120.1	14.0	0.86	4.4	6.6	8.8	13.3	17.6	335.0	40.7	-
A1-TP-07	CS-1	2.0	55.1	38.8	6.1	6.10	0.00	Non-Plastic			6.09	-	-	-	-	-	-	-	-	50.0	36.2	-
A1-TP-08	CS-1	3.0	41.2	38.6	20.2	20.0	0.20	22	20	2.0	4.41	132.2	8.4	0.23	14.7	18.4	21.5	26.9	31.3	208.0	36.0	-
A1-TP-09	CS-1	1.3	73.5	24.4	2.1	2.08	0.02	-	-	-	1.64	-	-	-	-	-	-	-	-	23.0	35.0	-
A1-TP-10	CS-1	1.0	8.8	79.3	11.9	11.8	0.12	Non-Plastic			2.18	-	-	-	-	-	-	-	-	58.0	34.8	-
A1-TP-11	CS-1	1.5	63.4	31.1	5.5	5.50	0.00	-	-	-	3.16	129.7	6.2	0.07	14.9	20.1	24.7	33.5	41.0	11.0	37.6	-
A1-TP-12	CS-1	3.0	3.1	41.6	55.3	54.7	0.55	30	23	7.0	17.2	-	-	-	-	-	-	-	-	353.0	40.2	-

Table 5.8 : Summary of Laboratory Test Results of Construction Material Samples

<table>
<tr><th rowspan="3">TP No.</th><th rowspan="3">Sample No.</th><th colspan="3">Particle Size Analysis (% passing)</th><th rowspan="3">Apparent Specific Gravity</th><th rowspan="2">Bulk Density</th><th rowspan="2">Water Absorption</th><th colspan="2">Modified Proctor</th><th>Soundness</th><th rowspan="3">3-Point CBR Test @95% Compaction</th><th rowspan="2">Flakiness Test</th><th rowspan="2">Elongation Test</th></tr>
<tr><th colspan="3">Sieve Analysis</th><th>MDD</th><th>OMC</th><th rowspan="2">Actual Loss (%)</th></tr>
<tr><th>Gravel</th><th>Sand</th><th>Silt/ Clay</th><th>(g/cm3)</th><th>(%)</th><th>(g/cm3)</th><th>(%)</th><th colspan="2">Corrected avg. Weight (%)</th></tr>
<tr><td>TPM-1</td><td>1</td><td>57.5</td><td>41.3</td><td>1.2</td><td>2.622</td><td>2.153</td><td>0.76</td><td>1.948</td><td>8.3</td><td>-</td><td>-</td><td colspan="2">3.16</td></tr>
<tr><td>TPM-2</td><td>2</td><td>51.8</td><td>47.4</td><td>0.8</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>4.314</td><td>27</td><td>-</td><td>-</td></tr>
<tr><td>TPM-3</td><td>3</td><td>58.2</td><td>40.6</td><td>1.2</td><td>2.939</td><td>2.007</td><td>1.20</td><td>2.072</td><td>10.2</td><td>4.384</td><td>29</td><td colspan="2">3.07</td></tr>
</table>

Table 5.9 : Summary of Laboratory Test Results of water samples

Borehole	Sample No.	Chemical Test of water			
		Sulphate content (mg/L)	Chlorite content (mg/L)	TDS (mg/L)	PH Value
A1-BH-02	A2-W-01	24	14	127	7.4
A1-BH-06	A2-W-02	22	17	117	7.7
A1-BH-17	A2-W-03	56	45	320	6.7

5.4 GEOTECHNICAL INTERPRETATION AND DESIGN

5.4.1 GENERAL

This section presents the geotechnical interpretation and assessment of the subsurface materials based on the geological, geophysical and geotechnical investigations. Rock characterization was undertaken on the discontinuity data and borehole data to get the rock classification and accordingly geotechnical parameters to be used in the foundation design and in estimation of support requirement for underground structures. Soil parameters were derived keeping in view of the in-situ and laboratory testing, and engineering judgment.

5.4.2 SOIL AND ROCK PARAMETERS

Soil and rock parameters were derived based on the laboratory test results (**Table 5.6** & **Annexure B7 & B8, Volume VII**), field studies and testing, engineering judgment and recent literature. Intact rock mechanical properties were determined by analyzing the laboratory test data.

Schmidt Rebound Hammer values (Rn) recorded on joint surfaces during discontinuity surveys were plotted on Schmidt Rebound Hammer Rebound Values (Rn) Chart (After ISRM 1981) corresponding to adopted unit weight for granite/ granodiorite and Rhyolite/ Andesite (**Figure 5.10**). The UCS values as produced from this correlation are summarised in **Table 5.10**. It is to note that in discontinuity surveys (DS-2-8, 10-11, 15 & 18-19) in Amphobolite, the UCS value estimated as 44MPa correponsing to average values of 27.27 and 26.32 kN/m^3 as Rn and unit weight respectively. Likewise, UCS of 42 MPa was estimated correponsing to average values of 26.80 and 25.15 kN/m^3 as Rn and unit weight respectively for granite/ granodiorite in discontinuity surveys (DS, 1, 9, 12-14, 16-17 & 20-21).

Table 5.10 : Summary of Rn, unit weight and estimated UCS

Rock Unit and considered discontinuity surveys		Schmidt Rebound Number (Rn)	Unit Weight kN/m^3	Estimated UCS (MPa)
Amphibolite (Mzb) DS-2-8, 10-11,15-16 & 18-19	Mean	27.27	26.32	42*
	Minimum	16.36	22.34	
	Maximum	36.64	29.50	
Granite/ Granodiorite (Ksg) DS-1, 9, 12-14, 17 & 20-21	Mean	26.80	25.15	44*
	Minimum	10.58	20.48	
	Maximum	33.43	28.32	

*Estimated against mean values of Rn and unit weights

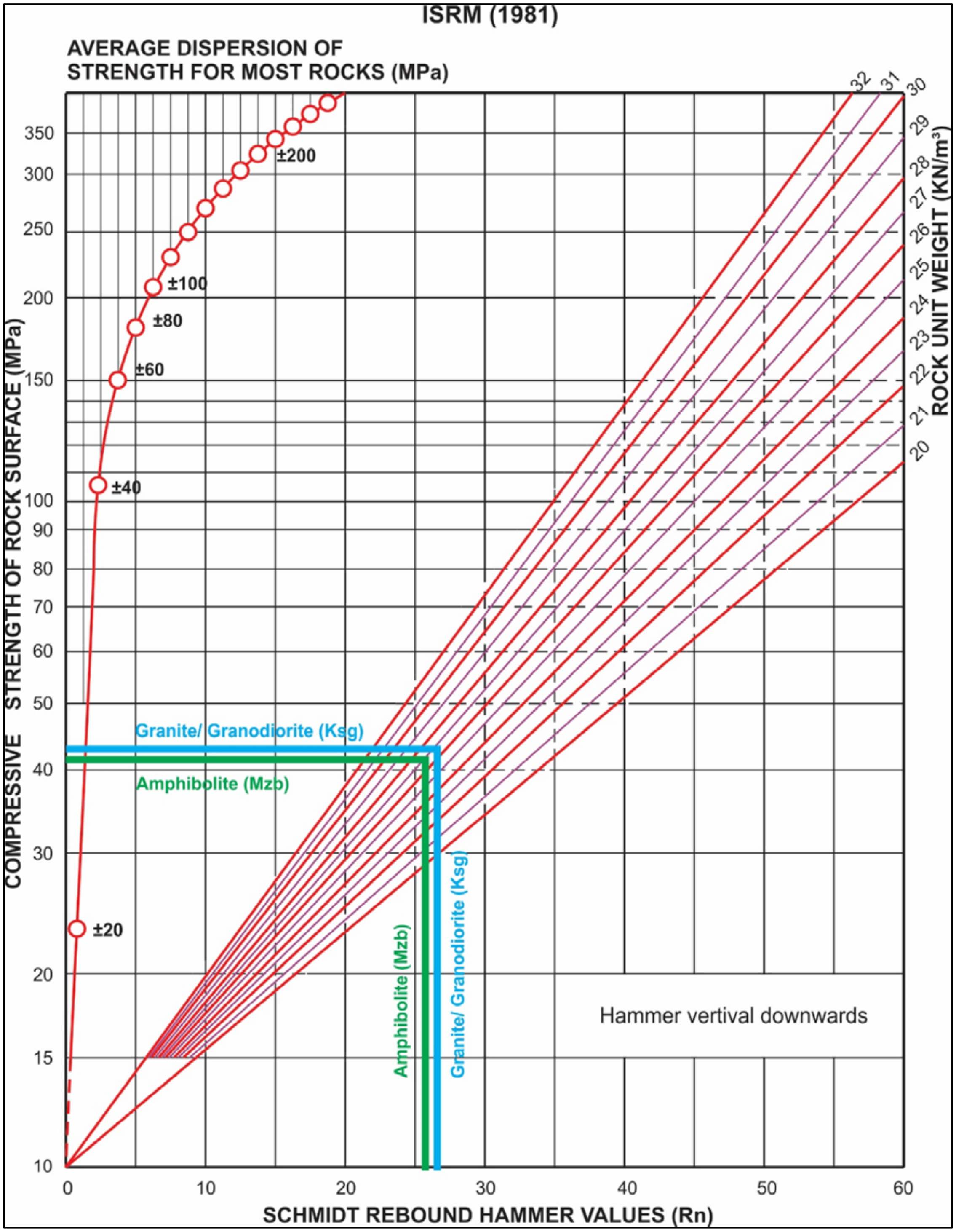

Figure 5.10: Plot showing correlation of correlation of Rn and UCS for amphibolite and granite.

The uniaxial compressive strength (UCS) and Point Load Strength Index (Is50) was measured in the laboratory of two rock units; Mzb (Amphibolite) and Ksg (Granite or granodiorite). In analysis, the results of UCS and Is50 were correlated (**Figure 5.11**) to derive relation between both parameters and to estimate the UCS of rest of the similar rock units having done point load testing only. The UCS based on the UCS testing and estimation based on point load test range from 18.08 to 111.43 with mean of 57.41 for Amphibolite. Based on the outcome of this analysis and that of from Schmidt rebound hammer test, a value of 55MPa has been adopted. Likewise, the UCS based on the UCS testing and estimation based on point load test range from 25.31 to 107.26 with mean of 51.75 for granite/ granodiorite. Based on the outcome of this analysis and that of from Schmidt rebound hammer test, a value of 50MPa has been adopted. It should be noted that the analysis of the Schmidt rebound hammer values yield lower values of the UCS (**Table 5.10**) which can be attributed to the relatively more weathered discontinuity surfaces at the rock outcrop. However, the UCS testing has been undertaken on relatively fresh rock specimens retrieved from boreholes. Therefore, UCS values adopted are based on the actual UCS testing to present realistic scenario.

The Elastic moduli for both rock units determined in the laboratory testing were found on very lower side (

Table 5.11), e.g. mostly 2-10GPa in comparison to >20GPa found by using Roclab (Rocscience). In considering both analyses output, values of 17.0GPa and 15.0 GPa were adopted for amphibolite and granite/ granodiorite respectively (

Table 5.11). A summary of other intact rock parameters including point load strength index, Poisson’s ratio, unit weight and water absorption are also provided in

Table 5.11.

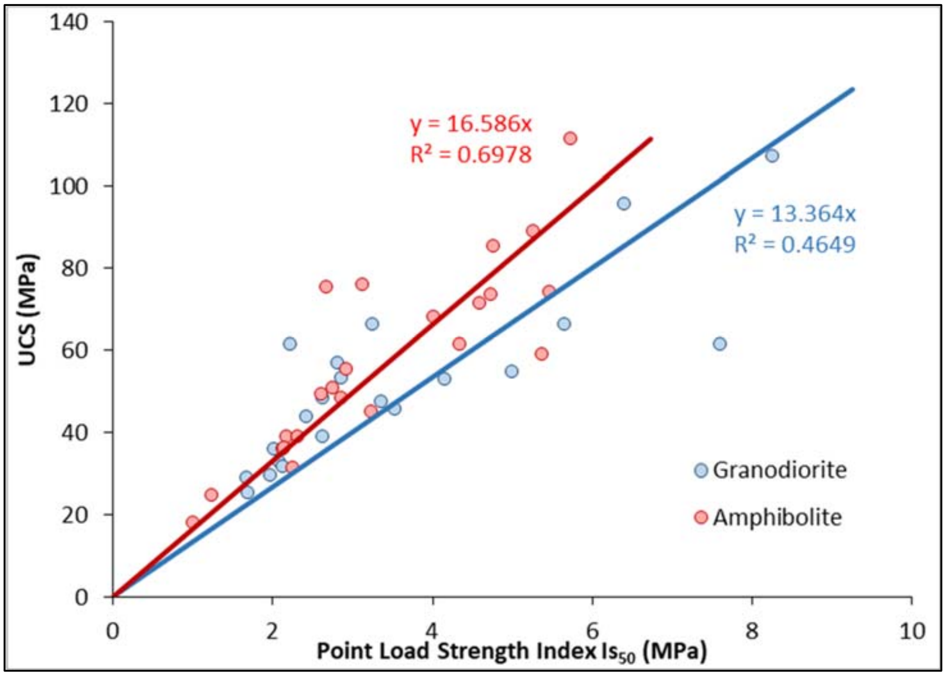

Figure 5.11: Plot showing correlation of point load index (Is_{50}) and UCS for rock units

Table 5.11: Summary of Intact Rock Parameters

Rock Unit		Point Load Index (Is_{50}) MPa	UCS (MPa)	E (GPa)	Poisson's Ratio	Unit Weight kN/m³	Water Absorption (%)
Amphibolite (Mzb)	Adopted	3.12	55.0	17.0	0.26	25.26	0.50
	Minimum	0.63	18.08	2.41	0.26	21.95	0.00
	Mean	3.12	54.86	15.04	0.31	25.26	0.50
	Maximum	4.34	111.43	50.00	0.36	30.06	1.65
Granite/ Granodiorite (Ksg)	Adopted	3.18	50.0	15.0	0.28	26.10	0.47
	Minimum	1.03	25.31	2.96	0.24	22.34	0.00
	Mean	3.18	50.47	4.92	0.32	26.10	0.47
	Maximum	8.66	107.26	9.00	0.35	31.61	0.82

Similarly, the soil parameters were also adopted (**Table 5.12**) based on the laboratory and field test data, and engineering judgment.

Table 5.12: Summary of Soil Parameters

Soil Unit		Atterberg's Limits			Bulk Unit Weight	NMC	Cohesion	Angle of Friction
		LL	PL	PI	(kN/m^3)	(%)	(KPa)	(°)
River bed material (Sandy Gravels)	Adopted	Non-Plastic			20.0	5.0	0	38.0
	Mean	Non-Plastic			21.76	6.2	0.4	38.3
	Minimum	Non-Plastic			21.76	3.2	0.3	37.4
	Maximum	Non-Plastic			21.76	9.0	0.5	39.9
Slope Wash Material/ Glaciofluvial Deposits (Silty sandy Gravels)	Adopted	27.0	21.0	6.0	18.0	10.0	10	37.5
	Mean	26.8	21.0	5.8	17.81	6.0	8.4	37.7
	Minimum	22.0	20.0	2.0	15.29	1.6	1.10	34.8
	Maximum	30.0	23.0	10.0	20.19	17.2	16.9	40.7

5.4.3 ROCK CHARACTERIZATION

At rock exposures and borehole cores, characterization of rock mass was undertaken to have an assessment of rock mass quality along the proposed tunnel route and at location of important project components. During discontinuity surveys, all important parameters of discontinuities (orientation, persistence, spacing, aperture, surface roughness and undulation, infilling, and estimation of joint wall strength through Schmidt hardness), were recorded and standard empirical rock classification systems, that is, Rock Mass Rating (RMR) after Bieniawski (1989) and Tunneling Quality Index (Q) system after Barton (1974, 1993) were used for rock mass classification. Likewise, the borehole logs were also prepared estimating these parameters for rock characterization and classification. Later, based on the rock classification, rock mass parameters for foundation and support design were derived.

5.4.3.1 ROCK MASS CLASSIFICATION

RMR and Q systems were used to classify the rock mass along the tunnel route and at important project site. The RMR system is based on the evaluation of following six parameters:

1. Uniaxial Compressive Strength of rock mass
2. Rock Quality Designation "RQD"
3. Spacing of the joints / discontinuities
4. Condition of joints / discontinuities
5. Ground water conditions
6. Orientation of joints / discontinuities

These parameters have been given appropriate weightage and accordingly rating as per their characteristics. The sum of all rating (1-100) will designate specific rock class together with the estimation of rock mass mechanical parameters and correspondingly guideline for support assessment for surface and subsurface excavation. RMR gives weightage to the orientation of rock mass discontinuities and adjust the RMR values according to its application, that is, in underground excavation, slopes, foundation, etc.

The Q system is a function of three major parameters given below:

1. Block size (RQD/Jn) representing the structure of the rock mass and a measure of particle size.

2. Inter-block shear strength (Jr/Ja) represents the roughness and friction characteristics of the joint walls or filling material.

3. Active stresses (Jw/SRF) represent the stress field within and outside the rock mass in tunnels.

The numerical value of the Q is defined by the following equation

$$Q = (RQD/Jn)\ (Jr/Ja)\ (Jw/SRF)$$

The determined Q values classify the rock into various categories and provide support design for each category. The Q value is plotted against equivalent dimension of excavation (De) which is span of tunnel or height of tunnel walls divided by excavation support ratio (ESR). ESR is generally taken as 1.6 for long term excavations.

Both RMR and Q systems have been applied on the project rock units. The values of RMR and Q were determined based on discontinuity data, borehole data and visual assessment (where discontinuity or borehole data is not available) of required parameters. The calculated values of RMR were adjusted for the orientation of discontinuities to classify the rock for foundation and underground excavations. However, the Q values were used only for the rock mass classification and estimation of support of headrace tunnel and adit.

The rock mass classification of all project rock units based on RMR and Q are summarized in **Table 5.13** and detailed sheets are provided in **Annexure B9, Volume VII**. The rock mass quality is fair to good as per RMR and poor to fair as per Q in Amphibolite. Likewise, it is fair to good as per RMR in granite/ granodiorite that becomes fair with the adjustment of the discontinuity orientations for tunnels. However, the rock mass quality is poor to good as per Q in granite/ granodiorite.

Table 5.13: Rock classification based on Q and RMR values

<table>
<tr><th>Rock Unit</th><th>Data Used</th><th>Q Values</th><th>Rock Class based on Q</th><th>RMR</th><th>Rock Class based on RMR</th><th>RMR for Foundation</th><th>RMR for Tunnel</th></tr>
<tr><td rowspan="4">Amphibolite (MZB)</td><td rowspan="3">Discontinuity Surveys</td><td rowspan="2">4.34-9.63</td><td rowspan="2">Fair</td><td>68</td><td>Good</td><td rowspan="3">Not Applicable (NA)</td><td>63 (Good)</td></tr>
<tr><td rowspan="2">45-59</td><td rowspan="2">Fair</td><td>43 - 50 (Fair)</td></tr>
<tr><td>1.00-3.59</td><td>Poor</td><td>40 (Poor)</td></tr>
<tr><td>Borehole data</td><td>-</td><td>-</td><td>42-56</td><td>Fair</td><td>(NA)</td><td>-</td></tr>
<tr><td rowspan="4">Granite/ Granodiorite (KSG)</td><td rowspan="3">Discontinuity Surveys</td><td>10</td><td>Good</td><td rowspan="2">61</td><td rowspan="2">Good</td><td rowspan="3">(NA)</td><td rowspan="3">42 – 54 (Fair)</td></tr>
<tr><td>4.02-9.97</td><td>Fair</td></tr>
<tr><td>3.45</td><td>Poor</td><td>48-58</td><td>Fair</td></tr>
<tr><td>Borehole data</td><td>-</td><td>-</td><td>49-59</td><td>Fair</td><td>(NA)</td><td>-</td></tr>
</table>

5.4.3.2 ROCK MASS PARAMETERS

Rock mass parameters for each lithic unit were obtained from Hoek & Brown Criteria (Hoek & Brown 2000) using computer program Roclab from Rocscience. Hoek- Brown criteria uses Geological Strength Index (GSI), material constant (mi), intact rock strength (UCS) and modulus (E), Excavation induced disturbance factor (D) and derive rock mass parameters. The input parameters (UCS and E of intact rock taken from

Table 5.11 for) and derived rock mass parameters are summarized in **Table 5.14**.

Table 5.14: Summary of Rock Mass Parameters

Rock Unit	UCS (MPa)	Intact Rock Modulus (GPa)	RMR Adopted (Range)	GSI (RMR-5)	Material Constant $(m_i)/(m_b)$	Disturbance Factor (D)	Rock Mass Global/UCS (MPa)	Rock Mass Modulus of Deformation (GPa)
Amphibolite (Mzb)	55	17.0	48 (42-54)	43	25/2.60	0.2	11.52/1.74	2.40
Granite/ granodiorite	50	15.0	47 (39-55)	42	30/3.0	0.2	11.23/1.48	2.30

5.4.4 Geotechnical Conditions and Design Considerations at Project Structures' Locations

5.4.4.1 Reservoir Area

The Artistic-I Hydropower scheme shall operate on run–of-the-river basis, therefore the reservoir created by the weir shall be shallow and of limited area. The area up stream of the weir is similar and is 150-250m wide with relatively gentle lower slopes in mostly overburden materials (**Figure 5.12**).

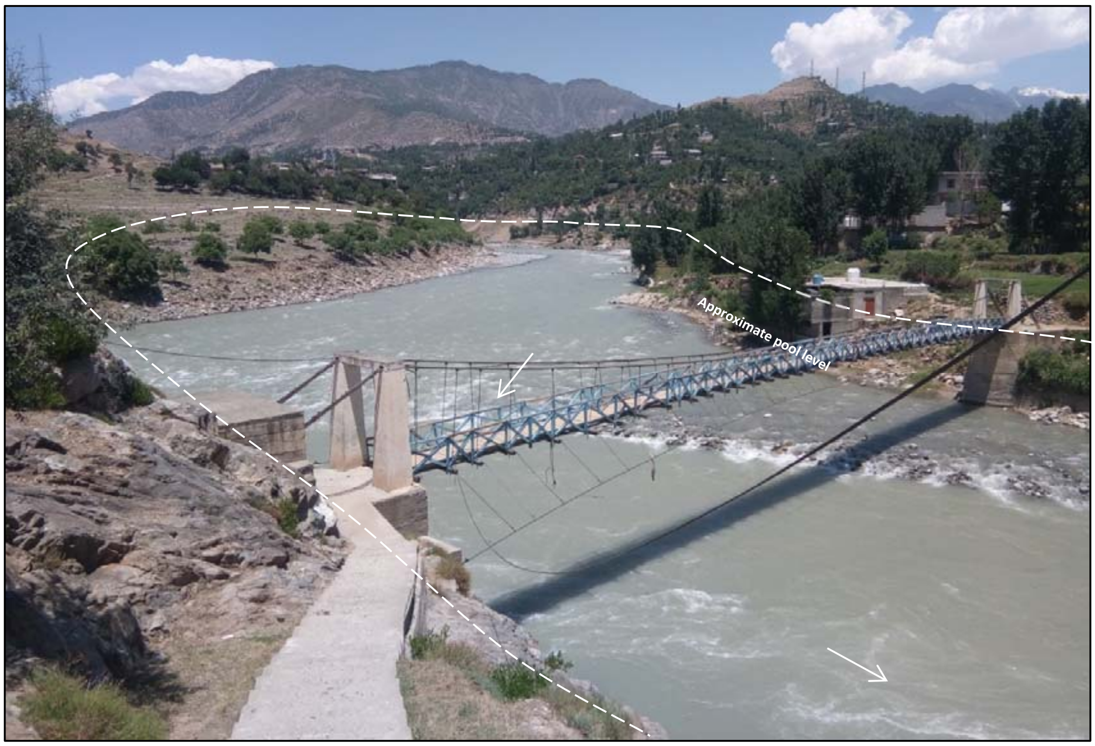

Figure 5.12: An upstream looking view of the reservoir area with approximate pool level. The existing suspension bridge is also visible in the foreground.

The upstream left periphery consists of rock exposures and overburden material of colluvial and fluvial origin. The rock exposures are not very much consistent but are spot exposures in the overburden material. Right periphery is also more or less same with more percentage of overburden material than rock. The overburden material along right bank is a slope wash material that has been derived from up slopes. The river bed materials comprise gravel, cobbles and boulders of igneous and metamorphic origin with sandy matrix (**Figure 5.2**).

It has been assessed in the field that the reservoir area is situated in overburden materials and it is likely that slope wash material present along the right abutment may not be very good material for water tightness. Therefore, the right bank wall of the intake structure has been extended towards upstream to prevent the contact of reservoir water with the slope wash material. This wall will also keep the reservoir within the river course. However, along left abutment rock comprising granite/ granodiorite/ amphibolite is present that may be good material for water tightness. Given the fact that foliation at this location is nearly parallel to river flow, some open relief joints are likely to be present that need to be investigated in the next stage studies and accordingly remediation needs to be incorporated in the detailed design stage. Generally, the slopes in the reservoir area are gentle and both in overburden and rock. The slopes may not require substantial treatment for the stability. However, minor treatment such as provision of rip-rap (grouted stone pitching) may help to stabilize the slopes at the problematic locations.

5.4.4.2 WEIR

The Panjkora River in the weir site is flowing from northeast to southwest and the width of river bed at the weir axis is about 70m, whereas the valley is about 200m wide. At the weir site, the subsurface conditions have been investigated through engineering geological mapping, discontinuity surveys, exploratory boreholes, test pits and seismic profiling. The locations of all investigations points at weir site are shown in drawing no. A1HP-FS-GE-WR-DWG-204 and details are given in **Table** 5.3 (boreholes),

Table 5.4 (test pits) and

Table 5.5 (seismic refraction profiles). A downstream view of the Artistic-I Weir site is shown in **Figure 5.13**.

The weir site geological map (A1HP-FS-GE-WR-DWG-204) shows that the area is occupied by both the rock outcrop at the left abutment and the overburden material (slope wash and old river bed material) at the right abutment (**Figure 5.13**). A subsurface geological section along the weir has been prepared based on the surface geology and interpretation of subsurface geology attached in drawing no. A1HP-FS-GE-WR-DWG-205. The river bed material is dominantly of cobbles and boulders of igneous and metamorphic origin with sandy matrix (**Figure 5.13**). The river bed material is loose at the top and relative density increases depth wise and appears to be good material for foundation of weir structure. However, it is pervious and will have seepage underneath the weir foundation. To prevent excessive seepage, a cut off wall/ secant piles extending down the river bed has been proposed along the weir and intake axes and along the upstream right bank wall.

The left abutment comprises of rock slope which is nearly vertical slope consisting of banded amphibolite and granite/ granodiorite. The contact of the rock is marked on drawing no. A1HP-FS-GE-WR-DWG-204. This contact shows that rock, a bit upstream of the weir, is amphibolite while in downstream area is mainly granite. Further upstream, granite / granodiorite is again exposed after the amphibolite. Regardless of the type the rock, the rock appears to be massive to foliated (**Figure 5.14**). One discontinuity survey (DS-19) has been undertaken on the left abutment slightly upstream of the weir axis. Another discontinuity survey (DS-20) was undertaken along the road but upstream of the DS-19 location. The samples taken from these discontinuity survey locations indicate that at the abutment rock is mainly amphibolite while upstream along the road, it is granite (**Table 1** & drawing no. A1HP-FS-GE-WR-DWG-204).

Figure 5.13: A broad downstream looking view of the proposed weir axis area.

The rock quality, as per ISRM guidelines for intact rock classification, is interpreted to be medium strong to strong and is generally massive to foliated, slightly to moderately weathered. The discontinuity surveys have indicated that the two joint sets are present in addition to foliation (**Figure A5** & **Figure A6**) along with some random joints. The trend of foliation is almost parallel dipping towards the west. The orientation of foliation and joint sets are shown drawing no. A1HP-FS-GE-WR-DWG-204 and the discontinuity data and summaries with stereo-net plots are provided in the **Annexure B1 & B2, Volume VII** of the Feasibility Report. The rock mass as characterized based on the discontinuity surveys is massive to foliated and is having foliation in northeast-southwest direction dipping in northwest direction. The output of kinematic analysis on DS-19 data does not highlight any modes of slope movement in existing scenario. Since not much rock cutting is involved in the placement of the weir, no disturbance/ excavation induced failures are likely. Upslope of the left abutment towards, the rock is underlain by thin layer of overburden and is exposed again making road cut along Peshawar-Dir Road.

The right abutment comprises unconsolidated materials of slope wash and ancient river bed material with vegetation (**Figure 5.15**). These deposits are believed to be lying on the underlying valley floor of the river bed material. This material comprises gravels to boulders and occasional rock blocks embedded in sandy silty matrix. The gravelly material is angular to subangular having mostly igneous origin. The rock is assumed to be deep, that is, about ~45m. The upslopes behind the right abutment comprise relatively steep and high rock outcrop slopes that have deposited slope wash material in the lower slope (at right abutment) and valley floor. From the field studies, no major movement of rocks was witnessed above the right bank slopes, therefore, these are assumed to be stable. However, slope cutting in the overburden material may require adequate slope evaluation for the placement of weir structure.

Figure 5.14: View of the left abutment where rock is present.

Figure 5.15: A view of right abutment area covered with slope wash material deposits.

Three boreholes; A1-BH-1, 2 & 3 were drilled along the weir axis up to a maximum depth of 35m to explore the subsurface. Similarly, three (3) test pits and two (2) seismic profiles (A1-SP-9 & 10) were also conducted to estimate the depth to bed rock in this area (drawing no. A1HP-FS-GE-WR-DWG-204). The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in **Figure 5.16** for A1-BH-1 & 2, and in

Figure 5.17 for A1-BH-3.

The exploratory drilling has revealed that the bed rock is present at depth from 30m at center of the river weir axis (drawing no. A1HP-FS-GE-WR-DWG-205). The borehole (A1-BH-1) along the left abutment is at rock exposure. Along the right abutment, the lower limit of overburden was not determined. At the valley center, the depth to bed rock is 30 m (A1-BH-2) at an elevation of 1035m.

The water table recorded during field investigations is at depth of 3.3 m (A1-BH-2) at valley center and at 5.8m (A1-BH-3) at right abutment below natural surface level, however, in borehole (A1-BH-1) along left abutment, water table was not encountered during field investigations.

The laboratory testing on selective core samples of A1-BH-1 & 2 have revealed that the bed rock comprising amphibolite of Banded Amphibolite (Mzb) is medium strong to strong as per ISRM intact rock classification; (Please refer **Table 5.6** for summary of Laboratory test results). The laboratory tests have shown that bulk density of core samples varies from 2.43 g/cm^3 to 2.72 g/cm^3 and dry density from 2.56 g/cm^3 to 2.71 g/cm^3.

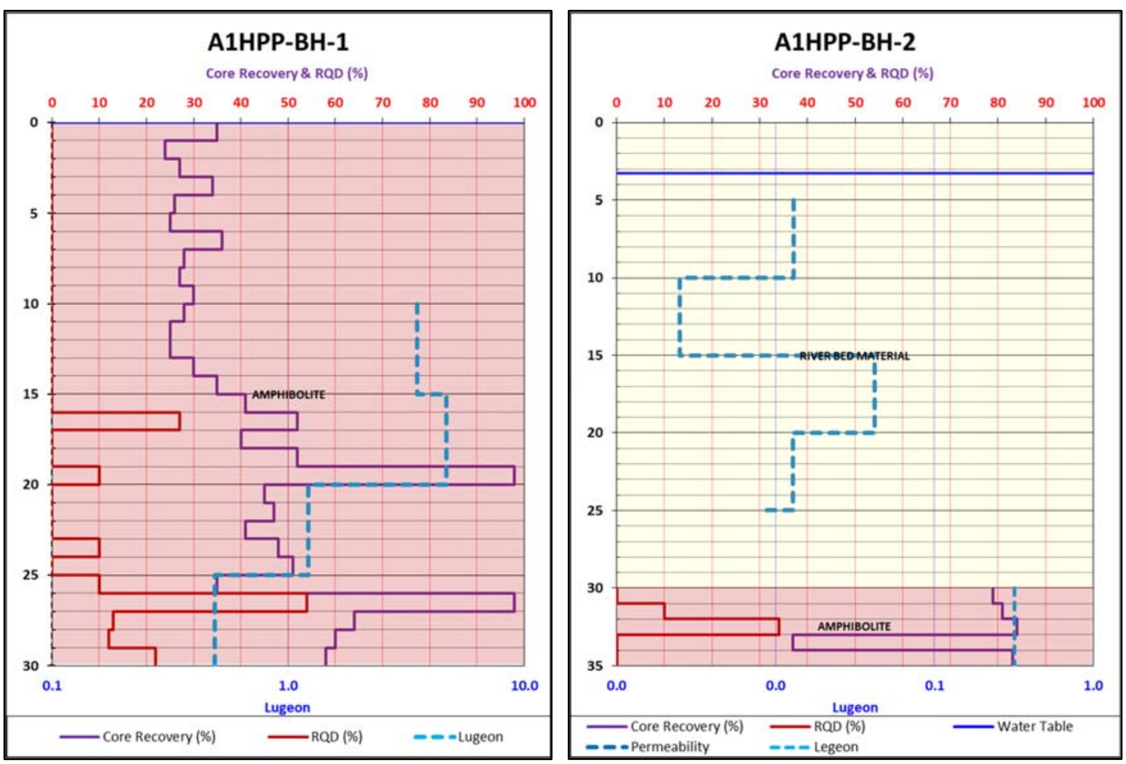

Figure 5.16: Plots showing subsurface profile as explored by the A1-BH-1 & 2.

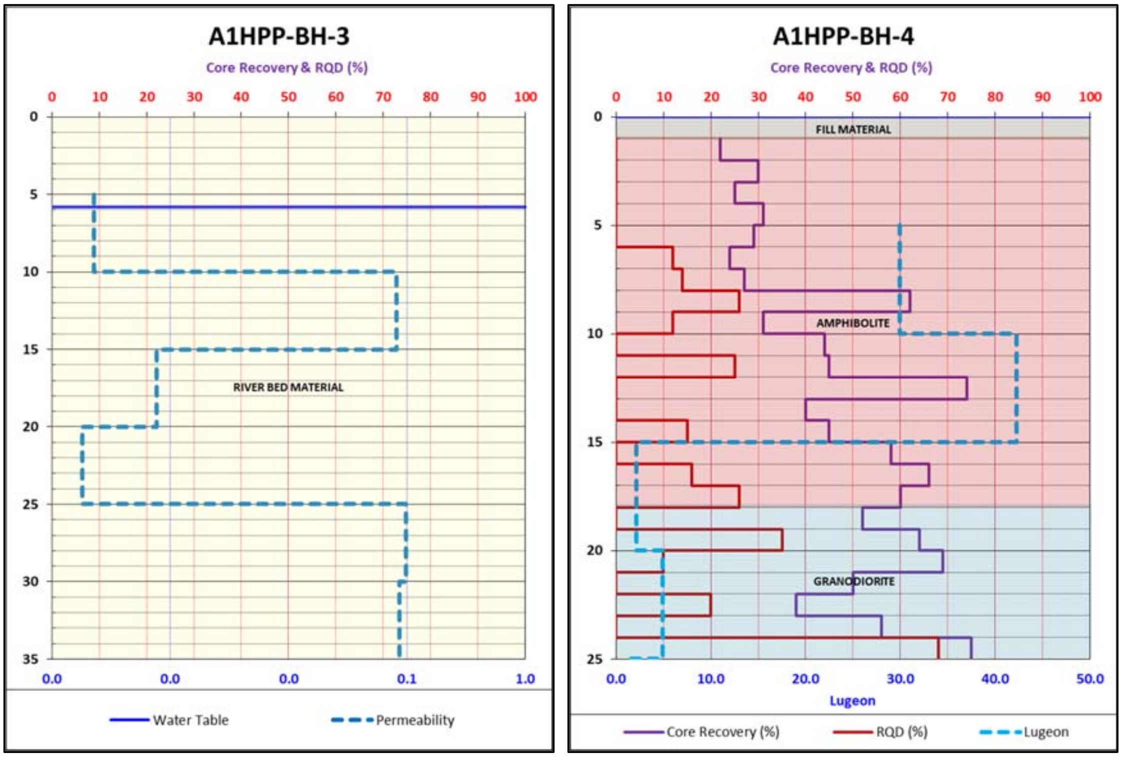

Figure 5.17: Plots showing subsurface profile as explored by the A1-BH-3 & 4.

Generally rock mass quality as determined from borehole and discontinuity data falls in fair class at weir site as per RMR (**Table 5.13**). However, the foundation of the weir will be placed on the river bed material which is about 30m thick in the valley. As per the US Army Corps of Engineers, Bearing Capacity of Soils Manual (EM 1110-1-1905), a nominal allowable bearing capacity of 1.5-2.0 kg/cm^2 is proposed to be used for slope wash materials comprising angular to rounded gravels, cobbles and boulders embedded in silty sandy matrix. Similarly, according to same reference, a bearing capacity value of 2.0 kg/cm^2 can be used for the structures to be founded on the river bed material comprising loose to medium compacted rounded to sub rounded gravels, cobbles and boulders embedded in sandy matrix. This allowable bearing pressures will require the removal of any encountered loose material and filling with granular fill compacted to 95% of its maximum dry density. However, the abovementioned figures do not consider the dimensions of the foundations. When the soil parameters given in Table 5.12 and the width (21.3 m), length (21.5 m) and depth (3 m) of the foundation divided by movement joints, are applied to General Bearing Capacity Equation, the allowable bearing capacity of the riverbed material is found around 5 kg/cm^2, which is sufficient to carry the loads transferred from the gated weir structure. The values of permeability of overburden material is given in **Table 5.15** varies from 1.85E-04 to 9.84E-02 cm/sec. The bed rock has shown relatively low range of permeabilities in most of the in-situ water pressure tests (**Table 5.16**).

However, the high values of permeabilities warrant the use of secant piles as a cut-off wall below the weir structure to stop/ minimize the underground water flow.

Table 5.15: Summary of permeability test results at weir site.

Borehole No.	Test No.	Test Depth [m]	Permeability (cm/sec)
A-1 BH-2	1	5	1.30E-02
	2	10	2.45E-03
	3	15	4.25E-02
	4	20	1.29E-02
	5	25	7.92E-03
A-1 BH-3	1	5	2.27E-04
	2	10	8.22E-02
	3	15	7.66E-04
	4	20	1.85E-04
	5	25	9.84E-02
	6	30	8.58E-02
	7	35	8.05E-02

Table 5.16: Summary of water pressure test results at weir site.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-1	1	5-10	3.53	Turbulent
	2	10-15	4.69	Turbulent
	3	15-20	1.22	Turbulent
	4	20-25	0.49	Turbulent
	5	25-30	0.47	Turbulent
A-1 BH-2	1	30-35	0.32	Turbulent

The weir structure would require cutting of slope wash/ river bed material at the right abutment as the thickness of overburden is in access of 45 m. The excavation with 1H:1V cut slope angle for the permanent slopes along weir abutment is proposed as per the conducted limit-equilibrium analysis (**Figure 5.18**) using parameters provided in **Table 5.12** and based on the local experience in these types of materials. However, the temporary slopes can be cut at an angle of 1H:1.5-2V.

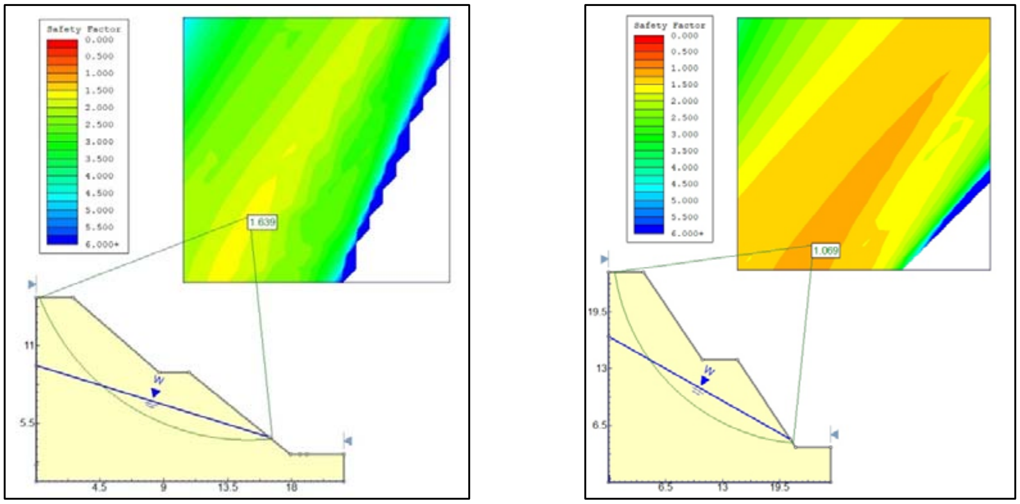

Figure 5.18: Plots showing outcome of limit equilibrium analysis at extreme condition i.e. with water table and earthquake loading (0.2g); for a overburden slope dressed at angle a) 1H:1V, b) 1H:1.5V.

5.4.4.3 INTAKE AND BOX CHANNEL

The intake from the weir will be placed on the right abutment bit upstream of the weir. The intake of the weir will be connected to intake of the free flow tunnel by a box channel of about 200m length. Both the intake of the weir and channel will be on the unconsolidated slope wash material lying on the underlying valley floor of the river bed material (A1HP-FS-GE-WR-DWG-204). This material comprises mostly gravels and cobbles with occasional boulders embedded in sandy silty matrix. The gravelly material is subangular to sub rounded having mostly igneous origin. The foundation material appears to be good enough to bear the load of intake structure and box channel. Towards the intake of free flow tunnel, rock is likely to be at shallow depth (>10m) that gradually comes to surface near the intake of free flow tunnel. The material appears to be medium dense to dense and may be very dense at greater depth where river bed material is present.

The box channel connecting intake of weir to the free flow tunnel intake will be mostly on the unconsolidated material comprising slope washes along the right bank of Panjkora River (drawing no. A1HP-FS-GE-WR-DWG-204 to 205). The geotechnical investigations have revealed that these unconsolidated materials are comprised of gravels, cobbles and boulders embedded in silty sandy matrix of mix origin. The proportion of granular materials varies both vertically and horizontally along the channel route and rock comprising Amphibolite of Banded Amphibolite or granite / granodiorite of Shandur Granodiorite interpreted to be present at depth greater than 40m. The geological sections at box channel (RD 0+020 & 0+140 m) are given in drawing no. A1HP-FS-GE-WR-DWG-205.

As per the US Army Corps of Engineers, Bearing Capacity of Soils Manual (EM 1110-1-1905), a nominal allowable bearing capacity of 1.5-2.0kg/cm^2 is proposed to be used for slope wash materials comprising angular to rounded gravels, cobbles and boulders embedded in silty sandy matrix. This allowable bearing pressures will require the removal of any encountered loose material and filling with granular fill compacted to 95% of its maximum dry density. The placement of the intake and box channel will involve the cutting of slope wash deposits. The excavation with 1H:1V cut slope angle for the permanent slopes along box channel is proposed as per the conducted limit-equilibrium analysis (**Figure 5.18**) using parameters provided in **Table 5.12** and based on the local experience in these types of materials. However, the temporary slopes can be cut at an angle of 1H:1.5-2V.

5.4.4.4 FREE FLOW TUNNEL

Free Flow Tunnel has been proposed about 200m downstream of the weir along right abutment where steep rock slope is present making the right river bank (**Figure 5.19**). The free flow tunnel shall off take from the intake in almost northeast direction for a distance of about 400m then it takes a curved bend towards south and is aligned in southeast direction up to further about 1.2km where it takes a smooth bend towards east and eastward to tunnel outlet. The tunnel shall be arched in shape with 8.2m of excavation diameter. The rock exposed along the tunnel alignment is mainly granite/ granodiorite. However, thin exposures of amphibolite are also present near tunnel intake and outlets (drawing no. A1HP-FS-GE-TNL-DWG-206 & 207). The length of the free flow tunnel is about 1600m starting from chainage 0+203 to 1+786. In the tunnel intake and outlet area, rock is either exposed or under thin cover of overburden/ vegetation.

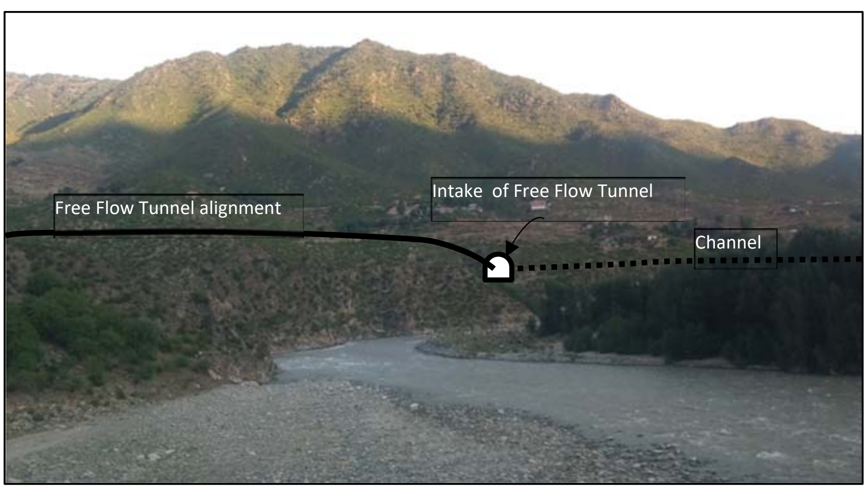

Figure 5.19: A broad view of the Box Channel and Tunnel Intake.

Five discontinuity surveys DS-8, DS-9, DS-14, DS-17 & DS-18 have been conducted along the tunnel stretch. Two discontinuity surveys DS-8 & DS-18 has shown rock as amphibolite while rest of the three discontinuity surveys show granite/ granodiorite (**Table 1** & A1HP-FS-GE-GNL-DWG-203 & A1HP-FS-GE-TNL-DWG-206). It is likely that the most of the tunnel stretch will be in granite/ granodiorite and amphibolite is present on the intake and outlet portals. As part of geotechnical investigation, two holes A1-BH-04 & 05 with the depth of 25m were drilled at the locations of intake and outlet of the free flow tunnel. Due to extreme weather conditions and inaccessible reaches, hole A1-BH-05 was drilled a bit upstream of the proposed location. Nevertheless, this hole was used for geological and geotechnical interpretation.

The subsurface conditions as explored by the boreholes and relevant in-situ tests are given together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in

Figure 5.17 for A1-BH-4 and in

Figure 5.20. The values of water pressure tests are given in **Table 5.17** for both holes.

The exploratory drilling (A1-BH-04) at the intake has revealed that the bed rock comprising amphibolite is present at an elevation of 1086m with only one meter overburden cover. The water table was not encountered in borehole. The granite / granodiorite is encountered at the depth of 18 m with an elevation of 1069m that has made the basis of interpreting an isolate body of granite/ granodiorite within amphibolite (drawing no. A1HP-FS-GE-TNL-DWG-207).

Table 5.17: Summary of water pressure test results of A1-BH-04 & A1-BH-05

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-4	1	2-5	29.91	Turbulent
	2	5-10	42.28	Washout
	3	10-15	1.98	Dilation
	4	15-20	4.91	Washout
	5	20-25	1.08	Void Filling
A-1 BH-5	1	5-10	19.16	Turbulent
	2	10-15	12.51	Turbulent
	3	15-20	5.69	Washout
	4	20-25	1.33	Dilation

The laboratory testing on selective core samples of A1-BH-4 have revealed that the bed rock comprising amphibolite of Banded Amphibolite and granite / granodiorite of Shandur Granite is generally medium strong to strong as per ISRM intact rock classification; (Please refer **Table 5.6** for summary of Laboratory test results). The laboratory tests have shown that bulk density of amphibolite core samples is 2.41 g/cm^3 while bulk density of granite / granodiorite is 2.89 g/cm^3. Generally rock mass quality as determined from borehole and discontinuity data falls in fair class at the intake site as per RMR (**Table 5.13**).

Likewise, borehole A1-BH-05 has revealed that the bed rock comprising amphibolite is present at an elevation of 1084m with only one meter overburden cover at the outlet portal location of the free flow tunnel. The granite / granodiorite was encountered at the depth of 10m with an elevation of 1075m. The laboratory testing on selective core samples of A1-BH-5 have revealed that the bed rock comprising amphibolite of Banded Amphibolite and granite / granodiorite of Shandur Granite is medium strong to strong as per ISRM intact rock classification; (Please refer **Table 5.6** for summary of Laboratory test results). The laboratory tests have shown that bulk density of amphibolite core samples is 2.82 g/cm^3 while bulk density of granite / granodiorite varies from 2.74 to 2.83 g/cm^3. Generally rock mass quality as determined from borehole and discontinuity data falls in fair class at tunnel outlet site as per RMR **(Table 5.13).**

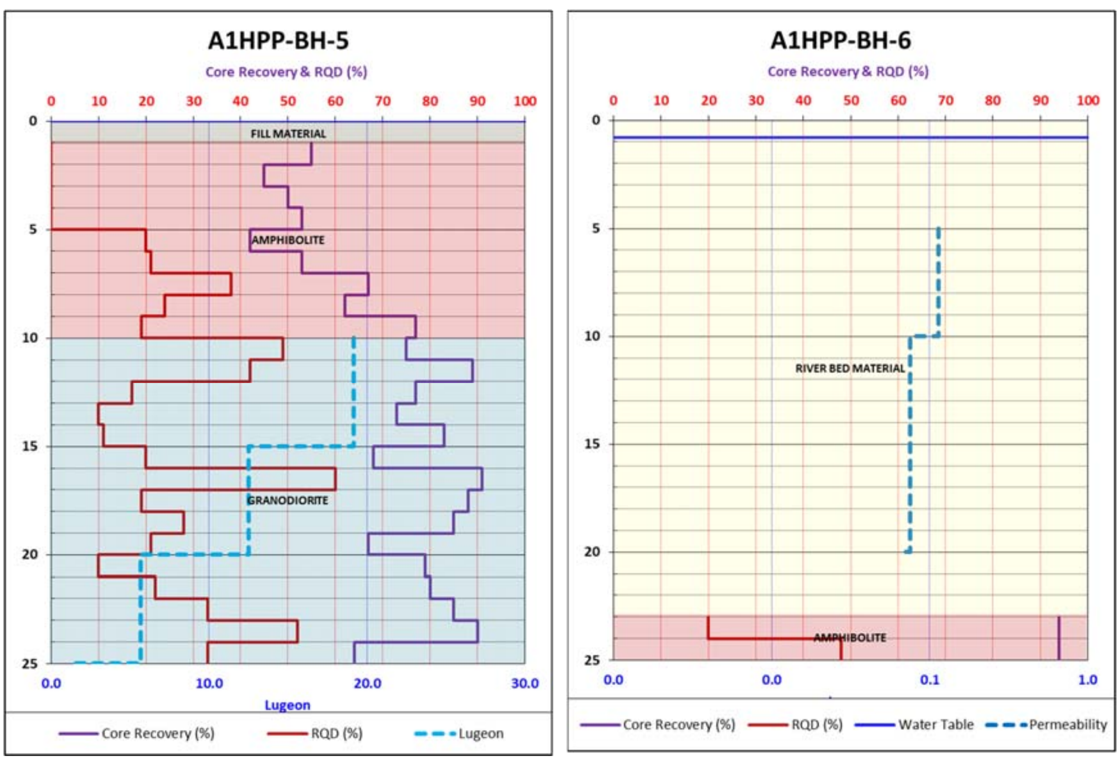

Figure 5.20: Plots showing subsurface profile as explored by the A1-BH-5 & 6.

Along rest of the alignment of the free flow tunnel, the intact rock quality is interpreted on the basis of discontinuity surveys and is medium strong to strong and very strong in places, as per ISRM guidelines for intact rock classification.

The rock mass characterization and classification along the free flow tunnel has been undertaken based on the discontinuity surveys and borehole data. Four discontinuity surveys (DS-9, 14, 17 & 18) have been conducted along the free flow tunnel, while one discontinuity survey (DS-8) has been conducted a bit downstream of the tunnel outlet and is used for rock characterization and classification at tunnel outlet. The orientation of foliation and joint sets are shown in drawings A1HP-FS-GE-GNL-DWG-203 & A1HP-FS-GE-TNL-DWG-206 and field data has been attached as **Annexure B2** while summaries of the discontinuity surveys are attached as **Annexure B1** of the **Volume VII** of the feasibility Report.

From intake to onward along the free flow tunnel, DS-18 & DS-17 have been used to interpret the rock mass conditions, while onward to tunnel outlet, DS-8, 9 and 14 were used for rock characterization. The interpreted geological information shows that the following rock types shall be expected along the tunnel route.

- Banded Amphibolite: This rock unit is present at the intake and outlet locations of free flow tunnel with some intrusions of granite/ granodiorite along the tunnel route. The rock is blocky to very blocky having foliation trend in northeast-southwest direction dipping both in northwest and southeast directions at moderate to very steep angles. As per discontinuity surveys, the discontinuities are generally extremely close to wide spaced, very low to very high persistent with very tight to very wide apertures and generally smooth to rough having planar to undulating surfaces. As per surface condition and geotechnical investigation in the project area, water table is not likely to be present above the proposed stretch of the tunnel in this rock unit through the discontinuities intersecting the tunnel alignment. This rock unit is present from tunnel intake to 0+450m chainage of the tunnel alignment, where it makes its contact with the granite/ granodiorite of Shandur Granodiorite. From tunnel chainage 1+640m to onward, this rock unit reappears till the outlet of the free flow tunnel. This rock unit is present about 25% of the total tunnel length of free flow tunnel.

- Granodiorite/ Granite: This rock unit is present from 0+450m chainage along the tunnel route and extends up to the 1+640m tunnel chainage. This rock is blocky to very blocky having foliation trend in northeast-southwest direction dipping northwest at moderate to steep angles. As per discontinuity surveys, the discontinuities are extremely close to moderately spaced, very low to very high persistent with very tight to very wide apertures and generally have rough and undulating rock surfaces. The rock quality as per ISRM guidelines for intact rock classification is to be medium strong to strong. As per surface condition and geotechnical investigation in the project area, water table is not likely to be present above the proposed stretch of the tunnel in this rock unit through the discontinuities intersecting the tunnel alignment. This rock makes about 75% of the total rock mass along the free flow tunnel.

The lithological detail of these rock types is given in Section 5.2.2.2.2.

The rock mass classes along the free flow tunnel alignment were assessed using rock mass classification systems; RMR after Bieniawski (1989) and Q after Barton et al. (1974 & 2002). A summary of the rock mass classes according to these systems are provided in **Table 5.18**, and detailed calculation sheets are provided in **Annexure B9, Volume VII**. Additionally, ground conditions in terms of tunnel stability and problems such as squeezing, spalling and bursting were also evaluated utilizing empirical schemes of Singh et al. (1992), Goel et al. (1994), Hoek and Marinos (2000), Hoek and Brown (1980) and Barton et al. (1974 & 2002). The details of tunnel segments, anticipated rock cover and corresponding ground conditions, exposed rock units and their characteristic and rock classification along whole tunnel route have been summarized in **Table 5.18**.

The chainage wise variation of RMR, Q and GSI of the total length of tunnel is given in **Figure 5.21**. According to the RMR classification, the complete tunnel length of 1583m (100%) will pass through fair rock.

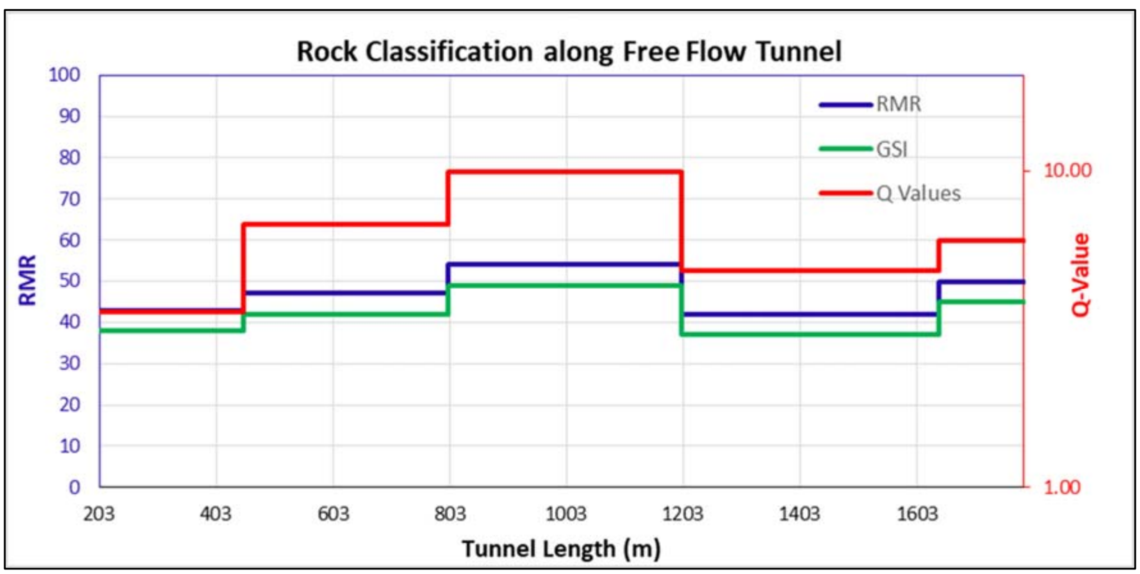

Figure 5.21: Variation of RMR, Q and GSI along Free Flow Tunnel

However, the characterization of rock masses through Q system concluded that the 1336m (84%) and 247m (16%) will pass through fair and poor rock mass classes, respectively. The assessment of rock classes is based on surface conditions and rock parameters gathered during the discontinuity surveys and boreholes drilled at the free flow tunnel intake and near outlet, however, along tunnel alignment, no bore hole is drilled due to high and inaccessible ridges. According to the RMR classification exercise conducted on borehole data, the rock quality falls in fair rock quality for both Banded Amphibolite and Shandur Granodiorite.

An assessment of the ground conditions for squeezing or rock bursting along the free flow tunnel route has also been made along with designing of the support. These details have been provided with headrace tunnel in Section 5.4.4.6.2.

5.4.4.4.1 BRIDGE ASSOCIATED WITH FREE FLOW TUNNEL

A bridge has been proposed a bit upstream of outlet of free flow tunnel connecting Timergara – Dir road to the part of project area that will provide access to the free flow tunnel structures for excavation. Three boreholes; A1-BH-6, 7 & 21 were drilled along the bridge axis up to a maximum depth of 25m to explore the subsurface. (drawing no. A1HP-FS-GE-TNL-DWG-206). The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability and water table in

Figure 5.20 for A1-BH 6, and in

Figure 5.22 for A1-BH-7 & 21. The values of permeability test are provided in **Table 5.19.**

The outcome of the investigations indicates that at the proposed bridge location near free flow tunnel, the valley floor is occupied by the unconsolidated deposits, slope wash materials making valley slopes and river bed alluvium making valley bed. The relative density of the slope wash deposits in terms of SPT (N) blows was found to be refusal, indicating dense to very dense relative density. The vales of field permeabilities were found to vary from 1.62E-02 to 1.14E-01 (**Table 5.19**). The rock is present on higher elevations and is assessed to be at deeper depth (23m) in the valley center near proposed bridge location (drawing no. A1HP-FS-GE-TNL-DWG-206). The foundation of the bridge will be seated on pile foundations. End bearing pile foundations have been proposed to transfer the bridge load to the underlying rock at the depth of 23 m by embedding the pile end 2 m into the bedrock, in the civil design studies

Table 5.18: Details of the rock profile and rock classification along Tunnel Routes

<table>
<tr><th rowspan="2">Section Name</th><th colspan="2">Tunnel Chainage</th><th>Length</th><th rowspan="2">Rock Unit</th><th rowspan="2">Rock Cover Thickness (m)</th><th colspan="2">Rock Class</th><th colspan="4">Ground Condition Assessment</th></tr>
<tr><th>From</th><th>To</th><th>(m)</th><th>RMR</th><th>Q</th><th>Hoek & Brown (1980)</th><th>Singh et al. (1992)</th><th>Goel et al (1994)</th><th>Barton et al (2002)</th></tr>
<tr><td rowspan="5">Free Flow Tunnel</td><td>203</td><td>450</td><td>247</td><td>MZB - Banded Amphibolite</td><td>20-60</td><td rowspan="5">Fair</td><td>Poor</td><td rowspan="6">Stable</td><td rowspan="16">Non-Squeezing</td><td rowspan="3">Self-Supporting</td><td rowspan="6">Medium Stress</td></tr>
<tr><td>450</td><td>800</td><td>350</td><td rowspan="3">KSG - Shandur Granodiorite</td><td>25-65</td><td rowspan="7">Fair</td></tr>
<tr><td>800</td><td>1200</td><td>400</td><td>65-143</td></tr>
<tr><td>1200</td><td>1640</td><td>440</td><td>62-145</td><td>Non-Squeezing</td></tr>
<tr><td>1640</td><td>1786</td><td>146</td><td rowspan="9">MZB - Banded Amphibolite</td><td>30-65</td><td>Self-Supporting</td></tr>
<tr><td rowspan="3">T-1</td><td>2889</td><td>3850</td><td>961</td><td>40-290</td><td>Good</td><td rowspan="8">Non-Squeezing</td></tr>
<tr><td>3850</td><td>4750</td><td>900</td><td>110-330</td><td rowspan="6">Fair</td><td rowspan="3">Minor Spalling</td><td rowspan="3">High Stress</td></tr>
<tr><td>4750</td><td>5077</td><td>327</td><td>300-360</td></tr>
<tr><td rowspan="2">T-2</td><td>5077</td><td>6650</td><td>1573</td><td>120-350</td><td>Poor</td></tr>
<tr><td>6650</td><td>7199</td><td>549</td><td>40-170</td><td>Fair</td><td rowspan="7">Stable</td><td rowspan="7">Medium Stress</td></tr>
<tr><td rowspan="6">T-3</td><td>7329</td><td>7560</td><td>231</td><td>30-160</td><td>Poor</td></tr>
<tr><td>7560</td><td>8200</td><td>640</td><td>110-210</td><td>Fair</td></tr>
<tr><td>8200</td><td>9140</td><td>940</td><td>90-240</td><td>Poor</td><td>Poor</td></tr>
<tr><td>9140</td><td>9750</td><td>610</td><td>KSG - Shandur Granodiorite</td><td>40-150</td><td>Fair</td><td>Good</td><td rowspan="3">Self-Supporting</td></tr>
<tr><td>9750</td><td>10280</td><td>530</td><td>MZB - Banded Amphibolite</td><td>30-150</td><td>Poor</td><td>Poor</td></tr>
<tr><td>10280</td><td>10315</td><td>35</td><td>KSG - Shandur Granodiorite</td><td>30-150</td><td>Fair</td><td>Fair</td></tr>
</table>

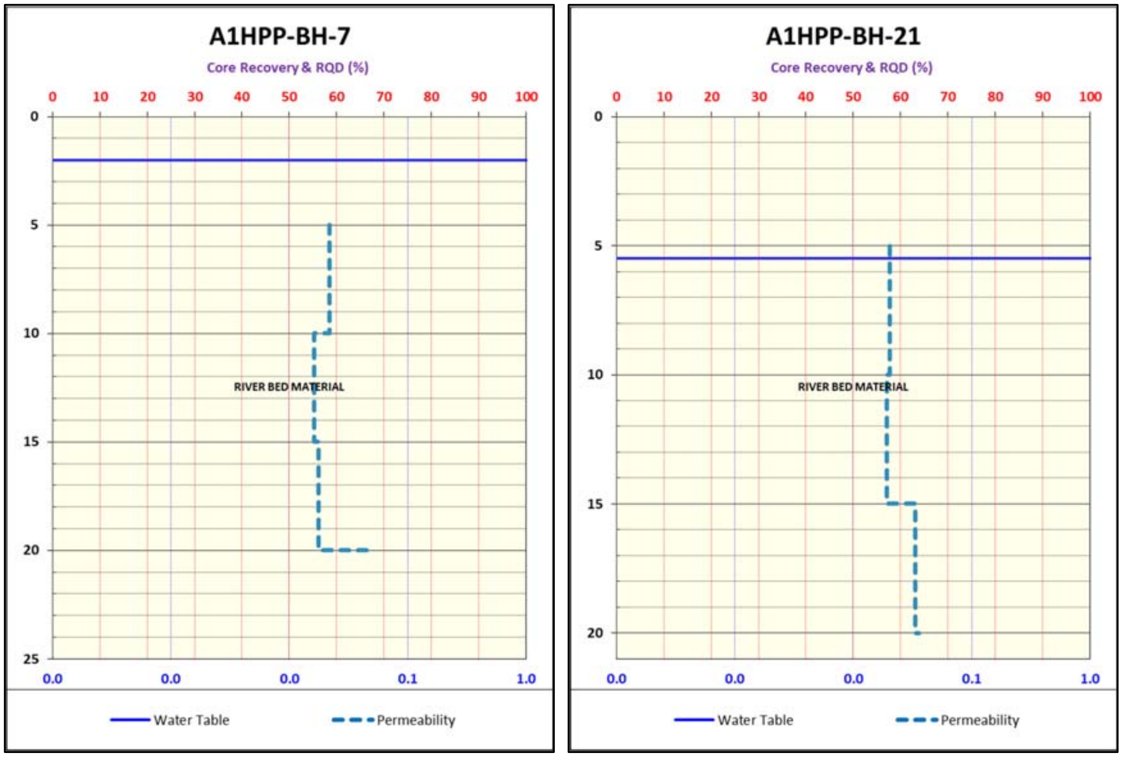

Figure 5.22: Plots showing subsurface profile as explored by the A1-BH-7 & 21.

Table 5.19: Summary of permeability test results at bridge near free flow tunnel.

Borehole No.	Test No.	Test Depth [m]	Permeability (cm/sec)
A-1 BH-6	1	5	1.14E-01
	2	10	7.52E-02
	3	15	7.50E-02
	4	20	6.99E-02
A-1 BH-7	1	5	2.19E-02
	2	10	1.62E-02
	3	15	1.76E-02
	4	20	4.81E-02
A-1 BH-21	1	5	2.02E-02
	2	10	1.92E-02
	3	15	3.34E-02
	4	20	3.59E-02

5.4.4.5 BOX CHANNEL, SAND TRAP AND INLET POND

Following the outlet of free flow tunnel, a box channel from chainage 1+786 to 2+285 (499 m long) has been proposed to link to Desander. Desander is about 215m long (Chainage 2285-2500) and is connected to Inlet pond via another box channel having length of 230m (from chainage 2500 to 2730) as shown in drawings A1HP-FS-GE-ST-DWG-208 & A1HP-FS-GE-

FB-DWG-210. Initial stretch of the box channel from free flow tunnel outlet to desander and desander to forebay will be mostly lying on the rock; banded amphibolite (**Figure 5.23**) which is mostly exposed or under thin cover (2-3 m) of slope wash material or vegetation (drawings A1HP-FS-GE-ST-DWG-208 & A1HP-FS-GE-FB-DWG-210). The segments of the box channel have been investigated with five test pits (A1-TP-04 to 08) up to maximum depth of 3.0m. These test pits have shown that rock is present mostly at shallow depth i.e. 1-3m depth. The bulk unit weight of the overlying unconsolidated material lies in range of 16.5-20.2kN/m^3. The unconsolidated mass is mainly comprised of angular to sub rounded gravels, cobbles and boulders embedded in fine silty sandy matrix. The unconsolidated mass will be excavated as evident from the civil drawings and the underlying rock is very good foundation material for the box channel structure.

Figure 5.23: A broad view of the Box Channel.

At the desander location, geotechnical investigations comprising one borehole (A1-BH-8), one seismic profile (A1-SP-8) and one test pit (A1-TP-5) have been conducted to explore subsurface conditions for the foundation materials. The locations of the investigation points are provided in drawing A1HP-FS-GE-ST-DWG-208. One discontinuity survey DS-8 has also been conducted at nearby rock outcrop that indicates the rock as massive to blocky and slightly weathered. The borehole (A1-BH-8) with a depth of 30m has revealed that the rock comprising amphibolite is present at 4.0m depth under slope wash material. At the depth of 28m, an isolate body of granite / granodiorite of Shandur Granodiorite is encountered (drawing A1HP-FS-GE-ST-DWG-209). As per the empirical classification of RMR, the rock is fair for the foundation of sand trap. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability and water table in **Figure 5.25**. The values of water pressure test are given in **Table 5.20**. The Lugeon values in the upper part are relatively high while these are quite reasonable at the lower depth. This leads to suggest that the rock is fairly jointed at shallow depth with relatively open joints induced by stress relief phenomenon, while at deeper horizons these are quite tight providing lower values of the permeability. The rock quality, as per ISRM guidelines for intact rock classification, is interpreted to be medium strong to very strong. As per discontinuity survey, the foliation has the same trend; northeast-southwest with dipping in northwest as that of the rest of upstream project area. Same rock is likely to be encountered at the desander location (**Figure 5.24**). Based on this discontinuity survey, the rock is reasonably strong and will provide good foundation material for the desander. The rock will, however, require blasting for the placement of desander and the connecting box channel segments.

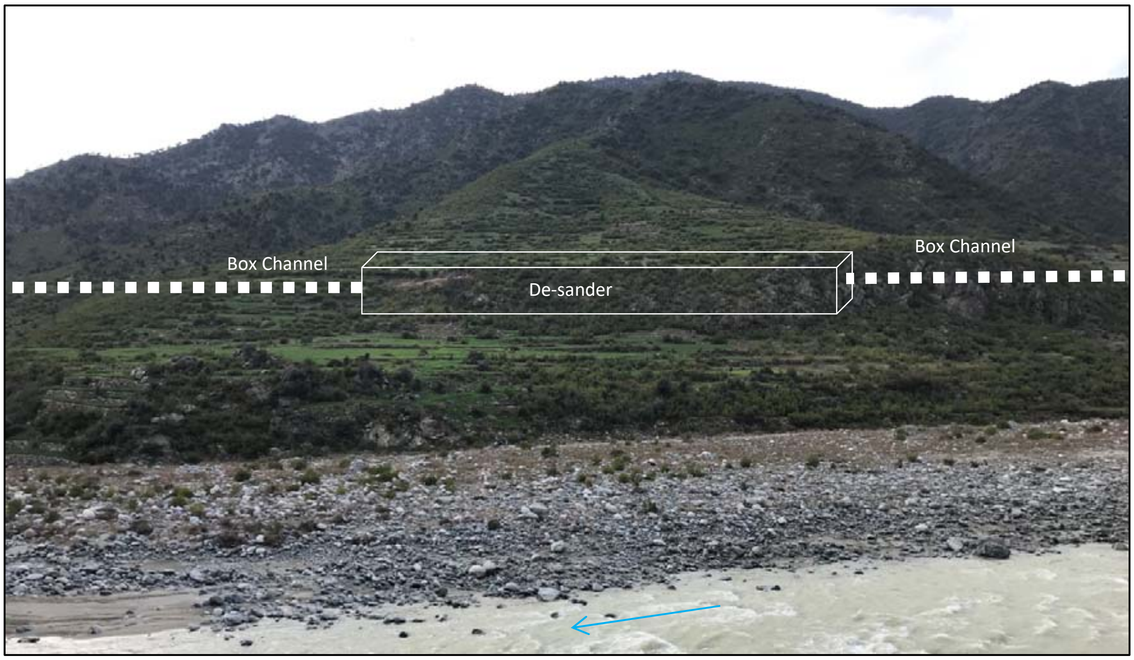

Figure 5.24: A broad view of the Box Channel and Sandtrap

Near the inlet pond location, one bore hole (A1-BH-9) and one seismic profile (A1-SP-7) were conducted for the evaluation of subsurface conditions. At this location, the rock comprising amphibolite is present inform of mostly rock outcrop or under thin cover of overburden (A1HP-FS-GE-FB-DWG-210 & 211). The inlet pond is likely to be connected to intake of headrace tunnel, which is again in the same material. One discontinuity survey DS-7 was conducted in close vicinity. The rock quality, as per ISRM guidelines for intact rock classification, is interpreted to be medium strong to strong. The orientation of foliation and joint sets are shown in drawing no. A1HP-FS-GE-FB-DWG-210 and field data has been attached as **Annexure B2, Volume VII** while summaries of the discontinuity surveys are attached as **Annexure B1, Volume VII**.

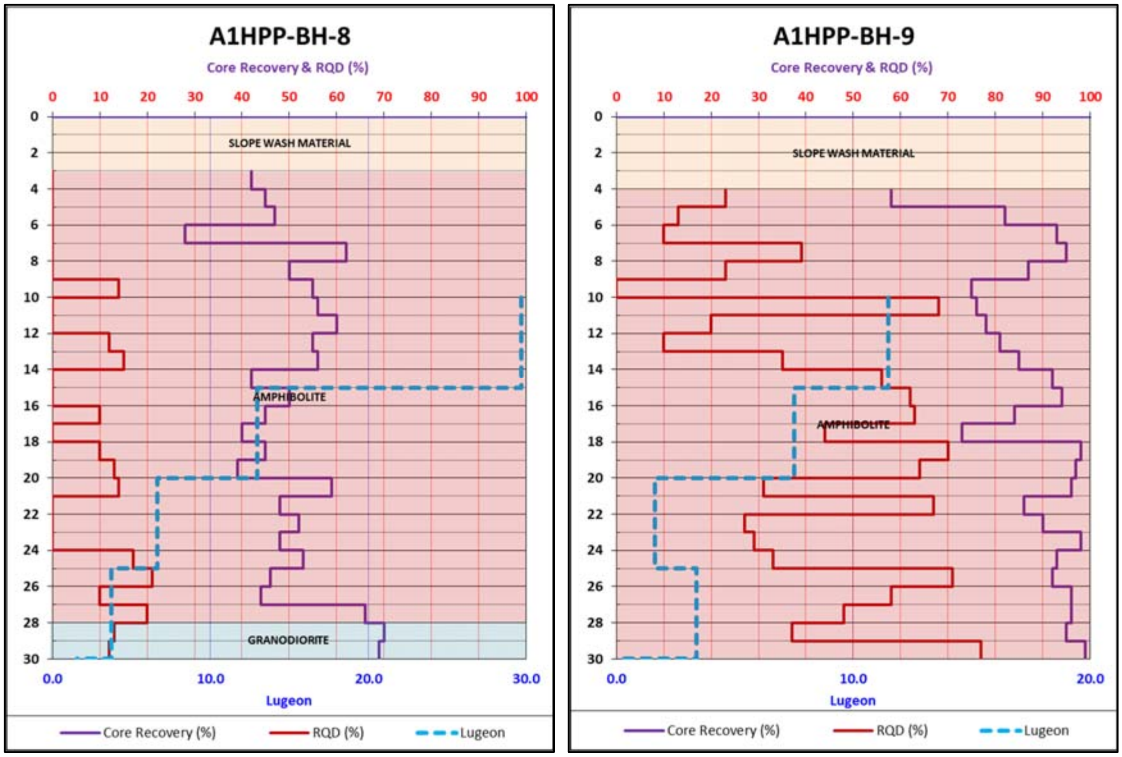

Figure 5.25: Plots showing subsurface profile as explored by the A1-BH-8 & 9.

Where required, the excavations for box channel, sand trap and inlet pond in overburden can be dressed at an angle 1V:1H with the provision of 4m wide after ever 10m bench height. However, the rock slopes can be cut at a steeper angle of 1H:3-4V and stabilized if kinematic analysis highlights any potential of rock falls.

Both the desander and the inlet pond are deep structures and have been seated on the bedrock thus no bearing capacity or settlement problem is expected.

5.4.4.6 HEADRACE TUNNEL AND ASSOCIATED STRUCTURES

The alignment of the Headrace tunnel is designed on the right bank of Panjkora River shall stretch from tunnel intake to Tunnel outlet downstream of Sahibabad town where powerhouse is proposed. The headrace tunnel is about 7296m long (from chainage 2+889 to 10+315). The headrace tunnel is sub-divided into three (3) segments namely, T1, T2 and T3. This division of headrace tunnel is just because of the junction formed by the proposed adit tunnel and a cut & cover section along the headrace tunnel. The adit tunnel has been proposed near chainage 5+076 of the headrace tunnel. However, the cut and cover section for crossing of tunnel in deep cut stream will intersect the headrace tunnel at chainage 7+199m. The length of segments T1 (Chainage 2889-5077), T2 (Chainage 5077-7199) and T3 (Chainage 7329-10315) are 2188m, 2122m and 2986m respectively. The cut and cover section will be 130m long.

In this section geological and geotechnical conditions have been discussed for tunnel intake, tunnel alignment, cut and cover crossing for the tunnel in deep cut stream, access adit, surge shaft and tunnel outlet area based on the surface and subsurface geotechnical investigations including discontinuity surveys, test pits, borehole and seismic profiling data. The related geological maps and sections based on the investigations and interpretations are attached as drawings A1HP-FS-GE-FB-DWG-210 & 211 for tunnel intake, A1HP-FS-GE-TNL-DWG-212 for headrace tunnel alignment, A1HP-FS-GE-TNL-DWG-213 for cut and cover section of HRT, A1HP-FS-GE-TNL-DWG-214 for access tunnel/ adit tunnel and A1HP-FS-GE-PH-DWG-216 & 217 for tunnel outlet.

5.4.4.6.1 TUNNEL INTAKE

The box channel connects the power conduit that links the tunnel intake through inlet pond (A1HP-FS-GE-FB-DWG-210 & **Figure 5.26**). These structures have been planned at rock outcrops or rock under thin cover of overburden. The investigations at the intake location comprise conducting of discontinuity survey; DS-7 and drilling of a borehole (A1-BH-9). The discontinuity survey has revealed that rock is generally blocky to massive having foliation trend in northeast direction dipping in northwest at moderate steep angle (i.e. 30-35 degrees). In addition to foliation, two joint sets have been identified and recorded during field investigations with some random joints. The orientations of the discontinuities have been plotted in drawing no. (A1HP-FS-GE-FB-DWG-210) and the joints data have been provided in **Annexures B1 & B2, Volume VII**. The rock appears blocky to massive and is medium to very strong on fresh surface with slight to moderate weathering profile from inward to surface (**Figure 5.26**). The discontinuities are generally extremely close to moderate spaced, very low to very high persistent with tight to wide apertures and generally smooth to rough and planar to undulating surfaces. The rock quality, as per ISRM guidelines for intact rock classification, is interpreted to be medium strong to strong.

A vertical borehole (A1-BH-9) with a depth of 30m drilled at this location has revealed that the rock is amphibolite of Banded Amphibolite which is present at 4m depth. Although the depth of the hole could not hit the tunnel alignment, even then the outcome of the hole was reasonable to assess the rock mass conditions surrounding the intake and part of the tunnel. Generally rock mass quality as determined from borehole and discontinuity data falls in fair class and determined to be good for foundation as per RMR empirical classification system (**Table 5.13**). The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability and water table in **Figure 5.25**. The values of water pressure test are given in **Table 5.20**. Again, the water pressure test values replicate the scenario of A1-BH-08, where higher values are at top and lower values are at deeper horizons.

Figure 5.26: A close view of the approximate location of the intake portal of the proposed headrace tunnel.

The laboratory tests have shown that bulk density of amphibolite core samples is 2.82 g/cm3 varies from 2.34 to 2.64 g/cm^3.

Table 5.20: Summary of water pressure test results at sand trap and inlet pond.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-8	1	5-10	29.7	Turbulent
	2	10-15	12.96	Dilation
	3	15-20	6.63	Turbulent
	4	20-25	3.71	Dilation
	5	25-30	1.58	Laminar
A-1 BH-9	1	5-10	11.47	Turbulent
	2	10-15	7.42	Laminar
	3	15-20	1.64	Turbulent
	4	20-25	3.39	Turbulent
	5	25-30	0.32	Laminar

5.4.4.6.2 HEADRACE TUNNEL ALIGNMENT

The headrace tunnel shall take off from the intake in almost southwest direction for a distance of about 700m (chainage 2+890-3+620) then it takes a bend towards south and is aligned in southwest direction up to further about 1.0km (chainage 3+620-4+620) where it takes a smooth bend towards southeast. The access adit will joint in this segment of the headrace at chainage 5+060-5+080. From this point to onward, the alignment continues parallel to river for about 5km to chainage 9+500, from where it makes smooth bend to east for about 650m to surge shaft (chainage 9+500-10+140) and finally it further turns eastward and continues further 175m to have its tunnel outlet portal at chainage10+315. A deep stream crosses the tunnel alignment at chainage 7199 - 7+329 making it day light for which a cut and cover tunnel section has been proposed.

The tunnel route corridor nearly 200-300 m wide, has been geologically mapped picking up various lithological and structural features. The geological map and the interpreted geological section of the headrace tunnel is attached as drawing no. A1HP-FS-GE-TNL-DWG-212. The subsurface rock mass conditions were assessed with the help of surface geological mapping and 10 discontinuity surveys (DS-1, DS-2, DS-3, DS-4, DS-5, DS-6, DS-7, DS-10, DS-11 & DS-12) conducted as part of present geological studies. The interpreted geological information shows that the following rock types shall be expected along the tunnel route.

- Dominantly Amphibolite (drawing no. A1HP-FS-GE-TNL-DWG-212) with subordinate intrusions of granite/ granodiorite in places is present along the tunnel corridor. The surface geology has shown presence of slope wash terraces along the alignment of headrace tunnel; however, those are surficial deposits and rock is present along the tunnel alignment. This rock is massive to blocky generally and very blocky in places having foliation trend in northeast-southwest direction dipping mainly in northwest at moderate to steep angles. As per discontinuity surveys, the discontinuities are generally extremely close to moderately spaced, very low to very high persistent with tight to wide apertures and generally smooth to rough surfaces having planar to undulating/ stepped surface profiles. The rock quality as per ISRM's guidelines is interpreted from medium strong to strong generally. However, couple of discontinuity surveys (DS-13 & DS-16) along the left bank of Panjkora River indicated rock as extremely to highly weathered showing friable behavior. This type of rock was also indicated near discontinuity survey DS-11 location along the tunnel, because on this rock the conducting discontinuity survey was not possible. This type of rock is likely to intersect the tunnel alignment having cumulative thickness of 300-500m where intact rock strength may be very poor to poor as per ISRM's strength classification of intact rock. From all the discontinuity surveys, it is found that rock is more fractured and very blocky towards the powerhouse site while weir site rock is massive to blocky. Massive to blocky rock makes about 50% rock; very blocky makes about 33% rock and friable rock with shearing may have cumulative length of about 7% along the headrace tunnel.

- Granodiorite/ Granite: This rock unit is present from chainage 9+140 m to 9+750 and from 10+280 to 10+315 along the tunnel route. These are massive bodies intruded in the country rock of banded amphibolite. This rock is very blocky having foliation trend in northeast-southwest direction dipping northwest and southeast owing to presence of consecutive syncline and anticline near powerhouse site. As per discontinuity surveys, the discontinuities are extremely close to widely spaced, low to very high persistent with tight to wide apertures and generally have rough and undulating rock surfaces. Localized shearing along the foliation are likely in this rock. Also, possibility of some limited reaches of extremely to highly weathered and friable rock is likely exhibiting very poor to poor intact rock strength. Intact strength of the rest of the rock mass is to be medium strong to strong as per ISRM guidelines for intact rock classification. This rock makes about 10% of the total rock mass along the tunnel.

The lithological detail of these rock types is given in Section 5.2.2.2.2.

It is known that the mechanical response of the rock mass is a function of the intact rock strength and the characteristics of the discontinuities for the stability and support requirement of the underground excavations. In order to take this in to account rock characterization and rock mass classification have been undertaken using empirical rock mass characterization and classification systems; RMR after Bieniawski (1989) and Q after Barton et al. (1974 & 2002). A summary of the rock mass classes according to these systems are provided in **Table 5.18**, and detailed calculation sheets are provided in **Annexure B9, Volume VII**.

The chainage wise variation of RMR, Q and GSI along the total length of tunnel along with the graphical percentages of each class is given in **Figure 5.27**. According to the RMR classification, the 961m (13%), 4865m (67%) and 1470m (20%) tunnel will pass through good, fair and poor-quality rock. However, the characterization of rock masses through Q system concluded that the 610m (8%), 3412m (47%) and 3274m (45%) will pass through good, fair and poor rock mass classes respectively. The assessment of rock classes is based on surface conditions and rock parameters gathered during the discontinuity surveys, however, along tunnel alignment, no bore hole is drilled due to high and inaccessible ridges. According to the RMR classification exercise conducted on borehole data, the rock quality falls in fair rock quality for both Banded Amphibolite and Shandur Granodiorite.

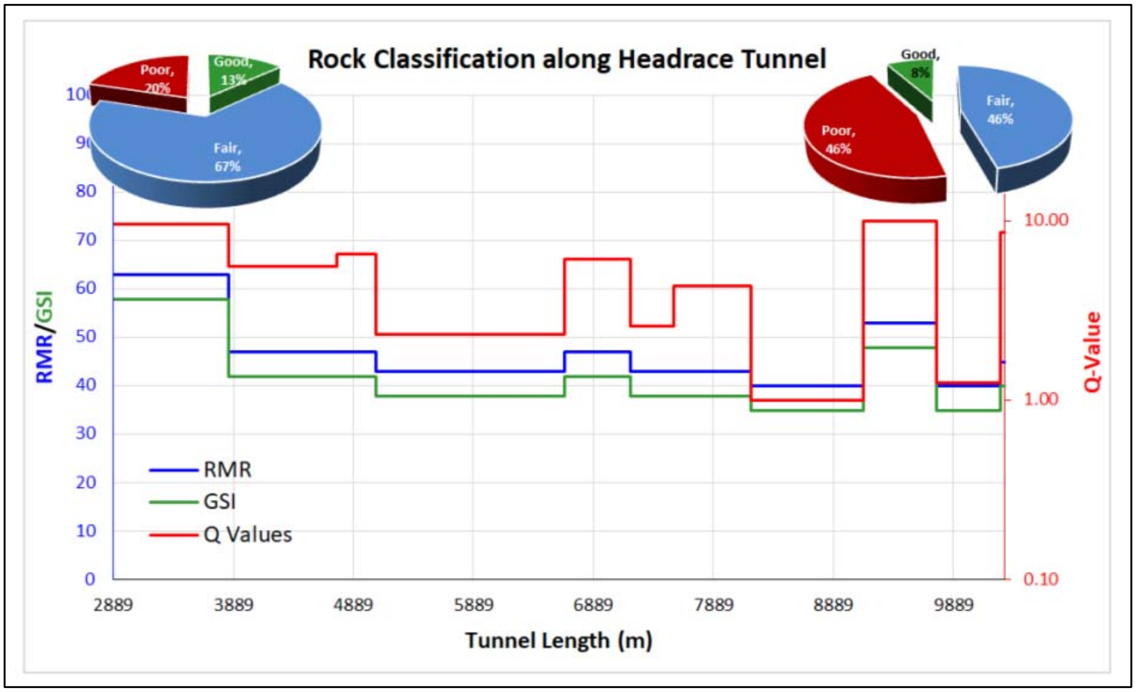

Figure 5.27: Variation of RMR, Q and GSI along the tunnel alignment.

5.4.4.6.3 ACCESS ADIT / ADIT TUNNEL

The access adit / adit tunnel about 270m long has been proposed almost after the first quarter of the alignment of headrace tunnel at chainage ~5+070 to facilitate/ speed up tunnel excavation. The surface geological map of the adit tunnel has been shown in drawing no. A1HP-FS-GE-TNL-DWG-214 along with locations of investigations points. The geological map shows that the portal will require removal of the overburden material which appears to be about 10-15m towards the valley. One borehole (A1-BH-10) with a depth of 30m was drilled near the intake of adit tunnel; one seismic profiling (A1-SP-6) was also carried out for the interpretation of sub-surface geological and geotechnical condition. The borehole is drilled at an elevation of 1083m, while rock encountered at the depth of 7m. The rock comprising amphibolite marks a contact with lower granite / granodiorite at the depth of 21m. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability, water pressure (Lugeon) and water table in **Figure 5.28**. The value of permeability was determined to be 3.99E-02 cm/sec. The Lugeon values in water pressure tests conducted in rock range from 0.8 to 7.49 Lugeon (**Table 5.21**). The higher values are at shallow depth/ near surface that lead to suggest relative higher degree of fracturing and jointing. However, these are interpreted to be lower at the adit tunnel depth.

Rock mass condition has been assessed based on the discontinuity surveys DS-4 & DS-5 that indicate well developed foliation with two to three joint sets. The joints are extremely close to moderately spaced, low to very high persistent with tight to wide apertures and having generally rough and undulating surfaces. The rock is assessed to be medium strong to strong. The rock mass quality is likely to be very blocky to blocky.

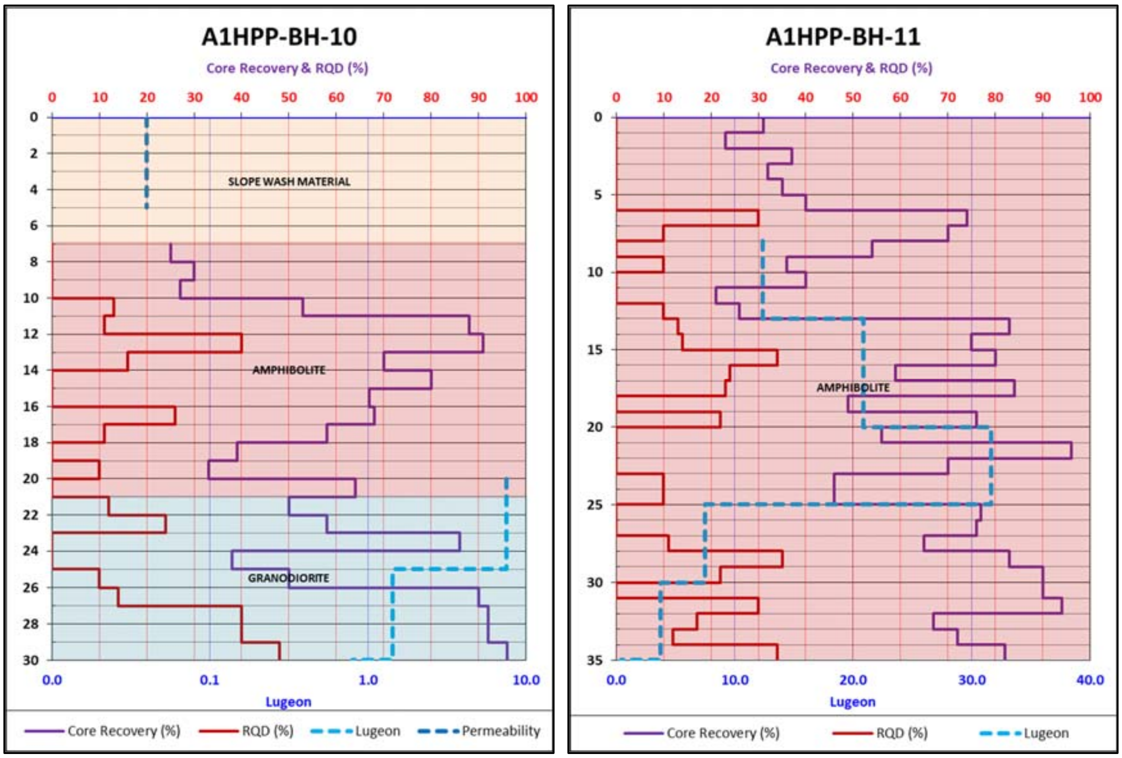

Figure 5.28: Plots showing subsurface profile as explored by the A1-BH-10 & 11.

Similarly, the empirical rock mass classification exercise was also carried out on borehole data for the assessment of rock quality. The borehole and discontinuity survey data classified the rock mass as fair rock quality.

Table 5.21: Summary of water pressure test results at adit tunnel intake.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-10	1	15-20	7.49	Washout
	2	20-25	1.43	Turbulent
	3	25-30	0.8	Turbulent

The outcome of the investigations indicates that the placement of the adit portal in rock will require about 30m cut toward the hill side that will involve mostly rock cutting. The height of the rock cut could be of the order of ~45 m. As a guideline, the rock cut can be dressed at slope 1H:3-4V with the provision of about 4m wide bench after 10m bench height. The overburden slope can be stabilized at an angle of 1H:1~1.5V. The kinematic analysis of the rock cut slope is recommended to be conducted as part of the next stage for the stability evaluation and support requirement, if any need.

5.4.4.6.4 EVALUATION OF THE GROUND CONDITIONS FOR FREE FLOW, HEADRACE AND ADIT TUNNELS

In order to evaluate the ground conditions along the tunnel's alignments, empirically proposed schemes and criteria were used. The proposed free flow tunnel alignment will pass through a minimum rock cover of 20 m, and a maximum of 145m. According to all used empirical criteria, adit tunnel and free flow tunnel will have no squeezing or rock bursting potential. However, headrace tunnel passes through relatively thick rock cover (**Table 5.18**). Initially, two empirical classification systems of Singh et al. (1992) and Goel et al. (1994) are utilized as a starting point of the assessment. Singh et al. approach uses the value of Q assuming the stress reduction factor (SRF) of 2.5, implying that if the values of overburden are greater 350 times of cube root of Q-value, the squeezing ground condition will be encountered. The approach concluded that all the rock masses will not induce any squeezing potential along the headrace tunnel. The graphical representations of results on the log-log graph of Singh et al. approach is given in **Figure 5.29**.

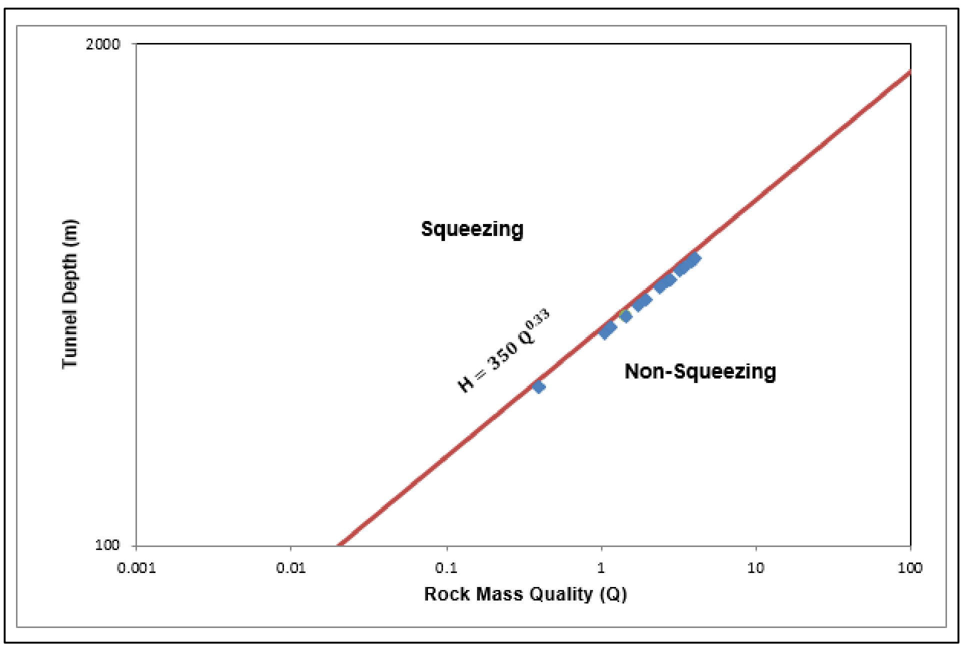

Figure 5.29: The ground conditions along tunnel alignments based on Singh et al (1992) approach.

Goel et al. approach uses the rock mass number (N-value), overburden and diameter/ width of the tunnel to evaluate the ground conditions along the headrace tunnel, this criterion ends up that the tunnel sections are non-squeezing and self-supporting. The results along the tunnel alignment on the log-log graph of Goel et al. criterion is presented in **Figure 5.30**. The detail assessment of ground condition along tunnel alignment is presented in **Table 5.18**.

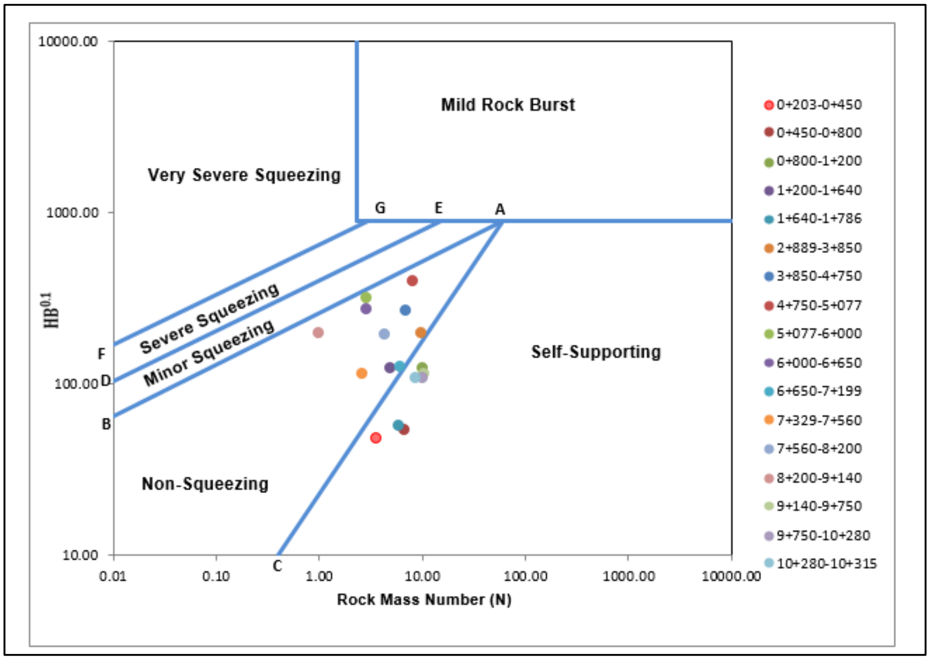

Figure 5.30: The ground conditions along headrace tunnel alignment based on Goel et al. (1994) approach.

Similarly, two others empirical approaches of Hoek and Brown (1980) and Barton et al. (2002) were utilized for ground conditions and field stress assessments, and results are presented in **Table 5.18**. Hoek and Brown approach uses the ratio of intact rock strength and sigma theta giving the stability conditions in the form of stable, minor spalling, severe spalling and rock burst, while in Barton et al. scheme, the ratio of intact rock strength to the maximum principle stress is used for ground stress assessment in the form of low, medium, high, mild and heavy rock burst conditions. The results of these approaches are similar that the ground conditions for rock masses will be stable for the length of tunnel having medium stress condition while high stress condition causing minor spalling from chainage 3850 m to 6650 m.

In order to cater the squeezing potential and strain potential assessment, Hoek and Marinos (2000) methodology was also examined that uses the ratio of rock mass strength and in-situ stress along abscissa and strain potential percentage along ordinate. The in-situ stress in terms of unit weight and overburden was determined. The strain percentage (tunnel closure/ tunnel diameter*100) was evaluated considering the diameter of 4.5m. The in-situ stresses in the present scenario are in moderate range so this approach concluded that the squeezing is not likely along the tunnel alignment. The graph of Hoek and Marinos is given in **Figure 5.31**.

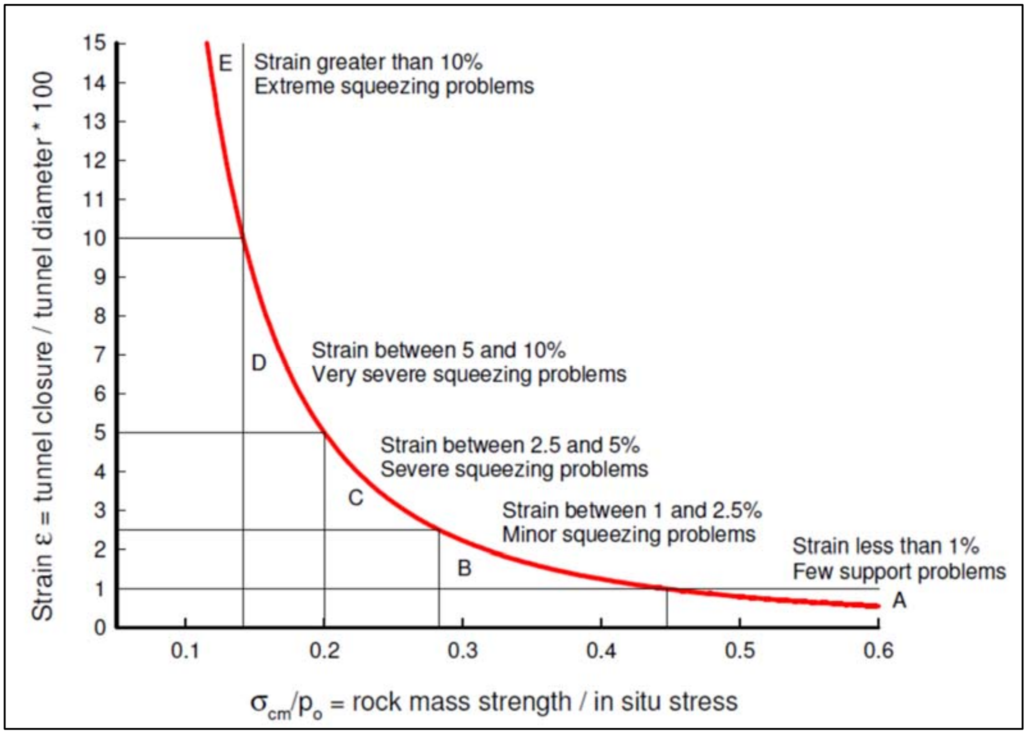

Figure 5.31: Relation between the rock mass strength/ insitu stress and percent radial strain of the tunnel (i.e. tunnel closure*100/ tunnel diameter), after Hoek & Marinos (2000).

5.4.4.6.5 TUNNEL SUPPORT FOR FREE FLOW, HEADRACE AND ADIT TUNNELS

Tunnel support is considered to be a function of mechanical response of rock mass. Empirical methods RMR and Q give guidelines for support design corresponding to rock classes. Along the tunnels, an assessment of rock mass quality has been made and both RMR and Q classification have been undertaken (Section 5.4.3.1).

Considering the rock mass quality as per RMR, the support estimation has been made in **Table 5.22** for good, fair and poor rock. This table gives an assessment of excavation method, estimation of rock reinforcement; length and spacing of rock bolts and thickness of shotcrete, and application of steel ribs subject to squeezing conditions.

Table 5.22: Support estimation based on RMR

Rock Category	RMR	Excavation	Rock bolts (20 mm dia fully grouted)	Shotcrete	Steel Sets
Good	60-80	Full face	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None

Rock Category	RMR	Excavation	Rock bolts (20 mm dia fully grouted)	Shotcrete	Steel Sets
Fair	41-60	Full face	Systematic bolts 4 m long, spaced 1.5 – 2.0 m in crown and walls with wire mesh in crown.	50 – 100 mm in crown and 30 mm in walls.	None
Poor	<40	Full face	Systematic bolts 4-5 m long, spaced 1.0 – 1.5 m in crown and walls with wire mesh in crown only.	100 – 150 mm in crown and 100 mm in walls.	Light to medium ribs spaced 1.5 m where required.

Likewise, support assessment based on the Q system was also made corresponding to rock classes fair to very poor. In this regard, Q values are plotted against ratio of Equivalent Dimension (De) of an excavation to Excavation Support Ratio (ESR) i.e. span/ ESR. De is the ratio of height of wall or span of the tunnel to the ESR, span in our case is 6.65 to 7.1m. ESR for permanent excavation is 1.6, span/ ESR ratio is used accordingly. Q values of fair to very poor were plotted against span/ESR on Q-chart of support categories. The SRF values corresponding to medium to high stresses are used. The length of bolts and unsupported span are calculated by the equations proposed by Barton et al. The bolt length is a function of tunnel excavation span and ESR, while maximum unsupported span is equal to the product of twice the ESR and 0.4 power of Q.

The plot given in **Figure 5.32** shows that the rocks that fall in fair to poor quality rock which indicates support of category 1, 4 and 5 (**Figure 5.32**). Considering the project conditions and wide acceptability of the Q system, the support recommended by the Q system have been adopted. The typical support categories as per Q system are provided in drawing no. A1HPP-FS-GEO-TNL-DWG-0500 for free flow tunnel and in A1HPP-FS-GEO-TNL-DWG-1100 for headrace and adit tunnels. The support categories are also summarized in **Table 5.23.**

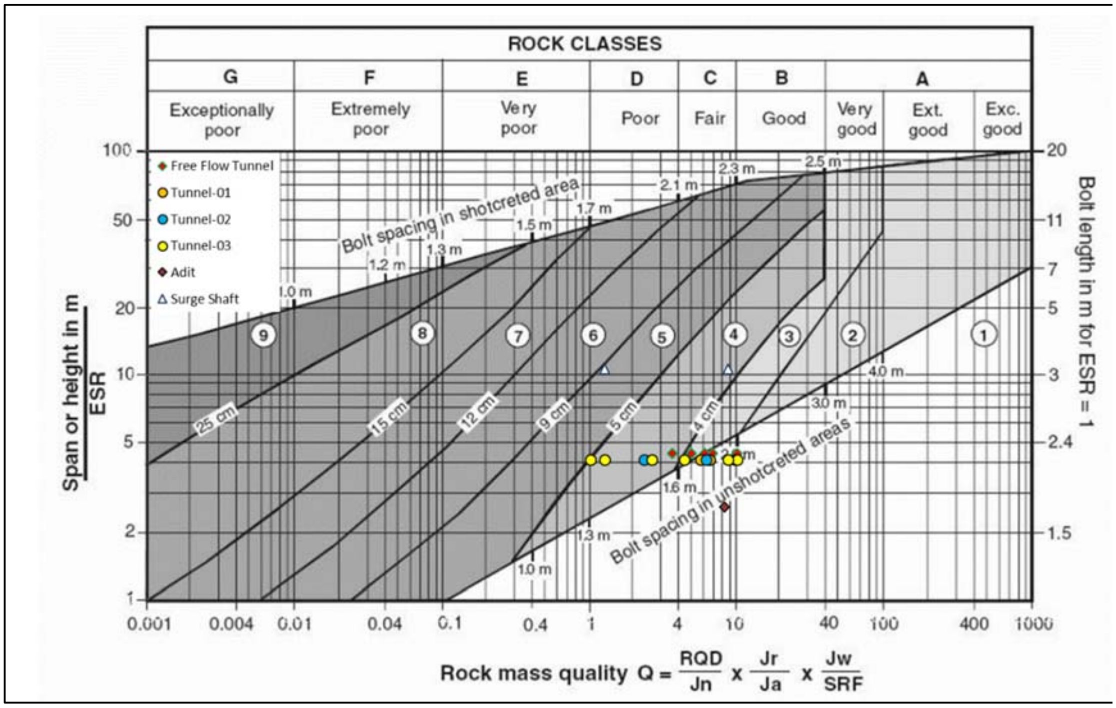

Figure 5.32: Estimated support corresponding to rock mass categories based on tunneling quality index Q- system.

Table 5.23: Support estimation based on Q- System

Rock Category	Q values	Rock bolts	Shotcrete
Good	10-40	Unsupported or spot bolts with length 2.6m	None/ on the crown, if required
Fair	4-10	Unsupported or spot bolts with length 2.6m	None/ on the crown, if required
Poor	1-4	Systematic with bolt length 2.6m, dia of 25mm at spacing 1.7~2.0 m.	4-10 cm on the crown and walls with wire mesh

5.4.4.6.6 Cut and Cover Section across Kotkay Khawar

A cut and cover section is present along the tunnel route along HRT chainage 7199-7329 with total length of about 130m. Along this section, slope wash material comprising gravel, cobble and occasional boulders embedded in fine matrix is present on both banks of the slopes (drawing no. A1HP-FS-GE-TNL-DWG-213). The rock exposed at higher elevation of cut and cover section is comprised mainly of amphibolite. Two discontinuity surveys; DS-3 at the right bank and DS-10 for the left abutment is projected on this section for the evaluation of rock quality. As per discontinuity surveys, the discontinuities are generally extremely close to wide spaced, very low to high persistent with very tight to very wide apertures and generally smooth to rough having planar to undulating surfaces. The intact rock quality as per ISRM guidelines is interpreted from medium strong to strong.

Three vertical boreholes; A1-BH-11, 12 & 13 (**Table** 5.3) were drilled along the cut and cover section up to the maximum depth of 35m. Similarly, three seismic profiles (A1-SP-3, 4 & 5) are also carried out to explore the sub-surface conditions. The borehole A1-BH-11 is drilled on the exposed rock comprising amphibolite on the left bank of Kotkay Khawar. The similar rock encountered at 7m depth at 1049m elevation in borehole A1-BH-12 in valley center, while in A1-BH-13, same rock was found at the depth of 7m at 1065m elevation drilled along the right bank of river. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in **Figure 5.33** for borehole A1-BH-11 and in **Figure 5.34** for borehole A1-BH-12 & 13. A subsurface profile along the cut and cover section is also provided based on the geotechnical investigations, geological and geophysical investigations in drawing no. A1HP-FS-GE-TNL-DWG-213.

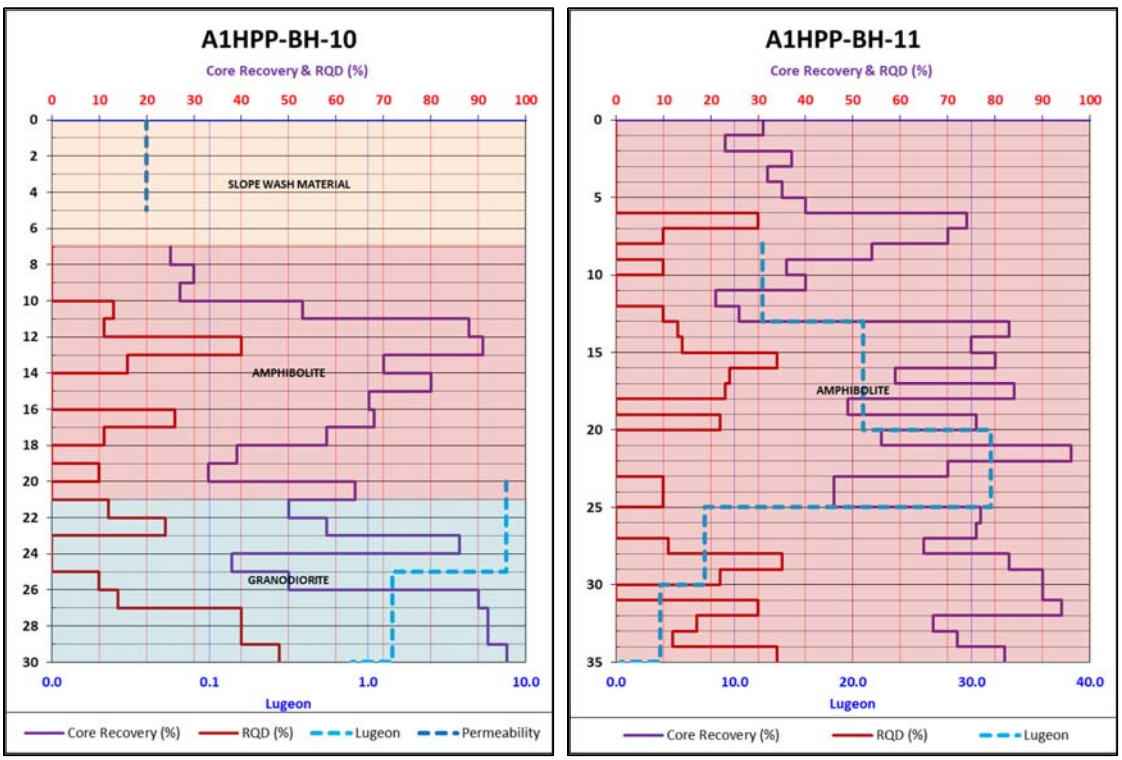

Figure 5.33: Plots showing subsurface profile as explored by boreholes A1-BH-10 & 11.

The summary of field permeability test result is given in **Table 5.24**, while the values of water pressure tests in all three boreholes are summarized **Table 5.25**. The permeability values (in terms of Lugeon) ranges from 0.43 to 35.08. The higher values of permeabilities are near surface while low values are in deeper horizons indicating relatively high degree of fracturing near surface and less underground. This could be attributed to the stress release relief phenomenon.

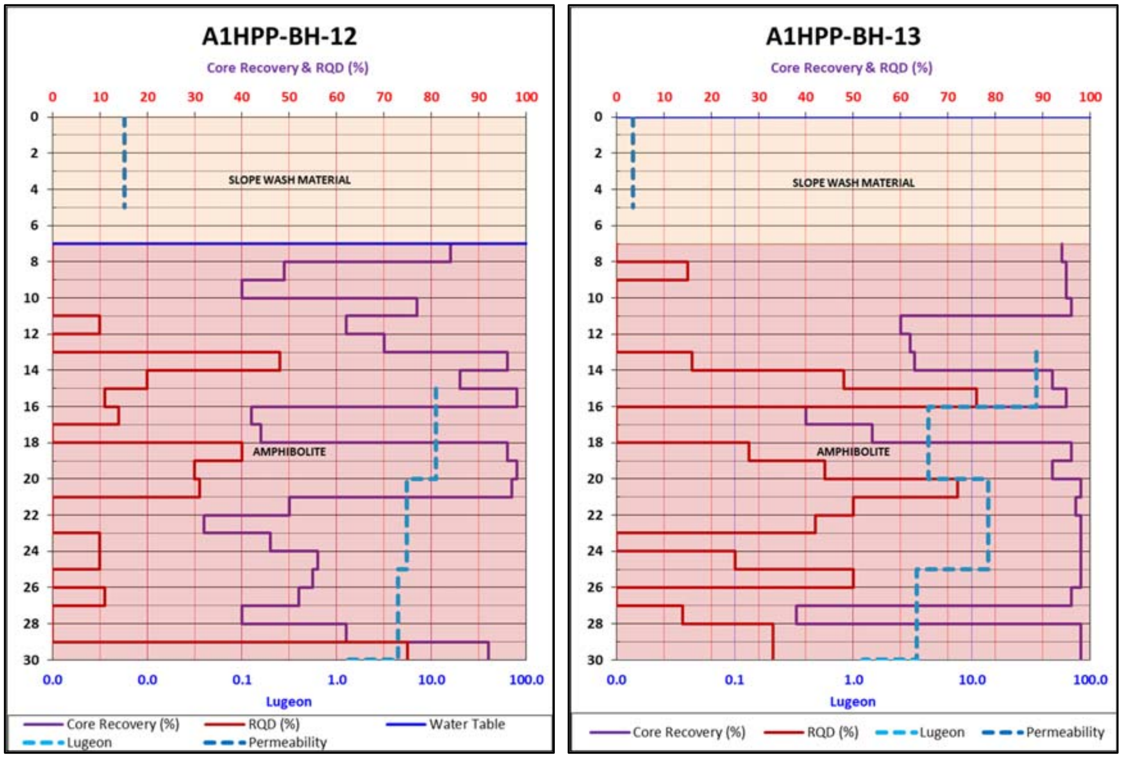

Figure 5.34: Plots showing subsurface profile as explored by boreholes A1-BH-12 & 13.

Generally, the rock mass quality determined by the discontinuity and borehole fall in fair category using RMR classification scheme which is reasonable to have the tunnel portals and providing a good foundation material for cut and cover section. Nevertheless, it has been proposed to connect the bottom of the structure to the bedrock with anchor bolts to ensure the stability of the tunnel. The proposed length and the spacing for rock bolts are 6 m and 3 m x 3 m, respectively.

Table 5.24: Summary of field permeability test results at cut and cover section.

Borehole No.	Test No.	Test Depth [m]	Permeability (cm/sec)
A-1 BH-12	1	5	1.43E-02
A-1 BH-13	1	5	1.39E-02

To place the portals, the slope wash material will have to be removed and rock cutting will be required in amphibolite. The rock has been designated as of fair quality and can be cut safely at angle 1H:3~4V with the provision of benches of adequate width. The right bank of the cut and cover section is prone to planar failure as the dip direction of foliation in northwest direction. However, the left bank is less prone to instability and slopes can be dressed following an angle of 1H:3~4V with the provision of benches of adequate width. The kinematic analysis of rock slopes in view of the orientations of the cut slope and discontinuities will further evaluate the slope stability conditions accordingly stabilization measures can be adopted in the next study phase. In addition to the tunnel intake, outlet portal and adit tunnel, this cut and cover section will provide two extra excavation faces that will speed up tunnel excavation. However, excavation with the dip of pronounced joint set is always recommended to get at least fair condition for excavation to minimal the instability induced by the intersection of joints and tunnel axis.

Table 5.25: Summary of water pressure test results at cut and cover section.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-11	1	5-8	12.36	Void Filling
	2	8-13	20.88	Washout
	3	15-20	31.64	Turbulent
	4	20-25	7.53	Dilation
	5	25-30	3.73	Turbulent
	6	30-35	0.43	Turbulent
A-1 BH-12	1	12-15	12.87	Turbulent
	2	15-20	7.61	Washout
	3	20-25	4.76	Turbulent
	4	25-30	1.2	Turbulent
A-1 BH-13	1	8-13	35.08	Washout
	2	13-16	4.3	Turbulent
	3	17-20	13.84	Washout
	4	20-25	3.46	Laminar
	5	25-30	1.2	Laminar

5.4.4.6.7 Surge Shaft and Outlet Portal Area

The surge shaft is proposed at the tunnel chainage of 10+140. According to surface geology, the surge shaft and tunnel outlet area shall be located in the granite/ granodiorite of Shandur Granodiorite (drawing no. A1HP-FS-GE-PH-DWG-216). The rock is generally under thin cover of overburden and/ or vegetation with spot exposures. One discontinuity survey DS-1 around the location of surge shaft has been conducted where rock outcrop is present. The summaries of discontinuity surveys with location and summary of discontinuities parameters are attached in

Table 5-1 and **Table** 5-2, respectively. The discontinuity summaries with stereo-net plots are provided in the **Annexure B1 & B2**, **Volume VII** of the Feasibility Report. The rock has foliation trend in northeast-southwest while dipping towards southeast. Foliation is well developed with two joint sets. The joints are extremely close to moderately spaced, very low to very high persistent, with tight to very wide apertures, and having smooth to rough and planar to undulating surfaces. The rock is assessed to be medium to strong as per ISRM's guidelines for intact rock strength classification.

During the geotechnical investigation, three boreholes (A1-BH-14, 15 & 16) were drilled to the maximum depth of 60m at the surge shaft and tunnel outlet area. The geological map of surge shaft and outlet area is given in drawing no. A1HP-FS-GE-PH-DWG-215 while the section along the power facilities is given in drawing no. A1HP-FS-GE-PH-DWG-216. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in **Figure 5.35** for borehole A1-BH-14 & 15 and in **Figure 5.36** for borehole A1-BH-16.

A1-BH-14 borehole drilled exactly at surge shaft location revealed that the granite / granodiorite of Shandur Granodiorite is present to the depth of 30m and under 4m thick cover of slope wash material; after 30m, the amphibolite of Banded Amphibolite is present to the maximum depth of exploration. Various laboratory tests on core samples were also taken as a part of investigation for better understanding of lithological, geological and geotechnical condition of rocks, the summary of laboratory testing is given in **Table 5.6**. Both rocks are strong to very strong, with range of bulk density from 2.91 g/cm^3 to 3.23 g/cm^3. The field tests were also conducted in borehole, the water pressure test results are summarized in **Table 5.26**. According to the in-situ test results, the Lugeon values ranges from 0.86 to 25.77 with mostly interpreted flow type is turbulent flow.

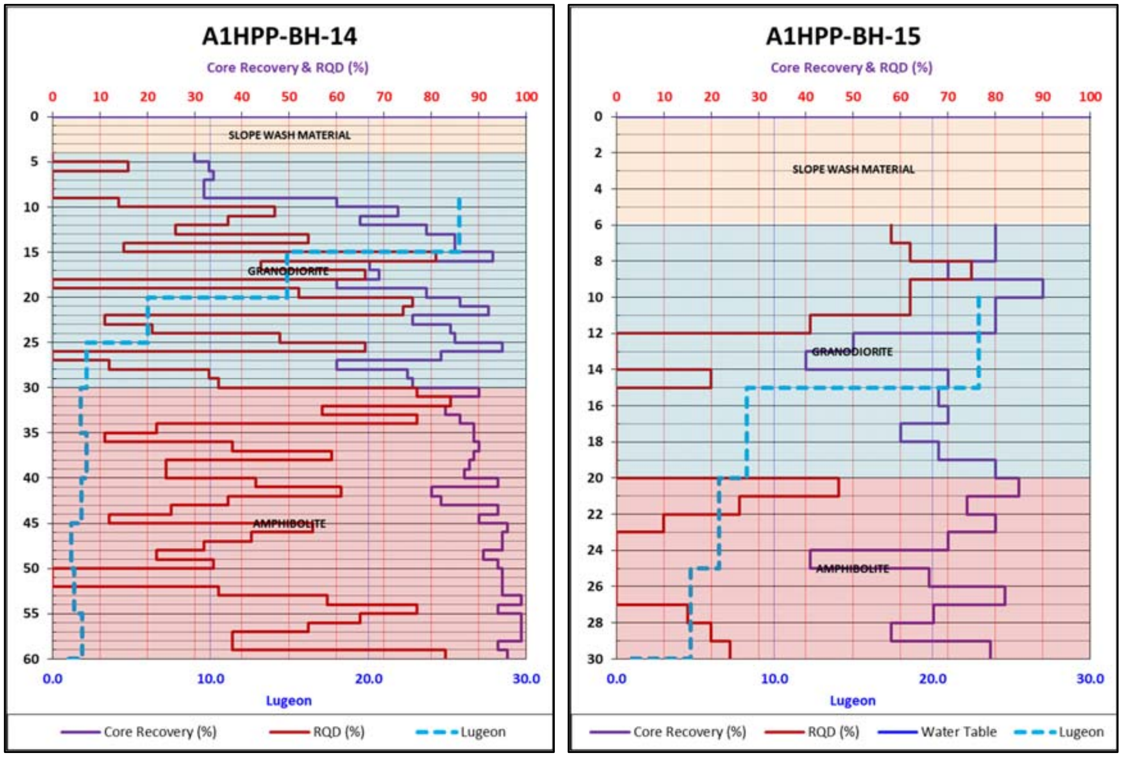

Figure 5.35: Plots showing subsurface profile as explored by the boreholes A1-BH-14 & 15.

Another borehole was drilled along headrace tunnel, between the location of surge shaft and outlet of headrace tunnel, i.e. A1-BH-15 with the maximum depth of 30m. The water table does not encounter in this borehole similar to the other two boreholes drilled in the vicinity. The rock comprising granite / granodiorite encountered in the borehole at 6 m depth with an elevation of 1081m, after another 18 m, this granite / granodiorite marked a contact with amphibolite with an elevation of 1067 m. The field tests results are given in **Table 5.28**. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in **Figure 5.35** for borehole A1-BH-15.

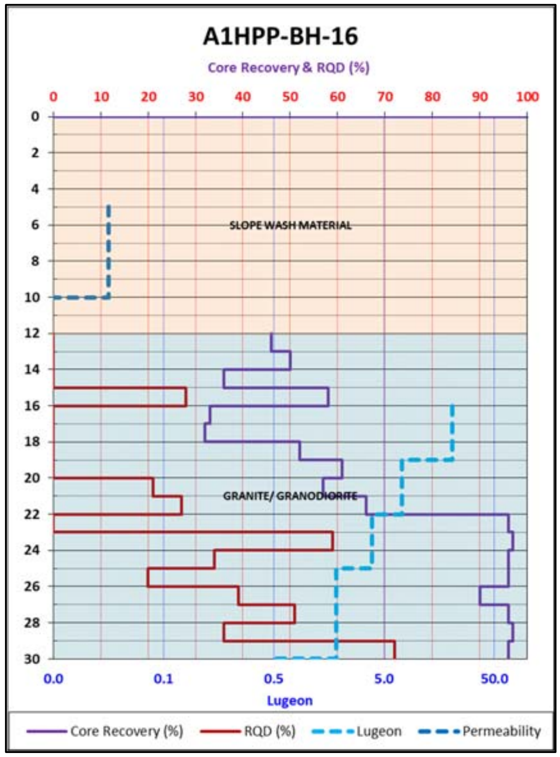

Figure 5.36: Plots showing subsurface profile as explored by the A1-BH-16.

Near the chainage of 10+280 of headrace tunnel, A1-BH-16 was proposed for rock quality near outlet of headrace tunnel. The borehole was drilled to the depth of 30 m started at the elevation of 1062 m. In contrary to two other boreholes, only one type of rock is encountered in this borehole i.e. granite / granodiorite of Shandur Granodiorite. This rock was found at the depth of 12m. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in **Figure 5.36** for borehole A1-BH-16. The in-situ test results of permeability in overburden and water pressure tests in rock are attached as **Table 5.27** and **Table 5.28,** respectively.

The excavation in overburden and rock will be required for the tunnel outlet portal. The permanent excavation in the overburden can be stabilized at an angle of 1H:1V with the provision of benches of adequate width after every 10m bench height. However, the rock excavation can be dressed at an angle of 1H:3-4V and shall be stabilized, if required, against surficial instability and/ or unstable blocks after kinematic assessment in the next study phase.

Table 5.26: Summary of water pressure test results at surge shaft.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-14	1	4.2-9.2	25.77	Turbulent
	2	10-15	14.85	Laminar
	3	15-20	6.02	Void Filling
	4	20-25	2.16	Turbulent
	5	25-30	1.8	Turbulent
	6	30-35	2.18	Turbulent
	7	35-40	1.84	Turbulent
	8	40-45	1.21	Laminar
	9	45-50	1.38	Laminar
	10	50-55	1.89	Turbulent
	11	55-60	0.86	Void Filling

Rock mass condition has been perceived based on the discontinuity survey DS-01, and utilizing three borehole data. For amphibolite rock, DS-02 was also projected for rock characterization. In DS-02 data, the rock foliation again has a trend in northeast-southwest while dipping towards southeast. Foliation is well developed with three joint sets. The joints are extremely close to moderately spaced, very low to low persistent, with tight to very wide apertures, and having smooth to rough and planar to undulating surfaces. The rock is assessed to be medium to strong as per ISRM's guidelines for intact rock strength classification. The rock quality assessed by borehole data falls in fair rock as per RMR classification scheme. According to discontinuity survey, the rock is dipping towards the valley at the tunnel outlet area posing a fair to poor condition for tunnel excavation. However, the foliation dipping in the southeast direction in conjunction with the dominant joint sets may pose problems in the form of rock falls. The detail rock mass classification for discontinuity surveys and borehole are attached as **Annexure B9, Volume VII**.

Table 5.27: Summary of permeability test results at headrace tunnel outlet.

Borehole No.	Test No.	Test Depth [m]	Permeability (cm/sec)
A-1 BH-16	1	5	1.58E-02
	2	10	5.07E-03

The excavation of the shaft is recommended from top to bottom down to the tunnel crown. The slope cut for outlet portal may require adequate design of support for stabilization especially in slope wash material. Support to the surge shaft wall will depend on the size of unstable wedges. The rock quality as per the Q is poor for amphibolite and fair for granite /

granodiorite that requires spot bolting and shotcreting of 40-90 mm in general in response to unstable wedges and specifically pattern bolting on a wall in specific direction.

Table 5.28: Summary of water pressure test results at headrace tunnel outlet.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-15	1	7-10	22.96	Turbulent
	2	10-15	8.24	Turbulent
	3	15-20	6.52	Laminar
	4	20-25	4.68	Washout
	5	25-30	0.48	Laminar
A-1 BH-16	1	13-16	20.85	Washout
	2	16-19	7.26	Turbulent
	3	19-22	3.9	Turbulent
	4	22-25	1.47	Dilation
	5	25-30	0.53	Turbulent

5.4.4.6.7.1 Surge Shaft support

The rock mass quality determined using Q system was found to be fair based on DS-01 and A1-BH-14 for granite/ granodiorite for about half-length of surge shaft. However, for amphibolite based on DS-02 and A1-BH-14 was poor. Detailed calculation sheets are provided in **Annexure B9, Volume VII**. The plotting of rock quality corresponding to surge shaft diameter of 17m on the Q-chart of support is provided in **Figure 5.32**. The surge shaft will be lined and shaft excavation is likely to be from top to bottom down to the tunnel crown. Generally, the support to the surge shaft wall depends on the size of unstable wedges. The rock quality as per the Q is poor to fair that requires spot bolting in general in response to unstable wedges and specifically pattern bolting on the walls. Since the lining of the shaft is likely to be provided after the completion of the excavation, medium to heavy steel ribs shall be provided at 1.5~2.0 m interval along with shotcrete (40-100mm) and spot bolting, if required, to cater gravitational falling of rock wedges during excavation and construction. The steel ribs and shotcrete will be buried afterward in the concrete lining to provide additional support. The section of the shaft is provided in drawing no. A1HPP-FS-GEO_SS_DWG-1300 together with the proposed support.

5.4.4.7 PENSTOCK

The penstock alignment starts right after the headrace tunnel outlet which has been explored by one test pit (A1-TP-10) and one seismic refraction profile (A1-SP-2). The subsurface conditions interpreted based on the geological mapping and conducted investigations indicate that the whole alignment will be in the rock overlain by the thin cover of overburden (drawing no. A1HP-FS-GE-PH-DWG-215 &16, **Figure 5.37**). The interpreted rock profile shows that the foundation of the penstock will be in rock which is a reasonably good material to provide the support to the penstock. The rock outcrop exposed at the lower part of penstock has foliation trend in northeast-southwest while dipping towards southeast. Foliation is well developed with two joint sets. The joints are extremely close to moderately spaced, very low to very high persistent, with tight to very wide apertures, and having smooth to rough and planar to undulating surfaces. The rock is assessed to be medium to strong as per ISRM's guidelines for intact rock strength classification. The rock excavation required to place the penstock shall be dressed at an angle of 1H:3-4V.

Figure 5.37: Approximate location of penstock and powerhouse.

5.4.4.8 POWER HOUSE AREA

The surface powerhouse is placed completely on bedrock however the tailrace channel is in riverbed material on the right bank of Panjkora River at the slope toe (drawing no. A1HP-FS-GE-PH-DWG-215 &16, & **Figure 5.37**). Currently, no direct access is present as the road is on the left bank. A small jeepable bridge constructed downstream of the powerhouse is present to access the village close to surge shaft area.

The powerhouse site has been explored by geological mapping, discontinuity surveys, two boreholes (A1-BH-17 & 18), two test pits (A1-TP-12 & 18) and two seismic profiles (A1-SP-1 & 2). The geological map of powerhouse area showing the locations of all investigations points is given in drawing no. A1HP-FS-GE-PH-DWG-215 while the section along the power facilities is given in drawing no. A1HP-FS-GE-PH-DWG-216. According to geological map, most of the valley floor is occupied by the unconsolidated deposits, slope wash materials making valley slopes and river bed alluvium at the valley floor. Generally, the unconsolidated deposits are heterogeneous and comprise angular to subangular rock fractions in silty sandy matrix in slope wash material while rounded to sub rounded embedded in sandy matrix in river bed material. The slope wash material is underlain by old river bed material at the valley floor, which is medium dense to very dense as per depth variation. The rock comprising granite/ granodiorite is present along the lower stretch of penstock and at the proposed site of powerhouse drawing no. A1HP-FS-GE-PH-DWG-215 & 16.

Two vertical boreholes (A1-BH-17 & 18) with the maximum depth of 30m were drilled for the assessment of overburden and rock at the powerhouse area. The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability (in terms of Lugeon) and water table in **Figure 5.38** for borehole A1-BH-17 & 18.

A1-BH-17 borehole drilled at proposed powerhouse location revealed that the granite/ granodiorite of Shandur Granodiorite is present at the depth of 4m, with overburden material comprising slope wash material consisting mainly gravels and cobbles with occasional boulders embedded in sandy silty matrix. The rock fragments are sub-angular to sub-rounded mainly of igneous origin. However, in borehole A1-BH-18, same rock is present at the depth of 15.7m. According to both the drilled holes, the powerhouse site will be founded on the same rock i.e. granite granodiorite which will provide very good foundation to support the powerhouse structure. As per the laboratory testing on core samples, the rock is medium strong to strong. The range of bulk density is from 2.25 g/cm^3 to 2.52 g/cm^3.The field tests were also conducted in borehole, the water pressure test results are summarized in **Table 5.29** while permeability test results are provided in

Table 5.30.

The results of water pressure tests generally indicate lower values of Lugeon i.e. <5 L, however, near surface relatively higher values were determined that indicate more fractured/ jointed rock near surface. The values of permeabilities in overburden are indication of bit high permeability reflecting typical characteristic of sandy gravel of river bed.

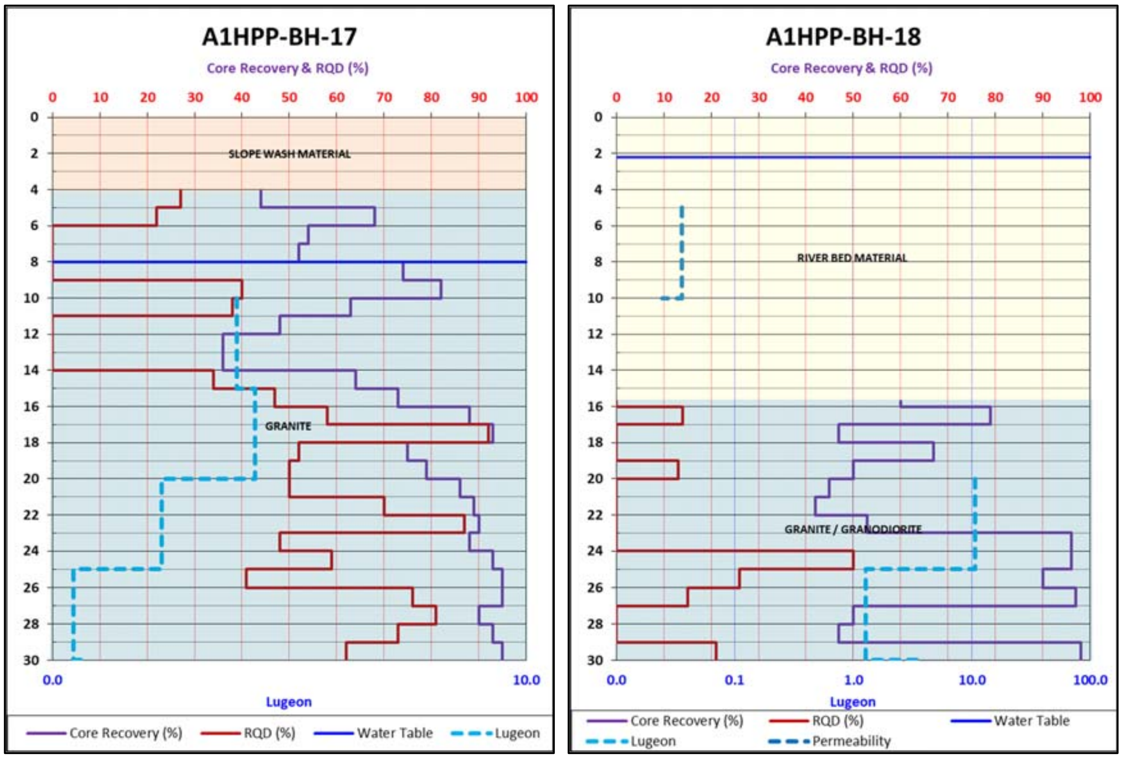

Figure 5.38: Plots showing subsurface profile as explored by the A1-BH-17 & 18

In order to place the powerhouse, excavation in overburden and rock will be required. The permanent excavation in the overburden can be stabilized at an angle of 1H:1V with the provision of benches of adequate width after every 10m bench height. However, temporary excavation can be made bit steeper. The rock excavation can be dressed at an angle of 1H:3-4V with the provision of bench of adequate width after every 10m bench height. The requirement of support for the stabilization of permanent rock cut slopes shall be evaluated based on the kinematic analysis in the next study phase.

Table 5.29: Summary of water pressure test results at powerhouse.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-17	1	5-10	3.89	Void Filling
	2	10-15	4.27	Turbulent

	3	15-20	2.31	Laminar
	4	20-25	0.45	Laminar
	5	25-30	0.69	Turbulent
A-1 BH-18	1	17-20	10.72	Turbulent
	2	20-25	1.27	Laminar
	3	25-30	3.9	Turbulent

Table 5.30: Summary of permeability test results in overburden at powerhouse.

Borehole No.	Test No.	Test Depth [m]	Permeability (cm/sec)
A-1 BH-18	1	5	3.56E-02
	2	10	2.44E-02

5.4.4.8.1 PROPOSED BRIDGE NEAR POWERHOUSE

A bridge associated with the powerhouse is proposed a bit downstream of powerhouse site. Two boreholes; A1-BH-19, & 20 were drilled along the bridge axis up to a maximum depth of 30m to explore the subsurface conditions (drawing no. A1HP-FS-GE-TNL-DWG-212, sheet 4). The subsurface conditions as explored by the boreholes and relevant in-situ tests are given below together with the Rock Quality Designation (RQD), core recovery, permeability and water table in

Figure 5.20 for A1-BH 6, and in **Figure 5.39, Table 5.31** for A1-BH-19 & 20. The values of permeability test are given in **Table 5.31** and of water pressure tests in **Table 5.32.**

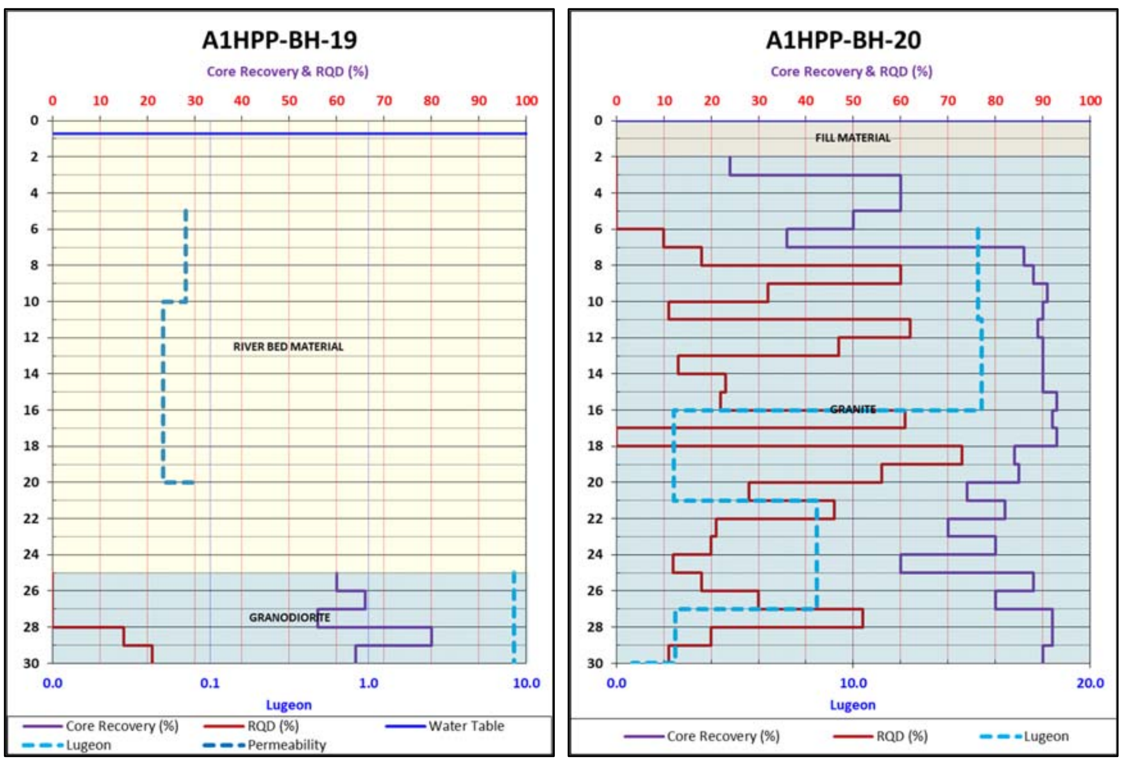

Figure 5.39: Plots showing subsurface profile as explored by the A1-BH-19 & 20.

The outcome of the investigations indicates that at the proposed bridge location near powerhouse, the right abutment and valley floor is occupied by the unconsolidated deposits, and river bed alluvium making valley bed. The relative density of the slope wash deposits in terms of SPT (N) blows was found to be refusal, indicating dense to very dense compaction. The vales of field permeabilities were found to vary from 4.96E-02 to 8.20E-02 (**Table 5.31**).

The rock is present on higher elevations behind the right abutment slopes and at a depth of 25m at right abutment along the bridge axis.

Table 5.31: Summary of permeability test results at bridge near powerhouse.

Borehole No.	Test No.	Test Depth [m]	Permeability (cm/sec)
A-1 BH-19	1	5	6.99E-02
	2	10	4.96E-02
	3	20	8.20E-02

However, along left bank of river, the rock comprising granite / granodiorite is present after 2m fill material. The rock is sound for the foundation of bridge as found by the laboratory testing conducted on rock core samples to be medium strong to strong.

The deep foundations comprising end bearing piles are adopted to support the bridge at the right abutment and in the valley. However, the left abutment can be supported by the open foundation to be placed on granite rock after removing top weathered layer.

Table 5.32: Summary of water pressure test results at bridge near powerhouse.

Borehole No.	Test No.	Test Section [m]	Lugeon Value	Interpreted Flow Type
A-1 BH-19	1	27-30	8.4	Washout
A-1 BH-20	1	3-6	15.28	Turbulent
	2	6-11	15.42	Turbulent
	3	11-16	2.42	Turbulent
	4	16-21	8.47	Turbulent
	5	22-27	2.5	Turbulent
	6	27-30	0.66	Turbulent

5.4.4.9 GEOTECHNICAL CONDITIONS ALONG THE PROPOSED ACCESS ROADS

Access roads to the surge shaft and tunnel portals are to be proposed as part of this study. Given the geology and rock conditions explored by the discontinuity surveys show a fair quality of rock having strike almost parallel slope face and moderately steep to steep dip into the face and towards the valley. The orientation of the foliation leads towards favorable conditions and no major slope failures are anticipated. However, minor rock falls as a result of intersection of foliation and other joint sets may induce localized slips and failures that need to be addressed. Most of the roads' alignment will pass in the slope wash material that has reasonable strength in terms of CBR (**Table 5.7**) to act as subgrade material. However, the cut slopes in overburden material will be stabilized at 1H:1V~1.5V, while banked slopes at an angle of 1H:0.5V~0.75V. The rock cut slopes can be dressed at an angle of 1H:3-4V with the provision of benches of adequate width after definite height interval.

5.5 CONSTRUCTION MATERIAL

5.5.1 GENERAL

The Artistic-I Hydropower Project is proposed to be constructed on right bank of Panjkora River near Sahibabad, District Upper Dir. The main components of the proposed project are; a gated weir, intake, free flow tunnel, box channel (type-I and type-II), sandtrap, forebay, power tunnel, surge shaft, valve chamber, penstock, powerhouse and tailrace. Most of these project components are reinforced cement concrete (RCC) structures, requiring about 280,643.0 cubic meters of conventional cement concrete.

Following construction materials have been identified;

- Coarse Aggregate
- Fine Aggregate (Sand)
- Cement
- Steel
- Water
- Rip Rap Material

The coarse and fine aggregates can be obtained from the river bed, tunnel and weir abutment excavation, or any other suitable quarry site. For the purpose to determine the soil and rock parameters for foundations of the structures as well as the properties of soil material for using as coarse and fine aggregate, necessary tests were conducted on soil and rock samples collected from different locations at the project area. For samples collection, a total of fifteen test pits were excavated from which twenty-nine number of rock samples were collected. In order to conduct the necessary tests, the soil samples were sent to UET Peshawar and National Centre of Excellence in Geology, University of Peshawar.

- The coarse and fine aggregate for construction can be obtained from nullah bed of Panjkora River, rock quarry or from nearby crush plant. The petrographic and ASR potential studies were also carried out on Panjkora River soil samples at feasibility stage.

- Furthermore, most of the project area is covered by Amphibolite Granite and Granodiorite. Granite and Granodiorite Rock will be abundantly encountered while carrying out the excavation of the tunnels. Therefore, the excavated material could be used as coarse aggregate, once crushed to the required grade, it can be used in concrete for the construction of different project structures. During the field studies, rock samples were collected from different locations of the project area for conducting petrographic ASR potential studies. These studies were carried out to identify the rock types and their suitability for using in concrete as aggregate. The petrographic test results are summarized in **Table 5-35**.

5.5.2 COARSE AGGREGATE

Based on construction material studies, suitable coarse aggregate is available in close vicinity of the project area. Coarse aggregate required for concreting of different project structure can be obtained from river bed, nearby quarry site or tunnel and weir excavation. The river bed material mainly comprises of sub-rounded to rounded boulders and gravel with sand and minor amount of fines (RBGM). These boulders and gravel consist of Granite, Granitic Gneiss, Granodiorite, and Amphibolite. The material deposited by the Panjkora River is dense, hard and durable which can serve the purpose of being used as aggregate in concrete.

The major rock exposed along tunnel alignment is interpreted to be Amphibolite, Fresh Granite, Altered Granite and Granodiorite. Therefore, sufficient quantity of concrete aggregates for the construction of the structures could be obtained by crushing the rock to the required grade from the tunnel excavation. The petrographic test results also reveal that the Amphibolite is hard, compact and non-ASR which can be used as an aggregate for concrete with Ordinary Portland Cement, while the other rocks like Granite and Granodiorite, reactive silica observed in the form of recrystallization and stained quartz could potentially be alkali- silica reactive if used as an aggregate in concrete with ordinary Portland Cement.

It is pertinent to mention that the deposited bed material of Panjkora River is also currently approved source of both fine and coarse aggregate for the under-construction Koto Hydropower Project which is at downstream of Artistic-I HPP.

Locations of the different borrow areas in the close vicinity of Artistic-I HPP are summarized in **Table 5-33**.

Table 5-33 Location of borrow areas in the vicinity of Artistic-I HPP

S/No.	Sample #	Location	Coordinates	
			Easting	Northing
1	S-1	Upstream of BH#7 location	772231	3886911
2	S-2	Downstream Sandtrap Road side	772735	3885997
3	S-3	Downstream of Charkum Bridge	772477	3884286
4	S-4	Kotkay Khwar	773126	3882018
5	S-5	Upstream Tail Race Channel	774583	3880128
6	S-6	Koto HPP Timargara	766999	3861931

5.5.3 FINE AGGREGATE

Manufacturing of concrete for different project structures will require fine aggregate (sand) of good quality. Good quality fine aggregate can be obtained from the ample source of Panjkora River bed material which, after necessary processing, can be used as fine aggregate for concrete manufacturing. Some of the location of borrow areas were identified which are described in **Table 5-33**.

The followings are interpretations based on the laboratory tests performed on soil and aggregate samples obtained from exploratory test pits at the project site.

- The soil encountered in all the test pits was gravely in nature. The percentage of gravel ranges from 51.8% to 58.2% whereas, sand ranges from 40.6% to 47.3%
- The petrographic test results revealed that the deposited material in river bed are different types of rock like Granite, Granodiorite, and Amphibolite origin. The Amphibolite is hard, compact and not susceptible to ASR while, the Granite Rock are prone to ASR and it should not be used with ordinary Portland cement.

The lab test results conducted on soil samples collected from Panjkora River are summarized in **Table 5-34**.

Table 5-34 Summary of laboratory test results conducted on soil samples collected from Panjkora River

S. No	Test Pit No.	Depth (m)	Gravel %	Sand %	Fines %	Classification	Specific gravity %	Water observation	Bulk Density	Direct shear		CBR			Sourness	Flakiness and elongation
										C	Phi	90	95	100		
1	TPM-1	3	57.3	41.3	1.2	Sandy Gravel	15.4	0.76	2.15	0	42	20.5	29.0	36.6	4.3%	3.16
2	TPM-2	3	51.8	47.4	0.8	Sandy Gravel	8.86	-	2.007	684	43	-	-	-	-	-
3	TPM-3	3	58.2	40.6	1.2	Sandy Gravel	9.47	1.20	130	557	44	18.5	27.5	33.5	4.4%	3.07
4	TP-1	3	90.3	7.9	2.2	Sandy Gravel	-	2.2	111	-	-	-	-	-	-	-
5	TP-2	57.5	22.3	1.3	0.9	Sandy Gravel	-	0.9	134	-	-	-	-	-	-	-

The tunnel alignment crosses lithologies like Amphibolite, Granite and Granodiorite Rock, which are hard and compacted. These rocks are present in the sufficient amount to be used for concrete aggregates, stone pitching and riprap material.

Petrographic analysis on samples indicated that some rocks i.e. alter granodiorites and alter granites are prone to ASR therefore, they can be used either with low alkali cement or volcanic ash / pozzolanic materials.

Other rocks i.e. Fresh Granite and Amphibolite are exposed in most of the project area. They are hard, compacted and non ASR hence, they can be used with Ordinary Portland Cement.

The rock samples were taken during field studies from different locations of the project for petrographic and ASR tests in order to identify the rock types and its suitability for being used as a concrete aggregate. For this purpose, twenty-nine number of rock samples were collected and sent to Geology Department, University of Peshawar. The test results' remarks are summarized sample wise in **Table 5-35**.

Table 5-35 Labortery test of rock samples and it used for Aggegate

S.NO	Sample No.	Location	Discontinuities Survey Location	Rock Type	Recommendation
1	DS-01(A)	Surge Shaft	DS-01(A)	Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
2	DS-01(B)	Tunnel Alignment	DS-01(B)	Foliated Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
3	DS-02	Tunnel Alignment	DS-02	Foliated Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
4	DS-03	Tunnel Alignment	DS-03	Foliated Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
5	DS-04	Tunnel Alignment	DS-04	Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
6	DS-05	Tunnel Alignment	DS-05	Altered Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
7	DS-06(A)	Tunnel Alignment	DS-06(A)	Massive Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate

S.NO	Sample No.	Location	Discontinuities Survey Location	Rock Type	Recommendation
8	DS-06(B)	Tunnel Alignment	DS-06(B)	Altered Granite	Reactive silica in the foam of recrystallization and strain quartz vein observed which can potentially cause of ASR if used as aggregate in concrete therefore the sample is not recommended as sole aggregate for concrete
9	DS-07	Tunnel Alignment	DS-07	Massive Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
10	DS-08	Sand Trap	DS-08	Massive Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
11	DS-09	Free Flow Tunnel	DS-09	Foliated Granite	The rock is ASR and should not be used as sole aggregate for concrete with ordinary portable cement
12	DS-10	Free Flow Tunnel	DS-10	Massive Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
13	DS-11	Free Flow Tunnel	DS-11	Deformed Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
14	DS-12	Free Flow Tunnel	DS-12	Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
15	DS-13	Free Flow Tunnel	DS-13	Foliated Granite	Reactive silica in the foam of recrystallization and strain quartz vein observed which can potentially cause of ASR if used as aggregate in concrete therefore the sample is not recommended as sole aggregate for concrete
16	DS-14	Free Flow Tunnel	DS-14	Foliated Granite	Reactive silica in the foam of recrystallization and strain quartz vein observed which can potentially cause of ASR if used as aggregate in concrete therefore the sample is not recommended as sole aggregate for concrete
17	DS-15	Free Flow Tunnel	DS-15	Massive Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate

S.NO	Sample No.	Location	Discontinuities Survey Location	Rock Type	Recommendation
18	DS-16	Free Flow Tunnel	DS-16	Epidosite	It composed of altered mineral however it is lacking any reactive foam of silica therefore it is suggestive of no effective possibility of alkali-silica reaction (ASR)
19	LB	Free Flow Tunnel	LB	Quartz – Feldspar Vein	Reactive silica in the foam of recrystallization and strain quartz vein observed which can potentially cause ASR if used as aggregate in concrete therefore the sample is not recommended as sole aggregate for concrete
20	DS-17	Free Flow Tunnel	DS-17	Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
21	DS-18	Free Flow Tunnel	DS-18	Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
22	DS-19	Weir	DS-19	Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
23	DS-19A	U/S Weir	DS-19A	Leuco-Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
24	DS-20	U/S Weir	DS-20	Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
25	DS-21	U/S Weir	DS-21	Leuco-Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
26	LS-01	U/S Weir	LS-01	Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate
27	LS-02	U/S Weir	LS-02	Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
28	LS-03	U/S Weir	LS-03	Amphibolite	The rock is hard and compact and having no effect of ASR can be used as aggregate
29	RB-4	U/S Weir	RB-4	Granite	The rock is hard and compact and having no effect of ASR can be used as aggregate

5.5.4 RIPRAP AND STONE MASONRY

Rocks i.e. Granite, Granitic Gneiss and Granodiorite are exposed in the vicinity of project area which are hard, compacted and durable. They are present in ample quantity and can be used for masonry works and riprapping.

The riprap/ stone pitching material will be required for protection works. Gabion walls will be required to prevent the river bank erosion.

In evaluating materials suitability following considerations shall be kept in mind;

- Riprap/ stone pitching durability affects the ability of the source to provide a consistent shape, size and gradation and the ability to resist weathering and other environmental influences.
- Durability is typically determined by laboratory tests; but durability can also be assessed by observing surface exposures, talus and waste piles or by examining rip-rap applications already using the potential source or similar source materials.
- Cracking, spalling, delaminating, splitting, dissolving and disintegrating are common forms of rock feature that effect the rock properties.
- Durability is a function of the rock's mineralogy, porosity, weathering, discontinuities and site conditions.
- In the close vicinity of the project area, a good quality of rock is available. Samples shall be collected and tested for its suitability as rip-rap material at next study or construction stages.

5.5.5 CEMENT

Cement will be procured from cement factories of Pakistan producing Ordinary Portland Cement (OPC). The OPC being produced by Pakistani Factories conform to BS-12 (1989) standard. There is no cement factory located in the close vicinity of the project area. The local market Mingora and Peshawar has been explored for obtaining initial information about the procurement of the cement (OPC) for local construction industry. It is found that the cement in the market is being procured from the nearest cement factories mentioned below.

- Cherat Cement Factory – Nowshera,
- Askari Cement Factory Nizampure– Nowshera,
- Best way Cement Factory – Islamabad,

- Wah Cement Factory – Hasanabdal
- Dewan Cement Factory – Hattar Taxila

5.5.6 STEEL

The quality of steel shall be ensured to meet accepted range of standard test from UET, Peshawar/CMTL Lahore or equivalent from elsewhere. While steel, like cement, is not locally available in close vicinity of the project area and shall be procured from nearest local markets i.e. Peshawar, or the required supplies of steel shall be made from ISO certified steel re-rolling mills, such as from Rawalpindi/ Islamabad and Punjab. It has been found that the reinforcement steel in the market is being procured from the nearest steel factories mentioned below.

- Ittehad Steel- Islamabad, about 285 km from Timergara city
- Fazal Steel Ltd - Islamabad about 285 km from Timergara city
- Pak Steel Re-Rolling Mills- Islamabad, about 300km from Timergara city
- Pakistan Steel Mills Corporation (pvt) Ltd-Lahore, Punjab about 628 km from Timergara city

5.5.7 WATER

Stream water of Panjkora River can be used for construction however, necessary tests should be conducted at construction stage of the proposed project. Some of the tests were conducted on water samples the results of which are summarized **Table 5-36.**

Table 5-36 Test Results of the water samples collected from Panjkora River

S.No	Test Type	Panjkora River water Samples Test Results			
		Sample-1	Sample-2	Sample-3	Recommended value
1	Sulphate	7.49	8.4	8.0	Max 400
2	Chlorite	13.97	12.5	10.0	Max 500
3	Sodium	4.97	4.37	3.1	Max 200
4	PH Value	6.72	6.96	6.1	6.50-8.50
5	TDS	55.33	47.33	102	Max 1000

5.5.8 LABORATORY TESTING FOR SOIL SAMPLES

All the test pits were properly logged, sampled and photographed. Test pit logs are given in **Annexure B, Volume VII** of the Feasibility Report. The selected samples were sent to UET, Peshawar Laboratory for testing. The results of laboratory tests on aggregate samples (course & fine) from test pits are briefly described and discussed here under and summarized in

Table 5-37.

The purpose of excavating test pits was to procure samples and to check the suitability of material to be used as an aggregate, back filling and for foundation design. For the determination of engineering characteristics of aggregate, around 70kg bulk samples were collected at every 3 meter depth or at change of strata, from each test pit. Disturbed samples collected from the test pits were sent to laboratory in Peshawar for performing the following tests: -

1. Sieve Analysis
2. Hydrometer Analysis
3. Specific Gravity and Water Absorption
4. Proctor
5. Unit Weight
6. CBR
7. Plasticity index
8. Alkali Silica Reaction (ASR) Potential

Table 5-37 Summaries of lab tests results conducted on soil samples

BH/TP No.	Grain Size Analysis (%)			Moisture Content (%)	Atterberg's Limits			Bulk Density (pcf)	Direct Shear Test		Modified AASHTO Compaction Test		3-Point CBR Test		
													Compaction		
	Gravel	Sand	Silt &Clay		Liquid limit (%)	Plastic limit (%)	Plasticity Index		Cohesion (KPa)	Friction Angle	Max. Dry Density (pcf)	Optimum Moisture Content (%)	90%	95%	100%
TP -1	77.6	21.6	0.8	1.9	Non-Plastic			121.6	8.0	39.9	-	-	-	-	-
TP -2	70.1	28.2	1.2	0.8	Non-Plastic			111.8	7.0	37.4	-	-	-	-	-
TP -3	0.8	49.2	49.8	2.4	Non-Plastic			101.6	24.0	40.6	-	-	-	-	-
TP -4	58.2	23.9	18.0	2.7	25	21	4	101.4	276.0	36.6	132.9	7.2	10.9	14.4	27.2
TP- 5	36.8	42.2	20.5	2.2	Non-Plastic			104.5	251.0	38.8	-	-	-	-	-
TP -6	48.8	20.6	30.6	6.3	30	20	10	97.7	335.0	40.7	120.1	14.0	4.4	8.8	17.6
TP -7	55.1	38.8	6.1	1.3	Non-Plastic			129.4	50.0	36.2	-	-	-	-	-
TP -8	41.1	38.6	20.2	5.2	22	20	2	103.9	208.0	36.0	132.2	8.4	14.7	21.5	31.3
TP -9	49.6	73.5	24.4	1.3	------------------------			138.8	23.0	35.0	-	-	-	-	-
TP10	8.8	79.3	11.9	4.6	Non-Plastic			121.1	58.0	34.8	-	-	-	-	-
TP-11	63.4	31.1	5.5	1.2	------------------------			112.6	11.0	37.6	129.7	6.2	14.9	24.7	41.0
TP-12	3.1	41.6	55.3	12.2	30	23	7	97.1	353.0	40.2	-	-	-	-	-

CHAPTER

6

SEISMIC HAZARD ASSESSMENT

CHAPTER 6

SEISMIC HAZARD ASSESSMENT

6.1. INTRODUCTION

The Artistic-I hydropower project is proposed in Upper Dir District about 34 km from Timergara city. The weir is proposed on Panjkora river near Darora village while powerhouse is proposed downstream of Sahibabad village along Peshawar- Dir road. The Artistic-I weir structure is proposed to be Barrage type which consists of a number of large gates that can be opened or closed to control the amount of water passes through and to regulate river water elevation upstream of gated structure/barrage for diversion. The maximum height of water above river bed elevation will be 10 meters. Both weir and powerhouse sites are along Peshawar- Dir road. Since, the scheme is along the right bank, small foot or jeep-able bridges are available to get to both sites. Two tunnels, Free Flow Tunnel (1.6 Km long) and Power Tunnel (7.4 km long) have been proposed along with box channel. De-sander is proposed between the Free Flow Tunnel and Power Tunnel. Another important structure along the Power Tunnel is cut and cover tunnel section that has been proposed along a deep cut stream day lighting the tunnel.

The location coordinates of Weir and Powerhouse sites of Artistic-I Hydropower Project are given below:

Weir	Latitude 35.098°N	Longitude 71.9835°E
Powerhouse	Latitude 35.024°N	Longitude 72.011°E

The maximum height of the proposed weir of the project is 10 meters with reservoir impounding capacity of about 0.335 million cubic meters (MCM), so according to ICOLD definition, this weir does not fall in the category of Large Dams. So ICOLD guidelines for selection of seismic parameters for large dams (2016) are not applicable for this Project. The Project should therefore be designed as per requirements of Building Codes or concrete hydraulic structures.

The Artistic-I Hydropower Project is located in the Kohistan Island Arc physiographic province, a seismically active region due to the continuing northward drifting of the Indian Plate and its subduction under the Eurasian Plate. The project region has been subjected to damaging earthquakes in the past and therefore it is imperative that a study of tectonic and earthquake history of the region be conducted to determine the seismic hazard to which the proposed project may be exposed to and to evaluate realistic seismic design parameters for the safe design of the project components.

As, the Artistic-I Hydropower Project is located in the collision zone of the Indian and Eurasian plates, therefore, it could face a severe earthquake hazard potential. The Geological Survey of Pakistan has placed the Project area in the "Serious Seismic Danger Zone". In Building Code of Pakistan, Seismic Provisions (2007), the project area falls in Zone-3. Moreover, within the scenario of the October 08, 2005 earthquake of Pakistan, it becomes important to be very cautious regarding the seismic hazard assessment for such an important project.

For the seismic hazard evaluation of Artistic-I Hydropower Project, following procedure was adopted:

- Study of regional geological and seismotectonic information collected from available literature and maps.
- Compilation of historical and instrumental earthquake data from National and International Observatories and analysis of the available earthquake record for completeness.
- Identification and characterization of potential seismic sources in the Project region.
- Evaluation of seismic hazard in accordance with current practices, including:
    - ER 1110-2-1806 - Earthquake Design and Evaluation for Civil Works Projects
    - EM 1110-2-6050 – Response Spectra and Seismic Analysis for Concrete Hydraulic structures
    - Building Code of Pakistan - Seismic Provisions (2007)

6.2. GEOLOGY OF THE REGION

6.2.1. GENERAL

The geology and geodynamics of the Karakorum-Himalayan region in northern Pakistan are characterized by the interactions of three principal tectonic units:

- The Eurasian Plate;
- The Kohistan Sequence; and
- The Indian Plate.

These tectonic units have distinctly different lithologies and tectonic settings and are separated by two major branches of the Indus suture, the Main Karakoram Thrust (MKT) and Main Mantle

Thrust (MMT). Both sutures are marked by the occurrence of a mélange including ultramafic rocks, the southern one also having a wedge of garnet granulites, considered to have recrystallized at a depth of more than 40 km.

The rocks making up the Kohistan sequence, between the two sutures, are predominantly calc-alkaline plutonics and volcanics with subsidiary volcano sedimentary and sedimentary rocks. Tahirkheli, et al., (1979) have suggested that the Kohistan sequence represents the crust and uppermost mantle of an extended island arc turned on end during the collision of the Indian-Asian landmasses. Later studies have shown that the structure of the area is too complex for such a simple interpretation and requires a detailed analysis before final conclusions can be reached about its nature.

6.2.2. THE EURASIAN PLATE

In the Karakorum area, Gansser (1964) distinguished three tectonic zones:

- A Karakorum Tethyan zone
- A central metamorphic zone with plutonic rocks – Karakorum Batholith; and
- A southern volcanic schist zone.

Of these, the last one is now considered to be a part of the Kohistan sequence occurring to the south of the Main Karakoram Thrust (MKT or the Northern Suture), whilst the first two occur to the north of the MKT.

6.2.3. THE NORTHERN SUTURE

In the section from Hunza to Chalt, there is an almost chaotic arrangement of large lenses, each several kilometers long and several tens of meters wide, of limestone, sandstone, conglomerate and mafic and ultramafic rocks in a matrix of chloritoid slates. The basic rocks with prominent volcanic breccias and greenschists are rich in epidote, chlorite and actinolite. The ultra-basics consist of serpentine, talc-chlorite schists, talc-carbonate schist, calcite-chlorite schists, chromite-chlorite schists, and minor relict harzburgite. Ultra-basic masses are apparently more abundant to the west of Chalt. There are large lenses of quartzite which may have formed in situ or which may be tectonic blocks and limestone intermixed with other sediments. The whole assemblage has the appearance of a major mélange with no simple repetitions, as expected in an imbricate zone. The structures in the high-grade metamorphic rocks contrast with those in the main mélange up-dip as seen from mineral lineations and folds with curvilinear hinges.

This tectonic zone is considered to mark the suture between the Kohistan sequence and the Eurasian Plate to the north. There is no evidence of blue-schists, of obducted high-pressure granulites or of an ophiolite, but instead large tectonic lenses of a mélange.

6.2.4. THE KOHISTAN ISLAND ARC

The principal rock units of the Kohistan Island Arc include, from south to north:

- Jijal Complex ; granulite, mafics, and ultramafics ;
- Kamila Amphibolite Complex; mostly norites;
- Chilas Complex; mafic and ultra-mafic layered complex of gabbros, norites, and dunite intersected by dikes and seams of anorthosite and chromitite;
- Kohistan Batholith; various calc-alkaline intrusives; and
- Kohistan Arc Sequence; various meta-sedimentary units and volcanic units typical of an island arc and fore-arc setting.

It is important to point out that geologic mapping has shown that the contacts of the major lithologic units in the Kohistan Island Arc area are faulted (e.g. Ghazanfar, et al., 1991), including the southern and northern boundaries of the Chilas Complex. The Kamila Complex is also dissected by numerous shear zones and is bounded to the north by a major shear zone (Kamila Shear Zone).

The Kohistan Island Arc was formed in the mid-Cretaceous and sutured to Asia around 100-85 million years ago. India, later collided with the arc after continued subduction beneath the arc complex, now accreted to the active continental margin. After full collision, the arc was tilted, uplifted and dissected, enabling examination of the crustal structure of an immature island arc. Suturing to the Asian active continental margin meant that the arc itself became an active continental margin, and the attendant crustal thickening produce an evolution in magmatism from basaltic to calc-alkaline. This is best observed in the phases of plutonism observed in the gabbro-norite plutons of the Chilas Complex and in the Kohistan Batholith, and also in the surrounding (meta-) volcanics into which these granitic sheets are intruded.

The Indus river gorge section through the Kohistan Island Arc reveals an informative section through an island arc from the Main Mantle Thrust (MMT) to which the arc forms the hanging wall, in the south to its footwall position against the Northern Suture. The arc itself is exposed for over 200 km north to south and about 300 km from east to west. The strike of the various tectonic units is approximately east-west; therefore, the deepest crustal regions are represented in the southern portions.

6.2.4.1. JIJAL GROUP

A complex of layered mafic and ultramafic intrusions occurs between Patan and Jijal, an area of about 200 km². In the north are garnet-clinopyroxene-plagioclase rocks containing relics of norite, and so it is likely that these are high-pressure metamorphic equivalents of the Chilas complex. The grain size is similar to that of the norite but garnets continued to grow after the deformation and locally grew to cover 8 cm especially in leucocratic veins. Hornblendites may contain hornblende-garnet, garnetite and garnet plagioclase. The overall composition is a high-pressure metamorphic assemblage and the rocks are equivalent to eclogite facies, thus representing the lower parts of the crust.

Towards the southern boundary of the complex there is an increase in proportion of clinopyroxenes and hornblendites, until the main ultramafic body is reached, which consists of clinopyroxenites, and dunites which have lenses of layered chromitite up to 5 m thick. It has been concluded that both the granulites and the dunites suffered granulite grade metamorphism at 600 – 700°C and 12 – 14 kb and at 800 – 850°C and 8 – 12 kb respectively (Jan & Howie, 1981). The Jijal Complex is possibly a tectonic fragment of the Chilas Complex that was subducted or downthrusted to a substantial depth against the MMT.

6.2.4.2. KAMILA AMPHIBOLITE BELT

This is composed primarily of norites; mostly at amphibolite facies (therefore pyroxenes have retrograded to hornblendes). Amphibolite metamorphism is assumed to have occurred during suturing to Asia. The belt also includes banded amphibolites with or without garnet, hornblendites, schists, garnet gabbros, and anorthosites, diorites, tonalities and granites and thin garnet quartzites and calc-silicate lenses. The proportion of amphibolite is commonly low. The belt is distinctive in that most intrusive rocks are concordant and parallel to the regional trend and have been intensely deformed, many of the coarser leucocratic types becoming augen gneisses. Ghazanfar, et al. (1991) is of the view that these are the oldest exposed unit of the Kohistan sequence and show ophiolitic character.

The Kamila belt is dissected by a number of small shear zones and is bounded to the north (adjacent to the Chilas Complex) by a major shear zone, the 'Kamila Shear Zone'. The belt represents the mid crustal regions of the primitive arc.

6.2.4.3. CHILAS COMPLEX

The Chilas Complex is a vast stratiform cumulate body over 300 km long and 8 km thick, dominated by intrusions of calc-alkaline gabbro-norites, which locally show layering (Ghazanfar, et al. 1991). It contains an upward sequence of hypersthene gabbro, major chromite-layered dunite, norite, gabbro, minor troctolite, harzburgite and dunite, and at the top, norite. Particularly impressive are rhythmically-alternating phase-graded cumulate layers up to 0.1 m thick, slump folds, syn-sedimentation faults, and sedimentary breccias. Some layers up to about 0.3 m thick are of almost pure anorthosite. Dykes of pyroxene-hornblende anorthosite cut both homogeneous and layered rocks. The lower dunites are up to 1 km thick and contain 3-m-thick compact chromitite seams. All these rocks show evidence of several phases of deformation. Isoclinal folds in norites have hypersthenes orientated in axial planar fabrics and the penetrative mineral fabric in the norites is parallel to the axial planes of folded pyroxene amphibolite dykes. These relationships suggested a tectonic origin for the main mineral fabrics in the complex.

It is most probably that Chillas Complex has intrusive relationships with the Kamila Amphibolites to the south and the Jaglot Group to the north. More than 85% of the unit comprises relatively monotonous gabbronorite (the gabbro-norite association) consisting of plagioclase, orthopyroxene, clinopyroxene, magnetite, ilmenite with or without magnetite, scapolite, biotite, quartz, K-feldspar and hornblende. Around 15% of the Chilas Complex comprises ultramafic rocks (dunite, troctolite, peridotite, pyroxenite, anorthosite and gabbro-norite) within a unit termed “the ultramafic association (UMA”. The UMA exhibits a range of original igneous textures including mineral layering, slumping, graded bedding, and syndepositional faults. The UMA is particularly well exposed around Chilas close to Nanga Parbat. Most workers have observed the gabbronorites being intruded by the UMA, although examples of the converse situation exist.

Ghazanfar et al. (1991) have shown both contacts of norite as fault which has led to the formation of norite mylonite in an otherwise very tough dark coloured rock with streaks of white or pale-white colour.

6.2.4.4. JAGLOT GROUP

The Jaglot Group extends in a semi-contiguous fashion for some 250 km east–west and up to 20– 30 km north–south. It has a probable intrusive relationship with the Chilas Complex to the south and, where not in intrusive contact with the Kohistan batholith is conformable with the Chalt Volcanic Group to the north. The Jaglot Group is a mixed, largely metasedimentary unit comprising metasandstones, carbonates, siltstones, mudstones and turbidites with local metabasalt, andesite and rhyolite volcanic rocks. Khan et al. (1997) described a 1–4 km wide, 15 km long basalt and dolerite dyke swarm, oriented NW–SE, at the base of a volcanic-rich unit (Thelichi Formation) within the Jaglot Group. The Jaglot Group has only relatively recently been recognized as an important cross-terrane unit.

6.2.4.5. KOHISTAN BATHOLITH

The Kohistan batholith extends over 270 km east– west (as mentioned above, the batholith in Kohistan is only part of a c. 2700 km long Trans-Himalayan batholith) and up to 50–60 km north–south. The batholith comprises a wide range of lithologies from hornblendite to leucogranite, but predominantly is gabbroic, gabbroic diorite and granite or trondhjemite in composition. Batholithic intrusions are largely small–medium- to medium–large volume plutons with significant vertical and horizontal dimensions. Intrusive bodies also take the form of sills, dykes, sheets, lopoliths and other smaller geometries. Many intrusions are complex and composite multi-intrusive bodies with up to four or five phases of intrusion. The most common major minerals are plagioclase, alkali feldspar, hornblende, biotite and quartz. The batholith is largely intrusive into the Chalt Volcanic Group (see below) and the Jaglot Group meta-sedimentary dominated unit, although Khan et al. (1997) also reported batholithic units intruding Kamila Amphibolites around Babusar. The batholith has been particularly uplifted and eroded close to Nanga Parbat and also west of Gilgit where volcano-sedimentary sequences unconformably overlie the batholith. Even the earliest pioneers recognized that there were probably three distinct phases of batholithic intrusion that could be differentiated on the basis of the presence or absence of well-developed penetrative fabrics with earlier gneissic like gabbros and granitoids intruded by un-deformed plutons that in turn were intruded by late granite sheets.

6.2.4.6. NORTHERN KOHISTAN ARC SEQUENCE

This is comprised of various volcanic and metasedimentary Groups – Dir and Chalt Groups. These include Eocene calc-alkaline basaltic-andesitic-rhyolitic lavas and pyroclastic deposits associated with the active continental margin stage of the arc complex.

There is a tectonic break between rocks of the northern suture and the volcanic and sediments belonging to the Chalt Group to the south, which make up the northern part of the arc. This group contains meta-greywackes and slates, epidotic grits and tuffs, hornblende-bearing tuffs, chlorite schists, schistose amphibolites, amygdaloidal pillow-bearing basalts and fragments basic volcanics. Further south near Gilgit and Raikhot there are graded psammites and pelites and locally thick piles of deformed pillow lavas, but these occur as screens betweens large plutons of diorite and tonalite.

The total thickness of deformed and weakly metamorphosed sediments and volcanics reaches several kilometers but this may involve repetitions by folding and thrusting. The rocks are folded by large upright, tight to isoclinal anticlines and synclines, which plunge east or west. They are cut by thin granitic dykes and by muscovite pegmatites, which are discordant to both cleavage and bedding.

6.2.5. INDIAN PLATE

The bedrock suites south of the Kohistan Island Arc and southern suture zone include those forming the pre-collisional stratigraphy of the Indian Plate plus the syn-and post-tectonic material eroded from the mountain ranges of the Himalayas, Karakoram, Hindukush, and Pamirs.

6.2.5.1. SALT RANGE

The Salt Range defines the Frontal thrust of the Himalayas, a thin-skinned structure riding on an evaporite decollement. The topographic relief of the Salt Range is produced by blind thrusts and ramp anticlines.

6.2.5.2. MOLASSE

Molasse sequences of detrital sediments form the Margalla Hills and the Punjab Plains. All tectonism is thin skinned with numerous southward-propagating thrusts that have produced numerous imbricate zones.

6.2.5.3. HAZARA SEDIMENTS

The Hazara metasedimentary belt is largely composed of Precambrian to Early Mesozoic sediments. The Precambrian sequence is composed of quartz schist, graphitic schist, marble and gneiss overlain by thick sequence of slate, phyllite and greywacke sandstone. The Precambrian sequence is unconformably overlain by quartzite and argillites.

6.2.5.4. MANSEHRA BATHOLITH

Imbricated slices of this granitic batholith, intruded into the metamorphic cover, are exposed in the Hazara Syntaxis. It is Cambrian in age.

6.2.5.5. METAMORPHIC COVER

This consists of late Precambrian – early Cambrian metasediments that have undergone a Palaeozoic low-grade metamorphism, and which are overlain by pre-collisional Mesozoic sediments. These were further metamorphosed and thrusted in the foothill of the MMT synchronous with full collision.

6.2.5.6. NANGA PARBAT GROUP

Rocks of the Nanga Parbat Group represent units belonging to the cratonic Gondwana basement, exposed in the Nanga Parbat – Haramosh Massif syntaxis. The Proterozoic gneisses of the Indian Plate have their northernmost exposure in the Nanga Parbat Syntaxis and represent the lowest structural levels of the Indian Plate observed. They have been mapped and subdivided into three lithostratigraphical groups (Madin et al., 1989).

6.2.6. LOCAL GEOLOGICAL SETTING

The local geological setting around project area has been interpreted based on the geological maps of published by Geological Survey of Pakistan (2006) and Searle & Asif (1995).

Quaternary Deposits

Stream Deposits

Stream deposits comprise gravels, cobbles and boulders with fine to coarse sand. The deposition is on-going process with the perennial and non-perennial streams. These cover the stream and river beds of active channels.

Alluvial deposits

These are old river or stream deposits making terraces along the valley slopes. These deposits comprise gravels, cobbles and boulders embedded in silty sandy matrix. Most of the settlements are situated on these deposits. The top layer of these deposits comprises fine materials and therefore, are being used for cultivation.

Slope Wash Material

Besides, the river and stream bed deposits, terraces comprised mainly of slope wash materials are present at the lower slopes and valley floor. The slope wash material has colluvial, fluvial and glacial origin based on the mechanism of downslope transportation and deposition. These are basically derived from the rock exposures present at higher elevation. Generally, these deposits are heterogeneous and comprise angular to subangular rock fractions in silty sandy matrix where origin is colluvial or glacial. However, these comprise rounded to sub-rounded rock fragments embedded in sandy matrix where their origin is alluvial. These normally possess thin to thick cover of silty/ clayey material and are under agriculture use. These materials are light gray to yellowish brown, firm to stiff, silty clay / clayey silt, overlying the material of varying size from gravel to boulders.

Scree

This material is situated on the hill slopes on higher elevation as loose angular rock fragments detached from the upslope hill faces and generally accumulated on slope faces. Often, these extend towards the old terraces of river bed material forming colluvial cover. Scree is generally very loose to loose but having high degree of interlocking because of angularity. In the older scree deposits, the rock fragments have been stuffed with fines coming from upslopes and transformed to soil, that is currently covered by vegetation transforming to slope wash material in the project area.

Rock Units

Lawari Pluton

Lawari Pluton is of Miocene age and comprises light to dark grey, fine to medium grained granite, granodiorite and diorite with occasional pegmatite, quartz veins, aplite sills and dykes. These rocks are exposed in northwest of Dir town.

Dir Group Rocks

Dir Group Rocks comprise Utror Volcanics, Barawal Banda Slates/ Phyllites/ Schists and Barawal Banda Quartzite and are believed to have Paleocene to early Eocene aged. The details of rock units are discussed in the following sections.

Utror Volcanics

Utror Volcanics were believed to be deposited in late Eocene. These are volcanic rocks comprising andesite, dacite, rhyolite with tuffs, agglomerate and pyroclasts. The color varies as grey, green, maroon red and at places white with fine to medium grained texture. Utror volcanic rocks are exposed in northeast of the Dir town making a slim belt that extends both northeastward and southwestward.

Barawal Banda Slates/ Phyllites/ Schists

Utror volcanics are underlain by Barawal Band meta sediments comprising slates, phyllites and schists. Their age has been interpreted as early Eocene. The rock units in this formation comprise grey, green and maroon in color, thinly bedded, fine to very fine grain textured, interbedded with occasionally silty phyllites, schists and slates. Occasional beds of light grey thinly bedded limestone are also present at places. These rock units are exposed in the north and south of Dir town and extend both in northeast and southwest directions.

Barawal Banda Quartzite

Barawal Banda Quartzite is overlain by Brawal Banda meta sediments (i.e. Slates, phyllites & schist). Its age is Paleocene and mainly comprises light to dark grey on fresh surface and brownish grey on weathered surface quartzite. It is found as thinly to thickly bed with fine grained texture. Chert patches are also present in places. Quartzite is exposed south of the Dir town and north of the Darora village. This has also extension in northeast and southwest directions.

Shandur Granodiorite

Shandur Granodiorite consists of light grey to brownish in colour, medium grained, hard and massive granite and granodiorite present as plutons in the preexisting rocks. This formation is believed to have early Paleocene age. A massive unit is exposed along the Peshawar-Dir Road upstream of Darora village. This also has massive exposures in the east and south east of the project area. Minor intrusions are laying also in the project area in Banded Amphibolite both upstream side near Darora village and south of Sahibabad village. The rock is massive and shows pronounced foliation in places. In the east of the project area, Shandur Granodiorite has intrusions in the Massive Amphibolite.

Barawal Banda Meta-volcanics

The Mesozoic (Late Cretaceous) rocks comprises of metamorphosed basaltic flows. These rocks are brownish and dark brown in colour and are not exposed in project vicinity. A thin belt of these rocks is present in the west of the project area extending northeast and southwest direction between Barawal Banda Slates, Phyllites & Schist and Barawal Banda Quartzite.

Deshai Diorite

Deshai Diorite comprises grey, greenish grey, medium to coarse grained diorite composed of plagioclase, hornblende, biotite with subordinate quartz, hornblended pegmatites and quartz veins.

Banded Amphibolite

Banded Amphibolite is believed to be of Middle Cretaceous age and is underlain by Shandur Granodiorite in the project area and also by the Barawal Banda Quartzite and so on. It shows light to dark green color on fresh surface and is gray to brown on weathered surfaces. It is generally fine to medium grained, foliated and composed of plagioclase, hornblende and quartz minerals. In the project area, this is widely exposed rock formation, it is massive to foliated and crushed in places. Most of the project components will be placed on this rock unit.

Massive Amphibolite

Massive Amphibolite is believed to be of Late Cretaceous age and is underlain by Shandur Granodiorite and by Banded Amphibolite in the east of the project area. It shows dark gray to brownish gray on fresh surface and is brown on weathered surfaces. It is generally fine to medium grained, massive and composed of plagioclase, hornblende, epidote, biotite and minerals.

6.3. REGIONAL TECTONIC FRAMEWORK

Earthquakes in the northern part of Pakistan are the result of ongoing northward subduction of the Indian plate beneath the Eurasian plate at a rate of around 40 mm/year. The north and northeast directed compression has produced major thrust faults like the Main Karakoram Thrust (MKT), Main Mantle Thrust (MMT), and the Main Boundary Thrust (MBT), as well as many active faults of variable length. Transpressional features in the area include strike slip faults named as Jhelum, Thakot, Puran and Raikot Faults. In addition to these, existence of shallow to deep crustal faults, like the NW trending Indus Kohistan Seismic Zone (IKSZ) of Armbruster et al. (1978) and Bagh-Balakot Fault (BBF) has also been proposed. The Himalayan region has been experiencing major earthquakes, like the 1905 Kangra earthquake, 1934 Bihar–Nepal, and 1950 Assam earthquake. All these earthquakes have approached or exceeded $Mw = 8.0$, but none was as destructive as the October 8, 2005 Kashmir-Hazara earthquake of $Mw = 7.6$. These great earthquakes occurred on the detachment under the outer and Lesser Himalayas rocks from the under thrusting Indian shield rocks. Gahalaut (2006) indicated the presence of three seismic gaps in some segments of the detachment and named one of them as the Kashmir Seismic Gap, which lies in the southeast of the NW Himalayan Syntaxis or Hazara Kashmir Syntaxis (HKS). The seismically active nature of Pakistan and its adjacent region is well known because of the occurrence of some of the biggest earthquakes of the world. Some events that caused loss of life and destruction in northern Pakistan during the recent past are the 1974 Pattan earthquake of $Mw = 6.2$, Rawalpindi earthquake of 1977 having $Mw= 5.5$, two Bunji earthquakes of $Mw= 5.3$ and $Mw = 6.3$ that occurred in 2002, two Batgram earthquakes of Mw 5.5 and $Mw = 5.8$ that took place in 2004, and the October 8, 2005 Kashmir Hazara earthquake with $Mw = 7.6$.

The geodynamic framework of northern Pakistan is characterized by the collision and coalescence of Eurasian and Indian Continental Plates, which were once separated by the oceanic domains, and creation of the Kohistan island arc in the late Cretaceous. The collisional process started in the late Eocene to early Oligocene with the formation of the Himalayan Ranges and this process still continues. Relative to Eurasia, the Indian plate is still moving northwards at a rate of about 4 cm/year. The subduction of the Indian plate beneath the

Eurasian plate has resulted in folding and thrusting of the upper crustal layers near the collisional boundary. The thrusting has been depicted from north to south in the shape of MKT (Main Karakoram Thrust), MMT (Main Mantle Thrust), MBT (Main Boundary Thrust) and SRT (Salt Range Thrust) the locations of which are shown in **Figure** 6-1.

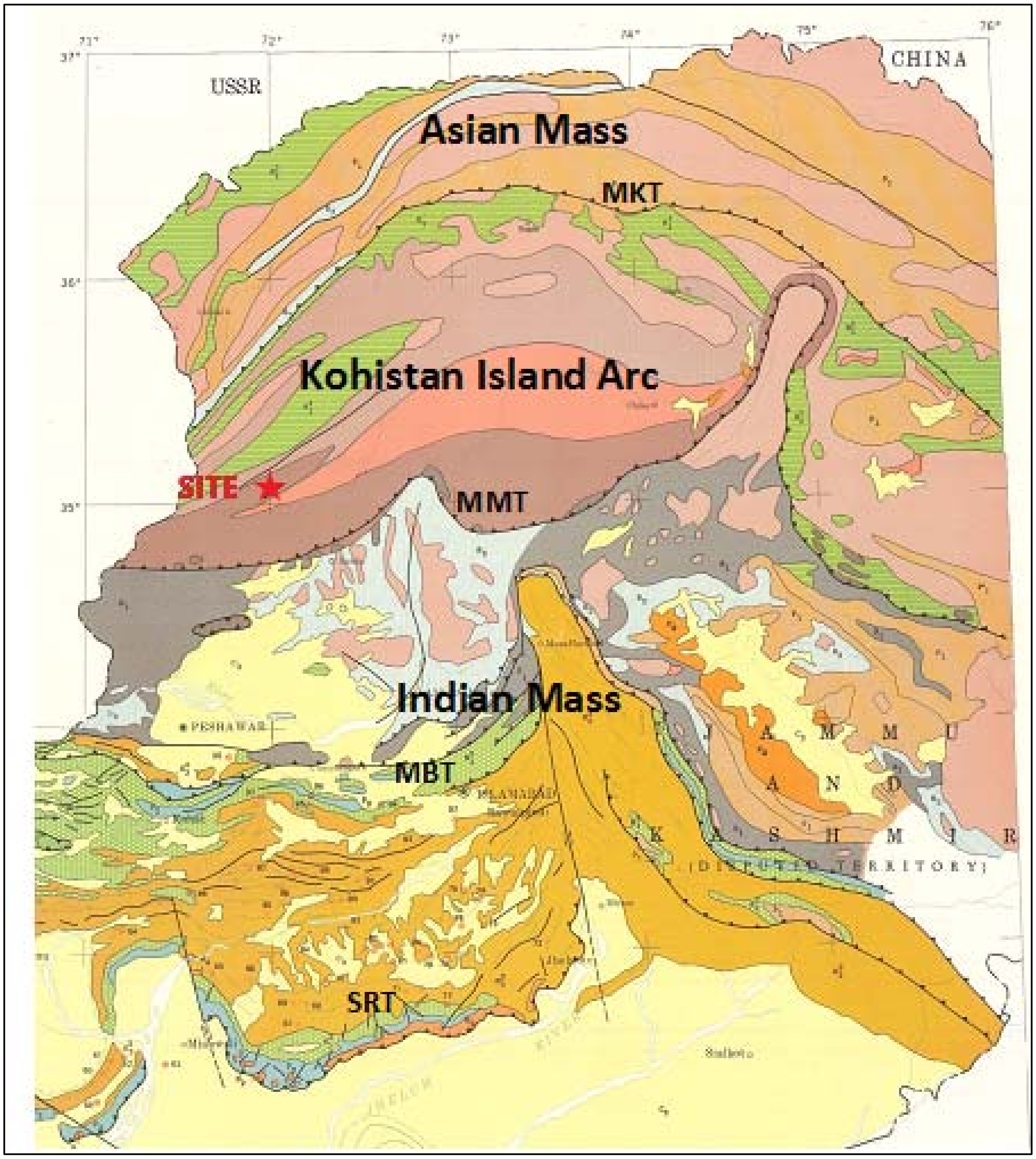

Figure 6-1: Generalized Tectonic Map of Northern Pakistan; by GSP (1982)

6.3.1. REGIONAL TECTONICS

The geology of northern Pakistan is a superb example of continental collision tectonics. In this area, the three of the world's greatest mountain ranges converge, the Himalayas, the Karakoram, and the Hindukush. The mountain building process that formed these ranges commenced in Cretaceous time when Indian plate started moving and was carried northward (Scotese et al., 1988). During that time (i.e. Early Cretaceous) Karakoram terrane sutured with eastern Hindukush along the Tirich Mir fault (Zanchi et el., 2000; Hildebrand et al, 2001). Soon after, the intra-oceanic Kohistan arc formed over a subduction zone that dipped beneath the arc, either to the south or to the north (Khan et al. 1993). It is widely accepted that the northward movement of India was concurrent with the accretion to Asia of an intra-oceanic arc system, the Kohistan arc that collided with Asia along the Shyok Suture or MKT. The southern margin of Asia, including the Kohistan arc, then became an Andean type convergent margin, until India collided with Asia. Thrusting of the Kohistan terrane southward over the northern Indian plate margin along the Main Mantle Thrust (MMT) probably took place in Late Cretaceous or Paleocene time and was completed by 55Ma, forming the Indus Suture Zone (Searle et al., 1999).

A detailed description of the salient features of the Kohistan magmatic arc and the adjoining Northwestern Himalayan Fold-and-Thrust Belt of the Indian plate is given below.

6.3.1.1. KOHISTAN MAGMATIC ARC

Kohistan is an intra-oceanic island arc bounded by the Main Mantle Thrust (MMT) to the south and the Main Karakoram Thrust (MKT) to the north. This E-W oriented arc is wedged between the northern promontory of the Indian crustal plate and the Karakoram block. Gravity data modeling indicates that the MMT and MKT dip northward at 35˚ to 50˚ and that the Kohistan arc terrain is 8 to 10 km thick (Malinconico, 1989). Seismological data suggests that the arc is underlain by the Indian crustal plate (Seeber and Armbuster, 1979, Fineti et al., 1979). The northern and western part of the arc, along MKT, is covered by a sequence of Late Cretaceous to Paleocene volcanic and sedimentary rocks. The central part of the arc terrain is mainly composed of Kohistan Batholith which comprises an early (110-85 Ma) suite of gabbro and diorite, followed by more extensive intrusions of gabbro, diorite and granodiorite (85-40 Ma) which are intruded by much younger dykes and sills of leucogranite (30-26 Ma).

The southern part of Kohistan is comprised of a thick sequence of mafic and ultramafic rocks. These rocks may be divided into three tectono-metamorphic complexes separated by major thrust zones. The Chilas Complex forms the northern and upper unit. It comprises layered norites and gabbros metamorphosed to granulite facies. It is characterized by a series of south-verging folds. It has been thrusted southwards over the Kamila Amphibolites Complex. The latter consists of amphibolites, meta-gabbro and orthogneisses. This sequence comprises a highly tectonised shear zone. Southward, it is thrusted over the Jijal Complex which forms a tectonic wedge between the Kamila Shear zone and the MMT. The Jijal Complex is largely comprised of garnet-pyroxene-granulites and ultramafic rock (Tahirkheli and Jan, 1979; Coward et al., 1986; Khan et al., 1993; Treloar et al., 1990; Miller et al., 1991).

6.3.1.2. NORTHWEST HIMALAYAN FOLD-AND-THRUST BELT

The Northwest Himalayan fold-and-thrust belt occupies a 250 km wide and about 560 km long irregularly shaped mountainous region stretching from the Afghan border near Parachinar up to the Kashmir Basin. The Hazara-Kashmir and Nanga Parbat Syntaxes form its eastern margin. It covers all the terrain between the Main Mantle Thrust (MMT) in the north and Salt Range Thrust in the south. This region comprises the mountain ranges of Nanga Parbat, Hazara, Southern Kohistan, Swat, Margalla, Kalachitta, Kohat, Potwar and Salt Range.

A major thrust fault, the Panjal-Khairabad Fault divides the NW Himalayan sequence into a deformed southern zone, often referred to as the external or foreland zone and a deformed and metamorphosed northern zone, also known as the hinterland zone (Pivnik & Wells, 1996). The foreland zone comprises the Hazara-Kashmir Syntaxis, Salt Range and Kohat-Potwar fold belt and the Kurram-Cherat-Margalla thrust belt, whereas the hinterland zone comprises the Himalayan crystalline nappe-and-thrust belt.

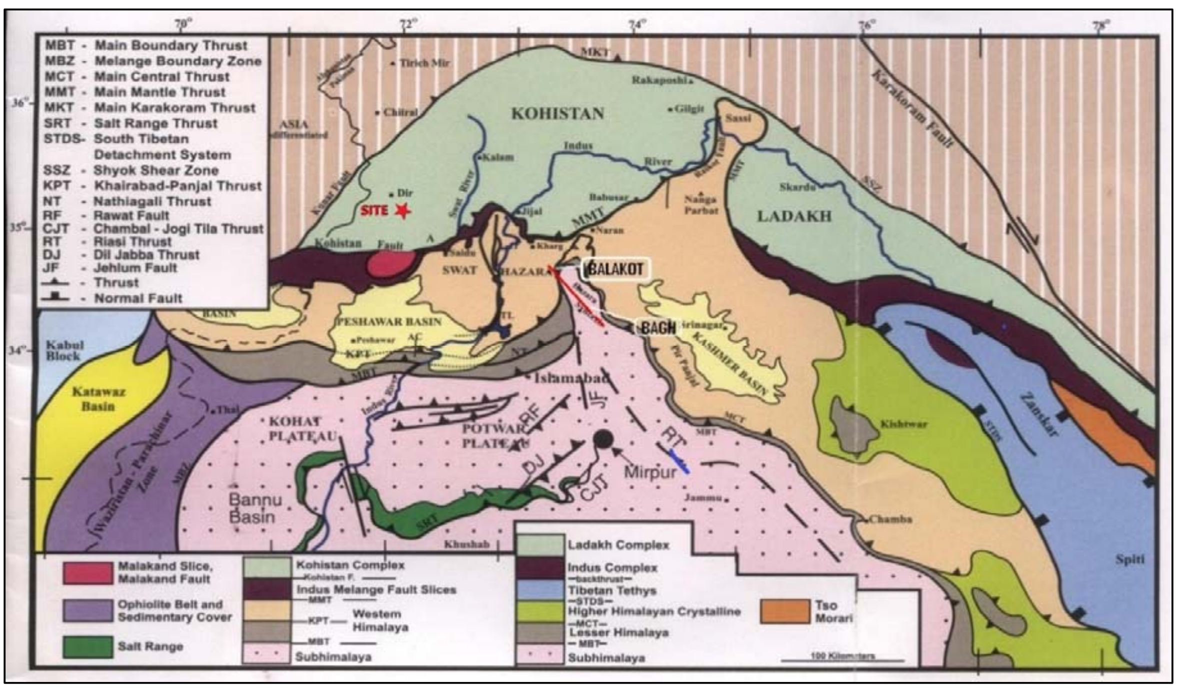

Figure 6-2: Tectonic Map of Northern Pakistan showings major faults in Northern Part of Pakistan (After Ahmad Hussain et al., 2004).

6.3.2. MAJOR TECTONIC FEATURES

The Project site is located in the Kohistan island arc, which is sandwiched between the Indian and the Eurasian plates. The major faults of the project region include, from north to south, the Main Karakoram Thrust (MKT), Kohistan Fault, Main Mantle Thrust (MMT), Panjal-Khairabad Thrust, Main Boundary Thrust (MBT) and Salt Range Thrust (**Figure** 6-2). The general trend of these faults is predominantly east-west with change in trend due to syntaxial bends. The general description of these major faults is as follows.

6.3.2.1. MAIN KARAKORUM THRUST (MKT)

This is the major regional fault representing the suture zone between the two colliding plates. This fault represents the northern boundary of the Kohistan island arc and runs eastward to join Indus suture zone in upper Himalayas and terminate at its junction with Karakoram fault. In the Chitral and Gilgit area, the rocks of Karakoram Batholith are thrusted over the rocks of Kohistan Batholith along MKT.

6.3.2.2. KOHISTAN FAULT

On the Geological Map of NWFP (2006) published by the Geological Survey of Pakistan, the contact between the Kamila amphibolies and the Satpat ultamafics to the south of Dasu are shown as the Kohistan fault. Along this fault, the rocks of the Kamila complex are thrust over the Satpat complex rocks. This fault runs almost parallel to MMT.

6.3.2.3. MAIN MANTLE THRUST (MMT)

Main Mantle Thrust (MMT) is a northward dipping regional thrust, which separate the Indian Plate from the Kohistan Island Arc. It extends from Khar (Bajaur Agency) in the west to the north of Naran (Kaghan Valley) in the east where it takes a northeast ward bend towards the east of Bunji and gets truncated by Raikot Fault.

The thrust inclines steeply near the surface; however, this inclination is believed to decrease considerably with depth likewise as interpreted for other local thrust faults of the region.

Structurally the Main Mantle Thrust is characterized by a number of northwest dipping high angle imbricate thrusts, which converge together in the east and being terminated as Raikot fault. A number of other sub-parallel shears associated with MMT and distributed near Chilas and Bunji merge together and join Raikot fault.

MMT is almost aligned sub-parallel to the Main Karakoram Thrust in the north and Main Boundary Thrust in the south except the Hazara-Kashmir Syntaxial area, where MMT remains unaffected and continues its journey in the northeast direction to join the Raikot fault. In the east it is abruptly juxtaposed against the Nanga-Parbat-Haramosh Massif, while in the west it meets the Main Karakoram Thrust in Afghanistan. Before joining the Main Karakoram Thrust, it is offset by northwest and northeast trending strike slip faults near Khwaza Khela and Besham. The Patan earthquake of December 28, 1974, having magnitude 6.2, was associated with MMT.

The Raikot fault zone and associated structures exhibit remarkable neotectonic features including fault scarps and exposures where Nanga Parbat gneisses overlie Pleistocene tillites. The earthquakes of November 2002 and January 2003 in Astore valley may be attributed to movement in this zone.

On the basis of the recorded seismicity and observed neotectonic features both the Main Mantle Thrust and Raikot fault are considered seismically active.

6.3.2.4. PANJAL-KHAIRABAD THRUST

The Panjal-Khairabad Thrust is an important active tectonic feature of regional significance. It runs northwards and parallel to the Main Boundary Thrust (MBT) on the eastern side of Hazara- Kashmir Syntaxis where it is normally called Main Central Thrust (MCT). These faults gradually converge and eventually join about 5 km north of Balakot. In the area west of Hazara-Kashmir Syntaxis, this fault is commonly called Panjal Thrust.

A left lateral strike slip fault cuts across both the Panjal Thrust and MBT approximately 6 km south of Balakot, from where onwards the Panjal Thrust continues its independent journey southwards. It is traceable up to Garhi Habibullah from where onward it is concealed beneath Quaternary deposits. The thrust comprises several segments having an aggregate length of about 130 km.

To the west this fault passes through the Gandghar range near Haripur and joins the Khairabad fault located on the northern side of the Attock-Cherat range, hence it is sometimes referred as the Panjal-Khairabad fault.

The geologic positioning and seismicity associated with the Panjal-Khairabad fault renders it as an active regional tectonic feature capable of generating large earthquakes.

6.3.2.5. MAIN BOUNDARY THRUST (MBT)

The most significant and active tectonic feature of regional extent is the Main Boundary Thrust (MBT). It is the main frontal thrust of the Himalayan Range, which runs along the Himalayan arc for almost 2500 km from Assam in the east to Kashmir and Parachinar in the west. The MBT along with other associated thrusts forms the sharp conspicuous Hazara-Kashmir

Syntaxis. This syntaxial bend is the most dominant tectonic feature of the area as all local major fault systems and geologic structures follow its trend. On the west side of this feature, the MBT initially follows a rather southwest trend and then extends westward reaching Parachinar. Near its surface trace, the MBT dips northward at a steep angle, which becomes sub-horizontal with depth. Islamabad-Rawalpindi area is located at a close distance south of the western limb of the MBT.

A number of large to major earthquakes have occurred along the Himalayan Arc east of the Hazara-Kashmir syntaxis during the last two centuries, which places it amongst the most active regions of the world. Much of the seismicity recorded during the last century is attributed to surface and subsurface extensions of the MBT and other associated thrusts. Based on this data, Seeber et al. (1981) have shown that great earthquakes occurring along Himalayan Arc are probably related to slips taking place along this quasi-horizontal detachment surface. Based on the above, the MBT is considered active having seismic potential sufficient enough to generate large to major earthquakes.

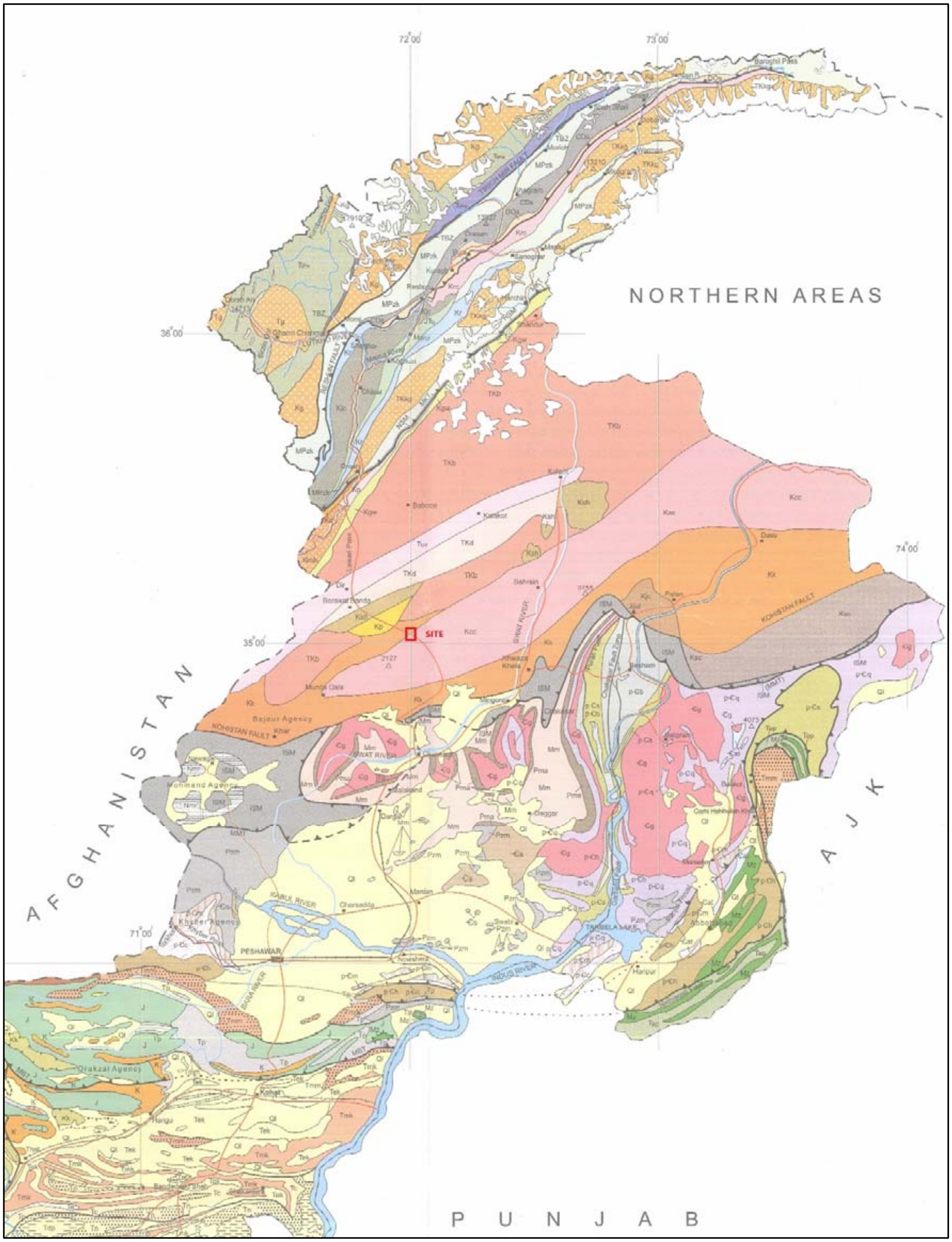

Figure 6-3: Geological Map of KPK; by GSP (2006)

Legends of **Figure 6-3** are presented in the following figure.

FIG. 3b

LEGEND

Ql — **Quaternary Alluvium:** Unconsolidated deposit of gravel, sand, silt and clay.

Qbf — **Quaternary Boulder Fan Deposit:** Mostly sandstone and limestone boulders and cobbles unconsolidated / poorly cemented.

CHITRAL AREA
(Asian Plate)

Tg — **Post-Collision Granite:** Include **Hot Spring granite** which is two mica granite with garnet and tourmaline. It is leucogranite, U-Pb ages indicate 24Ma. The Pluton is surrounded by granitic gneisses which are very similar to Hot Spring granite in composition. **Dorah An granite** is identical to the Hot Spring Pluton and has been intruded into Staurolite-schist and sillimanite K-feldspar migmatites. Age late Tertiary.

TKkg — **Karakoram Batholith & Associated Rocks:** Include **Buni Zom granodiorite** which consist of undeformed non-porphyritic biotite hornblende granite. It hosts the magnetite mineralization. **Kesu Koghuzi granite** is highly complex and has foliated dioritic rocks with minor acidic intrusions. **Gamu Bar pluton** (Dobargar and Zagar Umalsit) is the hornblende-biotite granodiorite to granite. Slightly porphyritic and yields K-Ar ages of 56 & 40 Ma.

MESOZOIC

Kg — **Pre-collision Intrusive Rocks:** Include **Tirich Mir pluton** which comprises hornblende-biotite granodiorite and has large (3-4cm) plagioclase phenocrysts. Rb-Sr biotite age of this pluton is 115± 4Ma. **Kafiristan granodiorite** is virtually similar to that of the Tirich Mir pluton. **Gazikistan granodiorite** which is a lenticular body and also identical to that of the Tirich Mir granodiorite pluton.

Krc / Kr — **Reshun Conglomerate(Krc) and Reshun Marble(Kr):** Two separate units are marked of marble, calcareous phyllite, red phyllite, conglomeratic phyllite and brownish gray conglomerate. Two thick marble/limestone outcrops follow the general strike direction throughout the Chitral District. The two carbonate outcrops surrounding the Chitral Slate form an anticlinal structure. It has been assigned Cretaceous age on the basis of Orbitolina fossils.

KJc — **Chitral Slate:** It comprises fine grained black slate and thinly laminated dark gray phyllite. At some places, the phyllite contains thin beds of impure gray marble. It is about 5000m thick and forms an anticlinal structure in the Chitral area. Age Jurassic to Cretaceous.

JTRg — **Koghuzi Greenschist and Calcareous Phyllite:** The **Koghuzi Greenschist** is pale green, fine grained containing sodic plagioclase, chlorite, actinolite, epidote and quartz. The **Calcareous Phyllite** is exposed between the Koghuzi Greenschist and the Chital Slate. It consists of calcareous phyllite with some marble. It is about 100m thick. Age Triassic to Jurassic.

TRPw — **Wakhan formation, Atark Unit and Tirich Boundary Zone:** The **Wakhan formation** in the Hindukush range to the north of Tirich Fault consists of amphibolite and greenschist facies paragneisses, slate, phyllite, and pelites with marble and cal-silicate quartzite. The **Atark Unit** consists of carbonate rocks, having a Permian section with megalodonts and possible rudists. Age Permain to Triassic. The **Tirich boundary zone** (TBZ) is associated with Tirich fault and consists of peridotite, and metagabbro, amphibolite and gneisses.

MPzk — **Karakoram metamorphic complex:** The Karakoram metamorphic complex in Chitral area between Tirich fault and northern suture consists of slate, greenschist facies phyllite, quartzite and limestone. It include Shah Jinali phyllites, and sediments and metasediments of Karakoram range.

PALEOZOIC

CDs — **Sarikol Shale and Tash Kupruk Unit undivided:** The **Sarikol Shale** consists of black shale, micaceous phyllite, brown dolomite and gray sandstone. On the basis of fossil Devonian to Early Carboniferous age has been assigned. The **Tash Kupruk Unit** consists of Late Devonian to early Carboniferous basaltic lava flows, volcani-clasts and carbonates. The lavas preserve phenocrysts of clinopyroxene in a groundmass of plagioclase, magnetite and phyritic material.

DOs — **Charun Quartzite and Shogram formation undivided:** The **Charun Quartzite** is white, medium grained and about 100m thick in Reshun area. It lies below the Shogram formation. The **Shogram formation** consists of a massive, medium bedded dolomite, gray, fossiliferous limestone and the upper part consists of fine to medium grained quartzite. The total thickness is about 800m and it is of Late Devonian (Frasnian) age.

NSM — **Northern Suture Melange (Shyok Suture):** Deformed and chaotic assemblages of volcanic rocks, limestone,red shales, quartzite and serpentinite.

KOHISTAN ISLAND ARC

TERTIARY

Tuv — **Utror Volcanics:** Andesite, rhyolite, dacite and tuffs interbedded with metasediments in the Western Kohistan arc. Age $^{40}Ar/^{39}Ar$ Honblende 55± 2 Ma or Eocene to Paleocene.

Tkb — **Kohistan Batholith:** Granites, granodiorites, quartz diorites with dykes and sheets of hornblende gabbros and leucogranits.Searle et al (1996) has reported Rb/Sr. Wr-110-90 Ma age. Miocene to Cretaceous.

Tkd — **Dir Metasediments:** Sandstone, siltstone and turbidites with rare intercalated marine limestone containing late Paleocene faunas (60-54Ma).

CRETACEOUS

Kp — **Purit formation:** Red shales with subordinate sandstone and conglomerate of continental fluvial origin and is correlative to the Reshun formation of Chitral area. Age Cretaceous.

Kmb — **Mirkhani Batholithe:** Quartz diorite to granodiorite in composition. Large porphyritic bodies of feldspar are seen with in the body. Age Cretaceous.

Kcc — **Chilas Complex:** Mafic-ultramafic stratiform plutonic complex, dominantly composed of gabbro-norite, pyroxene diorite-tonalite and olivine gabbro with minor ultramafic (chromite-layered dunite, peridotite, pyroxenite, hornblendite) and anorthosite associations. Age Cretaceous.

Ksc — **Sapat Complex:** Ultramafic-mafic stratiform complex. The basal part is completely serpentinized, dunite, peridotite, pyroxinite and rare chromitite at the base, anorthosite and pyroxenite in the middle and isotropic gabbros at the top. Age Cretaceous.

Kjc — **Jijal Complex:** High-pressure garnet granulite, layered gabbro at the top and layered ultramafic cumulates (peridotite, dunite, diopsidite, chromitite) at the base. Age Cretaceous.

Kd — **Drosh formation:** Drosh formation to the south of Main Karakoram Thrust (MKT) in Shishi valley ; thickly bedded porphyritic andesite with phenocrysts of plagioclase, pyroxene and hornblende; thin interbeds of red shale are common within the volcanics. Age cretaceous.

Kgw — **Gawuch formation:** Gawuch formation in the south of Main Karakoram Thrust (MKT) in the western Kohistan Arc in Chitral area; green color calcareous phyllite, with occasional bands of schist in the lower part followed by brown limestone.

Kp — **Peshmal Schist:** In the western Kohistan arc: green schist facies, slate, phyllite and psammnites with an early Cretaceous turbidite protolith (with strong volcano - clastic component). Age Cretaceous.

Ksh — **Shao formation:** In the southern Kohistan near Kalam, consists slate, limestone, and quartzite sequence. Age Cretaceous.

Kk — **Kamila Amphibolites:** Upper amphibolite-facies and calc-alkaline metabasalts intruded by subduction-related gabbroic plutons; all strongly sheared. Trondhjemites, as partial-melting products,common near contact with the Chilas complex. Common intrusions of diorites, granodiorites and granites. Age Cretaceous.

ISM — **Indus Suture Melange:** Includes, Shangla blueschist, Charbagh greenschist, Mingora ophiolites, Nawagai melange & Nawagai marble (Nmr), and Dargai ophiolites: Chaotic assemblage of serpenitinite, talc-Schist, greenschist, metabasalt and greenstone along the hanging wall of the Main Mantle Thrust.

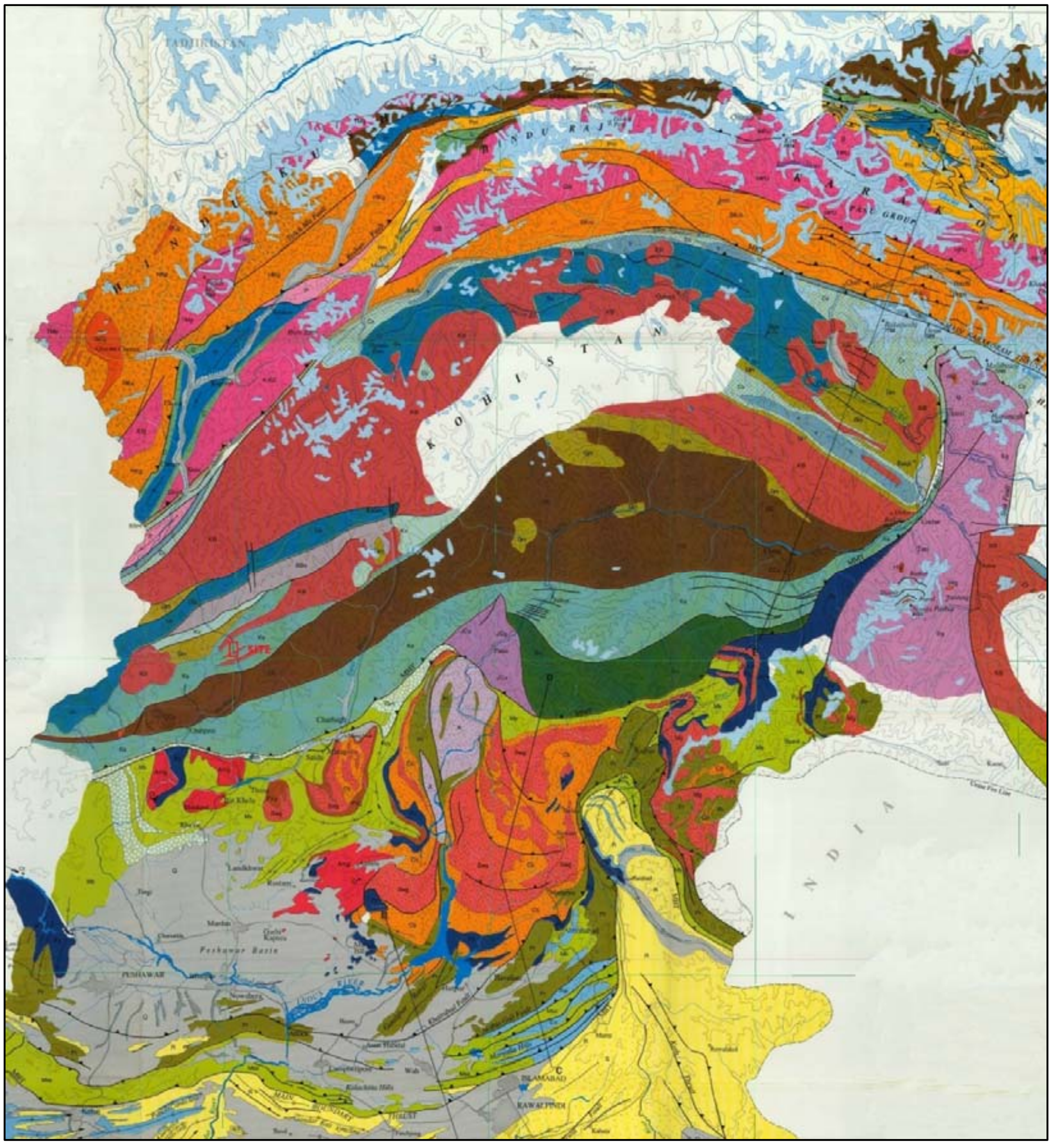

Figure 6-4: Geological Map of Northern Pakistan and Adjacent Areas; by Searle & Asif (1995).

6.3.3. LOCAL TECTONIC FEATURES

The root cause of most seismic events can be related to tectonic processes in the upper portions of the Earth crust. The Earth crust is divided into several plates. Buildup of strain within these plates or margins are due to the deformations taking place as the result of movements along or relative to the interfaces or margins of the plates. The northern parts of Pakistan are near to the collisional boundaries of Eurasian and Indian plates margins and therefore, seismically very active.

The project is located in the western part of the Kohistan island arc close to the boundary between the Kohistan Batholith and Chilas Complex. Near Kalam, Utror Volcanics and Dir

Meta-sediments are present overlying Kohistan Batholith. In the Geological Map of NWFP (2006) published by the Geological Survey of Pakistan **Figure 6-3**, the contact between the Kohistan Batholith and Chilas Complex is shown to be a normal contact but some researchers believe that this contact is faulted (Ghazanfar et al, 1991). In the Geological Map of Northern Pakistan edited by Searle & Asif (1995) presented in **Figure** 6-4, this contact is shown to be a faulted one.

In and around project area, exposed rock units have generally northeast-southwest trend dipping into northwest. In the vicinity of the project area, a regional fault named as Shandur Thrust is present about 12-14 km in the north of the project area. This thrust fault has been marked by the Utror Volcanics group of rocks in southeast while by Kalam Quartz Diorite associated with meta sediments in the northwest. The fault is dipping towards the northwest and is directed northeast-southwest ward. In the geological map produced by GSP, the contact of Kalam Quartz Diorite and Utror Volcanics has also been shown as faulted. This thrust fault has also the same orientation as that of Shandur Thrust. Both these faults are located about 12-14 km in the northwest of the project area.

6.4. EARTHQUAKE RECORD

6.4.1. GENERAL

Study of the earthquake record involved several activities:

- Investigation of the pre-instrumental or historical seismicity
- Examination of instrumentally recorded earthquake record
- Interpretative description of the Kashmir earthquake of October 8, 2005
- Analysis of the earthquake record
- Description of interpreted focal mechanisms

6.4.2. PRE-INSTRUMENTAL (HISTORICAL) SEISMICITY

Before the establishment of seismological observatories, which began at the beginning of 20th century, intensity data collected from the historical records was the only source of earthquake information. Historical Earthquake data is a general account of damage/ loss to life (human & animal) and property. The historical pre-instrument earthquake data has been collected from the description of the earthquakes given in the memoirs or records of travelers, historians and writers. Such earthquakes catalogues have been compiled by Oldham, 1893, Heukroth and Karim, 1970, Ambraseys et al. 1975 and Quittmeyer and Jacob, 1979 and presented in

Appendix-A. The historical earthquake data reflects that northern Pakistan, as a whole, has remained a house of prominent earthquakes. Taxila (25 A.D.) event is probably the most conspicuous one that changed style of building-construction out rightly. An important value of intensity data is that it establishes some understanding of the level of the damage that can be expected to occur in a given region.

The catalogue of historical earthquakes for this region is rather sparse and probably highly incomplete. Since the 1700's, the historical earthquake data for the northern areas of Pakistan are few and mainly concentrated on the centres of colonial administration. The important tremors for which damage data is available are as follows:

- Aristobulus of Cassandreia described that the first known historical account of seismicity of northern part of Pakistan in the fourth century B.C. He accompanied Alexander on his expedition to India, who pointed out that the country above the river Jhelum was subjected to earthquakes, which caused the ground to open up so much, that even the river beds were changed (Ambraseys et al., 1975).

- An important historical earthquake occurring in northern Pakistan was the destructive earthquake of 25 A.D., which ruined the city of Taxila, to which the intensity of IX-X has been assigned (Ambraseys et al., 1975). The effect of this earthquake still can be seen in the excavated remains of Jandial, Sirkap, and Dharmarajika. The building methods after this earthquake changed, including reduction in the height of buildings, improvements in masonry bracing density, and making the foundations more secure.

- On March 25, 1869, a large earthquake occurred in the Hindukush region, strongly felt at Kohat, Peshawar, Lahore, and at Khodjend and Tashkent, the shaking lasting 20 seconds;

- On May 22, 1871, a damaging shock was recorded at Gilgit with many aftershocks. This earthquake was strong enough to be felt as far as Meerut and Agra in India;

- On January 20, 1902, a large earthquake caused damage in the Chitral area and was felt widely in the Punjab and up to Simla;

- On July 8, 1909 an earthquake caused destruction in the region of Mankial and Kalam in the Swat valley where Lady Minot's Hospital was damaged and many houses collapsed, killing 10 people and cattle. Damage area extends to Dir, Karori and Alipurai and was felt in Gilgit, Besham, and to the north up to Tashkent; and

- The epicentral intensity of all these earthquakes is estimated to be not greater than VIII on the Modified Mercalli (MM) intensity scale.

6.4.3. INSTRUMENTAL SEISMICITY

The instrumental recording of earthquakes started in 1904 but very few seismic stations were established in the South Asian region until the 1960's. However, with the installation of high quality seismographs under the World Wide Standard Seismograph Network (WWSSN) established by the U.S. Coast and Geodetic Survey in 1960, the quality of earthquake recording in this region improved and resulted in a better understanding of the seismicity of Pakistan.

In Pakistan and most other parts of the world, the seismic record is too short and incomplete to develop a complete sample that is truly representative of the spatial and temporal distribution of shocks over a large period. Nevertheless, all the available information has been gathered for the period covering the last century, which was used to develop a satisfactory and safe assessment of seismic hazard for the project.

For this study, the instrumental record of earthquakes within about 300-km radius of the project was searched from available earthquake listing obtained mainly from:

- International Seismological Centre (ISC) England;
- National Earthquake Information Centre (NEIC) of the U.S. Geological Survey
- Pakistan Meteorological Department;
- PAEC Microseismic Network; and
- Tarbela Microseismic Network, WAPDA.

A composite catalogue of instrumentally recorded earthquakes was prepared by combining these earthquake listings. This is presented in chronological order showing:

- Origin time;
- Epicentral location;
- Depth of focus;
- Magnitude; and
- Data source.

In preparing this composite catalogue, more weight was given to the data listed in the ISC catalogue because data within this catalogue tends to be more accurate, being calculated with more data than is used in the other listings, and less likely to contain duplicates. Where available, body wave (m_b), surface wave (M_s) or local (M_L) magnitudes are also indicated. The source catalogues overlap considerably and both automatic and manual procedures that incorporate judgment about source catalogue reliability and priority were used to help eliminate duplicate entries from the combined listing.

During the present study, a composite list of seismic events that occurred in the project region and adjoining areas has been prepared. This composite list includes events within an area between latitudes: 33.5^0 and 37.5^0 and longitudes: 70^0 and 75^0. This composite catalogue of instrumentally recorded earthquakes for the project region is presented in Appendix-B.

The composite catalogue comprises 19,238 events of magnitude 3 and above covering a period up to December, 2018. The reporting agencies have given a variety of magnitudes viz: Body-wave magnitude (m_b), Surface-wave magnitude (M_S), Richter/Local magnitude (M_L) or Duration-magnitude (M_D) etc. Since, attenuation relationships are based on magnitude of given type, a single type must be selected. For data to be used in seismic hazard analysis, all the magnitudes were therefore converted to moment magnitude (M_W) by the following equations.

Conversion from M_S and m_b to M_W was achieved through latest equation suggested by Scordilis (2006):

$M_W = 0.67\ M_S + 2.07$ for $3.0 \le M_S \le 6.1$

$M_W = 0.99\ M_S + 0.08$ for $6.2 \le M_S \le 8.2$

$M_W = 0.85\ m_b + 1.03$ for $3.5 \le m_b \le 6.2$

For M_L up to 5.7, the value of M_L was taken equal to M_W as suggested by Idriss (1985) and supported by operators of local networks in Pakistan. Conversion of M_L to M_W beyond magnitude 5.7 was done by using the following equations suggested by Ambraseys and Bommer (1990) and Ambraseys and Bilham (2003):

$0.82\ (M_L) – 0.58\ (M_S) = 1.20$

$\text{Log Mo} = 19.09 + M_S$ for $M_S < 6.2$

$\text{Log Mo} = 15.94 + 1.5\ M_S$ for $M_S > 6.2$

$M_W = (2/3)\ \text{Log (Mo)} – 10.73$

Where m_b is body–wave magnitude, M_S is surface-wave magnitude, M_L is local magnitude, M_W is moment magnitude and Mo is seismic moment.

All available types of magnitudes in the catalogue were converted into a uniform magnitude-scale i.e. M_W (Moment magnitude) and given in Appendix-B. M_W represents area source rather than a point source and the same type of magnitude is mostly being used in the seismic hazard analysis.

6.4.4. KASHMIR EARTHQUAKE OF OCTOBER 08, 2005

During the wee hours of October 08, 2005, a devastating shallow focused earthquake with moment magnitude of Mw 7.6 occurred in the Pakistan's Kashmir Hazara Region. Its tremors were felt in a radius of over 1000 km with damages taking place in an area of 36000 sq km. More than 0.1 million people died and the rehabilitation of infrastructures damages are estimated to cost around five billion dollars. The Kashmir Hazara terrain is located on the NW margin of lesser Himalaya. The KHS is one of the bold tectonic scars which physically isolate this terrain from rest of the Himalaya. Other major tectonic features sculpturing this terrain in the shape of folds and faults are: Main Mantle Thrust (MMT), Main Boundary Thrust (MBT), Panjal Thrust (PT), Hazara Thrust (HT) and the Indus Valley Faults. All these mega structures are the abode of variable seismicity and generate earthquakes of low to high (damaging) magnitude. The seismic zones of the mega-crustal deformations in the Kashmir Hazara terrain, from where the earthquakes emanate, generally lies between 10 – 60 km surface depths. The earthquakes generated at this depth are categorized as shallow and are usually more hazardous. The earthquake resulted from the subduction of Indo-Pakistan plate beneath the Eurasian plate and it ruptured the southwest Jhelum Thrust (JT) fault. The fault was previously inferred to be as active in a region where the river incises directly into the Murree sandstones on the west side of the valley (footwall of JT), while it has abandoned large inset terraces along the east side (hanging wall of JT). The occurrence of Kashmir-Hazara earthquake confirms that the active Jhelum Thrust (JT) and Jhelum Fault (JF), in a region located well north of the Main Himalayan Frontal Thrust, accommodate roughly EW-oriented, present day shortening related to "zipper tectonics" within the part of the Kashmir Hazara Syntaxis (KHS). Maximum Modified Mercalli Intensity was X at Balakot, situated on the hanging wall side of the causative fault and the maximum ground motions in the same area were inferred to be 0.90 'g' from overturned vehicles in the direction parallel to the axis of valley. The earthquake was followed by a series of more than thousand aftershocks, hundreds of them exceeding magnitude 4.

This earthquake was caused by the movement due to rupture along a thrust fault named the "Balakot-Muzaffarabad-Bagh fault" which is a northern most branch of the Main Boundary Thrust (MBT) like Riasi Thrust, a main branch of the MBT in Kashmir. Ground ruptures and fresh landslides have been observed along this fault at many places near Muzaffarabad and Balakot. Teleseismic aftershock data and distribution of damage indicates that more than 120 km of this fault between Batagram and Bagh districts ruptured during the major earthquake.

The fault plane solution for the main shock given by Harvard Moment Tensor Solution shows a predominant thrust motion and its strike is compatible with the strike of the HFT.

6.4.5. ANALYSIS OF SEISMICITY

The spatial distribution of seismic events recorded in the project region and given in Appendix-B is plotted on **Figure** 6-5.

The distribution of observed seismicity on the seismicity map clearly shows that the project is located in a region of high seismicity. The concentration of seismicity in the northwest of the project area is from very highly active Hindukush seismic zone where intermediate to deep earthquakes are more predominant. About 80 % of total earthquakes listed in composite catalogue falls in this zone. Another concentration of earthquakes south of the project is related to seismically active Indus-Kohistan seismic zone and the Hazara-Kashmir Syntaxis where Kashmir earthquake of October 2005 occurred. The Nanga Parbat-Haramosh syntaxis east of the project area also shows high seismicity. The Jaglot Syncline area northeast of the project area, where Hamaran and Darel earthquakes occurred, also shows concentration of seismic activity. A number of small to moderated earthquakes are located around the project area indicating that project area is also seismically active.

The epicenters of three well-studied earthquakes of magnitude 5.9 or above have been recorded in Kohistan island arc east of the project area (Ambraseys, et al., 1975; Jackson & Yielding, 1983). These earthquakes are:

- Patan earthquake (28 December 1974); magnitude (Mb) 5.9; 90 km south of the site; close to the surface expression of MMT;
- Hamran earthquake (3 September 1972); magnitude (Mb) 6.3; 55 km northeast of the site; within the Kohistan Island Arc; and
- Darel earthquake (12 September 1981); magnitude (Mb) 6.1; 20 km northeast of the site; within the Kohistan Island Arc.

The locations of these events are shown in **Figure** 6-6. While the Patan earthquake (28.12.1974) is located close to the surface expression of the MMT, the Hamran earthquake of 3.9.1972 and Darel earthquake of 12.9.1981 occurred within the Kohistan Island Arc, east of the project site. This shows that active tectonic features are present within or below the Kohistan island arc.

Both spatial and temporal clustering or concentrations of seismic activity have been observed in the project region and is distributed over a large area and has not yet been associated with any known tectonic structure in the area. Previously, the cluster of seismicity north of Darel valley has been associated with the Jaglot syncline but recent geological maps have not shown this syncline as fault associated. Importantly, however, the results of new mapping have shown that the boundaries or contacts of the main lithologic units in Kohistan are faulted. In this respect, it is pointed out that the Darel earthquake occurred close to the northern boundary of the Chilas Complex.

6.4.6. FOCAL DEPTH AND MECHANISM

The reported focal depths of earthquakes included in the composite list range from 0 km to more than 300 km. In general, the deeper events are related to Hindukush seismic zone whereas other areas have focal depths less than 100 km. In the Kohistan Island Arc, the depths of most of the earthquakes are generally shallower than 70 km and nominal depth of 33 km is mentioned for majority of these events in all the earthquake catalogues, due to the low-resolution in depth calculation in the absence of a proper recording network in this region.

It is important to note that majority of the earthquakes in Kohistan island arc area having magnitude 5 to 6 are located up to about 60 km depth while majority of the events with magnitude greater than 6 remained concentrated in the focal depth less than 50 km. The focal depth of October 08, 2005 earthquake (Mw=7.6) which occurred in Himalayan Fold Belt south of Kohistan island arc was less than 26 km.

The available fault plane solutions of earthquakes in this region show predominantly thrust mechanism. Jackson and Yielding (1983) have reanalysed the phase data of three prominent earthquakes described above. Fault plane solutions for these earthquakes are presented in **Figure** 6-6. The fault plane solution of Kashmir earthquake of October 08, 2005 is also shown on **Figure** 6-6. Fault plane solutions for these earthquakes all show a thrust source mechanism in keeping with the tectonic model described above involving subduction and underthrusting of the Indian Plate beneath the Eurasian Plate. The northeast to north-northeast dipping planes of these fault plane solutions are possibly representing the causative rupture which is in conformity with the observed northward dips of the major thrusts of the region.

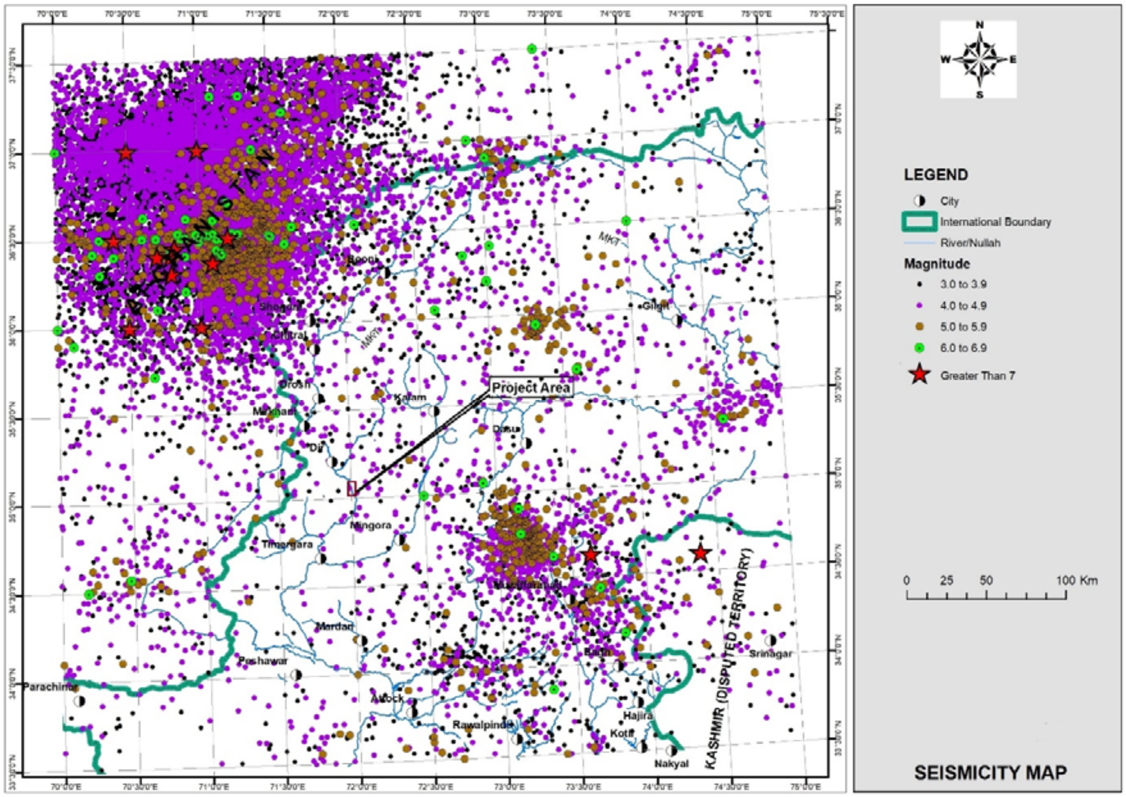

Figure 6-5: Seismicity Map of the Project Region

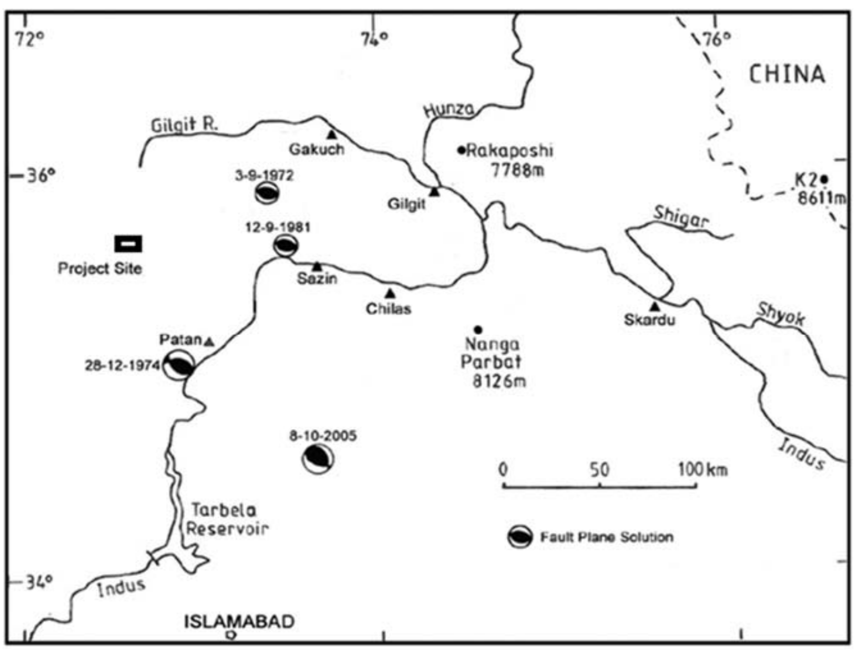

Figure 6-6: Fault Plane Solutions of Significant Events of Kohistan Region.

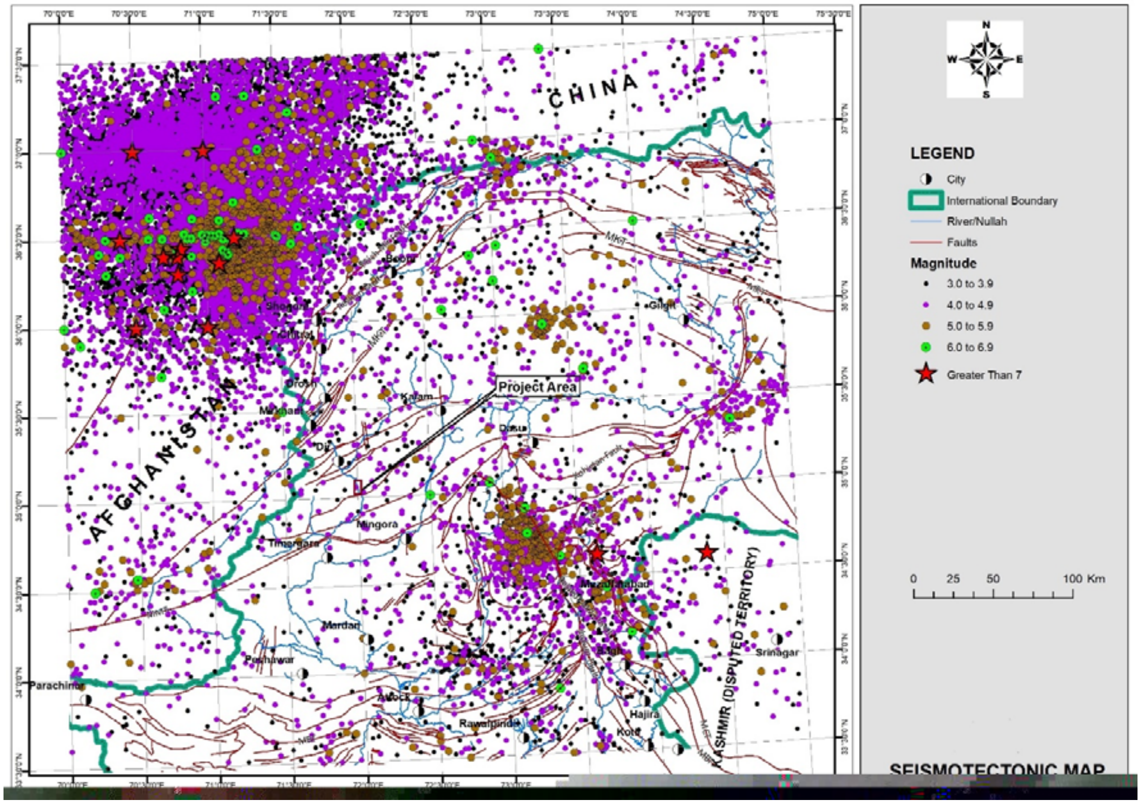

Figure 6-7: Seismotectonic Map of Project Region.

6.5. SEISMOTECTONIC ANALYSIS

From the available tectonic and seismic data of the project region, an understanding about the seismotectonic set up of the project can be developed. A seismotectonic map of the Project region showing active faults and recorded seismicity is shown in **Figure** 6-7.

6.5.1. IDENTIFICATION AND DESCRIPTION OF SEISMIC SOURCES

The available seismic and tectonic data provides several evidences of the seismic activity along the major faults i.e. Main Mantle Thrust (MMT) and Kohistan Fault passing south of the site and Main Karakoram Thrust (MKT) passing northwest of the project.

Based on this understanding of the seismotectonic setting and faults of the area, the seismogenic features which may significantly influence the seismic hazard for Artistic-I Hydropower Project are:

- Main Karakoram Thrust (MKT),
- Kohistan Fault,
- Main Mantle Thrust (MMT), and

- Shandur Thrust

Main Karakorum Thrust (MKT): This is the major regional fault representing the suture zone between the two colliding plates. This fault represents the northern boundary of the Kohistan island arc and runs eastward to join Indus suture zone in upper Himalayas and terminates at its junction with Karakoram fault. In the Chitral and Gilgit area, the rocks of Karakoram Batholith are thrusted over the rocks of Kohistan Batholith along MKT.

Kohistan Fault: On the Geological Map of NWFP (2006) published by the Geological Survey of Pakistan, the contact between the Kamila amphibolies and the Satpat ultamafics to the south of Dasu are shown as the Kohistan fault. Along this fault, the rocks of the Kamila complex are thrust over the Satpat complex rocks.

Main Mantle Thrust: Main Mantle Thrust (MMT) is a northward dipping regional thrust, which separates the Indian Plate from the Kohistan Island Arc. It extends from Khar (Bajaur Agency) in the west to the north of Naran (Kaghan Valley) in the east where it takes a northeast ward bend towards the east of Bunji and gets truncated by the Raikot Fault. The thrust inclines steeply near the surface; however, this inclination is believed to decrease considerably with depth likewise as interpreted for other local thrust faults of the region.

The MMT is almost aligned sub-parallel to the Main Karakoram Thrust in the north and to the Main Boundary Thrust in the south except in the Hazara-Kashmir Syntaxial area, where the MMT remains unaffected and continues its journey in a northeast direction to join the Raikot fault. In the east it is abruptly juxtaposed against the Nanga-Parbat-Haramosh Massif, while in the west it meets the Main Karakoram Thrust in Afghanistan. Before joining the Main Karakoram Thrust, it is offset by northwest and northeast trending strike slip faults near Khwaza Khela and Besham. The Patan earthquake of December 28, 1974, having magnitude 6.2, is thought to have been associated with movement on the MMT.

The Raikot fault zone and associated structures exhibit remarkable neotectonic features including fault scarps and exposures where Nanga Parbat gneisses overlie Pleistocene tillites. The recent earthquakes of November 2002 and January 2003 have been attributed to movement on this tectonic feature.

On the basis of the recorded seismicity and observed neotectonic features both the Main Mantle Thrust and Raikot fault are considered seismically active.

Shandur Thrust: In the vicinity of the project area, a regional fault named as Shandur Thrust is present about 12-14 km in the north of the project area. This thrust fault has been marked by the Utror Volcanics group of rocks in southeast while by Kalam Quartz Diorite associated with meta sediments in the northwest. The fault is dipping towards the northwest and is directed northeast-southwest ward. In the geological map produced by GSP, the contact of Kalam Quartz Diorite and Utror Volcanics has also been shown as faulted. This thrust fault has also the same orientation as that of Shandur Thrust. Both these faults are located about 12-14 km in the northwest of the project area. The inclusion of these faults in the hazard analysis would cover the hazard associated with near-site faults, as lot of observed seismicity in this area could be associated with the fault.

6.6. SEISMIC HAZARD ANALYSIS

For seismic hazard evaluation, both probabilistic and deterministic methods were applied.

6.6.1. PROBABILISTIC PROCEDURE

6.6.1.1. PSHA METHODOLOGY

In probabilistic seismic hazard assessment (PSHA), the seismic activity of seismic source (line or area) is specified by a recurrence relationship, defining the cumulative number of events per year versus the magnitude. Distribution of earthquake is assumed to be uniform within the source zone and independent of time.

The principle of the analysis, first developed by Cornell (1968) and later refined by various researchers, is to evaluate at the site of interest the probability of exceedance of a ground motion parameter (e.g. acceleration) due to the occurrence of a strong event around the site. This approach combines the probability of exceedance of the earthquake size (recurrence relationship), and probability on the distance from the epicentre to the site.

Each seismic source zone is split into elementary zones at a certain distance from the site. Integration is carried out within each zone by summing the effects of the various elementary source zones taking into account the attenuation effect with distance. Total hazard is finally obtained by adding the influence of various sources. The results are expressed in terms of a ground motion parameter associated with return period (return period is the inverse of the annual frequency of exceedance of a given level of ground motion).

The seismic hazard model used in the present analysis was developed based on findings of the seismotectonic synthesis. The seismic hazard model relies upon the concept of seismotectonic zones and does not include linear or discrete fault sources. Each seismic source zone is defined as a zone with homogenous seismic and tectonic features, inferred from geological, tectonic and seismic data. These zones are first defined, and then a maximum earthquake and an earthquake recurrence equation are elaborated for each of these seismic source zones.

The seismic parameters attached to the various seismic source zones are: a recurrence relationship relating the number of events for a specific period of time to the magnitude; the maximum earthquake giving an upper bound of potential magnitude in the zone; and an attenuation relationship representing the decrease of acceleration with distance.

The probabilistic seismic hazard evaluation requires a detailed analysis of distribution of observed seismic data to the seismic sources, determination of b-value and activity rate of each seismic source and assigning maximum magnitude potential to each seismic source.

6.6.1.2. SOURCE MODELING – AREA SOURCES

For the definition of seismic sources, either line (i.e. fault) or area sources can be used for source modelling. Because of uncertainty in the epicentre's location, it is not possible to relate the recorded earthquakes to the fault sources and to develop recurrence relationship for each fault and use them as exponential model. The project region was therefore divided into five seismic area source zones (area sources) based on their homogeneous tectonic and seismic characteristics, keeping in view the geology, tectonics, seismicity and fault plane solutions of each area source zone. These seismic area source zones in the northern part of Pakistan are shown in **Figure** 6-8.

Each of these area sources was assigned a maximum magnitude based on recorded seismicity and potential of the faults within the zone and a minimum magnitude based on threshold magnitude observed in the magnitude-frequency curve for the zone. As the shallow earthquakes are of more concern to seismic hazard, the minimum depth of the earthquakes is taken as 5 km for all area sources except for deep Hindukush zone where minimum depth was taken as 80 km. The source zone parameters used in probabilistic hazard analysis are given in **Table** 6-1.

Table 6-1: Seismic Area Source Zones Parameters for Probabilistic Analysis

Zone No.	Seismic Area Source Zone	No. of Earthquakes above Min. Magnitude	Minimum Magnitude Mw	Activity Rate /Year	b-Value	Maximum Magnitude Mw
1	Hindukush	8612	4.0	148.48	1.06	8.0
2	Karakoram	232	4.0	3.655	1.03	7.5
3	Kohistan	594	4.2	10.24	1.08	7.5
4	Eastern Himalayas	431	4.0	7.431	1.13	8.0
5	Western Himalayas	373	4.0	6.431	1.28	7.0

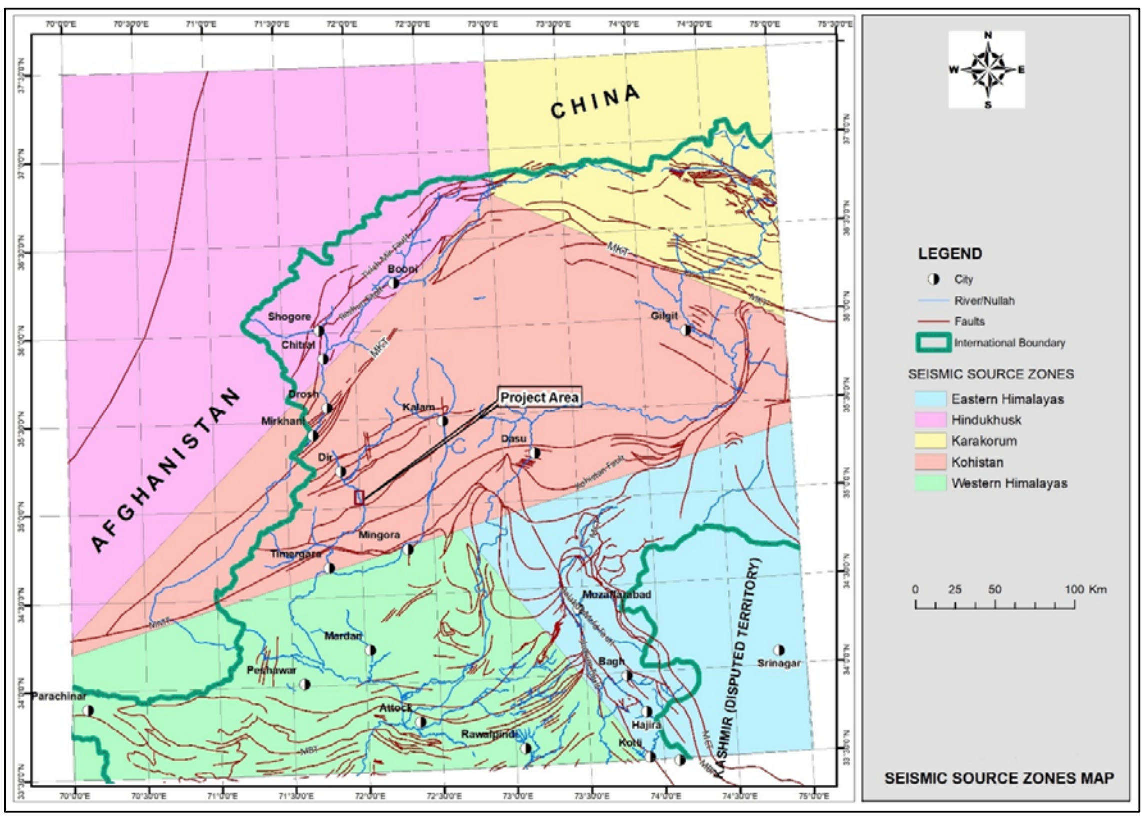

Figure 6-8: Seismic Area Source Zones used for Probabilistic Analysis.

6.6.1.3. Earthquake Recurrence Model

A general equation that describes earthquake recurrence may be expressed as follows:

$$N(m) = f(m, t) \qquad (1)$$

Where N (m) is the number of earthquakes with magnitude equal to or greater than m, and t is time period.

The simplest form of equation (1) that has been used in most engineering applications is the well-known Richter's law which states that the cumulated number of earthquakes occurred in a given period of time can be approximated by the relationship

$$\text{Log } N(m) = a - b\,m \qquad (2)$$

Equation (2) assumes spatial and temporal independence of all earthquakes, i.e. it has the properties of a Poisson model. Coefficients 'a' and 'b' can be derived from seismic data related to the source of interest. Coefficient 'a' is related to the total number of events occurred in the source zone and depends on its area, while coefficient 'b' represents the coefficient of proportionality between log N (m) and the magnitude.

The composite catalogue of earthquakes prepared for the Project region provided the necessary database for the computation of b-value for each seismic area source zone.

The composite earthquake list contains limited number of earthquakes prior to 1960 and only few of these earthquakes have been assigned magnitude values. Due to installation of WWSSN, the earthquake recording in this region improved and a better and complete recording of earthquake data are available after 1960. A basic assumption of seismic hazard methodology is that earthquake sources are independent. Thus, catalogues that are used to estimate future seismic activity must be free of dependent events such as foreshocks and aftershocks. To the extent possible such events were also eliminated manually, as there are insufficient data to apply rigorous procedures such as that of Gardner and Knopoff (1974) to eliminate foreshocks and aftershocks from the composite earthquake catalogue.

The completeness analysis of the overall data for the region showed that earthquake data around magnitude M_w=4.0 is complete after 1960. The converted moment magnitude for the period between 1961 and 2018 was therefore used in the PSHA after excluding the aftershocks. A separate list of earthquakes occurring in each area source zone was prepared through GIS software and magnitude-frequency curves were made for each seismic area source. The b-value for each seismic area source zone was calculated using linear regression through least square method. The minimum magnitude for each area source zone was selected from the magnitude-frequency curve based on completeness checks suggested by Woeffner and Weimer (2005).

The b–values, minimum magnitude and the activity rates for the five seismic area source zones used in the probabilistic analysis are shown in **Table** 6-1.

6.6.1.4. MAXIMUM MAGNITUDE

To each seismic area source zone, a maximum magnitude potential was assigned based on the maximum observed seismicity in the historical seismic record and enhancing by 0.5 magnitude the maximum observed magnitude in the instrumental seismic record for that area seismic source zone or determining the maximum magnitude of the longest active fault in the area using Well & Coppersmith equation (1994). The maximum potential magnitude used for each seismic area source zone is given in **Table** 6-1.

6.6.1.5. ATTENUATION RELATIONSHIPS

Because of lack of sufficient strong–motion data covering a larger range of magnitudes and distances, attenuation relationships for the South Asian Region cannot be developed. A number of attenuation equations have been developed from strong motion data collected in other parts of the world. As shallow earthquakes are of more concern for hazard analysis of Artistic-I hydropower project, attenuation equations developed for such conditions were considered for use in the hazard analysis for all seismic area sources except deep Hindukush seismic source. For probabilistic hazard analysis, the latest available NGA equations developed under Pacific Earthquake Engineering Research (PEER) Centre, USA by Abrahamson and Silva (2008), Boore & Atkinson (2008) and Campbell & Bozorgnia (2008) were used as these equations are valid for tectonically active regions with shallow crustal faulting worldwide. For Hindukush area source, Youngs et al. (1997) attenuation equation applicable for subduction zones was used.

6.6.1.6. RESULTS OF PSHA

The probabilistic seismic hazard analysis was carried out using EZ-FRISK software developed by Fugro USA Land Inc. All the parameters defined in **Table** 6-1 were incorporated in the model. The mean total hazard curve was obtained by giving equal weighting to all the attenuation equations used. The total hazard curve obtained for the weir site is shown in **Figure** 6-9, where dense gravelly soil foundation condition (V_{S30}=700 m/sec) is present. The total hazard curve obtained for the powerhouse site is shown in **Figure** 6-10, where hard rock foundation condition (V_{S30}=1500 m/sec) is present. The mean total hazard curves show the annual frequency of exceedance (inverse of return period) of the peak horizontal ground acceleration expected at the project sites. The major contribution to the total hazard is from

Kohistan and Hindukush seismic area sources. The results of PSHA obtained for the weir site area are summarized in **Table** 6-2 for dense gravelly soil foundation condition with V_{S30}=700 m/sec, which is the expected foundation condition at the weir site. The results of PSHA obtained for the powerhouse site area are summarized in **Table** 6-3 for hard rock foundation condition with V_{S30}=1500 m/sec, which is the expected foundation condition at the powerhouse site.

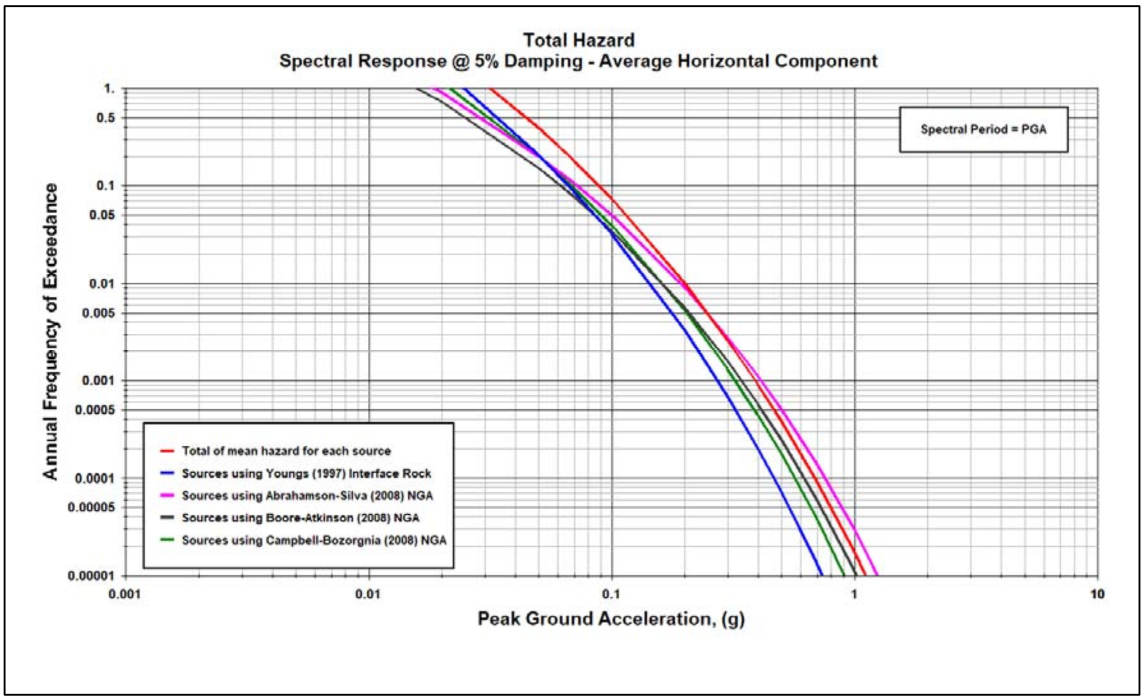

Figure 6-9: Total Seismic Hazard Curve for Project Site for Weir Site (Dense Soil foundation condition).

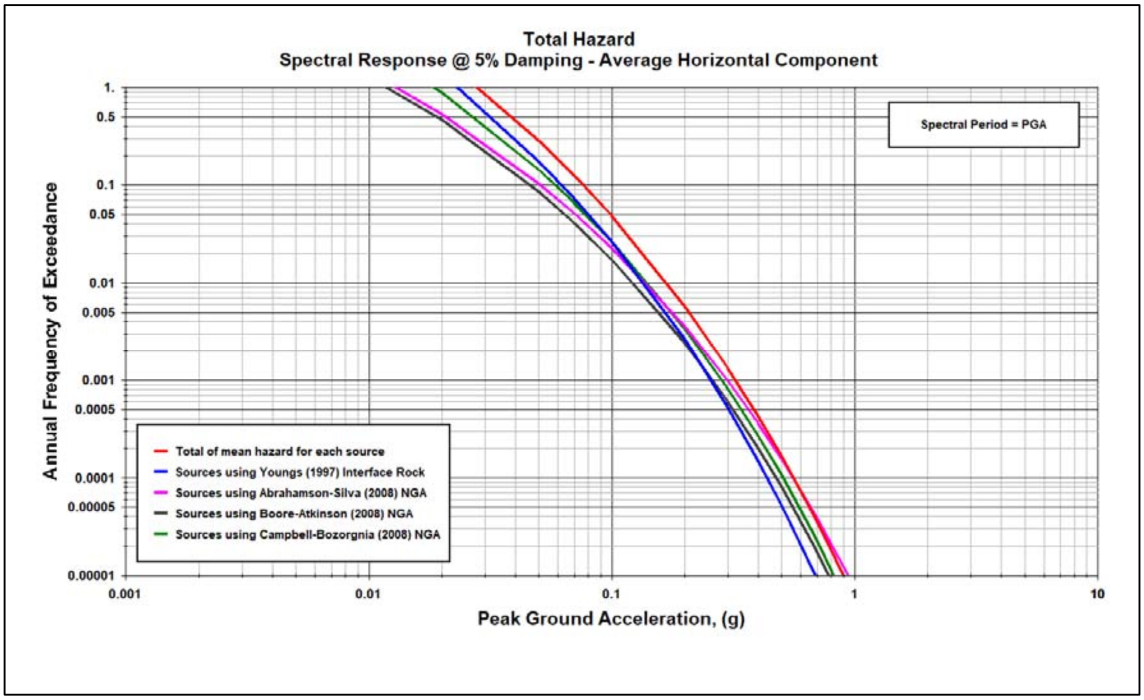

Figure 6-10: Total Seismic Hazard Curve for Powerhouse Site (for hard rock foundation condition).

Table 6-2: Peak Ground Acceleration for Different Return Periods obtained through PSHA for Weir Site (Dense Soil)

Annual Frequency of Exceedance	Return Period (years)	Peak Ground Acceleration (g)*	
0.007	145	0.22	OBE
0.002	475	0.32	DBE
0.001	975	0.39	MDE
0.00033	3000	0.52	
0.0001	10000	0.68	

* PGA for dense gravelly soil foundation condition (V_{S30}=700 m/sec)

Table 6-3: Peak Ground Acceleration for Different Return Periods obtained through PSHA for Powerhouse Site (Hard Rock)

Annual Frequency of Exceedance	Return Period (years)	Peak Ground Acceleration (g)*	
0.007	145	0.19	OBE
0.002	475	0.26	DBE
0.001	975	0.32	MDE
0.00033	3000	0.42	
0.0001	10000	0.56	

* PGA for hard rock foundation condition (V_{S30}=1500 m/sec)

6.6.2. Deterministic Procedure

In the deterministic procedure, critical seismogenic sources (active or potentially active faults) that represent a threat to the project are identified and a maximum magnitude is assigned to each of these faults.

The capability of the faults is ascertained through observation of historical and instrumental seismic data and geological criteria, such as rupture length – magnitude relationship or fault movement – magnitude relationship.

The maximum seismic design parameter is then obtained by considering the most severe combination of maximum magnitude and minimum distance to the project site, independently of the return period.

The main tectonic features around the Project site which could be controlling the maximum earthquake hazard are as follows:

- Main Karakoram Thrust (MKT),
- Kohistan Fault,
- Main Mantle Thrust (MMT), and
- Shandur Thrust

Empirical correlations have been developed between maximum potential of a fault and key fault parameters like rupture length, fault area, fault displacement and slip rate. Out of these fault parameters, only fault lengths are known with sufficient accuracy. For the faults around the site, the half rupture length of the faults has been taken for determination of maximum magnitude potential. The maximum earthquake magnitude (in moment magnitude M_W) of each of the fault was calculated using Wells & Coppersmith (1994), Nowroozi (1985) and Slemmons et al. (1982) relationships between fault rupture length and magnitude and is given in **Table** 6-4 below.

Table 6-4: Critical Faults and Their Maximum Earthquake Potential

Tectonic Feature	Total Fault Length (km)	Maximum Magnitude Potential (M_W)			Selected Maximum magnitude M_W
		Wells & Coppersmith (1994)	Nowroozi (1985)	Slemmons et al. (1982)	
Main Karakoram Thrust (MKT)	200	7.5	7.5	7.6	7.5
Kohistan Fault	150	7.3	7.3	7.4	7.3
Main Mantle Thrust (MMT)	200	7.5	7.5	7.6	7.5
Shandur Thrust	90	7.0	6.9	7.0	7.0

The peak horizontal ground acceleration at the site caused by the earthquake of maximum magnitude occurring at the closest distance to fault was then calculated by using the latest attenuation relationships developed by various researchers from strong motion data from USA and worldwide. As shallow crustal earthquakes are more important for the assessment of seismic hazard to the project, therefore, equations applicable for shallow crustal earthquakes were employed. For the deterministic analysis, the same three NGA equations used for probabilistic analysis were used. The NGA equations are preferable for the evaluation of seismic hazard in the near field as these are based on a broad spectrum of data recorded in the near field. For all the seismic sources, thrust rupture mechanism have been assumed. The 50-percentile (median) values of the peak horizontal ground acceleration (PGA) were obtained by three attenuation relationships developed for tectonically similar environments are given in **Table** 6-5 for hard rock foundation condition with shear wave velocity of V_{s30}=1500 m/sec and are given in **Table** 6-6 for dense gravelly soil foundation condition with shear wave velocity of V_{s30}=700 m/sec.

Table 6-5: Peak Horizontal Ground Acceleration (PGA) for Hard Rock Condition

Tectonic Feature	Maxi-mum Magni-tude (M_W)	Closest Distance to Fault (km)	Median Peak Horizontal Acceleration (g)			
			Abrahamson & Silva (2008)	Boore & Atkinson (2008)	Campbell & Bozorgnia (2008)	Average PGA
Main Karakoram Thrust (MKT)	7.5	42	0.09	0.12	0.11	0.11
Kohistan Fault	7.3	40	0.13	0.16	0.15	0.15
Main Mantle Thrust (MMT)	7.5	43	0.12	0.16	0.15	0.14
Shandur Thrust	7.0	12	0.20	0.22	0.34	0.25

Table 6-6: Peak Horizontal Ground Acceleration (PGA) for Dense Gravelly Soil Foundation Condition

Tectonic Feature	Maxi-mum Magni-tude (M_W)	Closest Distance to Fault (km)	Median Peak Horizontal Acceleration (g)			
			Abrahamson & Silva (2008)	Boore & Atkinson (2008)	Campbell & Bozorgnia (2008)	Average PGA
Main Karakoram Thrust (MKT)	7.5	42	0.15	0.13	0.18	0.15
Kohistan Fault	7.3	40	0.18	0.17	0.23	0.19
Main Mantle Thrust (MMT)	7.5	43	0.17	0.17	0.22	0.19

Tectonic Feature	Maxi-mum Magni-tude (M_W)	Closest Distance to Fault (km)	Median Peak Horizontal Acceleration (g)			
			Abrahamson & Silva (2008)	Boore & Atkinson (2008)	Campbell & Bozorgnia (2008)	Average PGA
Shandur Thrust	7.0	12	0.29	0.24	0.42	0.32

6.7. SELECTION OF SEISMIC DESIGN PARAMETERS

6.7.1. DEFINITIONS

According to the ER 1110-2-1806 - Earthquake Design and Evaluation for Civil Works Projects, the definitions of design earthquakes are as follows.

6.7.1.1. 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. Since a project site may be affected by earthquakes generated by various sources, each with its own fault mechanism, maximum earthquake magnitude, and distance from the site, multiple MCE’s may be defined for the site, each with its own characteristic ground-motion parameters and spectral shape. The MCE is evaluated using DSHA methods informed by results from a PSHA. Since different sources may result in differing spectral characteristics, selection of “maximum” ground motion parameters may need to consider different sources and magnitude events to represent the full range of possible maximum loadings e.g., peak ground acceleration from one source may be higher than from another, but reversed for 1s spectral acceleration values. Therefore, both sources may need to be considered in analysis to assess the full range of potential “maximum” loadings. There is no return period for the MCE.

6.7.1.2. 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 severe damage or economic loss may be tolerated. For critical features, the MDE is the same as the MCE. For all other features, the minimum MDE is an event with a 10% probability of exceedance in 100 years (average return period of 975 years) assessed using a PSHA informed by the results of a site-specific DSHA. A shorter or longer return period for non-critical features can be justified by the project team based on the Hazard Potential Classification for Civil Works Projects in **Annexure-C2, Volume VII**. A project with a low hazard potential classification may consider return periods less than 975 years, while projects with a significant or high hazard potential classification may consider longer return periods. The MDE can be characterized as a deterministic or probabilistic event.

6.7.1.3. 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 (average return period of 145 years) assessed using a PSHA informed by the results of a site-specific DSHA. The associated performance requirement is that the project functions with little or no damage and without interruption of function. 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.

6.7.1.4. DESIGN EARTHQUAKE FOR APPURTENANT STRUCTURES (DBE)

As a minimum, appurtenant structures (penstocks, powerhouses, intake structures, rock caverns etc.) should be designed in accordance with the applicable seismic code for buildings or other structures. Consequently, the site -specific design earthquake ground motion should have a return period equal to that specified in the seismic building codes, which is typically 475 years. The same ground motion is recommended Weiland (2011) and by Building Code of Pakistan Seismic Provisions (2007).

6.7.2. SEISMIC DESIGN PARAMETERS

Design seismic parameters for different project structures are selected on the basis of the results provided by probabilistic and deterministic approaches, and in compliance with the recommendations of ER 1110-2-1806 - Earthquake Design and Evaluation for Civil Works Projects.

6.7.2.1. WEIR

As per ER 1110-2-1806 - Earthquake Design and Evaluation for Civil Works Projects, Hazard Potential Classification for Civil Works Projects in **Annexure-C2, Volume VII**, the project weir falls in Low Hazard Potential class.

It is expected that failure of the project weirs would not present a great social hazard, therefore the designer can choose a Maximum Design Earthquake (MDE) acceleration lower than MCE (which is equivalent to 10,000 years return period earthquake). ER 1110-2-1806 - Earthquake Design and Evaluation for Civil Works Projects recommends to adopt 975 years or less return period ground motion for Low Hazard Potential Hydraulic structures. As the project weir is categorized as Low Hazard Potential Hydraulic structure, therefore the recommended ground motion for MDE is 0.39g (corresponding to a return period of 975 years) based on results of probabilistic analysis and is 0.32g based on results of deterministic analysis for weir founded on dense soil foundation condition. The MDE design response spectra for design of weir with dense soil foundation condition is shown in **Figure** 6-11.

The OBE acceleration for the weir structure is selected from the results of the probabilistic analysis which is presented in **Figure** 6-9 in terms of annual frequency of exceedance of different levels of ground motion. 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 acceleration corresponding to 50% probability of exceedance in 100 years (i.e. a return period of 145 years) may be adopted for design of weir structure of the project for which PGA value is 0.22g for dense soil foundation condition. The OBE design response spectra for design of weir with dense soil foundation condition is shown in **Figure** 6-12.

6.7.2.2. POWERHOUSE

For the design of powerhouse structures, ground motion having 475 years return period is recommended, as also applied in Building Code of Pakistan Seismic Provisions (2007). The recommended ground motion for design earthquake for powerhouse structures is 0.26g as the foundation of powerhouse is expected to be placed on hard rock with V_{s30} equal to 1500 m/sec.

The DBE design response spectra for design of powerhouse with hard rock foundation condition is shown in **Figure** 6-13.

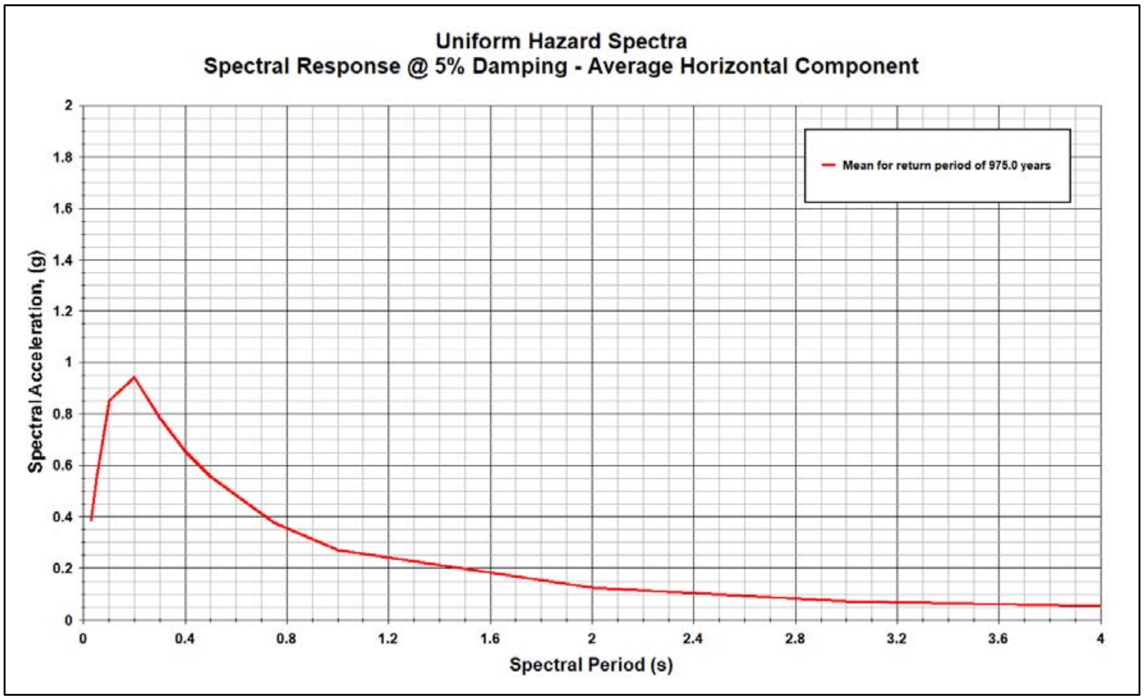

Figure 6-11: MDE Uniform Hazard Spectra obtained through PSHA for Weir Site with dense soil foundation condition

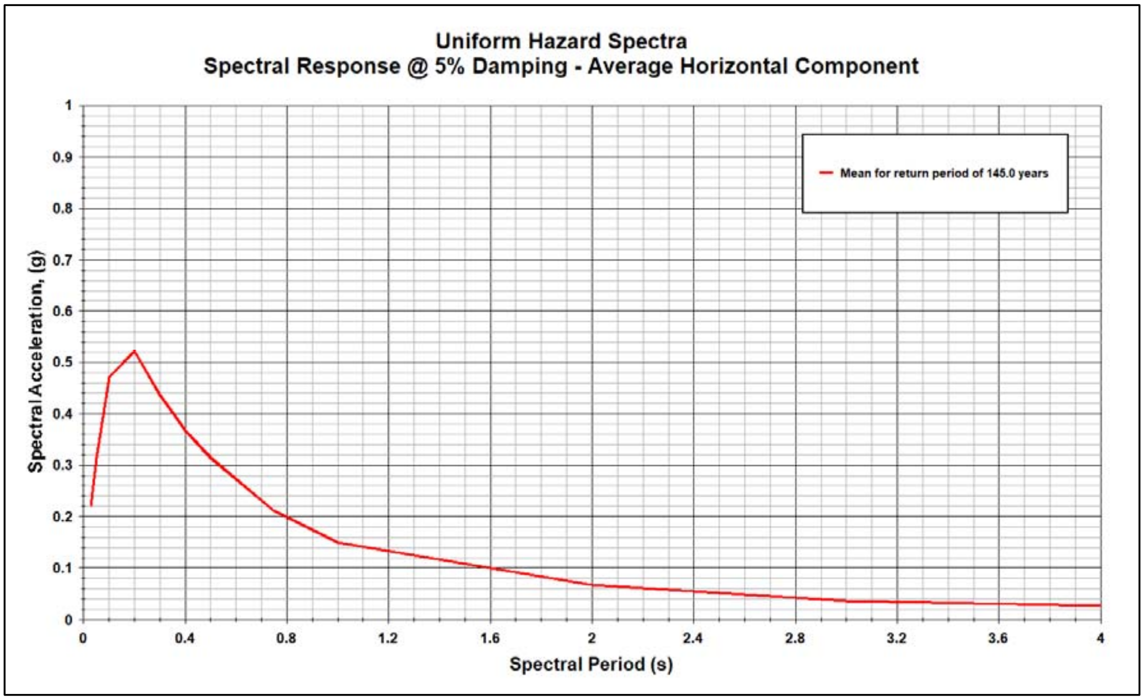

Figure 6-12: OBE Uniform Hazard Spectra obtained through PSHA for Weir Site with dense soil foundation condition

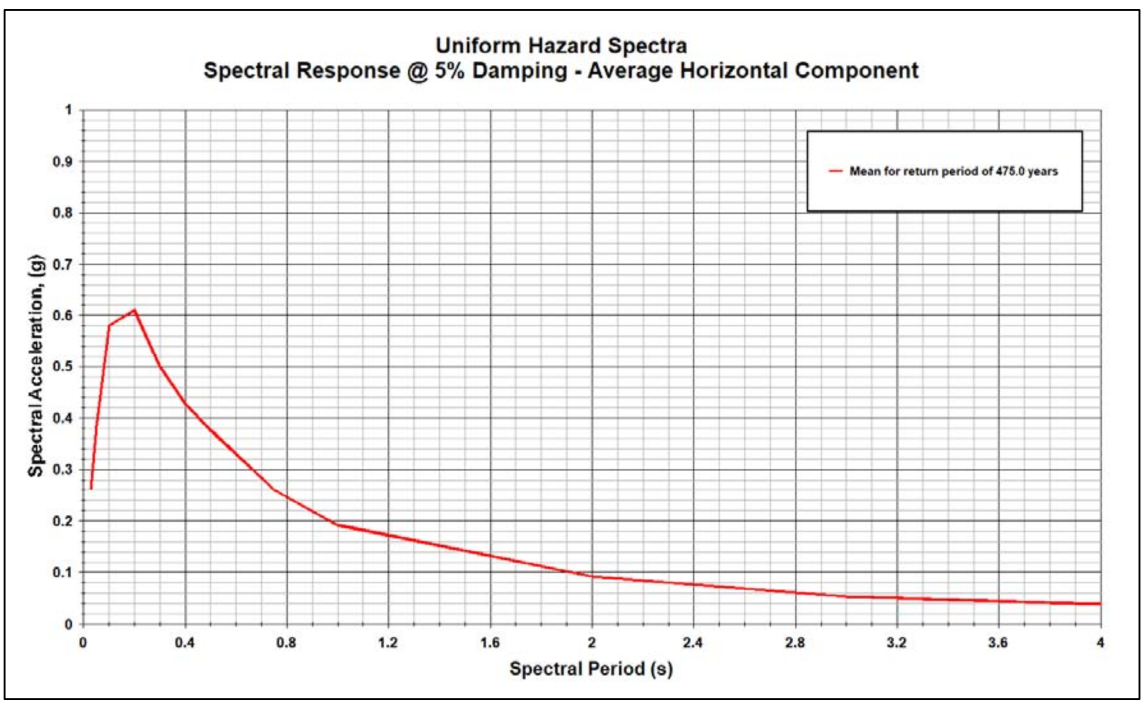

Figure 6-13: DBE Uniform Hazard Spectra obtained through PSHA for Powerhouse Site with hard rock foundation condition

6.7.2.3. HEADRACE TUNNEL

The headrace tunnel will pass through the rock formations. For the design of headrace tunnel structures, ground motion having 475 years return period is recommended by Weiland (2011). The recommended ground motion for design earthquake for critical structures of the headrace tunnel is 0.26g (for hard rock foundation condition with V_{s30} equal to 1500 m/sec). However, where there is no life hazard and economic loss is acceptable, PGA of 0.19g may be adopted with the consent of the owner of the project.

The DBE design response spectra for design of headrace tunnel passing through hard rock is shown in **Figure** 6-14.

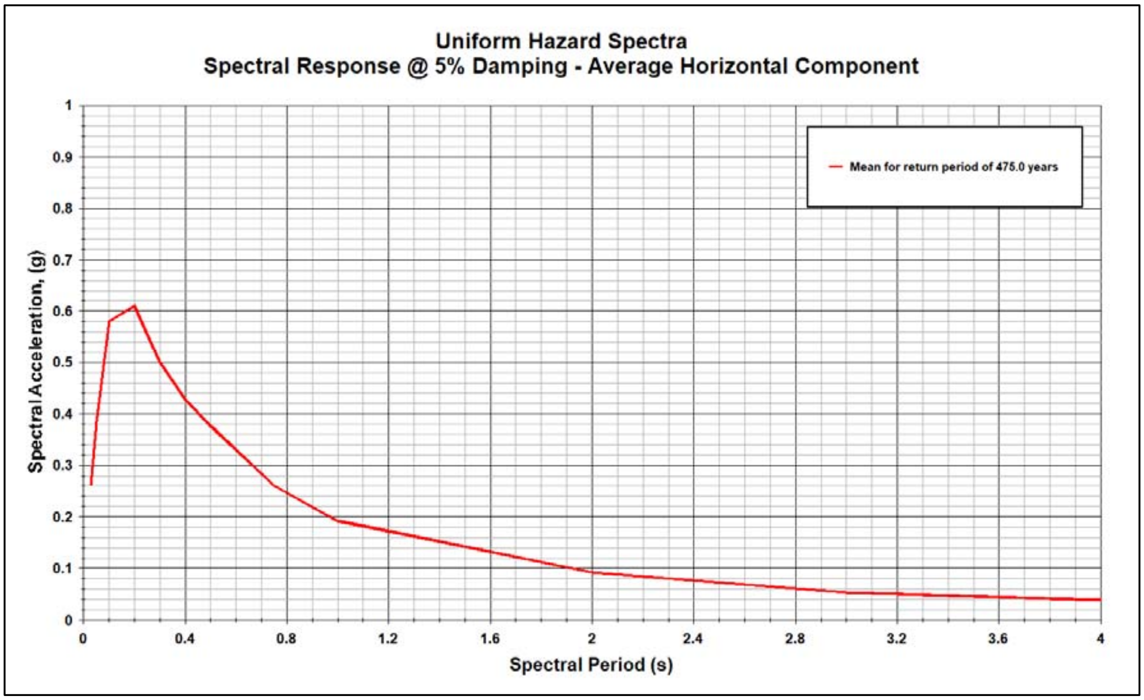

Figure 6-14: DBE Uniform Hazard Spectra obtained through PSHA for Headrace Tunnel

6.8. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations regarding study of seismotectonic setting of Artistic-I Hydropower Project and the resulting seismic design parameters are as follows:

a) The project is located in the Kohistan Island Arc which is sandwiched between Indian and the Eurasian tectonic plates and very active seismically.

b) A number of moderate sized earthquakes have been recorded in Kohistan Island Arc during the last 100 years.

c) A number of active faults are present around the project site.

d) The main seismotectonic features considered critical for the seismic hazard for the Project are as follows:

- Main Karakoram Thrust (MKT),
- Kohistan Fault,
- Main Mantle Thrust (MMT), and
- Shandur Fault

e) Both probabilistic and deterministic seismic hazard evaluations were made to determine the expected ground motions at the project site.

f) The recommended horizontal Peak Ground Acceleration (PGA) associated with Operating Basis Earthquake (OBE) for weir structure is 0.22g.

g) The recommended horizontal Peak Ground Acceleration (PGA) associated with Maximum Design Earthquake (MDE) for weir is 0.39g based on probabilistic analysis and 0.32g based on deterministic analysis, as the weir is categorized as Low Hazard Potential Hazard structure.

h) The recommended Design Basis Earthquake (DBE) for powerhouse and critical structures of headrace tunnel is 0.26g.

i) The recommended horizontal Peak Ground Acceleration (PGA) for all other project structures is 0.22g if resting on soil foundation and is 0.19g if placed on rock foundation or within rockmass.

j) Uniform hazard spectra for MDE, OBE and DBE associated ground motions are given for use in the seismic resistant design of the project structures.

k) It is recommended that in-situ shear wave velocity profile of the subsurface material at weir and powerhouse sites may be obtained for authenticating the assumption of V_{s30}.

l) For safety monitoring purpose Strong Motion Accelerographs may be installed at the Weir and Powerhouse sites.

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CHAPTER

7

PROJECT LAYOUT ALTERNATIVES AND OPTIMIZATION STUDIES

CHAPTER 7

PROJECT LAYOUT ALTERNATIVES & DESIGN OPTIMIZATION STUDIES

7.1 INTRODUCTION

7.1.1 GENERAL

Pakistan has been facing a chronic shortage of energy. With the passage of time, the gap between demand and supply from the national power stations is widening. Water and Power Development Authority (WAPDA) has been trying hard to narrow the gap, through installation of thermal power stations (with steam and gas turbines as well as combined cycle units). The power generation through these stations is not only expensive but also is not convenient to rely upon, due to ever increasing cost of oil and depleting resources. Water is the primary source of energy in Pakistan. The shortage of energy can be minimized by exploring small and medium hydel projects in Khyber Pakhtunkhwa Province.

Raw hydropower sites identified by Pakhtunkhwa Energy Development Organization (PEDO) in Khyber Pakhtunkhwa Province needs to be explored in detail. In this regard, PEDO under Government of Pakistan (GOP) policy is encouraging the private investors, to develop infrastructure and hydropower projects in the province.

In view of the above, PEDO has entered into an agreement with M/s Artistic Milliners (Pvt) Ltd, Karachi to develop Artistic-I HPP Raw Site at Panjkora River, Sahib Abad in District Upper Dir of northern part of Khyber Pakhtunkhwa Province, Pakistan.

M/s Artistic Milliners (Pvt) Ltd., Karachi has entered into an agreement with JV of M/s BAK Consulting Engineers, Peshawar and M/s DOLSAR Engineering Inc. Co. of Turkey to provide consultancy services for carrying out Feasibility Study of the above site.

One of the main scopes of a feasibility study in hydel projects is to determine the best layout of the project as well as to optimize the dimensions of the structures belonging to this layout. Since, Artistic-I HPP is a run-of-river type project, water conveyance system between weir and powerhouse can be constructed both at the right or left bank of the river. On the other hand, since the project is at a raw site, alternative locations for weir and powerhouse can be studied according to topographical, environmental, social and in-situ geological conditions as well as to utilize the maximum head potential, considering the rights of other projects which are located upstream of Artistic-I Weir and downstream of HPP.

In view of the above, the Consultants developed technically possible layout alternatives, studied advantages and disadvantages of them to make comparisons, thus to present the best one to be studied further in detail. Selection of the best layout was achieved by taking the same design discharge into account for all layout alternatives.

Following the determination of best layout, the dimensions and capacities of the structures comprised by this layout is optimized. The optimization procedure involves first to assume a range of possible design discharges on the basis on hydrological studies. Special consideration is given to compensation flows and lowest natural flows.

Increasing design discharge, increases dimensions of the structures, thus their bill of quantities and costs. Increasing design discharge also increases the power and energy generation of the project. However, at an optimal point the annual net benefit of the project reaches to a maximum value from where increasing design discharge further becomes meaningless. Since the marginal benefit gained by further discharge increase cannot overcome or compensate the cost increase sufficiently, that point reflects the optimum decision.

As mentioned above, the comparative costs and energy benefits were estimated and economic analyses were then conducted for each design discharge within the context of this study. The design discharge which has the annual maximum net benefit (difference of annual benefit and annual cost) was selected as the optimum one among others. As different diameter options for power tunnel, penstock and surge shaft were taken into account together with the design discharge alternatives, the optimization study also resulted in with the best dimensions of those structures. Furthermore, the optimum installed capacity has also been revealed which is the main aim of project sizing.

7.1.2 LOCATION OF PROJECT

The projects weir site as per LoI was located about 2 km downstream of Darora village and about 4 km upstream of Sahibabad village. The powerhouse site as per LoI was located about 4 km downstream of Sahibabad village.

The tentative coordinates of the project as per LoI are illustrated in **Table** 7.1.

Table 7.1 : Project Coordinates as per LoI

Location	Northing	Easting	Elevation
Weir / Intake	35°04’55.58”	72°59’32.33”	1046.94 m
Powerhouse	35°01’17.56”	72°00’58.83”	986.58 m

The new project coordinates finalized by the Consultants after site visits and mutual in-house discussions between experts are given in **Table** 7.2**.**

Table 7.2 : Proposed New Project Coordinates

Location	Northing	Easting	NWL / TWL
Weir / Intake	35°05’52.77”	71°59’00.08”	1071.00 m
Powerhouse	35°01’28.32”	72°00’40.77”	990.00 m

The new weir site is located near Darora village and about 6.7 km upstream of Sahibabad village. The powerhouse site is located about 3.5 km downstream of Sahibabad village.

7.2 PROJECT LAYOUT ALTERNATIVES

The Consultants made desk studies based on satellite imagery available from google earth and mark various layout alternatives on the image to be studied during site visit of experts. The project layout alternatives are presented in **Figure** 7.1.

The Consultants prepared and submitted the Inception report on April 10th, 2019. A presentation on the Inception report has been delivered to Panel of Experts (POE) on April 23rd, 2019 at the office of PEDO.

The PoE and the PEDO were also informed about the Sponsors and Consultants meeting held on 19th April 2019 in the PEDO office where it was communicated by PEDO that there is no other hydropower project upstream of Artistic-I HPP between Artistic-I weir and Sharmai power house. The Sharmai powerhouse is located about 1330 m upstream of the newly proposed Alternative-4 Weir (W4). Therefore, possibility of shifting of weir further upstream could be explored.

During the presentation on April 23rd, 2019, it was discussed with PoE and PEDO officials and who also agreed for utilization of maximum of available resources.

The issue was further clarified during the meeting held between various sponsors of hydropower projects on Panjkora River and the PEDO on 24th April, 2019 to remove the conflicts/confusion that exits about location of weirs and powerhouses of various raw project sites identified on cascade of Panjkora River.

In view of the above, the Consultants started looking for possibility of shifting Artistic-I weir further upstream to the suitable location where it shouldn't have any negative impact on the output of Sharmai hydropower project. In this regard, the tailrace water level of Sharmai powerhouse has been inquired and confirmed from the investor of Sharmai hydropower project.

Therefore, a new location for Alternative-4 Weir (W4) has been identified at about 985 m upstream from its previous location. Now, weir (W4) is about 2190 m upstream of Alternative 1 & 2 Weir (W1& W2). This alternative offers maximum head and hence maximum annual energy and revenue compared to all other downstream alternatives. This may involve resettlement of a few houses but that can be compensated.

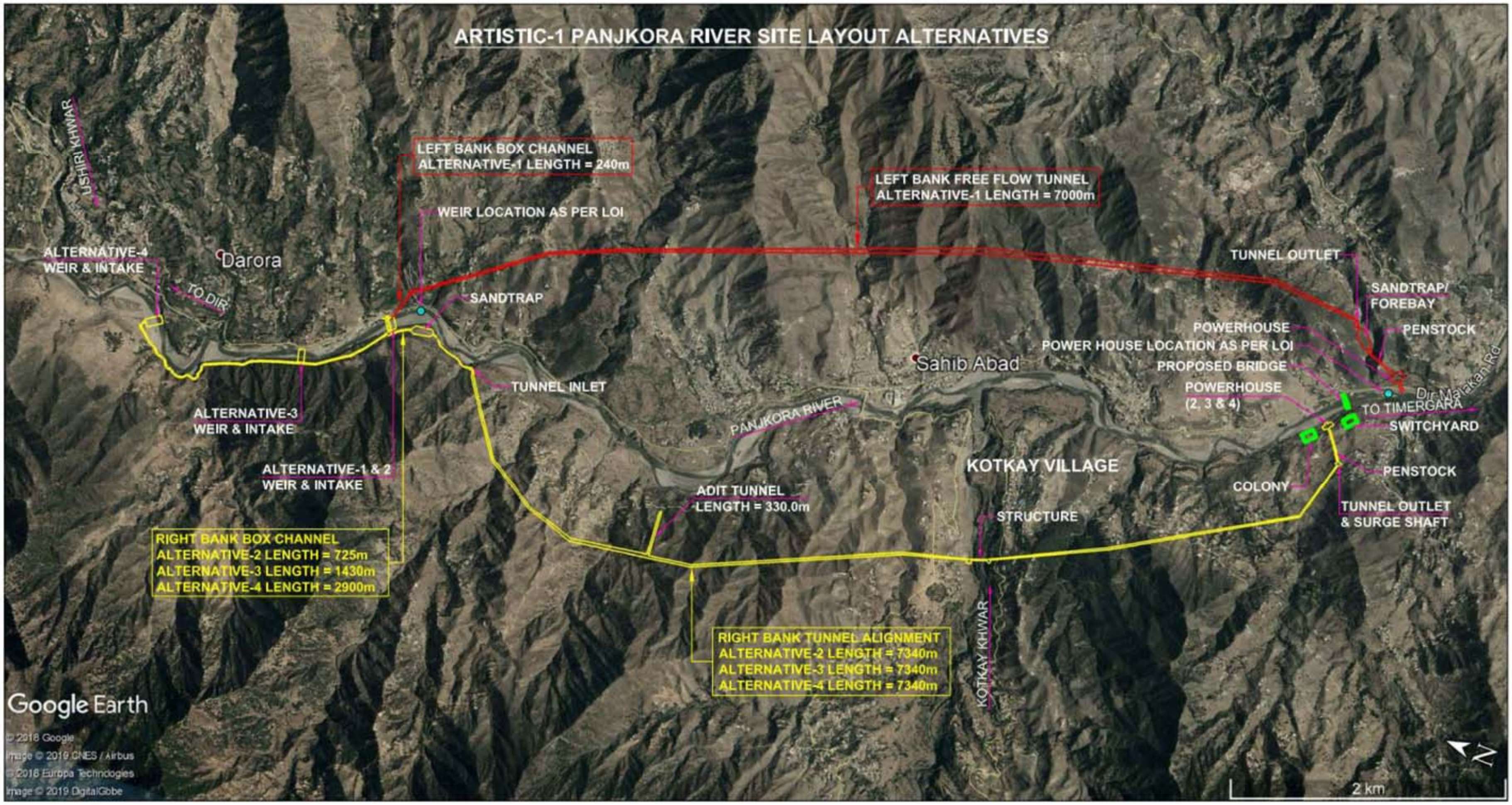

Figure 7.1 : Project Layout Alternatives

7.2.1 ALTERNATIVE 1 (LEFT BANK LAYOUT)

The weir site coordinates as per LoI are not appropriate due to the low elevation of existing asphalt road N-45 on the left bank as this road was over topped/flooded during 2010 flood at various location including this section of the road. Therefore, in all the alternatives the weir location will be different from the one with coordinates provided in the LoI.

Left bank box channel alignment will continue along the road below N-45 road elevation before crossing it underneath to join the tunnel inlet portal. Bridge over the channel would be required where it crosses the road N-45.

The tunnel inlet portal would be located toward hillside downstream up to 200 m where rock is exposed/outcrops near an existing house and where it has a sufficient tunnel cover thickness. The expected road widening of N-45 should also be kept in mind in planning structures on the left bank.

No suitable location for adit tunnel was identified during site visit for the left bank alternative.

The sand trap at the end of the Alternative-1 tunnel should be constructed before the tunnel inlet to save economy of the project and to avoid sedimentation in the tunnel.

The penstock alignment crosses a deep and steep tributary Uch khwar and valley at an angle inclined to contours, which is not appropriate for an exposed penstock. Carrying the penstock beneath the valley within as a buried / tunnel section is better.

The powerhouse location as provided in LoI was not suitable for left bank alternative due to presence of habitation nearby, which is therefore shifted downstream to a relatively suitable location. Furthermore, the tail water canal will cross the existing asphalt road and therefore bridge over the tailrace would be required

7.2.2 ALTERNATIVE-2, 3 AND 4 (RIGHT BANK LAYOUTS)

7.2.2.1 WEIR SITE

The weir site coordinates provided in the LoI are not appropriate due to the low elevation of existing asphalt road N-45 on the left bank as this road was over topped/flooded during 2010 flood at various location including this section of the road. Therefore, consultants identified three alternate project sites for the weir of Right Side Alternatives which are discussed below.

Alternative 2 Weir is identified about 250 m upstream of the weir site given in the letter of intent. Constructing Weir at this site will cause the submergence of few houses due to ponding of water on the upstream.

Alternative 3 Weir is located about 705 m upstream of Alternative 2 weir, which will result in need of reconstruction of a mosque on the upstream. Finally, Alternative 4 Weir (W4) has been shifted upstream from its previous location to a new location which is about 2190 m upstream of Alternative 1 & Alternative 2 weir (W2 & W1). This alternative provides maximum head and hence maximum annual energy and revenue compared to all other downstream alternatives. This may involve resettlement of a few houses but that can be compensated.

7.2.2.2 Right Bank Conveyance Box Channel

The canal alignment will pass through the toe of terrace deposits near the Panjkora River. The terrace materials slope and its stability are yet to be seen after determining geotechnical parameters of this material during geological investigations. The upstream portion of the box channel will be aligned in such way that it would minimize the effect on the houses in the vicinity of box channel.

7.2.2.3 Right Bank Sand Trap

The structure is placed near the toe of the hill at terrace deposits, the only place where such structure can be placed and economy in excavation can be achieved.

During review of alternatives, search for another location of sand trap was done but topography does not allow any other suitable location as compared to the previous location. There exists a location in the vicinity of the weir (W4) but that location is not efficient one due to minimal difference of level of flushing and river bed.

7.2.2.4 Right Bank Tunnel Inlet

The alignment of box channel, before free flow tunnel inlet, passes through a steep terrain where for the sake of economy, a rectangular section is proposed. Depending upon the Alternatives 2, 3 & 4 there will be a box channel at the upstream end of the sand trap, the length of which depends upon the option selected.

The rectangular box channel will lead to a tunnel through a tunnel inlet which will have a transition for hydraulic requirement and a rock overburden for stability requirement.

7.2.2.5 Pressure Conduit in the Kotkay Khwar

The tunnel crosses Kotkay Khwar approximately in the downstream half of weir-powerhouse alignment. The tunnel will be day-lighted here which will help in managing construction activities from four faces which shall have a substantial impact on the reduction of construction time of this critical activity. As per preliminary findings the tunnel will be converted into pressure conduit like super passage which will be deep enough than the

Khwar bed level. Accordingly, this structure will have least scouring effect of the floods generated in the valley and passing in the Khwar.

7.2.2.6 Right Bank Surge Tank, Penstock Alignment and Powerhouse Location

The exit (outlet) location of tunnel was fixed according to the location and approximate dimensions of powerhouse as well as the route of penstock and height of surge tank. According to preliminary hydraulic calculations the minimum diameter of the surge tank shall be 12 m, and the height corresponding to this diameter is ~100 m. However, these dimensions will be checked and refined in detail design.

An exposed type of penstock route is designed for this stage. However, after geotechnical investigations, if the depth of slope wash material is found to be thick and unstable, then in order to be on the safe side, even expensive, a vertical shaft for the penstock (buried type of penstock) may be preferred.

The powerhouse (Alternative 2, 3, 4) is seated in the relatively plan area to avoid excessive cutting and to minimize possible cost of excavation and having slightly milder environmental impacts. Power house level shall be fixed and optimized for different discharge levels in the river and tailrace level to get maximum energy from the design discharge. A surface power house is proposed for the Artistic-I Hydropower project. Switch yard and colony/residence for operational staff is proposed at a location in the vicinity of power house.

7.2.2.7 Provision of Road Bridges

The right bank layout alternatives alignment would require construction of two vehicular bridges i.e. one at the weir and other at the power house location, respectively as per project's requirement for access during and after construction.

7.2.3 Salient Features of Layout Alternatives

Salient features of the layout alternatives given in the Revised Inception Report are given below.

Description	Alternative 1 (Left Bank)	Alternative 2 (Right Bank)	Alternative 3 (Right Bank)	Alternative 4 (Right Bank)
Slope Stability Issues at Weir / Intake Location	(W1) Relatively higher than W2 Alternative	(W2) Small	(W3) Small	(W4) Small
Sand Trap Location	Difficult / Not suitable	Excellent	Excellent	Excellent

Description	Alternative 1 (Left Bank)	Alternative 2 (Right Bank)	Alternative 3 (Right Bank)	Alternative 4 (Right Bank)
Tunnel inlet / Outlet Portal	Difficult / Involving Social Problems	Reasonable	Reasonable	Reasonable
Power House	Suitable	Suitable	Suitable	Suitable
Environmental & Social Issues	Severe	Less Severe	Mild	Less Severe
Access Bridges at Weir & Power House	Not Required	2 Nos.	2 Nos.	2 Nos.
Multi span culvert / Bridge for at Weir & Tailrace crossing Timergara-Upper Dir Road	2 No.	Not Required	Not Required	Not Required
Box Channel Length	240 m	725 m	1430 m	2900 m
Power Tunnel Length	7000 m	7340 m	7340 m	7340 m
Penstock Length	231 m	261 m	261 m	261 m
Total Length (Box Channel + Tunnel + Penstock)	7471 m	8326 m	9031 m	10501 m
Gross Head	65 m	60 m	64.5 m	79 m
Design Discharge	110 m^3/s	110 m^3/s	110 m^3/s	110 m^3/s
No. of Turbine Units	3	3	3	3
Combined Efficiency (Assumed for Comparison)	90.3 %	90.3 %	90.3 %	90.3 %
Power Potential (Tentative for Comparison)	53.57 MW	47.99 MW	51.87 MW	64.05 MW
Annual Energy (Tentative for Comparison)	268.45 GWh	241.98 GWh	260.70 GWh	321.08 GWh
Plant Factor (Tentative for Comparison)	57.20%	57.56%	57.37%	57.23%
Net Annual Revenue (Tentative for Comparison) @Rs. 10/unit	Rs.2684.54 Million	Rs.2419.80 Million	Rs.2606.95 Million	Rs.3210.76 Million

7.2.4 COMPARISON BETWEEN ALTERNATIVE-3 AND ALTERNATIVE-4

Description	Alternative 3 (Right Bank)	Alternative 4 (Right Bank)
Additional Power Potential of Alternative-4 compared to Alternative-3 (Tentative for Comparison)	12.18 MW	
Additional Annual Energy produced by Alternative-4 as compared to Alternative-3 (Tentative for Comparison)	60.38 GWh	
Additional Annual Revenue from Alternative-4 as compared to Alternative-3 (Tentative for Comparison)	Rs.603.81 Million	
Additional Cost of Box Channel from Alternative-4 Weir (W4) to Alternative-3 Weir (W3) (Tentative for Comparison)	Rs.2,511.331 Million	

7.2.5 CONCLUSIONS & RECOMMENDATIONS

The Consultants after detailed discussions, analysis and comparison of all project layout alternatives, come to the conclusion that right bank Alternative 4 would be more practical and beneficial from construction, geological and geotechnical, power and energy production aspects. Alternative 4 would offer maximum power potential, annual energy and consequently annual revenue while having least diversion and construction problems.

From the above discussion it was concluded that Alternative 4 (Right bank) is better than the other Alternatives due to following reasons:

- Sufficient space is available for the construction and diversion arrangement near the weir site as compared to other alternatives.
- W4 site offers additional head of about 14.5 m and consequently higher power potential as compared to W3 site.
- The alternative 4 offers tentative higher power potential of about 64.05 MW as compared to 51.87 MW by Alternative-3. Furthermore, Alternative-4 offers tentative annual energy of about 321.08 GWh as compared to 260.7 GWh by Alternative-3. The Alternative-4 offers net additional annual revenue of about Rs. 603.81 Million compared to Alternative-3.

Taking all these factors into consideration; Alternative-4 is recommended for further study.

7.2.6 SELECTED PROJECT LAYOUT ALTERNATIVE

At Panjkora River, a gated weir with a height of about 10 m is envisaged. The gross head is about 81 m while the design discharge is 110 cumecs in the Revised Inception Report. However, a detailed study has been carried out at discharge optimization studies (See **Section 7.6**).

The height of weir is limited by the steep slope of river as well as restriction of provision of storage to ensure availability of water at all times of any downstream proposed hydropower. A gated weir combined with under sluices would be constructed for passing 1 in 100 year return period flood and with under sluices to remove sediments as well.

After submission of Revised Inception Report, Consultants carried out additional site visits as well as detailed desk studies and concluded to convert the box canal to a free flow tunnel between chainage Km 0+194 - Km 1+777, due to high amount of excavation which will result in severe social problems.

An intake structure capable of carrying design discharge at normal pond level of weir is anticipated on the right side of the valley. From the intake, discharge would be conveyed to sand trap / desander first through a 175 m long box channel and then a 1583 m long free flow tunnel and finally a box channel which is 442 m long. From sand trap, discharge would be conveyed to forebay / headpond through connecting box channel which would be about 235 m in length. Diverted flows from forebay / headpond would be conveyed to turbine units through power tunnel about 7480 m long and penstock which would be about 156 m long.

The powerhouse is to be placed on a location where terraced fields exist and have relatively milder slope involving an economical cut than the upstream and downstream steep sloped formation. The powerhouse will be equipped with Francis turbines and the other equipment like high pressure valves, generators, governors, transformers and the electrical equipment.

The project layout will be optimized by carrying out power and energy calculations for different tunnel and penstock diameters (See **Section 7.5**).

The project layout would require construction of one bridge at powerhouse and another bridge combined with the weir. The bridge at powerhouse will be constructed prior to construction of powerhouse, penstock and tunnel outlet/surge chamber, which will be used during construction. While bridge at weir will be composite with the weir and a temporary access shall be required during construction.

7.3 DESIGN WORKS FOR OPTIMIZATION STUDY

7.3.1 DETERMINATION OF GROSS HEAD

Project sizing and optimization studies are carried out after the selection of most suitable layout for the project components.

After approval of Alternative-4 right bank layout by PEDO, the locations of weir and powerhouse, the water levels required for power and energy generation calculations have been finalized.

According to 1/1.000 scaled, available topographical map, the river bed elevation at weir axis is 1061.00 m. The height of weir is limited to ensure not to have any negative impact on Sharmai HPP, which is the upstream project. As a result, a weir composed of 8 nos. radial gates having 10 m height has been designed to evacuate the design flood safely, without permitting any increase in the water level of the pond. Thus, the normal operating water level and the maximum flood level of the project is determined as **1071.00 masl.**

The tailwater level of Artistic-I HPP when all units are in operation is selected as **990.00 masl**. Thus:

Gross head between Weir and HPP = 1071.00 – 990.00 = **81 m.**

7.3.2 DETERMINATION OF LENGTHS OF WATER CONVEYANCE SYSTEM COMPONENTS

Following the preliminary design of weir, the layout of an intake structure has been prepared (See attached drawings).

Between intake structure and sand trap the design discharge and the continuous flushing discharge is planned to be conveyed through a free flow conveyance system comprising box channels and a tunnel. The preliminary dimensions of channel and free flow tunnel were selected by using Manning's equation. Checks for flow regime and water velocity are satisfied to maintain a sub-critical flow and sufficient freeboard. In order to minimize local losses, the minimum radii of horizontal curves were calculated hydraulically and applied. Moreover, minimum distance criterion between counter-curves was followed. The alignment of channel offers minimum excavation. **The length of box channel** is determined as **617 m** (175 m between intake and free flow tunnel and 442 m between free flow tunnel and sand trap). The base slope of the channel was selected as 0.0004. **The length of free flow tunnel** is determined as **1583 m**. The base slope of the tunnel was selected as 0.0005 (See attached drawings).

Between forebay and sand trap, the design discharge is planned to be conveyed through a connecting box channel. Since the forebay is designed just upstream of power tunnel inlet, the flow within the channel is free (open channel) flow. The preliminary dimensions of channel were selected by using Manning's equation. **The length of connecting box channel** is determined as **235 m.** The base slope of the channel was selected as 0.0004 (See attached drawings).

Between power tunnel inlet and end point of box channel, a forebay structure is designed. The dimensions of the structure were calculated accordingly to feed the turbine units throughout 1.5 minutes, according to various commissioning scenarios and to maintain safe evacuation of the design discharge by a side spillway. The forebay structure will provide a transition between a free surface flow and a closed conduit pressurized flow for the power station. The normal water level of the forebay was found as **1069.33 masl**, after hydraulic loss calculations (entrance sill loss, thrash rack loss, skimmer wall loss, pier loss, gate slot loss and friction loss within intake; as well as transition and friction losses within sand-trap including exit sill and gate slot losses; in addition to these the friction loss along the box channels and free flow tunnel and transition loss to forebay) between pond of Artistic-I Weir and Forebay. As a result, the gross head becomes:

Gross head between Forebay and HPP = 1069.33 – 990.00 = **79.33 m.**

Following the forebay, the alignment of power tunnel between inlet and exit points was studied on the topographical map. The base slope of the power tunnel was determined, both taking into account the height of clear cover above the tunnel, and the height required for surge tank. After preparing the profile drawing, **the length of power tunnel is finalized as 7480 m** (See attached drawings). By mutual in-house discussions, it was decided to design outer (excavation) cross section of tunnel as "D-shaped" whereas the inner (concrete lining) cross section as "horseshoe" for the ease of construction and to save economy of the project.

Horseshoe section of power tunnel is connected to the circular cross section of penstock by means of a steel transition pipe. At the end of transition, a valve chamber is planned, from which the penstock starts. The alignment of penstock was determined according to the powerhouse location and the topography. After preparing the profile drawing, **the length of penstock is finalized as 156 m** (See attached drawings).

The abovementioned lengths of water conveyance system components were used both in hydraulic friction loss calculations and in preparation of bill of quantities and construction cost calculations.

7.3.3 DETERMINATION OF DIMENSIONS OF ALTERNATIVES

The decisive parameter in this context is the design discharge. The choice of the design discharge has the significant impact on the structures of the hydropower project. The quantities of the structures and thereby its costs increase with increasing design discharge.

Reviewing the flow duration curve at Artistic-I Weir site (See **Figure** 7.2), seven discharges, namely Q = 80, 85, 90, 95, 100, 105 and 110 cumecs, which corresponds to 28% - 38% exceedance of flow duration, were selected to be included in the optimization study.

For each design discharge, three different power tunnel diameters, which result in water velocities approximately V = 2.25, 2.50 and 2.75 were planned to be optimized. Hydraulic parameters such as pressurized flow area, wet perimeter, hydraulic radius and water velocity for each horseshoe tunnel alternative are calculated and listed in **Table** 7.3. These hydraulic parameters were utilized in frictional hydraulic loss calculations for tunnel.

The thickness of concrete lining for each tunnel diameter alternative is also given in **Table** 7.3. Since amphibolite and granite/granodiorite outcropping along the tunnel alignment, are classified as generally good / fair rock, the preliminary thickness of concrete lining is decided by dividing the diameter of tunnel into thirteen and rounding up or down to the multiples of 5 cm. Minimum concrete lining for power tunnel is selected as 0.50 m.

Table 7.3 : Power Tunnel Diameter Alternatives

Design Discharge	Diameter of Tunnel	Thickness of Concrete Lining	Cross Sectional Area	Wet Perimeter	Hydraulic Radius	Water Velocity
Q (m^3/s)	D (m)	t (m)	A (m^2)	P (m)	R (m)	V (m/s)
80,00	5,95	0,50	29,36	19,44	1,51	2,72
	6,20	0,50	31,88	20,25	1,57	2,51
	6,55	0,50	35,58	21,40	1,66	2,25
85,00	6,10	0,50	30,86	19,93	1,55	2,75
	6,40	0,50	33,97	20,91	1,62	2,50
	6,75	0,50	37,79	22,05	1,71	2,25
90,00	6,30	0,50	32,92	20,58	1,60	2,73
	6,60	0,50	36,13	21,56	1,68	2,49
	6,95	0,55	40,06	22,71	1,76	2,25
95,00	6,45	0,50	34,53	21,07	1,64	2,75
	6,75	0,50	37,79	22,05	1,71	2,51
	7,15	0,55	42,40	23,36	1,82	2,24
100,00	6,65	0,50	36,67	21,73	1,69	2,73
	6,95	0,55	40,06	22,71	1,76	2,50
	7,30	0,55	44,19	23,85	1,85	2,26
105,00	6,80	0,50	38,35	22,22	1,73	2,74
	7,10	0,55	41,81	23,20	1,80	2,51
	7,50	0,60	46,65	24,50	1,90	2,25
110,00	6,95	0,55	40,06	22,71	1,76	2,75
	7,25	0,55	43,59	23,69	1,84	2,52
	7,70	0,60	49,17	25,16	1,95	2,24

For each design discharge, three different penstock diameters, which result in water velocities approximately V = 5.0, 5.5 and 6.0 m/s, were planned to be optimized and given in **Table** 7.4.

Table 7.4 : Penstock Diameter Alternatives

Design Discharge	Diameter of Penstock	Water Velocity	Average Wall Thickness
Q (m^3/s)	D (m)	V (m/s)	t (mm)
80.00	4.10	6.06	13.00
80.00	4.30	5.51	14.00
80.00	4.50	5.03	14.00
85.00	4.25	5.99	14.00
85.00	4.45	5.47	14.00
85.00	4.65	5.01	15.00
90.00	4.35	6.06	14.00
90.00	4.55	5.54	14.00
90.00	4.80	4.97	15.00
95.00	4.50	5.97	14.00
95.00	4.70	5.48	15.00
95.00	4.90	5.04	15.00
100.00	4.60	6.02	15.00
100.00	4.80	5.53	15.00
100.00	5.05	4.99	15.00
105.00	4.70	6.05	15.00
105.00	4.95	5.46	15.00
105.00	5.15	5.04	16.00
110.00	4.85	5.95	15.00
110.00	5.05	5.49	16.00
110.00	5.30	4.99	16.00

For each design discharge and tunnel diameter alternative, the diameters for surge shaft were determined through hydraulic calculations carried out by Pressel's Method. In these calculations, the height of the shaft was kept between 74 m and 77 m by taking into account the available vertical distance between natural ground surface and the crown level of power tunnel. Since Francis type of turbine is the most suitable one for Artistic-I HPP project, in downsurge calculations, the duration of turbine opening was assumed as 30 seconds, whereas for upsurge calculations, the duration of turbine closing was assumed as 6 seconds. The surge shaft alternatives are listed in **Table** 7.5**.**

Table 7.5 : Surge Shaft Alternatives

Design Discharge	Diameter of Power Tunnel	Diameter of Surge Shaft	Height of Surge Shaft
Q **(m^3/s)**	**D_T** **(m)**	**D_S** **(m)**	**H** **(m)**
80	5,95	14,00	74
	6,20	13,40	75
	6,55	12,60	76
85	6,10	14,50	74
	6,40	13,70	76
	6,75	13,20	75
90	6,30	14,80	75
	6,60	14,20	75
	6,95	13,50	76
95	6,45	15,10	76
	6,75	14,60	75
	7,15	13,80	76
100	6,65	15,50	76
	6,95	15,00	75
	7,30	14,40	75
105	6,80	15,80	76
	7,10	15,40	75
	7,50	14,70	75
110	6,95	16,10	77
	7,25	15,60	76
	7,70	15,10	75

Next structure that would be optimized in this study is free flow tunnel. It was decided to design both outer (excavation) cross section and the inner (concrete lining) cross section of the tunnel as "D-shaped" for ease of construction and to save economy of the project. The dimensions of free flow tunnel were calculated according to discharges, which are 10% higher than the design discharge. The excess 10% discharge taken into the conveyance system is for continuous flushing of sand trap. Taking base slope as s = 0.0005 and Manning's n = 0.014, the diameters (D) and the water depths (d) of tunnel for each discharge alternative were determined. The "d/D" ratio for the tunnel was kept around 0.9 in order to reach the most economic cross section as well as a sufficient freeboard for the free flow. The preliminary thickness of concrete lining is decided by dividing the diameter of tunnel into thirteen and rounding up or down to the multiples of 5 cm. Minimum concrete lining for power tunnel is selected as 0.55 m. Hydraulic properties and dimensions of free flow tunnel alternatives are listed in **Table 7.7.**

Table 7.6 : Free Flow Tunnel Alternatives

Alt. No	Q_{PH} (m^3/s)	Q_{Tunnel} (m^3/s)	D (m)	d (m)	A (m^2)	P (m)	R (m)	V (m/s)	$V^2/2g$ (m)	d/D (-)
1	80.00	88.0	6.50	5.87	36.05	19.08	1.89	2.44	0.30	0.902
2	85.00	93.5	6.65	6.00	37.72	19.51	1.93	2.48	0.31	0.902
3	90.00	99.0	6.80	6.10	39.29	19.82	1.98	2.52	0.32	0.896
4	95.00	104.5	6.95	6.17	40.78	20.07	2.03	2.56	0.33	0.888
5	100.00	110.0	7.10	6.23	42.23	20.28	2.08	2.60	0.35	0.878
6	105.00	115.5	7.20	6.48	44.17	21.09	2.09	2.61	0.35	0.900
7	110.00	121.0	7.35	6.49	45.44	21.11	2.15	2.66	0.36	0.883

The last structure that would be optimized in this study is box channel. Taking base slope as s = 0.0004 and Manning's n = 0.014, the widths (b) and the water depths (h) of channel, for each discharge alternative were determined. The "b/h" ratio for the channel was kept around 1.32 ~ 1.34 in order to reach the narrowest land use, minimum excavation and better structural stability and reinforcement use. The internal heights (H) of the box channel alternatives were calculated by adding 50 cm freeboard to the heights of water (h) and rounding them up by multipliers of 5 cm. For preliminary design stage, the thickness of box channel concrete was taken as 50 cm.

Hydraulic properties and dimensions of box channel alternatives are listed in **Table** 7.7.

Table 7.7 : Box Channel Alternatives

Alt. No	Q (m^3/s)	b (m)	h (m)	A (m^2)	P (m)	R (m)	V (m/s)	$V^2/2g$ (m)	H (m)
1	88.00	5.45	4.08	22.21	13.60	1.63	1.98	0.20	4.60
2	93.50	5.55	4.19	23.25	13.93	1.67	2.01	0.21	4.70
3	99.00	5.70	4.26	24.26	14.21	1.71	2.04	0.21	4.80
4	104.50	5.80	4.36	25.27	14.51	1.74	2.07	0.22	4.90
5	110.00	5.90	4.45	26.27	14.80	1.77	2.09	0.22	5.00
6	115.50	6.00	4.54	27.25	15.08	1.81	2.12	0.23	5.10
7	121.00	6.10	4.63	28.22	15.35	1.84	2.14	0.23	5.20

7.3.4 TOTAL NUMBER OF OPTIMIZATION ALTERNATIVES

According to aforementioned tables, 7 different design discharges together with 3 different power tunnel diameters and 3 different penstock diameters decided for each discharge; result in 7 x 3 x 3 = **63 alternatives** that are included in the optimization study for Artistic-I HPP.

7.4 COST ESTIMATES OF ALTERNATIVES

7.4.1 CONSTRUCTION COST

The construction cost of civil works was estimated on the basis of rates of various items of work as provided in the latest available Composite Schedule of Rates (CSR) for district Upper Dir of Khyber Pakhtunkhwa Province. Difficulty factor was also included therein.

The construction costs of the structures were estimated by multiplying the quantities of work items by unit prices (rates) in PKR. The rates of work items which are not present in the CSR were taken from the similar previous projects. In case of cost of E&M equipment, quotation of foreign manufacturers for similar projects was taken into account. Equipment which is manufactured in Pakistan has also been priced accordingly.

Quantities of work have been taken from the preliminary design drawings.

It is accepted that cement and reinforcement will be hauled from Peshawar (240 km).

Concrete aggregates can be maintained by crushing Panjkora River alluvium material and/or excavated rock material from tunnel. Hauling distance of concrete aggregates was taken as 1 km.

7.4.1.1 BOX CHANNEL

Free flow channel is designed as two barrelled box section since the design discharges are high and to protect the canal against potential debris flows. Left and right sides of the box together with the top part will be backfilled with excavated material, resulting in a buried structure. The thickness of backfill above the top of the box channel was designed as 1 m. A stabilized road, which will be constructed by grading and compacting subbase and base course material, for operation and maintenance purposes, was designed on the backfill.

According to the surface geological map and site visit observations, it is assumed that 60% of the excavation material will be stiff soil whereas 10% soft soil and 30% soft rock.

The excavation and fill volumes of box channel are calculated from AutoCAD Civil 3D models prepared for each alternative.

The cement dosage assumed for box concrete is 350 kg/m^3.

The reinforcement weight per cubic meter of concrete was accepted as 100 kg/m^3.

The construction costs of box channel alternatives are given in **“Annexure D1 Volume-7”**.

7.4.1.2 FREE FLOW TUNNEL

The free flow tunnel is 1583 m long. Taking the geological formations into consideration, it is assumed that 87% alignment will be excavated in fair rock, and 13% in weak rock types.

As mentioned before, the excavation section and the concrete lining section of the tunnel is D-shaped. The excavation and concreting volumes are calculated according to D-Shape section.

The cement dosage assumed for concrete lining, shotcrete and grouting is 350 kg/m^3, 450 kg/m^3 and 100 kg/m^3, respectively.

The reinforcement weight per cubic meter of concrete is accepted as 75 kg/m^3.

The hauling distance for excavated rock material from tunnel to disposal area is accepted as 5 km.

The construction costs of free flow tunnel alternatives are given in "**Annexure D2 Volume-VII"**.

7.4.1.3 POWER TUNNEL

The power tunnel is 7480 m long. However, an adit has been planned to decrease the hauling distance within the tunnel, thus decreasing the cost as well as duration of construction. Another improvement is achieved by daylighting the tunnel alignment across Kotkay Khwar valley. The adit tunnel and the Kotkay Khwar passage divides the power tunnel into three segments, namely as T1, T2 and T3, lengths of which are 2187 m, 2122 m and 3001 m, respectively.

The construction costs of T1, T2 and T3 segments are calculated and then summed up.

Taking the geological formations into consideration, for T1 tunnel, it is assumed that 23% of the alignment will be excavated in good rock, whereas 77% in fair rock.

For T2 tunnel, the classification is as 92% fair, 8% weak rock.

For T3 tunnel, the classification is as 25% good, 34% fair, 14% weak and 27% very weak rock.

As mentioned before, the excavation section of the tunnel is D-shaped whereas the concrete lining section is horseshoe. The excavation and concreting volumes are calculated according to these sections.

The cement dosage assumed for concrete lining, shotcrete and grouting is 350 kg/m^3, 450 kg/m^3 and 100 kg/m^3, respectively.

The reinforcement weight per cubic meter of concrete is accepted as 75 kg/m^3.

The hauling distance for excavated rock material from tunnel to disposal area is accepted as 5 km.

The construction costs of power tunnel alternatives are given in **"Annexure D3 Volume-VII"**.

7.4.1.4 SURGE SHAFT

Surge shaft will be excavated with circular cross-section. Since it is a sound rock and the diameter of alternatives ranges from 12.60 m to 16.80 m, the thickness of concrete lining was assumed between 105 cm and 140 cm. The excavation and concreting volumes are calculated according to these diameters, lining thickness and circular sections.

The geotechnical works such as rock bolts, anchorages, contact grout, steel mesh and shotcrete were calculated according to the geological classification accepted for T3 tunnel portion.

The cement dosages, reinforcement usage and hauling distances are taken same as power tunnel.

The construction costs of surge tank alternatives are given in **"Annexure D4 Volume-VII"**.

7.4.1.5 PENSTOCK

It is anticipated that one line of main pipe will serve the power station up to a point where further branches (manifolds) may take off for each generating unit.

The static head on the penstock, between normal water level of forebay and penstock axis elevation at valve chamber, is 46.38 m. This head increases to 79.38 m at the entrance of power plant. Therefore, the wall thickness of penstock will be variable from valve chamber to turbines.

Three different calculations were carried out for each penstock diameter and design discharge alternative. The first one is minimum wall thickness, considering the diameter of the penstock and corrosion rate. The second one is the pipe wall thickness according to the maximum static head, i.e. maximum static internal pressure. The last one is the pipe wall thickness to resist the maximum dynamic head, which is composed of the maximum static head plus the increase in internal pressure due to water hammer effect at emergency shut down of turbines.

Following the abovementioned hydraulic studies, the average pipe wall thicknesses were calculated for each alternative (See **Table** 7.4), to be used in the cost calculations.

Steel material of St 52-3 type as per DIN 17100 standards was assumed to be used in manufacturing of penstock. The limits for the tensile strength of steel is 510-608 MPa, whereas the yield strength is 353 MPa ($t < 16$ mm) and 343 MPa ($16 < t < 40$ mm). The modulus of elasticity is 206.182 GPa and the corrosion rate is accepted as 2 mm.

The excavation along penstock alignment will be carried out by a trapezoidal section, bottom width of which is assumed as two times of penstock diameter. The slopes at the sides of trapezoidal excavation section were accepted as 1V/1,5H. Since slopewash material outcrops throughout the alignment, the classification of excavation was accepted as 70% soil, 20% soft rock and 10% sound rock.

The penstock will be supported by concrete anchor blocks at locations where the curvature of alignment changes. Additional anchor blocks will be provided where the slope of alignment is constant, at maximum distance of 75 m in between. The length of anchor block has been accepted as three times of the penstock diameter and the thickness of concrete was assumed as 30 cm. Since the blocks are massive concrete structures, surficial reinforcement of 30 kg/m^3 was considered to be sufficient to counteract against shrinkage cracks.

The construction costs of penstock alternatives are given in **“Annexure D5 Volume-VII”**.

7.4.1.6 POWERHOUSE

The powerhouse will be composed of mainly four blocks, units bay, erection bay, service bay and transformer bay.

At this stage, a lump sum unit cost (**40 USD/kW**) was accepted, for the construction works of power plant and tailrace canal, such as excavation, foundation treatment, formwork, reinforcement and concreting, steel roof etc., from similar previous projects.

The lump sum unit cost is multiplied by the installed capacity of the plant, calculated for each tunnel and penstock diameter alternative, subject to optimization study.

The currency is taken as **1 USD = 160.00 PKR**.

7.4.1.7 ELECTRO MECHANICAL EQUIPMENT

The powerhouse will be equipped with Francis turbines and the other machinery like turbine inlet valves, generators, governors, transformers, electrical devices and installations, gates, cranes and switchgear etc.

At this stage, a lump sum unit cost (**250 USD/kW**) was accepted, for the manufacture, transportation and installation of such E-M equipment, from similar previous projects. While assigning this unit cost, the capacity of the plant and number of units, has been taken into consideration. According to the hydropower calculations the installed capacity of the power plant ranges from ~50 MW to ~72 MW, for different alternatives (See **Section 7.6**).

The lump sum unit cost is multiplied by the installed capacity of the plant, calculated for each tunnel and penstock diameter alternative, subject to optimization study.

The currency is taken as **1 USD = 160.00 PKR.**

7.4.2 FACILITY COST

The construction costs of the aforementioned structures are summed up and increased by 5% to get the facility cost, which includes construction cost plus contingency. Contingency is the allowance for possible increases in costs as a result of physical conditions which adversely affect the construction or installation of the works and which could not be foreseen during the costing period.

The facility costs of optimization alternatives are listed in **Table** 7.13.

7.4.3 PROJECT COST

The facility costs of each alternative are increased by 3% to get the project cost. The 3% of facility cost is considered to compensate for the preparation of detailed design and tender documents, engineering consultancy and construction supervision services, Owner's expenses, administration and legal costs, custom duties and taxes, and the escalation on the local costs from feasibility stage to the commissioning stage.

The project costs of optimization alternatives are listed in **Table** 7.13.

7.4.4 INTEREST DURING CONSTRUCTION

Interest during construction (IDC) accounts for the opportunity cost of capital that is committed during the construction of a project. If the money used to construct the project (capital) was available for some other investment (opportunity), the investor would expect a certain return. Because the investor loses the opportunity to commit this capital to another use, IDC is treated as a cost (*Reference: Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments, ASCE, 1989*).

The above definition mentions that the project cost explained above does not reflect the actual cost of the project to the investor from financial point of view. The income, which would arise from the interest given by the banks to such a capital equal to the project cost for such a duration equal to construction time (say 3 years), is considered as an additional cost to the investor, in feasibility studies of hydel projects.

In other words, if the investor deposited his capital in a bank, instead of realizing a hydel project, the capital in the bank would have earned interest, during the construction period and the contractor would have more money at the end of this period. This illustrates the fact that there is a cost for the investor that arises from having his capital tied up in an asset (hydel project). The interest that the investor could have earned during construction period but decided to give up by investing his money to the hydel project instead of putting it in a bank, is evaluated as an additional cost for the project.

Interest during construction is computed according to the equation given below:

$$\mathbf{I_{DC} = [(1 + i)^n - 1] \times P_C}$$

Where:

I_{DC} : Interest during construction (PKR)

i : Interest rate (%)

n : Construction period (years)

P_C : Project cost (PKR)

The interest rate (i) is taken as **10.75%**

The construction period (n) has been envisaged as **3 years**.

However, as per construction schedule of such projects, some structures (like river diversion canal) are built first whereas some structures are built at the end (like power plant) and some structures are built throughout the whole period (like power tunnel). Therefore, for the optimization study, it is assumed that the expenditures will concentrate at half of the construction period, i.e. 1.5 years. The interest during construction is calculated by considering the time span between the middle and the end of construction period.

The interests during construction for optimization alternatives are listed in **Table** 7.13.

7.4.5 INVESTMENT COST

Investment cost is calculated by adding interest during construction to project cost.

The investment costs of optimization alternatives are listed in **Table** 7.13.

7.4.6 Annual Costs

Annual costs of a hydropower project comprise its amortized investment cost plus its yearly operation, maintenance, and interim replacement costs (*Reference: Civil Engineering Guidelines for Planning and Designing Hydroelectric Developments, ASCE, 1989*). These costs are calculated separately and then summed up to get the total annual cost of the project, which in turn is subtracted from the annual benefit to reach the net benefit of the project.

7.4.6.1 Operation and Maintenance Cost

Operation and maintenance (O & M) costs represent the average annual costs of maintaining a hydropower project at full operating efficiency throughout its useful life. This cost includes the salaries of operating personnel, the cost of labour, plant, and supplies for ordinary maintenance and repairs; and applicable supervisory and overhead costs.

Operation and maintenance cost is computed by multiplying the related coefficients by the facility costs of structures / facilities, given in Section 7.4.1, and then by summing them up.

The operation and maintenance cost coefficients are listed in **Table** 7.8.

Table 7.8 : Operation and Maintenance Cost Coefficients

No	Structures / Facilities	O & M Cost Coefficients
1	Dam body	0.005
2	Cofferdam / Diversion	0.005
3	Spillway	0.010
4	Tunnel (concrete lined)	0.005
5	Tunnel (unlined)	0.030
6	Bottom outlet	0.005
7	Penstock	0.020
8	Valves, gates	0.010
9	Timber gates	0.080
10	Roads (stabilized)	0.040
11	Roads (asphalt)	0.010
12	Bridges (concrete)	0.030
13	Bridges (steel)	0.030
14	Bridges (timber)	0.080
15	Construction site and permanent buildings	0.010
16	Pump station buildings	0.015
17	Pump motor and equipment	0.015
18	Transformer and switchyard	0.015
19	Surge tank	0.010
20	Powerhouse buildings	0.010
21	Powerhouse E-M equipment	0.015
22	Electricity Transmission Line	0.015
23	Canals (trapezoidal, concrete lined)	0.020
24	Hydraulic Structures (Weir, Conduit, Forebay, Sand Trap etc.)	0.010

The O & M costs of optimization alternatives are listed in **Table** 7.13.

7.4.6.2 Replacement Cost

Major powerhouse and equipment components may require replacement before the end of the projected project life. Examples are generator windings, turbine runners, thrust bearings, pumps, air compressors, communications equipment, generator, voltage regulation and excitation equipment, and certain types of transformers. The replacement cost for a facility is the estimated future cost of such replacements, converted to an equivalent average annual value over the entire project life.

The annual replacement cost for each project is estimated by:

a) computing the portion of the construction cost of each major component (including contingencies) that requires replacement during the life of the project, then
b) computing the present worth of that cost based on its composite service life (the weighted and combined service lives of all major components) and the project interest rate and finally
c) amortizing the present worth amount over the composite service life.

This procedure results in the determination of the amount required to be deposited annually in a sinking fund, earning interest at the project interest rate, in order to accumulate an amount equal to the estimated replacement cost.

According to the aforementioned procedure, replacement costs of each project component are computed by multiplying the related coefficients (factors) by the facility cost for the structures / facilities. These individual replacement costs are then summed up to calculate the total annual replacement cost of the project.

Replacement factors for different structures or facilities are computed according to the equation given below:

$$\mathbf{R_F = R_R \times i / [(1 + i)^t - 1]}$$

Where:

R_F : Replacement factor

R_R : Replacement ratio (in decimals)

i : Interest rate (in decimals)

t : Replacement period (years)

The interest rate (i) was considered 10.75% as it is the accepted project interest rate. It is applied to the above formula as 0.1075.

The replacement factors calculated for various structures are listed in **Table** 7.9.

Table 7.9 : Replacement Factors for Various Structures

No	Structures / Facilities	Service Life (years)	Replacement Period (years)	Replacement Ratio (%)	Replacement Factor
1	Dam body	150	45	2	0.000022
2	Cofferdam / Diversion	150	45	2	0.000022
3	Spillway	150	45	2	0.000022
4	Tunnel (concrete lined)	150	45	2	0.000022
5	Tunnel (unlined)	150	45	2	0.000022
6	Bottom outlet	75	45	2	0.000022
7	Penstock	75	45	50	0.000549
8	Valves, gates	75	45	50	0.000549
9	Timber gates	20	20	100	0.016028
10	Roads (stabilized)	100	45	2	0.000022
11	Roads (asphalt)	100	45	2	0.000022
12	Bridges (concrete)	100	45	2	0.000022
13	Bridges (steel)	100	45	50	0.000549
14	Bridges (timber)	30	30	100	0.005271
15	Construction site and permanent buildings	65	20	10	0.001603
16	Pump station buildings	35	20	10	0.001603
17	Pump motor and equipment	35	35	100	0.003103
18	Transformer and switchyard	40	28	90	0.005884
19	Surge tank	150	45	2	0.000022
20	Powerhouse buildings	75	20	10	0.001603
21	Powerhouse E-M equipment	35	35	100	0.003103
22	Electricity Transmission Line	45	45	100	0.001097
23	Canals (trapezoidal, concrete lined)	150	45	2	0.000022
24	Hydraulic Structures (Weir, Conduit, Forebay, Sand Trap etc.)	150	45	2	0.000022

The replacement costs of optimization alternatives are listed in **Table** 7.13.

7.4.6.3 Interest and Amortization Cost

The amortization of investment cost is the process of spreading a project's cost over its economic life in order to determine an equivalent annual cost. This process requires the computation of an amortization factor based upon the annual interest rate and economic life. The interest rate for a project must be adjusted annually throughout the planning process. An identical interest rate is used for both interest and amortization and interest during construction calculations.

$$\mathbf{a = [\ i \times (1 + i)^n\ ] / [\ (1 + i)^n - 1\ ]}$$

Where:

a: Amortization factor

i: Prevailing rate of interest (in decimals)

n: Economic life (years)

The interest rate (i) is taken as 10.75%.

The service life (n) of the subject hydel project is accepted 50 years.

$$\mathbf{a} = [0.1075 \times (1 + 0.1075)^{50}\ ] / [\ (1 + 0.1075)^{50} - 1\ ] = \mathbf{0.10815594}$$

The interest-depreciation costs of optimization alternatives are listed in **Table** 7.13.

7.4.6.4 Total Annual Cost

As mentioned before, the total annual cost of the project is computed by summing up the O&M cost, Replacement cost and Interest-and Amortization cost. This total cost will be compared to the annual benefit of the project to decide whether it is economically feasible or not.

The total of annual costs of optimization alternatives are listed in **Table** 7.13.

7.5 POWER, ENERGY AND ANNUAL BENEFIT CALCULATIONS

As mentioned before, 63 alternatives are decided to optimize design discharge and diameters of power tunnel and penstock, together. The installed capacity and annual average energy generation for each alternative is computed by carrying out hydropower calculations.

7.5.1 HYDROPOWER CALCULATIONS

The first input for the calculation is water availability at weir site. Utilizing historical daily flow data (1961-2017) measured at different gauging stations, the ten daily average flows were calculated and flow duration curve was prepared as given below.

Table 7.10 : Ten Daily Flows at Artistic-I Weir Site

10 Daily		Q (cumec)	10 Daily		Q (cumec)
Jan	I	18.7	Jul	I	172.9
	II	18.2		II	165.1
	III	19.6		III	156.6
Feb	I	21.3	Aug	I	139.7
	II	26.9		II	116.7
	III	29.8		III	92.6
Mar	I	38.1	Sep	I	72.1
	II	60.1		II	55.9
	III	74.4		III	43.0
Apr	I	90.8	Oct	I	36.2
	II	106.3		II	33.5
	III	121.4		III	28.8
May	I	129.1	Nov	I	26.1
	II	135.1		II	24.0
	III	144.2		III	21.1
Jun	I	162.4	Dec	I	24.3
	II	173.8		II	20.2
	III	180.0		III	19.7

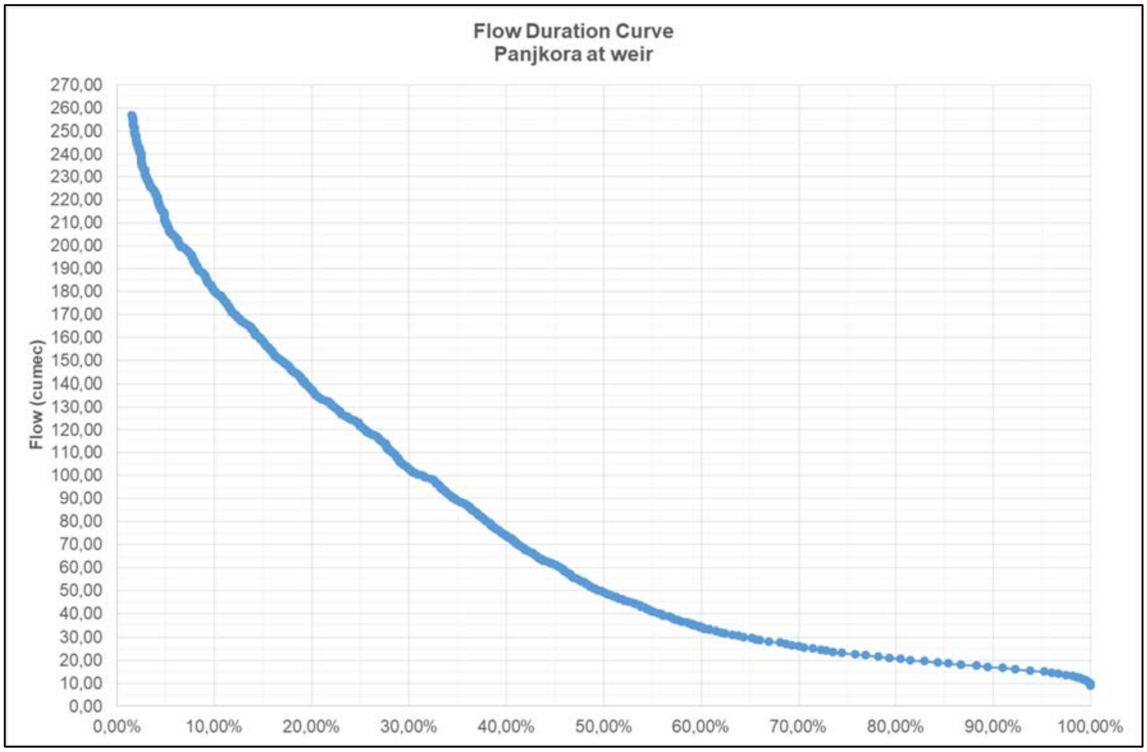

Figure 7.2 : Flow Duration Curve at Artistic-I Weir Site

In power and energy computations, not only the ecological / environmental flow requirements but also the downstream water rights were deducted from the inflows at weir site, given in **Table** 7.10. The water releases are as under:

- The Ecological/Environmental flows which were calculated by USA Montana Method (15% of mean monthly flow),
- The water demand of the prospective irrigation project downstream,
- The water demand of Markaz Micro Hydro Power Plant downstream.

The aforementioned water rights are listed in **Table** 7.11. The E-Flows will be released from Artistic-I Weir. However, the water demands of prospective irrigation project and the existing micro power plant will be released from the sand trap because of two reasons:

- These facilities are located downstream of sand trap.
- The water demands of these facilities will firstly be used for continuous flushing of sand trap especially during low flow seasons.

Table 7.11 : Downstream Water Rights

MONTH	E - Flow (m^3/s)	Prospective Irrigation Project (m^3/s)	Markaz Micro HPP (m^3/s)	Total Release (m^3/s)
JAN	2.83	2.00	1.00	5.83
FEB	3.90	2.00	1.00	6.90
MAR	8.63	2.00	1.00	11.63
APRIL	15.93	4.00	1.00	20.93
MAY	20.42	4.00	1.00	25.42
JUNE	25.81	4.00	1.00	30.81
JULY	24.73	4.00	1.00	29.73
AUG	17.45	4.00	1.00	22.45
SEP	8.55	4.00	1.00	13.55
OCT	4.93	2.00	1.00	7.93
NOV	3.56	2.00	1.00	6.56
DEC	3.21	2.00	1.00	6.21

Q_d is the design discharge alternative for the project. After releasing E-flow from Artistic-I Weir and releasing irrigation and micro plant demands from the sand trap, the discharges that can be diverted to the power plant are determined. Divertible flows were then checked whether they are adequate to maintain the safe operation of turbines without cavitation.

In this regard, it is planned to install two large equal units and one small unit for Artistic-I HPP. The design discharges of units, for all optimization alternatives were selected in such a way that, during low flow seasons, the minimum operation discharge of small unit would be greater than the minimum divertible flow.

Reviewing **Table** 7.10, the minimum average inflow at weir site is 18.20 m^3/s on January. Since 5.83 m^3/s discharge has to be released on this month (See **Table** 7.11), the minimum divertible discharge is 18.20 - 5.83 = **12.37 m^3/s.** In order to be on the safe side, the minimum operating discharge of the small unit was accepted as 10 m^3/s.

Minimum operation discharge of the small unit is considered as 40% of its design discharge since the turbine type of this project is vertical axis Francis.

Table 7.12 : Design Discharges and Minimum Operation Discharges of Turbine Units for Optimization Alternatives

Alt. No	Total Discharge Capacity of HPP	Design Discharge of Large Units	Minimum Operation Discharge of Large Units	Design Discharge of Small Unit	Minimum Operation Discharge of Small Unit
	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
1	80	27.50	11.00	25.00	10.00
2	85	30.00	12.00	25.00	10.00
3	90	32.50	13.00	25.00	10.00
4	95	35.00	14.00	25.00	10.00
5	100	37.50	15.00	25.00	10.00
6	105	40.00	16.00	25.00	10.00
7	110	42.50	17.00	25.00	10.00

Following the determination of unit discharges and divertible flows, hydraulic losses for each divertible flow were calculated.

Frictional losses within the power tunnel and penstock were computed by Manning's equation.

Minor losses such as trash rack, gate slot, transition and entrance losses at forebay, bend (curvature) losses along the alignment of tunnel and penstock, reduction (transition or section change) loss between tunnel and penstock, valve losses both at the valve chamber and turbine inlet valve, trifurcation losses at the end of penstock etc., are accepted as 3.0 m in total when total design discharge passes through the waterway system, referring to the detailed hydraulic design reports of similar previous projects. In summary the maximum minor loss is 3.0 m. However, it is reduced by the square of ratio of divertible flow to design discharge, at times when divertible flows are less than the design discharge.

Frictional losses and minor loss are then summed up to get the total loss for the relevant diverted flow.

Thereafter, the net heads for all divertible flows were computed by subtracting the total hydraulic losses from the gross head (79.38 m, See **Section 7.3.2**) between forebay and powerhouse.

Power generation for each divertible 10 daily average flow was computed by the following formula:

$$P = 9.81 \times \eta_{Tu.} \times \eta_{G} \times \eta_{Tr.} \times Q \times H_{net}$$

Where:

P : Power generation (kW)

$\eta_{Tu.}$: Turbine efficiency

η_G : Generator efficiency

$\eta_{Tr.}$: Transformer efficiency

Q : Flow diverted from weir to HPP (m^3/s)

H_{net} : Net head with respect to diverted flow (m)

Since the manufacturer has not been decided by the Sponsor yet, the efficiencies were taken from previous similar projects, achieved by the manufacturers.

The turbine, generator and transformer efficiencies are accepted as 0.94, 0.98 and 0.99, respectively, resulting in a combined efficiency of **0.912**, for the determination of installed capacity of the plant, i.e. when design discharge is diverted to plant.

In power calculations, during those months when less discharge than the design discharge is diverted to plant, the turbine, generator and transformer efficiencies are accepted as 0.90, 0.97 and 0.99, respectively, resulting in a combined efficiency of **0.864**.

By this method, the reduction in power generation during low flow periods was taken into account.

The peaking operation of the project during low flow seasons has not be allowed in this study, as it involves storage upstream for some duration which is not permitted to ensure the availability of water to proposed projects downstream.

The computed power generations were multiplied first by 24 hours and then by 10 days to figure out the corresponding energy generation for each divertible flow. All of these energy productions were then summed up to get the annual outcome.

The hydropower calculations for the alternatives are given in **“Annexure D6 Volume-VII”**.

7.5.2 Annual Benefits

The annual benefit of each alternative was computed by multiplying its annual average energy generation by the unit energy price (tariff).

The Sponsor declared that the tariff for Artistic-I HPP project can be presumed as **11 PKR/kWh**.

7.6 OPTIMIZATION STUDY

The optimization procedure involves first to assume a range of possible design discharges (See **Chapter 4**) on the basis on hydrological studies after selecting the general layout (See **Section 7.2**) of the proposed hydropower project. Then comparative cost estimates (See **Section 7.4**) and energy benefits (See **Section 7.5**) are estimated for each alternative. In order to make a comparison between the alternatives, the annual marginal net benefits are calculated by subtracting total annual costs from annual benefits. Optimization study is then conducted for each alternative and given in **Table** 7.13, in which the best option is accepted as the one which has the maximum annual marginal net benefit.

As can be seen from **Table** 7.13, the best option for each design discharge alternative is illustrated in yellow ink. The one in green ink, figures out the best option among the other bests (yellow ones).

Optimization study points out that free flow tunnel, power tunnel and E - M equipment costs dominates the selection, among other work items. The power tunnel options which have the minimum diameter come out as the optimum for design discharge alternatives. However, smaller diameters than these alternatives haven't been preferred technically as the velocity of pressurized water within the tunnel exceeds ~2.75 m/s (See **Section 7.3.3**).

The best options are illustrated in **Table** 7.14 and **Figure** 7.3. Among them **Q = 100 m^3/s** has the maximum annual net benefit and deserves to be selected as the design discharge.

Table 7.13 : Optimization Study for Artistic-I HPP Project

Discharge	Free Flow Tunnel Diameter	Power Tunnel Diameter	Penstock Diameter	$V_{penstock}$	Surge Shaft Diameter	Surge Shaft Height	Installed Capacity	Energy Generation	Free Flow Tunnel Construction Cost	Box Channel Construction Cost	Power Tunnel Construction Cost	Surge Shaft Construction Cost	Penstock Construction Cost	Powerhouse Construction Cost	E - M Equipment Construction Cost	Total Construction Cost	Facility Cost	Project Cost	Interest During Construction	Investment Cost	Operation & Maintenance Cost	Replacement Cost	Interest & Amortization Cost	Total Annual Cost	Annual Benefit	Marginal Net Benefit
(m^3/s)	(m)	(m)	(m)	(m/s)	(m)	(m)	(MWe)	(GWh)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR)	(PKR/year)	(PKR/year)	(PKR/year)	(PKR/year)	(PKR/year)	(PKR/year)
			4.100	6.06			49.56	263.53					142,819,306	317,214,878	1,982,592,985	15,180,234,802	15,939,246,542	16,417,423,938	2,717,230,135	19,134,654,073	114,679,202	7,368,572	2,069,526,484	2,191,574,257	2,898,780,548	707,206,290
80.00	6.50	5.95	4.300	5.51	14.00	74	49.69	264.02	2,209,984,313	506,519,453	9,588,098,364	433,005,503	159,204,611	318,034,948	1,987,718,424	15,202,565,616	15,962,693,896	16,441,574,713	2,721,227,304	19,162,802,017	103,510,212	7,345,161	2,072,570,851	2,183,426,224	2,904,205,038	720,778,813
			4.500	5.03			49.79	264.39					167,862,194	318,645,506	1,991,534,412	15,215,649,744	15,976,432,231	16,455,725,198	2,723,569,336	19,179,294,534	103,758,534	7,363,608	2,074,354,615	2,185,476,757	2,908,243,674	722,766,918
			4.100	6.06			50.45	266.94					142,819,306	322,885,313	2,018,033,207	15,755,287,335	16,543,051,702	17,039,343,253	2,820,163,331	19,859,506,584	117,896,597	7,505,877	2,147,923,588	2,273,326,061	2,936,288,579	662,962,518
80.00	6.50	6.20	4.300	5.51	13.40	75	50.58	267.43	2,209,984,313	506,519,453	10,160,806,468	394,239,275	159,204,611	323,705,383	2,023,158,646	15,777,618,149	16,566,499,057	17,063,494,028	2,824,160,499	19,887,654,528	106,727,607	7,482,466	2,150,967,955	2,265,178,028	2,941,713,069	676,535,041
			4.500	5.03			50.67	267.80					167,862,194	324,315,941	2,026,974,634	15,790,702,278	16,580,237,391	17,077,644,513	2,826,502,531	19,904,147,044	106,975,929	7,500,913	2,152,751,719	2,267,228,561	2,945,751,706	678,523,145
			4.100	6.06			51.37	270.46					142,819,306	328,750,381	2,054,689,882	16,589,459,377	17,418,932,346	17,941,500,317	2,969,478,373	20,910,978,690	122,499,700	7,653,411	2,261,646,541	2,391,799,652	2,975,084,040	583,284,388
80.00	6.50	6.55	4.300	5.51	12.60	76	51.50	270.96	2,209,984,313	506,519,453	10,989,025,662	357,670,380	159,204,611	329,570,451	2,059,815,321	16,611,790,192	17,442,379,701	17,965,651,092	2,973,475,542	20,939,126,634	111,330,710	7,630,000	2,264,690,909	2,383,651,619	2,980,508,530	596,856,911
			4.500	5.03			51.59	271.32					167,862,194	330,181,009	2,063,631,309	16,624,874,320	17,456,118,036	17,979,801,577	2,975,817,574	20,955,619,151	111,579,032	7,648,447	2,266,474,672	2,385,702,152	2,984,547,167	598,845,015
			4.250	5.99			52.76	274.26					156,971,783	337,655,487	2,110,346,794	15,786,836,782	16,576,178,621	17,073,463,980	2,825,810,615	19,899,274,595	119,784,741	7,837,561	2,152,224,735	2,279,847,036	3,016,845,412	736,998,375
85.00	6.65	6.10	4.450	5.47	14.50	74	52.88	274.72	2,281,963,073	515,056,302	9,929,972,261	454,871,082	165,817,345	338,442,875	2,115,267,970	15,801,390,908	16,591,460,454	17,089,204,267	2,828,415,773	19,917,620,041	120,056,274	7,860,014	2,154,208,903	2,282,125,192	3,021,900,568	739,775,376
			4.650	5.01			52.97	275.06					183,190,938	339,034,976	2,118,968,603	15,823,057,236	16,614,210,097	17,112,636,400	2,832,294,000	19,944,930,401	120,485,622	7,883,076	2,157,162,681	2,285,531,378	3,025,701,951	740,170,573
			4.250	5.99	13.70		53.83	278.24					156,971,783	344,481,764	2,153,011,026	16,503,556,309	17,328,734,124	17,848,596,148	2,954,101,905	20,802,698,052	123,857,004	8,003,417	2,249,935,347	2,381,795,768	3,060,671,185	678,875,418
85.00	6.65	6.40	4.450	5.47	13.70	76	53.95	278.70	2,281,963,073	515,056,302	10,630,406,466	421,665,895	165,817,345	345,269,152	2,157,932,202	16,518,110,435	17,344,015,956	17,864,336,435	2,956,707,063	20,821,043,498	124,128,537	8,025,870	2,251,919,516	2,384,073,923	3,065,726,342	681,652,419
			4.650	5.01	13.70		54.04	279.05					183,190,938	345,861,254	2,161,632,835	16,539,776,762	17,366,765,600	17,887,768,568	2,960,585,290	20,848,353,858	124,557,884	8,048,932	2,254,873,294	2,387,480,110	3,069,527,724	682,047,615
			4.250	5.99			54.73	281.62					156,971,783	350,264,626	2,189,153,913	17,354,803,340	18,222,543,507	18,769,219,812	3,106,473,335	21,875,693,146	128,548,677	8,149,546	2,365,986,139	2,502,684,362	3,097,798,069	595,113,707
85.00	6.65	6.75	4.450	5.47	13.20	75	54.85	282.08	2,281,963,073	515,056,302	11,475,391,406	386,002,236	165,817,345	351,052,014	2,194,075,090	17,369,357,466	18,237,825,339	18,784,960,099	3,109,078,493	21,894,038,592	128,820,210	8,171,999	2,367,970,308	2,504,962,518	3,102,853,226	597,890,708
			4.650	5.01			54.94	282.42					183,190,938	351,644,116	2,197,775,722	17,391,023,793	18,260,574,983	18,808,392,232	3,112,956,720	21,921,348,952	129,249,557	8,195,061	2,370,924,086	2,508,368,704	3,106,654,608	598,285,904
			4.350	6.06			56.15	284.40					161,226,800	359,349,823	2,245,936,396	16,526,717,909	17,353,053,804	17,873,645,418	2,958,247,782	20,831,893,201	125,609,259	8,331,575	2,253,092,976	2,387,033,809	3,128,441,915	741,408,106
90.00	6.80	6.30	4.550	5.54	14.80	75	56.27	284.86	2,355,003,100	526,428,841	10,394,107,307	484,665,642	169,912,700	360,159,042	2,250,994,013	16,541,270,644	17,368,334,176	17,889,384,202	2,960,852,691	20,850,236,893	125,879,817	8,354,417	2,255,076,955	2,389,311,189	3,133,449,118	744,137,929
			4.800	4.97			56.39	285.28					189,965,087	360,900,372	2,255,627,325	16,566,697,674	17,395,032,558	17,916,883,535	2,965,404,076	20,882,287,611	126,381,676	8,382,312	2,258,543,431	2,393,307,418	3,138,036,246	744,728,828
			4.350	6.06			57.19	288.14					161,226,800	365,985,701	2,287,410,630	17,253,022,313	18,115,673,429	18,659,143,631	3,088,254,745	21,747,398,376	129,697,815	8,493,486	2,352,110,298	2,490,301,599	3,169,502,736	679,201,136
90.00	6.80	6.60	4.550	5.54	14.20	75	57.31	288.59	2,355,003,100	526,428,841	11,109,417,722	447,549,520	169,912,700	366,794,920	2,292,468,247	17,267,575,048	18,130,953,801	18,674,882,415	3,090,859,654	21,765,742,069	129,968,373	8,516,329	2,354,094,277	2,492,578,979	3,174,509,938	681,930,959
			4.800	4.97			57.43	289.01					189,965,087	367,536,249	2,297,101,559	17,293,002,078	18,157,652,182	18,702,381,748	3,095,411,039	21,797,792,787	130,470,232	8,544,223	2,357,560,753	2,496,575,208	3,179,097,066	682,521,858
			4.350	6.06			58.07	291.33					161,226,800	371,661,878	2,322,886,737	18,672,285,703	19,605,899,988	20,194,076,988	3,342,299,910	23,536,376,897	137,320,653	8,650,371	2,545,598,950	2,691,569,974	3,204,625,218	513,055,244
90.00	6.80	6.95	4.550	5.54	13.50	76	58.20	291.78	2,355,003,100	526,428,841	12,531,451,529	403,626,819	169,912,700	372,471,097	2,327,944,354	18,686,838,438	19,621,180,360	20,209,815,771	3,344,904,819	23,554,720,590	137,591,211	8,673,214	2,547,582,930	2,693,847,354	3,209,632,421	515,785,067
			4.800	4.97			58.31	292.20					189,965,087	373,212,427	2,332,577,666	18,712,265,468	19,647,878,742	20,237,315,104	3,349,456,204	23,586,771,308	138,093,070	8,701,109	2,551,049,405	2,697,843,583	3,214,219,548	516,375,965
			4.500	5.97			59.40	293.70					167,862,194	380,143,270	2,375,895,438	17,140,076,087	17,997,079,891	18,536,992,288	3,068,037,608	21,605,029,896	130,648,874	8,804,281	2,336,712,301	2,476,165,455	3,230,698,864	754,533,409
95.00	6.95	6.45	4.700	5.48	15.10	76	59.52	294.12	2,427,128,242	534,932,165	10,749,008,346	505,106,431	185,611,905	380,914,554	2,380,715,961	17,163,417,604	18,021,588,484	18,562,236,139	3,072,215,690	21,634,451,829	131,105,639	8,831,509	2,339,894,458	2,479,831,606	3,235,314,261	755,482,655
			4.900	5.04			59.61	294.44					194,341,330	381,503,428	2,384,396,428	17,176,416,371	18,035,237,189	18,576,294,305	3,074,542,442	21,650,836,747	131,353,108	8,849,519	2,341,666,584	2,481,869,211	3,238,838,115	756,968,904
			4.500	5.97			60.45	297.37					167,862,194	386,888,963	2,418,056,017	17,875,654,358	18,769,437,076	19,332,520,188	3,199,704,573	22,532,224,761	134,780,277	8,968,808	2,436,993,933	2,580,743,018	3,271,065,404	690,322,386
95.00	6.95	6.75	4.700	5.48	14.60	75	60.57	297.79	2,427,128,242	534,932,165	11,475,391,406	465,395,371	185,611,905	387,660,246	2,422,876,539	17,898,995,875	18,793,945,669	19,357,764,039	3,203,882,655	22,561,646,694	135,237,043	8,996,037	2,440,176,090	2,584,409,169	3,275,680,801	691,271,632
			4.900	5.04			60.66	298.11					194,341,330	388,249,121	2,426,557,006	17,911,994,642	18,807,594,374	19,371,822,205	3,206,209,407	22,578,031,612	135,484,512	9,014,047	2,441,948,216	2,586,446,774	3,279,204,655	692,757,881
			4.500	5.97			61.47	300.91					167,862,194	393,388,572	2,458,678,577	19,459,546,782	20,432,524,121	21,045,499,844	3,483,217,989	24,528,717,833	143,349,497	9,147,502	2,652,926,516	2,805,423,515	3,309,959,373	504,535,858
95.00	6.95	7.15	4.700	5.48	13.80	76	61.59	301.32	2,427,128,242	534,932,165	13,051,566,497	425,990,534	185,611,905	394,159,856	2,463,499,099	19,482,888,298	20,457,032,713	21,070,743,695	3,487,396,071	24,558,139,766	143,806,263	9,174,730	2,656,108,673	2,809,089,666	3,314,574,770	505,485,105
			4.900	5.04			61.68	301.65					194,341,330	394,748,731	2,467,179,566	19,495,887,065	20,470,681,419	21,084,801,861	3,489,722,823	24,574,524,684	144,053,731	9,192,740	2,657,880,799	2,811,127,271	3,318,098,624	506,971,353
			4.600	6.02			62.83	303.77					181,031,184	402,136,918	2,513,355,740	17,910,405,685	18,805,925,969	19,370,103,749	3,205,924,987	22,576,028,736	136,753,347	9,310,474	2,441,731,593	2,587,795,415	3,341,464,864	753,669,449
100.00	7.10	6.65	4.800	5.53	15.50	76	62.96	304.18	2,504,269,334	543,635,614	11,230,974,735	535,002,160	189,965,087	402,921,834	2,518,261,461	17,925,030,226	18,821,281,737	19,385,920,189	3,208,542,749	22,594,462,939	137,026,466	9,332,924	2,443,725,361	2,590,084,752	3,346,009,132	755,924,380
			5.050	4.99			63.07	304.57					201,223,431	403,652,564	2,522,828,524	17,941,586,362	18,838,665,681	19,403,825,651	3,211,506,263	22,615,331,914	137,342,495	9,355,519	2,445,982,465	2,592,680,479	3,350,239,693	757,559,214
			4.600	6.02			63.85	307.20					181,031,184	408,647,856	2,554,049,102	19,217,000,941	20,177,850,988	20,783,186,518	3,439,802,793	24,222,989,310	143,858,735	9,483,025	2,619,860,161	2,773,201,920	3,379,159,937	605,958,017
100.00	7.10	6.95	4.800	5.53	15.00	75	63.97	307.61	2,504,269,334	543,635,614	12,531,451,529	493,916,322	189,965,087	409,432,772	2,558,954,824	19,231,625,482	20,193,206,756	20,799,002,958	3,442,420,555	24,241,423,513	144,131,853	9,505,475	2,621,853,929	2,775,491,258	3,383,704,205	608,212,948
			5.050	4.99			64.09	307.99					201,223,431	410,163,502	2,563,521,886	19,248,181,618	20,210,590,699	20,816,908,420	3,445,384,069	24,262,292,489	144,447,882	9,528,070	2,624,111,033	2,778,086,985	3,387,934,766	609,847,782
			4.600	6.02			64.74	310.17					181,031,184	414,304,622	2,589,403,887	20,137,525,190	21,144,401,450	21,778,733,493	3,604,574,699	25,383,308,192	148,895,655	9,627,992	2,745,355,539	2,903,879,186	3,411,909,780	508,030,594
100.00	7.10	7.30	4.800	5.53	14.40	75	64.86	310.59	2,504,269,334	543,635,614	13,448,441,469	456,439,079	189,965,087	415,089,537	2,594,309,609	20,152,149,731	21,159,757,217	21,794,549,934	3,607,192,461	25,401,742,395	149,168,773	9,650,442	2,747,349,308	2,906,168,523	3,416,454,048	510,285,525
			5.050	4.99			64.97	310.97					201,223,431	415,820,267	2,598,876,672	20,168,705,867	21,177,141,161	21,812,455,395	3,610,155,975	25,422,611,371	149,484,802	9,673,037	2,749,606,411	2,908,764,250	3,420,684,609	511,920,359
			4.700	6.05			66.09	310.83					185,611,905	423,002,415	2,643,765,096	18,508,055,276	19,433,458,039	20,016,461,780	3,312,903,008	23,329,364,789	141,654,148	9,783,258	2,523,209,361	2,674,646,767	3,419,092,643	744,445,876
105.00	7.20	6.80	4.950	5.46	15.80	76	66.24	311.31	2,554,966,971	552,208,730	11,598,807,503	549,692,656	196,807,279	423,965,886	2,649,786,791	18,526,235,815	19,452,547,606	20,036,124,034	3,316,157,287	23,352,281,321	141,994,209	9,810,947	2,525,687,920	2,677,493,076	3,424,415,320	746,922,244
			5.150	5.04			66.33	311.60					216,118,902	424,542,159	2,653,388,496	18,549,725,417	19,477,211,688	20,061,528,038	3,320,361,876	23,381,889,914	142,462,531	9,834,776	2,528,890,265	2,681,187,572	3,427,598,929	746,411,356
			4.700	6.05			67.12	314.12					185,611,905	429,565,797	2,684,786,228	19,851,333,231	20,843,899,892	21,469,216,889	3,553,346,940	25,022,563,829	149,032,910	9,957,802	2,706,338,894	2,865,329,605	3,455,351,914	590,022,309
105.00	7.20	7.10	4.950	5.46	15.40	75	67.27	314.61	2,554,966,971	552,208,730	12,920,906,090	523,287,511	196,807,279	430,529,268	2,690,807,923	19,869,513,770	20,862,989,459	21,488,879,142	3,556,601,218	25,045,480,361	149,372,971	9,985,491	2,708,817,453	2,868,175,914	3,460,674,591	592,498,677
			5.150	5.04			67.36	314.90					216,118,902	431,105,541	2,694,409,628	19,893,003,372	20,887,653,541	21,514,283,147	3,560,805,808	25,075,088,954	149,841,293	10,009,320	2,712,019,798	2,871,870,410	3,463,858,199	591,987,789
			4.700	6.05			68.12	317.35					185,611,905	435,990,939	2,724,943,370	21,478,517,368	22,552,443,237	23,229,016,534	3,844,609,482	27,073,626,015	157,804,152	10,135,864	2,928,173,451	3,096,113,466	3,490,847,489	394,734,023
105.00	7.20	7.50	4.950	5.46	14.70	75	68.27	317.83	2,554,966,971	552,208,730	14,544,718,736	480,076,718	196,807,279	436,954,410	2,730,965,065	21,496,697,908	22,571,532,803	23,248,678,787	3,847,863,760	27,096,542,547	158,144,213	10,163,552	2,930,652,010	3,098,959,775	3,496,170,166	397,210,391
			5.150	5.04			68.36	318.12					216,118,902	437,530,683	2,734,566,770	21,520,187,510	22,596,196,885	23,274,082,792	3,852,068,350	27,126,151,141	158,612,535	10,187,382	2,933,854,355	3,102,654,271	3,499,353,775	396,699,503
			4.850	5.95			69.41	318.14					192,150,317	444,216,394	2,776,352,463	19,720,233,850	20,706,245,543	21,327,432,909	3,529,880,426	24,857,313,335	149,937,672	10,278,910	2,688,466,071	2,848,682,654	3,499,495,278	650,812,624
110.00	7.35	6.95	5.050	5.49	16.10	77	69.53	318.50	2,631,898,570	560,892,978	12,531,451,529	583,271,599	211,217,947	444,968,544	2,781,053,403	19,744,754,570	20,731,992,298	21,353,952,067	3,534,269,584	24,888,221,651	150,420,030	10,306,476	2,691,808,989	2,852,535,495	3,503,462,039	650,926,543
			5.300	4.99			69.64	318.84					223,469,838	445,679,002	2,785,493,762	19,762,157,277	20,750,265,140	21,372,773,095	3,537,384,631	24,910,157,726	150,754,715	10,329,196	2,694,181,506	2,855,265,417	3,507,208,916	651,943,498
			4.850	5.95			70.44	321.30					192,150,317	450,807,225	2,817,545,159	20,508,497,541	21,533,922,418	22,179,940,090	3,670,977,971	25,850,918,061	154,315,341	10,441,264	2,795,930,324	2,960,686,929	3,534,254,623	573,567,695
110.00	7.35	7.25	5.050	5.49	15.60	76	70.56	321.66	2,631,898,570	560,892,978	13,315,330,008	539,873,283	211,217,947	451,559,376	2,822,246,099	20,533,018,260	21,559,669,173	22,206,459,248	3,675,367,128	25,881,826,376	154,797,698	10,468,830	2,799,273,242	2,964,539,770	3,538,221,384	573,681,614
			5.300	4.99			70.67	322.00					223,469,838	452,269,833	2,826,686,458	20,550,420,967	21,577,942,015	22,225,280,276	3,678,482,176	25,903,762,452	155,132,384	10,491,550	2,801,645,758	2,967,269,692	3,541,968,261	574,698,569
			4.850	5.95			71.56	324.73					192,150,317	457,968,800	2,862,304,998	22,308,572,583	23,424,001,212	24,126,721,248	3,993,187,621	28,119,908,869	164,056,439	10,639,421	3,041,335,156	3,216,031,015	3,572,024,006	355,992,991
110.00	7.35	7.70	5.050	5.49	15.10	75	71.68	325.09	2,631,898,570	560,892,978	15,104,792,752	498,564,168	211,217,947	458,720,950	2,867,005,937	22,333,093,302	23,449,747,967	24,153,240,406	3,997,576,778	28,150,817,185	164,538,796	10,666,987	3,044,678,074	3,219,883,857	3,575,990,767	356,106,910
			5.300	4.99			71.79	325.43					223,469,838	459,431,407	2,871,446,296	22,350,496,009	23,468,020,809	24,172,061,434	4,000,691,826	28,172,753,260	164,873,481	10,689,707	3,047,050,591	3,222,613,779	3,579,737,644	357,123,866

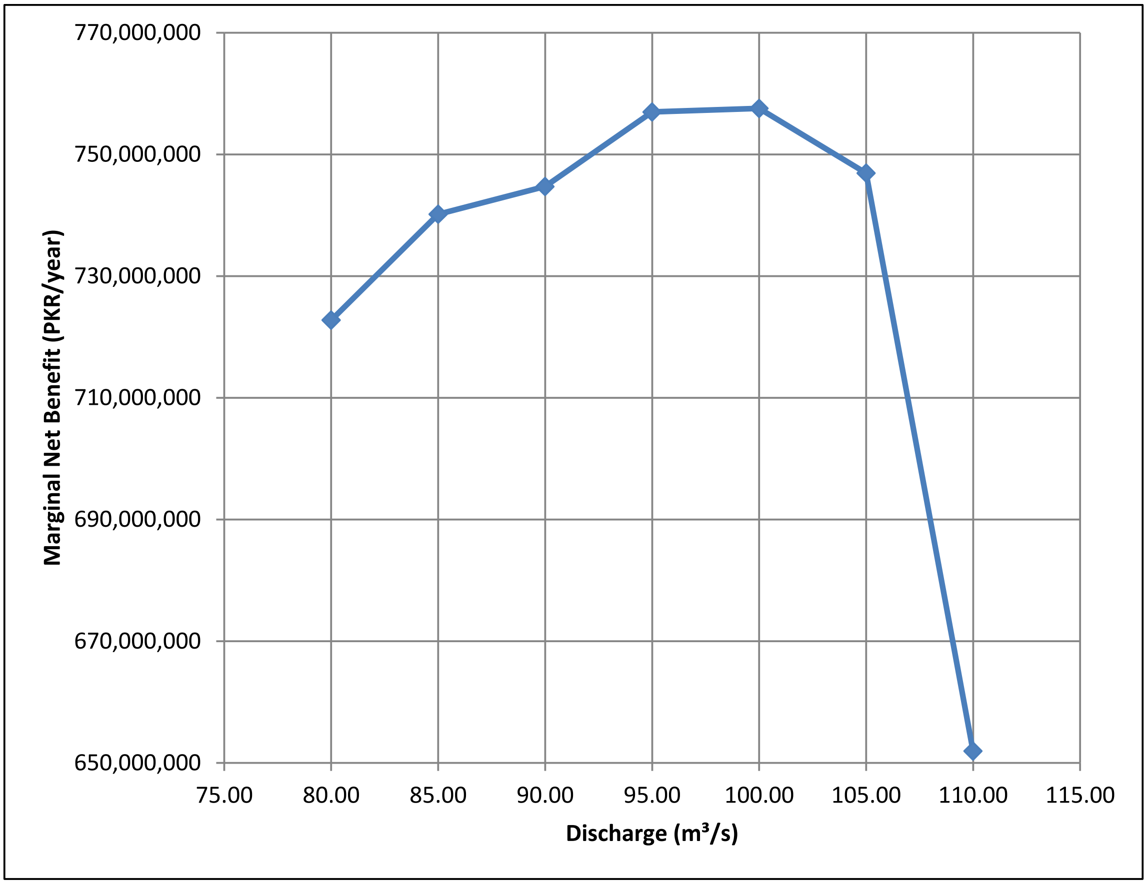

Figure 7.3 : Optimization Graph for Artistic-I HPP

Table 7.14 : Best Options for Design Discharge Alternatives

Q_d (m^3/s)	Diameter of Free Flow Tunnel (m)	Diameter of Power Tunnel (m)	Diameter of Penstock (m)	Diameter of Surge Shaft (m)	Box Channel Width (m)	Box Channel Height (m)	Installed Capacity (MW)	Average Energy Generation (GWh/year)	Marginal Net Benefit (PKR/year)
80	6.50	5.95	4.50	14.00	5.45	4.60	49.788	264.386	722,766,918
85	6.65	6.10	4.65	14.50	5.55	4.70	52.974	275.064	740,170,573
90	6.80	6.30	4.80	14.80	5.70	4.80	56.391	285.276	744,728,828
95	6.95	6.45	4.90	15.10	5.80	4.90	59.610	294.440	756,968,904
100	7.10	6.65	5.05	15.50	5.90	5.00	63.071	304.567	757,559,514
105	7.20	6.80	4.95	15.80	6.00	5.10	66.245	311.310	746,922,244
110	7.35	6.95	5.30	16.10	6.10	5.20	69.637	318.837	651,943,498

7.7 CONCLUSIONS

It is pertinent to mention here that the costs listed in **Table** 7.13 are not the overall cost of the project. As can be seen from the attached drawing, the other components of the project such as the diversion system and the weir, intake, sand trap, box channel between sand trap and forebay, forebay, Kotkay Khwar passage, valve chamber, adit tunnel, access bridges, access roads and service roads for construction activities and material hauling, site camp buildings, land acquisition and energy transmission line etc., haven't been included in the optimization study since these facilities do not affect the study or the effect is ignorable.

As can be seen from **Table** 7.13 and **Table** 7.14, by this detailed study, the design discharge, diameters of free flow tunnel, power tunnel, penstock and surge shaft, dimensions of box channel and consequently the installed capacity of the power plant, have been optimized at once.

The proposed characteristics due optimization study for final dimensioning are as under:

Box Channel:

Type of cross section	: Rectangular. reinforced concrete
Flow regime	: Open channel. subcritical
Capacity	: 110 m^3/s
Bottom Slope	: 0.0004
Manning's "n" for concrete	: 0.014
Width	: 5.90 m
Water depth at full capacity	: 4.45 m
Freeboard	: 0.55 m
Height	: 5.00 m
Velocity of water at full capacity	: 2.09 m/s
Length of channel	: 617 m

Free Flow Tunnel:

Type of internal cross section	: D-shaped, reinforced concrete
Type of excavation cross section	: D-shaped
Diameter of internal cross section	: 7.10 m
Diameter of excavation cross section	: 8.20 m
Bottom slope of tunnel	: 0.0005
Length of tunnel	: 1583 m

Power Tunnel:

Type of internal cross section	: Horseshoe, reinforced concrete
Type of excavation cross section	: D-shaped
Diameter of internal cross section	: 6.65 m
Diameter of excavation cross section	: 7.95 m

Bottom slope of tunnel (between tunnel inlet and Kotkay Khwar): 0.001

Bottom slope of tunnel (between Kotkay Khwar and valve chamber): 0.009

Length of tunnel	: 7480 m

Surge Tank:

Type of internal cross section	: Circular, reinforced concrete
Type of excavation cross section	: Circular
Diameter of internal cross section	: 15.50 m
Diameter of excavation cross section	: 18.10 m
Height of surge shaft	: 76 m (above tunnel crown)

Penstock:

Length	: 156 m
Diameter	: 5.05 m
Pipe wall thickness	: 10 mm ~ 15 mm
At the end	: Trifurcation

Power House:

Tailwater level	: 990.00 m
Gross head from Artistic-I Weir	: 81.00 m
Gross head from forebay	: 79.33 m
Net head (at design discharge)	: 70.50 m
Turbines	: 3 Nos. (2 Large + 1 Small)
Design discharge	: 100 m^3/s (2 x 37.50 + 1 x 25.00) m^3/s
Type of turbines	: Vertical Francis
Assumed rated efficiencies	: 0.94 x 0.98 x 0.99 (Trbn., Gen., Tr.)
Installed Capacity	: 63.071 MWe
Average Annual Energy Generation	: 304.567 GWh

Power Planners International

63 MW Artistic-1 Hydropower Project by Artistic Hydro-I Private Limited at Panjkora River, District Upper Dir, KPK

Report No. PPI-334.2-Final/20

www.powerplannersint.com

Interconnection Study of 63 MW Artistic-1 Hydropower Project

By

Artistic Hydro-I Private Limited at Panjkora River, District Upper Dir, Khyber Pukhtunkhwa

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2	07/07/2020	Mujahid Ali Zaidi	Samreen Fatima Shirazi	Revised based on PESCO Comments received vide letter no. **CE (Dev)/4444-45 dated 22-06-2020**

Executive Summary

- The Final Report of 63 MW Artistic-1 Hydro Power Project by Artistic Milliners Pvt. Ltd. at District Upper Dir, Khyber Pakhtunkhwa, referred to as Artistic-1 HPP in the remainder of the report, is submitted herewith after incorporating comments received from PESCO vide letter no. CE (Dev)/4444-45 dated 22-06-2020
- The updated transmission plan and load forecast from PESCO has been used for the study, vide data permission letter no.GM (Tech)/Dev 5596-99 dated 08-10-2019.
- The study objective, approach and methodology have been described and the plant's data received from the Client is validated.
- A couple of options were investigated for the interconnection of this project. One possible interconnection scheme is to connect the plant to 132 kV Warai Grid but due to the unavailability of line bays at Warai, this scheme was dropped. Another possible point of interconnection is a 132 kV grid proposed by PESCO at Munda.
- The possibility of connecting Artistic-1 HPP to Munda 132 kV Grid Station via 40 km double circuit has been investigated in this report.
- In view of planned COD of Artistic-1 HPP in June, 2026, the proposed interconnection schemes has been assessed for steady state conditions through detailed load flow studies for summer 2026.
- Steady state analysis by load flow reveals that the proposed scheme is adequate to evacuate the maximum power of 63 MW of the plant under normal conditions and no constraints are caused by the interconnection of Artistic-1 HPP in the 132 kV network of PESCO in the load flow scenarios of summer 2026.
- The short circuit levels of the Artistic-1 HPP 132 kV are 5.43 kA and 1.79 kA for 3-phase and 1-phase faults, respectively, in the year 2025-26. Therefore, industry standard switchgear of a short circuit rating of 40 kA would be sufficient for installation at 132 kV switchyard of Artistic-1 HPP, as the maximum short circuit levels for the year 2025-26 were also found to be well within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 132 kV switchgears. There are no violations of the power rating of the equipment in the vicinity of Artistic-1 HPP in the event of fault conditions.

- The dynamic stability analysis of proposed schemes of interconnection has been carried out. The stability has been tested for the worst cases, i.e. three phase fault right on the132 kV bus bar of Artistic-1 HPP substation followed by trip of a 132 kV single circuit from Artistic-1 HPP has been performed for fault clearing of 5 cycles (100 ms), as understood to be the normal fault clearing time of 132 kV protection system. Also the extreme worst case of stuck breaker (breaker failure) has been studied where the fault clearing time is assumed 9 cycles i.e. 180 ms for single phase fault. The stability of the system for far end faults of 3-phase occurring at Artistic-1 132 kV bus bar has also been checked. The system is stable for all the tested fault conditions.
- The proposed scheme of interconnection have been subjected to Load Flow, Short Circuit and Dynamic Stability Analysis and found to be feasible for interconnection of Artistic-1 HPP with the PESCO network.

TABLE OF CONTENTS

1. Introduction

1.1. Background

Khyber Pakhtunkhwa has a rich potential of small and big hydropower projects in the province. A lot of private investors are coming in to tap this huge natural resource. Artistic Hydro-I Pvt. Ltd. is one such investor which plans to develop a 63 MW hydropower plant at Munda, Upper Dir. The project site is located about 40 km from Munda G/S. The net output planned to be generated from the site is about 63 MW of electrical power. The electricity generated from this project would be supplied to the grid system of NTDC through 132 kV grid of PESCO available in the vicinity of this project. Artistic-1 HPP is expected to start commercial operation by June 2026. The approximate location of Artistic-1 HPP can be seen in the map attached in Appendix – B and the neighboring network is evident from Sketch-2 attached in Appendix - B.

1.2. Objectives

The overall objective of the Study is to evolve an interconnection scheme between Artistic-1 HPP and PESCO network, for stable and reliable evacuation of 63 MW of electrical power generated from this plant, fulfilling the N-1 reliability criteria. The specific objectives of this report are:

- To develop scheme of interconnections at 132 kV for which right of way (ROW) and space at the terminal substations would be available.
- To determine the performance of interconnection scheme during steady state conditions of system, normal and N-1 contingency, through load-flow analysis.
- To check if the contribution of fault current from the plant unit increases the fault levels at the adjoining substations at 132 kV voltage levels to be within the rating of equipment of these substations, and also determine the short circuit ratings of the proposed equipment of the substation at Artistic-1 HPP.
- To check if the interconnection withstands dynamic stability criteria of post fault recovery with good damping.

1.3. Planning Criteria

The planning criteria required to be fulfilled by the proposed interconnection is as follows:

Steady State:

Voltage	± 5 %, Normal Operating Condition
	± 10 %, Contingency Conditions
Frequency	50 Hz Nominal
	49.8 Hz to 50.2 Hz variation in steady state
	49.4 - 50.5 Hz, Min/Max Contingency Freq. Band
Power Factor	0.80 Lagging; 0.85 Leading

Short Circuit:

132 kV Substation Equipment Rating of 40 kA

Dynamic/Transient:

The system should revert to normal condition after transients die out with good damping, without losing synchronism. The system is tested under the following fault conditions:

a) Permanent three-phase fault on any primary transmission element; including: transmission circuit, substation bus section, transformer or circuit breaker. It is assumed that such a fault shall be cleared by the associated circuit breaker action in 5 cycles.

b) Failure of a circuit breaker to clear a fault ("Stuck Breaker" condition) in 9 cycles after fault initiation.

2. Assumptions of Data

As per the data provided by the client following data has been modeled:

2.1. Artistic-1 HPP Data

No. of Units	= 3
Gross Capacity of Power Project	= 72.167 MW [(27.003×2) + (18.161×1)]
Net Capacity of the Power Project	= 63.071 MW [(23.652×2) + (15.767×1)]
Lump sum MVA capacity	= 91 MVA
Generating Voltage	= 11 KV

The difference between the installed capacity (Maximum Output) and net capacity (Actual Output) of plants can be explained through the following argument:

P = 9.81 x ηTu. x ηG x ηTr. x Q x Hnet

Where:

P : Power generation (kWe, "e": electrical power)

ηTu. : Turbine efficiency (Accepted as 0.94)

ηG : Generator efficiency (Accepted as 0.98)

ηTr. : Transformer efficiency (Accepted as 0.99)

Q : Design discharge (m3/s)

Hnet : Net head with respect to Q (m)

In Artistic-1 project, the design discharges of large units and small unit were selected as 37.5 m3/s and 25.0 m3/s, respectively .Hence

Units	Discharge (m^3/s)	Hnet (m)	Power (MWe
All Units	100.0	70.50	63.07
Large Units (2	37.5	~70.5	23.65
Small Unit	25.0	~70.5	15.76

The detailed parameters, which have been used in this study, for all the machines are attached in Appendix – B.

2.2. Network Data

The 132 kV network in the area near Artistic-1 HPP, is shown in Sketches in Appendix-B. The latest Generation Expansion Plan and Load Forecast of NTDC, as available, and latest network data and load forecast of PESCO, vide data permission letter no. GM (Tech)/DEV 5596-99 dated 08-10-2019 has been used as shown in Appendix-A.

3. Study Approach and Methodology

3.1. Understanding the Problem

Artistic Milliners Pvt. Limited is developing a hydropower project in the Upper Dir on River Panjkora with the aim of exporting a maximum of 63 MW supply to the grid. The site of proposed project is located at a distance of about 40 km from the proposed 132 kV Munda G/S. The Munda G/S is expected to loop in-out between Timergara 132 kV G/S and Khar Bajawar 132 kV G/S. The proposed Artistic-1 Hydropower Project is going to be embedded in the transmission network of PESCO through this nearest available 132 kV network.

The adequacy of PESCO network of 132 kV in and around the proposed site of Artistic-1 HPP has been investigated in this study for absorbing and transmitting this power fulfilling the reliability criteria.

3.2. Approach to the Problem

The following approach has been applied to the problem:

- The scenario of summer 2026 has been selected for the study of Artistic-1 HPP. Thus, lines in the vicinity of this plant will be loaded to the maximum extent, allowing us to judge the complete impact of the plant on the transmission system in its vicinity.
- The scenario of summer 2026 has also been completely analyzed for the system, considering maximum hydel dispatches and the maximum power demand in the system.
- An interconnection scheme without any physical constraints, such as right of way or availability of space in the terminal substations, have been identified.
- Technical system studies have been conducted for peak load conditions, to confirm technical feasibility of the interconnection. The schemes will be subjected to standard analyses such as load flow, short circuit, and transient stability to gauge the strength of the machines and the proposed interconnection under disturbed conditions.

4. Development of Interconnection Scheme

4.1. The Existing Network and the Proposed Scheme of Interconnection

The existing 132 kV network available around the proposed location of Artistic-1 HPP is shown in Sketch-1 in Appendix-B.

Two grid stations were considered for interconnection of Artistic-1 HPP i.e. 132 kV grid stations of Warai and Munda.

A direct connection to Warai 132 kV grid station is not possible due to unavailability of line bays at the grid station.

The connection to Munda is possible with reasonable line length. Artistic-1 can be connected to Munda with a 40 km double circuit. The conductor for the scheme is Lynx, so that power can easily be evacuated even during N-1 contingency.

Hence, this scheme of interconnection has been studied for load flow analysis in this report.

5. Detailed Load Flow Studies

The base cases have been developed for the peak conditions of summer 2026 using the network data of NTDC available with PPI and the updated transmission plan and load forecast of PESCO. Detailed load flow studies have been carried out for summer 2026. The plant has been modelled in detail according to the client provided information mentioned in Chapter- 2 and attached in Appendix - B.

5.1. Peak Load Flow Case Summer 2026

5.1.1. Peak Load Flow Case Summer 2026 – Without Artistic-1 HPP

The results of load flow for this base case are plotted in Exhibit 0.0 of Appendix-C. The system plotted in this Exhibit shows 132 kV network in the vicinity of Artistic-1 HPP including the 132 kV substations of Munda, Khar Bajawar, Chakdara, Timergara, etc.

The load flow results show that the power flows on all circuits are within their specified normal current carrying rating. The voltages are also within the permissible limits.

N-1 contingency analysis has been carried out and the plotted results are attached in Appendix – C as follows:

Exhibit-0.1 Munda to Khar Bajawar 132 kV Single Circuit

Exhibit-0.2 Munda to Timergara 132 kV Single Circuit

Exhibit-0.3 Timergara to Koto 132 kV Single Circuit

Exhibit-0.4 Timergara to Chakdara 132 kV Single Circuit

Exhibit-0.5 Timergara to Chakdara New 132 kV Single Circuit

5.1.2. Peak Load Flow Case Summer 2026 – With Artistic-1 HPP

The results of load flow for the base case with Artistic-1 HPP interconnected are shown in Exhibit 1.0 of Appendix-C. The power flows on the circuits under normal conditions are seen well within the rated capacities. Also, the voltages on the bus bars are within the permissible operating range of ± 5 % off the nominal

We find no capacity constraints on the 132 kV circuits under normal conditions i.e. without any outages of circuits as shown in Exhibit 1.0 in Appendix - C

N-1 contingency analysis has been carried out and the plotted results are attached in Appendix – C as follows:

Exhibit-1.1 Artistic-1 to Munda 132 kV Single Circuit

Exhibit-1.2 Munda to Khar Bajawar 132 kV Single Circuit

Exhibit-1.3 Munda to Timergara 132 kV Single Circuit

Exhibit-1.4 Timergara to Koto 132 kV Single Circuit

Exhibit-1.5 Timergara to Chakdara 132 kV Single Circuit

Exhibit-1.6 Timergara to Chakdara New 132 kV Single Circuit

We find that power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 10 % off the nominal for contingency conditions' criteria. We find no capacity constraints on 132 kV circuits under normal and contingency conditions.

5.2. Off- Peak Load Flow Case Summer 2026

An off-peak case has been developed from the peak 2026 case considering 80% loads and off-peak hydel dispatches in the system. The normal case for this analysis is shown in Exhibit – 2.0 in Appendix – C.

The power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 5 % off the nominal.

We find no capacity constraints on 132 kV circuits under normal conditions i.e. without any outages of circuits, as shown in Exhibit 2.0 in Appendix - C.

N-1 contingency analysis has been carried out and the plotted results are attached in Appendix – C as follows:

Exhibit-2.1 Artistic-1 to Munda 132 kV Single Circuit

Exhibit-2.2 Munda to Khar Bajawar 132 kV Single Circuit

Exhibit-2.3 Munda to Timergara 132 kV Single Circuit

Exhibit-2.4 Timergara to Koto 132 kV Single Circuit

Exhibit-2.5 Timergara to Chakdara 132 kV Single Circuit

Exhibit-2.6 Timergara to Chakdara New 132 kV Single Circuit

The power flows on the circuits are seen well within the rated capacities and the voltages on bus bars are also within the permissible operating range of ± 10 % off the nominal for contingency conditions' criteria.

We find that there are no capacity constraints in the proposed connectivity scheme even in the off-peak scenario.

5.3. Conclusion of Load Flow Analysis

From the analysis discussed above, we conclude that the proposed connection of Artistic-1 HPP with PESCO network according to proposed scheme is adequate to evacuate its power under normal as well as contingency conditions. Hence, there are no constraints in connecting Artistic-1 HPP to the proposed 132 kV Munda Grid for the evacuation of 63 MW power.

6. Short Circuit Analysis

6.1.1. Methodology and Assumptions

The methodology of IEC 909 has been applied in all short circuit analyses in this report for which provision is available in the PSS/E software used for these studies.

The maximum fault currents have been calculated with the following assumptions under IEC 909:

- Set tap ratios to unity
- Set line charging to zero
- Set shunts to zero in positive sequence
- Desired voltage magnitude at bus bars set equal to 1.10 P.U. i.e. 10 % higher than nominal, which is the maximum permissible voltage under contingency condition.

For evaluation of maximum short circuit levels we have assumed contribution in the fault currents from all the installed generation capacity of hydel, thermal and nuclear plants in the system in the years 2024 i.e. all the generating units have been assumed on-bar in fault calculation's simulations.

The assumptions about the generator and the transformers data are the same as mentioned in Chapter.2 of this report.

6.1.2. Fault Current Calculations Year 2026 - without Artistic-1 HPP

In order to assess the short circuit strength of the 132 kV network without Artistic-1 HPP, three-phase and single-phase fault currents have been calculated for PESCO in the vicinity of the site of the Plant near Munda. The results are attached in Appendix – D.

The short circuit levels have been calculated and plotted on the bus bars of 132 kV of substations lying in the electrical vicinity of our area of interest and are shown plotted in the Exhibit 3.0 attached in Appendix-D. Both 3-phase and 1-phase fault currents are indicated in the Exhibit 3.0 which are given in polar coordinates i.e. the magnitude and the angle of the current. The total fault currents are shown below the bus bar.

The tabular output of the short circuit calculations is also attached in Appendix-D for the 132 kV and 11 kV bus bars of our interest. The total maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 6.1. We see that the maximum fault currents do not exceed the short circuit ratings of the equipment at these 132 kV substations which normally are 31.5 kA for older substations and 40 kA for new substations.

Table-6.1
Maximum Short Circuit Levels without Artistic-1 HPP – Year 2026

Substation	3-Phase fault current, kA	1-Phase fault current, kA
Munda 132 kV	6.14	1.32
Khar Bajawar 132 kV	4.41	0.77
Timergara 132 kV	9.47	2.58
Koto 132	6.19	1.73
Chakdara 132 kV	17.60	4.89
Chakdara New 132 kV	18.12	4.84
Lal Qila 132 kV	5.78	1.46

6.1.3. Fault Current Calculations Year 2026 - with Artistic-1 HPP

Fault currents have been calculated for the electrical interconnection of proposed scheme. Fault types applied are three phase and single-phase at the 132 kV bus bar of Artistic-1 HPP itself and other bus bars of the 132 kV and 11 kV substations in the electrical vicinity of Artistic-1 HPP. The graphic results are shown in Exhibit 3.1.

The tabulated results of short circuit analysis showing all the fault current contributions with short circuit impedances on 132 kV bus bars of the network in the electrical vicinity of Artistic-1 HPP and the 132 kV bus bars of Artistic-1 HPP itself are placed in Appendix-D. Brief summary of fault currents at significant bus bars of our interest are tabulated in Table 6.2.

Table-6.2
Maximum Short Circuit Levels with Artistic-1 HPP – Year 2026

Substation	3-Phase fault current, kA	1-Phase fault current, kA
Artistic-1 132 kV	5.43	1.79
Munda 132 kV	7.57	1.98
Khar Bajawar 132 kV	4.90	0.93
Timergara 132 kV	10.80	3.02
Koto 132	6.78	1.87
Chakdara 132 kV	18.39	5.08

Chakdara New 132 kV	18.94	5.02
Lal Qila 132 kV	6.17	1.55

Comparison of Tables 6.1 and 6.2 shows an increase in short circuit levels for three-phase and single-phase faults due to connection of Artistic-1 HPP on the 132 kV bus bars in its vicinity. We find that even after some increase, these fault levels are much below the rated short circuit values of the equipment installed on these substations.

6.1.4. Conclusion of Short Circuit Analysis

The short circuit analysis results show that for the proposed scheme of interconnection of Artistic-1 HPP, we don't find any violations of short circuit ratings of the already installed equipment on the 132 kV bus bars in the vicinity of the plant due to fault current contributions from Artistic-1 HPP. Therefore industry standard switchgear of the short circuit rating of 40 kA would serve the purpose as per NTDC requirement taking care of any future generation additions and system reinforcements in its electrical vicinity.

7. Dynamic Stability Analysis

7.1. Assumptions and Methodology

7.1.1. Dynamic Models Assumptions

The assumptions about the generator and its parameters are the same as mentioned in Chapter 2 of this report.

We have employed the generic dynamic models available in the PSS/E model library for dynamic modeling of the generator, exciter and the governor as follows;

Generator	GENSAL
Excitation System	EXST1
Speed Governing System	HYGOV
Power System Stabilizer	STAB2A

7.1.2. Dynamic Models Assumptions

The scenario of summer 2026 has been selected for the study because it represents the peak load season after the COD of Artistic-1 HPP and thus the loading on the lines in the vicinity of Artistic-1 HPP will be maximum, allowing us to judge the full impact of the plant.

The proposed Artistic-1 HPP has been modeled in the dynamic simulation as per data provided by client. All the power plants of WAPDA/NTDC from Tarbela to Hub have been dynamically represented in the simulation model.

7.1.3. Presentation of Results

The plotted results of the simulations runs are placed in Appendix-E. Each simulation is run for its first one second for the steady state conditions of the system prior to fault or disturbance. This is to establish the pre fault/disturbance conditions of the network under study were smooth and steady. Post fault recovery has been monitored for ten seconds. Usually all the transients due to non-linearity die out within a few seconds after disturbance is cleared in the system.

7.1.4. Worst Fault Cases

Four phase faults are considered as the worst disturbance in the system. We have considered 3-phase fault in the closest vicinity of Artistic-1 HPP i.e. right at the 132 kV bus bar of Artistic-1 HPP substation, cleared in 5 cycles, as normal clearing time for 132 kV i.e. 100 ms, followed by a permanent trip of a 132 kV single circuit from Artistic-1 HPP to Munda. Also to fulfil the Grid Code criteria case of stuck breaker (breaker failure) single phase fault has also been studied where the fault clearing time is assumed 9 cycles i.e. 180 ms.

7.2. Dynamic Stability Simulations Results

The detailed parameters used for the Stability Analysis have been tabulated in Appendix – E.

a) Fault at 132 kV Artistic-1 HPP

Fault Type: 3-Phase			
Fault Location: Artistic-1 132 kV bus bar			
Fault Duration: 5 cycles (100 ms)			
Line Tripping: Artistic-1 to Munda 132 kV single circuit			
Variable	**Bus/Line**	**Response**	**Figure No.**
Voltage	1. Artistic-1 11 kV 2. Munda 132 kV 3. Timergara 132 kV 4. Khar Bajawar 132 kV 5. Koto 132 kV 6. Chakdara 132 kV	The voltages of all the bus bars recover after fault clearance	1.1
Frequency	Artistic-1 132 kV	Recovers after fault clearance	1.2
MW/MVAR Output of the Plant	Artistic-1 unit-1 11 kV	Recovers after damping down oscillations	1.3
Speed and $P_{mechanical}$ of the Plant	Artistic-1 unit-1 11 kV	Recovers after damping down oscillations	1.4
Line Flows (MW/MVAR)	Artistic-1 to Munda 132 kV intact single circuit	Attains steady state value after damping of oscillations	1.5
Rotor Angles	1. Artistic-1 11 kV 2. Koto 132 kV 3. Shigo Kas 132 kV 4. Golengol 132 kV 5. Lavi 132 kV 6. G.Brotha 500 kV(reference angle)	Damps down quickly and attain a steady state value	1.6

b) Fault at 132 kV Artistic-1 HPP (Stuck Breaker)

Fault Type: 1-Phase			
Fault Location: Artistic-1 132 kV bus bar			
Fault Duration: 9 cycles (180 ms)			
Line Tripping: Artistic-1 to Munda 132 kV single circuit			
Variable	**Bus/Line**	**Response**	**Figure No.**
Voltage	1. Artistic-1 11 kV 2. Munda 132 kV 3. Timergara 132 kV 4. Khar Bajawar 132 kV 5. Koto 132 kV 6. Chakdara 132 kV	The voltages of all the bus bars recover after fault clearance	2.1
Frequency	Artistic-1 132 kV	Recovers after fault clearance	2.2
MW/MVAR Output of the Plant	Artistic-1 unit-1 11 kV	Recovers after damping down oscillations	2.3
Speed and $P_{mechanical}$ of the Plant	Artistic-1 unit-1 11 kV	Recovers after damping down oscillations	2.4
Line Flows (MW/MVAR)	Artistic-1 to Munda 132 kV intact single circuit	Attains steady state value after damping of oscillations	2.5
Rotor Angles	1. Artistic-1 11 kV 2. Koto 132 kV 3. Shigo Kas 132 kV 4. Golengol 132 kV 5. Lavi 132 kV 6. G.Brotha 500 kV(reference angle)	Damps down quickly and attain a steady state value	2.6

c) Fault at 132 kV Munda HPP

Fault Type: 3-Phase			
Fault Location: Munda 132 kV bus bar			
Fault Duration: 5 cycles (100 ms)			
Line Tripping: Munda to Khar Bajawar 132 kV single circuit			
Variable	**Bus/Line**	**Response**	**Figure No.**
Voltage	1. Artistic-1 11 kV 2. Munda 132 kV 3. Timergara 132 kV 4. Khar Bajawar 132 kV 5. Koto 132 kV 6. Chakdara 132 kV	The voltages of all the bus bars recover after fault clearance	3.1
Frequency	Artistic-1 132 kV	Recovers after fault clearance	3.2
MW/MVAR Output of the Plant	Artistic-1 unit-1 11 kV	Recovers after damping down oscillations	3.3
Speed and $P_{mechanical}$ of the Plant	Artistic-1 unit-1 11 kV	Recovers after damping down oscillations	3.4
Line Flows (MW/MVAR)	Munda to Timergara 132 kV intact single circuit	Attains steady state value after damping of oscillations	3.5
Rotor Angles	1. Artistic-1 11 kV 2. Koto 132 kV 3. Shigo Kas 132 kV 4. Golengol 132 kV 5. Lavi 132 kV 6. G.Brotha 500 kV(reference angle)	Damps down quickly and attain a steady state value	3.6

d) Fault at 132 kV Timergara HPP

<table>
<tr><td colspan="4">Fault Type: 3-Phase</td></tr>
<tr><td colspan="4">Fault Location: Timergara 132 kV bus bar</td></tr>
<tr><td colspan="4">Fault Duration: 5 cycles (100 ms)</td></tr>
<tr><td colspan="4">Line Tripping: Timergara to Chakdara New 132 kV single circuit</td></tr>
<tr><td>Variable</td><td>Bus/Line</td><td>Response</td><td>Figure No.</td></tr>
<tr><td>Voltage</td><td>1. Artistic-1 11 kV
2. Munda 132 kV
3. Timergara 132 kV
4. Khar Bajawar 132 kV
5. Koto 132 kV
6. Chakdara 132 kV</td><td>The voltages of all the bus bars recover after fault clearance</td><td>4.1</td></tr>
<tr><td>Frequency</td><td>Artistic-1 132 kV</td><td>Recovers after fault clearance</td><td>4.2</td></tr>
<tr><td>MW/MVAR Output of the Plant</td><td>Artistic-1 unit-1 11 kV</td><td>Recovers after damping down oscillations</td><td>4.3</td></tr>
<tr><td>Speed and $P_{mechanical}$ of the Plant</td><td>Artistic-1 unit-1 11 kV</td><td>Recovers after damping down oscillations</td><td>4.4</td></tr>
<tr><td>Line Flows (MW/MVAR)</td><td>Timergara to Chakdara 132 kV intact single circuit</td><td>Attains steady state value after damping of oscillations</td><td>4.5</td></tr>
<tr><td>Rotor Angles</td><td>1. Artistic-1 11 kV
2. Koto 132 kV
3. Shigo Kas 132 kV
4. Golengol 132 kV
5. Lavi 132 kV
6. G.Brotha 500 kV(reference angle)</td><td>Damps down quickly and attain a steady state value</td><td>4.6</td></tr>
</table>

7.3. Conclusion of Dynamic Stability Analysis

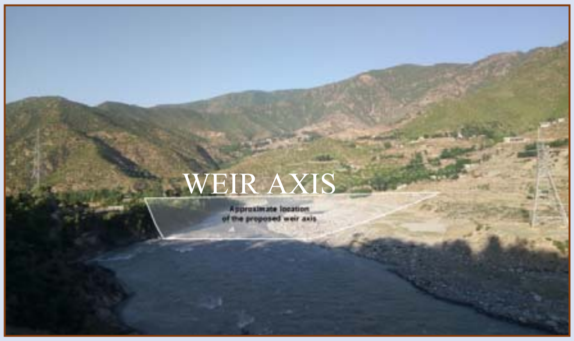
The results of dynamic stability carried out for summer 2026 show that the system is very strong and stable for the proposed scheme for the severest possible faults of 132 kV systems near to and far from Artistic-1 HPP under all events of disturbances. Therefore there is no problem of dynamic stability for interconnection of Artistic-1 HPP; it fulfills all the criteria of dynamic stability.

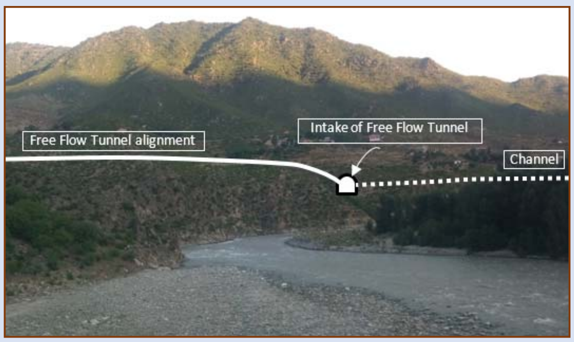
8. Conclusions

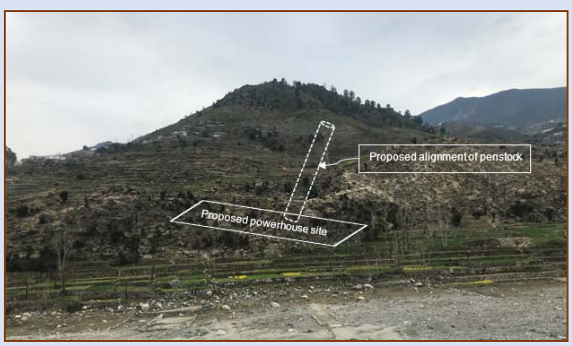
- The Final Report of 63 MW Artistic-1 Hydro Power Project by Artistic Hydro-I Private Limited in Upper Dir, Khyber Pakhtunkhwa, is submitted herewith.
- A couple of options were investigated for the interconnection of this project. One possible interconnection scheme is to connect the plant to 132 kV Warai Grid but due to the unavailability of line bays at Warai, this scheme was dropped. Another possible point of interconnection is a 132 kV grid proposed by PESCO at Munda.
- The possibility of connecting Artistic-1 HPP to Munda 132 kV Grid Station via 40 km double circuit has been investigated in this report.
- In view of planned COD of Artistic-1 HPP in 30 June, 2026, the proposed interconnection schemes has been assessed for steady state conditions through detailed load flow studies for summer 2026.
- Steady state analysis by load flow reveals that the proposed scheme is adequate to evacuate the maximum power of 63 MW of the plant under normal conditions and no constraints are caused by the interconnection of Artistic-1 HPP in the 132 kV network of PESCO in the load flow scenarios of summer 2026.
- The short circuit levels of the Artistic-1 HPP 132 kV are 5.43 kA and 1.79 kA for 3-phase and 1-phase faults, respectively, in the year 2025-26. Therefore, industry standard switchgear of a short circuit rating of 40 kA would be sufficient for installation at 132 kV switchyard of Artistic-1 HPP, as the maximum short circuit levels for the year 2025-26 were also found to be well within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 132 kV switchgears. There are no violations of the power rating of the equipment in the vicinity of Artistic-1 HPP in the event of fault conditions.
- The dynamic stability analysis of proposed schemes of interconnection has been carried out. The stability has been tested for the worst cases, i.e. three phase fault right on the 132 kV bus bar of Artistic-1 HPP substation followed by trip of a 132 kV single circuit from Artistic-1 HPP has been performed for fault clearing of 5 cycles (100 ms), as understood to be the normal fault clearing time of 132 kV protection system. Also the extreme worst case of stuck breaker (breaker failure) has been studied where the fault clearing time is assumed 9 cycles i.e. 180 ms for single phase fault. The stability of the system for far end faults of 3-phase occurring at Artistic-1 132 kV bus bar has also been checked. The system is stable for all the tested fault conditions.

- The proposed scheme of interconnection have been subjected to Load Flow, Short Circuit and Dynamic Stability Analysis and found to be feasible for interconnection of Artistic-1 HPP with the PESCO network.

ARTISTIC HYDRO I (Pvt.) Ltd.
KARACHI, PAKISTAN







ARTISTIC-I HYDROPOWER PROJECT

DRAFT

FEASIBILITY STUDY

VOLUME - VI (EIA REPORT)

AUGUST 2020

ARTISTIC-I HYDROPOWER PROJECT CONSULTANTS

A Joint Venture of

BAK CONSULTING ENGINEERS, PAKISTAN & DOLSAR ENGINEERING **TURKEY**

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TABLE OF CONTENTS

ANNEXURES

LIST OF TABLES

LIST OF FIGURES

MKT	:	Main Karakoram Thrust
MMT	:	Main Mantle Thrust
NEQS	:	National Environmental Quality Standards
NGO	:	Non-Government Organization
NOC	:	No Objection Certificate
NTFPs	:	Non-Timber Forest Products
O&M	:	Operation & Maintenance
PAPs	:	Project Affected Persons
PEDO	:	Pakhtunkhwa Energy Development Organization
PEPA	:	Pakistan Environmental Protection Agency
PHYDO	:	Pakhtunkhwa Hydropower Development Organization
PRA	:	Participatory Rural Appraisal
RWL	:	Reservoir Water Level
TOR	:	Terms of Reference
VC	:	Village Council
WAPDA	:	Water and Power Development Authority
WB	:	World Bank

EXECUTIVE SUMMARY

Hydropower has been providing flexible, low-cost, and low-emission renewable energy for more than 100 years. In addition to producing electricity, many of today's hydropower facilities provide flood control, irrigation, water supply, and recreational opportunities. Hydropower deployment also delivers public health and environmental benefits—reduced greenhouse gas emissions, reduced air pollutant emissions, and reduced water consumption—and is facilitating the integration of increased levels of variable generation, such as wind and solar in various regions of our country.

Government of Khyber Pakhtunkhwa is continuously putting immense effort through PEDO in implementing economically sound and environment friendly hydropower projects throughout the province. PEDO is also encouraging public-private partnership and private investors. This effort has gained momentum in recent years. The present study is also an outcome of this hectic effort of the PEDO.

The proposed Artistic-I Hydropower Project is a run-of-river project on Panjkora River which is situated on Chakdara-Chitral road. This is one of the potential raw sites identified by Artistic Hydro I, (Pvt) Ltd, Karachi.

The Environmental Impact Assessments (EIA) are being carried out keeping in view the instructions contained in the Khyber Pakhtunkhwa (KP) Environmental Protection Act 2014, IEE/EIA Regulations 2000 and Technical guidelines prepared by Pak EPA for Hydropower projects. The estimated power potential of Artistic-I Hydropower Project is 62.606 MW which falls in schedule "II" of IEE/EIA Regulations 2000.

Objective and Functions of EIA

The overall purpose of the EIA is to identify the potential environmental and social impact of the proposed project and evaluate them following the process, which is acceptable to regulatory authorities in Pakistan and the project lenders. In this process, the EIA seeks to identify measures to minimize any anticipated adverse impact of the proposed Project, at least to the level that it meets the national and good international industry practice (GIIP) criteria for evaluation of environmental and social impacts.

The scope of the EIA includes the environmental and social impacts of all activities required in the immediate vicinity of the proposed Project Site.

Study Area

The spatial boundaries of the Study Area for the EIA are selected to cover all areas where any measurable change to any component of the environment is likely to take place, directly or indirectly, due to any activity directly associated with the proposed project. The selection of the study area takes into account the environmentally sensitive receptors that are most likely to be impacted by the Project's development activities. It also takes into account the different stages of the project specifically construction and operation. The study area is selected to be large enough to allow the assessment of the Valued Ecosystem Components (VECs) that maybe affected by the Project activities.

Policy and Legal Framework

The EIA process of the Project will be governed by various instruments, namely the policies of the Government of Pakistan, the laws of the Government of Khyber Pakhtunkhwa Province, international environmental agreements to which Pakistan is a party.

Project Description

The Artistic-I is a run of the river hydropower project to be constructed on the Panjkora River in district Upper Dir of Khyber Pakhtunkhwa Province.

The coordinates of Artistic-I weir are (35˚05'52.77" N, 71º59'0.08" E) and of Powerhouse are (35˚01'28.32" N, 72°00'40.77" E). The project weir site is located near Darora Village and about 6.7 km upstream of Sahibabad village. The Powerhouse site is located about 3.5 km downstream of Sahibabad village. Both the Weir and Power House sites are easily accessible through N-45 (Chakdara-Dir) Asphalt Road. Length of the Panjkora River up to the weir site is about 105 km. Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km and at powerhouse location is approximately 3235 sq.km. The total land required for the project is approximately 606421.43 sq. m or 149.85 acres.

Alternatives

Project site alternatives were given due consideration keeping in view environmental, social and economic aspects. The present site was found most appropriate and practical.

Anticipated Impacts

Impact on land:

Some cultivated and barren land in nearby villages, some walk paths, riverbed and a piece of mountain where box channel and tunnel will be constructed are likely to be affected. The legitimate owners of these properties will be properly compensated in time as per their demand and regulatory provisions.

Impact on socio-economic conditions

No significant impact is observed on human life during pre-construction period. It is observed that the project is environment friendly which will help improve the socio-economic conditions of the area by providing them employment opportunities, improvement of existing civic infrastructure i.e. Roads and bridges and health services.

Impact during Construction Stage

Disturbance and change in landscape, land use, drainage etc, due to disposal of material obtained from excavation from borrow pits, blasting of rocks, erosion, change in stream regime, likelihood of ambient air quality and noise deterioration, degradation due to construction activities, vehicular movement, labour camp problems, pollution of stream during construction, effects on lower riparian, aquatic life, disturbance to livestock herds and migratory birds are some of the negative impacts which were identified during scoping sessions, however, environmental management plan will be able to mitigate these negative impacts.

Biological Impacts

Due to construction activities, farm trees and crops may face limited risk of significant biological impacts which may be mitigated with the help of the concerned Farmers and land owners. Disturbance and threat to wildlife and species of flora in the project area seem to be insignificant. However, seasonal movement of common wildlife, disturbance of natural habitat of fish movement and seasonal migration of wildlife due to construction works possibly impacts somewhat on weir site. These impacts will be mitigated through Environmental Management Plan (EMP).

Socio-Economic and Cultural Impacts

Baseline Socio-Economic situation was studied to ascertain possible impacts on demography of the project area; possible impact on social cultural and religious practices; impacts on social/cultural norms, values and rituals; impact on gender; possible impact on existing civic amenities of people and domestic animals during and after implementation of the project; possible displacement of households, infrastructure, lands and public roads and civic paths, social security, conflicts etc. No indigenous people were found in the project area. No religious and historical monuments are available near the project area which might be affected.

Poverty and Vulnerability aspects of the project population were given due consideration during EIA Studies. It was found that the minimum income of per house hold was Rs. 10,000 to 15,000 per month which exceeded in some cases even more than Rs. 35,000 per month. These income figures relate to the project affected persons only.

Environmental Management Plan

The Environmental Management Plan (EMP) provides the organizational requirements, management and monitoring plans to ensure that the necessary measures are taken by Consultant/Contractor to avoid potentially adverse effects and maximize potential benefits of the Project as identified in preceding Section of the EIA and to operate in conformance with applicable laws and regulations of KP and Pakistan. The EMP is a standalone document.

Environmental Management System

The Environmental Management System (EMS) ensures that the measures introduced in the EMP are implemented. The framework for the EMS is provided. The EMS that will be developed for the Project will be developed in line with the policies, plans and procedures described by the Khyber Pakhtunkhwa EPA.

Mitigation measures are clear and concise descriptions of the actions that must be executed to mitigate the impacts of the project. Where relevant, targets, indicators, trigger points are incorporated into the management measure. Implementing and monitoring responsibilities are also identified in the mitigation and monitoring plan.

Institutional Implementation

Effective implementation and functioning of the EMP depends on adequate human and financial resources, clearly defined responsibilities for environmental management, appropriate training and good communication.

The following are commitments, which will be achieved:

A. Putting environmental matters high on the agenda of meetings;

B. Highlighting the importance of environmental issues in relation to the HSE considerations in business decisions and communication with stakeholders;

C. Evaluating environmental aspects, before final decisions are reached;

D. Being fully aware of the main environmental hazards associated with the Contractor and Sub Contractor activities and the systems, procedures and field practices in place to manage these hazards;

E. Immediately and visibly responding and being involved in investigating incidents or other abnormal events related to environmental and HS issues;

F. Seeking internal and external views on environmental issues; and recognizing their achievement.

Public Consultation

As part of the EIA process, consultations are undertaken with communities and institutions that may have interest in the proposed project or may be affected by it. The consultation process was designed to be consistent with the relevant national and provincial legislation. Consultations with the Project stakeholders were undertaken in April and October 2019. Separate meetings with institutional stakeholders were arranged in Dir, Wari, Gandegaar, Darora and Sahib Abad.

Conclusion

The proposed project is socio-environmentally friendly and sustainable. People agree with the proposed project but have the following reservations:

The electricity generated locally must be supplied to local population which has very little requirements; rest of the electricity may be utilized according to Government Policy. They agreed to provide their lands and property but needed full justice in entitlement matrix and demanded that compensation rates should be calculated on the existing market rates and payments should be made to the legitimate owners before commencement of project activities. They added that malpractices of all kinds must be checked and controlled by the responsible authorities and the process of estimation and payment should be transparent. Local population must be given preference in employment.

These studies have identified alternative actions, mitigation activities, monitoring programme and other necessary aspects related to the social and environmental components of the project. They will be effectively incorporated into the Detailed Design and Implementation Process, which will help controlling environmental and social impacts to an acceptable level.

CHAPTER 1: INTRODUCTION

1.1. GENERAL

This document presents the environmental and social impact assessment (EIA) of Artistic-I Hydropower Project which is the part of feasibility study of the project. This has been prepared in accordance with the guideline of Khyber Pakhtunkhwa Environmental Protection Agency (KP-EPA) and other international environmental legislation and guideline such as World Bank's Environmental and social Safeguard policies.

This report provides information on project activities, baseline environmental and social conditions of the project area, positive and negative social and environmental impacts of proposed activities and their mitigation measures. Recommendation on environmental management and monitoring measure and institutional arrangement for environmental management and monitoring are also the key part of this report. Present chapter has been divided into three major segments: i) introduction to the proposed project; existing power potential of Pakistan with particular focus on hydropower potential of Khyber Pakhtunkhwa and project need and justification; ii) brief introduction of Project developer and environmental consultant; iii) introduction to EIA study including purpose and Scope of EIA, its methodology and major phases carried out during the study.

1.2. PROJECT RATIONALE AND JUSTIFICATION

Energy is an essential ingredient of socio-economic development of a country, and electricity is one of the most widely used form of energy. Dependence on electricity is gaining momentum all over the world. Keeping up the balance between electricity demand and supply is the major challenge particular in developing countries including Pakistan. At the time of independence, Pakistan inherited 60 MW of power generation capability for a population of 31.5 million, yielding 4.5 units per capita consumption. Twelve years later, when WAPDA was created in 1959, the generation capacity had increased to 119 MW. In 1964-65, the electricity generation capability rose to 636 MW from 119 in 1959, and power generation to about 2,500 MKWh from 781 MKWh. The rapid progress witnessed a new life to the social, technical and economic structures of the country, mechanized agriculture started, industrialization picked up and general living standards improved. The task of accelerating the pace of power development picked up speed and by 1970, in another five years the generating capability rose from 636 MW to 1331 MW with installation of a number of thermal and hydel power units. In the year 1980 the system capacity touched 3000 MW which rapidly rose to over 7000 MW in 1990-91.

Electricity crisis worsens in Pakistan in 2008 as shortage of Electricity has increased up to

4000MV. Pakistan's industrial consumers were facing an electric power deficit due to low water levels at hydroelectric dams. Year 2011 started with electricity shortages and worst load shedding of all time and ending with the same situation. Summers were worst period for Pakistan people where in some areas load shedding of even 16 to 18 hours were witnessed but the winters were also worst of all with up 8 hours of load shedding. Prices of electricity were also kept increasing. Electricity shortages caused losses to industry, in turn causing many closures and loss of jobs for people of Pakistan. For the last two decades Pakistan has a series of crises in power sector and there is a shortfall because electricity demand is growing day by day and the resources to produce electricity are not used efficiently.

Pakistan though deficient in fuel resources has ample power potential from wind, water and solar. As for as hydropower is concerned, Pakistan is blessed with immense power potential from water resources including rivers, canals and river tributaries. All most all major rivers of the country have sufficient amount of potential to generate hydroelectricity. Pakistan is endowed with hydropower resources of about 60,000 MW (PPIB, Pakistan). **Figure 1-1** indicates the river wise hydropower potential of Pakistan.

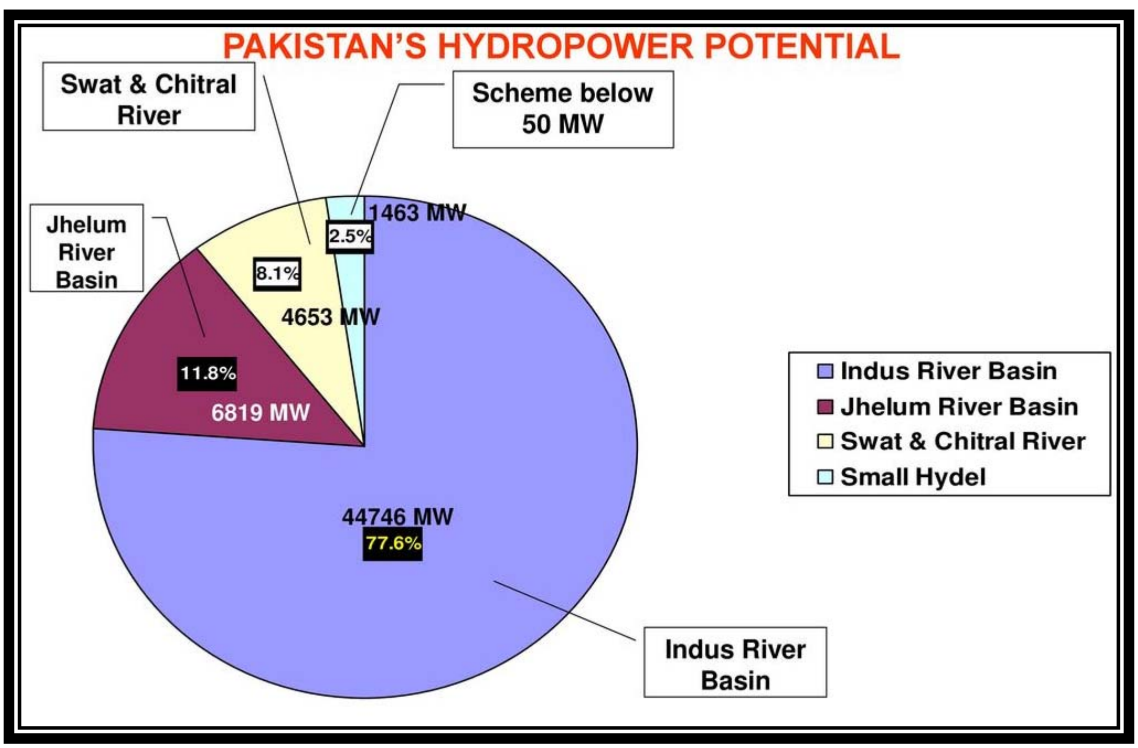


Figure 1-1 River wise hydropower Potential of Pakistan

Energy is critical for the developing countries not only for social development and human welfare but also as a catalyst for overall development in the New Millennium. Energy in the form of electricity provides the basic infrastructural input to the national economic growth. The per capital electric consumption is considered as an index of a nation's progress and development.

1.3. POWER SECTOR OF PAKISTAN

Pakistan's installed capacity to generate electricity has surged up to 33,836 MW by February 2019 which stood at 23,337 MW in 2014, showing the growth of 45 percent in five years.

Electricity – generation by source (2019)

- Furnace oil: 14% of total
- Natural gas: 31% of total
- Coal: 16% of total
- Hydroelectric: 29% of total
- Nuclear: 4% of total
- Renewable (Solar & Wind): 5% of total
- Others (Biogas, Waste Heat Recovery etc.): 1% of total

The Power sector was restructured in 1998 with the creation of PEPCO (Pakistan Electric Power Company. Prior to 1998, there were two vertically integrated utilities, i.e., KESC, which served the Karachi area and WAPDA which served the rest of the country. Later on, WAPDA's power wing has been structured into distinct corporate entities comprising of 4 GENCOs, 10 DISCOs and one TransCO. These 10 DISCOs are responsible for distribution to the end users. KESC meet its overall demand with its own generation plus purchase from NTDC, IPPs and from Karachi Nuclear Power Plant.

1.4. INSTALLED HYDROPOWER CAPACITY OF PAKISTAN

Pakistan is endowed with a hydel potential of more than 40,000 MW, in which the total installed capacity of the hydropower stations in the country is about 10132.53 MW in 2019. Most of the hydropower station lies in the Khyber Pakhtunkhwa province. The province has an estimated power potential of generating nearly 30,000 MW. The need for development of these immense hydropower potential in the province cannot be over-emphasized.

1.5. PROJECT BACKGROUND

The Artistic- I Hydropower project is a run-of-the river project to be constructed on Panjkora River in district Upper Dir of Northern areas of Khyber Pakhtunkhwa province. The weir site is located near Darora village and about 6.7 km upstream of Sahibabad village. The power house site is located about 3.5 km downstream of Sahibabad village. Both weir and power house sites are easily accessible through N-45 (Chakdara-Dir) Asphalt Road. The power potential of the project is estimated to be about 62.606 MW. Project location map of Artistic-I HPP site at Panjkora River is given as **Figure 1-2.**

The catchment of the Artistic-I HPP lies in the upper region of the Panjkora River, a tributary / sub system of a Swat river basin and can be classified as a “high mountain catchment” which originates from glacier zone. Two major tributaries join at Chukiatan, just downstream of Dir town to form Panjkora River. On the way downstream it joins a number of small tributaries evacuating the discharge from different valleys. The stream flow patterns are followed by the seasonal change in temperatures. Glaciers are visible above altitude of 4000 amsl. The highest mountain peak ranges from 600 amsl up to 5750 amsl while river bed elevation at weir site is 1071amsl and tail water level at powerhouse site is approximately 990 amsl. Length of the Panjkora River up to the weir site is about 105 km. Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km and at powerhouse location is approximately 3235 sq.km.

Figure 1-2 Location of the Artistic-I HPP

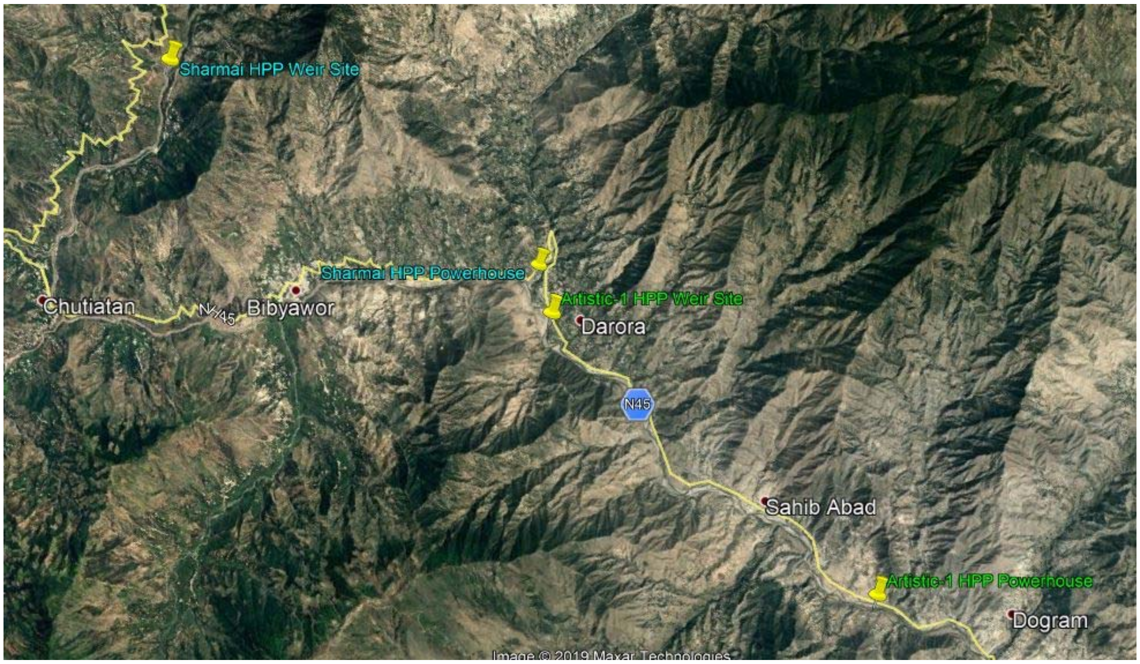


Figure 1-3 Location of Weir sites & Powerhouse sites of Artistic-I HPP & Sharmai HPP

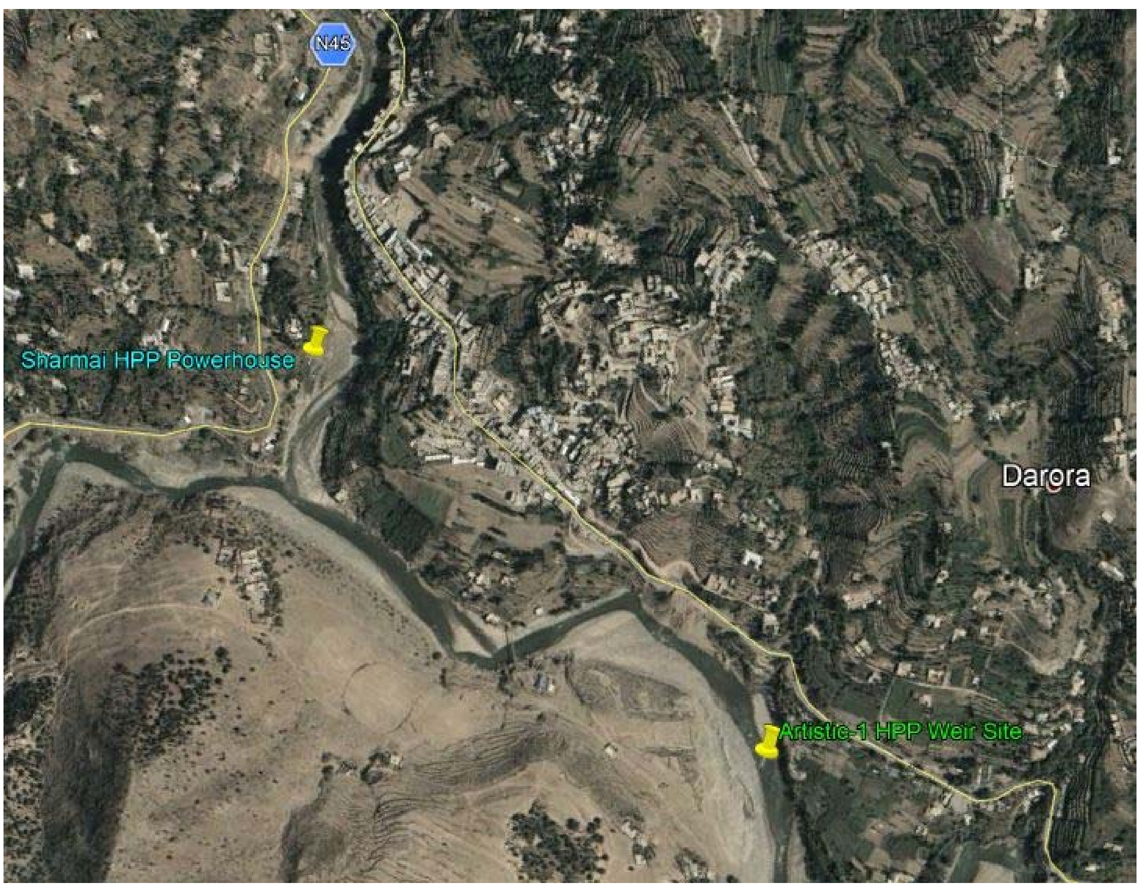


Figure 1-4 Artistic-I HPP Weir Location & Sharmai HPP Powerhouse Location

1.6. CONCEPT OF THE EIA STUDIES

Environmental Impact Assessment (EIA) is a systematic process for evaluating the environmental consequences of any proposed Policy, Plan or Program initiative in order to ensure that the various concerns are fully identified and appropriately addressed at the earliest stage of decision-making at par with economic and social considerations. The economic, social, and environmental change is inherent to development. Whilst, development aims to bring about positive change, it can lead to conflicts. In the past, the promotion of economic growth, as the motor for increased well-being, was the main development thrust with little sensitivity towards adverse social or environmental impacts. The need to avoid adverse impacts and to ensure long term benefits led to the concept of sustainability. This has become accepted as an essential feature of the development if the aim of increased well-being and greater equity in fulfilling basic needs is to be met for the present and future generations.

EIA thus, has three main functions:

i. To predict positive and adverse impacts.

ii. To find ways to minimize/manage adverse impacts.

iii. To enhance positive effects.

The third function is of particular importance. The EIA provides a unique opportunity to demonstrate ways in which the environment may be improved as part of the development process. The EIA also predicts the conflicts and constraints between the proposed project, program or sectoral plan and its environment. It provides an opportunity for mitigation measures to be incorporated to minimize the problems. It enables monitoring programs to be established to assess future impacts and provide data on which managers can take informed decisions to avoid environmental damage. EIA includes the study of various baseline parameters viz. air, land, water, flora, fauna and social aspects. The principal phenomenon or pathways of impacts are land/soil impacts, air pollution impacts, noise and health effects, ecology impacts including endangered species assessment, geological hazards assessment, water pollution and aquatic impacts, etc.; whereas related analysis of social impacts is achieved through social impact assessment wherever necessary integration of these parameters gives an overall perception of both positive and adverse impacts due to any project construction.

With reference to hydropower development in our country, it is pertinent to point out that EIA is now a mandatory requirement and has to be carried out according to the Terms of Reference (ToR) defined by the, Government of Pakistan. International financial institutions have also laid down stringent environmental guidelines for developmental projects and financial assistance is possible only after the borrowing agency has fully committed itself to adopt adequate provisions for environmental conservation, management and impact minimization/ mitigation. Since, the Stockholm Conference in 1972, there is a co-evolutionary race between the thrust of development on the one hand and the stringency of newer concerns in EIA on the other. It has many positive fall outs, notwithstanding some acrimonious debates on many occasions that have racked up between environmentalists and developers.

The positive outcome includes acceptance of internalization of environmental concerns by industry/ institutions connected with development, evolution of policy planning frameworks and technological innovations, which minimize negative/adverse impacts of the developmental activities on environmental resources. The ‘clean technologies’, ‘green rating’ and ISO 14000 certification are some of the important outcomes that have followed the environment development debate. The complexity of EIA varies greatly from project to project and depends vastly on the magnitude of operations involved in the developmental activity of the projects to be undertaken in that particular area. Further, EIA studies have to be conducted within several intrinsic and external constraints, which call for the focused expertise of individuals, who are involved in EIA and also for the prior firming up of the detailed project reports (DPR) by the development authorities and decision-makers.

It is well known that in the process of impact assessment and prediction one must bear in mind the irreversibility and reversibility of the impact(s) of development on the various environmental aspects and resources. There are some project activities which create impacts that are temporary in nature. Noise and air pollution, for example, constitute a temporary impact by a developmental activity on a dam construction site. These impacts are reversible because they are likely to cease and normal environmental quality will be restored once the construction activity is completed. Similarly, adverse impact on water quality (physio-chemical characteristics) of a river receiving effluents from an industry is likely to be brought back to normal levels after installation of effluent treatment plant or relocation of the industry, etc. However, there are other impacts which are irreversible and even with the best of technology in place, nothing can be done to reverse the process and bring such environmental resources back.

EIA report is based on analysis and findings of collected data and field observations. It contains baseline information on the present environment of the project area and Environmental Impact Assessment for different components of the proposed project. The mitigation plan has been devised to overcome the adverse impacts in the project area.

1.7. OBJECTIVE AND SCOPE OF EIA

The overall purpose of the EIA is to identify the potential environmental and social impact of the proposed project and evaluate them following the process which is acceptable to regulatory authorities in Pakistan and the project lenders. In this process, the EIA seeks to identify measures to minimize any anticipated adverse impact of the proposed Project, at least to the level that it meets the national and good international industry practice (GIIP) criteria for evaluation of environmental and social impacts.

The specific objectives of this EIA were to:

i. Assess the existing environmental conditions in the project area, including the identification of environmentally sensitive areas.

ii. Assess the proposed activities to identify their potential impacts, evaluate the impacts, and determine their significance.

iii. Assess effects on aquatic ecology.

iv. Propose appropriate mitigation and monitoring measures that can be incorporated into the design of the proposed activities to minimize any damaging effects or any lasting negative consequences identified by the assessment.

v. Assess the proposed activities and determine whether they comply with the relevant environmental regulations in Pakistan and Khyber Pakhtunkhwa (KP) and the requirements of project lenders.

vi. Prepare an EIA report for submittal to the Khyber Pakhtunkhwa Environmental Protection Agency (KP-EPA) and the lenders.

The scope of the EIA includes the environmental and social impacts of all activities of the proposed project in the immediate vicinity of the proposed project site during construction and operation phases of the project. To evacuate power from the proposed project, transmission line to be constructed by National Transmission and Dispatch Company (NTDC) falls in the category of associated project. It is essential that NTDC undertake the EIA of the transmission line and develop a sound EMP consistent with the national legal environmental requirements. The scope of this EIA does not include the design, construction, and operation of the transmission line for evacuation of the power produced by this project.

1.8. METHODOLOGY

In this study, standard methods were followed for EIA. All the methods were structured for collection and organization of environmental baseline data and identification of environmental impacts using different survey tools and discussions with different stakeholders. The information, thus gathered, has been analysed and presented in the form of a number of visual formats for easy interpretation and decision-making.

1.9. STUDY AREA

The study area related to EIA of the project comprised the following features / aspects:

a) Catchment area of the project
b) Influence zone area that is the area in the region within 5 km radius from the project site and the reservoir margins, where the impacts can possibly be visualized, excluding the upstream areas of higher elevation as there would be no adverse impacts.
c) The project study area is spread over the following components:

   i. Catchment area of the project.

   ii. Weir Site area

   iii. Powerhouse area

   iv. Proposed Labour camps / contractor’s offices area

   v. Downstream settlements along both sides of the river from the weir site to the powerhouse site

   vi. Proposed staff residential colony/offices area

A reconnaissance survey was carried out in the project area during the year 2019. Thereafter, several visits were made to understand the terrain and vegetation of the study area as well as catchment area of the project.

During these visits, the preliminary interpreted data were tested and necessary corrections made after knowing proper ground truths. The physiographic features on satellite imagery appearing in different tones and textures were used to correlate image elements and ground features for accurate identification. During the field visit, emphasis was laid on ground verification for refinement of the land use/ land cover classification scheme.

d) Different forest classes identified and the degraded areas and scrubs delineated for erosion mapping. The high-altitude grasslands/alpine pastures and agricultural areas also identified and delineated.
e) Fauna of the study area was identified and lists of various classes were compiled.
f) Rare and endangered species were identified referring to the Red Data Book of Pakistan (2003) and other available literature.
g) Socioeconomic and cultural resources of the study area were also assessed.

1.10. SURVEYS

Preliminary and then detailed environmental surveys were conducted, in the study area, in April, May and June, 2019 to collect data related to geology, flora, fauna, forest types and ecological parameters including soil types. During these surveys, data and information were collected on physical and biological attributes of the study area. In addition, detailed surveys and studies were also conducted for understanding aquatic ecology and fish life of Panjkora River and its tributaries. A comprehensive socioeconomic survey of the project affected villages and families was also conducted. The detailed questionnaires used for the collection of data on villages and individual households. Detailed environmental surveys were also conducted in the reservoir area. For this purpose, the prepared land use and land cover map was checked with respect to various attributes such as land features, rivers, forests and vegetation types on the ground in the reservoir, project and other parts of the study area.

Spatial database on the physiographic features was prepared based on the various data sources including Survey of Pakistan (SoP), topographic sheets, and satellite images data. These data were extracted and presented in accordance with the standard EIA methodology used for such studies. The section on climatology has been taken from the detailed report of the project. This section contains the source of database and detailed methodology adopted for deriving water discharge series at the weir site, design flood and sedimentation rate, etc. The regional geology and seismotectonic of the region are discussed based on various data sources. Particularly, the discussion on project geology has been based on the data available in the project report and field observations in selective pockets of different project affected sites. The landslides and geomorphology have been discussed based upon field observations at particular locations. Land use and land cover mapping was carried out by standard methods of analysis of remotely sensed data followed by ground truth, which included use of image elements like tone, texture, shape, location, association, pattern, etc. and were adopted for vegetation mapping and ancillary information like elevation and land forms.

Different forest classes were identified and the degraded areas and scrubs were delineated for the purpose of erosion mapping. The high-altitude grasslands/ alpine pastures and agricultural areas were also identified and delineated. The non-forest land cover in the form of rocky land, moraines, glaciers, lakes, etc. was also delineated for the calculation and classification of erosion intensity. Soil resource mapping of the proposed project area was prepared from the basic data/map of soil classification contained in Soil Survey of Pakistan. Forest types and plant species were recorded during the field visits and the floristic data for the catchment were sourced from the published literature. Rare and endangered species were identified referring to the Red Data Book of IUCN Pakistan (2003) and other available literature.

In order to collect the information on the fauna (mammals, avifauna, herpeto fauna, and butterflies) in the catchment area of Panjkora River, primary as well as secondary sources were utilized. The Forest Working Plans of the Forest Divisions falling in the project area were referred for secondary information on the wildlife of the catchment area. Interviews of the local villagers for the presence of various animal species within each locality were also taken to have first-hand information.

1.11. IMPACT PREDICTION

Prediction of impacts has been based on a broad matrix group ‘ecosystem’ constituted by physical and biological components. The vulnerability of an ecosystem to various impacts resulting from an activity or multiple activities were identified and accordingly impacts predicted. The main theme of the ecosystem approach in visualizing impacts on various sets of environmental data revolves around the idea that natural processes and patterns are likely to be affected under impacts of a developmental activity. In natural ecosystems, the impacts would surely change the existing state of equilibrium. In managed ecosystems and human societies, impacts could be of positive as well as adverse consequence. Similarly, in case of natural ecosystems, likelihood of adverse impacts could be seen in terms of temporary or permanent impacts. In the absence of long-term data availability on various environmental variables and the paucity of studies on their likely responses to changes under developmental activities, it is difficult to predict impacts with a high degree of exactness and certainty. For example, it will not be possible to predict impacts of such a developmental activity on the behavioural patterns of animal and bird populations except for the fact that their habitats may come under stress. In that sense, these predictive impacts could be said to have a limitation. The quantification of various parameters like agricultural lands / residential area, commercial area, reservoir area and built up area was done.

The mitigation measures and environmental monitoring have been worked out in the light of environmental impacts assessed. The resettlement issues have been taken care of and for this purpose estimates of the affected population were made according to the census of 2017 and physical survey of the study area. Potential resettlement areas have been identified and visited for further evaluation. Interviews, field visits/surveys, scoping sessions with officials/notables and concerned stakeholders were also made for the accomplishment of the study.

CHAPTER 2: REGULATORY LAWS AND THE INSTITUTIONAL FRAMEWORK

2.1. GENERAL

This section provides an overview of the current national and international legislation, policies and guidelines, which will have a bearing and relevance to the planning, design, implementation and operation of the project. It is mandatory to comply with all appropriate national legislation relating to the environment in Pakistan and to obtain all regulatory clearances required. Letters of no objection to the project have to be issued by the relevant national and provincial environmental regulatory authorities. The project will also be required to conform to the World Bank Operational Manual (Policy) and Asian Development Guidelines.

2.2. POLICY REQUIREMENTS

The main Federal Government policy documents that are directly applicable to the proposed project are the National Conservation Strategy, Provincial Conservation Strategy, the Resettlement Policy and the Pakistan Power Policy of 2002. The Ministry of Environment is responsible at the Federal level for policy, planning and implementation in respect of environmental aspects in Pakistan. The Pakistan Environmental Protection Council (PEPC) headed by the Chief Executive of Pakistan is the highest inter-ministerial and multi-stakeholder decision making body for such matters. The various Federal Government policy documents on environment have also been made applicable to all the provinces of Pakistan. Accordingly, the Ministry of Environment of KP is responsible for the compliance/implementation of all the environmental regulations in the Khyber Pakhtunkhwa Province.

2.3. THE PAKISTAN NATIONAL CONSERVATION STRATEGY (PNCS)

The Pakistan National Conservation Strategy (PNCS) is the principal policy document for environmental issues in the country and was developed and approved by the Government of Pakistan on March 1, 1992. The PNCS works on a ten-year planning and implementation cycle, and deals with 14 core areas, which are: a) maintaining soils in cropland b) increasing irrigation efficiency c) protecting watersheds d) supporting forestry and plantations e) restoring rangelands and improving livestock f) protecting water bodies and sustaining fisheries g) conserving biodiversity h) increasing energy efficiency i) developing and deploying material for renewable energy j) preventing/abating pollution k) managing urban wastes supporting institutions for common resources m) integrating population and environmental programmes, and n) Preserving the cultural heritage.

2.4. SARHAD PROVINCIAL CONSERVATION STRATEGY (SPCS)

United Nations Environment Programme, the World Wildlife Fund and International Union for Conservation of Nature (IUCN), and the World Conservation Union (WCU) proposed and then funded the development of a global strategy for the rational development and conservation of natural resources, called the World Conservation Strategy (WCS) - Living Resource Conservation for Sustainable Development. It was launched in 1980. After the completion of National Conservation Strategy of Pakistan, the KP Government approved the preparation of Sarhad Provincial Conservation Strategy (SPCS), 1992. The SPCS used a two-track approach during the two years of strategy finalization activities i.e. preparation of an environmental profile, institution strengthening and awareness raising were implemented in parallel. The SPCS is the principal plan for implementing the National Conservation Strategy in KP. Its specific objectives are: a. Treatment of the fundamental social problems that are the underlying cause of environmental degradation. b. Conservation, rehabilitation, and sustainable development of natural resources such as forests, water, soil and wildlife. c. Protection of living environment from air, water and soil pollution. d. Development of high-quality environmental protection mechanism, including appropriate legislation, development planning mechanism, environmental quality standards and participatory and regulatory institutional arrangements. e. Improvement of institutional and financial capacity to achieve sustainable development of the province’s natural resources. f. Protection and conservation of the cultural heritage of the KP. g. Rising of public awareness and understanding of conservation and sustainable development.

2.5. KHYBER PAKHTUNKHWA COMPREHENSIVE DEVELOPMENT STRATEGY 2010-2017 (SECTION 29; ENVIRONMENT)

Khyber Pakhtunkhwa, historically, has established a high profile in the environmental arena in Pakistan. The province was the first to begin the implementation of Pakistan's National Conservation Strategy, and formulated the first-ever Sarhad Provincial Conservation Strategy in 1992. The provincial Environment Department (ED) oversees the affairs of the Environmental Protection Agency (EPA), which is the key agency dealing, with the environmental agenda in the province. The ED also oversees the affairs concerning fisheries, forests and wildlife, and transport sub-sectors. Amongst the most pressing environmental problems in KP are a high population growth rate and population density; a narrow rural economic base; an exodus to urban centres; congestion and pollution; the brunt of Afghan refugees; waterborne diseases; lack of awareness, education and research; and inadequate institutional infrastructure. Almost all Comprehensive Development Strategy (CDS) proposed priority measures will be required to be environmentally assessed to ensure their compliance with the environmental regulations. These assessment measures include the modification of the PC-I to include environmental impact, and the use of the PC-II for financing the Environmental Investigation Agency. There are also a large number of measures, proposed under the various sectors in the CDS which, once implemented, will directly contribute to the environmental improvements in the province. Key measures are: a) Improvement of the spatial planning and management of urban land; b) Improvement in planning for urban transportation systems; c) Updating of the urban development plans; d) Bringing of cultivable wasteland into farming, through the provision of irrigation and land development with the help of bulldozers and tractors; e) Provision of new access to safe drinking water, with appropriate supervision of quality, especially in un-served or underserved areas, and improved maintenance and reliability of the existing supplies; f) For the irrigation and drinking water supply strategy (DWSS), promotion of water saving measures and local water harvesting schemes, reducing unaccounted for water, promoting metering and so on; g) Promotion of new arrangements for collaboration with communities and for public private partnership in water supply; h) Preparation of the provincial DWSS; i) Refining and finalizing the Provincial Sanitation Strategy and preparing for its implementation, including a programme of incentives, giving 20% match funding to the national programme; j) For the irrigation and DWSS, establishing a management information system to ensure evidence based municipal planning; k) Promotion of alternative energy resources; l) Implementation of the Third Flood Sector Project and 10-Year Comprehensive Flood Protection Plan; m) Implementation of small dams, rainwater harvesting ponds and actions to harness hill torrents; n) Rehabilitation and improvements to existing irrigation schemes; for the irrigation and DWSS, establishment of water quality management and monitoring; o) Upgrading of capacity in integrated water resources management and production of a master plan; p) Expansion of large and medium-scale water storage capacity for the irrigation and DWSS, a feasibility study on groundwater potential and regulatory mechanisms and preparation of a plan for the financial sustainability of irrigation and drainage; q) Together with these measures, however, the Environmental Protection Agency (EPA) of the Environment Department will require resources to continue strengthening its capacity in the areas of environmental awareness raising, environmental monitoring and compliance, and strengthening of review processes (e.g. IEE and EIA) in the province.

2.6. POLICY FRAMEWORK

Based on the NCS, policies are being framed for institutional strengthening and human resource development for environmental protection, especially at the local and provincial level. The NCS is a policy document that deals with the core environmental issues in Pakistan at the macro level and recommends an action plan to address these issues. As a signatory to the Convention on Biological Diversity in 1992, it was also mandatory for Pakistan to develop a national strategy for the conservation of biodiversity. The Biodiversity Action Plan (BAP) recognizes that at the project level Environmental Impact Assessment is used as a tool to identify the environmental impacts of any proposed project and suggests ways for reducing adverse impacts.

2.7. RESETTLEMENT POLICY OF PAKISTAN, 2002

An important aspect of EIA is consideration of the displacement and relocation of the project affected population. A new resettlement policy has yet to be approved by Government but amendments to the Land Acquisition Act of 1894 have been made from time to time. The Resettlement Policy of Pakistan (2002) is currently in a draft form with the Pakistan Environmental Protection Agency. The policy has been formulated to ensure an equitable and uniform treatment of the resettlement issues throughout Pakistan. This policy will apply to all development projects involving adverse social impacts, including land acquisition, loss of assets, loss of income, loss of business and other possible losses. The draft Resettlement Policy addresses those areas, which are not taken care of in the Land Acquisition Act of 1894 (LAA), and will be applicable wherever any public sector or private development project affects people, families or communities, even when there is no displacement of population. The legal procedures for land acquisition have the objective of providing adequate compensation for the loss of income to those who suffer loss of individual or communal property, including common assets, productive assets, structures, other fixed assets, income and employment, loss of community networks and services, pastures, water rights, public infrastructure like mosques, shrines, schools, graveyards and any consequential losses.

2.8. THE PAKISTAN POWER GENERATION POLICY 2002

The Power Generation Policy of the Government of Pakistan (GoP) aims to reform the power sector through restructuring and deregulation. The aim is to help the country to meet its future power needs. WAPDA and Karachi Electric Supply Company (KESC) are the two main producers and distributors of electricity in Pakistan. KESC has already been privatized, whilst WAPDA is still a public organization. WAPDA owns 54% of national electricity generation and distribution and serves about 88% of the electrical customers in Pakistan. WAPDA has prepared a Hydropower Development Plan- Vision 2025"to meet the deficit of electricity through proposed provision of additional generation capacity. The objectives of the power policy are to: a. Provide sufficient capacity of power generation at the least cost to avoid capacity shortfall. b. To encourage and ensure exploitation of indigenous resources, human resources, participation of local engineering and manufacturing capabilities. c. To ensure that all stakeholders are looked after in the process. d. To safeguard the environment, the requirements of the Pakistan Environmental Protection Act (PEPA), 1997 relating to environmental protection, environmental impact and social soundness assessment shall have to be met.

2.8.1. FEDERAL STATUTORY FRAMEWORK FOR ENVIRONMENTAL MANAGEMENT AND ASSESSMENT

The key items of the existing regulatory framework at the Federal level that have implications for the proposed project are identified and discussed below. These include Ordinances, Acts, Laws, Regulations, Rules and Guidelines.

2.8.2. THE PAKISTAN ENVIRONMENTAL PROTECTION ORDINANCE 1983

The Pakistan Environmental Protection Ordinance, 1983 (PEPO 1983) was the first legislation designed specifically for the protection of the environment in the country. The Pakistan Environmental Protection Agency was established in 1984. This is the primary government institution dealing with environmental issues. Significant work on developing environmental policy was carried out by the late 1980s, which culminated in drafting of the Pakistan National Conservation Strategy. Provincial Environmental Protection Agencies were also established at about the same time. The National Environmental Quality Standards were established in 1993 and then revised in 2000. The enactment of PEPA No XXXIV of 1997, conferred broad- based enforcement powers to the Environmental Protection Agencies. The publication of the Pakistan Environmental Protection Agency Review of IEE and EIA Regulations (IEE- EIA Regulations), 2000, provided the necessary details on the preparation, submission, and review of Initial Environmental Examinations (IEE) and Environmental Impact Assessments (EIA). In addition to the PEPA of 1997, Pakistan's' statute books contain a number of other laws that have clauses concerning the regulation and protection of the environment. A summary of the laws and regulations relevant to the proposed Artistic-I project in the context of environmental assessment and management of the project are given in **Table** 2-1**.**

Table 2-1 Major Sectors of Pakistan Environmental Legislation

S. No	SECTOR	LEGISLATION
1	Environmental Protection	The Pakistan Penal Code (1860) Pakistan Environmental Protection Act, No. XXXIV of 1997
2	Land Use	The Pakistan Penal Code (1860) The Canal and Drainage Act (1873) The Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh Local Government Ordinance(s) (1979/80)

S. No	SECTOR	LEGISLATION
		On farm Water Management and Water Users' Associations Ordinance (1981) Indus River Water Apportionment Accord (1991) Statutory Notification S.R.R. 742 (1993)
3	Water Quality and Resources	The Pakistan Penal Code (1860) The Motor Vehicles Ordinance (1965) and Rules (1969) The Baluchistan, Punjab and Sindh Local Government Ordinance(s) (1979/80) Statutory Notification S.R.R. 742 (1993) Statutory Notification S.R.R. 1023 (1995)
4	Air Quality	The Motor Vehicles Ordinance (1965) and Rules (1969)
5	Noise	The Motor Vehicles Ordinance (1965) and Rules (1969)
6	Toxic or Hazardous Substances	- The Pakistan Penal Code (1860) - The Explosives Act (1884) - The Agricultural Pesticides Ordinance (1971) and Rules (1973)
7	Solid Waste and Effluents	- The Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh Local Government Ordinance(s) (1979/80) - Pakistan Environmental Protection Act, No. XXXIV of 1997
8	Marine and Fisheries	- The West Pakistan Fisheries Ordinance (1961) - The Khyber Pakhtunkhwa Fisheries Rules (1976)
9	Forest Conservation	- The Punjab Forest (sale of timber) Act (1913) - The Forests Act (1927). - The Khyber Pakhtunkhwa Hazara Forest Act (1936) - The West Pakistan Firewood and Charcoal (Restrictions) Act 1964 - The Punjab Plantation and Maintenance of Trees Act (1974) - The Cutting of Trees (Prohibition) Act (1975) - The Khyber Pakhtunkhwa Management of Protected Forests Rules (1975) - The Baluchistan, NWFP, Punjab and Sindh Local Government Ordinance(s) (1979/80) - The Khyber Pakhtunkhwa (Conservation and Exploitation of Certain Forests in Hazara Division)

S. No	SECTOR	LEGISLATION
		Ordinance (1980) - The Khyber Pakhtunkhwa Forest Development Corporation Ordinance (1980) - The Protection of Trees and Brushwood Act of 1949
10	Parks and Wildlife Conservation Protection	- The West Pakistan Ordinance (1959) - The Punjab Wildlife (Protection, Preservation, Conservation and Management) Act (1974) and Rules (1974) - The Khyber Pakhtunkhwa Wildlife (Protection, Preservation, Conservation and Management) Act (1975) and Rules (1976) - Northern Areas Wildlife Preservation Act (1975) - The Pakistan Plant Quarantine Act (1976) - Islamabad Wildlife (Protection, Preservation, Conservation and Management) Ordinance (1979/80) - The Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh Local Government Ordinance(s) (1979/80) - Export and Control Order (1982)
11	Mineral Development	The Regulation of Mines and Oil-Fields and Mineral Development (Government Control) Act (1948)
12	Cultural Environment	- The Antiquities Act (1975) - The Punjab Special Premises (Prevention) Ordinance (1985)
13	Livestock	- West Pakistan Goats (Restriction) Ordinance (1959) - The Grazing of Cattle in Protected Forests (Range Lands) Rules (1978) - Pakistan Animal Quarantine (Import and Export of Animals and Animal Products) Ordinance (1979/80) - The Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh Local Government Ordinance(s) (1979/80)
14	Resettlement	- Land Acquisition Act 1894 - Project Implementation and Resettlement Ordinance - Draft Resettlement Policy of Pakistan,2002 - The Telegraphy Act (1910)

S. No	SECTOR	LEGISLATION
		- The West Pakistan Water & Power Act (1958) - The Electricity Act IX (1910)
15	Public Health and Safety	- The Pakistan Penal Code (1860) - The Public Health (Emergency Provisions) Ordinance (1944) - The Baluchistan, Khyber Pakhtunkhwa, Punjab and Sindh Local Government Ordinance(s) (1979/80) - The West Pakistan Epidemic Diseases Act (1979/80)

Source: Pakistan Environmental Assessment Procedures, Pakistan EPA, Islamabad.

2.8.3. THE PAKISTAN ENVIRONMENTAL PROTECTION ACT (PEPA) NO. XXXIV OF 1997

This comprehensive piece of legislation has evolved over time to provide the legal framework for the preparation and implementation of national environmental policies. It is entitled “The Pakistan Environmental Protection Act,1997 (PEPA 1997)”. The PEPA was enacted in 1997, repealing the PEPO of 1983. The PEPA 1997 provides the framework for implementation of the National Conservation Strategy, including the protection and conservation of species, wildlife, habitats and biodiversity, along with the conservation of renewable resources. The PEPA also establishes the standards for the quality of the ambient air, water and land, along with the establishment of Environmental Tribunals and appointment of Environmental Magistrates. The need and nature of Initial Environmental Examinations (IEE) and Environmental Impact Assessments (EIA) are given along with the need for promotion of public education and awareness of environmental issues through the mass media. The PEPA of 1997 is the basic legislative tool empowering the government to frame regulations for the protection of the environment. This enabling Act is applicable to a broad range of issues and extends to air, water, soil, marine, and noise pollution, as well as to the handling of hazardous wastes. Penalties have been prescribed for those contravening the provisions of the Act. The key features of the Act that have a direct bearing on the Artistic-I Hydropower Project are the following:

Section 11(1) states that “Subject to the provisions of this Act and the rules and regulations made there under, no person shall discharge or emit, or allow the discharge or emission of, any effluent or waste or air pollutant or noise in an amount, concentration or level, which is in excess of the National Environmental Quality Standards.” The Pakistan Environmental Protection Agency (Pak-EPA), the body mainly responsible for enforcing the PEPA of 1997, has published National Environmental Quality Standards (NEQS), which are applicable to all the projects. These are given as **Annexure 1** Drinking water quality standards of Pakistan and Section 12(1) requires that "No proponent of a project shall commence construction or operation unless he has filed with the Federal Agency an Initial Environmental Examination [IEE] or, where the project is likely to cause an adverse environmental effect, then an Environmental Impact Assessment [EIA],and has obtained from the Federal Agency approval in respect thereof. "Section 12(2) the Federal Agency shall review the Environmental Impact Assessment report and accord its approval subject to such conditions as it may deem fit to impose, or require that the Environmental Impact Assessment be resubmitted after such modifications as may be stipulated, or reject the project as being contrary to environmental objectives. Section 14 requires that "Subject to the provisions of this Act, no person shall generate, collect, consign, transport, treat, dispose of, store, handle, or import any hazardous substance except (a) under a license issued by the Federal or Provincial Agency and in such manner as may be prescribed; or (b) in accordance with the provisions of any other law for the time being in force, or of any international treaty, convention, protocol, code, standard, agreement, or other instrument to which Pakistan is a party". Enforcement of this clause requires the Pakistan Federal or Provincial EPA to issue regulations regarding Licensing procedures and to define 'hazardous substance'.

2.9. THE PROJECT IMPLEMENTATION AND RESETTLEMENT ORDINANCE OF 2001

The Government has proclaimed an ordinance entitled "Project Implementation and Resettlement of the Affected Persons Ordinance 2001", later referred to as the "Resettlement Ordinance". This ordinance will be used to safeguard the interests of the persons/groups, who have to be involuntarily resettled due to land acquisition caused by a proposed project. This Ordinance establishes that the resettlement of the involuntarily displaced persons is done as a matter of right and not by way of charity or any such sentiment. In addition, the Affected Persons (APs) shall be accepted as special groups, who in the supreme interest of the country have accepted/undergone involuntary displacement. The proposed Ordinance shall be supplementary to the Land Acquisition Act of 1894, as well as other Laws of Pakistan, and, wherever such items are included in the Draft Resettlement Policy.

2.9.1. THE LAND ACQUISITION ACT, 1894 (INCLUDING LATER AMENDMENTS)

The Land Acquisition Act of 1894 sets out the rules and procedures for acquiring land and immovable assets needed for development. The Act sets out the methodology for compensating the owners of affected land and assets. The Act comprises 55 Sections dealing with area notifications, surveys, acquisition, compensation, apportionment awards, dispute resolution, penalties and exemptions. However, it does not cover the aspect of resettlement of the affected population. In this respect, the GoP is in the process of formulating appropriate laws and policies with the assistance of the ADB. It should be noted that there have been frequent revisions to the Land Acquisition Act and that the latest revisions will apply.

2.9.2. THE ANTIQUITIES ACT, 1975

The Antiquities Act of 1975 ensures the protection of cultural resources in Pakistan. The act is designed to protect defined “antiquities “from destruction, theft, negligence, unlawful excavation, trade and export. Antiquities have been defined in the Act as ancient products of human activity, historical sites, or sites of anthropological or cultural interest and national monuments. The law prohibits new construction in the proximity of a protected antiquity and empowers the Government of Pakistan to prohibit excavation in any area, which may contain articles of archaeological significance. The guideline procedure for Environment Assessment recommended by the Pakistan EPA reads as follows:

“If the proponent or the consultant identifies an archaeological site that appears to be of importance but the site is not listed, they should discuss the site with the relevant conservation authority”. “The relevant conservation authority should inform the Responsible Authority of their assessment of the significance of the likely impact of the proposed development early in the process, in order for the Responsible Authority to determine the level of documentation required. The EPA will then be in a position to review the level of reporting required in the light of advice from the Archaeology Department”. The Federal Department of Archaeology and Museum, Government of Pakistan, is the sole custodian of all articles of archaeological finds and historical heritage. The above powers have now been given to the provinces after the devolution of Federal Authority.

2.9.3. THE TELEGRAPHY ACT, 1910

The Telegraphy Act of 1910 was promulgated for installation of telegraph poles and stringing. The Act allows provision for installing poles and towers without the need to acquire any land. However, there is provision for temporary acquisition of land during the construction period of such infrastructure. In such circumstances, compensation is made just for the loss of crop for a specific period of temporary occupation for construction.

2.9.4. THE WAPDA ACT NO. XXXI OF 1958

WAPDA Act No XXXI of 1958 provides for the unified and coordinated development of the water and power resources of Pakistan (then West Pakistan). This Act authorizes WAPDA to construct and operate electrical transmission lines, entrusting powers and obligations to them as a licensee under the Telegraphy Act of 1910. The WAPDA Act also establishes policy for land acquisition and compensation, as well as the degree of liability of WAPDA for damages sustained by landowners and other parties.

2.9.5. THE ELECTRICITY ACT, NO IX OF 1910 WITH ELECTRICITY RULES OF 1937

The Electricity Act of 1910 and Electricity Rules of 1937 relate to the supply and use of electrical energy in Pakistan. This Act applies together with supplementary rules that have been issued from time to time.

2.9.6. THE FOREST ACT OF 1927, AND LATER AMENDMENTS

The Forest Act of 1927 establishes the right of the Government to designate areas for reserved forest, village forest and protected forest, and they may acquire such areas in order to prohibit or restrict the public use of such resources or other activities within them.

2.10. THE PROTECTION OF TREES AND BRUSHWOOD ACT OF 1949

The Protection of Trees and Brushwood Act of 1949 prohibits the cutting or lopping of trees and brushwood without the permission of the Forest Department.

2.10.1. THE LOCAL GOVERNMENT ORDINANCE OF 1979

Section 93 of the Local Government Ordinance of 1979 pertains to environmental pollution. Under this Ordinance, the local councils are authorized to restrict activities causing pollution to air, water or land. They may also initiate schemes for improving the environment.

2.10.2. THE NORTH-WEST FRONTIER PROVINCE WILDLIFE (PROTECTION, PRESERVATION, CONSERVATION AND MANAGEMENT) ACT, 1975

Nothing hereinafter provided shall be deemed to authorize any person to hunt in the reserved or protected forests or protected waste land as constituted and declared under the provisions of the Forest Act, 1927 (Act XVI of 1927), or the Hazara Forest Act, 1936 (N.-W. F. P. Act VI of 1937), or on any person's private property without permission. According to this Act, no person shall:

a) Hunt any wild animal by means of a gun, drop spear, deadfall, gun trap, explosive projectile, bomb, grenade, baited hook, net, snare or any other trap, an automatic weapon, or a weapon of a calibre used by the Pakistan Army or Police Force or by means of a projectile containing any drug or chemical substance likely to anaesthetize, paralyze, stupefy or render incapable an animal whether partly or totally;

b) Hunt any protected animal;

c) Hunt any game animal except under a permit and in accordance with the provisions of this Act or the rules;

d) Provided that no person shall hunt any game animal other than birds or hares with a shot-gun or with non-magnum rifle of 22 calibre or less use, or have in his possession any net, snare, bhagwa, poison or like injurious substance for the purpose of hunting a game animal, use vehicle of any type to pursue any game animal, or to drive or stampede game animal for any purpose;

e) Shoot any game animal from any conveyance or from within two hundred yards of the conveyance.

2.11. THE WEST PAKISTAN FISHERIES ORDINANCE, 1961(ORD. XXX OF 1961)

This Ordinance may be called the West Pakistan Fisheries Ordinance, 1961.This Act pertains to different regulatory and control measures relating to Fisheries. The relevant important provision of this are reproduced below.

Table 2-2 Important Provision West Pakistan Fisheries Ordinance, 1961

1	**Section 6:** No person shall use 1[any dynamite, electric shock or other explosive substance] in any water with intent thereby to catch or destroy any of the fish that may be therein.	Destruction of fish by explosive
2	**Section 8:** No person shall kill, capture, or possess any species of fish specified in the second column of the First Schedule, of a size less than that specified in the third column of the said Schedule against such species.	Fish that shall not be taken
3	**Section 9:** (1) No person shall use or employ for the capture of any species of fish, in any water other than private water, any net, cage, trap or other contrivance for taking fish or fixed engine, except during the period permitted. [Provided that in the case of trout, only such gear and in such number shall be used or employed as may be specified in the license or permit, (2) Licenses shall be issued by authorities, on payment of fees and on conditions as may be prescribed.	Net, fixed engine trap, etc. shall not be employed without a permit or license.

4	**Section 10:** Every person in possession of any fishing license or permit shall produce his license or permit, as the case may be, on a demand made by the Inspector of Fisheries or any other person authorized in this behalf by the Director of Fisheries.	Duty to produce license or permit on demand made by employees of Fisheries Department
5	**Section 11:** (1) Not withstanding anything contained in this Ordinance, Government may, by notification, declare any water to be a sanctuary for fish mentioned in the First Schedule for a period, which may be specified, and during such period, no person shall kill, capture or possess such fish without a special permit issued under this Ordinance by the Director of Fisheries.	Power to declare any water to be a sanctuary for fish

2.11.1. The Explosives Act, 1884 (IV of 1884)

This Act may be called the Explosives Act, 1884; and it extends to the whole of Pakistan. This deals with the manufacture, possession, transportation, possessing, storage, using, selling or importation of dangerous explosives.

2.11.2. Pakistan Penal Code, 1860

The provisions of the Pakistan Penal Code of 1860 fix the penalties for violation of statutory instruments in the country. These include pollution of air, waterbodies and land. The Penal Code 1860 provides for and deals with a wide spectrum of offences and related punishments under the law.

2.11.3. Provincial Government Statutory Framework

The proposed Artistic-I HPP is to be located in the KP Province. The following KP laws are likely to be relevant and have to be taken into consideration.

a. Forest

i. NWFP (KP) Forest Ordinance 2002

ii. NWFP (KP) Forestry Commission Act 1999

iii. NWFP (KP) Management of Protected Forests Rules 1975

iv. NWFP (KP) River Rules 1952

v. NWFP (KP) Protection of Trees and Bush wood Act 1949

b. Fisheries

i. NWFP (KP) Fisheries Rules 1976

c. Wildlife/Fauna/Non-Timber Flora

i. NWFP (KP) Wildlife (Protection, Preservation and Management) Act 1975

ii. NWFP (KP) Wildlife (Protection, Preservation, Conservation and Management) Act1975

d. Protected Areas

i. NWFP (KP) Wildlife (Protection, Preservation and Management Act 1975-National

ii. Sanctuaries, Game Reserves, Private Game Reserves)

e. Freshwater

i. NWFP (KP) River Protection Ordinance 2002

ii. NWFP (KP) Local Government Ordinance 2001 (Clause 4.3.2.1)

2.12. INSTITUTIONAL FRAMEWORK RELEVANT FOR EIA IN PAKISTAN

The success of environmental assessment as a means of ensuring that development projects are environmentally sound and sustainable depends in a large measure on the capability of regulatory institutions to operate in an effective manner to achieve the objective. The institutional framework for decision making and policy formulation on environmental and conservation issues are briefly described below.

2.12.1. FEDERAL GOVERNMENT INSTITUTIONS

Headed by a Federal Minister, the Ministry of Environment, Local Government and Rural Development, is the main government organization responsible for the protection of environment and resource conservation. The Ministry works with the Pakistan Environmental Protection Council (PEPC) and the Federal and Provincial Environmental Protection Agencies and was established under the provisions of the PEPA of 1997.

Two organizations, the Pakistan Environmental Protection Council (PEPC) and the Pakistan EPA, are primarily responsible for administering the provisions of the PEPA of 1997. The EPC oversees the functioning of the Pakistan EPA. The Federal Government has formed the PEPC.

Its members include the President of Pakistan (or someone appointed by the President), as the Chairperson; the Minister of the Ministry of Environment as the Vice-Chairperson; Governors of the Provinces; Ministers in charge of the subject of environment in the Provinces; the Secretary to the Federal Government is the in charge of the Ministry of Environment, Local Government and Rural Development; the Director General of the Federal EPA; Heads of Federal and Provincial Environmental Protection Departments; environmentalists and community representatives, including scientists. The functions and powers of the Council include formulation of national environmental policy, enforcement of the PEPA of 1997, approval of the NEQS, incorporation of environmental considerations into national development plans and policies and to provide guidelines for the protection and conservation of biodiversity in general and also for the conservation of renewable and non-renewable resources. The Federal Government has also formed the Federal EPA, which is headed by a Director General and has wide ranging functions given in the PEPA of 1997.

These include preparation and co-ordination of national environmental policy for approval by PEPC, administering and implementing the PEPA of 1997 and preparation, revision or establishment of NEQS. The Federal EPA has overall jurisdictions over EIA/IEE issues. Federal jurisdiction is applicable to the projects, which are:

a. On federal land

b. Military projects

c. Involving trans-national impacts and

d. Having trans-province impacts

For all other cases, the concerned provincial Responsible Authority shall have jurisdiction over EIA and IEE issues. The Federal EPA reserves the rights to review any Environmental Report at any time and to suspend the powers it has delegated to any Responsible Authority if it believes those powers have not been properly used.

2.12.2. Provincial Government Institutions

Each provincial government has its own environmental protection institution responsible for pollution control. The provincial EPAs and the Environmental Protection Departments (EPDs) are the provincial counterparts of the Federal EPA, which is authorized to delegate powers to its provincial counterparts. The Provincial Environmental Protection Agencies are formed by the respective Provincial Governments. A Director General who exercises powers delegated to him by the concerned Provincial Government heads the Provincial EPA. The reports covering IEEs and EIAs are submitted to the concerned Provincial EPAs for approval. For public works, responsibility for IEE management, review and granting or refusing of environmental approval, will be vested in the Planning and Development Departments (referred as P&Ds) responsible for economic and development planning at federal and provincial levels. At the provincial level, the KP holds all the required administrative powers regarding land acquisition, resettlement and rehabilitation of displaced people of any development project. For this project, various government departments at Federal, Provincial and District level will interact and collaborate for implementation of the project. One of the prerequisites which will require immediate action relates to the handling of environmental issues. For construction of the project, reservoir area upstream of the weir, land required for the Box Channel, Inlet pond and Powerhouse area will need to be acquired. The project area is covered within the administrative jurisdiction of District Administration of Upper Dir. The Land Acquisition Act of 1894 with its amendments will need to be applied for acquisition of the land. Other land-based assets will be acquired according to the rules and regulations applicable for acquiring such assets.

2.12.3. International and National Non-Governmental Organizations (NGOs)

International environmental and conservation organizations, such as the International Union for the Conservation of Nature (IUCN) and the World Wildlife Fund for Nature (WWF), have been active in Pakistan for some time. Both these organizations have worked closely with the Government and have played an advisory role with regard to the formulation of environmental and conservation policies. Ever since the Rio Summit, a number of national environmental non-governmental organizations (NGOs) have also been formed, and are engaged in advocacy and, in some cases, research. The most prominent national environmental NGOs, such as the Sustainable Development Policy Institute (SDPI) and Shirkatgah, are members of the Pakistan National Committee of IUCN. The International Fund for Agricultural Development (IFAD) has also been active for some time. Much of the Government's environmental and conservation policy has been formulated in consultation with leading NGOs, who have also been involved in drafting new legislation on conservation.

2.13. SPECIFIC EIA REQUIREMENTS FOR ARTISTIC-I HYDROPOWER PROJECT

2.13.1. Basis for the Environmental Study

The Pak-EPA under the powers conferred upon it by the PEPA of 1997 provides the necessary details for the preparation, submission, and review of the Initial Environmental Examination (IEE) and the Environmental Impact Assessment (EIA) for the proposed developments. Categorization of projects for IEE and EIA is one of the main topics of the IEE-EIA Regulations of 2000. Projects have been classified on the basis of expected degree and magnitude of environmental impacts and are included in different schedules contained in the IEE-EIA Regulations of 2000. The projects listed in Schedule-I include those where the range of environmental issues is comparatively narrow and the issues can be understood and managed through less extensive analysis. Schedule-B projects require an IEE to be conducted, rather than a full-fledged EIA, provided that the project is not located in an environmentally sensitive area. The projects listed in Schedule-II are generally major projects and have the potential to affect a large number of people. Projects in environmentally sensitive areas are also included in Schedule-II. The impact of such projects may be irreversible, and could lead to significant changes in land use and the social, physical and biological environment. The development of hydropower projects of more than 50 MW capacity fall under Schedule II (which requires EIA). Therefore Artistic- I HPP with a capacity of 62.606 MW is evaluated in Schedule II category of the IEE-EIA Regulations of 2000. This project, therefore, falls in Category II and requires a full EIA. The details of the classification criteria for Schedule-II and Schedule-I are given in **Table 2-3.** The major international Conventions and Treaties signed by Pakistan are presented in **Table 2-4**

2.14. EIA REQUIREMENTS OF POTENTIAL FINANCING INSTITUTIONS

2.14.1. THE WORLD BANK

Potential financing and managing institutions for the proposed project include the World Bank. The environmental assessment requirements of the World Bank are clearly laid out in its safeguard policies and procedures and considered to constitute International Best Practice. The crucial documents are the Bank's Operational Policies (OP) and Bank Procedures (BP). Operational Policy 4.01and Bank Procedure 4.01 (amended in March 2007 and revised in Feb.2011) clearly outline the requirements for Environmental Assessment for World Bank managed development projects and programmes. These two documents are supported by a Guidance Note on Environmental Assessment. All three of these documents are publicly available on the website of the World Bank, along with the Environmental Assessment Sourcebook and toolkits. The sourcebook has a section specifically dealing with dams and also electricity transmission lines. The way that the World Bank makes sure that these environmental safeguards are incorporated into the Bank's lending policy is clearly set out in OP/BP 4:00 on the use of borrower systems to address environmental and social safeguards.

The basic philosophy that underpins the World Bank approach to environmental assessment is that all development should be environmentally sound and sustainable in the broadest sense, covering both the natural and human/social aspects of development. No person is to be made worse off as a result of any intervention. Any potential adverse impacts are to be avoided by appropriate changes in intervention design. Where this is not possible, the potential adverse impacts are to be fully mitigated by appropriate interventions and the costs of these are to be included in the economic appraisal of the proposed intervention. In addition, the aim of the World Bank's environmental assessment process is to ensure proposed interventions maximize their environmental benefits, often adopting suitable design elements to enhance positive impacts. The World Bank Guidance Note on Environmental Assessment has a categorization of projects according to their type, size and likely degree of impact and outlines the different procedures needed for each category. The proposed project falls into World Bank Category A under both Section (a) being a dam and reservoir, and also Section (l) being a hydropower development. The World Bank has an Operational Policy specifically for Water Resources Management (OP4.07 dated February 2000), which is of direct relevance to the proposed project. There is also a Bank Procedure for projects on International Waterways (BP 7.50, dated October 1994), which is of the utmost importance to the proposed project. BP 7.50 outlines the Bank's requirements for dealing with trans-boundary water projects, of which the Indus Water Treaty of 1960 is critical in addressing this issue. Other relevant World Bank policies and guidelines include OP/BP 4.02 on Environmental Action Plans (EAPs), which outline the need for and nature of an EAP. An EAP is required for all Categories A projects, and also if there are significant adverse impacts that cannot be avoided by changes in the design of the proposed intervention. The EAP is to include targeted mitigation programmes, with cost estimates and an implementation programme. An EAP also includes an environmental management and monitoring framework with recommendations for appropriate institutional arrangements for its implementation. Biodiversity considerations form an intrinsic part of the environmental assessment process. The World Bank has a guideline for showing how biodiversity issues are to be mainstreamed into the development process. This is available on the Bank's website. Similarly, public consultation is to be an intrinsic part of the environmental assessment process. The requirements for pubic consultation are clearly stated in Update No 26 of the Environmental Sourcebook, dated May, 1999.

2.14.2. THE ASIAN DEVELOPMENT BANK

The Asian Development Bank (ADB) could be another potential funding institution for the proposed project. The environmental assessment requirements of the ADB are clearly laid out in their Environmental Assessment Guidelines of 2003 and available on the ADB website. Under the ADB classification system, any dam or reservoir is classified as a Category A, as is any project requiring relocation of people. Category A requires a full EIA to be carried out and the formats for reporting are clearly give in Appendix 2 of the 2003 ADB Guidelines. The section headings for an EIA report are given and for a Summary EIA report maximum page length for each section are prescribed. The ADB have also produced sector guidelines for environmental assessment and rapid environmental assessment checklists, including one for hydropower.

2.14.3. OTHER INTERNATIONAL PROCEDURES FOR ENVIRONMENTAL ASSESSMENT OF DAMS

There are also other international institutions dealing with questions concerning the environmental assessment of dams. These include the World Commission on Dams, which carried out a major review of the environmental consequences of dam construction, and the International Commission on Large Dams (ICOLD). In addition, the Equator Principles, which are a set of guiding environmental principles for both public and private concerns are starting to be used as a framework for environmental management, particularly in the mining and power sectors.

2.15. IMPLICATIONS FOR THE PROPOSED PROJECT

Under the national regulatory framework, the project proponent is the Pakhtunkhwa Energy Development Organization (PEDO) and they are legally bound to follow the national requirements for environmental assessment. The regulatory authority for environmental assessment is the Khyber Pakhtunkhwa Environmental Protection Agency. The proposed Hydro Power Project is a Schedule II project under the Pakistan national classification system and requires a full EIA. Under both the World Bank and Asian Development Bank classifications, the proposed project falls under Category A and requires a full EIA. This EIA report has been structured to satisfy not only the national EA requirements but also at the same time those of the World Bank and the Asian Development Bank.

Table 2-3 Details of the classification criteria for Projects Under Schedule-I and Schedule-II

SCHEDULE II	**LIST OF PROJECTS REQUIRING AN EIA** The Projects in Schedule A are generally major projects and have the potential to affect a large number of people. They also include projects in environmentally sensitive areas. The impact of such projects may be irreversible and could lead to significant changes in land use and the social, physical and biological environment. **Agriculture and Livestock** No EIA's required unless a specific proposal is designated by the Responsible Authority, which could be the result of significant impacts being discovered at the IEE stage. **Energy**

	Thermal Power Generation over 200 MW, Hydroelectric Power Generation over 50 MW, Petroleum Refineries Major Power transmission lines (above 11kV) including Grid Stations, Nuclear Power Plants **Manufacturing and Processing** Major manufacturing of chemicals, pesticides or fertilizer Petrochemical complexes Major tanning and leather finishing Man-made fibres and resin projects greater than10 crore (100million) rupees in value Industrial Estates (including export processing zones)Large scale food processing such as sugar mills, refineries, breweries, distilleries, soft drinks, milk and dairy products greater than 10 crore rupees in value Large scale industrial plants such as: synthetic resins, plastics and manmade fibres, paper and paperboard containers and boxes, plastic products, textiles except apparel, printing and publishing, paints and dyes, oils and fats greater than1 crore rupees in value Cement plants **Mining and Mineral Processing** Major mineral development including; mining and processing of coal, gold, copper, iron, and precious stones Major smelting plants Major non-ferrous metals, iron and steel rolling **Transport** Major Ports and Harbours development Major Airports Federal or Provincial Highways or major roads greater than 5 crore rupees in value Maintenance (rebuilding or reconstruction of existing roads is excluded from the requirement of an EIA). Major railway works **Water Management; Dams, Irrigation and Flood Protection** Dams and reservoirs with a maximum storage volume greater than 50 million cubic meters or a surface area greater than 8square kilometres Irrigation and drainage serving more than 15,000 hectares **Water Supply and Treatment** Major urban water supply infrastructure, including major headworks and treatment plants **Waste Disposal** Waste disposal and/or storage of hazardous or toxic wastes (including landfill sites, incineration of hospital toxic waste) Waste disposal facilities for domestic or industrial wastes, where more than 10,000 cubic meters of waste will be handled annually

	Urban Development and Tourism Land use studies and urban plans (large cities) Large scale tourism developments **Environmentally Sensitive Areas** Any project, which will be situated in an environmentally sensitive or critical area, should be carefully investigated, and the results communicated to the Responsible Authority, who will advise whether an EIA is necessary (see "Guidelines for sensitive and critical areas").
SCHEDULE I	**LIST OF PROJECTS REQUIRING AN IEE** These projects include those where the range of environmental issues are comparatively narrow and the issues can be understood and managed through less extensive analysis. These are projects not generally located in environmentally sensitive areas or smaller proposals in sensitive areas. **Agricultural and Livestock** Agro-industrial installation: large poultry farms and beef cattle Lots Repacking, formulation or warehousing of agricultural produce **Energy** Thermal Power Generation less than 200 MW Hydroelectric power generation less than 50 MW Electrical transmission lines (11kV or smaller), and large distribution projects Major waste to energy generation projects Oil and gas transmission systems Oil and gas extraction including exploration, production, gathering systems, separation and storage **Manufacturing and Processing** Man-made fibres and resin projects less than 10 crore (100million) rupees in value Food processing such as sugar mills, refineries, breweries, distilleries, soft drinks, milk and dairy products less than 10crore rupees in value.

	Sizable ceramics and glass manufacturing Sizable apparel manufacturing including dying and printing Manufacturing wood products on a sizable scale **Mining and Mineral Processing** Commercial extraction of sand, gravel, limestone, clay other minerals not included in Schedule A Crushing, grinding and separating processes Minor smelting Plants **Transport** Ports and Harbours Development for ships less than 500 gross tons Federal or Provincial Highways (except maintenance, rebuilding or reconstruction of existing metalled roads) less than 5 crore rupees in value. **Water Management; Dams, Irrigation and Flood Protection** Dams and Reservoirs with a storage volume less than 50million cubic meters or a surface area less than 8 square kilometre Irrigation and Drainage serving less than 15,000 hectares Small-scale irrigation systems **Water Supply and Treatment** Minor head works and small systems **Waste Disposal** Waste disposal facility for domestic or industrial wastes, where less than 10,000 cubic meters of waste will be handled annually **Urban Development and Tourism** Urban development projects, including large rural hotels, schools and universities Public facilities which have significant off-site impacts (i.e. Hospital wastes) Housing Estates Any other projects that the EPA may require

SCHEDULE C	**LIST OF PROJECTS NOT REQUIRING IEE OR EIA** Essentially Schedule 'C" combines everything not in Schedules 'A 'and 'B'. As is the case for 'A' and 'B' projects, Schedule 'C' projects are also subject to review if they are situated in an environmentally sensitive or critical area. No attempt is made here to detail these projects; however, some illustrative examples are provided below: a. Construction of homes, offices and small commercial buildings, subject to compliance with existing zoning laws; b. Reconstruction/rehabilitation of roads including sealing; c. On-farm dams; d. Projects promoting energy efficiency; and e. Lining of existing canals and/or watercourses.

Source: Government of Pakistan, Pakistan Environmental Protection Agency, "Policy and procedures for the filing, review and approval of environmental assessments".

Table 2-4 Major International Conventions and Treaties Signed by Pakistan

S. No.	Treaties/ Convention	Brief Description
1	The Convention on Biological Diversity	Pakistan signed this convention in 1992. The objective of this convention is conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including those by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies and by appropriate funding
2	The Convention on Conservation of Migratory Species of Wild Animals - 1979	The Convention on the Conservation of Migratory Species of Wild Animals (CMS), 1979, requires countries to take action to avoid endangering migratory species. The term "migratory species" refers to the species of wild animals, a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries. The parties

S. No.	Treaties/ Convention	Brief Description
		are also required to promote or cooperate with other countries in matters of research on migratory species.
3	The Convention on Wetlands of International Importance, Ramsar 1971	Pakistan is a signatory to the said Convention. The principal obligations of contracting parties to the Convention are: a) To designate wetlands for the List of Wetlands of International Importance; b) To formulate and implement planning to promote wise use of wetlands, to carry out EIA before transformations of wetlands, and to make national wetland inventories. c) To establish nature reserves on wetlands and provide adequately for their wardening and through management to increase waterfowl populations on appropriate wetlands; d) To train personnel competent in wetland research, management and wardening; e) To promote conservation of wetlands by combining farsighted national policies with coordinated international action, to consult with other contracting parties about implementing obligations arising from the Convention, especially about shared wetlands and water system. f) To promote wetland conservation concerns with development aid agencies. g) To encourage research and exchange of data for 9 sites in Pakistan that have been declared as wetlands of International Importance or Ramsar Sites (WWF –Pak 2000). None of these wetlands is located within or in close vicinity of the project area.
4	Convention on International Trade	This convention came into effect in March 1973 at Washington. In all 130 countries are signatory to this

S. No.	Treaties/ Convention	Brief Description
	of Endangered Species of Wild Fauna and Flora (CITES) –1973	convention with Pakistan signing the convention in 1976. The convention requires the signatories to impose strict regulation (including penalization, confiscation of the specimen, etc.) regarding trade of all species threatened with extinction or that may become so, in order not to endanger further their survival.
5	IUCN Red List 2000	The red list is published by IUCN and includes those species that are under potential threat of extinction. These species have been categorized as: a) Endangered: species that are seen to be facing a very high risk of extinction in the wild in the near future, reduction of 50% or more either in the last 10 years or over the last three generations, survive only in small numbers, or have very small populations. b) Vulnerable in Decline: species that are seen to be facing a risk of extinction in the wild, having apparent reductions of 20% or more in the last 10 years or three generations. c) Vulnerable: species that are seen to be facing a high risk of extinction in the wild, but not necessarily experiencing recent reductions in population size. d) Lower Risk: species that are seen to be facing a risk of extinction that is lesser in extent that for any of the above categories e) Data Deficient: species that may be at risk of extinction in the wild but at present there is insufficient information available to make a firm decision about its status

CHAPTER 3: PROJECT DESCRIPTION

3.1. INTRODUCTION

This chapter provides the introduction of proposed Artistic-I HPP including technical components of the project as well as the specific functioning of each component as the part of Hydropower Plant. The chapter also includes other project related information such as location and physical accessibility of the project, need and objectives and technical viability of the project and its current status in terms of implementation. Also included in the chapter is environmental classification of Hydropower projects and standing position of Artistic-I HPP under this classification. Project related description is the key component of environmental assessment process. Adverse and beneficial environmental and social impacts of the project are resulted from interaction between project activities and baseline environmental conditions of the project area. Therefore, it requires an in-depth description of proposed project components and activities to provide clear understanding of potential impacts related to the projects and their mitigation measures.

3.2. BACKGROUND

Pakistan is presently facing severe power shortages. This shortfall is increasing day by day. Pakistan has rich and cheap hydel power resources particularly in Khyber Pakhtunkhwa province, which are lying untapped. Hydel Power is the cheapest source of energy as compared to thermal power. Feasibility Study document is required for the development of hydel potential to enable the investor to make decision for investments in the hydel sector.

The M/s Artistic Milliners (Pvt.) Ltd. Karachi, Pakistan has engaged JV of BAK Consulting Engineers, Peshawar and M/s Dolsar Engineering Inc. Co of Turkey to carry out Feasibility Study of proposed Raw site Artistic-I HPP for hydropower development. Consultants have collected the essential data regarding the project from different sources and through various site visits.

3.3. PROJECT LOCATION AND ACCESSIBILITY

The Artistic-I HPP is located in Upper Dir District of Khyber Pakhtunkhwa. Upper Dir is situated about 265 km from Peshawar, while proposed intake weir and power house sites are located about 27 km and 31 km downward to Timergara from Dir city, respectively. As the proposed project is located at Village Sahibabad which is near the starting point of Dir Upper District, so, it is more accessible from Peshawar city.

Table 3-1 Route Names and Distances Between Different Locations

Route Name	Distance
Peshawar- Chakdara	156.6 km
Chakdara-Timergara	39 km
Timergara- Sahibabad	40 km
Peshawar- Sahibabad	235.6 km

The site location and power potential as per LoI is given as under:

Table 3-2 Site location Coordinates as per LoI

Location	Northing	Easting	Elevation
Weir / Intake	35°4'55.58"	71°59'32.33"	1046.94 masl
Power House	35°1'17.56"	72°0'58.83"	986.58 masl

The power potential of the project is estimated to be about 49 MW as per LoI. The project's weir site is located about 2 km downstream of Darora village and about 4 km upstream of Sahibabad village. The power house site is located about 3.5 km downstream of Sahibabad village. Both weir and power house sites are easily accessible through N-45 (Chakdara-Dir) Asphalt Road.

However, the new project coordinates finalized by consultants after site visits and mutual in-house discussions between experts are as under.

Table 3-3 Proposed New Project Coordinates

Location	Northing	Easting	NWL/TWL
Weir / Intake	35°5'52.77"	71°59'0.08"	1071 masl
Power House	35°1'28.32"	72°0'40.77"	990 masl

After this, the power potential of the project is estimated to be about 62.606 MW. The new project weir site is located near Darora Village and about 6.7 km upstream of Sahibabad village. The Power House site is located about 3.5 km downstream of Sahibabad village. Both the new Weir and Powerhouse sites are easily accessible through N-45 (Chakdara-Dir) Asphalt Road.

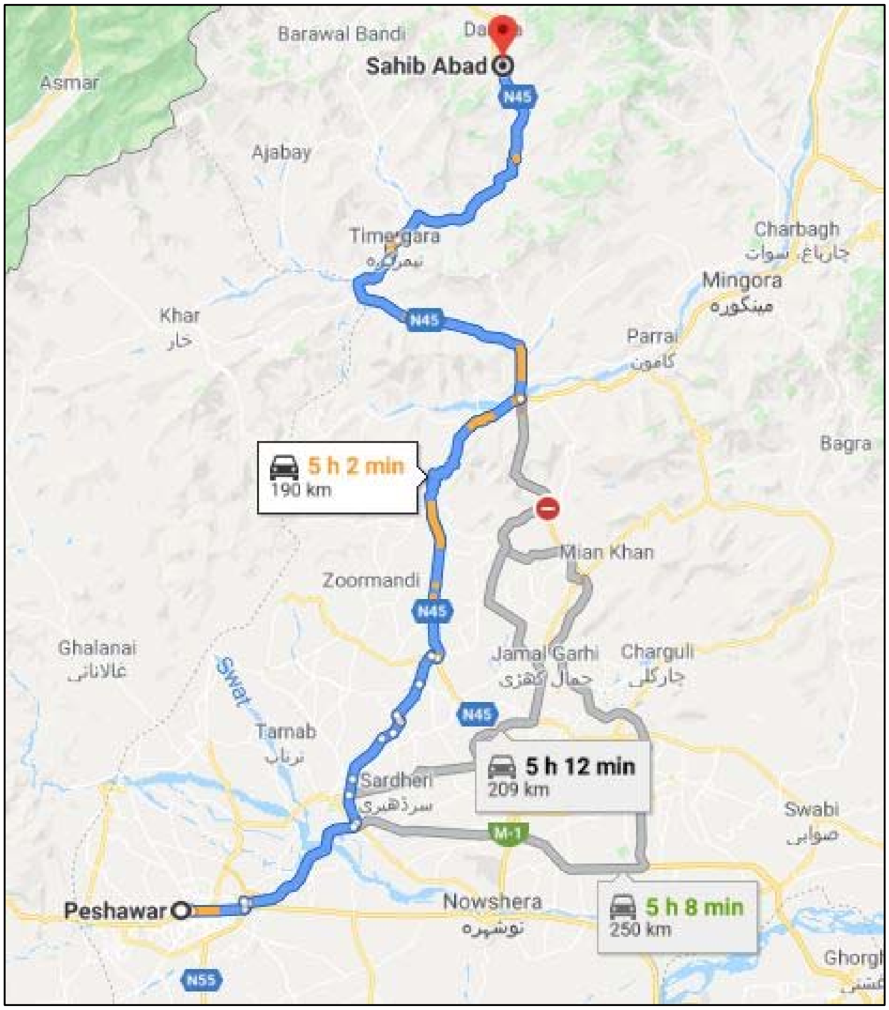


Figure 3-1 Project accessibility from Peshawar

3.4. PROJECT LOCATION MAP AND LAYOUT

Project location map of Artistic-I Raw site at Panjkora River is given as **Figure 1-2.**

3.5. CATCHMENT AREA OF THE PROJECT

The catchment of the Artistic-I HPP lies in the upper region of the Panjkora River, a tributary / sub system of a Swat river basin and can be classified as a “high mountainous catchment” which originates from glacier zone. Two major tributaries join at Chukiatan, just downstream of Dir town to form Panjkora River. On the way downstream, it joins a number of small tributaries evacuating the discharge from different valleys. The stream flow patterns are followed by the seasonal change in temperatures. Glaciers are visible above altitude of 4000 amsl. The highest mountain peak ranges from 600 amsl up to 5750 amsl while river bed elevation at weir site is 1061 amsl and river bed elevation at powerhouse site is at approximately 986.58 amsl. Length of the Panjkora River up to the weir site is about 105 km.

Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km and at powerhouse location is approximately 3235 sq.km. Catchment area map is attached as **Figure 3-2** and **Figure 3-3** below.

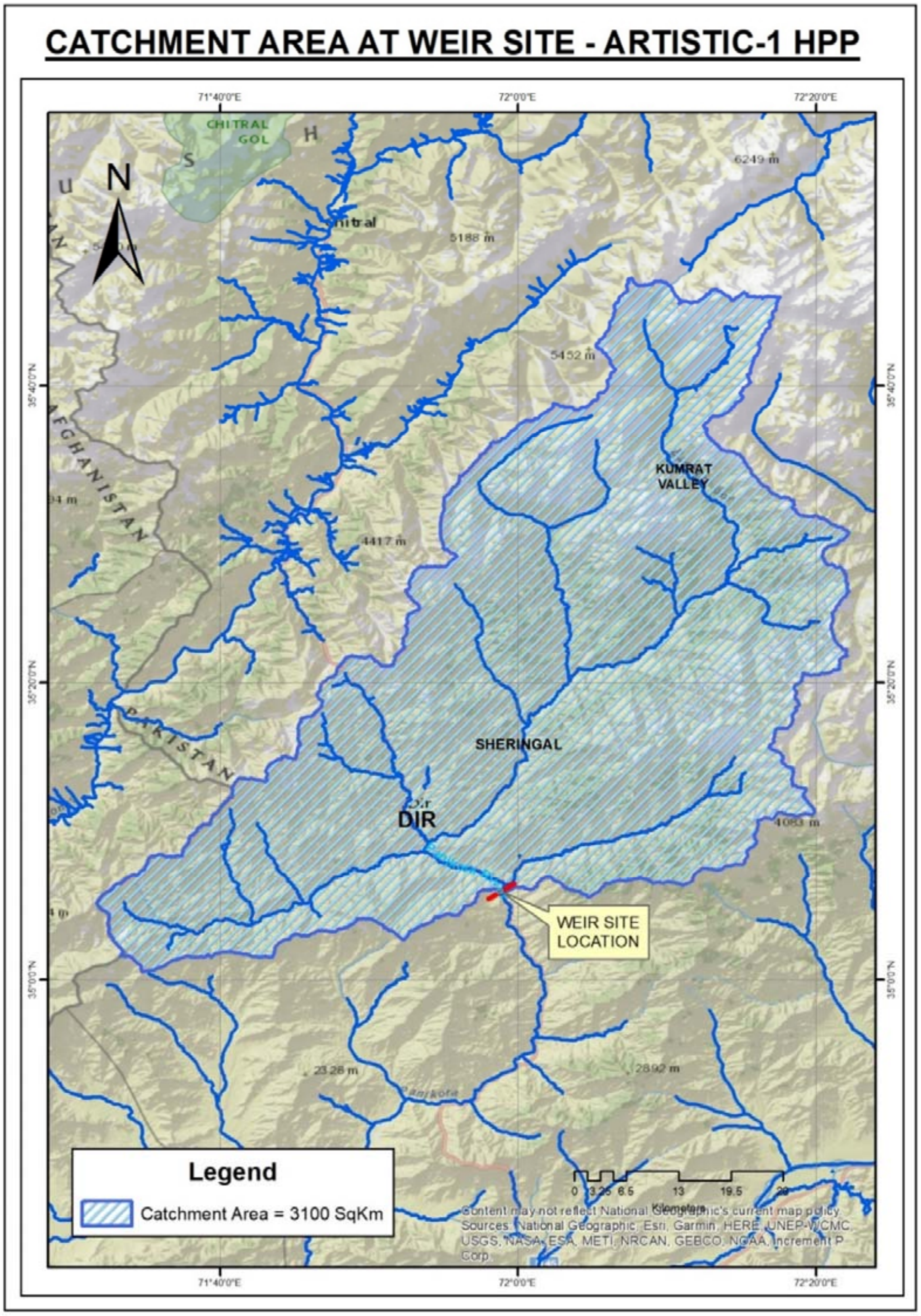


Figure 3-2 Catchment Area Map of Artistic-I Hydropower Project – At Weir Site

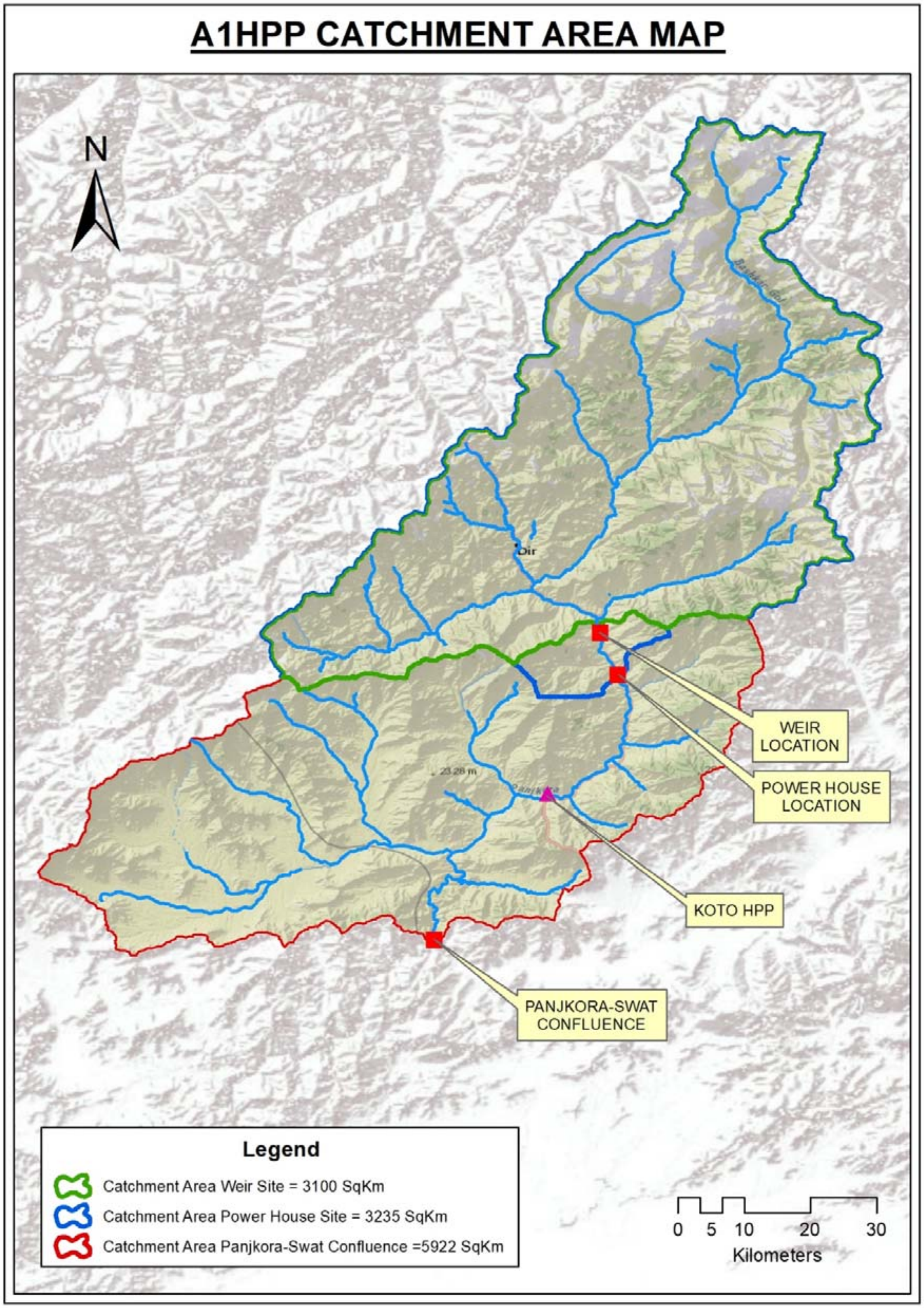
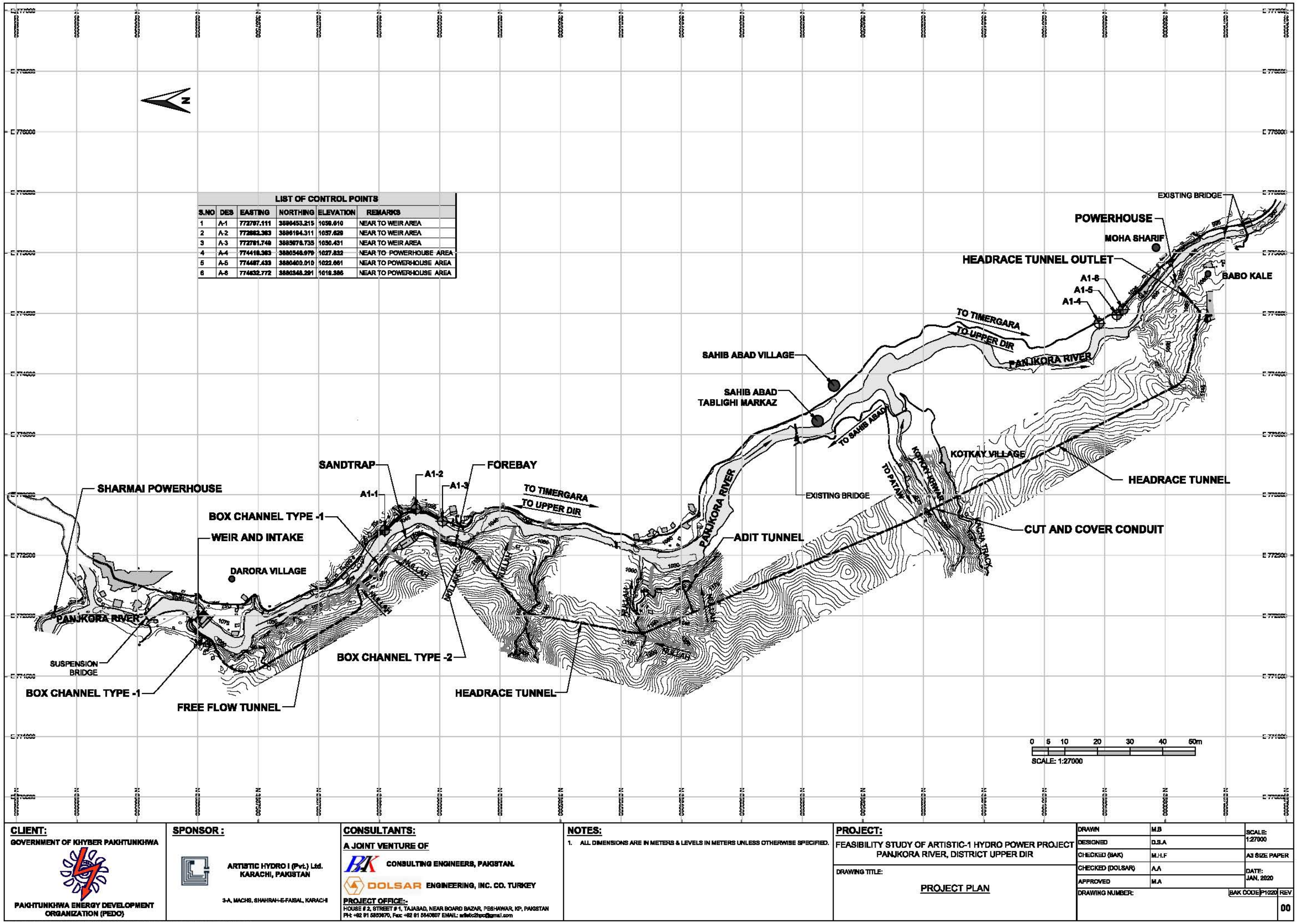


Figure 3-3 Catchment Area Map of Artistic-I Hydropower Project – At Weir, Powerhouse and Panjkora-Swat River Confluence



LIST OF CONTROL POINTS

S.NO	DES	EASTING	NORTHING	ELEVATION	REMARKS
1	A-1	772707.111	3886453.215	1059.610	NEAR TO WEIR AREA
2	A-2	772862.363	3886194.311	1057.629	NEAR TO WEIR AREA
3	A-3	772761.749	3885976.735	1050.431	NEAR TO WEIR AREA
4	A-4	774416.363	3880546.979	1027.832	NEAR TO POWERHOUSE AREA
5	A-5	774487.433	3880400.010	1022.661	NEAR TO POWERHOUSE AREA
6	A-6	774632.772	3880348.291	1019.386	NEAR TO POWERHOUSE AREA

Figure 3-4 Artistic-I HPP Layout

3.6. OBJECTIVES OF THE PROJECT

Pakistan is endowed with plenty of natural resources, including water resources. Besides water supply and irrigation, water resources are also utilized to produce electricity. National water resources have rich potential for hydropower generation, estimated as 60000 MW which could be economically harnessed. Out of this vast hydropower potential only 11% has been developed so far. Hydropower is the best available option in the recent scenario of meeting challenges of projected future energy demands of our country as it is sustainable, reliable, renewable, clean, low cost and indigenous, thus, can be the principal source of energy. It is therefore imperative to put all-out efforts towards development of the untapped hydropower potential without further delay. Accordingly, there is a transition in policy priority i.e. shifting from development of gas/oil based thermal power plants with merits of comparatively shorter construction time and lower capital investment to hydropower generation.

The Private Power and Infrastructure Board (PPIB) has already been successful in attracting significant investment in developing hydropower projects, which are currently at different stages of implementation. The world-over, hydropower projects are characterized with a variety of technical and economic constraints and bottlenecks, Pakistan being no exception. These include hydrological risks, resettlement and environmental issues, regulatory matters, market dynamics and financing problems. In the past, no attention was ever paid to address these impediments in development of hydropower projects. The government has now taken a number of initiatives to remove all the factors hampering Independent Power Producers (IPPs) in developing hydropower projects.

Focus is on creating synergy among various stakeholders including regulatory bodies. A policy framework has been evolved recently to allow certain re-openers to cover cost variations due to geological surprises in tunnels excavation, cost escalation on civil works and cost variations in resettlement etc. Consequently, tariff determination for the hydropower projects will be done at three stages vis-à-vis on approval of feasibility report, on finalizing the EPC (Engineering, Procurement and Construction) contract and finally on attaining the COD (Commercial Operation Date). It is of great satisfaction that PPIB has updated its well-documented report on the “Hydropower Resources of Pakistan”. On one hand, it provides comprehensive information on the hydropower potential in the country duly supported with authentic data, highlighting salient features of the investor-friendly power policy in vogue; on the other hand, the report deals with status of various hydropower projects in operation as well as projects currently under planning and implementation. The report is aimed at facilitating the prospective investors to develop and operate hydropower projects profitably.

In lines with the committed policy of the government to improve socio-economic conditions in all regions at a fast pace, development of hydropower projects is a key element of the overall plan prepared in this direction. Besides, providing electricity at an affordable price, implementation of hydropower projects will bring in prosperity to the country in general and to the rural and remote areas in particular. These cherished goals can only be achieved with the effective support and earnest participation of the private sector. It is envisaged that in response to the investor friendly power policy, additional investments, domestic as well as foreign, would be attracted in the hydropower sector in the immediate future.

Similar to rest of the world, electricity demand in Pakistan is increasing at huge pace. Proposed Artistic-I HPP is the part of efforts of Khyber Pakhtunkhwa government to exploit the indigenous hydropower resources of the province to produce the low cost and environment friendly electricity through public sector investment. Particular objectives of the proposed development are as follows;

- To share power generation efforts of Government of Pakistan at low cost by exploiting the indigenous hydro resources of the country;
- To provide an input to cope with the electricity demand, generally in Pakistan and particularly in KP;
- To ensure the exploitation of indigenous renewable energy resources of the KP as per Power Policy of Pakistan, 2002 and KP policy of hydropower generation projects, 2006.

3.7. PROJECT STATUS

Artistic-I HPP is at feasibility stage at the moment. After the approval of feasibility study, project will enter into the implementation phase through the award of construction contract. As stated earlier, this EIA has been conducted as the part of feasibility study of the project. Consideration of environmental and social aspects at an early stage of the project is necessary to ensure the environmental and social sustainability of the project. The construction of proposed hydropower project will be completed within the period of approximately 5 years including the pre-construction phase of the project.

3.8. ENVIRONMENTAL CLASSIFICATION OF HYDROPOWER PROJECTS

Hydro-power projects can be classified on the following basis:

- Storage capacity (Run-of-the-river or reservoir projects);
- Size (small, medium and large);

- Head (high or low) and
- Purpose (single or multi-purpose).

A brief description and environmental consideration of each classification are provided below:

3.8.1. RUN-OF-THE-RIVER TYPE PROJECTS

This type of hydropower generation utilizes the flow of water within the natural range of the river. Therefore, no or little impoundment takes place. Construction activities of run-of-the-river project tend to be less significant than reservoir project, reducing possible environmental and social impacts associated with it. The absence of any sizable reservoir helps to limit both social and the environmental impacts, as the river is not transformed into a lake.

Run-of-the-river HPP may be of two types; i) low head RoR project and ii) high head RoR project. Run-of-the-river projects, which divert only a small fraction of the river, present significant environmental advantages when compared to projects which utilize all the river flow. However, high head Run-of-the-river plants might require mitigation measures such as minimum ecological flow downstream of the river diversion to ensure sufficient water for aquatic habitats. Hydroelectric power plants may be classified as low head (up to 10 m), medium head (up to 100 m) and high head (above 100 m). Artistic-I HPP falls under the category of medium head r un-of-the-river hydropower projects having gross head of 81 m.

3.8.2. RESERVOIR TYPE PROJECTS

Reservoir type projects involve impounding of water behind a dam to enable flow regulation throughout the year (on a daily or monthly basis) or even exceptionally on a multi-annual basis for very large reservoirs. The environmental impacts of reservoir type projects originate from the construction activities involved in building the dam, embankments and power plant. Reservoir construction raises resettlement of communities and many other social conflicts in the project area.

3.8.3. SMALL, MEDIUM AND LARGE PROJECTS

Depending upon power output, hydropower plants are classified as small (up to 10 MW), medium (up to 100 MW) and large (above 100 MW). There are also mini and micro power plants with capacities in the range of 100 Kw to 1 MW. According to the mentioned classification, Artistic-I HPP falls under the category of medium hydropower plants having estimated power output as 62.606 MW. A frequently used and accepted rule of thumb is that environmental impacts are roughly proportional to area inundated therefore; it is generally assumed that the environmental impacts of small, mini or micro hydropower projects are limited.

3.8.4. MULTIPURPOSE PROJECTS

Increasingly today, projects are designed with several water uses in mind, and these are called multipurpose projects. Water stored in dams is usually used for energy production, irrigation, agriculture, drinking purpose etc. Besides the general environmental and social impacts of hydropower projects, multipurpose projects also pose the cumulative environmental and social impacts due to intended uses of water. The only purpose of Artistic-I HPP is the energy production.

3.9. ARTISTIC-I HPP- CONVEYANCE SYSTEM DESCRIPTION

Artistic-I HPP entails the construction of Run-of-the-river hydropower plant of capacity 62.606 MW. Run-of-the-river plant mainly produces energy from the available flow of the river, taking advantage of the natural elevation drop of a river. Water is diverted with the help of a structure named as weir to forebay via an approach channel or tunnel. Water from forebay moves into the penstock or pipe and channelled to the turbine and then returned to the river. Run-of-the-river plants have either no storage or short-term storage, allowing for some adaptations to the demand profile. Power generation is dictated by the local river flow conditions and thus depends on precipitation and Run of the river and may have substantial daily, monthly or seasonal variations.

Artistic-I power house covered area will be approximately 1440 square meters. Artistic-I weir is proposed at location which offers relatively better geology and ease in river diversion during construction, as river becomes wider. Feasibility level design of all the hydraulic structures i.e. weir / Intake, spillway, sandtrap, sedimentation outlets, inlet pond / forebay, power intake portals / tunnels, surge chamber etc. will be carried out as per best engineering practices with backup calculations. The characteristics of the structures according to design are summarized as follows:

3.9.1. WEIR

Figure 3-5 Site for Weir

Design flood discharge (Q_{500})	:4445 m^3/s
Design flood discharge (Q_{100})	:3208 m^3/s
Weir type	: Broad Crested (Gated Weir)
Spillway apex elevation	:1071.00 m
River bed elevation	:1061.00 m
Weir length	:97 m
Weir width	:72.56 m
Stilling basin length	:26 m
Stilling basin width	:97 m

Foundation bottom elevation	:1057.95 masl
Energy dissipating basin elevation	: 1057.95 amsl
Energy dissipating basin width	: 82 m
Energy dissipating basin length	: 26 m
Width of spillway	: 82 m
Discharge from gated weir	:3002 cumecs
Discharge from under sluices	: 217 cumecs
Total discharge	: 3219 cumecs
Crest elevation of upstream walls	: 1073.00 masl
Crest elevation of downstream walls	: 1069.75 masl
Under sluices	: 2 No.s
Dimensions of under sluice gates	: 4.5 m x 5.0 m
Thickness of middle pier btw gates	: 2 m
Energy dissipating basin elevation	:1059.4 masl
Energy dissipating basin length	: 22.76 m
Crest elevation of downstream walls	:1069.75 masl

3.9.2. DIVERSION SYSTEM:

Design flood discharge (Q_{10})	: 1586 cumecs
Type of diversion channel	: Trapezoidal section (RCC)
Side slopes of channel	: 1.5
Bottom width of channel	: 22 m
Channel height	: 4 m
Water depth at Q_{10}	: 3.84 m

Bottom slope of channel	: 0.0133
Length of channel	: 452.78 m
Manning's "n" for rip-rap	: 0.016

3.9.3. INTAKE:

Service gates and racks	: 4 Nos.
Gate and rack dimensions (net)	: 5 m x 6.8 m (W x H)
Inlet sill height	: 3 m
Base elevation of intake structure	: 1064 masl
Middle piers	: 3 Nos.
Thickness of middle piers	: 2.5 m
Length of transition structure	: 64.7 m

3.9.4. FREE FLOW TUNNEL:

Type of internal cross section	: D-shaped, reinforced concrete
Type of excavation cross section	: D-shaped
Diameter of internal cross section	: 7.10 m
Diameter of excavation cross section	: 8.20 m
Bottom slope of tunnel	: 0.0005
Length of tunnel	: 1,583 m

3.9.5. BOX CHANNEL TYPE-I:

Type of cross section	: Rectangular, reinforced concrete
Flow regime	: Open channel, subcritical
Capacity	: 110 m^3/s
Bottom Slope	: 0.0004

Manning's "n" for concrete	: 0.014
Width	: 5.90 m
Water depth at full capacity	: 4.45 m
Freeboard	: 0.55 m
Height	: 5.00 m
Velocity of water at full capacity	: 2.09 m/s
Length of channel	: 615 m

3.9.6. SAND TRAP:

Spans	: 6
Width of each span	: 8 m
Middle piers	: 6 Nos
Net total width of sand trap	: 98 m
Water depth at the beginning	: 6.50 m
Water depth at the end	: 8.46 m
Minimum particle size to be settled	: 0.3 m
Velocity of water at the beginning	: 0.296 m/s
Velocity of water at the end	: 0.236 m/s
Crest elevation of the structure	: 1070.60 masl
Water level within the settling basin	: 1069.64 masl
Flushing pipe	: 1 Nos
Starting base elevation of flushing pipe	: 1057.18
Diameter of flushing pipes	: 1.1 m
Total flushing discharge	: 10.2 cumecs

Velocity of water in flushing pipe	: 10.73 m/s
Top elevation of end sill	: 1064.95 masl
Length of end sill block	: 7 m
Length of transition	: 15.65 m
Length of exit gates block	: 6.65 m
Exit gates	: 6 Nos
Gate dimensions (net)	: 4 m x 5 m (W x H)
Length of transition to box channel	: 17.70 m

3.9.7. BOX CHANNEL TYPE-2:

Type of cross section	: Rectangular. reinforced concrete
Flow regime	: Open channel, subcritical
Capacity	: 100 m^3/s
Bottom Slope	: 0.0004
Manning's "n" for concrete	: 0.014
Width	: 5.50 m
Water depth at full capacity	: 4.46 m
Freeboard	: 0.54 m
Height	: 5.00 m
Velocity of water at full capacity	: 2.04 m/s
Length of channel	: 245 m

3.9.8. INLET POND:

Normal water level	: 1069.33 masl
Minimum water level	: 1065.71 masl

Length of inlet pond	: 105 m
Water depth at the beginning	: 5.33 m
Water depth at the end	: 21.01 m
Base elevation at the beginning	: 1064.00 masl
Base elevation at the end	: 1048.32 masl
Crest elevation of inlet pond	: 1070.50 masl
Side spillway width	: 60 m
Side spillway capacity	: 100 cumecs
Apex elevation of side spillway	: 1069.40 masl
Bottom slope of side spillway	: 0.01
Crest elevation of stepped spillway	: 1064.00 masl
Width of stepped spillway	: 20 m
Step height	: 1 m
Chute slope	: 1
Length of chute	: 21 m
Base elevation at the end of chute	: 1041.50 masl
Type of energy dissipating basin	: Rough bed (Riprap)
Length of energy dissipating basin	:10 m

3.9.9. TUNNEL INTAKE STRUCTURE:

Inlet sill height	: 2.75 m
Base elevation of the structure	: 1051.07 masl
Crest elevation of the structure	: 1070.50 masl
Racks	: 3 Nos

Width of racks	: 4.75 m
Height of racks (net)	: 13.80 m
Service gate	: 1 Nos
Width of gate	: 6.65 m
Height of gate	: 9.20 m
Diameter of air vent pipe	: 1.20 m

3.9.10. POWER TUNNEL:

Type of internal cross section	: Horseshoe, reinforced concrete
Type of excavation cross section	: D-shaped
Diameter of internal cross section	: 6.65 m
Diameter of excavation cross section	: 7.65 m
Bottom slope of tunnel (between tunnel inlet and Kotkay Khwar)	: 0.001
Bottom slope of tunnel (between Kotkay Khwar and valve chamber)	: 0.009
Length of tunnel	: 7460 m

3.9.11. ADIT TUNNEL:

Length	: 267 m
Diameter	: 3.5 m
Bottom Slope	: 0.064

3.9.12. SURGE TANK:

Type of internal cross section	: Circular, reinforced concrete
Type of excavation cross section	: Circular

Diameter of internal cross section : 17.30 m

Diameter of excavation cross section : 20.20 m

Maximum downsurge : 1035.55 masl

Maximum upsurge : 1095.45 masl

Top elevation of surge tank : 1101.00 masl

Bottom elevation of surge tank : 1027.97 masl

Height of surge shaft : 73 m (above tunnel crown)

3.9.13. Penstock:

Length : 149 m

Diameter : 5.05 m

At the end : Trifurcation

3.9.14. Power House:

Figure 3-6 Site view of Power House area

Tailwater level : 990.00 m

Gross head from Artistic-I Weir : 81.00 m

Gross head from forebay	: 79.33 m
Net head (at design discharge)	: 70.50 m
Turbines	: 3 Nos. (2 Big + 1 Small)
Design discharge	: 100 m^3/s (2 x 37.50 + 1 x 25.00) m^3/s
Type of turbines	: Vertical Francis
Assumed rated efficiencies	: 0.94 x 0.98 x 0.99 (Trbn., Gen., Tr.)
Installed Capacity	: 62.606 MWe
Average Annual Energy Generation	: 304.567 GWh

Note. All the measurements/Dimensions are tentative and approximated.

3.10. PROJECT PHASES AND ACTIVITIES

Major phases of the project are listed below:

- Site evaluation and design phase;
- Pre-construction and construction phase;
- Operation and maintenance phase; and
- Decommissioning and reclamation

Each phase would involve the following general activities;

3.10.1. SITE EVALUATION AND DESIGN PHASE ACTIVITIES

The purpose of site evaluation is to determine whether a given site is suitable for a Run-of-the-river hydropower plant. The technical and delineation of drainage basins and estimates of flow in Panjkora River was investigated in detail. On this basis present site was allocated for the Artistic-I HPP where reasonable flow of water and suitable head is available for hydroelectric power generation up to the capacity of 62.606 MW. A topographic survey had been performed during the site evaluation phase in order to establish the basic project design and layout to locate the intake and powerhouse; weir; access roads; pipes and channels; and other project components.

Geo technical investigations such as drilling were also performed. Borrow areas for sand and gravel would be delineated and tested. Access roads would need to be constructed to support such activities. Ecological studies as mentioned in later chapters have been conducted on the terrestrial and aquatic biota of the project area. A comprehensive survey related to socio-cultural and religious resources of the area was also conducted as the part of EIA study.

3.10.2. PRE-CONSTRUCTION AND CONSTRUCTION PHASE ACTIVITIES

Pre-construction phase activities include:

- Site preparation activities such as clearing and grading;
- Construction of access roads;
- Construction of a camp for the project staff and workers;
- Preparation and use of material and equipment lay down areas;
- Concrete ingredients (e.g., sand and aggregate) may need to be extracted and hauled to the site if an appropriate borrow area cannot be found on the site; and
- A refuelling station (with diesel and gas storage tanks) would likely be used during construction.

3.10.3. CONSTRUCTION PHASE ACTIVITIES INCLUDE:

- Construction of the weir and intake system;
- Construction of sandtrap;
- Construction of head race tunnel, forebay and pipelines (Penstock);
- Construction of the powerhouse and installation of the turbine and generator; and Construction of an electrical substation and transmission line.

3.10.4. OPERATIONAL AND MAINTENANCE PHASE ACTIVITIES

No additional land-disturbing activities and associated impacts are anticipated during the operation phase. Routine operation of the Artistic-I HPP facility to produce electricity would most likely be automated. Maintenance activities could include periodic replacement of various facility components.

3.10.5. Decommissioning and Reclamation Phase Activities

Decommissioning of Artistic-I HPP could range from mothballing to full removal of turbines, generators, and other equipment for reuse or for scrap. Buildings, concrete pads, foundations, intake and tailrace facilities would be removed. Underground components would be removed to a depth of at least three feet to ensure an unobstructed root zone for re-vegetation. More deeply buried components might be abandoned in place.

CHAPTER 4: DESCRIPTION OF THE ENVIRONMENT

4.1. OVERVIEW

This section describes the physical, biological and socio-economic environment in the project area. It also examines the existing environmental conditions of the project area to provide a baseline against which the project impacts can be measured and monitored in future. The information provided in this section is both quantitative and qualitative and is based on primary and secondary data, collected through field surveys conducted specifically for this study and desk studies related to the project area.

4.2. BASELINE CONDITIONS

The baseline conditions covering the existing physical, biological and socioeconomic environment of the project as well as study area; have been derived from the field surveys, desk studies, visits to the Government departments and other relevant agencies, discussions with the affected people and notables of the area.

4.3. STUDY AREA

The project study area mainly includes areas where the weir, staff residential colonies/offices, tunnel route, powerhouse, contractor camps/Labour camps, etc. will be constructed. In addition, it also includes the surrounding areas where the influence of the project implementation will occur.

4.4. BASELINE STUDY PURPOSE

The purpose of baseline study is to fulfil the following objectives:

a) To get the data about the physical, biological and socio-economic environment of the project area

b) To understand the current situation of the area comprehensively

c) To rationalize the decisions according to the ground realities

The main environmental conditions, likely to be affected due to project execution are:

i. Physical Environment

ii. Biological Environment

iii. Socioeconomic Environment

4.5. PHYSICAL ENVIRONMENT

Physical environment includes topography, geology and soils, land use, climatology, atmosphere and water resources.

4.5.1. GEOGRAPHY

Upper Dir district is a district in Malakand Division of Khyber Pakhtunkhwa province in Pakistan. The town of Dir is the district headquarters. The district is situated in the northern part of Pakistan. It lies on the southeast side of the Hindu Kush and the major river is Panjkora River which flows southwest through the region. It is bounded by Chitral District on the North, Swat valley on the North-East, Afghanistan on the West, Lower Dir on the south and South-West.

Sahibabad (the project area) is situated in Upper Dir, its geographical coordinates are “35° 02' 54" North, 72° 00' 14" East. It lies about 75 km from Chakdara in the Hindu Raj Ranges (Southern Hindu Kush). The area is linked with Chakdara by a metallic road via Timergara Town. The town is located on the Chakdara-Chitral road. The area comprises gently rolling topography, high ridges, cliffs and rugged hills while relief of the area is moderate.

4.5.2. TOPOGRAPHY

The topography of the district is dominated by high mountains. The most important mountain range is the Hindu Raj. It runs from northeast to south-west along the northern borders with Chitral district. In winter, whole area remains snow-covered. The mountains in the western part of the district are covered with forests, while the eastern mountain range, Dir Kohistan, is barren. Dir Kohistan is the origin of the main river of Chitral i.e. Panjkora River. District head quarter, Upper Dir is connected with metal led or shingled roads to all Tehsil Headquarters. The district is totally mountainous, so, there is no railway and airport.

4.5.3. GEOLOGY, ROCKS AND SOIL

According to the survey of Pakistan and reconnaissance geological surveys carried out in different parts of the area by the geology department of Peshawar and Punjab University, two geological formations exists in the area, which are composed of igneous and metamorphic rock. Igneous rocks are granodiorites, diorites, quartz-diorites, granites, norites, hornblendites, pyroxenites and peridotites. Metamorphic rocks include phyllites, quartzites, quartz-schists, marbles and calcareous schists, amphibolites gneisses. Generally, soil of the area is loamy, sandy loamy and clayey in nature but gravelly, where the rocks are exposed and dominant. In upper areas mostly on steep slopes, the soil is exposed, therefore susceptible to erosion and readily washed away by rains. Deep and rich soil occurs on moderate slopes and such areas are mostly terraced and used for cultivation purposes such as maize, rice, wheat etc.

4.5.4. Climate

The summer season is moderate and warm, where June and July are the hottest months. On average, the maximum and minimum temperature in June is about 33 and 16 degrees centigrade, respectively. Winter season is severely cold and harsh. Temperature rapidly falls from November onwards. During the months of December, January, and February, temperature normally falls below freezing point. The mean maximum and minimum temperature in January are 11 and -2 degrees centigrade, respectively.

4.5.4.1. Climate Data

a) Daily rainfall data for Dir from 1970-2017.

b) Precipitation data of Lower Dir for period of 2010-2015.

c) Monthly data of rainfall for Chakdara and Amandara headwork.

d) Climate data of Dir for period of 1981-2010 including maximum temperature, minimum temperature, humidity, sunshine hour etc.

Mean monthly rainfall and temperature data of climate station at Dir are tabulated below and shown in **Figure 4-1** and **Figure 4-2.**

4.5.4.2. Temperature

Temperature varies considerably during different months of the year and during the same months at different localities of the area. The average minimum temperature at Dir station in December is -1.1°C and average maximum in July 32.3°C at the same station. Frost is also experienced and is common in winter south to north dry breeze lows during summer. Avalanches also happen sometime in winter. The winter season is long and extends from November to March. Rains and snow occur during this season. The temperature falls below freezing point. The details are given below in the **Table 4-1**.

Table 4-1 Mean Monthly Rainfall and Temperature: Dir Station (1981-2010)

Month	Min Temp(°C)	Max Temp(°C)	Precipitation (1981-2010) (mm)
January	-2.5	12	112.5
February	-0.8	12.6	176
March	3.1	16.8	256.5
April	7.4	23	166
May	11.5	28.5	90.5
June	15.1	32.3	56.4
July	18.6	31.7	154.5
August	18.2	30.6	147.5
September	13.7	29.3	76
October	7.1	25.4	72.3
November	2.3	20.3	59.1
December	-1.1	14.6	79.9
	Average 7.7	**Average 23.1**	**Annual Sum: 1447.2**

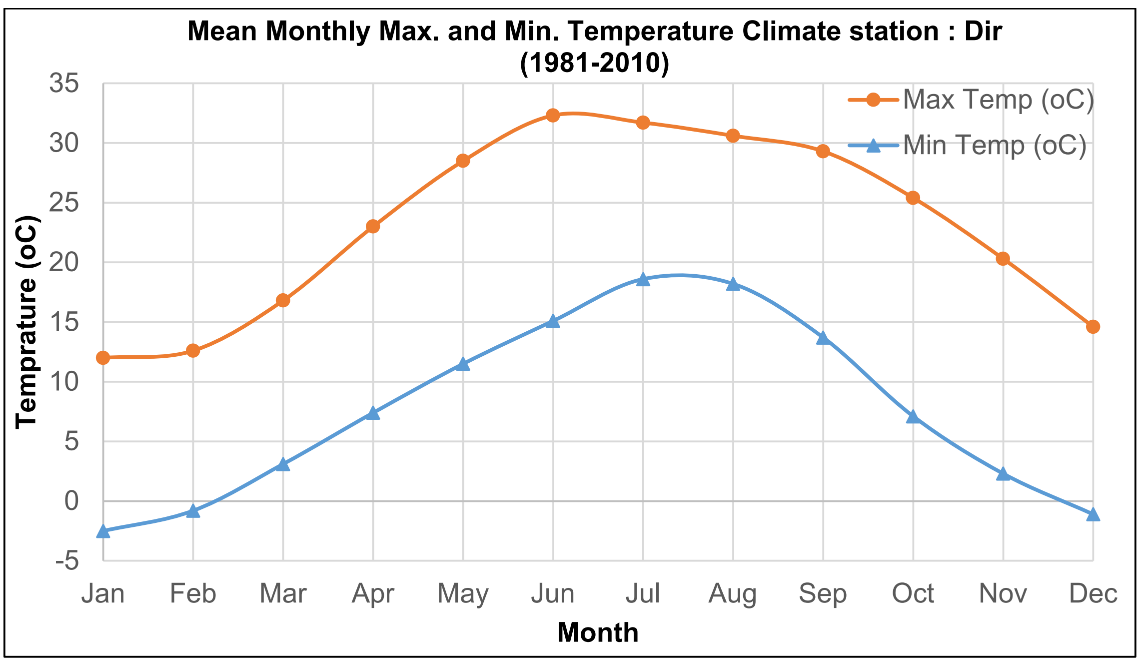


Figure 4-1 Mean Monthly Max. And Min. Temperature at Climate Station Dir Station

Table 4-2 Monthly Mean Max Temperature

STATION - DIR												
MONTHLY MEAN MAX TEMP. (°C)												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	13.5	9.5	19.1	22.4	31.3	34.0	32.2	31.9	29.2	25.3	18.8	15.1
2012	8.6	9.6	16.7	23.1	26.6	32.2	34.6	32.9	28.5	23.6	19.5	12.4
2013	12.4	12.0	18.1	23.1	29.2	33.6	32.1	30.8	30.1	25.8	17.5	14.5
2014	12.8	12.2	14.5	22.6	27.0	33.4	33.4	31.9	30.7	22.6	17.9	16.1
2015	12.9	13.2	17.5	24.6	29.2	31.5	32.0	31.6	30.2	25.0	16.1	14.8
2016	14.6	17.7	18.4	22.7	30.4	33.3	32.9	31.9	31.2	28.5	22.8	20.1
2017	10.1	15.4	18.7	25.3	30.5	32.5	32.4	32.1	30.7	28.0	21.7	17.4
2018	16.4	16.0	21.3	24.9	27.6	33.3	32.4	32.9	31.3	24.5	18.8	15.9
2019	9.9	11.4	17.2	24.7	27.5	31.3	33.6	32.6	31.7	24.7	-	-

Source: Pakistan Meteorological Department

Table 4-3 Monthly Mean Minimum Temperature

STATION - DIR												
MONTHLY MEAN MIN TEMP. (°C)												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	-2.4	-0.4	3.2	7.0	12.6	16.6	18.6	19.0	14.6	7.6	4.4	-1.7
2012	-5.1	-2.4	1.1	8.2	9.3	13.6	18.1	18.9	13.7	6.3	1.5	-0.6
2013	-3.1	-1.4	2.3	5.8	10.7	16.5	19.8	18.5	14.1	9.0	0.8	-1.1
2014	-1.4	-0.7	2.9	7.1	10.5	15.9	19.6	16.4	13.7	8.1	1.5	-2.2
2015	-2.7	-0.2	2.0	7.3	10.6	13.2	18.1	16.1	9.9	6.1	1.4	-2.3
2016	-2.6	-1.9	3.0	6.1	11.0	14.5	17.3	14.4	12.3	6.4	2.1	-0.9
2017	-2.6	-1.2	2.6	6.8	10.7	14.2	18.2	15.7	11.2	5.7	0.9	-2.2
2018	-3.5	-0.2	5.5	9.0	10.9	14.6	19.2	18.7	12.8	5.6	2.0	-1.9
2019	-2.5	-1.0	1.8	9.4	10.2	13.2	19.5	18.5	16.6	7.9	-	-

Source: Pakistan Meteorological Department

4.5.4.3. PRECIPITATION / RAINFALL

The distribution of rainfall is controlled by two factors, namely, moon-soon winds and the relative elevation. The tract receives more rainfall during moon-soon as the moon-soon winds are full of moisture on its arrival to the tract. Rainfall increased with increasing elevation up to 2134 m (7,000 ft.) and then decreases due to reduced humidity. The amount of rainfall received during winter season is more than that of summer season. The highest average rainfall recorded during the month of March is about 256.5 mm. whereas, the total annual precipitation of Dir district is 2435.2 mm (1981-2019).

Table 4-4 Mean Monthly Rainfall for Different Climate Stations in and around Project Area (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Dir	109	178	231	165	87	54	143	146	81	67	55	72	1388
Lower Dir	51	160	94	109	32	42	67	116	45	48	37	25	827
Zulam Bridge	83	98	90	69	37	27	85	119	44	10	18	21	699
Amandara Head work	46	80	92	57	21	15	71	112	31	29	16	28	597
Malakand	47	75	85	58	50	20	64	92	33	30	24	31	610
Chakdara	62	86	111	79	46	10	110	113	46	21	24	54	762

Monthly rainfall data of different stations is given in the annexure.

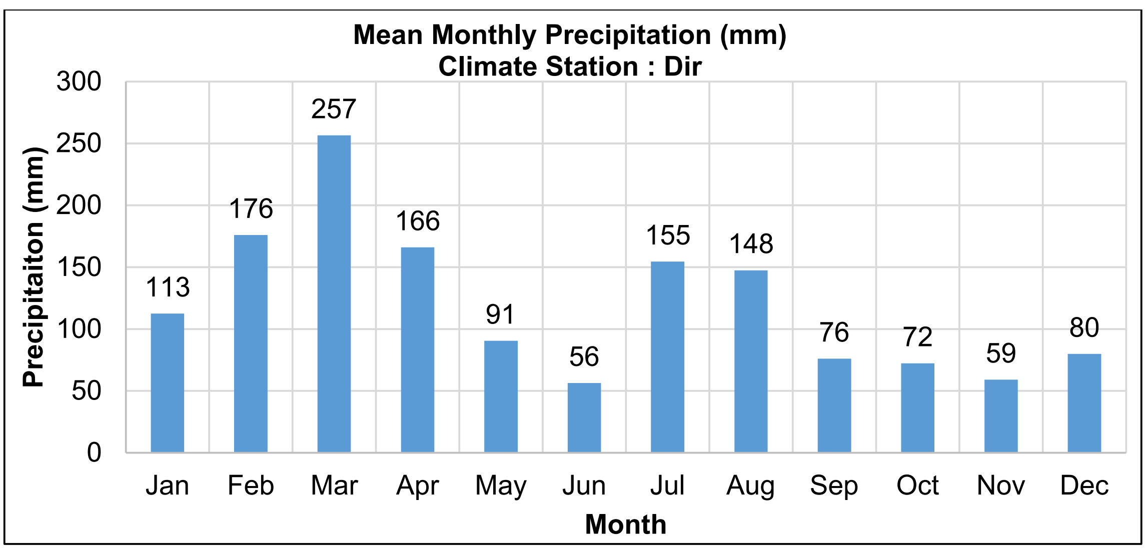


Figure 4-2 Mean Monthly Precipitation (mm) at Climate Station Dir

Table 4-5 Monthly Total Rain

STATION - DIR												
MONTHLY TOTAL RAIN												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2011	42	369	142	134	38	36	71.3	179.7	74	107.4	63	5
2012	136	182	131	116.5	76	21.8	27.9	64.9	152.6	69	36.2	114.4
2013	28	253	239.4	132	46.6	47.6	124	200.4	65.6	77	51.4	32.2
2014	12	191	360.4	157	109	28.4	98	138	79	84	59	0
2015	117	241	252	183	102	98	175	146	35	103	182	63
2016	114.5	101	323	236	88	73	114	176	43	8	9	29
2017	290	190	91	114	65	86	62	106	97	40	26	44
2018	30	140	152	230	108	81.7	162	106	36	53	99	26
2019	142	222	129	190	85	91	88.6	85.2	35	105	-	-

Source: Pakistan Meteorological Department

4.5.5. HYDROLOGY

Artistic-I Hydropower project is a run-of-river project to be constructed on Panjkora River in district Dir of Northern areas of Khyber Pakhtunkhwa province.

Hydrological studies presented in this section have been carried out to ascertain the water availability and its seasonal variations and floods of different return periods.

4.5.5.1. HYDROLOGICAL DATA

a) Daily flow data of Swat River at Chakdara (Maintained by Surface Water Hydrology SWHP, WAPDA) for period of 1961-2015.

b) Daily flow data of Panjkora River at Shigo Kas (Maintained by Pakhtunkhwa Energy Development Organization (PEDO) from 2009-2017.

c) Daily flow data of Panjkora River at Zulam Bridge (Maintained by Surface Water Hydrology SWHP, WAPDA) from 1999-2006.

d) Daily flow data of Panjkora River Downstream of Koto River (Maintained by Pakhtunkhwa Energy Development Organization (PEDO) for period of 2005-2017.

e) Daily flow data of Panjkora River at Sharmai (Maintained by Pakhtunkhwa Energy Development Organization (PEDO) from 2005-2018

f) Daily flow data of Swat River at downstream of Mohmand Dam (Maintained by Surface Water Hydrology SWHP, WAPDA)

g) Sediment Data at Chakdara (1963-2015) and also for short duration at Koto and Zulam Bridge

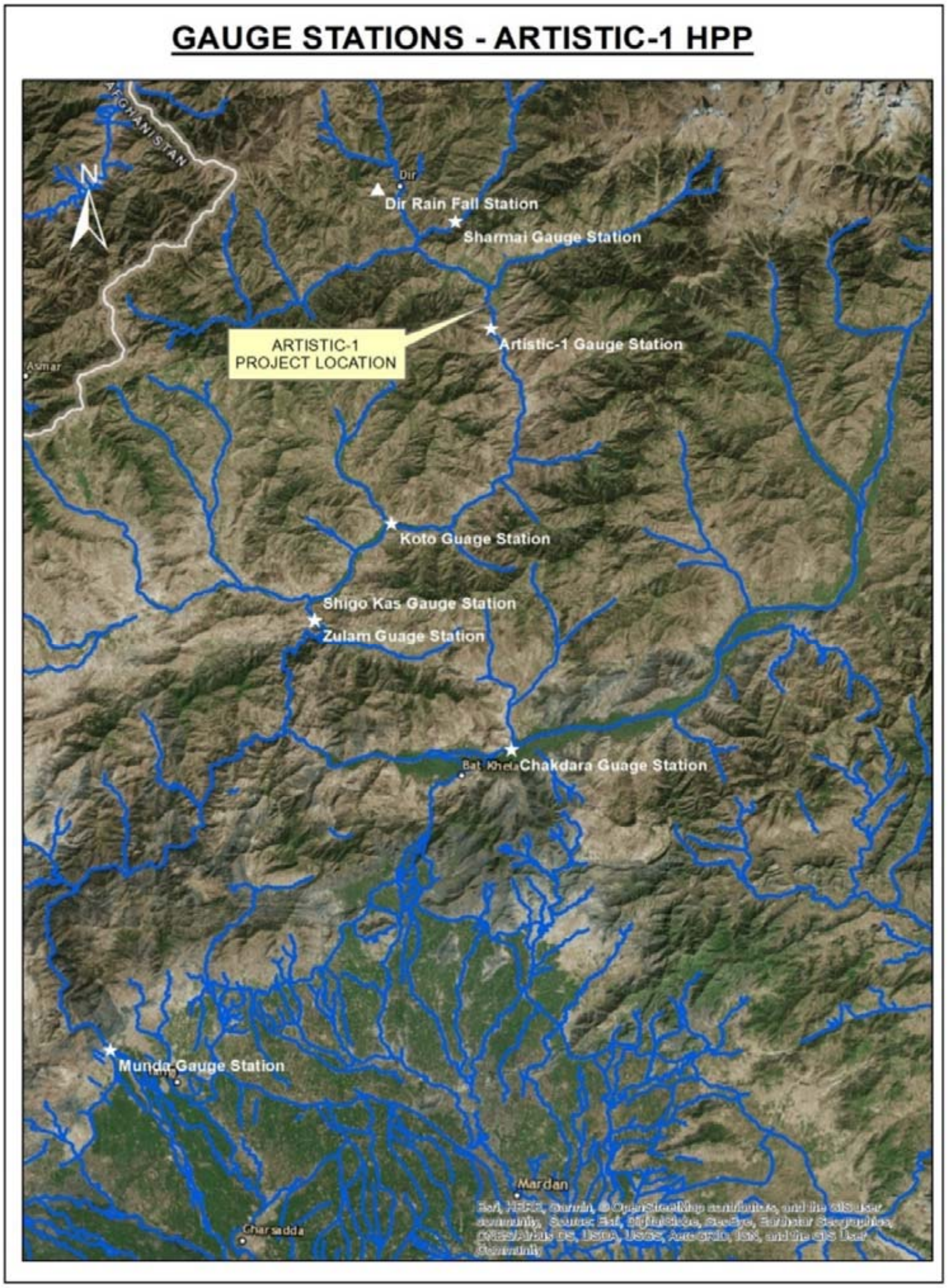


Figure 4-3 Shows the location of the stream gauges

Table 4-6 Summary of Mean 10-Daily Flow (cumecs) of Different Gauging Stations

Month	10 Daily	Panjkora at Sharmai	Panjkora at Koto	Panjkora at Zulam Bridge	Swat at Chakdara
Jan	I	11.33	25	29.4	50.24
	II	11.31	24.2	36.92	50.16
	III	11.48	23.9	33.93	52.64
Feb	I	13.61	31.4	37.18	57.49
	II	16.64	42.1	47.6	70.85
	III	18.83	52	59.8	73.38
Mar	I	22.63	63.3	67.72	91.97
	II	36.76	118.2	93.7	123.16
	III	53.21	127.6	138.35	155.85
Apr	I	70.14	174.1	147.87	173.65
	II	94.32	165.1	195.97	223.03
	III	101.15	173.4	206.48	259.59
May	I	123.85	188.4	203.57	282.43
	II	133.32	192.5	212.35	306.5
	III	128.89	176.4	179.59	340.95
Jun	I	128.8	170.8	170.72	393.94
	II	118.55	167.6	171.18	430.45
	III	122.11	161.3	157.22	457.41
Jul	I	104.58	147.1	126.78	448.61
	II	93.46	127.4	104.3	432.4
	III	86.3	142.6	112.3	397.26
Aug	I	79.14	121.6	101.67	359.62
	II	66.55	97.2	103.27	307.69
	III	50.73	72.1	79.15	245.94
Sep	I	40.59	69.7	69.92	189.16
	II	32.73	56.9	55.88	149.24
	III	26.32	44.3	71.18	115.25
Oct	I	22.88	38.7	75.63	95.82
	II	20.2	35	66.78	89.69
	III	18.54	33.3	47.09	78.28
Nov	I	19.68	35.5	46.88	69.86
	II	19.46	33.6	43.98	64.56
	III	15.36	25.5	37.53	59.98
Dec	I	14.08	25.2	35.02	66.04
	II	13.17	25.4	34.77	55.63
	III	12.11	24.5	97.23	54.61

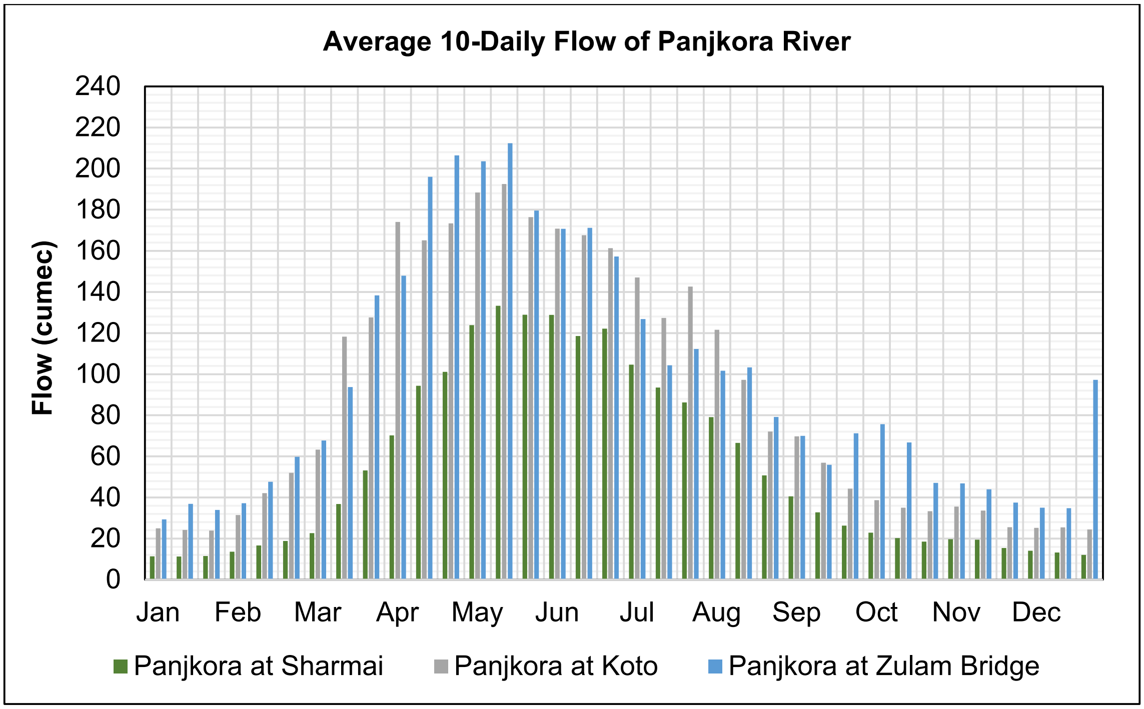


Figure 4-4 Average 10-Daily Flow of Panjkora River

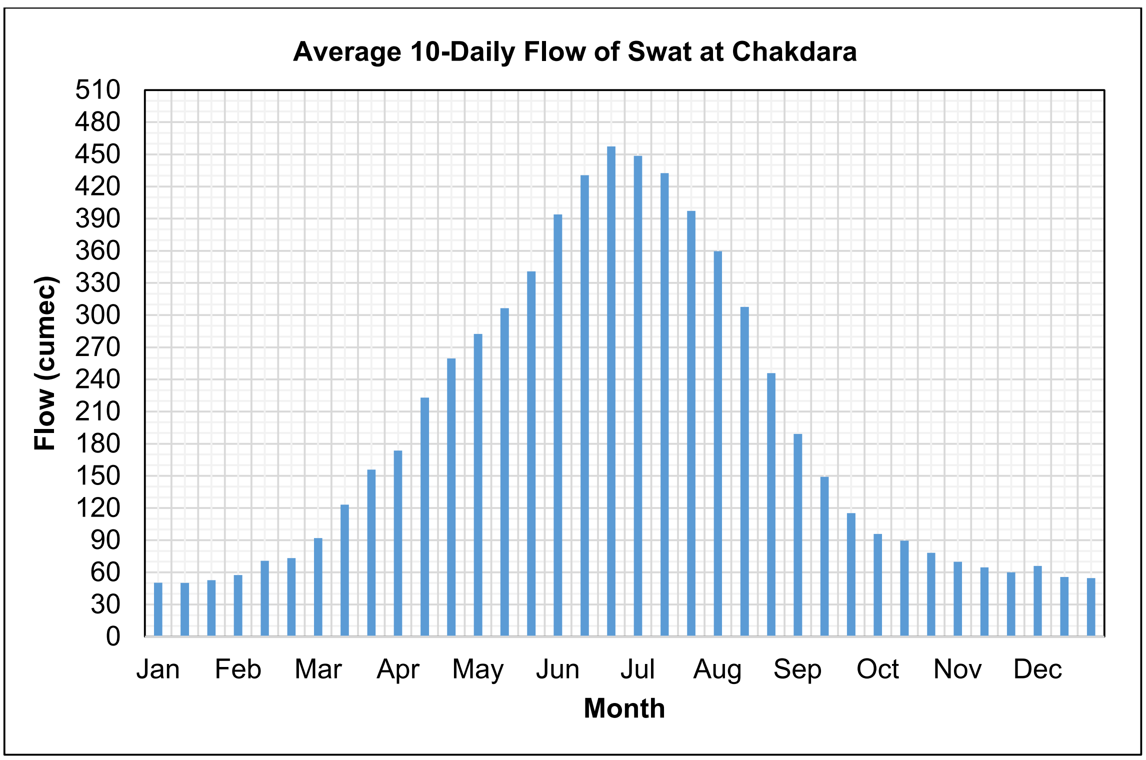


Figure 4-5 Average 10-Daily of Swat at Chakdara

Figure 4-6 Gauge Installation at Artistic- I Site

Figure 4-7 Flow Measurements at Artistic- I

4.5.6. WATER AVAILABILITY STUDIES

To estimate the water availability, a longer period of hydrological record must be available to rely upon. In case of Artistic-I hydropower project, daily flow record of Panjkora River at Sharmai and Koto Gauge stations is available on the records of Pakhtunkhwa Energy Development Organization (PEDO) for 14 years (2005-2018) & 13 years (2005-2017), respectively. While for the same river at Zulam Bridge gauge station records for the period of 8 years (1999-2006) are available on the record of Surface Water Hydrology (SWHP), WAPDA which is not sufficient to rely upon due to its availability for short periods. However, daily flow records of Swat River at Chakdara for the period of 55 years (1961 to 2015) are available on the records of Surface Water Hydrology (SWHP), WAPDA which can be used for the estimation of hydrological parameters for the Artistic-I Hydropower Project. Detailed description of **Table 4-7** is provided in Hydrology Report. Mean 10-daily flow of Panjkora River at weir derived from Chakdara Vs Koto is recommended for further design studies. Low flow analysis will be carried out to ensure adequate water supply for power generation. Series of low flow events will be selected by computation and arranging in order of magnitude. The minimum independent flow rate of certain duration will be determined and then Sequential Mass Curve Analysis of inflow and power demand will yield a rough estimate of water required to meet the power demand. The analysis will determine the deviation of flows around its mean values.

Table 4-7 Estimated 10-Daily Flow of Panjkora River at Weir Site

Month	10 Daily	Chakdara Vs Koto	Sharmai Data	Koto Data
Jan	I	18.7	19.6	22.3
	II	18.2	19.6	20.6
	III	19.6	19.9	20.4
Feb	I	21.3	23.6	26.8
	II	26.9	28.8	36
	III	29.8	32.6	44.4
Mar	I	38.1	39.2	54.1
	II	60.1	63.6	101
	III	74.4	92.1	109
Apr	I	90.8	121.4	148.7
	II	106.3	163.3	141.1
	III	121.4	175.1	148.2
May	I	129.1	214.4	161
	II	135.1	230.8	164.4
	III	144.2	223.2	150.7
Jun	I	162.4	223	145.9
	II	173.8	205.3	143.2
	III	180	211.4	137.8
Jul	I	172.9	181.1	125.6
	II	165.1	161.8	108.8
	III	156.6	149.4	121.8
Aug	I	139.7	137	103.9
	II	116.7	115.2	83.1
	III	92.6	87.8	61.6

Month	10 Daily	Chakdara Vs Koto	Sharmai Data	Koto Data
Sep	I	72.1	70.3	59.5
	II	55.9	56.7	48.6
	III	43	45.6	37.9
Oct	I	36.2	39.6	33.1
	II	33.5	35	29.9
	III	28.8	32.1	28.4
Nov	I	26.1	34.1	30.3
	II	24	33.7	28.7
	III	21.1	26.6	21.8
Dec	I	24.3	24.4	21.5
	II	20.2	22.8	21.7
	III	19.7	21	20.9
Period:		**1961-2017**	**2005-18**	**2005-17**

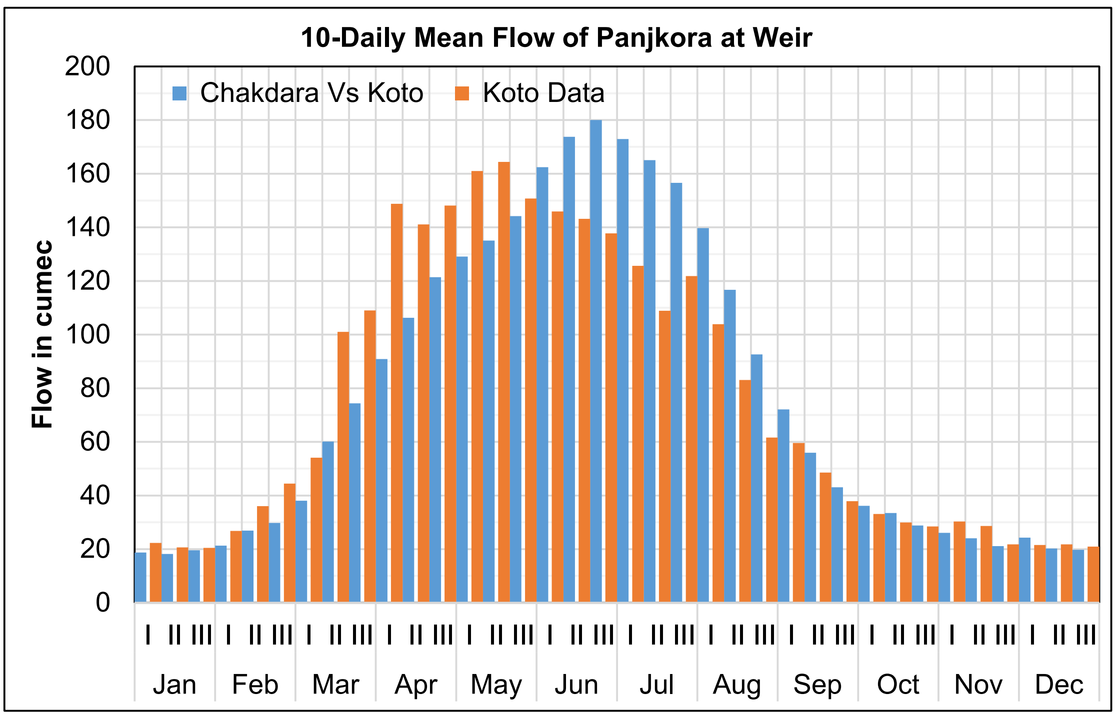


Figure 4-8 10-Daily Mean Flow of Panjkora River at Weir

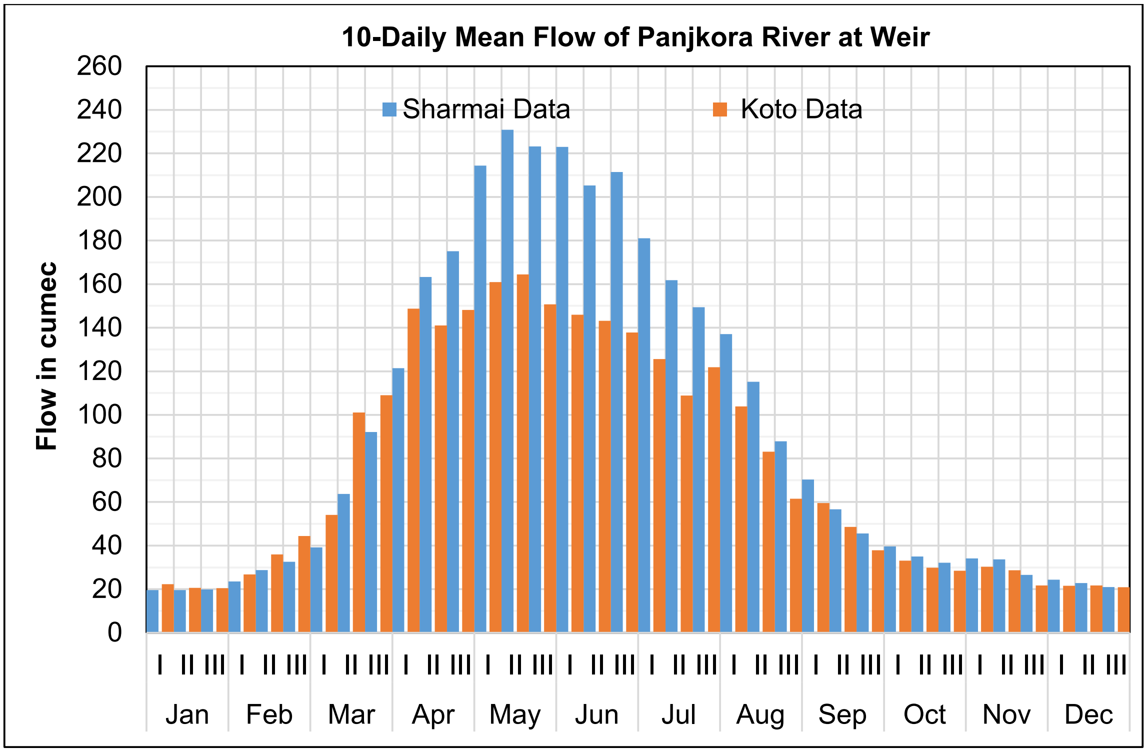


Figure 4-9 10-Daily Mean Flow of Panjkora River at Weir

Figure 4-10 Water Sampling at Artistic- I Site

4.5.7. FLOW DURATION CURVE

Availability of flows at the proposed weir/intake site was checked using detailed flow duration curve analysis. A flow duration curve (FDC) shows relationship between magnitude and frequency of stream flows for a particular river basin at a particular location. FDC provides estimation of cumulative percentage of time that a given quantity of flow is equalled to or exceeded which helps in planning and capacity sizing of a power plant. Flow series generated at weir from available record of Panjkora River at Koto, Sharmai and Chakdara have been used for flow availability against different exceeding probabilities as summarized and shown in **Figure 4-11** below.

Table 4-8 Summary of Flow Availability Against Different Exceeding Probabilities

%	Chakdara Vs Koto	Sharmai Data	Based on Koto Data
20.00%	138	165	132
22.50%	129	156	126
25.00%	121	145	120
27.50%	114	135	113
30.00%	**103**	**121**	**105**
32.50%	98	110	99
35.00%	89	98	90
37.50%	82	90	84
40.00%	74	83	77
45.00%	61	72	63
50.00%	**49**	**57**	**55**
55.00%	41	46	48
60.00%	34	40	41.5
65.00%	29	35	33
70.00%	26	30	30
75.00%	23	27	27
80.00%	20.5	24	23
85.00%	18.5	21	21
90.00%	16.8	19	17.5
95.00%	**15**	**16.5**	**14.8**
Period:	**1961-17**	**2005-18**	**2005-17**

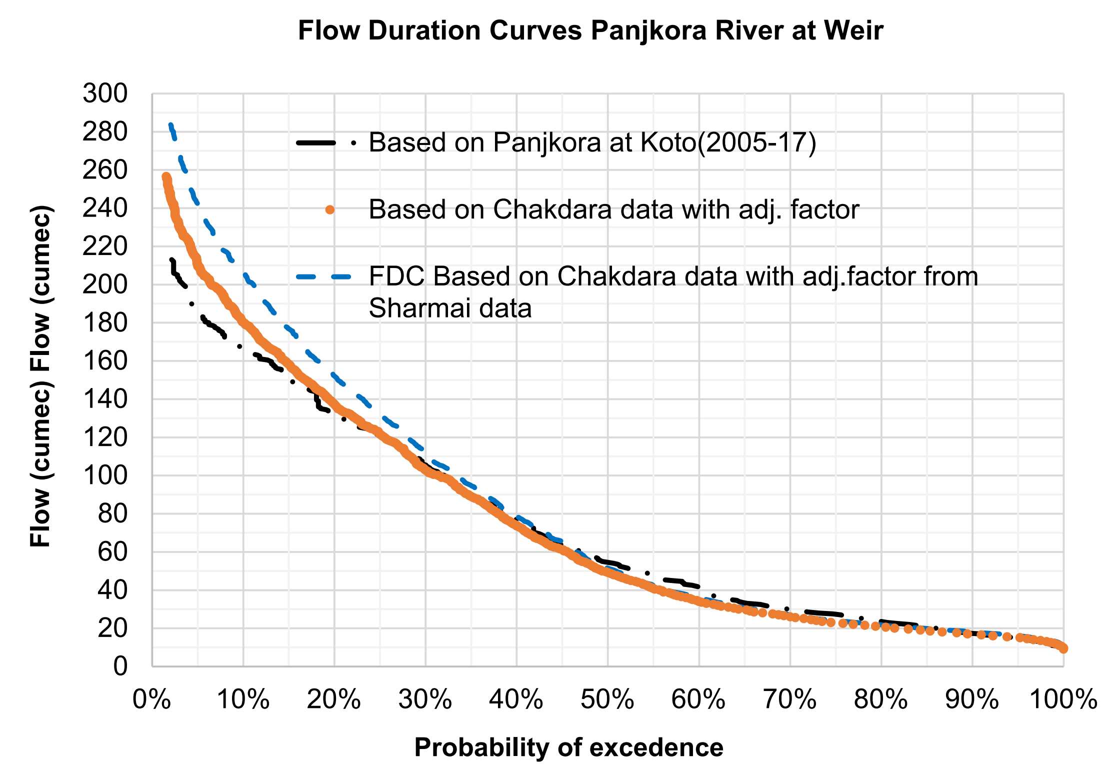


Figure 4-11 Flow Duration Curves of Panjkora River at Weir

4.5.8. SEDIMENT INFLOW STUDIES

Sediment yields would be estimated using the sediment records of the relevant streams of the area. Historical data of the sediment is available at the Chakdara gauge station at Swat River while sediment samples for short duration are available at Koto and Zulam Bridge at Panjkora River.

Apart from the historical available data, Artistic-I Hydropower Consultants have now installed the stream gauge just downstream of the weir location where water samples are collected twice a month. The samples will be sent to the laboratory for the estimation of sediment content and gradation analysis.

Table 4-9 Climatic Data at DIR Station

Period: 1981-2010			**WMO No: 41508**				**IC AO ID: N/A**			**Elevation: 1369 m**		
Latitude: 35° 12' N Longitude: 71° 51'E										**Established in 1966**		
Height = Barometer Cistern (amsl) = **1370 m** Anemometer (agl) = **5.9 m** Steven Screen (amsl/agl) = **1369 m/1.2 m**												
Month	**Atmospheric Pressure (hPa/gpm)**						**Dry Bulb Temperature (°C)**			**Relative Humidity (%)**		
	Station Level			**Sea Level**								
	00 UTC	**03 UTC**	**12 UTC**	**00 UTC**	**03 UTC**	**12 UTC**	**00 UTC**	**03 UTC**	**12 UTC**	**00 UTC**	**03 UTC**	**12 UTC**
January	868	868.3	866.6	1541.4	1544.6	1534	-0.5	-0.1	83	88.6	86	51.5
February	866.8	867.3	865.5	1531.8	1535.1	1525.6	1	1.4	10.4	90	87.5	50.3
March	866.1	866.4	864.6	1526.4	1530.3	1518.1	4.6	5.4	14.9	88	85.4	46.9
April	864.8	865.1	863.2	1516.5	1521.1	1506.9	8.7	11.5	20.6	84.7	74.6	42.8
May	862.2	862.6	860.6	1493.3	1499.4	1482	12.7	17.3	25.9	80.8	62.4	38
June	858.8	859.2	857.2	1463.1	1468.4	1449	16.4	21.8	29.5	76.3	56	35.9
July	857.5	857.9	855.9	1449.7	1454.1	1437.6	19.5	22.8	29.4	86.6	74.4	52
August	859	859.5	857.6	1464.7	1469.6	1453.7	19.4	21.4	28.5	90.1	83	57.4
September	862.9	863.3	861.3	1501	1505.6	1490.4	14.6	16.6	26.1	88.5	82.6	49.3
October	867.1	867.5	865.1	1538.4	1542.7	1526.6	8.2	9.5	21.2	86.4	81.6	39.7
November	868.9	869.4	867.1	155.8	1557.7	1538.4	3.7	4.4	15.3	83.4	80.5	41.6
December	869	869.5	867.7	1551.3	1556.2	1544.8	1	1.4	10.4	84.4	82	51.2
Annual	**864**	**864.5**	**862.5**	**1508.2**	**1513.8**	**1498.2**	**8.8**	**11.2**	**19.7**	**86.9**	**77.7**	**47.3**

Table 4-10 Climatic Data at DIR Station

Period: 1981-2010	**WMO No: 41508**	**IC AO ID: N/A**	**Elevation: 1369 m**
Latitude: 35° 12' N Longitude: 71° 51'E			**Established in 1966**
Height = Barometer Cistern (amsl) = **1370 m** Anemometer (agl) = **5.9 m** Steven Screen (amsl/agl) = **1369 m/1.2 m**			

Month	**Mean Temperature (°C)**	**Minimum Temperature (°C)**			**Maximum Temperature (°C)**			**Wind**					
		Lowest			**Highest**			**Speed (knots)**			**Direction**		
		Mean	**Extreme**	**Date**	**Mean**	**Extreme**	**Date**	**00 UTC**	**03 UTC**	**12 UTC**	**00 UTC**	**03 UTC**	**12 UTC**
January	4.9	-2.5	-10.6	13/1989	12	23	6/2002	0	0.1	1.5	…...	…...	…...
February	6.1	-0.8	-13.9	5/1984	12.6	25.8	10/1993	0	0.1	1.7	…...	…...	…...
March	10	3.1	-7.5	5/2000	16.8	30.6	30/1985	0	0.1	1.9	…...	…...	…...
April	15.2	7.4	-1.1	1/1990	23	35	28/2006	0	0.2	2.1	…...	…...	…...
May	20.1	11.5	2.2	2/2004	28.5	38.5	12/2001	0.1	0.2	2.3	…...	…...	…...
June	23.8	15.1	8.3	1/1986	32.3	41.5	21/1986	0	0.1	2.7	…...	…...	…...
July	25.1	18.6	9.6	30/2001	31.7	40.6	3/1999	0	0.1	2.5	…...	…...	…...
August	24.4	18.2	7.9	28/1988	30.6	37.4	1/1983	0	0.1	1.9	…...	…...	…...
Sept	21.4	13.7	3.3	30/1982	29.3	36	26/2009	0	0.1	2	…...	…...	…...
October	16.3	7.1	0.1	30/1982	25.4	34	2/2009	0	0.1	1.8	…...	…...	…...
November	113	23	-721	26/1984	20.3	30.5	2/2007	0	0.2	1.2	…...	…...	…...
December	6.8	-1.1	-9.4	27/1984	14.6	27.8	10/1998	0	0.1	1.3	…...	…...	…...
Annual	**15.3**	**7.5**	**-13.9**	**2/1984**	**22.8**	**41.5**		**0**	**0.1**	**2.2**	**…...**	**…...**	**…...**

Table 4-11 Climatic Data at DIR

Period: 1981-2010	**WMO No: 41508**	**IC AO ID: N/A**	**Elevation: 1369 m**
Latitude: 35° 12' N Longitude: 71° 51'E			**Established in 1966**
Height = Barometer Cistern (amsl) = **1370 m** Anemometer (agl) = **5.9 m** Steven Screen (amsl/agl) = **1369 m/1.2 m**			

Month	**PRECIPITATION (MM)**								**Sunshine**	**Total Clouds (Oktas)**		
	Mean	**Wettest Month**		**Driest Month**		**Rainy Days**	**Heaviest fall in 24 hrs.**					
		Amount	**Year**	**Amount**	**Year**		**Extreme**	**Date**	**Hours**	**00 UTC**	**03 UTC**	**12 UTC**
January	112.5	375.8	1992	1.5	1995	6.3	93	30/1992	134.5	3.4	3.8	4.4
February	176	297	2010	24	1997	8.7	98	18/2003	127.5	4.1	4.4	5
March	256.5	526.9	1988	26	2004	11.6	110	11/1993	150	3.9	4.4	5.2
April	166	353	1995	30	2000	10.5	87	26/2005	193.6	3.2	3.4	4.8
May	90.5	206.2	1992	7	2001	8.8	55	1/1989	2503	2.4	2.4	4.5
June	56.4	152.6	2001	1.8	2000	7.3	71.6	14/2001	267.1	1.6	13	4.2
July	154.5	395	2010	29.5	1982	10.6	149	29/2010	254.1	4.1	3.8	4.8
August	147.5	296	1983	35	2009	11	81.8	19/1983	225	4.4	4.1	4.9
September	76	240	1991	21	2006	8.1	98	24/1993	217.1	2.5	2.4	4
October	72.3	406.3	2004	7	2007	4.9	166	10/2004	215.3	1.2	1.4	2.8
November	59.1	255	1986	0	3 Years	3.9	84	26/1986	181.4	1.8	2.3	2.8
December	79.9	288	1990	0	3 Years	5.2	102	11/1986	146.9	3.2	3.6	3.9
Annual	**1447.2**	**2149**	**1986**	**911.4**	**2001**	**96.9**	**166**		**2368.6**	**3.2**	**3.3**	**4.3**

4.5.9. CATCHMENT AREA

Catchment area is of Artistic-I HPP is discussed in **Section 3.5.**

Catchment area of the Panjkora River at weir location is estimated to be 3100 sq.km **(Figure 3-2)** and at powerhouse location is approximately 3235 sq.km **(Figure 3-3).**

4.5.10. WATER RESOURCES AND DRAINAGE

Precipitation is the major source of water supply which is received in the form of rains and snow. The snow is the most important source of water supply which is ultimately gives rise to springs and perennial streams. Water from the streams and spring is supplied through water channels and gravitational flow pipe lines to the nearby population both for irrigation and drinking purposes. Other source of water is the high-altitude lakes. The area is drained by Panjkora River. The flow in the streams increases with the snow melting during hot season generally by the end of June and gradually subsides by the first week of July. The water of these streams is used for irrigation and drinking. As the winter and summer rains are generally of long durations, plenty of springs and streams flow throughout the district. Water of springs, streamlets and rains, coming from the upper areas join Panjkora River at Chokiyatan and Darora. The main tributaries of Panjkora River are Kumrat and Usheri khwar.

4.5.10.1. SURFACE WATER

The main surface water resource of the project area is the Panjkora River, which runs along Barikot village and joins downstream at Swat River. There are numerous smaller nullahs that discharge into the Panjkora River from left and right side. The main Panjkora River and its major tributaries are all perennial and receive water from the winter accumulated snow, apart from seasonal snowfall and rains. The tract also has many springs and the spring water is principally used as drinking water.

4.5.11. LAND USE-STATISTICS

Land use in the area is linked with physiography, soils and water availability. Population pressure also plays a pivotal role in land usage patterns. According to Land cover Atlas of Pakistan 20112, the land utilization in Dir District is as under:

Reported Area	:	361386 ha
Alpine Pasture	:	36264 ha
Sub Alpine	:	4627 ha
Dry Temperate	:	68265 ha
Moist Temperate	:	71940 ha
Oak	:	2508 ha
Sub-tropical Chir Pine	:	8142 ha

Sub-tropical Board-leaved	:	799 ha
Shrubs and Bushes	:	31820 ha
Rangeland	:	27354 ha
Snow and glaciers	:	43469 ha
Agriculture land	:	45924 ha
Barren land	:	12603 ha
Settlements	:	1065 ha
Water bodies	:	6606 ha

4.5.12. AMBIENT AIR QUALITY AND NOISE

Though no formal record is available for quality of atmospheric air in the Project area however, it is evident that the ambient air quality of the project area on both Weir and Powerhouse proposed sites is free of pollution at present and within the acceptable limits. During implementation of the project, construction activity will generate an accountable noise and dust in the atmosphere of the project area. Although, there are no noise levels specified for construction in the National Environmental Quality Standards (NEQS), a noise level of 86 dB for day time and 35 dB for night time has been specified for vehicular noise pollution. During construction, it is expected that these levels will be violated. Dust level consisting of Particulate matters and Smoke have also not been specified in the NEQS for ambient air, but emission limits from stationary sources should not exceed 40% or 2 (Ringleman Scale) for smoke. Particulate matter should not exceed 200-500 milligram/Nm3 depending upon energy source.

4.5.13. LOCAL FAULTS

The project site is located in the Kohistan island arc, which is sandwiched between the Indian and Eurasian plates. The major faults of the project region include, from north to south, the Main Karakoram Thrust (MKT), Kohistan Fault, Main Mantle Thrust (MMT), Panjal-Khairabad Thrust, Main boundary Thrust (MBT) and Salt Range Thrust. The general trend of these faults is predominantly east-west with change in trend due to syntaxial bends.

4.6. BIOLOGICAL RESOURCES

4.6.1. NATURAL FLORA

The forests in the project area are the largest and most important resource and play a vital role in the economy of the area as a source of supply of timber, fuel wood, forage and grazing. Their other benefits in terms of watershed value, source of water supply for the rivers, aesthetic value, wild life habitat and grazing grounds are also important. The coniferous forests are largely protected forests burdened with all types of rights of extraction of timber and firewood, grass cutting and grazing for local use, unless specifically disallowed in certain areas. In commercial sale of conifer forests, 60% of the sale price is the community's share and the rest 40% is received by the provincial Government.

4.6.2. FOREST TYPES

The forest area can be classified in the following forest type.

- Mixed fir (Abies pindrow) and Spruce (Picea smithiana) forest
- Mixed fir (Abies pindrow) and Spruce (Picea smithiana) forest, Kail (Pinus wallichian) and broad leave species forest.
- Pure Kail forests
- Oak (Quercus species) forests
- Chir forests
- Alpine pastures

4.6.3. MIXED FIR AND SPRUCE FOREST

These forests are mostly confined to the extreme remote corners of the watershed up streams of the Usheral Planning Units and are heavily grazed by nomadic herds of animals during summer. Fir and spruce trees are mostly mature and over matured with almost no regeneration or younger trees. Generally, regeneration of Fir and Spruce is poor except in few cool and shady places in shape of group. Trees of both species are cut on large scale for the construction purpose. Quercus, Walnut, Populus, Acer and Aesculus species form the underwood on favourable locations, Berberis, Indigoferaa and Vibernum are the undergrowth species.

4.6.4. MIXED FIR, SPRUCE, KAIL, DEODAR AND BROAD LEAVE SPECIES

These forests comprise of varying mixture of coniferous trees Fir Spruce, Blue pine and Deodar. These forests also have a varying intermixture of evergreen and deciduous broad-leaved species. The forests exist in different compartments of Usheral, Niag and Luqman Planning Units. Stocking of the forests is poor due to past felling as well as current illicit cutting. Especially Kail and Deodar species are diminishing at high rate. In these forests, principal species is Fir, which is mixed with spruce and scattered Kail, while sporadic trees of Yew (Taxus Baccata) are found in the forests. Other board- leaved species associate are walnut (Juglans regia), birds cherry (Prunus padus), Maple (Acer spp) and poplar (populas ciliata). The undergrowth consists of Viburnium spp. Indigofira spp.etc. The ground flora consists of grasses, herbs and fern.

4.6.5. PURE KAIL FORESTS

These forests have occupied a considerable area over the planning area. The crop consists of almost pure kail species. Other coniferous species are Deodar, Fir, Spruce and Yew in the upper parts with Chir at lover level. But these species form a negligible percentage of the forests. Deodar and Kail are the valuable species; therefore, they are under heavy pressure of ilicit cutting. As a result, the crop is composed mainly of saploing, pole and middle-aged trees. Mature and over mature trees are very few and regeneration is not sufficient. The broad-leaved species consist of Quercus, Walnut, Birds cherry Amlok, Horse chestnut, some trees of chinar and Alder are also found along nalas. The under growth is composed of Berberis lyceum, Indigofera and other associated species.

4.6.6. OAK SCRUB FORESTS

A considerable area is occupied by this forest type is in the Planning Area. It touches coniferous forests at higher elevations. This forests type is exploited for fuelwood, lopped for fodder and browsed by livestock so a large proportion of it been reduced to small bushes. Scrub forests of Oak seem to show continuity and potency everywhere. However, the burning and clear-felling practices have made these forests open and sporadic. This practice is common in the area to get bushwood and to get land for farming. Thorny bushes such as Berberis, Rosa, Rubus species are found in the forests type as undergrowth.

4.6.7. CHIR FORESTS

These forests are present in few compartments of Luqman and Karo. The forests exist in lower reaches are within the easy access of local people. Therefore, these forests are in much degraded form and damage is still in progress. Regeneration of Chir is very poor due to heavy grazing pressure. Board-leaved associated are Quercus species, Olive (Oleo cuspidata) and Phulai (Acacia modesta), while the undergrowth consists of Sanatha (Dodonea viscosa).

4.6.8. ALPINE PASTURE

The plan area includes a small fragment of alpine pasture, especially in Usheral. The pasture supports a variety of grasses, herbs and forbs and has no commercial timber value because tree growth is not possible due to extreme low temperature. It has high to moderate potential for seasonal grazing during summer. Gujjar nomads who owed herds of sheep, goat and cattle visit the pasture regularly each year.

The common species of grasses are polygonum, Oxytropis and Potentilla.

4.6.9. INJURIES TO WHICH CROP IS LIABLE

There are two types of factors due to which injuries may occur to crops i.e. Natural and anthropogenic factors; some injuries occur naturally like windfall, snowfall, insects attack and diseases, all these factors count in Natural factors while that of Anthropogenic factors are as follows;

4.6.9.1. GRASS CUTTING

It is common practise in the area that local people protect grass in summer for making hay at the beginning of autumn for their cattle during the winter season. Kail and Chir seedlings get invariable cut with grass. Very often the seedlings are cut intentionally by the people to prevent invasion by the tree growth.

4.6.9.2. GRAZING AND BROWSING

The population of the area enjoys unlimited grazing rights. Free grazing and browsing have done much damage to the forest of the area. Although, light grazing may under certain conditions, help natural regeneration and retards the fire hazards by keeping down the grasses and shrubs. But excessive grazing reduces the soil cover and accelerates the grazing process. Even it retards regeneration by breaking up the soil at steep places and harden it elsewhere.

Generally, in the area damage done by the grazing and browsing is more near the habitations and water points. In addition to this, a considerable damage is also done to these forests by nomad’s herds on their way to and from alpine pasture.

4.6.9.3. LOOPING

Broad leaves species such as Oak Horse chestnut, etc, have been subjected to destructive looping for leaf fodder while coniferous species are looped for firewood.

4.6.9.4. ENCROACHMENT

The problem of encroachment upon the forest area is ever accelerating due to rapid growth in population and land hunger. Since the forest, area is not properly demarcated with boundary pillar, therefore this render the area highly vulnerable to encroachment for agriculture, in addition to creating dispute among the right-holder.

4.6.9.5. ILLICIT CUTTING

Illicit cutting is common in the forests to meet their domestic needs as well as income earning purpose. Almost all the people have adopted timber smuggling as their profession and earning millions of rupees through this illegal business. A large number of unauthorized sawing machines are operating in the area, where illegal timber business on local level has become a routine matter, which is a serious threat for the remaining forests. Mostly, the forest of the resource area has been cut illegally at the hands of the local timber smugglers, black markets, as reported by socio-economic section of Forest Management Centre, which has resulted in large scale deforestation in the area Niag, Karo. However, keeping in view the history, it can be foreseen that if the illicit cutting of the forests continue as such the remaining inadequate resource will be exhausted unless the Government adopts some very special measure.

4.6.9.6. CLIMATIC CAUSES

The leading shoots of Kail and Chir are snapped in heavy snowfall; however, the extent of damage depends upon the intensity of snowfall, resulting in forking of the main stem. Frost is also one of the climatic causes, which injure the forest. Late frost kills seedling of broad-leaved species such as walnut and horse chestnut. Drought is extremely detrimental to newly germinated seedlings and mortality is prevalent in Kail and Deodar species.

Lightning strikes Fir and Spruce trees, these trees are not killed but injury impairs the timber of trees struck. Wild animals, wind and insects do not damage the forest to any great extent.

4.6.10. FLORAL SURVEY METHODOLOGY

The sampling design for field Inventory was developed keeping accuracy, limitations and available resources under consideration. The basic principle: a collection of accurate data with available resources in terms of financial, time and technical capacities has been followed. Based on ground conditions Line transact method was used for the collection of field data, sample plot of fixed radius 5.64 m^3 or 100 m^2 for trees, 10 m2 for shrubs and 1 m^2 for herbs within the fixed radius plot were designed to collect data. Random sampling was adopted to collect data, ten plots on each transect were taken for trees, herbs and shrubs. Following are the results of survey method adopted, which are given in the **Table 4-12** below.

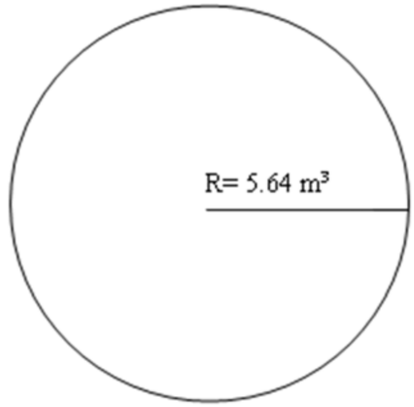


Table 4-12 Floral Survey Results

Family	Botanical Name	Vernacular Name	Local Name	IUCN Status
Coniferae	Abies pindrow	Parthal	Achar	Least Concern
	Cedrus Deodara	Diar	Ranzrna	Least Concern
	Juniperus squamata	Parthal	Kachar	Least Concern
	Picea smithiana			Least Concern
	Pinus geradiana	Chilgoza	Chilgoza	Near Threathen
	Pinus willichiana	Biar	Pewuch	Least Concern
	Taxus baccata	Barmi	Banrya	Least Concern
Cupilifereae	Alnus nitida	Shrol	Girey	Least Concern
	Betula u tilis	Bhurj	Bruj	Data Defficient
	Quercus dilatata	Barungi	Tor Banj	Endangered
	Quercus incana	R him	Spin Banj	Least Concern
	Quercus ilex			Least Concern
	Quercus semicarpifolia	Banchar	Kanar	Least Concern
Ebenaceae	Diosporus lotus	Amlook		NA
Euphobiaceae	Euphorbia royleans	Thordana		Endangered

Family	Botanical Name	Vernacular Name	Local Name	IUCN Status
Filicineae	Adiantum capius veneris		Sumbal	Least Concern
	Male Ferrr		Kunji	NA
Gnetacea	Ephedra spp	Usmani Booti		Least Concern
Hamomeli dacea	Parroti jacquomantina	Pasher	Beranj	Least Concern
Juglandaceace	Juglans regia	Akhroot	Ghuz	Least Concern
Labiateae	Mentha Salvestris	Podina		Least Concern
	Plectranthus ragous	Bui	Sperkai	NA
Leguminoseae	Indigofera gerardiana	Kianthi	Ghoreja	Vulnerable
	Indigofera weightii	Kianthi	Ghoreja	NA
	Mimosa spp			Least Concern
	Sophora spp			Mimosa spp
	Trifolium repense			Least Concern
Lythraceae	Punica granatus			Least Concern
Meliaceae	Melia azedrach	Bakian	Bakiana	Least Concern
Moraceae	Ficus glomerata	Gular	Injir	Least Concern
	Ficus religiosa	Pipal	Pipal	Least Concern
	Morus alba	Tut	Tut	Least Concern
	Morus serrata	Tut	Tut	Least Concern
Oleacea	Olea cuspidate	Kau	Khuna	Nearly Threathen
Platanceae	Platinus orientalis	Chinar	Chinar	Data Defficient
Ranunculaceae	Peoina emodi	Mamekh		Least Concern
Rhamnaceae	Zizyphus nummuleria	Beri	Markhanria	NA

Family	Botanical Name	Vernacular Name	Local Name	IUCN Status
	Zizyphus sativa	Beri		Least Concern
Rosaceae	Cotoneaster spp		Shin Lakhta	NA
	Fragaria indica		Sehra-tut	Least Concern
	Potentetilla ambigua			Least Concern
	Potentetilla parviflora			Vulnearble
	Prunus armenica	Hori		Data Defficient
	Prunus cornuta	Kalakat	Bareet	Least Concern
	Prunus eubernea	JangliBadam		Least Concern
	Prunus padus	Kalakat	Bareet	Least Concern
	Pyrus pashia	Batangi		Least Concern
	Rosa mosehata	Pulwari	Kirrai	Least Concern
	Rubus spp		Corach	NA
	Spiraea spp		Jijrai	NA
	Sorbus tomentosa			Extint in the wild
Rutaceae	Skimmia laureole	Ner	Nazar Panra	NA
	Xanthoxylum alatum	Timber	Dambara	Endanger
Acanthacea	Adhatode vesical	Bhekar		Nearto Therathen
	Strobilanthus attenuates			NA
	Strobilentus glutonousus			NA
Ampelidaceae	Vitis Lanta		Parwathis	NA
	VItis himalayana			NA
Anacardiceae	Pistacia integsima	Kangar		Least Concern
	Rhus continus	Ban		Vulnerable

Family	Botanical Name	Vernacular Name	Local Name	IUCN Status
	Rhus semialata	Titar		Least Concern
Apocynaceae	Nerium odorum	Kaner	Gandiral	Least Concern
Berberidaceae	Berberis lyciumx	Simbul	Kurai	Endanger
	Podophyllum emodi	Bankari	Kankora	Least Concern
Caprifoliaceae	Lonicera quinquelocularis	Phut		NA
	Vibernium continifolium			Least Concern
	Vibernum stellulatum			Least Concern
Compositeae	Artemisia spp	Tarkha		Least Concern
	Saussurea lappa	Kut	Lassora	NA
	Saussurea cardicans			NA
Saliceae	Populas alba	Sofeda	Sapedar	Least Concern
	Populas ciliate	Palach		Least Concern
	Popolus nigra	Sofeda		Data Deficient
	Salix tetrasperma		Kharwala	NA
	Salix spp		Wala	NA
Sapindaceae	Asculus indica	Bankor	Jawza	Vulnerable
	Acer caesium		Tharkanh	Data Deficient
Urticaceae	Ficus palmate			Least Concern
Umbeliferea	Carum spp	Zera	Zankai	NA
	Cannabis satwa	Bhang	Bhang	NA
Valeriancaeae	Valeriana pyrolaefolia	Mushk Bala	Mushk Bala	NA
Verbinaceae	Vitex spp	Marwan		NA
Violaceae	Viola serpens	Banafsha		NA

The above-mentioned Species are endemic to District Upper Dir. These species are locally found in wide spread range in the mountains of Upper Dir. Taxus Bacccata which belongs to the family Coniferaeand is locally known as “Banrya” is found in the area which is an endangered tree species both locally and internationally. The specie is also listed in the IUCN red list as Endangered. Across most of its range through the Himalayas, Taxus Baccatahas been heavily exploited for its leaves and bark which are used to produce the anti-cancer drug.

4.6.11. UNDER-GROWTH SPECIES

4.6.11.1. COMMON SHRUBS

The common shrubs are Parrotia Jacquemontiana (beranj), Vibernum spp (asm), Indigofera spp (Jawaka), Cotoneaster spp (kharowa), spirea spp, Berberis spp, Rubus spp.and Sephora griffithi.

4.6.11.2. GRASSES

The common grasses found in Dir are Cynodom dactylon, Agropyron canaliculatum, Avena sativa and Epoasoides.

4.6.11.3. MEDICINAL PLANT

The plants of Medicinal importance found are Valeriana wallicshii, podo-phullum emodii, Saxifraga spp Artemisia maritima, Viola serpens and Atropoa belladonna.

4.6.12. WILD VEGETABLES

For vegetables, they are mostly dependent on their agricultural land. In rare cases and very few people are collecting wild vegetables. Mostly they collect *Allium sepa, caltha alba, Dryopteris remosa, Urtica dioica, Pteris aquilina, Rumex dentatus and Rumex alpinus.*

4.6.13. MEDICINAL PLANTS AND OTHER NON-TIMBER FOREST PRODUCTS (NTFPS)

Among the NTFPs some medicinal plants Zira (Carum species), honey, edible mushroom and Walnut fruit are exported on a very low scale. Most of the medicinal herbs found in the area are either used locally in medicines or are eaten by cattle, sheep and goats of the locals and nomad Gujars. Since the area falls in dry temperate zone hence the ground flora is low in diversity and density. In spite of all natural and man induced traumas to the land there is vivid scope for persuasion, culture and commercial exploitation of high valued medicinal herbs and other available NTFPs through organized communities following the innovative concept of Participatory integrated Natural Resource Management and actualizing the Village Plans. This will support the livelihood at the household level and ultimately reduce the pressure on the tree crops. Like wild vegetation, most of the people are unaware about the medicinal plants. Mainly they are dependent on the allopathic medicine and rarely using medicinal plants. Knowledge of traditional medicine practices has not yet sufficiently transferred from the elders to the young generation. Major Medicinal plants found in the area are given in the **Table 4-13** below.

Table 4-13 Medicinal Plants and other Non-Timber Forest Products

Local Name	Scientific Name
Muskkbala	Valeriana wallichii
Ratanjot	Geranium rotundifolium
Tamaku Saag	Atropa belladonna
Ner	Skimmia laureola
Skimmia laureola	Ban Kakri Podophyllum emodi
Guoaban	Onaosma echiodes
Jhan/Chau	Artemisia maritime
Banafsha	Viola serpens
Raisha Khatmi	Laveteria kashmuriana
Zakhmi Hayat	Saxifrage ligulata
Musli Sufed	Asparagus filicinus
Mamekh	Paeonia emodi
Ispaghol	Plantago Spagolla
Sumal	Berberis lycium
Kuthi	Sassurea lappa
Rattan Jot	Thymus Serphyllum
Ajwain	Hyocymus niger
Bhang	Cannabis sativa

Saussurealappa belonging to the family Compositeae locally known as “Lassora/ Kuthi” is a well identified medicinal plant is found in the area, due to its medicinal values commonly this is used in numerous indigenous systems of medicine all over the world. Due to high consumption of medicinal plants, their population size has been decreased day by day. Among them *Saussurealappa* is most on the edge of extinction due to high rate of exploitation by local people. They usually do inappropriate carrying, handling and collection due to which they loss a major quantity of medicinal plants. According to IUCN *Saussurealappa* protection status is critically endangered. *Saussurealappa* is a tremendously endangered species because of its high medicinal importance. Decrease in the population number of the natural plant species is due to some major ecological causes, such as deforestation, loss of habitat, invasive and high consumption. Due to of limited geographical ranges and precise territories endemic and erratic taxa of the area are at risk. The plant communities in the study area have been largely exploited due to some of these reasons like, excess intake of medicinal resources to cure the diseases, deforestation for fuel, increased tourism, population explosion and lack of sentience.

Fauna

The area is quite rich in mammalian and avian Wildlife species, of which the following species are worth mention: Common leopard, Markhor, Monal, Koklas and Tragopan Pheasants, Himalayan snow cook and snow partridge. The Wildlife of the area is ruthlessly destroyed by the locals since times. Pheasants are shot or trapped for their beautiful skins. The whole Plan area falls in the management jurisdiction of Divisional Forest Officer, Dir stationed at Thimargara. Khyber Pakhtunkhwa Wildlife (protection, preservation and management) Act 1975 does extend in the area, yet in actual practice locals have all the liberty to kill as many animals and birds as they can afford to do. This practice must be checked through implementation of Wildlife Act 1975 in true spirit, and giving incentives to locals. It is a well-established fact that underdeveloped and deprived areas throughout the country, province and region must now be placed at top priority for special development programs. The Development of Wildlife resources available in the area and commercializing these for the livelihood support through organized communities in the need of time. This can better be achieved through village plan based on Participatory Integrated Natural Resources Management Framework.

4.6.13.1. DRY TEMPERATURE EVERGREEN OAK-DEODAR HABITAT

The habitat is widespread on both banks of Panjkora River from 1,300 to 1,800 m with chief cover of Quercus ilex. Cedrus deodara does occur with oak which has been largely removed because of the nearness of the habitat to the river and habitations. Chukor, Wolf, Monkey, Red fox, Common otter and Porcupine were reported to be found in this habitat. The habitat is also favoured by Markhor and Black bear in winter.

4.6.13.2. DRY TEMPERATURE CONIFEROUS HABITAT

Generally occurring above the oak habitat up to 2,700 m elevation, the vegetation consists of Deodar, Blue pine, Chilgoza pine and Spruce with pure and mixed occurrence. Fir is also met on cooler aspects. Other associates include Juglans regia Parrotia jacquemontiana, Pistacia mutica, Aesculus indica etc. Major wildlife species reported were Chukor, Koklas pheasant, Monal pheasant, Common otter, Common leopard, Black bear, Wolf, Monkey, Red fox, Flying squirrel, Musk deer and Porcupine.

4.6.13.3. SUB-ALPINE AND ALPINE HABITAT

This habitat, above the coniferous forests from 1,800 m to 4,000 m has moderate sized rees individually or in groups and well-developed shrub layers. Main species are Betula utilis, Juniperus spp, Salix spp, Rhododendron spp, Sorbus spp, etc. The habitat extends beyond tree limit and to permanent snow fields and also includes some fairly large sized fresh water alpine lakes. Wildlife species reported in PRA included Snow leopard, Brown bear, Black bear, Marmot, Markhor, and Ibex, Musk deer, Monal pheasant, Himalayan Snow cock and Snow partridge. The area supports a variety of vegetation from Scrub forests to the alpine pastures. The forest comprises of various species of trees like blue pine, deodar, fir, spruce, bird cherry, walnut, acer and birch etc. The district is home to a great diversity of wildlife. It supports some of the endangered mammals. **Table 4-14** including those mammals and their present status in Upper Dir.

Table 4-14 Endangered Mammals in District Dir

Mammal	Status	Reason	IUCN Status
Rhesus monkey (Macaca mulatta)	Rare	Due to shooting and trapping because of their fondness for ripening maize crop.	Least Concern
Wolf (Canis lupus)	Vary rare	Due to degraded habitat and Persecuted by people because of its depredation on domestic flocks of goats and sheep	Least Concern
Jackal (Canis aureus)	Common but reducing gradually	Because of diseases (rabies) and raiding orchard crop but useful in controlling rodent's population	Least Concern
Brown bear (Ursus arctos)	Extremely rare	Due to hunting and destruction of their habitat	Least Concern
Black bear (Selenarctos tibetanus)	Disappear (listed in the I.U.C.N. Red Data Book)	Due to deforestation and hunted because of its depredations to crop	Least Concern
Marten (Martes foina)	Common	It has ability to adapt to a wide variety of habitat	Least Concern
Otter (Lutra lutra)	Rare	Due to great commercial value of its skin	Least Concern

Mammal	Status	Reason	IUCN Status
Leopard cat (Felis bengalensis)	Extremely rare	Due to unavailability of prey animals and commercial value of its fur	Least Concern
Common leopard (Panthers pardus)	Extremely rare	Due to high hunting pressure and its habitat is continuous to decline because of increased human settlement	Endangered
Squirrel (Petaurista petaurista)	Common but reducing	Due to increasing grazing pressure and grass cutting	Least Concern
Porcupine (Hystrix indica)	Common	Due to increase in human population and gradual destruction of wilderness area	Least Concern
Bat (Rbinolophus ferrumeqinum)	Common but reducing	Required very humid and sheltered dark roosting place but due to deforestation and overgrazing its habitat is declining	Least Concern

According to local survey and consultation with WWF-Pakistan the above-mentioned species are endemic to the area and are found according to the status mentioned in the above list. Among the list *Panthers pardus* (Common leopard) is found in the area is Vulnerable globally and according to WWF-Pakistan the specie is endangered in context of Pakistan. Black Bear is an endangered species while the brown bear as a species is classified as Least Concern by the IUCN, the subspecies in Pakistan is highly endangered and populations are dwindling. The Species declining is due to posed threats like shrinkage of habitat, deforestation and retaliatory killing.

4.6.14. Avi-Fauna

Birds are valued for more than their beauty. They protect the environment by consuming insect pest in agricultural fields and forests, and help pollination and disperse seeds of many economically important plant species. Deforestation, overgrazing, soil erosion, rampant hunting, and agricultural practices pose more specific threats to birds. The **Table 4-15** given below includes birds and their present status in the area.

Table 4-15 Avi-Fauna in District Dir

S.No	Birds	Status	S.No	Birds	IUCN Status
1	Paddy Bird (*Ardeola grayii*)	Common	20	Black partridge (*Francolinus francolinus*)	Least Concern
2	Little egret (*Egretta garzetta*)	Frequent	21	Gray partridge (*Francolinus pondicerianus*)	Least Concern
3	Heron (*Ardea cinerea*)	Common	22	Quail (*Coturnix coturnix*)	Least Concern
4	Black shouldered kite (*Elanus caeruleus*)	Frequent	23	Koklass pheasant (*Pucrasia macroopha*)	Least Concern
5	Black kite (*Milvus migrans*)	Common	24	Kalij pheasant (*Lophura leucomelana hamiltonii*)	Least Concern
6	Bearded vulture (*Gyoaetus barbatus*)	Rare	25	Wood cock (*Scolopax rusticola*)	Least Concern
7	Scavenger vulture (*Neophron perconpterus*)	Common	26	Tit (*Parus major*)	Least Concern
8	Sparrow hawk (*Accipiter badius*)	Rare	27	Tree creeper (*Certhia himalayana*)	Least Concern
9	Rock dove (*Columba livia*)	Common	28	Crow (*Dicrurus macricerus*)	Least Concern
10	Little brown dove (*Sterptopelia senegalensis*)	Abundant	29	House sparrow (*Passer domesticus*)	Least Concern
11	Rose-ringed parakeet (*Psitacula krameri*)	Common	30	Kingfisher (*Nalcyon smyrnensis*)	Least Concern
12	Eurasia cuckoo (*Cuculus conorus*)	Common	31	Roller (*Coracias benghalensis*)	Least Concern
13	Koel (*Eudynamys scolopacea*)	Common	32	Woodpecker (*Dendrocopos*	Least Concern

S.No	Birds	Status	S.No	Birds	IUCN Status
				assimilis)	
14	Owl, (*Otus bakkamoena*)	Common	33	Myna (*Acridotheres tristis*)	Least Concern
15	Eagle owl (*Bubo bubo*)	Rare	34	Jay (*Garrulus lanceolatus*)	Vulnerable
16	Nightjar (*Caprimulgus europaeus*)	Frequent	35	Pipit (*Anthus sylvanus*)	Endangered
17	Swift (*Apus affinis*)	Common	36	Hoopoe (*Upupa epops*)	Least Concern
18	Buzzard eagle (*Butastus teesa*)	Rare	37	Dipper (*Cinclus pallasii*)	Least Concern
19	Botted eagle (*Hieraaetus pennatus*)	Frequent	38	Robin (*Sanicoloides fulicata*)	Least Concern

Reference: Shermai Feasibility

4.6.15. Aquatic Fauna and Flora

The temperature of Panjkora River is extremely low, throughout the year. Secondly, the flow of stream is very fast, so the conditions are not favourable for aquatic fauna and flora, and only that fish can sustain whose adhesive organs attach itself to the rock bed and those fish that rely for their good on that flora or fauna which are present in this river.

4.6.16. Fish

Few species of fish are found in this river including brown trout and swat's trout (schizothdax) swati fish is also present on-stream banks, masher and rainbow trout are also found in some seasons due to migrations. Site specific data on aquatic culture is lacking. Only recreational fishing is undertaken and there are no commercial fishermen in the area. No study has been done on the indirect economic benefit of trout fishing. According to Assistant Director (AD) Kalkot Fish Hatchery, Serai to Kumrat, is a favorite area of trout fish while the down-stream areas are favourable for Swati fish. Trout includes both Rainbow and brown while others are Katsary along with some other species etc; sufficient environmental flow is kept for the fish and other aquatic life survival. For free movement of fish and to avoid negative impacts on fish movement, provision of fish ladder is also suggested in this project.

The Fish species found in the Panjkora are given in the table.

Table 4-16 Fish Species in Panjkora River

Scientific name	English name	Local name
Triplophysa choprai	Singhat Machli	Braithai
Glyptosternum riticulatum	Chakaar Machli	Chakia Mahay
Salmo Trutta	Brown trout	Trout
Onchorhyncus	Rainbow trout	Trout
Xinentodon Cancila	Crow fish	Ka Machli
Channa gachua	Daoly Machlee	Katay Mahee
Schizothorax plagiostomus	Galali	Swati
Racoma labiata	Chunr	Churn

4.6.17. Rare or Endangered Species

There is no rare or endangered species in the vicinity of Artistic-I hydropower project.

4.6.18. Water Quality

Water samples of Panjkora River were collected. Laboratory results are shown in Annexure-1 which shows that water in Panjkora River is good for irrigation purposes because there are no industries in the project area which discharges their effluent in Panjkora River. The water from nullah/river and springs are also supposed to be safe for consumption. No water quality tests were taken from these Nullahs or springs.

4.6.19. Air Quality

The air quality of the project area and its vicinity is generally good in natural conditions. The major reason is that there is no industrial setup in the project vicinity but the level of traffic is a bit high. However, the level of ambient (suspended) dust may increase during windy conditions and by more traffic movement which may occur during construction activities.

4.6.20. Noise

The roads are available in the project area but the intensity of traffic is somehow limited and the level of noise is assumed to be low. During construction, generally, the ambient noise level in the project area is assumed to be less than the permissible limits of 85 dBA as fixed by Pak – EPA, NEQS, 2000 or the WHO noise guidelines that prescribe a limit of 55 dBA with respect to receptors in outdoor areas.

4.7. SOCIO-ECONOMIC ENVIRONMENT

4.7.1. GENERAL

This section provides the information on socioeconomic and cultural environment of the project area including political and administrative setup, settlement pattern, demographic characteristics, and availability of social amenities, occurrence of religious and cultural sites, indigenous people and gender issues. To ascertain the information regarding socioeconomic and cultural environment of the project area, detailed field survey of the project area was conducted by the Consultant's environmental and social team. During this survey, project affected persons, individuals and relevant departments were consulted as well as secondary resources of information were also depended upon to establish socioeconomic environment of the project area. During socioeconomic survey, all houses/households were selected. The visit schedule was circulated before visiting the area for the collection of required data/information.

Social assessment being an integral component of the Environmental Studies was carried out for this project during EIA. The main objective of studying social aspects of the project was to gain insight into certain social characteristics, problems, conflicts and expected bottlenecks to be utilized for design choices during detailed designing stage of the proposed project.

4.7.2. ADMINISTRATIVE AND POLITICAL SETUP

The proposed project falls within the administrative jurisdiction of Upper Dir district. After ceasing Nazim System in the recent past, the old system of administration has been restored. Now the Deputy Commissioner is the district administrative controller assisted by the Assistant Commissioners at Sub-Division/Tehsil levels. All the Nation Building Departments are available at Upper Dir Head Quarter including Forest, Agriculture, Revenue, Food, Excise & Taxation, Health, Education, Police, C&W and Public Health Engineering Department etc. Dir state was ruled by different Chiefs and rulers till 1969, when it was merged with then Province of West Pakistan and declared a district of KPK in 1970. In 1996, District Dir was bifurcated into two districts i.e. Lower Dir and Upper Dir.

4.7.3. HOUSING CHARACTERISTICS AND NATURE OF CONSTRUCTION

In the project area, most of the houses are small and katcha and semi pacca type. On average, the houses are generally composed of two rooms and a separate room for animals.

4.7.4. OCCUPATIONS

Usually rural Khyber Pakhtunkhwa is dominated by the agricultural workers i.e. farmers, tenants, agricultural labours etc. In Sahibabad project area, agricultural lands are limited. People adopt farming as an occupation and adopt other professions too. In Upper Dir, 33.7% male population has been reported economically active including skilled and semi-skilled agricultural and fishery workers, service workers, shop and market sales workers, plant and machine operators, technicians, forest labours, craft and related trade workers.

4.7.5. HOUSEHOLD EXPENDITURE PATTERN

Detailed information was gathered during the baseline survey about the household expenditure patterns. It was concluded that on the overall basis, the respondents spent major part of their total expenses to meet food costs and non-food expenditures come second. The household expenditure pattern in respect of the sample population is shown in **Table 4-17.**

Table 4-17 Average Annual Family Expenditure (PKR)

Item	Food Items	Non-Food Items	Education	Health	Social Activities	Other	Total
Expense	60440	20200	7860	12400	10660	7320	118880
%age of Total	50.84	17	6.61	10.43	8.96	6.16	100

4.7.6. RACES AND TRIBES

The majority of the population in this area is Yousafzai, Mishwani and Swati Pashtuns while the ruling class was Khosro, while Painda Khel and Sultan Khel are the main sections. Besides these, there are other small tribes like Katani, Roghani, Wordag, Sadat (Miangan), Swati, Akhunkhel, Tajik and Gujjars. In the project area Kohistani tribe and its sub-sections are dominant.

4.7.7. LANGUAGES

Language is the human capacity for acquiring and using complex systems of communication, language is one specific example of such a system. Pashto is commonly spoken language. Urdu is understood usually because people of the area live in Punjab & Sindh provinces to earn livelihood. Kohistani is also spoken by the people of Dir Kohistan area but this Kohistani language of Dir Kohistan is quite different than that of Kohistan District of Hazara division. English language is also understood by the literate population.

4.7.8. Religion

Majority of the people are Muslim and belong to Hanfi School of thought, some other school of thoughts also exist in different parts of the district.

4.7.9. Dress

The common dress amongst the males and females is Shalwar Qameez and Chadar. In winter warm coats, sweaters, waist coats, woollen cap (Pakol) are used by males. Footwear is used according to weather conditions i.e. boots & chappals etc.

4.7.10. Food

Wheat, maize, rice, beef, mutton, fish, vegetables, pulses especially mash and gram, chapali kabab, milk and lassi are common food items used by the people of Upper Dir.

4.7.11. Dwellings

Mixed construction material is used in construction of houses i.e. cement, bricks, stones, steel, wood & clay. Well-off people who have ample source of income construct cemented houses while people of low-income group use clay and stones for constructing Katcha houses. The area is full of forest trees; hence wood of different kinds is used for roof making and door preparation. Diar wood is cheap and easily available in the project area. Rooms in the houses are few while open area is ample to accommodate animals, fire wood and so on.

4.7.12. Culture and Traditions

People of the district are very simple, hospitable and good Pakhtuns loving their customs, traditions and cultural values. They are hardworking people, live and die for their honour and dignity. Jirga System is very dear to them for settlement of conflicts. They like mela bazaars which are held on weekly basis.

4.7.13. Marriages

Marriages are usually arranged by the parents at early ages and celebrated with extravagant spending and serving of food to the guests, relatives and friends.

4.7.14. DEATHS

Deaths are commemorated strictly according to Islamic way of life. People of area, relatives and friends attend funeral in large numbers.

4.7.15. HEALTH FACILITIES

Economic development and social progress are closely linked with the state of health of the population. Health facilities are essential not only to provide clean and disease-free atmosphere to live but also to enhance the efficiency and productivity. The state of health of an area and its population depends on availability of clean drinking water, sanitation facilities and number of doctors available in the medical units. It is essential to keep people not only free from communicable diseases but also to make sure quality of life and reduction in mortality rate. People of the project area are facilitated with the rural level facilities like Dispensaries, Rural Health Centre, and Basic Health Units etc. The main medical facilities are available in the Upper Dir Hospitals. Development Statistics of medical institutions is shown in the following table.

Table 4-18 Medical Institutions in Upper Dir District in 2010-2011

Sr. No	Name of Institutions	Nos.
1	Hospitals	5
2	Dispensaries	10
3	Rural Health Centres	-
4	TB Clinics	1
5	Sub-Health Centres	2
6	Mother Child Health Centre (MCHC)	2
7	Basic Health Units (BHUs)	32
8	Leprosy Centres	3

Source: KPK Development Statistics 2011

4.7.16. GENDER ROLES

Dir Upper and especially Dir Kohistan area, where the project is proposed, reflects male dominated society where gender roles and responsibilities are well-defined. Male population works outside for livelihood earnings while women shoulder the responsibility of household activities. Some agricultural activities are also shared by women. Improving trends in female education are opening new vistas of employment for females in education and medical sectors. Women decision making role is confined to the domestic sphere. Women are strict parda observers and their interaction with the outsiders is not allowed. Information regarding female roles is provided by the male family members.

4.7.17. Educational Facilities

Education is the key to development efforts that have been made by the government and private investors to boost up literacy rate in Upper Dir district. The following table shows the number of educational Institutions in District Upper Dir.

Table 4-19 Educational Institutions in Upper Dir

S. No.	Institution	Male	Female	Total
1	Primary Schools	580	203	783
2	Middle Schools	63	23	86
3	High Schools	36	7	43
4	Higher Secondary Schools	5	2	7
5	Degree Collages	1	1	2
6	Govt. Colleges of Management Sciences	-	-	1
7	Technical Vocational Centres	-	-	2
8	Govt. Universities	-	-	1
9	Private Primary Schools	-	-	113
10	Private Secondary Schools	-	-	28
11	Maktab Schools	-	-	83

Source: KPK Development Statistics 2011

Shringal University is situated in Shringal Upper Dir. High Schools are also available is the project area. There is a network of Govt. Primary Schools in the area. The increase in number of educational institutions and enrolment of students is an indicator of the increase in literacy rate.

4.7.18. Communication and Transport Facilities

The project area has wireless loop telephone and mobile telephone facilities. The area is equipped with telephonic exchange. More than 15 post offices are providing postal services to the people. Commercial Banks are also available. The project area has public transport facilities up to Dir Upper and Dir Lower. From Upper and Lower Dir transport is available for Swat, Peshawar, Lahore and Karachi. Private transport is also available for the population of the area.

4.7.19. CIVIC AMENITIES

The existence of civic amenities in an area like drinking water, electricity, sanitation and drainage, roads, streets & street lights indicate the social improvement in the society.

4.7.19.1. ROADS

The project area is a far-flung mountainous area of Upper Dir. The existing road is in good condition. It’s a metalled road but most of the sections are damaged and under construction for a long time. Snowfall, torrential rains and frequent sliding further deteriorate its condition. Repair and construction work are slow; however, the project area is easily accessible. The government and NGOs have cemented some streets in some villages.

4.7.19.2. DRINKING WATER

Drinking Water is mostly fetched from the springs which are of good quality. Public Health Engineering Department is responsible for water schemes. For domestic use water is uplifted or brought from the river also. Quality of water is good and groundwater has been explored in some areas.

4.7.19.3. ELECTRICITY

Mostly the area is electrified though WAPDA connections and some areas have private generating systems which are economical than the government tariff.

4.7.19.4. DRAINAGE & SANITATION

Project area has good slopes that help in quick disposal and run of wastewater during the rainy season. The outlet is River Panjkora or its tributaries. However, in populated areas wastewater is drained out to the river, which creates some pollution.

4.7.19.5. STREETLIGHTS

Streetlight Facilities are very meagre in the project area. Some areas like main Upper Dir Bazar, Sahibabad Bazar are equipped with streetlights.

4.7.20. AGRICULTURAL SERVICES & INSTITUTIONS

Agricultural Extension, Animal husbandry and other related departments are available in the area and provide services to the local farmers. Loan facilities are available from the commercial banks. Marketing of production is done easily through trucks and small vehicles.

4.7.20.1. CROPS

Temperatures in December, January and February reach below zero usually. Maximum rainfall month is March with average 240 mm. Cropping pattern suited to the climate of Upper Dir includes maize, rice, wheat, barley, mustard, onion and vegetables. Fruits include walnut, persimmon, apple, pears, plums, apricot, fig, loquat and mulberry. Walnut trees are in abundance in the project area. Goats, sheep and cow are common livestock reared in the project area. The animal products are utilized domestically as well as for marketing. Agricultural production is usually utilized for domestic use because landholdings are small. Irrigation is done through private civil channel system/ Barani.

4.7.21. INDUSTRY TRADE & TRADE CENTRES

There is no big industry in the district. Cottage industry is available which is limited to manufacturing of zari caps, woollen cloth for waist coats, caps and chaddars. Furniture is also manufactured extensively because high quality wood i.e. Walnut and Diar is available on cheaper rates. Knives of Dir are well known. Major trade centres are Upper Dir Sheringal, Barawal, Darora and Warai where trade of food grains, walnut, peas, potato and furniture is done. Mostly daily use edible items and other amenities are brought from big cities including Peshawar, Rawalpindi, Lahore, Faisalabad, Gujranwala and Karachi.

4.7.22. POVERTY, VULNERABILITY AND HOUSEHOLD INCOME

People of the project area are not well-off generally. Some people who have business, income from the family members living abroad, forest ownership or regular employment, run their domestic affairs properly but majority of people hardly earn their livelihood. Poor people are living without fundamental freedom of action and choice. They often lack food, shelter, education and health. They also face extreme vulnerability to ill health, economic dislocation and natural disasters especially in odd weathers.

4.7.23. STAKEHOLDERS CONSULTATIONS

The sociologist for gathering both qualitative and quantitative input for social assessment undertook Focus Group Discussions with the Stakeholders and administering village profile questionnaire in the project area. The base-line information has been collected from the primary stakeholders as well as from the secondary data available in various reports. Public consultations in the project area constituted an important activity in the overall field work conducted for social assessment study. Irrigation, Forest, Agriculture, District Administration and local government functionaries were contacted for discussing the proposed projects who assured their support as and when needed. The detail of which is given in chapter 6.

4.8. ECOLOGICAL WATER DEMAND AND DOWNSTREAM WATER USAGE

4.8.1. River Tributaries

The main source of Panjkora River is Kumrat and Osherai, nearly 70 km and 30 km from Dir town. Glaciers, waterfalls of the valley feed the river. The Panjkora River flows through the entire Valley via Dir, Sahibabad, and Temargara and joins the Swat River in the Mohmand. The other streams/ nullahs present in the area also contribute towards increasing the water quantity in the river.

4.8.2. Downstream Degradation

The release of clear water either through the outlets or power plant, will upset the regime of the natural channel on the downstream side of the powerhouse, in the form of degradation of the channel bed and banks. The degradation process progressively moves downstream, until it reaches a point where the quantities of the sediment being transported result in a stable channel, or equilibrium. The one exception to a clear water release would be a reservoir that has planned sluicing with low-level outlets, having a capacity equal to the high river discharges for moving large amounts of sediments into the downstream channel.

4.8.3. Lower Riparian Water Use Study

The environmental water requirements, downstream of the weir are the water needed to sustain the ecology of the downstream reach of the river. The ecology of the downstream reach consists of plant life, wildlife, and aquatic life including of fisheries. It should also include the river bed losses and the bank charges, which are likely to affect the groundwater table along the river banks. The depression of the groundwater recharge to the banks, is nominal due to steep mountains on the sides and the rocky strata that hardly allow infiltration. Water use study survey of the river was conducted downstream of the weir site to Power house site, where the river flow will considerably be reduced after the project construction. Water use studies determine the consumptive and non-consumptive water use of communities along the river. It was essential to identify the concerns of the communities due to flow reduction there in the river in their villages/localities.

4.8.4. Settlements

There are several settlements/villages from the weir site to the powerhouse site. These settlements are on the right and left bank of the river. All these settlements are a cluster of houses at different places along the river. In all these settlements few houses are at a high altitude while clusters are closer to the river.

4.8.5. DRINKING WATER SUPPLY

The source of obtaining drinking water in all the villages is almost through spring water and water supply schemes. All of the communities' favour spring water, which they perceive as good and river water being of inferior quality due to its turbidity and possible contamination from upstream users.

4.8.6. SAND AND GRAVEL EXTRACTION

Substantial quantities of sand and gravel get accumulated closer to the river banks during the summer season, when the river water recedes. This accumulated sand and gravel are lifted up from the river banks and stored along the sides. This is marketed to the end users in construction works. Persons involved in the sand and gravel collection and its marketing business apprehensions that their business will be adversely affected, which needs some mitigation measures. They can be provided with the employment opportunities in the Project construction works during the project implementation stage on priority.

4.8.7. FLOATING TIMBER WOOD

Floating wood is collected from the rivers occasionally in the area and logs have particularly a good market value. This is through a dangerous practice as logs are mainly washed down during the flood season and lives have been lost when trying to retrieve logs from the river. A negative concern has been expressed by the communities about the loss of floating timber wood due to the project construction.

4.8.8. WASHING

Washing is also one of the uses of water for the settlements along the river/stream, this use is in the summer season only.

4.8.9. FISHING

Fish catching reported in the area is rare and at some places in limited quantity. The catching of fish is mostly as a hobby and for their own use and no one is dependent for their livelihood on this business. They catch fish during the summer season only. Summer is the best season for fishing, as the larger summer flows are recognized as being more productive in terms of fish catch. Fish catching are being done with fish nets and fishing rods. Fish is not included in the regular diet nor is it considered prestigious to be served on special occasions.

4.8.10. COMPENSATION WATER REQUIREMENT

Compensation water releases from the Weir do not consist of only environmental water requirement but also include riparian rights of water users in the downstream reach of the river. The riparian rights consist of water supply for the domestic and commercial use, established irrigation use and water needed for dilution of the sewage entering the river from various sources. The environmental water requirement downstream of the proposed Weir is the water needed to sustain the ecology of the downstream reach of the river. The ecology of the downstream reach consists of plant life, wildlife, and aquatic life including fisheries. It should also include the river bed losses and bank charges, which are likely to affect the groundwater table along the river banks. The depression of the groundwater table may affect the riverine forests. The groundwater recharge to the banks is nominal due to steep mountains on the sides and rocky strata that hardly allow infiltration.

4.8.11. ENVIRONMENTAL WATER RELEASE FROM THE WEIR SITE

The proposed project is a run-of-the stream project involving diversion of water from approximately 1 km down from Darora village through a headrace tunnel, leading to a penstock, which in turn will feed the powerhouse. The combined flow from the powerhouse i.e. tailrace discharge will be released back into the Panjkora River near Sahibabad. The diversion of water for the project may have adverse impacts on the downstream users of the streams, thereby requiring adequate management and mitigation measures among others to be put in place well in advance. Currently, there is no major dependency on the river segment (between weir site and powerhouse) of the Panjkora River except Sahibabad Tablighi Markaz hydropower plant. Although, all these settlements depend mostly upon streams flowing in the river from the surrounding areas, the drinking water needs are met through spring waters. The water use study conducted indicates that the general water use in the area consists of water required for cattle, tourists and water requirement for ecological sustenance. Construction of Artistic-I HPP will result in reducing the flow downstream in about 10 km stretch of the river from the weir site to the powerhouse site. This may have some adverse impacts on the aquatic life, fowl life, downstream people and other environmental elements in this reach.

4.8.12. ENVIRONMENTAL FLOWS

The river is the only ecosystem that connects other ecosystems, carries water, transports dissolved minerals, sediments and nutrients to maximum places before emptying into its natural outlet. How much water would flow through a river channel? The sediment and nutrient load carried by a river is decided by the nature of the catchment and the rainfall or snow fall pattern. Flowing rivers connect different ecosystems like glaciers, forests, riparian zones, flood plains, mangroves etc. on their way. Flowing rivers also create flood plains, sand deposits, deltas, etc. Rivers, while draining the land, carry out groundwater recharge by percolating into deeper aquifers. All rivers do not necessarily flow directly to the seas or open oceans. High flows of different frequency are important for channel maintenance, bird breeding, algae control, wetland flooding and maintenance of riparian vegetation. Moderate flows may be critical for cycling of organic matter from river banks and for fish migration, while low flows of different magnitudes are necessary for fish spawning, water quality maintenance, the use of the river by local people, etc.

Hence, it is imperative to understand the inextricable linkages between flowing rivers and dependencies of communities, which is at the core of the ‘environmental flows’ concept. Considering this reality, devising ways for mainstreaming community concerns and efforts in water management within a river basin in general and e-flows in particular is a challenging task. The term environmental flow refers to the quantity, quality, and timing of water flow needed to sustain ecosystems and the services they provide to humans (Dyson et al. 2003; Poff et al. 2010).

A distinction should be made between the natural flow regime of a river that would maintain ecosystems in a pristine state and an environmental flow. An environmental flow has the goal of allocating sufficient water to ecosystems to maintain. Since the concept emerged in the mid-20th century, more than 200 methods for estimating environmental flows have been developed globally. These methods can be classified into four approaches (23.1; Tharme 2003). Hydrology-based methodologies use historical discharge records to make environmental flow recommendations, usually expressed as a fixed proportion of flow intended to sustain river health (e.g. 10% of average annual discharge). Hydraulic-rating methodologies rely on basic hydraulic parameters (e.g. depth, wetted perimeter) that relate to habitat for aquatic biota; environmental flow recommendations are made by plotting acceptable levels of reduction in these parameters against discharge. Hydraulic rating methodologies preceded more sophisticated habitat simulation methodologies that employ hydrological, hydraulic and biological response data to quantify suitable instream physical habitat available to target species, usually fish, under different flow regimes. Habitat-discharge curves depicting the range of habitat for biota as a function of flow are then used to determine environmental flow recommendations. Holistic methodologies aim to approximate the natural flow regime and often employ some of the tools of hydrology-based, hydraulic rating and habitat-simulation approaches. (Reference: A Primer on Environmental Flows Latha Anantha & Parineeta Dandekar, 2012). In the absence of a specific guideline or recommendations in Pakistan for the amount of water (residual water) to be retained in a water reach as an environmental flow when water is diverted for hydropower purposes, the following method was considered to evaluate ecological flow:

4.8.13. CEMAGREF MODEL

For the determination of ecological flow, a formula representing a function of the available mean monthly discharges and the mean annual discharges, was used as presented below,

Qe = {(0.0651 X Qm+ 2) /100} x Qa

Where Qe = Mean monthly ecological flow (m3/s)

Qm= Mean monthly flow (m^3/s)

Qa = Mean annual flow (m^3/s)

The formula was also used for feasibility study for Madian HPP, Koto HPP feasibility and feasibility study of the Gabral-Kalam HPP and was developed by CEMAGREF which is an Agricultural and Environmental Engineering Research Organization of (Antony) France. The model is also recommended by the International Association of Small Hydropower. The CEMAGREF Model is used as a reference to calculate the mean monthly ecological or residual flows in Koto hydropower project feasibility study. The results are given in **Table 4-20** Environmental flows calculated by CEMAGREF Model in low flow seasons are less than calculated as 15% by USA method. So, nearly 4.58 m^3/s as by USA Montana method is considered to be appropriate as environmental flow from October to March and 18.814 m^3/s from April to September in this river reach. The water released continuously from the weir site along with the water augmented through the streams and nullahs will be sufficient /adequate to meet the ecological and environmental requirements of the downstream area between the weir and powerhouse sites during the operational stage of the project. Walk-through survey indicated that agriculture field blocks along river sides are located near weir and power house site but they are rain fed. So, environmental flow of the above-mentioned quantity is recommended for downstream requirements and to maintain ecological flows in between weir and powerhouse for this river reach.

Table 4-20 Mean Monthly Flow and Ecological Flows Calculation

Month	Mean Monthly Flow	Ecological flows calculated by CEMAGREF model	15% as Calculated by USA (Montana Method)
January	18.83	2.508	2.825
February	26.00	2.871	3.900
March	57.53	4.466	8.630
April	106.17	6.928	15.925
May	136.13	8.444	20.420
June	172.07	10.263	25.810
July	164.87	9.898	24.730
August	116.33	7.442	17.450
September	57.00	4.439	8.550
October	32.83	3.216	4.925
November	23.73	2.756	3.560
December	21.40	2.638	3.210

CHAPTER 5: PROJECT ALTERNATIVES

The Project alternatives are considered for analysing the most feasible option, keeping in view technical and economic factors as well as acceptability from environment and social aspects. Among the hydropower project alternatives ranging from run-of-river, run-of-river cum peaking storage and storage projects etc. exist. Similarly, within the category of hydropower projects, various alternatives relating to location, layout, design of structures, construction methods and schedules, operation modalities, environmental management systems during construction and operation etc. are commonly evaluated on environmental grounds for projects selection. Apart from this, a power generation project or no power generation in the context of the country in question is also a part of alternative analysis. In this chapter, an attempt has been made to evaluate the various available alternatives of the proposed project in the environmental perspective as well as in technical, social and economic regards.

The Consultants made desk studies based on satellite imagery available from Google earth and mark various layout alternatives on the image to be studied during site visit of experts. The Consultants before carrying out detailed topographical survey have included additional areas under survey boundaries in advance to study various project alternatives in detail. The assessment of alternatives for hydropower projects should address both (i) the energy production alternatives to the proposed scheme, (including both hydro and non-hydro projects, as well as the no-project alternative) and (ii) the alternatives and options that were envisaged and discussed between the technical and E&S teams during project preparation when optimizing the location, size, structural design, construction principles and operation of the scheme. The assessment of alternatives should take into account relevant Strategic Environmental Assessments and other strategic level documents, regional programmes, basin management plan or any bi-lateral/multi-lateral agreements related to the water body. The assessment of alternatives shall also clearly describe whether the considered alternatives are under the control of the developer to implement at the project level, or whether they were decided at the strategic level by third parties (for example, by a competent national authority).

5.1. NO PROJECT ALTERNATIVE

This alternative prevents the implementation of the proposal, and therefore, will forfeit the beneficial impacts of Artistic-I HPP. The project aims to add power to the national grid. At present, most of the population of Pakistan has no access to electricity. Similarly, limitation exists to access clean energy in rural areas. In order to address such a lacunae, rapid development of power projects in Pakistan is of utmost importance. Furthermore, electricity is synonymous with development. For the purpose of lighting, cooking, heating, commerce, and industry reliable and dependable power supply is essential. KP and Pakistan are going through an acute power shortage. The gap between supply and demand has crossed 5,000 MW. The proposed Project will supply some needed power to reduce the current gap. Environmentally, this Project will contribute towards improving the air quality as in the long run it will displace fossil fuels used in power generation. For years, the matter of balancing Pakistan's supply against the demand for electricity has remained a largely unresolved matter. Pakistan faces a significant challenge in revamping its network responsible for the supply of electricity. Pakistan's electricity producers are now seeking parity in returns for both domestic and foreign investors, which make it as one of the key unresolved disuse in overseeing a surge in electricity generation when the country faces growing shortages. As of 2013, massive long duration electricity shortages continued with continuous failure to provide reliable service, and rampant corruption being met by public protests, unauthorized connections, and refusal by consumers to pay for intermittent service. Electricity generation in Pakistan has shrunk by up to 50% in recent years due to an over-reliance on fossil fuels. In 2008, availability of power in Pakistan fell short of the population's needs by 15%. Pakistan was hit by its worst power crisis in 2007, when production fell by 6000 MW and massive blackouts followed. Load shedding and power blackouts have become more severe in Pakistan in recent years.

Measures have already been taken to restrict demand by using an inverse tariff by which well to do customers using larger amounts of electricity pay a higher rate per unit. The situation is causing serious economic losses to the country as well as being politically and socially divisive and could gradually lead to a risk of social unrest. The current situation with insufficient installed power generation capacity is very serious and untenable.

Thus, a project like **Artistic-I HPP** is necessary for the country. Thus, the no project alternative, as it does not benefit local communities and the environment and also hinders the national social, economic and financial development is rejected from environmental grounds.

5.2. ALTERNATIVES TO ELECTRICAL ENERGY

The possible alternatives to electrical energy could be solar power, wind power, thermal power, fossil fuel and firewood. Power import from neighbouring countries is another option. Solar and wind power are also sources of clean energy which create or produce very less environmental degradation. However, the potentiality of both solar and wind power on a large extent depends on the sunshine hours and wind velocity which may not be available all times. The major constraint is that it cannot be regulated. The energy will be available when there is sunshine or gushing winds and the energy cannot be stored in large quantities because of the technological difficulties. Besides, there are problems associated with these sources. Imported solar panels are complex in technology and expensive to maintain. The power generated from solar power is very small to be used for lighting, heating and cooking purposes and not feasible to cater the services to a larger population. The problems in operation of wind power are lack of time series data of wind, trained human resources to intricate design of wind power etc. In addition, providing wind power for large populations in Pakistan is technically and financially challenging and cannot at the moment be an alternative to hydropower. Thermal power plants are associated with serious environmental problems like air pollution, waste pollution, noise pollution, temperature pollution etc. Besides coal and petroleum products, the basic input required for the conventional thermal power plants are not available in Pakistan and have to be imported. The current price trends of these materials are continuously spiralling upwards, and this is an issue of high investment costs, trained human resources and spare parts etc. Therefore, thermal power option based on coal and petroleum products is not a viable option for Pakistan.

The use of firewood and solid waste for electricity generation by the use of thermal technology is another option. But the issue of air pollution and forest degradation already are environmental problems of serious concern which will further aggravate the natural environment. For these reasons, the thermal power options evaluated above seem inappropriate for Pakistan on environmental as well as economic grounds. Regarding the import of electricity from other countries like China Iran etc., electricity is already in short supply in both the countries. Pakistan to some extent is importing power from China. There are various problems and issues associated with the import of power from China. Such problems include; low capacity transmission line to import bulk electricity, no power during the peak periods, low voltage at certain hours of the day, and own irregular supply schedule, whereas accessibility and the high mountain barrier has made establishment of the transmission grid impractical and costly to import power from China. For these reasons, power import from neighbouring countries can never be considered as a sustainable solution for Pakistan.

In view of the in-country available water resources, suitable topographic gradients for harnessing the water resources for power generation with minimum environmental and social damage, the alternative discussed for electricity generation are inferior to the hydropower projects in the context of Pakistan and have been discarded on environmental and economic grounds.

5.3. NO FOREST ALTERNATIVE

One of the considerations in the selection of the project structural sites and project support facility sites is to avoid forest areas as far as possible. The proposed project alternative is the most minimum forest requiring option considering the power output, geological and geotechnical suitability. It is in this context; it has been assessed that the impacts due to Artistic-I HPP will not induce any significant impacts on the green cover of the area as well as any stratification of the forest.

5.4. ALTERNATIVE REGARDING TECHNOLOGY, OPERATION, PROCEDURES, TIME SCHEDULES AND RAW MATERIALS TO BE USED:

To provide a maximum job opportunity, the selected construction technology alternative is a mix of labour and machine based. The power plant will be operated in tune with the available hydrology. Consideration is given to the environmental requirement to release the environmental downstream flow from the diversion point as to the standard provisions. As far as possible, raw materials required for the project will be sourced from the local area except for timber and fuelwood.

5.5. ALTERNATIVE FOR ENVIRONMENT MANAGEMENT SYSTEM

The project is very sensitive on minimizing environmental impacts. The consultant has analysed various alternatives of spoil disposal, placing of crusher units and location of camps. While selecting sites for different activities, due consideration has been given to the environmental impacts and their environmental management. The project has developed an environmental management plan for the construction and operation periods giving due recognition to the environmental aspects of the area.

5.6. PROJECT LAYOUT ALTERNATIVES

The project location and layout alternatives have given due consideration on the design alternatives while selecting the alternatives. The Consultants made desk studies based on satellite imagery available from Google earth and marked various layout alternatives on the image to be studied during site visits of experts. The project layout alternatives are presented in **Figure 5-1.** The Consultants before carrying out detailed topographical survey have included additional areas under survey boundaries in advance to study various project alternatives in detail. The layout alternatives and their merits and demerits are discussed in detail.

5.6.1. ALTERNATIVE-1 (LEFT BANK LAYOUT)

The weir site coordinates as per Letter of Intent (LoI) are not appropriate due to the low elevation of existing asphalt road N-45 on the left bank as this road was over topped/flooded during 2010 flood at various location including this section of the road. Therefore, in all the alternatives the weir location will be different from the one with coordinates provided in the LoI.

Left bank box channel alignment will continue along the road below N-45 road elevation before crossing it underneath to join the tunnel inlet portal. Bridge over the channel would be required where it crosses the road N-45. The tunnel inlet portal would be located toward hillside downstream up to 200 m where rock is exposed/outcrops near an existing house and where it has a sufficient tunnel cover thickness. The expected road widening of N-45 should also be kept in mind in planning structures on the left bank. No suitable location for Adit tunnel was identified during site visit for the left bank alternative.

The sand trap at the end of the Alternative-1 tunnel should be constructed before the tunnel inlet to save economy of the project and to avoid sedimentation in the tunnel. The penstock alignment crosses a deep and steep tributary Uch khwar and valley at an angle inclined to contours, which is not appropriate for an exposed penstock. Carrying the penstock beneath the valley within as a buried / tunnel section is better. The powerhouse location as provided in LoI was not suitable for left bank alternative due to presence of habitation nearby, which is therefore shifted downstream to a relatively suitable location. Furthermore, the tail water canal will cross the existing asphalt road and therefore bridge over the tailrace would be required.

5.6.2. ALTERNATIVE-2 3 AND 4 (RIGHT BANK LAYOUT)

5.6.2.1. WEIR SITE

The weir site coordinates provided in the LoI are not appropriate due to the low elevation of existing asphalt road N-45 on the left bank as this road was over topped/flooded during 2010 flood at various location including this section of the road. Therefore, consultants identified three alternate project sites for the weir of Right-Side Alternatives which are discussed below. Alternative 2 Weir is identified about 250 m upstream of the weir site given in the letter of intent. Constructing Weir at this site will cause the submergence of few houses due to ponding of water on the upstream. Alternative 3 Weir is located about 705 m upstream of Alternative 2 weir, which will result in need of reconstruction of a mosque on the upstream. Finally, Alternative 4 Weir is identified about 1200 m upstream of Alternative 2 weir. This option will result in greater head and having a good reservoir due to topography of the valley. However, a protection wall will be needed on the upstream side to keep the houses safe from the reservoir water. All the options discussed above are subject to the consent and approval of the client and to see the effect of other projects in the vicinity of the proposed options.

5.6.2.2. RIGHT BANK CONVEYANCE BOX CHANNEL

The canal alignment will pass through the toe of terrace deposits near the Panjkora River. The terrace materials slope and its stability are yet to be seen after determining geotechnical parameters of this material during geological investigations.

5.6.2.3. RIGHT BANK SAND TRAP

The structure is placed near the toe of the hill at terrace deposits, the only place where such structure can be placed and economy in excavation can be achieved.

During layout Alternative studies, if the weir at the upstream gets approved then there are two probable locations of sand trap which will be studied in detail at later stage.

5.6.2.4. RIGHT BANK TUNNEL INLET

The alignment of box channel, before tunnel inlet, passes through a steep terrain where for the sake of economy, a rectangular section is proposed. Depending upon the Alternatives2, 3& 4 there will be a box channel at the upstream end of the sand trap, the length of which depends upon the option selected. The rectangular box channel will lead to a tunnel through a tunnel inlet which will have a transition for hydraulic requirement and a rock overburden for stability requirement.

5.6.2.5. PRESSURE CONDUIT IN THE KOTKAY KHWAR

The tunnel crosses Kotkay Khwar approximately in the downstream half of weir-power house alignment. The tunnel will be day-lighted here which will help in managing construction activities from four faces which shall have a substantial impact on the reduction of construction time of this critical activity. As per preliminary findings, the tunnel will be converted into pressure conduit like super passage which will be deep enough than the Khwar bed level. Accordingly, this structure will have least scouring effect of the floods generated in the valley and passing in the Khwar.

5.6.2.6. RIGHT BANK SURGE TANK, PENSTOCK ALIGNMENT AND POWERHOUSE LOCATION

The exit (outlet) location of tunnel was fixed according to the location and approximate dimensions of powerhouse as well as the route of penstock and height of surge tank. According to preliminary hydraulic calculations, the minimum diameter of the surge tank shall be 12 m, and the height corresponding to this diameter is ~100 m. However, these dimensions will be checked and refined in detail design. An exposed type of penstock route is designed for this stage. However, after geotechnical investigations, if the depth of slope wash material is found to be thick and unstable, then in order to be on the safe side, even expensive, a vertical shaft for the penstock (buried type of penstock) may be preferred.

The powerhouse (Alternative 2, 3, 4) is seated in the relatively plan area to avoid excessive cutting and to minimize possible cost of excavation and having slightly milder environmental impacts. Power house level shall be fixed and optimized for different discharge levels in the river and tailrace level to get maximum energy from the design discharge. A surface power house is proposed for the Artistic-I Hydropower project. Switch yard and colony/residence for operational staff is proposed at a location in the vicinity of power house.

5.6.2.7. PROVISION OF ROAD BRIDGES

The right bank layout alternatives alignment would require construction of two vehicular bridges i.e. one at the weir and other at the powerhouse location, respectively as per project's requirement for access during and after construction.

Table 5-1 Salient Features of Layout Alternatives

Description	Alternative 1 (Left Bank)	Alternative 2 (Right Bank)	Alternative 3 (Right Bank)	Alternative 4 (Right Bank)
Slope Stability Issues at Weir / Intake Location	(W1) Relatively higher than W2 Alternative	(W2) Small	(W3) Small	(W4) Small
Sand Trap Location	Difficult / Not suitable	Excellent	Excellent	Excellent
Tunnel inlet / Outlet Portal	Difficult / Involving Social Problems	Reasonable	Reasonable	Reasonable
Power House	Suitable	Suitable	Suitable	Suitable
Environmental & Social issues	Severe	Less Severe	Less Severe	Mild
Access Bridges at Weir & Power House	Not Required	2 Nos.	2 Nos.	2 Nos.
Multi span culvert / Bridge for at Weir & Tailrace crossing Timergara-Upper Dir Road	2 No.	Not Required	Not Required	Not Required
Box Channel Length	240 m	725 m	1430 m	2900 m
Tunnel Length	7000 m	7340 m	7340 m	7340 m
Penstock Length	231 m	261 m	261 m	261 m
Total Length (Box Channel + Tunnel + Penstock)	7471 m	8326 m	9031 m	10501 m
Gross Head	65 m	60 m	64.5 m	79 m
Design Discharge	110 m^3/s	110 m^3/s	110 m^3/s	110 m^3/s
No. of Turbine Units	3	3	3	3
Combined Efficiency (Assumed for Comparison)	88.4%	88.4%	88.4%	88.4%

Description	Alternative 1 (Left Bank)	Alternative 2 (Right Bank)	Alternative 3 (Right Bank)	Alternative 4 (Right Bank)
Power Potential (Tentative for Comparison)	52.47 MW	47.00 MW	50.80 MW	62.72 MW
Annual Energy (Tentative for Comparison)	265.74 GWh	239.54 GWh	258.06 GWh	317.83 GWh
Net Annual Revenue (Tentative for Comparison) @Rs. 10/unit	Rs.2657.43 Million	Rs.2395.36 Million	Rs.2580.62 Million	Rs.3178.33 Million

5.7. CONCLUSIONS & RECOMMENDATIONS

The Consultants, after detailed discussions, analysis and comparison of all project layout alternatives, come to the conclusion that right bank Alternative 4 would be more practical and beneficial from construction, geological and geotechnical aspects. Alternative 4 would offer maximum power potential, annual energy and consequently annual revenue, while having least social and construction problems.

From the above discussion it was concluded that Alternative 4 (Right bank) is better than the other Alternatives due to following reasons:

- The site area of alternative 4 is mostly barren and there will be fewer impacts on Environment and local community.

- As the area is barren, so, sufficient space is available for the construction and diversion arrangement near weir site as compared to other alternatives.

- W4 site offers additional head of about 14.5 m and consequently higher power potential as compared to W3 site.

- The Alternative 4 offers tentative higher power potential of about 62.72 MW as compared to 50.80 MW by alternative 3. Furthermore, alternative 4 offers tentative annual energy of about 317.83 GWh as compared to 258.06 GWh by alternative 3. The alternative 4 offers net additional annual revenue of about Rs. 597.71 Million as compared to alternative 3.

- There will be least social problems as the reservoir water will not cause the submergence of houses on the upstream.

Taking all these factors into consideration; Alternative 4 is recommended for further study. Further study on the selected layout will be started after its approval from PEDO and the availability of detailed topographical survey maps and geological maps.

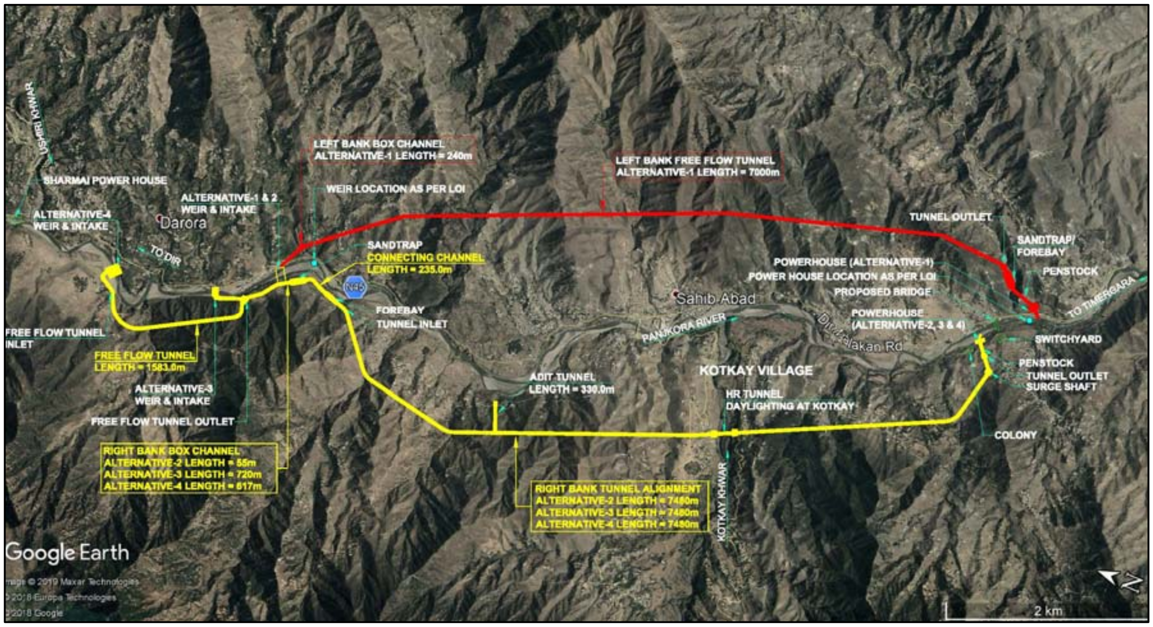


Figure 5-1 Projects Layout Alternatives

CHAPTER 6: STAKEHOLDERS CONSULTATION

As part of the EIA process, consultations are undertaken with communities and institutions that may have interest in the proposed project or may be affected by it. This Section documents the consultation process for the EIA of the proposed Project and summarizes its results. The consultation process was designed to be consistent with the relevant national legislation and other international organization on social and environmental sustainability.

6.1. REGULATORY REQUIREMENTS

Public consultation is mandated under national environmental law. The Pak-EPA, under Regulation 6 of the IEE-EIA Regulations 2000, has issued a set of guidelines of general applicability and sectoral guidelines indicating specific assessment requirements. These guidelines have been adopted by the KP-EPA for use in its jurisdiction. This includes Guidelines for Public Consultation, 1997 (the 'Guidelines'), that are summarized below:

6.2. OBJECTIVES OF PUBLIC INVOLVEMENT

'To inform stakeholders about the proposed project, to provide an opportunity for those otherwise unrepresented to present their views and values, providing better transparency and accountability in decision making, creating a sense of ownership with the stakeholders'.

6.3. STAKEHOLDERS

'People who may be directly or indirectly affected by a proposal will clearly be the focus of public involvement. Those who are directly affected may be project beneficiaries, those likely to be adversely affected, or other stakeholders. The identification of those indirectly affected is more difficult, and to some extent it will be a subjective judgment. For this reason, it is good practice to have a very wide definition of who should be involved and to include any person or group who thinks that they have an interest. Sometimes, it may be necessary to consult with a representative from a particular interest group. In such cases, the choice of representative should be left to the group itself. Consultation should include not only those likely to be affected, positively or negatively, by the outcome of a proposal, but should also include those who can affect the outcome of a proposal'.

6.4. MECHANISM

'Provides sufficient relevant information in a form that is easily understood by non-experts (without being simplistic or insulting), allow sufficient time for stakeholders to read, discuss, consider the information and its implications and to present their views, responses should be provided to issues and problems raised or comments made by stakeholders, selection of venues and timings of events should encourage maximum attendance'.

6.5. TIMING AND FREQUENCY

Planning for the public consultation program needs to begin at a very early stage; ideally it should commence at the screening stage of the proposal and continue throughout the EIA process.

6.6. CONSULTATION TOOLS

Some specific consultation tools that can be used for conducting consultations include; focus group meetings, needs assessment, semi-structured interviews; village meetings and workshops.

6.7. IMPORTANT CONSIDERATIONS

'The development of a public involvement program would typically involve consideration of the following issues; objectives of the proposal and the study; identification of stakeholders; identification of appropriate techniques to consult with the stakeholders; identification of approaches to ensure feedback to involved stakeholders; and mechanisms to ensure stakeholders' considerations are taken into account'.

6.8. PRINCIPLES OF STAKEHOLDER CONSULTATION

The stakeholders' consultation activities were executed based on the following principles:

- Transparency
- Openness
- Accessibilities and;
- Inclusion

6.9. CONSULTATION METHODOLOGY

Consultations with the Project stakeholders were undertaken in early May and in second half of June 2019. The main document for distribution to stakeholders during the consultations was the Background Information Document (BID) that informed the stakeholders about the EIA process and provided a background about the Project. The feedback from the communities was recorded and the detailed logs of consultations with the attendees were prepared. Separate meetings with institutional stakeholders were arranged in Upper Dir and Peshawar.

6.10. STAKEHOLDERS CONSULTED

6.10.1. COMMUNITY STAKEHOLDERS

Stakeholders are groups or individuals that can affect or take affect from a project's outcome. Affected Communities include population that is likely to be affected by the Project activities. Potential impacts of the Project on the local environment include disturbances and changes to the physical and biological environment, such as, land transformation, noise disturbances, and air and water quality issues. These disturbances can result in indirect socioeconomic impacts, such as, physical or economic displacement. These impacts are expected to reduce with the increased distance from the Project facilities. A basin wide study approach was used for the EIA of Artistic-I HPP; therefore, rural communities were consulted along the Panjkora River. In addition to the Potentially Affected Communities, nomad communities frequenting the area, local government and local Non-Government Organization (NGO) officials were also consulted.

Exhibit 1 lists the community stakeholders consulted. Consultation were conducted in representative number of communities while ensuring that people from various segments of the society participate in the consultation, to ensure proper coverage of possible stakeholder concerns.

Exhibit 1: List of Community Stakeholders Consulted

Stakeholders (village)	Union council	Consultation Group	Date Consulted
Jaba	Kotkay	Male	May 13, 2019
Kotkay	Kotkay	Male	May 15, 2019
Sharkhunai	Kotkay	Male	May 13, 2019
Kasuna	Kotkay	Male	May 03, 2019

6.10.2. INSTITUTIONAL STAKEHOLDERS

The institutional stakeholders consulted for the Project included relevant government agencies, NGOs and private sector. The list of stakeholders consulted is shown in **Exhibit** .

Exhibit 2: List of Institutional Stakeholder

Stakeholders	Date Consulted
Government and Related	
Forest Department, Upper Dir	April 09, 2019
Livestock Department, Upper Dir	April 11, 2019
Fisheries Department, Upper Dir	April 12, 2019
Veterinary Department, Upper Dir	April 08, 2019
Education Department, Upper Dir	April 10, 2019
Irrigation Department. Upper Dir	April 15, 2019
Wildlife Department, Upper Department	April 09, 2019
District Administration, Upper Department	
NGOS	
Worldwide Fund for Nature- Pakistan (WWF)	May 20, 2019

6.11. CONSULTATIONS MECHANISM

6.11.1. COMMUNITY CONSULTATION

The Potentially Affected Communities (PAC) were visited and consultations were conducted with the community members within their settlements to encourage and facilitate their participation. Representatives, notables and other interested groups from the Potentially Affected Communities were invited.

Photographs of Community Consultations at Weir and Powerhouse Sites

Figure 6-1 Consultation with Powerhouse Site Community

Figure 6-2 Consultation with Powerhouse Site Community

Figure 6-3 Consultation with Weir Site Community

6.11.2. Institutional Stakeholder Consultation

Letters to inform experts/institutional stakeholders about the objective of the consultation process and to arrange meetings with the stakeholders were dispatched in advance. BID and a detailed Institutional Stakeholder Consultation documents were enclosed with the letters for the information of the stakeholders.

For institutional consultation, EMDS organized meetings in Peshawar, and Peshawar for government departments and agencies, academics and NGOs were sent a week before the meeting and these were followed up with phone call to ensure maximum participation. The key agenda items for the meetings with the communities, experts/institutional stakeholders, fishermen and sand miners' communities included:

- An overview of the Project description to the community representatives;
- Description of the EIA process that will be undertaken for the Project and presentation of a structure of the EIA report to facilitate understanding of the report;
- List of the possible environmental and social impacts of the Project.

6.11.3. Consultation Team

An EIA specialist led the team, which comprised of stakeholder consultation experts and social organizer that were familiar with the area and the local languages.

Exhibit 3: Summary of Concerns Expressed in Scoping Consultation

Concerns Expressed by Stakeholders	How they are Addressed
Water Level of Panjkora River and Adjoining Tributaries	
The residents of the villages surveyed were concerned that the tunnel boring activities and construction of a weir would drastically reduce the water level in Panjkora River and its adjoining streams and springs. Panjkora River and its tributaries are the main source of water for the inhabitants of the area and the water is used for drinking and other domestic purposes. A decrease in the water levels of the springs and streams would aggravate the existing water shortage. Additionally, a change in water supply of the streams would affect the livestock of the villages as well as the livestock has specific drinking habits and locations. A change in the drinking habits of the livestock may affect their productivity, and consequently, the livelihood of the locals.	Technical expert explain that small amount of water diverted to tunnel which will not reduce the water availability in the river. Mitigation measures will be taken including monitoring of these springs and ensuring availability of water to communities, in case of an adverse impact due to construction, are described.
A reduction in the water level of the river would also impact its ability to dispose of waste and dilute sewage, resulting in deteriorating water quality.	
Lack of Basic Amenities	
All the communities that were surveyed predominantly highlighted the lack of basic amenities, such as safe drinking water, educational institutes, and hospitals and other medical institutes, etc., available to them. The locals were hopeful that the construction of the Powerhouse and consequent project activities would encourage the government and other private organizations to build roads, water infrastructure, schools, clinics, and other basic amenities in the area. Moreover, the residents also requested that scholarships should be provided to their children to ensure that they receive quality education.	Local prosperity of the area should increase due to direct and indirect employment by the Project However, strategies to improve the general socioeconomic condition outside of Project impacts are beyond the scope of the EIA. Corporate Social Responsibility (CSR) of project will meet some of these recommendations where possible.
The survey respondents also expressed their opinion that	Electricity produced in the

Concerns Expressed by Stakeholders	How they are Addressed
since they are the ones who are cooperating and bearing the full impact of the project construction, the government or the company responsible for the Project should provide them with free electricity.	Project will be supplied to the national grid. The Government has the deciding power as to whom the electricity will be supplied to.
Lack of Employment Opportunities	
Inhabitants of the villages primarily earn their livelihood from fishing, sand collection, and agricultural activities. However, there is a lack of other job opportunities that locals might engage in and earn from. The residents of the areas expect that the Project would generate various employment opportunities that they could benefit from. However, the locals were concerned that people from other cities and surrounding areas would occupy most of the jobs and requested that individuals from villages directly impacted by the Project be employed on a priority. The locals felt that they lack the training and skills required for Project related jobs and suggested that they should be provided with specific trainings to prepare them accordingly.	Hiring of locals will be enhanced as described by measures. The locals felt that they lack the training and skills required for Project related jobs and suggested that they should be provided with specific trainings to prepare them accordingly.
Effect on Environment and Local Health	
The construction of the Project would involve inflow of heavy machinery, vehicles, waste dumping, and blasting and excavation activities. All these activities would result in noise pollution, air pollution and water pollution leading to environmental degradation. The locals expressed their concern regarding the deteriorating quality of the environment and consequent increase in incidence of diseases and impact on health of villagers. Additionally, the increased inflow of traffic would damage the existing infrastructure and lead to road congestion. Another factor that the locals were concerned about was	The mentioned impacts have been carefully assessed. Mitigation measures to make sure that the impacts are within acceptable limits and meet local and international EHS standards are described along with the impact assessment.

Concerns Expressed by Stakeholders	**How they are Addressed**
the negative impact of the dam on the area's natural beauty.	
Security Risk	
The survey respondents were apprehensive that the inflow of outsiders from surrounding cities and towns would pose a threat to the security of the villages as theft and petty crimes might become more frequent. Moreover, the inflow of traffic would make roads unsafe for children who walk to schools and may increase incidence of accidents.	Maintenance of law and order is the responsibility of local government. Project Developer will cooperate with the Government to address any security related issue arising due to its operation. For road safety proper traffic management plan will be developed.
Damage to Households and Village Infrastructure	
Residents were concerned about the impact of cutting, blasting and tunnel excavation activities as they produce strong vibrations that affect the structural soundness of houses and buildings. Villagers also expressed fear of increase in frequency of landslides as tunnel excavation activities would also make surrounding land unstable. Landslides, already a frequent occurrence in the area, restrict the mobility of the villages and also limit their access to necessary resources.	Construction blasting will be consistent with Pakistan and international safety standards. In Environmental Management plan (EMP) will proper describes impacts due to blasting and proposed mitigation measures. Potential land sliding areas due to the project activities have been identified and will be acquired as part of the Project.
Threat to Culture, Privacy and Mobility	
	The Stakeholder Engagement Plan (SEP) will be implemented. It contains a grievance procedure for timely resolution of community complaints. It also contains provision of sufficient resources to the community

Concerns Expressed by Stakeholders	How they are Addressed
	relations officers to enable them to monitor negative perceptions and associated tensions, and to address them in a timely fashion.
Livelihood of Local Community	
The community collects wood and sand from Panjkora River for own use and sale in market. However, the community is concerned that the construction of a dam will block the downstream flow of the river and restrict the supply of driftwood and sand, consequently impacting their livelihood. Moreover, the villagers feared that because their supply of wood from the river will diminish, they will have to turn to cutting trees in the forest to fulfil their domestic needs. The villagers also earn their livelihood from fishing activities and they were concerned reduced water level of the river will impact their earnings.	Sediment mining management guidelines will be prepared and implemented to meet community needs for sand and to avoid damage to river ecology. Environmental flow of the river will be maintained for survival of fish and other aquatic community.
Others	
Villagers do not prefer to resettle in another location. However, if there is no other option, they demand that alternate villages and houses should be built for them.	The Project will meet national as well as international Land Acquisition and Involuntary Resettlement guidelines. The associated Resettlement Action Plan (RAP) will be developed which describes the resettlement related impacts and procedures.
Some residents were apprehensive that locals would colonize the river banks that will dry up due to the construction of the dam. However, in flooding seasons when the dam would release water, these villages would get inundated and there would be loss of lives.	The river will not completely dry-up.
Locals wanted to ensure that the valuation of their land	The associated RAP

Concerns Expressed by Stakeholders	How they are Addressed
would be done on the present value and suggested that costing of different types of trees on their lands should also be included.	describes the resettlement related impacts and procedures.
Residents of different villages were worried that the transmission lines laid down for the Project would pose a threat to the safety of the locals and also negatively affect the scenic beauty of the area.	The development of transmission lines will be under an independent project undertaken by NTDC.

Exhibit 4: Summary of Institution Stakeholder Consultation

Stakeholder	Response
Forest Department	Case for NOC is in process
Agriculture Department	No objection
Livestock Department	No objection
Fisheries Department	No objection
Education Department	No objection
Irrigation Department	Case for NOC is in process
Soil Conservation Department	Case for NOC is in process
Mineral Department	Case for NOC is in process
Wildlife Department	Case for NOC is in process

6.12. FUTURE CONSULTATIONS

The Project management will continue community engagement activities throughout the life of the plant. Visits will be undertaken in all the communities twice or more times in a year, depending on the number of concerns raised under each consultation. Ongoing community engagement activities relevant to the EIA include:

i. Ongoing reporting on progress on the implementation of environmental and social management measures identified during the EIA process and recording of comments on the effectiveness of these measures;

ii. Updating communities about new project developments and recording comments on these; and,

Table 6-1 List of Consultation with Government Department Officials

NAME & DESIGNATION	Name of Institute and Address	Date	Contact Number
Mr. Ihsan ud Din **SDFO**	Forest Department, Upper Dir	April 09, 2019	0346-7474308
Mr. Obaid-ul Rahman **District Director Agriculture**	Agriculture Department, Warai Upper Dir	April 10, 2019	0944-881518 /03028060644

NAME & DESIGNATION	Name of Institute and Address	Date	Contact Number
Mr. Muhammad Pervaiz **Agriculture officer**	Agriculture Department, Warai Upper Dir	April 10, 2019	03009050061
Dr. Mahtab Senior officer	Livestock Department, Upper Dir	April 11, 2019	
Dr. Khalil-ur-Rahman Director Livestock	Livestock Department, Upper Dir	April 11, 2019	
Mr. Wali Khan **Supervisor Fisheries**	Fisheries Department, Upper Dir	April 12, 2019	0301-3903014
Mr. Ajeebullah **ADO**	Education Department, Upper Dir	April 10, 2019	0301-55572821
Mr. Shahid **SDO Irrigation**	Irrigation Department. Upper Dir	April 15, 2019	03458839223

Figure 6-4 District Education Officer Male

Figure 6-5 Meeting with SDFO Forest Warai

Figure 6-6 District Director Agriculture

Figure 6-7 District Director Live Stock

CHAPTER 7: ENVIRONMENTAL MANAGEMENT & MONITORING PLAN

7.1. INTRODUCTION:

Artistic-I Hydropower Project design has incorporated a weir instead of a dam. The topography of the project area, combined with the elevation difference between head pond on and the powerhouse tailrace discharging has made it possible to generate electrical energy which would otherwise have been possible only with a dam about three times the height of the proposed weir. By adjusting project design in terms of reduction in head pond elevation, the inundation area and largely the negative environmental impacts, have been minimized. The environmental and social costs have also been considerably reduced by incorporating cost effective corrective measures in the planning and design of the project components.

7.2. ADOPTED ASSESSMENT PROCEDURE

To assess the environmental impacts of the project in accordance with EPA guidelines, the protocol used for the assessment of impacts is given in table below. The adverse and positive impacts on various parameters were assessed by considering the following environmental impact scaling factors:

1. Magnitude and degree of impact
2. Extent or proportion of the impacts and the area affected by the impact
3. Time or duration and frequency of the impact
4. Probability or likelihood of the impact
5. Importance or sensibility of the impacts
6. Risk or possibility of environmental catastrophe of the impact

Table 7-1 Checklist of Environmental Issues Relating to Hydropower Projects (Based on EPA Guidelines)

Environmental Component	Environmental Issue	Impacts Scaling Factors					
		A	B	C	D	E	F
1. PHYSICAL							
Water	Water Availability	Low	Medium	Project life/seasonal	Low	Significant	Low
	Water Quality	Low	Small	-do-	Low	Small	Insignificant
	Erosion	Very Low	Small	-do-	Insignificant	Insignificant	Nil
	Sedimentation	Medium	Small	-do-	Medium	Insignificant	Nil
	Floods	Medium	Small	-do-	Low	Significant	Low
	Riverbed Morphology	Low	Small	-do-	Low	Insignificant	Nil
Land	Land Submergence	Low	Small	-do-	Low	Insignificant	Nil
	Geology/ Seismology	Low	Large	-do-	Low	Significant	Low
	Land Severance due to Reservoir	Very Low	Small	-do-	Very Low	Insignificant	Nil
Climate	Climate Change	Very Low	Small	-do-	Low	Insignificant	Nil
	Microclimate	Low	Small	-do-	Low	Insignificant	Nil
Atmosphere	Dust	Small	Small	During Project Construction	Low	Insignificant	Nil
	Noise	Low	Small	-do-	Low	Insignificant	Nil
	Air Quality	Low	Small	-do-	Low	Insignificant	Nil

2. HUMAN							
Social	Population	Low	Small	Project Life	Medium	Significant	Nil
	Demography	Insignificant	Very Small	-do-	Very Low	Insignificant	Nil
	Land Ownership	Low	Medium	-do-	Medium	Insignificant	Nil
	Social Cohesion	Low	Small	-do-	Low	Insignificant	Nil
	Social Attitude	Low	Small	-do-	Low	Insignificant	Nil
	Gender and Age	Medium	Small	-do-	Low	Low	Nil
	Health	Low	Small	-do-	Very Low	Insignificant	Nil
	Safety	Low	Small	-do-	Low	Significant	Nil
Economics	Income	High	Medium	-do-	High	Significant	Positive
	Employment	High	Medium	-do-	High	Significant	Positive
	Land Value	High	Medium	-do-	High	Significant	Positive
	Resettlement	Medium	Small	-do-	Medium	Insignificant	Negative
Economics	Livestock	Low	Small	-do-	Low	Low	Nil
	Fisheries	Medium	Small	-do-	Low	Medium	Nil
	Cultivation	Medium	Small	-do-	Low	Low	Nil
	Transport/ Communication	Medium	Small	Short Period	Medium	Medium	Nil
	Recreation	Low	Small	Project Life	Low	Low	Nil
Cultural	Lifestyle	Very small	Nil	Project Duration	Low	Very Low	Nil
	Historical /Archaeological Sites	Very small	Nil	-do-	Low	Insignificant	Nil

	Aesthetics	Small	Very small	-do-	Low	Insignificant	Nil
3. BIOLOGICAL							
Fauna	Wild life communities /Habitat	Small	Small	Project Duration	Low	Insignificant	Nil
	Fish Communities /Habitat	Small	Medium	-do-	Medium	Very low	Negative
							Reservoir
	Reptile Communities/Habitat	Insignificant	Small	-do-	Very Low	Insignificant	Nil
Flora	Forest Trees	Low	Medium	-do-	Low	Insignificant	Nil
	Terrestrial Vegetation	Small	Low	-do-	Low	Insignificant	Nil
	Aquatic Vegetation	Small	Low	Project Duration	Medium	Low	Nil

A. Magnitude and degree of impacts
B. Extent or proportion of the impact and area affected by the impact
C. Time or duration and frequency of the impact
D. Probability or likelihood of the impact
E. Importance or sensibility of the impact
F. Risk or Possibility of environmental catastrophe of the impact

7.3. CONSTRUCTION PHASE

The project Environmental Management Plan (EMP) includes an organizational structure, roles and responsibilities of the various entities, an impact mitigation plan, an environmental monitoring plan, communication and documentation, and environmental training. The Contractor will assume overall responsibility for compliance with environmental and social management requirements of the government of KP and the lenders. The Engineering, Procurement and Construction (EPC) contractor will assume overall responsibility for the environmental performance of all the subcontractors, i.e., it will ensure that they effectively implement all environmental management measures stipulated in the EMP and in the contracts.

The contractor company's project manager will discharge the company's environmental and social responsibility as part of project implementation management. The company will appoint an environmental and social inspector to assist the project manager and provide policy support on all environmental and social matters. The company will coordinate with relevant government departments (e.g., the KP Environmental Protection Agency) and other stakeholders through the environmental and social inspector. Each subcontractor will appoint an environmental and social officer to help its resident engineer to implement the EMP and provisions specific to its contract.

7.4. OPERATIONAL PHASE

Considering the nature of the Project, environmental and social management during the operational phase of the powerhouse will be minimal and routine matter. Management of wastes from residential quarters and offices will be the main task. The management of the powerhouse will induct one environmental and social officer.

7.5. ENVIRONMENTAL MITIGATION PLAN (EMP)

A detailed mitigation plan for the construction phase has been prepared for engineering designing. In essence, the mitigation plan contains:

I. A comprehensive listing of mitigation actions,

II. The persons responsible for ensuring full implementation of the action,

III. The persons responsible for monitoring the action, and

IV. A timescale for the implementation of the action to ensure that the objectives of mitigation are fully met.

The mitigation measures will be translated into environmental requirements and specifications for detailed design and construction, with legally binding effect.

7.6. ENVIRONMENTAL RESOURCES UNDER PROJECT IMPACT

1. The impacts regarding population displacement and land acquisition exist though to a moderate degree and are discussed in this Chapter.
2. There are no historical, cultural monuments shrines, mosques requiring salvaging.
3. Sediment load in terms of watershed erosion/ silt runoff may affect the life of the head pond if allowed at excessive filling rate. The weir design provides a limited control of sediment load by sluicing during flood flows. Sand trap has also been provided ahead of intake of the headrace.
4. The environmental problems due to project construction would require contractor to provide safety of workers against accidents, workers camp sanitation, prevention and control of water-borne diseases, dust, odour, fumes, noise and vibrations resulting from drill-blasting operations.
5. The environmental problems related to the diminution of river flow downstream of the weir at Artistic-I are not significant in terms of the downstream beneficial uses as the Panjkora river is not used for agriculture irrigation or drinking water supply at downstream.
6. Head pond management would be essential to control water pollution, eutrophication, water quality, insect vector disease hazards, and head pond bank stability.

At the end of this chapter a **Table 7-7** has been prepared for Artistic-I Hydropower Project to enumerate environmental issues concerning project location, design, construction, operation including enhancement measures for environmental resources and values.

i. Project Location Impacts

ii. Land Area Requirement

iii. Land for Project Structure

Land area of appropriate size is required for the project structures like the weir, intake for headrace tunnel, sand trap, surface surge chamber, temporary diversion channel and power house. A total of 149.85 acres permanent land will need to be acquired for the project structures and dumpingsites, whereas temporary land of 18.64 acres will be required for labour camps, storage and dumping sites, as discussed in chapter 8 in detail.

Submergence of Land by Headpond

Miner impacts on land would be due to submergence of land under the head pond estimated at 24.78 acres (10.03 hectares).

Construction Corridors

Construction corridors are only temporary parts of the construction phase and required only for related activities. Thus, after finalisation of the construction activity, the areas of construction corridors will be rehabilitated in their original ecological status.

Workers Camp and Storage Areas

During construction phase, areas for residential colonies for professional staff and labour as well as equipment storage sites would be needed. Due to the mountainous character of the region, suitable land areas are rare. Furthermore, area is famous for tourism, thus, the land price is very high. However, it is pointed out that most of the workforce would daily commute between construction sites and nearby villages or towns (Kotkay, etc) considerably reducing the requirement of housing needs at the sites of project construction. The provision of jobs to local people not only save the project cost but also provide the jobs opportunity to the local community. The land required for construction camps and for storage area has been estimated as 19 acres.

7.7. GREEN HOUSE GASES EMISSION

The Project will result in Greenhouse Gas (GHG) emissions. Increases in greenhouse gas concentrations in the atmosphere results in global warming which has adverse impacts including climate change and ocean acidification. However, the Project has far fewer emissions as compared to other power generation methods such as from the combustion of fossil fuels. The project will result in the following sources of GHG emissions mainly due to the embodied GHG emissions from construction materials and due to emissions from project transport. GHG emissions (methane) due to biomass loss and decay due to inundation by Artistic-I HPP's Reservoir will be minor due to the small reservoir and low vegetation density in the area. These will further be reduced by the implementation of a Reservoir Clearing Plan. It is possible that the power generation by the hydropower project will offset more carbon-intensive generation such as that through coal-based thermal power plants. However, due to the complexities in calculating GHG offsets this analysis is not presented in this section. Much of the embodied emissions are contained within concrete production. Artistic-I is a run of the river project, the steel and concrete requirements, estimated from the Bill of Quantities, is presented in **Table 7-2**.

Table 7-2 Embodied Emission from Materials used in Construction

Material	Mass Tonnes	Emission Factor (tonnes of CO_2/ tonnes of material)	Emissions (tonnes of CO_2 e)
Concrete	397,610	0.228	90,655
Steel	29,191	2.89	84,262
Total			**175,017**

Mitigation Measures:

1. Implement a Reservoir Clearing Plan
2. Offsets for emissions from vehicles include:

a. Make sure vehicles are maintained

b. Regular inspection of vehicle exhaust emissions to meet required NEQS standard for exhaust emissions.

7.8. EXCAVATION AND BLASTING

Being in a hilly terrain, the projects will require excavation for alignment of abutments and may likely blasting especially tunnel works, contain underground activities similar to mines. As a result, workers may be exposed to dangers such as collapses, cave-ins, toxic or suffocating gas emissions, gas explosions, dust explosions, component falls, and floods. In addition, hiding, storing, transporting and exploiting explosives such as dynamite, which are used in work such as rock blasting and tunnelling, potentially dangerous. Big bursts are inevitable in the unauthorized storage and usage processes.

Such physical work has the propensity to alter the landscape, due to cutting of trees and/or levelling mounds and hills, and also create dust pollution. Moreover, use of dynamite also poses risks to the safety of the workers as well as general public as a whole.

Any excavation work during the construction activities, whether permanent or temporary, may lead to loss of soil. Erosion of soil can also occur from removal of vegetation cover, runoff from unprotected excavated areas, etc. Excavations on slopes would also decrease its stability. It is expected that minor level of short-term risk is associated with the type of construction activities that are likely to take place. The current land formation is fairly stable therefore no major impact is associated with regards to slope stability. The duration of the risk is expected to be short and the spatial scale of risk is small because the excavation effects are not likely to affect areas further than 200 meters from the project facilities.

Mitigation Measures

The best place for disposal of excavated material seems to be both right and left bank of Panjkora River from where top soil has been washed out as a result of successive seasonal floods and particularly severe flood of 2010. This material will cover boulders and gravels up to some extent and help in restoration of the affected lands.

Vegetation loss will be avoided as much as possible and limited to demarcated construction area. Slope stabilization measures will be adopted such as adequate vertical and horizontal drains, cross drainage etc. Slope movements will be monitored around excavation work areas. Top six inches' soil should be protected before excavation and should be placed back after completion of construction work.

It is very important to plan before starting work in order to avoid trench cave-ins. In addition, to reduce the possibility of accidents, it is necessary to take proper precautions according to the soil type, to build suitable ramps for safe access to the excavation site, to carry out the inspections of excavation work machines and to work with competent drivers and operators. Blasting may be done where it is absolutely necessary, use safety measures in handling explosives, prepare blasting schedules along with warning sirens, and ensure minimum damage to the landscape.

In compliance to the GoP guideline, the Contractor will be strictly advised for controlled blasting like use of explosives for relatively hard rock in order to shatter and break the rock.

These blasting activities are for a short time period and anticipated temporary impacts are disturbing the ambient air level in particular the emissions of NO2, CO, and NO are generated during the explosions. However; the Contractor will be strictly advised to implement the following pollution prevention and control techniques:

- Alternatives to blasting, such as hydraulic hammers or other mechanical methods will be preferred wherever applicable;
- The correct burning of the explosive,
- A consistent blasting schedule by Contractor, minimizing blast-time changes; specific warning to alert all workers and third parties in the surrounding areas (e.g. local communities).
- Trained personnel shall be handling explosives and safety management has been considered;

- Blasting-permit procedures shall be followed; and,
- Blasting sites should be checked post-blast by qualified personnel of Contractor for malfunctions and unexploded blasting agents, prior to resumption of work.

Controlled Blasting Mechanism

Controlled blasting methods will be used to control blast induced effects in tunnel such as, over-break, fractures within remaining rock walls and ground vibrations etc.

Adopting various techniques of controlled blasting such as line drilling, trim (cushion) blasting, smooth (contour or perimeter) blasting, pre-splitting etc,; selecting and employing various parameters of blast design; using modern technology such as precise timing delays, varied density of explosives product by using bulk explosives; muffle blasting at a very critical and congested areas normally employed for mitigation of adverse impact of blasting.

The drilled holes in control blasting usually have a tighter spacing than production holes, are lightly loaded and are fired simultaneously before the production holes.

Drilling and blasting currently utilizes many different varieties of explosives with different compositions and performance properties. Higher velocity explosives are used for relatively hard rock in order to shatter and break the rock, while low velocity explosives are used in soft rocks to generate more gas pressure and a greater heaving effect.

As the name suggests, drilling and blasting works as follows:

- A number of holes are drilled into the rock, which are then filled with explosives.
- Detonating the explosive causes the rock to collapse.
- Rubble is removed and the new tunnel surface is reinforced.
- Repeating these steps until desired excavation is complete.

The positions and depths of the holes (and the amount of explosive each hole receives) are determined by a carefully constructed pattern, which, together with the correct timing of the individual explosions, will guarantee that the tunnel will have an approximately required cross-section.

During operation, blasting mats may be used to contain the blast, suppress dust and noise, for fly rock prevention.

As a tunnel or excavation progresses the roof and side walls need to be supported to stop the rock falling into the excavation. The philosophy and methods for rock support vary widely but typical rock support systems will include:

- Rock bolts or rock dowels
- Shotcrete
- Ribs or mining arches and lagging
- Cable bolts
- In-situ concrete

Typically, a rock support system would include a number of these support methods, each intended to undertake a specific role in the rock support such as the combination of rock bolting and shotcrete.

7.9. MUCK MATERIAL

Excavation work including drill-blasting will result in muck material. This will be used as fill material, as far as possible, for structure of weir, powerhouse and the stabilization of the head pond banks, embankment of access roads, coffer dams and for terracing of hill slopes. However, if there is any surplus amount left after aforementioned activities then it will be disposed of properly by following the standard protocols.

Table 7-3 Details of Dumping Sites Capacity Allocated for Excavated Material

S.No	ID	Dumping Site Location	Area (acres)	Total Muck Material m^3 (Approx.)
1	D1	Weir Site	7.65	232219
2	D2	Box channel and Sandtrap	12.73	386435
3	D3	Headrace Tunnel Inlet	8.35	253313
4	D4-a	Adit Tunnel	7.83	237530
5	D4-b	Adit Tunnel	8.00	242842
6	D5-a	Cut and Cover Conduit	5.22	158495
7	D5-b	Cut and Cover Conduit	2.15	65225
8	D6	Powerhouse Site	5.84	177313
Total			**57.77**	**1,753,372**

Table 7-4 Details of Muck Material Produced during Construction Phase

S.No	Structure	Excavated Material (m3)	Back fill (m3)	Total Muck Material (m3)	Dumping Site
1	Diversion Works	101,554	13,190	88,364	**D1**
2	Weir	86,770.24	24,972	61,798	**D1**
3	Fish Ladder	820	-	820	**D1**
4	Intake	49,761	17,037	32,724	**D1**
5	Sandtrap	323,450	23,223	300,227	**D2**
6	Box Channel	187,871	39,000	148,871	**D1, D2**
7	Free Flow Tunnel	103,192	-	103,192	**D1, D2**
8	Inlet Pond	109,124	22,176	86,948	**D3**
9	Power Tunnel	441,843	-	441,843	**D3, D4-a, D5-a, D5-b, D6**

S.No	Structure	Excavated Material (m3)	Back fill (m3)	Total Muck Material (m3)	Dumping Site
11	Surge Shaft	30,120	-	30,120	**D6**
12	Valve Chamber	62,724	-	62,724	**D6**
13	Penstock	4,374	-	4,374	**D6**
14	Powerhouse and Tailrace	56,555	7,886	48,669	**D6**
15	Access Roads and Bridges	136,710	18,500	118,210	**D1, D4-a, D4-b, D5-a, D5-b, D6**
	Total			**1,528,885**	

7.10. SANITARY WASTEWATERS

In order to manage sanitary wastewater from the construction camps, a system of sewers would be laid, leading to on-site wastewater treatment and disposal. This would be essential to prevent pollution of Panjkora River.

7.11. SOLID WASTE MANAGEMENT PLAN

Background

Artistic Hydro I is going to establish a hydropower project on Panjkora River, District Upper Dir. The current camp accommodations will be located near water reservoirs. Around 300 labours will be resident of the labour camp during the construction phase of project. The aim of this plan will be the safe disposal of solid waste that will be produced in the camp. This waste management plan incorporates the basic principles of waste management, source reduction, reuse, recycle/recover, treatment and disposal. Artistic Hydro I is committed to conducting operations within the accepted environmental standards of KP-EPA. These methods are important in reducing the environmental footprint of operations.

- Source reduction is the elimination or decrease of the volume or toxicity of waste by adopting practical methods such as using alternative materials or processes. This can be achieved by material elimination, inventory control and management, material substitution, process modification and improved housekeeping, maintenance and training.

- Reuse is achieved by using a product more than once for the same application or for different purposes.
- Recycling of products that typically have one use is an excellent method of reducing the volume of waste generated at a worksite. Sorting the products, so that they can be managed in bulk, eliminates the need for additional handling and allows for different products to be managed by efficient recycling processes.
- Waste treatment is used to reduce the volume, mass and/or toxicity of the material prior to disposal due to contaminants contained within the waste. There are a number of treatment options including thermal, chemical, biological and physical processing which may be used separately or combined to be the most effective and efficient.
- Disposal of waste is the final option for waste management. When disposing of waste, the type of waste, volume, location and final containment must be considered. The waste disposal options available to the municipal solid waste generated in the camp include composting, control dumping and use as protective material from harsh environment.

Purpose of the Plan

This Camp Construction Waste Management Plan (WMP) will detail how waste generated will be safely managed. The management of camp wastes are stringently regulated and require planning and implementation of those plans to handle waste in a complaint manner. The ultimate goal of waste management is to safely manage waste streams in at the source of generation and disposed of in an environmentally friendly way.

This Waste Management Plan will cover

- Waste types including characterization of waste and waste management methods
- Segregation at the spot of generation
- Reduce, reuse and recycle the waste as much as possible.
- Appropriate Disposal of Solid Waste

Solid Waste Generation at Construction Camp:

The total number of labours that will work on the camp site will be around 300 during the construction phase. The amount of total waste generated will be shown in **Table 7-5**. According to various research findings, the average waste generation in the developing countries is around 0.4-0.8 kg/capita/day. At the construction site generated solid waste may consist of biodegradable waste (food waste and wood debris), plastic (PET bottles and PE bags), paper (newspaper and white papers), cardboard, cans of drinks and so on.

Table 7-5 Solid Waste Generation at Camp Site

S. No	Labours	Per capita/day	Per day Solid Waste (kg)	Per Month (kg)	Per Year (kg)
1	300	0.4	120	3600	43,200
2	300	0.8	240	7200	86,400

Solid Waste Collection:

Solid waste collection will be carried out at the camp site. Dustbin will be installed on the camp site. Dustbins with different colours i.e. blue, grey and green will be installed for different types of waste such as recyclable, non-recyclable and biodegradable waste. On spot segregation will be carried out to avoid the mixing of solid waste. Workers will be aware about the different types of dustbins that which waste will be dumped in which colour of bin. Furthermore, throughout the whole camp various types of banners and poster will be hanged to aware the workers regarding the proper solid waste management.

Figure 7-1 Various Colours of Dustbins for different types of Waste

Waste Disposal:

Solid waste disposal will be the last option that will be used for the solid waste management at the camp site. Reduce, reuse, recycle and recover universal phenomena should be adopted at the camp site. To manage the biodegradable waste compost pits will be established at the camp site. As major portion of generated solid waste at camp will be consist of biodegradable waste thus a number of compost pits (around 10) will be constructed at the camp site. The size of the compost will be 5 m3 for each compost. According to recent study in Peshawar around

21% of produced solid waste consists of biodegradable. So, by following the outcomes of the present study around 630 kg biodegradable waste will be generated in the camp. The produced compost will be used as a fertilizer for the plantation which will be carried out in the surroundings of the camp. However combustible waste such as wood, grasses, debris and so on will be segregate from the wood waste and will be used as source of fuel wood. The compost pit will be concreted to avoid the chances of ground water contamination.

Figure 7-2 Compost Pit for conversion of Biodegradable waste into Compost

Plastic waste generated at the camp site most probably consist of pet bottles and PE bags. However, government of KP is going to imposed ban on the use of PE bags from December, 2019 onward. So, the generation of PE bags at camp site will be zero. Regardless of that if PE bags are produced at the camp site even though due to strict policies of KP-EPA only biodegradable PE will be available in KP. These biodegradable PE can be degraded through natural process. Thus, a separate pit will be constructed to dump these PE bags. PET bottles will be reuse for several purposes such as for drinking water, as holder for electric bulb to avoid from rain water and so on. Furthermore, it can be used for plantation of flowers and other ornamental plants.

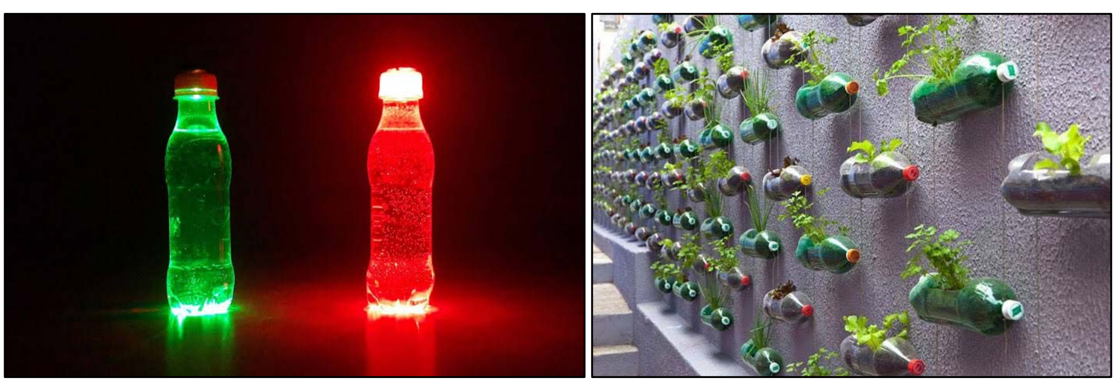


Figure 7-3 Use of Plastic Bottles for Plantation and for Electric Bulb

Combustible waste which may contain papers, cardboard and so on will be used for several purposes. Cardboard can be used for ceiling of labours' camp as the winter is very harsh and prolonged in the project area. It will help to get some relief for the workers from the harsh environment. However, it can be used as a source of fuel via incineration or it can be used as bulky materials for the compost, which will enhance the quality of produced compost.

7.12. NOISE AND POLLUTION DUE TO VEHICLES EXHAUST

Noise, gaseous emission and dusty atmosphere will result from movement of heavy vehicles for transportation of equipment and construction materials. Similar effects would be caused by drill-blasting for the tunnel, pressure shaft and caverns. The contractor would be required to control noise and exhaust pollution by construction management techniques which are sensitive to these effects.

7.13. IMPACTS ON PHYSICAL ENVIRONMENT

7.13.1. WATER QUALITY

It is expected that river water quality will deteriorate during construction phase. This will mainly be due to the increase of suspended solids, turbidity and waste. This change in water quality will be temporary and over a short distance of the reach which, will not be significant because the reach is neither used for agricultural irrigation nor for drinking water supply. During operation phase, river water quality will undergo cyclical changes due to restricted flow.

7.14. BIOLOGICAL ENVIRONMENT

Impacts on biological environment of the project area with respect to forest, wildlife, fishery and protected areas/reserves are discussed in the following sections.

7.14.1. FORESTS

Forests in the project region occur only in the upper valley areas. Thus, these forests remain unaffected by the project construction and operation.

7.14.2. PLANTATION PLAN

In order to compensate the trees to be cut in project implementation, a plantation plan is prepared with the consultation of Upper Dir Forest Division which is given below.

Loss of Fruit Trees

During the implementation of the project, no fruit trees will be affected by the project.

Loss of Non-Fruit or Farm Trees

As provided in the below table, during the implementation of the project 210 non-fruit/farm trees will be affected by the project and will be compensated.

Table 7-6 Loss of Non-Fruit or Farm Trees

Trees	Small	Medium	Large	Total
Bakine	55	-	20	**75**
Wild Anar	-	-	7	7
Ailynthus	30	-	27	57
Mulberry	-	-	17	17
Eucalyptus	4	-	9	13
Robinia	17	13	11	41
Total	**106**	**13**	**91**	**210**

The valuation of compensation for trees is based on their market values. For wood trees, unit prices are obtained from Forest Departments, who assess the prices every year based on market rates. The cost of the non-fruit or Farm trees along with unit rates adopted are calculated at the village level considering the types and volume measurements in case of forest trees.

7.14.3. Free Distribution Plan

A total of 350 fast growing tree species will be distributed among the local community for planting on their farm land and woodlots.

7.14.4. Wildlife

The wildlife will be affected to the extent that project requirements of land for construction of roads, building structures, construction corridors and dumping of excavated material will have to be met. Occupation of land for project implementation will result in loss of habitats for flora and fauna in head pond area like trees, insects and so on, which do not include any endangered species; thus establishment of wildlife protection area is not needed as a mitigation measure because wildlife of the area will move to safer places during submergence. Roads built for the project may provide entrance to sensitive and unspoilt regions. This will lead to disturbance of wildlife by human activities. Finally, heavy vehicular traffic for transportation of men and material, as well as blasting and construction noise will drive out animals from their habitats, though, for a temporary and short period.

7.14.5. FISHERY

Panjkora River in the project area does not support fishery on a commercial scale nor there any anglers' activity at any time in the area. This is confirmed by the representative from fishery department during meeting. Therefore, the impacts of construction and operation activities on fishery would be insignificant. However, the head pond holds a considerable fishery potential after the construction of the Project. With appropriate management of this potential, head pond fishery development during operation phase will substantially enhance the beneficial impact of the project on the local population.

7.15. IMPACTS ON SOCIO-ECONOMIC ENVIRONMENT

The impacts during construction and operation of the project on socio-economic environment relate to land acquisition, houses, economic trees, culture, infrastructure, women and indigenous groups in the project area.

7.15.1. LOSS OF HOUSES AND POPULATION DISPLACEMENT

No houses will be taken over to construct the powerhouse on the right bank of Panjkora River while 3 houses on the weir side of the project will be taken over. These houses are occupied by 26 persons who constitute the population which is subject to displacement. Furthermore, there is no impact on commercial assets.

7.15.2. INFRASTRUCTURE

There is no infrastructure like roads, village tracks, telephone/ transmission lines which will be subject to inundation by the project head pond.

7.15.3. ECONOMY

Project implementation in terms of construction and operation will create employment opportunities which will help mitigate local opposition. This will also stimulate local economy. This will reduce population emigration and help find work for local unskilled workers. Also, local market will benefit from increase in demand for consumer goods. Increased income in the project area will encourage the formation and growth of local businesses resulting in new indirect employment opportunities.

7.15.4. CULTURE

Historical and cultural sites in the form of mosques, shrines, graveyards or of archaeological significance will not be affected as the same do not exist at the sites of the project components or the head pond area.

7.15.5. Women in Project Area and Indigenous People

During the construction phase an inflow of outside workers will disturb the local socio-cultural life of the project area. As a result, women could be restricted by a stricter application of pardah. There are no other vulnerable groups, nor any indigenous people in the project area.

7.16. OPERATION PHASE

7.16.1. Reduced Worker Numbers

With the completion of project construction work, the area will see an exit of most of the workers, and any associated negative impacts will fade (just permanent project staff will remain). At the same time, the business opportunities (including local employment) that will have been associated with the pre-construction and construction phases will come to an end. This may be experienced as a negative economic shock, since there are not any obvious plans for other large infrastructure development projects in the Artistic-I area to maintain a high level of economic activity in the immediate area.

7.16.2. Maintenance of Minimum Environmental Flow

There are no glacial lakes in the catchment and therefore the project area is free from the risk of Glacial Lake Outburst Flood (GLOF). The catchment is supplied with snow-melt water and rainfall, most of which is channelled through many smaller tributaries that join the Panjkora River. The main feature of the physical environment that the project is dependent on and which the project is likely to impact especially during operation is the hydrology of the Panjkora River at downstream of the dam which in turn may impact the aquatic ecosystem. So, overcome this issue a brief study will be accrued out for the river flow throughout the year. On the basis of aforementioned study, a measurable water flow will be assured even during the dry season which will fulfil the requirement of aquatic life in the project area.

7.16.3. Occasional Sediment Purging

Accumulated sediments in the desilting chambers will have to be evacuated from time to time, depending on the sedimentation rate in the Panjkora River. Purging of the desilting chambers may result in occasional turbidity pulses in downstream parts of the river, depending on how this process is undertaken; however, this will be a very transient effect. This can be mitigated by undertaking sediment purging during the monsoon, when turbidity in the river is at a maximum, in any case. It is expected that temporary degradation of aquatic habitat and any disturbance of fish will be minimal, if undertaken at a time when the river has high suspended sediment loads (June-September). These additional sediments will be flushed quickly, into the project area and then further downstream.

7.16.4. Maintaining Cleared Right-of-Way for Transmission Line

Regular clearing of the vegetation within the right-of-way, especially near the tower foundations, will maintain stunted vegetation and reduce the quality of wildlife habitat; however, areas between the tower foundations can be allowed to grow to a height of about two meters, which will provide cover for most wildlife that need to move through the right-of-way. Negative visual aesthetics of the transmission line will persist, with regular clearing of the right-of-way; nevertheless, the alignment will remain “green”, just with lower elevation vegetation, or cultivated crops.

Table 7-7 Environmental Management Plan

Environmental Aspect & potential Impact	Remedial Measures	Approximate Location	Means of Implementation	Institutional Responsibility	
				Implementation	Supervision
Design/Pre-construction Components					
Site Selection	Minimize loss of natural flora -Compensation should be paid for crop -Replanting of plants	- Weir site -Reservoir area -Powerhouse -Colony area	Proper planning in consultation with DFO and Agriculture officer should be done and compensation budget should be allocated accordingly.	Forest & Agriculture Dept/ Client	Forest & Agriculture Dept/ Client
Geotechnical and Geophysical Studies	-Compensation of land -Minimize loss flora -Replanting	- Weir site -tunnelling sites -powerhouse	Proper planning in consultation with DFO and Agriculture officer should be done	Consultant	Forest & Agriculture Dept/ Client
Construction stage					
Permanent and Temporary Land Loss	- All the land required for different project components is community owned barren land which would be provided voluntarily; no land base infrastructure will be affected during construction as well as operational	- Weir site -Reservoir area -Powerhouse -Colony area	Proper planning. Measures to be added in relevant parts of contract documents. Payments to the affectees will be made	Contractor	Consultants will supervise the construction work whereas PEDO may monitor the ongoing activities

	phases of the project. The permanent land for project components such as weir, powerhouse, offices, etc. as well as temporary land will be taken on lease if required. The amount of lease is part of project civil cost and is not added in Environmental Management Cost. -Design for maximum use of excavated material at various stages of the construction process, - Payment of compensation at market rates for land required by the project prior to work commencement including other assets.		by the proponent of the project.		
Labour Camp	- The camp site will be established near the project site and at least 500 m away from local population with prior approval of Resident Engineer (RE). The camp will have proper dormitory and toilets with proper sanitation system. The contractor should build septic tanks for	- Weir site -powerhouse site -tunnel site	Proper planning and measures to be added in the relevant parts of contract documents.	Contractor	Consultants

	environment friendly discharge of the sewage effluent. The contractor will be bound to comply with rules and procedures defined for this respect and from time to time with the emerging situation with the approval of the Resident Engineer as described in the tender documents.				
Generation of Waste	-Activities at the camp need to be conducted in a manner to ensure that waste generation of any kind may be restricted to a minimum level by managing efficiently and properly. Solid waste collection points should be established in the Labour camps. A system of collection, storage and transportation should be in place to transfer the solid wastes to a temporary waste site. The solid wastes so deposited in the land fill should be covered with earth after each filling. -The best possible way to handle the	-Labour camp -Weir site -powerhouse site -tunnel site	Proper planning and measures to be added in the relevant parts of contract documents	contractor	Client

	waste is to keep waste to its lowest possible level at site. For this the contractor will arrange environmental awareness /education sessions with the workers for reducing waste at site. -The Contactor will also outline guidelines for waste management by involving them for keeping their waste minimum at source during work to avoid any environmental threat. -All workers involved in the use of such materials will receive proper training to manage them and shall use protection equipment such as gloves, masks, uniforms, etc for safety purposes. -All danger sites will be communicated properly with tailor-made sign boards depicting like dangerous etc. both in English and in Urdu languages. In designing such boards standard communication principles and guidelines will be				

	followed for workers and public safety. In machinery maintenance activities cover the soil under the machinery with plastic sheet to collect any spell. --Avoid any spills of oils or fuels to the soil or river. If the soil is contaminated, it shall be immediately removed and treated in the main camp. -Used oil will be stored in sealable drums and should not be mixed with other substances such as petrol and other solvents. Used oils may be returned to the appropriate agencies for disposal and further usage if any.				
Borrow Area	-No private land will be acquired for the borrow areas. -The Contractor will ensure that selected borrow areas are clearly demarcated and approved by the engineer including the allowed depth of the excavation before starting	-Borrow area site	Proper planning. Measures to be added in relevant parts of contract documents. Payments to the affectees will be made by the proponent of the	Contractor	Client

	excavation. -The borrow areas will be levelled. The Contractor will not leave the borrow pits in such a condition that they are unsuitably filled with rain water and cause the problem for the community. -If the borrow area is near to the settlements, then it should be fenced completely. If agriculture land needs to be used as borrowing area, then the Contractor will adopt the following methods during the digging process. • Fix the location of excavation. • Remove thirty centimetres of the top soil and keep it on reserved site for re-spreading in the field. • Excavate up to one-meter depth. • Maintain the slope as far as possible. • Place the top soil back during the restoration process.		project.		

	• Pay compensation for any damages/ crop losses. Following the above criteria, after identification and approval by the Engineers, the Contractor will mark borrow areas location.				
Water Pollution	-Appropriate control measures will be taken to avoid degradation of water quality. -The presence, storage and use of chemicals and fuels near river can result in localized contamination and decrease in water quality. Improper disposal of oil contaminated materials from vehicles and machinery can cause pollution. -Proper sanitation and waste disposal procedures will help to reduce the contamination of water resources. Every effort will be made by the contractor to prevent such pollution wherever, possible and minimize these effects.	-Labour camp -Weir site -powerhouse site -tunnel site	Proper planning. Measures to be added in relevant parts of contract documents.	Contractor	Client/EPA

	-All residual waters from domestic uses in the camps will be treated in septic tanks, conveniently dimensioned in accordance with the number of workers involved in the project, before releasing to the surrounding environment.				
Air Pollution	-Techniques to consider for the reduction and control of air emissions from construction and commissioning sites include the daily use of water-browsers, near colony areas to wet dirt roads, in order to keep the emission of dust minimum level. Minimizing dust from open area sources, including storage piles, by using control measures such as installing enclosures and covers, and increasing the moisture content. -Contractor's contractual obligation to keep the dust and smoke low by using machinery which is well maintained and is almost noise less	-Labour camp -Weir site -powerhouse site -tunnel site	Measures to be added in relevant parts of contract documents.	Contractor	Client/ EPA

	and all Katcha roads and paths are sprinkled with water after regular intervals. -The contractor must avoid/ control the dust and smoke by carefully storing and distributing the construction material so as to cause minimum dust. During transportation, covering of vehicle with sheet will be done. Unloading of vehicles will be done on designated sites.				
Noise and vibrations	-Noise level would be localized and can be prevented by taking preventive measures like use of mufflers and silencers. -The workers operating machinery and vehicles must be conscious of speed limits. Avoid unnecessary horns. It is necessary to take necessary measure to generate unnecessary noise. -Contractor’s contractual obligation to use new, well maintained and low	-Weir site -powerhouse site -tunnel site - near sensitive receptors	Measures to be added in relevant parts of contract documents.	Contractor	Client / EPA

	noise machinery preferably during day time. The drivers, operators and workers working on or near the heavy machinery must be provided ear plugs. -The contractor will ensure use of newer, well maintained machinery that creates minimum noise and emissions, as per National Environmental Quality Standards (NEQS 2000). Environment Specialist will ensure that this clause is added into the bids and contracts. Night time construction activities will be strictly discouraged, and only be carried out in exceptional cases, with prior permission of Resident Engineer. Noise monitoring will be carried out near sensitive receptors on a monthly basis. The NEQS for noise residential areas is 55 dB (A) in the day time and 45 dB (A) at night. It is recommended that noise levels close to sensitive				

	receptors do not exceed 55 dB (A) during the day time as required by the NEQS.				
Traffic Accidents	-Warning signboards should be displayed properly at appropriate locations during construction period to avoid accidents.	-Weir site -powerhouse site -tunnel site	Careful monitoring and maintenance of accident incident register	Contractor	Consultants/ Client
Safety of workers and local community	-Social cohesion and brotherhood campaigns shall be launched within the workers and in communities for better relationship and to avoid conflicts. -Worker shall be asked to care and protect the local traditions and ethics. -The contractor will ensure that proper HSE protocols are in place, including protective gear, drinking water, sanitation, energy supply and overall safety for the labour. Evacuation plans in case of fire or any other accidents will also be prepared, and drills carried out to	-Labour camp -Weir site -powerhouse site -tunnel site	Careful monitoring and maintenance of accident incident register	Contractor	Consultants/ Client

	ensure the labour is aware of responding to such a situation.				
Ecological Impacts					
Loss of Habitat	-Land used temporally should be restored to its original condition. -All structure erected by the contractor will be dismantled and removed. -Any rubble generated from the dismantling of campsite will be dumped at an approved disposal site. Once the area has been cleared of all materials, the ground will be prepared for rehabilitation. The area shall then	-Weir site -powerhouse site -tunnel site	Careful monitoring and mitigation measures should be added in contract document	contractor	Client/ EPA

	be left to rehabilitate through the process of natural succession. -Systematic search, capture and safe release of species inhabiting the right of way (for the weir structure). -The contractor is liable to comply with all relevant laws and regulations in Pakistan and KPK concerning water pollution, sanitation, and wastewater discharge and solid waste disposal as defined in tender documents.				
Tree cutting and Agricultural land damage	-The NoC will be issued by the government in the light of explaining actual position of the trees to be cut and preparing estimates by the Upper Dir forest division. Payments will be paid by the proponent as prescribe by the forest department according to their related policy. The policy of the forest department will be followed which has already been worked out for the nearest ongoing HPP i.e. Koto	-Weir site -powerhouse site -tunnel site -downstream agricultural land	Compensation and plantation	contractor	Client/ forest and agriculture departments

	HPP. -The agricultural crops sown in the area are generally maize, potato and vegetables for which agriculture department of the area will be requested to prepare estimates for compensation. -During scoping visits the site was visited for calculating approximate number of trees which are expected to be affected. They are roughly 210 in number. It is expected that living and working areas will be established at places which are free of forest trees.				
Earth Works for construction of weir, box channel, tunnel, penstock and Power house causing loss of land and trees.	- Maximize re-use of material in different construction phases and to avoid or reduce the need to find distance areas for the deposition of excavated materials. - Farm trees will be planted on appropriate places to replace the existing trees.	-Weir site -powerhouse site -tunnel site	Proper planning and Careful monitoring	Contractor	Consultants/ Client

	Plantation through free distribution of fast-growing tree species in spring and monsoon - The best place for disposal of excavated material seems to be both right and left bank of Panjkora river from where top soil has been washed out as a result of severe flood of 2010. This material will cover boulders and gravels upto some extent and help in restoration of the affected lands. -Vegetation loss will be avoided as much as possible and limited to demarcated construction area. - Slope stabilization measures will be adopted such as adequate vertical and horizontal drains, cross drainage etc. -Slope movements will be monitored around excavation work areas. -Top six inches soil should be protected before excavation and				

	should be placed back after completion of construction work. -It is very important to plan before starting work in order to avoid trench cave-ins. In addition, to reduce the possibility of accidents, it is necessary to take proper precautions according to the soil type, to build suitable ramps for safe access to the excavation site, to carry out the inspections of excavation work machines and to work with competent drivers and operators. Blasting may be done where it is absolutely necessary, use safety measures in handling explosives, prepare blasting schedules along with warning sirens, and ensure minimum damage to the landscape. -In compliance to the IFC standards, the Contractor will be strictly advised for controlled blasting like use of explosives for relatively hard rock in				

	order to shatter and break the rock. • Alternatives to blasting, such as hydraulic hammers or other mechanical methods will be preferred wherever applicable; • The correct burning of the explosive, • A consistent blasting schedule by Contractor, minimizing blast-time changes; specific warning to alert all workers and third parties in the surrounding areas (e.g. local communities). • Trained personnel shall be handling explosives and safety management has been considered; • Blasting-permit procedures shall be followed; and, • Blasting sites should be checked post-blast by qualified personnel of Contractor for malfunctions and				

	unexploded blasting agents, prior to resumption of work.				
Soil erosion and land sliding	-Good engineering design will protect erosion and land sliding in the project area. -Effective mitigation measures and sound environmental management practices will be specified in the contracts to ensure minimum soil erosion and land sliding.	-Weir site -powerhouse site -tunnel site	Proper planning, implementation & monitoring	Contractor	Consultants/ Client
Water Turbidity	-Monitor water flow during construction and maintain the minimum ecological requirement for all rivers to ensure water is available downstream all the time. -Maintain the desired hydrological connectivity in the system (upstream-downstream and maintain low water temperature necessary for survival of the moderately flow-sensitive species found at this site; -Ensure riverine protection through observing the 6-30m away from the		Proper planning and designing and Careful monitoring	contractor	Consultant Client/ EPA

	river banks and planting of indigenous riparian trees to reduce sedimentation. -Provide compensation and sediment channels in the weir as well as physical removal of sediment.				
Aquatic life	-For avoiding any disturbance and threat to the fish population, construction of proper fish ladder will have to be considered on priority basis while developing detailed design. -Minimize activities to areas of construction and initiate habitat restoration immediately after construction works are through; and -Restore disturbed areas to near-to-nature to blend with the immediate environment. -It is proposed that fish seeding should be introduced. Fish breeding and commercial exploitation should be monitored regularly. Similarly,	Weir site -powerhouse site -tunnel site -downstream river	Proper planning and monitoring	contractor	Consultant/client and fisheries department

	protection will be provided at the intake tunnel.				
Social Impacts					
Public safety	• prevention of site • public access to resources • protection from injuries and diseases • control of dust fume and noise and • increase in road hazards	-Weir site -powerhouse site -tunnel site -labour camp	Awareness and monitoring	contractor	Consultants/ Client
Impact on civic infrastructure	-Contractor's contractual obligations to impose strict control over operators and drivers of all types of vehicles/machinery. Awareness may be given to them. The position of infrastructure and underground installation should be precisely located to avoid any damage. -Should the damage take place, the contractor must be bound to carry out repair immediately. - Ensure existing road access is maintained & provide bridge access	Weir site/connecting roads	Proper planning, implementation & monitoring	Contractor	Consultants/ Client

	across the river at appropriate place.				
Employment of labour	-The project should incorporate and maximize the use of local labour force. Despite the low level of formal education, there are several activities within the project for non-qualified labour. There may also exist, locally, semi-qualified labour force, such as carpenters, drivers, bricklayers, masons etc would get the employment opportunity.	-Weir site -powerhouse site -tunnel site -labour camp	Careful monitoring and mitigation measures should be added in contract document	Contractor	Consultants/ Client
Night time security	Provision of appropriate light system	Weir site -Powerhouse site -Tunnel site - Colony area	Contract documents	Contractor	Consultants/ Client
Operational Stage Impacts					
Powerhouse peaking and Noise	-Careful peaking (water) is needed -Well maintained machinery	-Powerhouse site/area	Proper monitoring and planning, implementation	Client	Client/EPA
Switchyard	-Compensation	-Powerhouse	Proper Planning and	Client	Client

	-Rehabilitation	site	implementation		
Transmission Line impacts on land, crop and tree damage	-Compensation -Rehabilitation	-Transmission line alignment area	Careful design and planning by Client & Design consultants.	Consultant	Client
Weir operations Natural Hazards and Damage to flora and fauna	-Flood warning system -Systematic rescue and capture - Environmental flow release	-Between weir and powerhouse	Careful design and planning by Client & Design consultants	Client	Client/EPA
Loss of jobs for temporary workers	Jobs alternatives opportunities	Project area	Promote eco-tourism in the area	Local government	Local government
Occasional Sediment Purging	Sediment purging during the monsoon Environmental flow release	Desilting chambers	Sediment purging during the monsoon	Client	Client/PEDO

7.17. OCCUPATIONAL HEALTH AND SAFETY

Occupational Health and Safety covers all personnel working under the project and will be in line with the General Rules and Regulations on Occupational Health and Safety (OHS) in Construction, Manufacturing and Mining and Service Industries, 2006 (RGOB). They will also be consistent with World Bank EHS guidelines on health and safety. The Occupational Health and Safety program will aim to ensure that the workplace is safe and healthy by: addressing the hazards and risks at the workplace; outlining the procedures and responsibilities for preventing, eliminating and minimizing the effects of those hazards and risks; identifying the emergency management plans for the workplace or workplaces; and, specifying how consultation, training and information are to be provided to employees at various workplaces. Some of the risks/hazards associated with workplaces are due to working close to or at blasting sites associated with the various project construction activities. Other risks associated with the project construction phase include risk of increase of vector borne and other different diseases. The following sections will be implemented during the construction phase to address and ensure workers’ health and safety.

Screening and regular unannounced checking of workers.

As per the procedure for hiring foreign workers, all contractors and labour agencies are required to make all prospective workers undergo medical tests to screen for diseases and sicknesses, prior to selection and employment of any foreign worker. It will be ensured that all workers undergo medical tests to screen diseases at source and at sites. In addition to this, the Project Management will also undertake sudden, unannounced checks on workers to look for diseases such as HIV, STDs, and hepatitis.

Minimizing hazards and risks at the workplace.

To ensure safety at all work sites, the following will be carried out:

- Installation of signboards and symbols in risky and hazardous areas, to inform workers to be careful.
- Construction of barricades around construction sites and deep excavated pits, to cordon off and deter entry of unauthorized personnel and workers into these areas.
- Providing a safe storage site/area for large equipment such as power tools and chains, to prevent misuse and loss.
- Proper Housekeeping: Ensuring that materials are all stacked, racked, blocked, interlocked, or otherwise secured to prevent sliding, falling, or collapse. Brick stacks

will not be more than 7 feet in height and for concrete blocks they will not be more than 6 feet high.

- Removing all scrap timber, waste material and rubbish from the immediate work area as the work progresses.
- Where scaffolds are required, ensuring that each scaffold or its components shall be capable of supporting its own weight and at least 4 times the maximum intended load applied or transmitted to it. The platform/scaffold plank shall be at least 15 inches wide and 1.5 inches thick. The rope should be capable of supporting at least 6 times the maximum intended load applied or transmitted to that rope. Pole scaffolds over 60 feet in height shall be designed by a registered professional engineer and shall be constructed and loaded in accordance with that design. Where scaffolds are not provided, safety belts/safety nets shall be provided.
- Ensure that all ramps or walkways are at least 6 feet wide, having slip resistance threads and not inclined more than a slope of 1 vertical and 3 horizontal.
- Stacking away all excavated earth at least 2 feet from the pit to avoid material such as loose rocks from falling back into the excavated area and injuring those working inside excavated sites.
- Constructing support systems, such as bracing to adjoining structures that may be endangered by excavation works nearby.
- Only a trained electrician to construct, install and repair all electrical equipment to prevent risks of electrical shocks and electrocution.
- Install fire extinguishers and/or other fire-fighting equipment at every work site to prepare for any accidental fire hazards.

Provision of Personal Protective Equipment:

Risks to the health and safety of workers can be prevented by provision of Personal Protective Equipment (PPEs) to all workers. This will be included in the construction cost for each Contractor. Depending on the nature of work and the risks involved, contractors must provide without any cost to the workers, the following protective equipment:

- Helmet shall be provided to all workers, or visitors visiting the site, for protection of the head against impact or penetration of falling or flying objects.
- Safety belt shall be provided to workers working at heights (more than 20 ft) for works such as roofing, painting, and plastering.
- Safety boots shall be provided to all workers for protection of feet from impact or penetration of falling objects on feet.

- Ear protecting devices shall be provided to all workers and will be used during the occurrence of extensive noise.
- Eye and face protection equipment shall be provided to all welders to protect against sparks.
- Respiratory protection devices shall be provided to all workers during occurrence of fumes, dusts, or toxic gas/vapour.
- Safety nets shall be provided when workplaces are more than 25 feet (7.5 m) above the ground or other surfaces where the use of ladders, scaffolds, catch platforms, temporary floors or safety belts is impractical.

The specific PPE requirements for each type of work are summarized below **(Table 7-8).**

Table 7-8 PPE Requirement List

Type of Work	PPE
Elevated Work	Safety helmet, safety belt (height greater than 20 ft), footwear for elevated work.
Handling work safety	Helmet, leather safety shoes, work gloves.
Welding and cutting work	Eye protectors, shield and helmet, protective gloves.
Grinding work	Dust respirator, earplugs, eye protectors.
Work involving handling of chemical substances	Dust respirator, gas mask, chemical-proof gloves. Chemical proof clothing, air-lined mask, eye protectors.
Wood working	Hard hat, eye protectors, hearing protection, safety footwear, leather gloves and dust respirator.
Blasting	Hard hat, eye and hearing protection.
Concrete and masonry work	Hard hat, eye protectors, hearing protection, safety footwear, leather gloves and dust respirator.
Excavation, heavy equipment, motor graders, and bulldozer operation	Hard hat, safety boots, gloves, hearing protection.
Quarries	Hard hat, eye protectors, hearing protection, safety footwear, leather gloves and dust respirator.

Procedures to Deal with Emergencies such as Accidents, Sudden Illness and Death of Workers:

First aid kits will be made available at all times throughout the entire construction period by the respective contractors. This is very important, because all work sites are quite far from the nearest Basic Health Unit. In addition to the first aid kits, the following measures should be in place:

- Provision of dispensaries by the individual EPC contractor.
- A vehicle shall be on standby from the Project Office so that emergency transportation can be arranged to take severely injured/sick workers to the nearest BHU for immediate medical attention.
- A designated Health Officer/worker for the Project will be identified as a focal person to attend to all health and safety related issues. This employee's contact number will be posted at all work sites for speedy delivery of emergency services. The focal person shall be well versed with the medical system and facilities available at the nearest hospital.
- Communication arrangements, such a provision of radios or mobile communication for all work sites, for efficient handling of emergencies, will be made.

Record Maintenance and Remedial action:

The Project Management will maintain a record of all accidents and injuries that occur at the work site. This work will be delegated by the contractor to the site supervisor and regularly reviewed every quarter by project management. Reports repaired by the contractor shall include information on the place, date and time of the incident, name of persons involved, cause of incident, witnesses present and their statements. Based on such reports, the management can jointly identify any unsafe conditions, acts or procedures and recommend for the contractor to undertake certain mitigative actions to change any unsafe or harmful conditions.

Compensation for Injuries and Death

Any casualty or injury resulting from occupational activities should be compensated as per the Labor law. Where compensation is sought by the injured party, proper procedures for documentation of the case will be followed, including a detailed report on the accident, written reports from witnesses, report of the examining doctor and his/her recommendation for treatment. Each individual contractor will be responsible for ensuring compensation for the respective workers.

Awareness Programs

The Project management will undertake awareness programs through posters, talks, and meetings with the contractors to undertake the following activities:

- Dissemination sessions will clarify the rights and responsibilities of the workers regarding interactions with local people (including communicable disease risks, such as HIV/AIDS), work site health and safety, waste management (waste separation, recycling, and composting), and the illegality of poaching.
- Make workers aware of procedures to be followed in case of emergencies such as informing the focal health person who in turn will arrange the necessary emergency transportation or treatment.

Nomination of a Health and Safety Focal Person

Within each site (especially if different sites are being implemented by different contractors), a Health and Safety Focal Person will be appointed. The Terms of Reference for the focal person will mainly be as follows:

- Function as the focal person/representative for all health and safety matters at the workplace;
- Responsible for maintaining records of all accidents and all health and safety issues at each site, the number of accidents and its cause, actions taken and remedial measures undertaken in case of safety issues;
- Be the link between the contractor and all workers and submit grievances of the workers to the contractor and instructions/directives on proper health care and safety from the contractors back to the workers;
- Ensure that all workers are adequately informed on the requirement to use Personal Protective Equipment and its correct use;
- Also responsible for the first aid kit and making sure that the basic immediate medicines are readily available.

7.18. MONITORING PLAN

Two types of monitoring will be conducted: compliance monitoring and impact or effect monitoring. Compliance monitoring will be the responsibility of consultants and client to monitor the field activities. The PEDO will also shoulder the responsibility of monitoring as their official obligation during construction and thereafter. The environmental and social inspectors of client, consultants and EPC contractor will carry it out. The effects monitoring will be carried out in line with the requirements in the mitigation plan focusing on soil erosion, water quality (covering suspended solids, turbidity, biological oxygen demand, and dissolved oxygen), air quality (covering suspended particulate matters), noise (to be measured at selected sensitive receivers during construction creating noise), and socio-economic aspects (covering complaints and employment created by the proponents of the project). A detailed monitoring plan will be developed during the design phase of the project, when specific information on field activities is known. The monitoring schedule will be linked to the construction schedule.

7.19. COMMUNICATION, DOCUMENTATION AND COMPLAINTS

An effective mechanism for communicating environmental information will be established. The data and information will be systematically filed and stored in a central location. Periodic meetings will be held involving the client, consultant, contractor, environmental and social officers to review the implementation of the EMP and monitoring results, and to resolve any problems. The contractor's environmental and social supervisor will produce periodic monitoring and evaluation reports. At the end of the construction phase, the contractor will prepare a final monitoring and evaluation report which will be part of a project completion report.

In addition, at the project site the contractor will establish a social complaint register to document all complaints received from local the community. The register will also record the measures taken to mitigate these concerns. All complaints will be sent to the Contractor's company environmental and social inspector and project manager for their information and further action and if not resolved at these levels then grievances redress committee will look into these problems.

7.20. ENVIRONMENTAL TRAINING

The contractor's environmental and social supervisor will train subcontractors, and other staff engaged for the project. Training will cover the requirements of the EIA and the EMP and will emphasize sensitizing project staff to environmental and social aspects. A training program will be prepared during the detailed design phase.

7.21. CUMULATIVE IMPACT ASSESSMENT

Introduction

Artistic Hydro I (Pvt.) Ltd plans to develop the feasibility study of 62.606 MW Artistic-I Hydropower Project in Upper Dir, KP. The Government of Pakistan (GoP) awarded the Artistic-I project to the Artistic Hydro I (Pvt.) Ltd, an investment company that acquires, develops, constructs, owns and operates renewable power generation projects. M/S BAK Consulting Engineers in joint venture with M/S Dolsar Engineering Inc. Co. Turkey prepared Environmental and Social Impact Assessment (EIA) and will develop the Resettlement Action Plan (RAP) for the Project in conformance with;

a. The national requirements including that of the Khyber Pakhtunkhwa Environmental Protection Agency (KP-EPA).
b. International Finance Corporation's (IFC) Environmental and Social Performance Standards (PS).

Rationale for Cumulative Environmental and Social Impact Assessment

Environmental and social impact assessment (EIA) is now an established tool, and a mandatory requirement in almost all the countries in the world for assessing the environmental and social impacts of development projects. The emphasis of EIA is on the environmental and social impact of a single project. Even if all the projects in a geographical location are studied through their respective EIA studies, how the projects will collectively change the environment is not captured in the studies. This assertion is based on the understanding that environment and ecosystems are non–linear systems. The cumulative impact of a number of projects will not be equal to the sum of incremental impacts of individual projects—it is likely to be more. Therefore, considering the limitations of EIA studies, the countries and organizations, understanding the importance of environment and a possible change in it as the key factor to impact its biophysical integrity, now emphasize and direct the project proponents and donors to conduct assessment of cumulative environmental and social impacts of the projects.

Cumulative impacts are those that result from the incremental impact of a project or developments when assessed in combination with other existing and reasonably foreseeable future developments in a rationally set geographical and temporal scale. Cumulative impacts of a project are limited to those impacts only which are generally recognized as important on the basis of scientific concerns and concerns of the local communities located around the project area which can be affected by the project development and other developments in their vicinity.

Cumulative Impact Assessment (CIA) signifies a systematic impediment in environmental and social impact assessment (EIA) because the spatial horizon of impact assessment is expanded and multifaceted as compared to EIA and the interactions between human activities and Valued Environmental and Social Components (VECs) increase in number and intricacy. The overall objectives of a cumulative environmental assessment studies are:

- Safeguard the subject and future development's cumulative social and environmental impacts and risks to not exceed a threshold that could compromise the sustainability of Valued Environmental and Social Components (VECs);
- Ensure that the subject and future development's value and feasibility are not limited by cumulative social and environmental impacts and risks; and

- Support development of regional governance structures for decision making and managing cumulative impacts.

Methodology for Cumulative Impacts Assessment.

There are a number of guidelines for conducting cumulative environmental and social impact assessments. The methodology used in this Study has been adapted from the guidelines of International Finance Corporation. The key steps of the Study are shown in **Figure 7-4.**

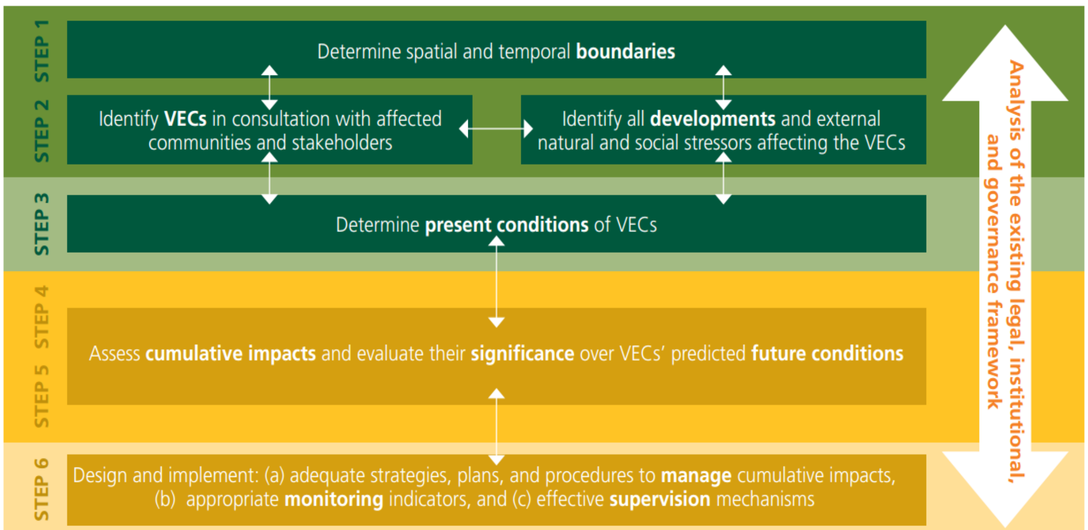


Figure 7-4 Key Steps of the Study

Source: International Finance Corporation. Good Practice Handbook—Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets. 2014

Spatial and Temporal Boundaries

The spatial and temporal boundaries for the CIA are defined in this section together with justification for their selection.

Spatial Boundaries

The Study Area selected for the CIA (CIA Study Area) includes the Panjkora River from Sahibabad village to Koto village. It also includes segment of the Ushera Dara and Kumrat Dara, which meet with the Panjkora River in village Darora, a site which is located around 500 meter above the weir site of this project. Significant tributaries which are important breeding areas for fish and also recharge the rivers with water included Ushera Dara Nullah and Kumrat Dara Nullah. All the aforementioned Nullah are also included in the CIA Study Area as the tributaries and the main river constitute an integrated and interdependent ecosystem. On Panjkora River, various hydropower projects are in progress which include Koto hydropower and Sharmai Hydropower. Koto Hydropower Project is located in the downstream area of that project, while Sharmai Hydropower lies upstream of that project.

Figure 7-5 Spatial Boundaries Map

Temporal Boundaries:

The temporal scope of the CIA spans a period of 35 years up till the year 2055. This includes the first 5 years of construction of the Artistic-I and a further 30 years of its operation.

Hydropower Projects Development Plan

Pakistan is going through an acute power shortage. The gap between supply and demand has crossed 5,000 MW. Over the last decade, the development of hydropower resources in Pakistan has become a priority for the governments. This shortfall has resulted in prolonged power cuts of about 8 hours a day across both states and has adversely affected economic growth and development; thus, becoming one of the top challenges facing the political leadership.

Major Existing, Planned and Under Construction Hydropower Project on Panjkora River

According to the latest information available, the major hydropower projects in the Jhelum Basin are listed in **Table 7-9.** Information about their installed capacity, executing agency and progress status (existing, under construction or planned) is also provided.

Table 7-9 List of the Major Hydropower Projects on River Swat in Various Stages of Development by Different Agencies

No	Project	Installed Capacity (MW)	Executing Agency	Project Status	Reservoir type
01	Artistic-I	62.606	Artistic Hydro 1	Feasibility Study	Run-of-river
02	Koto HPP	40.8	PEDO	Under Construction	Run-of-river
03	Sharmai HPP	150	Saphire Electric Co.	Under Construction	Dam

Ecosystem Services Review:

Ecosystem Services, as defined by the World Resources Institute (WRI), 'are the benefits that people get from nature. Examples include fresh water, timber, climate regulation, recreation and aesthetic values. Ecosystem services are an important class of Valued Environmental and Social Components as the livelihoods of the communities depend on them, and are therefore discussed separately in this section.

The Ecosystem Services Review is an initiative to view the environment as an integrated system. The framework that is being used in this study has been developed by World Resources Institute (WRI, 2011). This new framework systematically addresses impacts on ecosystem services, defined by WRI (2011) as "the many benefits—large and small, direct and indirect that ecosystems provide to people", and thereby links people and their environment.

The benefits humans obtain from ecosystems are generally divided into four categories:

i. Provisioning services are the goods or products obtained from ecosystems, such as food, timber, medicines, fibre, and freshwater;

ii. Regulating services are the benefits obtained from an ecosystem's control of natural processes, such as climate, disease, erosion, water flows, and pollination, as well as protection from natural hazards;

iii. Cultural services are the nonmaterial benefits obtained from ecosystems, such as recreation, spiritual values, and aesthetic enjoyment; and

iv. Supporting services are the natural processes that maintain the other ecosystem services, such as nutrient cycling and primary production.

Identification of Ecosystem Services Associated with the River:

Identification of ecosystem services was carried out through a review of the Socioeconomic Baseline of the EIA of Artistic-I. Ecosystem services in the categories of regulating and supporting services are not of significance in the CIA Study Area. The following provisioning ecosystem services were identified:

Provisioning Services:

i. Fishing

ii. Sand Mining

iii. Driftwood Use as a Fuel

iv. Land irrigation

v. Domestic Uses of River Water

vi. Pumping of River Water by River–side Restaurants

Cultural Services:

i. Tourism and Recreation

ii. Hydropower project for main Religious centre

Determination of Priority Ecosystem Services:

Priority ecosystem services were determined based on two criteria including significance of community dependence on the ecosystem service and whether or not the Project will impact the ecosystem service. These ecosystem services are described below, along with information and analyses to assess their priority. Prioritization of ecosystem services is summarized at the end of this section.

Fishing

Fish hunting was carried out along the project area for the sake of business, food and recreation. The fish intensity is higher in the above stream area of the proposed project, while it decreases as we move in the downstream. In the project area fish catching was practiced for the sake of food, business and for recreation. The fish season was prolonged almost throughout the whole year due to extreme cold weather. Seasonal permits for fishing using rods and cast nets are issued by the KP Fisheries and Wildlife Department, but most of the fish caught is without permits as enforcement is weak. The most common fish species caught include Singhat Machli (*Triplophysa choprai*), Chakaar Machli (*Glyptosternum riticulatum*), Brown trout (*Salmo Trutta*), Rainow trout (*Onchorhyncus*), Crow fish (*Xinentodon Cancila*), Daoly Machlee (*Channa gachua*), Galali (*Schizothorax plagiostomus*) and Chunr (*Racoma labiata*). It is reported that most of the fish is self–consumed whereas the some of it is sold commercially as well. Commercially fish was sold to the local hotel especially for the tourists, however some fish was sold to the middle man for the export to the other cities. It may be noted that a large part of the fishing activity is illegal, i.e., is undertaken without license from the Fish Department. The fishermen are, therefore, reluctant to share information on the fishing activities and its volume. Fishing will be affected by the proposed project. The creation of the barrier and diversion of water to the tunnel will decrease the volume of water in the river and decrease the habitat, thereby, impacting fish populations in the proposed project area of Panjkora River. But as the dependence on fish for the local community as a livelihood was very low, thus overall impact is not significance. However, presence of some endangered fish species such as trout increase the significance of that impact. With the construction of this project may lead to decrease the population of trout fish which is already endangered species in the area. Furthermore, the project may affect the migratory fish of the river. To overcome this problem fish ladder will be established. However, the other hydropower projects are established at far distance from that project. Thus, overall impacts of theis project will be low as compare to River Swat where hydropower projects are established at very short distance.

Sand Mining

Sand mining is carried out along the whole proposed project area and it's downstream and upstream as well especially at those places where there are population or any commercial activities such as hotel are under construction. The mineable sand resource is being extracted to meet small–scale construction demand, involving construction and maintenance of local residential and commercial buildings. The mining techniques are crude, involving use of labour for sand dredging. However mechanical extraction was observed at some areas in the CIA Study Area. The sand is mined using shovels and spades and is loaded onto animals or vehicles, by means of which it is transported to the roadside. The extraction is carried out in areas where the flow of the river is gentle, the width is wide or where due to meandering of the river sand bars area created. The operation continues throughout the year except in the flood season. However, as sand mining is carried out to meet the local requirement for the construction of their own houses. Thus, the demand is very low and only a small amount of sand mining was carried out.

The construction of this project will have positive impacts on the overall economy of the area. As it was already practiced in the area during the construction phase of KHPP, the local land owner was paid for the sand mining. Furthermore, job opportunities were also provided to the local people. Thus, overall, it increases the economic conditions of the area. However, during the construction phase sand mining may affect the aquatic life in the area. Use of heavy machinery may lead to the degradation of the natural habitat of the aquatic life. Especially it will badly affect the endangered trout species. Furthermore, the extraction of sand and stone may lead to cause turbidity which will affect the quality of the water by increasing the load of dissolved and suspended particles. Nevertheless, the digging of tunnel for the present project may lead to generate the sand and rocks which can be used as alternative construction materials instead of river sands. Thus, the project may have positive impacts on the river in case of sand mining. However, these aforementioned negative effects will be only associated with the construction phase. Thus, there impact will be not as significant.

Driftwood used as Fuel

Fuel wood is the main source of energy for domestic cooking and heating. Respondents, interviewed as part of the EIA of Artistic-I reported that fuel wood is collected from the farm lands and dead–fallen trees in the forests. Driftwood use as a fuel is likely to be affected by the project at the box channel site and power house site. At the point of power house, a small village of Koto is located. These peoples use driftwood as a source of fuel. With the construction of power house, it may alter the path for the local community to transport their fuel wood. However, the main path to that village is far away from power house. Furthermore, the main source of fuel wood lies above the power house site. Thus, overall project will not cause any difficulty for the villagers for the collection of fuel wood.

Land Irrigation

The local community in the proposed project area highly rely on the livestock and agriculture practices. The main crop is maize, rice, wheat, barley, mustard, onion and vegetables. The agriculture area will not be disturbed due to project activities. However, on the left bank of river, extensive agriculture practice is carried out. Irrigation channel is also well established in the left bank of river. However, on the right bank of river, neither irrigated channel exists nor will any agriculture fields be damaged from the proposed project. So, overall there will be no significant effect on the agriculture lands of the area due to construction of this hydropower project.

River Water usage for Hotel and Domestic Purposes

The main source of Panjkora River is Kumrat and Osherai, nearly 70km and 30 km from Dir town. The Panjkora River flows through the entire Valley via Dir, Sahibabad, and Timergara and joins the Swat River in the Mohmand. The other streams/ nullahs present in the area also contribute towards increasing the water quantity in the river. Along the both banks of the rivers small villages are present. Though the population of these villages were not too much populated but still cluster of houses were found along the both end of the rivers. In addition, few hotels and restaurants were also constructed along the left bank of the river. The establishment of this project will lead to decrease the flow of water along the tunnel side especially during the winter season when the river water volume will already decrease due to extreme climate conditions. However, the river water is not use by any of hotel and restaurants. The hotel and restaurants use ground water for the needs as they get easy access to ground water.

Tourism and Recreation

Recreational dependence on the river was reportedly high in the proposed project area, based on the EIA of Artistic-I. Kumrat Valley is the famous site of recreation and tourism in the area. Kumrat valley is located around 70-80km from the Dir town. The tourism activities in the aforementioned site are fishing, boating and picnic point. However, boating is very limited in the valley. Most of the respondent stated that river–based activities, dependency on the fish is very limited in the area. Thus, impact of propose project on fish is very limited. The river view in the summer which is the primary season for the visitors will not be affected by the Project as there will be enough water volume in the river during this period. The river is not the main source of fish purchased by the hotels, the fish caught from the river is illegal, and fish produced in the farms downstream is commonly available and consumed. The dependence of local community on income from fishing was very limited as well.

The impact of the Project on tourism will not be significant. Furthermore, local communities do not rely on the river for recreation to any significant extent, therefore, it was not considered significant in terms of community dependence. However, a small hydropower plant was functional in between the weir and power house area. This power plant makes sure the availability of electricity to the religious Tablighi centre. The propose project may affect this power plant. However, due attention should be given to make sure the provision of water for electricity generation to that power plant during the construction and operational phase of the proposed project.

Forest Degradation

Dir including upper and lower Dir are dominated with the pine species which take hundreds of years to get mature. The proposed project is in Upper Dir but the proposed project area didn't contain any of pine species. The project area is dominated with Bakine *(Melia azedarach),* Ailanthus (*Ailanthus altissima*), Eucalyptus (*Eucalyptus globulus*) and so on trees species. The construction of the project will lead to degradation of the few trees as dense forest in not present in the project area. Only few numbers of trees will fell down to make the area clear for the construction of the hydropower project. Cutting of trees will not affect the ecology of the area nor will it enhance the soil erosion. The impact of project on forest will be not highly significant. Furthermore ten (10) sapling will be planted for cutting of each single tree.

Results of Prioritization

Significant community dependence was signified by Yes (Y) as was Project impact. Insignificant community dependence and the absence of impact by the Project were signified by No (N). The significance for both the parameters has to be Y for an ecosystem to qualify as a priority ecosystem service **(Table 7-10).**

Table 7-10 Prioritization of Ecosystem Services

Ecosystem Service	Significant Community Dependence	Impacted by Project	Priority Ecosystem Service
Fishing	N	Y	N
Sand Mining	N	N	N
Driftwood Use as a Fuel	Y	Y	Y

Ecosystem Service	Significant Community Dependence	Impacted by Project	Priority Ecosystem Service
Agriculture	N	N	N
Forest	Y	N	Y
Tourism and Recreation	N	N	N
Domestic Use of River Water	N	N	N
Pumping of River Water by River–side Restaurants	N	N	N

Dir especially Kumrat Valley is an area which is very famous for its natural beauty and hub of tourism and recreation in the whole country. Every year thousands of people visit to the area. Panjkora River and lush green forest of Dir make the area a favourable spot for tourism. Panjkora River which is mainly fed with the water of glaciers flow between the whole valley and meet the Swat River at Mohmand. On the Panjkora River, hydropower projects were proposed, among which few are under construction i.e. KHPP and Sharmai HPP, while the feasibility study of Artistic-I HPP is in progress. The construction of these projects on Panjkora River have positive and negative impacts which may include job opportunities, forest degradation, agriculture land degradation and so on. However, there are only few negative impacts which have some significant impact due to construction of this project. Nevertheless, these impacts can be managed by adopting the proper mitigation measures or by paying proper compensation.

CHAPTER 8: ENVIRONMENTAL COST ESTIMATE

8.1. GENERAL

The social and resettlement aspects of the project are important components of environmental and social impact assessment. These cover the areas of reservoir, powerhouse, residential colonies etc. together with the rehabilitation/resettlement of the affectees being impacted by the project. Keeping in view the sacrifices to be made by the affectees, it is their right that they must be compensated properly and timely. Furthermore, their assets should be evaluated, keeping in view the market rates, and their post-project situation must be better or at least maintained to their previous standards. If the affectees of the project are satisfied with the resettlement policy, this could serve as an encouraging/ facilitating example for other similar types of projects being planned in the area.

The Chapter has been prepared for undertaking the resettlement and rehabilitation of affected persons and includes, identification of categories of impact, number of affected persons with inventory of affected assets and other losses, entitlement of compensation, and other mitigation and rehabilitation assistance measures, resettlement strategy, entitlement for compensation and assistance to restore their livelihood and budgetary allocation etc. The RAP will deal with the various issues related to the affectees of the project area, which are discussed in the following subsections:

8.2. OBJECTIVES

The RAP of Artistic-I HPP has been prepared under the general policy guidelines and procedures developed by the Government of Pakistan for projects involving involuntary resettlement. The objectives of the RAP of this project are:

a) To avoid or minimize involuntary resettlement wherever feasible, exploring all viable alternative project designs.

b) Where involuntary resettlement is unavoidable, resettlement plans should be conceived, developed and executed as development programmes, wherein re-settlers are provided with sufficient investment resources and opportunities to share their project benefits.

c) Persons to be displaced should have their former living standards and income earning capacity improved, or at least restored, and should be provided with adequate support during the transition period.

d) Community participation should be encouraged during the planning and implementation of resettlement.

e) All the project affectees should be provided due compensation for their land and land-based assets, in addition to houses and shops, such as trees, infrastructure, community buildings etc.

f) Housing/building structure compensation should be provided to the adversely affected population. In this specific situation, only houses/building structures are planned to be compensated.

g) Ensure that the compensation process will be fully transparent; and

h) Considering the growing requirements and complexity of resettlement in this development project, it is better to gear up the concerned government agencies and departments to upgrade their institutional capacity to design and implement RAP.

8.3. SOCIAL IMPACT ASSESSMENT

With the construction of the project, there will be some significant impacts on the physical, biological and socioeconomic parameters including resettlement issues of this project. To evaluate the impacts before the project execution, a socioeconomic study for the project was carried out with the objective to ascertain the overall socio-economic conditions as a part of the social impact assessment. July, 2010 flood affected many aspects of socio-economic life of the people as well as some physical infrastructure of the area. The area has suffered a significant loss of livelihood due to the flood that has caused damage to the land, crops, livestock and infrastructure. Under such circumstance, it is of primary importance to gauge the current socioeconomic conditions of the population residing in the project area that is once again likely to suffer due to the implementation of the project.

The main idea was to assess the overall impact of the project on the local population. The impact was studied through the socio-economic baseline survey and public consultation process for project sustainability under pre and post project conditions. The specific social assessment aims were:

a) Define the demographic, sociological and economic characteristics of the project area;

b) Incorporation of interest of vulnerable population; including ethnic minorities;

c) Define the gender issues and incorporate the interest of women;

d) Level of acceptance of the project by the local community;

e) Identification of project potential adverse effects, i.e., resettlement issues and spelling out remedial measures as per national laws/policy, local culture and traditions;

f) Conduct public consultation sessions to assess the locals' need, demands and possible options for the sustainability of the proposed project;

8.4. METHODOLOGY FOR SOCIAL AND RESETTLEMENT PLANNING

Under this specific phase of the study, methodology adopted for the resettlement planning are preparation of inventories of affected land and land-based assets including houses/buildings and the affectees. The ultimate objective was to enable those displaced by the project to improve their living standards. Affected houses/buildings and the population, and impacts were identified through a series of following steps:

a) Surveys and preparation of maps that identify such features as population settlements, agricultural land, infrastructure, natural vegetation areas.

b) A focus census that enumerates the affected people.

c) An inventory of affected land and land-based assets including houses/building structures at the household, enterprise and community level.

d) Socioeconomic surveys and studies of representative number of the affected people as necessary. The survey conducted included the following major components;

   i. Demographic characteristics
   ii. Education and literacy levels
   iii. Nature of occupations and sources of income
   iv. Income levels
   v. Household expenditure patterns
   vi. Housing characteristics and amenities
   vii. Access to social amenities
   viii. Situation analysis of women
   ix. Perceptions and protective measures suggested about the project

e) Analysis of the surveys and studies to establish compensation parameters, to design appropriate income restoration and sustainable development initiatives and to identify the baseline monitoring indicators.

f) Consultation with affected populations regarding mitigation of effects and development opportunities.

g) All the above-mentioned studies generated the required information for the appropriate resettlement planning of the affectees.

8.5. LEGAL AND POLICY FRAMEWORK

The review of legal, administrative and regulatory framework governing acquisition of property for development purposes, and resettlement of affected population in Pakistan, is presented in this section. It also discusses the relevant legislation, regulation and reviews of legal procedures.

8.5.1. LAND ACQUISITION ACT

8.5.1.1. GENERAL

The present general law for acquisition of land for public purposes such as urban development, new roads, railway lines and canals, etc. was introduced in the year 1894 as the Land Acquisition Act, 1894 (LAA). This Act remains the primary law governing land acquisition in Pakistan today and is the principal general statute laying down the framework for the exercise of the right of eminent domain of the State.

In addition to the provisions of the Act, regulations setting out the procedure for land acquisition have been provided in the Punjab Land Acquisition Rules, 1983; published in the Gazette of the Punjab Extraordinary, dated February 22, 1983. These rules are applicable in the Punjab but also used as guideline in other provinces. There is another body of general regulations called the Standing Order No. 28, which is followed by the KP and Punjab. For the acquisition of land, the above-mentioned Act, rules and regulations are followed by all Government Agencies / Departments.

The LAA lays down definite procedures for acquiring private land for projects and payment of compensation. The rights of people whose land is to be acquired are fully safeguarded. Even for entering private land or carrying out surveys and investigations, specified formalities have to be observed and notifications have to be issued. Damage to the crops during survey and investigations has to be compensated. The affected persons, if not satisfied, can go to the Court of Law to contest the compensation award of the Land Acquisition Collector (LAC).

8.5.1.2. BRIEF REVIEW OF IMPORTANT FEATURES OF LAA

In accordance with the Act, the legal process is initiated by an application from the Government agency that requires the land as it is the Requiring Body (RB). As land is a provincial subject according to the Constitution of Pakistan, the next step is for the Provincial Government to deem it necessary to acquire land, and it then takes the following actions.

Under Section 4, it causes the publication of preliminary notification notifying that the land is needed for a public purpose. This permits entry, survey and investigations of the land in question by an authorized Government servant. He shall pay compensation for any damage caused by such entry. The purpose of a notification under Section 4 is to enable the authorities to carry out preliminary investigations for deciding whether the land intended to be acquired is suitable for the purpose for which it is needed. The process of acquisition must start with a notification under Section 4. It is a condition precedent to the exercise of any further powers under the Act. Notification date of Section – 4 is considered as cut-off date.

Under Section 5, a formal notification is issued that the particular land is needed for a public purpose. This notification is published in the official Gazette and the Collector is required to cause public notice to be given of the substance of the notification. Issuance of Section 5 has to take place not later than one year after notification of Section 4.

Any person interested in any land which has been notified under Section 5 may, within thirty days after the issuance of the notification, object to the acquisition of the land under Section 5-A. The Collector shall hear the objection, make necessary inquiries and submit a report within 90 days to the appropriate Government authority. This authority must announce its decision, which shall be final, within 90 days, otherwise the objection shall be deemed to have been admitted and the acquisition proceedings will come to an end. When the Provincial Government is satisfied, after considering the report, if any, made under Section 5-A that any particular land is required for public purpose, a declaration to that effect shall be made by an authorized officer of the Provincial Government under Section 6. This should follow within six months of the publication of the Section 5 notification.

After the declaration under Section 6, the Commissioner Land Acquisition shall direct the Collector to take order for the acquisition of land under Section 7. The Collector then notifies Section 8 to cause the land to be marked out, measured and planned (if this was not done after Section 4). Under Section 9, the Collector gives notice to all the interested people that the Government intends to take possession of the land and if they have any claims for compensation then those be made to him at an appointed time. Section 10 delegates powers to the Collector to record statements of persons possessing any interest in the land or any part thereof as co-proprietor, sub-proprietor, mortgage and tenant or otherwise.

The most important section of the Act is Section 11; it enables the Collector to make inquiry into measurements, value and claim, and issue the final award." Included in the award is the lands' true area, his view of what compensation is warranted, and the apportionment of that compensation to all interested people. Though this section is the one that contains the final award, there are two other sections i.e. Section 23 and Section 24, which actually precede Section 11. This is because these two sections pertain to compensation and the criteria to be followed (Section 23) or not to be followed i.e. Section 24 in arriving at appropriate compensation.

Under Section 23 are included such items as the market value of the land at the time of notification of Section 6, and various damages that have been sustained at the time possession was taken. Matters to be neglected in awarding compensation i.e. Section 24 includes such items as the degree of urgency which led to the acquisition, any disinclination of the person interested in the land to part with it, any expected increase in value of the land from its future use, etc. When the Collector has made an award under Section 11, he will then take possession under Section 16 and the land shall thereupon vest absolutely with the Government, free from all encumbrances.

Another section of note is Section 18, which pertains to persons still dissatisfied with the award who may request the Collector to refer the case to the court for determination and decision. This does not affect the taking possession of the land by the Government. In cases of emergency, where the Board of Revenue considers it expedient to take possession of any land at any time before an award under Section 11 has been made, it shall notify this act in writing to the Collector intimating in addition the date by which the land is required by it. Under Section 17, the Collector can, after causing a notice to this effect to be served on the person or persons interested in the land, take possession of the land subject to the liability to pay any amount, which may be incurred on account of acquisition. This specific section will not be applicable in this project as the acquisition of land is being done through normal applicable procedures.

From operational point of view, the LAA is a provincial law and each province has its own version and interpretation of this law, mostly procedural in nature. These differences lead to different dispensations in compensation and resettlement packages for the affectees of projects. Provincial governments have also evolved mechanisms for calculation and payment of compensation, suited to their specific needs and socio-cultural contexts. The procedures so far adopted for compensation, grievance redress, appeal periods, interest rate calculations, etc. do not aggregate to the resettlement policy. Recourse is often taken to adhoc arrangements, agreements and understandings for resettlement in difficult situations.

8.5.2. Policy Framework

8.5.2.1. Background

The experience of development during the last century that led to massive human sufferings and dislocation in the name of development has confirmed that people have to be at the centre of all development processes. To achieve long term social benefits in development projects, the people must be consulted, compensated for their losses and assisted in rebuilding their lost assets and livelihoods to enjoy at least the same standard of living, which they have before the project. Very often affected people are poor and vulnerable and therefore, unable to absorb the adverse impacts on their lives. They need significant help to restart their normal lives and re-establish their livelihoods. Mere payment of cash compensation under the LAA is not enough to restore livelihood and living standards.

8.5.2.2. National Resettlement Policy (March 2002)

National Resettlement Policy has been formulated (which is still in draft shape) to not only cover the affected persons (APs) in the existing systems but also to ensure an equitable and uniform treatment of the resettlement issues all over Pakistan. This Policy will apply to all the development projects involving adverse social impacts, including land acquisition, loss of assets, income, business, etc. It has addressed those areas, which are not looked after in LAA (1894) and will be applicable wherever the people, families or communities are affected by any public sector or private development project, even when there is no displacement. The Policy also aims to compensate for the loss of income to those who suffer due to loss of communal property including common assets, productive assets, structures, other fixed assets, income and employment, loss of community networks and services, pastures, water rights, public infrastructure like mosques, shrines, schools, graveyards etc.

8.5.2.3. Policy Objectives

The Policy objectives are relevant to other policies and laws of the Government of Pakistan, including the following:

a. Avoid or minimize adverse social impacts in a project wherever possible and where adverse impacts cannot be avoided, the mitigation measures and resettlement activities should be conceived and executed as development programs and the affected persons be provided opportunity to share the project benefits.

b. Project affected persons (PAPs) be provided with sufficient compensation and assistance for lost assets that will assist them to improve or at least restore their living standards, income earning or production capacity to the pre-project levels.

c. Provide a development opportunity to all the vulnerable groups (including poverty groups, women headed households, refugees and those without security of tenure /usufruct rights, etc.). The vulnerable population should receive special assistance to bring them at least to a minimum living standard at par with the pre-project level.

d. All population adversely affected by the project, should be eligible for sharing the social and economic benefits, envisaged after completion of the project.

8.5.2.4. PRINCIPLES OF THE POLICY

The Policy is based on the following principles, whereas the Guidelines will explain all the resettlement issues at operational and procedural levels.

a) To minimize involuntary resettlement, the proponents should consider alternative planning and design standards, and finalize an option with the minimum adverse impacts.

b) Involuntary resettlement should be conceived and executed as a part of the project and full cost of resettlement and compensation be included in the project costs and benefits.

c) Key stakeholders (including affected communities and APs) are fully consulted regarding the project' design, implementation and operation, and all activities are carried out through a participatory process.

d) All APs residing in, working, doing business, or cultivating land, or having rights over resources within the project area as on the date of the census surveys are entitled to compensation for their lost assets, incomes, jobs and businesses at replacement cost, on the cut-off-date notified in the Official Gazette.

e) APs losing their incomes, jobs and employment, should get additional development assistance that enables them to improve their incomes to restore their standard of living to pre-project level.

f) APs losing all of their productive assets (farm land, house or business), or in case of partial loss when the remaining assets are not viable for continued use, will be entitled for full compensation for the entire affected assets at replacement cost.

g) APs affected by partial impact on their assets i.e. suffering partial loss of land or structures while the remaining assets remain viable for continued use, and where the livelihood is not land-based, the compensation for affected assets would be paid in cash.

h) Affected population should be informed fully and consulted in a timely manner, in order to enable them to make the informed decisions on resettlement and compensation options.

i) Existing social and cultural institutions of the affected communities and their host communities should be supported and integrated.

j) Absence of a formal legal title to land by some affected person should not be a bar to qualify for compensation of his/her lost assets (structure, houses, trees, etc.), business and incomes, including rehabilitation assistance measures.

k) Special provisions should be made for the vulnerable groups in a project, over and above their entitlements for compensation and other assistance to improve their living standards to minimum socially acceptable level.

l) Where in a project the cultural minorities or indigenous peoples (tribal communities) are affected, the social and economic benefits they receive be in harmony with their cultural preferences and be decided in consultation with the affected communities.

m) Any acquisition of, or restriction on access to resources owned or managed by the APs as a common property will be mitigated by arrangements ensuring access of those APs to equivalent resources on a continuing basis.

n) Project proponents shall resolve maximum possible claims and unresolved issues related to the tenure status and ownership of land and other assets, prior to initiating any land acquisition activity. However, just for this reason, the scheduled commencement of the project work should not be delayed.

o) The usufruct rights of the APs shall be protected.

p) Resettlement programs will have adequate institutional set-ups to ensure effective design, planning, consultation and implementation of compensation, resettlement and rehabilitation measures, supervision and monitoring of the resettlement and rehabilitation measures.

q) A clear mechanism of grievance redress should form part of the resettlement and rehabilitation process.

r) Resettlement transition period be minimized and the acquisition of assets, compensation, resettlement and rehabilitation activities (except where long-term rehabilitation measures such as vocational training are recommended) be completed prior to the initiation of construction work.

s) In resettlement and compensation, the gender biases should not deny to the women their due entitlements. Affected women will have equal access to all income restoration programs. In addition to receiving the compensation, the women should be eligible for financial credit for starting their own businesses, etc. and to restore their income and livelihoods.

8.5.2.5. IMPACTS COVERED

This policy covers direct social and economic impacts that are caused by;

a. The involuntary taking over of land resulting in:

   i. Relocation or loss of shelter;
   ii. Loss of assets or access to assets; or
   iii. Loss of income sources or means of livelihood, whether or not the affected persons must move to another location; or

b) The involuntary restriction of access to legally designated parks and protected areas resulting in adverse impacts on the livelihoods of the displaced persons.

c) Where necessary to achieve the objectives of the Policy, the Resettlement Plan or Resettlement Policy Framework also includes measures to ensure that displaced persons are;

   i. Offered support after displacement, for a transition period, based on a reasonable estimate of the time likely to be needed to restore their livelihood and standards of living; and

   ii. Provided with development assistance in addition to compensation measures such as land preparation, credit facilities, training, or job opportunities.

8.5.2.6. CRITERIA FOR ELIGIBILITY

Displaced persons may be classified in one of the following three groups:

a. Those who have formal legal rights to land (including customary and traditional rights recognized under the laws of the country);

b. Those who do not have formal legal rights to land at the time the census begins but have a claim to such land or assets provided that such claims are recognized under the laws of the country or become recognized through a process identified in the resettlement plan;

c. Those who have no recognizable legal right or claim to the land but they are occupying the land.

Persons who encroach the project area after the cut-off date established by the borrower are not entitled to compensation or any other form of resettlement assistance.

8.5.2.7. PROJECTS' RESETTLEMENT PRINCIPLES AND OBJECTIVES

The development projects that displace people involuntarily can generally give rise to economic, social and environmental problems. Involuntary resettlement may cause severe long-term hardship, impoverishment, and environmental damage without the application of appropriate measures to mitigate these impacts. The RAP provides details regarding the likely impacts resulting from this intervention and the mitigatory measures that will be adopted to address these adverse impacts.

The main objectives of the RAP are to:

a. Present a strategy for achieving the objectives of the National Resettlement Policy;

b. Provide a framework for implementation of the stated strategies to ensure timely acquisition of assets, payment of compensation and delivery of other benefits to PAPs.

c. Provide details on the policies governing land expropriation, the range of adverse impacts and entitlements, and implementation of the project facilitating the PAPs' efforts to improve their living standards, income earning capacity and production levels or, at least restore them to pre project levels;

d. Provide details on the public information, consultation and participation, and grievance redress mechanism in the project planning, design and implementation;

e. Identify and provide an estimate of required resources for implementation of recommended strategies; and

f. Provide a framework for supervision, monitoring and evaluation of resettlement implementation.

g. Given the growing requirements and complexity of resettlement in development projects, the government agencies and departments should upgrade the institutional capacity to design and implement RAPs.

8.5.2.8. ENTITLEMENT AND COMPENSATION MATRIX

In the light of review of LAA, 1894 and Policy Framework (World Bank OP 4.12), and consultations with the affected people, the following Entitlement and Compensation Matrix (ECM) as summarized in **Table** 8-1 is prepared for the project keeping in view the nature of losses, entitlements and implementation issues. The said ECM will be applied for determining the compensation of the affectees.

The answers to some of the frequently asked questions related to compensation are given below in accordance with the guiding principles laid out for such purposes;

a) What will be the entitlements for different categories of affectees (based on the severity of impacts)?

   This has been precisely identified and given in the ECM **(Table** 8-1**),** which covers all types of affectees and their entitlements. This ECM is based on the National Resettlement Policy.

b) What will be the status of title and non-title holders? Who are eligible for what?

   In case of title holders

   i. One-time cash compensation grant for facilitating alternative housing/ land

   ii. Shifting charges to resettle somewhere else

   iii. Transition period allowance

   iv. Trainings of the affectees for their capacity building to restore their livelihoods

   In case of non-title holders

i Compensation for the lost structure (if owner) as per assessed values/price by District Officer Revenue (DOR), provided it is certified by the land owner.

ii The owners' income is below the poverty line.

iii Cash compensation for shifting of the house from proposed RoW.

iv Trainings of the affectees for their capacity building to restore their livelihoods.

c) How will the prices for different affected assets / infrastructure / livelihood / community property, etc, be determined?

The construction rates of various types of structures are adopted after consulting the Building Department and receiving their rates notified each quarter regularly. These rates reflect current replacement costs, without depreciation. These structures are divided into three main categories;

i. Pacca houses with concrete roof / corrugated sheet roofing,
ii. Semi-pacca houses with blocks / stones / masonry, mud mortar and T-iron-girder
iii. Katcha structures / houses with stone walls / mud mortar, sirky or tree wood batten roof. All the three types of structures were assessed at the following rates for their damages as follows:

Damages: Pacca building @ Rs.2000/ sq. ft, Semi-pacca building @ Rs.1500/sq. ft and Katcha building @ Rs.1000/ sq. ft.

d) What prices will be used? (Mere mention of market prices is not sufficient); how will those prices be collected?

Compensation framework (Section–5, sub-section 5.3) covers all these prices in detail for each type of affected land, private and commercial building structures and other immoveable land-based assets. These prices are based on the current market prices ascertained through the field investigations and consultation with the affectees, relevant government departments, local real estate dealers and transactions made in the project area within the last one year. These prices have been collected, computed accordingly as given in the Resettlement Budget and Financing chapter.

e) The affected community will be paid cash compensation for the structures through the Management Committee along with the shifting assistance.

Community facilities/common property resources will be reconstructed/ improved/rehabilitated at project cost

8.6. POTENTIAL RESETTLEMENT IMPACTS OF THE PROJECT

8.6.1. GENERAL

The proposed Artistic-I HPP is run-of-river type hydropower project, with a planned capacity of 62.606 MW. The main resettlement impacts are related with the construction of the project components. The project components consist of Weir, Headrace Tunnel, penstock, powerhouse, tailrace tunnel, etc. with staff residential colony and offices. For construction of all these components, a total 149.85 acres of land consisting of 3 houses, 117.09 acres agriculture land, 28.63 acres plan barren land and 4.13 acres mountainous land will be affected. The detail of the affected land is provided in **Table 8-1.**

Table 8-1 Entitlement and Compensation Matrix

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
1	Loss of agricultural land	Legal owner of the land, as identified by the revenue record in the Land Acquisition Assessment report.	i. Replacement land if available, or ii. Cash compensation under LAA-1894 &National Policy on Involuntary Resettlement (replacement value assessed by DOR plus15% compulsory land acquisition cost)	a. Assessment of quantity and quality of land b. Assessment of market value c. Assessment of replacement value of land d. Title updating e. Payment of cash compensation f. APs will be fully informed of the entitlements and procedures regarding payment
2	Loss of crops to cultivable land by farmers, (tenants/share croppers)	Farmers, tenants and share croppers of the land under contract	i. Cash compensation for crop loss to farmer, ii. tenant/share cropper, based on market iii. value of crops as per National Policy on Involuntary Resettlement. Preference in employment during construction activities as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. Preference in permanent employment to	a. Individuals identified by the Land Acquisition Assessment Report as tenant or share cropper of land b. Cash grant as determined by assessment will be paid after taking possession of the land c. The legal owner certifies the tenancy

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
			the unskilled Labour and technically qualified people in operation and maintenance of the project.	
3	Loss of trees/perennials	Persons with legal ownership of the land where the trees are located and crops are grown	i. Compensation at the market value, based on productivity and age of trees assessed as per LAA-1894 & National Policy on Involuntary Resettlement.	a. Assessment of loss and market value of the loss b. Payment of cash compensation for the losses c. Additional cash grant to cover the replacement value of the lost trees / perennials (if necessary)

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
4	Loss of residences/ commercial structures by owner	(a) Legal owner of the structures	. Cash compensation for the structures at the market/replacement value as per LAA-1894 & National Policy on Involuntary Resettlement. i. One-time cash grant to transfer the structures to new location as per National Policy on Involuntary Resettlement. iii. Transitional period allowance to affected households and businesses as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. iv. Trainings of the affectees for their capacity building as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. v. Preference in employment during construction activities as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. vi. Preference in permanent	a. Payment of compensation for the b. losses c. APs will be fully informed about d. their entitlement and assisted in obtaining it A transfer grant to each household will be paid during or after vacating the project sites Removal cost for commercial structure at the same rate to the owners of structures

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
			employment to the unskilled Labour and technically qualified people in operation and maintenance of the project.	
5	Loss of business by shops/business owners due to dislocation	Owner/operator of the business as recorded by the census survey	i. Business restoration grants to owners, renters and lease holders as per National Policy on Involuntary Resettlement. ii. Illegal landlords occupying the government land/public parks will not be eligible for business restoration grant but illegal shop	a. All persons recorded by the b. census survey Cash grant to be paid after taking possession of land

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
			owners will be eligible for business restoration grant as per National Policy on Involuntary Resettlement. iii. Trainings of the affectees for their capacity building as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. iv. Preference in employment during construction activities as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. v. Preference in permanent employment to the unskilled Labour and technically qualified people in operation and maintenance of the project.	

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
6	Loss of income, employment/work opportunity of full-time/part time workers	Workers of affected business as recorded in the census survey	i. One-time cash compensation as per National Policy on Involuntary Resettlement. ii. Trainings of the affectees for their capacity building as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. iii. Preference in employment during construction activities as income restoration and rehabilitation measure as per National Policy on Involuntary Resettlement. iv. Preference in permanent employment to the unskilled Labour and technically qualified people in operation and maintenance of the project.	a. All persons recorded by the census survey b. Cash grant to be paid after taking possession of land b. c. Involvement of the incumbents in project civil works
7	Impacts on public utilities like piped water supply, electricity, telephone, etc.	Legal owner of the structure(s) with utility services or only the legal owner of the utility services as identified by Land Acquisition Assessment	i. Cash compensation for the utility facilities at reconstruction cost as per LAA-1894 & National Policy on Involuntary Resettlement. ii. One-time cash grant to transfer/re-install the utility services to new	a. Payment of cash compensation for the losses b. Verification of the ownership records c. APs will be fully informed about their entitlement and assisted in obtaining it

Sr. No.	Nature of Loss	Definition of Entitled Person	Entitlements	Implementation Issues
		Report (LAAR)	location as per National Policy on Involuntary Resettlement.	d. A transfer/re-instalment grant for identified utilities to each household/structure owner (renter) will be paid during or after vacating the project sites
8	Adverse impact on the host communities due to relocation of APs during and after the implementation of the project	Affected or host area/village where the APs will relocate	i. Provision for additional civic amenities (roads, tube well for drinking water, community slab latrines, addition to community facilities) as per National Policy on Involuntary Resettlement.	a. Assessment of community needs b. Consult the host population and provision for common property resources c. Implement the mitigation programs d. All affectees are settled on agriculture land and they will shift to their adjacent ownership area, hence no major host population is involved.

Table 8-2 Land Required for the Project Area

S#	Project Component	Land Required (Acres) / Affected			
		Irrigation/ Cultivated	Barren/ Plan	Mountainous	Total
1	Weir and Reservoir Area	11.21	28.17	0	39.38
2	Free Flow Tunnel, Box Channel and Sandtrap	26.28	0	4.13	30.41
3	Adit Tunnel	5.75	0	0	5.75
4	Cut and Cover (Kotkay Khwar)	4.42	0.46	0	4.88
5	Powerhouse/Switch yard, Access Roads, Staff Colony etc	35.04	0	0	35.04
6	Dumping Sites	34.39	0	0	34.39
Total		**117.09**	**28.63**	**4.13**	**149.85**
	Labour Camps, Contractor Offices, etc. (Temporary on Lease)	Will be provided on contractor demand and most probably barren land will be selected for this purpose.			

8.6.2. Impacts of Project Components

The HPP will be constructed on Panjkora River in district Dir Upper of Northern areas of Khyber Pakhtunkhwa province. The Weir site is located near village Darora and Powerhouse is located upstream of the under-construction Koto Hydropower Project near Sahibabad village. The project sites are approachable from Wari, district Dir Upper. The catchment of the Artistic-I HPP lies in the upper region of the Panjkora River, a sub system of a Swat river basin and can be classified as a “high mountain catchment”. About 35.04 acres land will be acquired for the construction of the powerhouse, Staff Colony, offices and residences at powerhouse site for Artistic-I HPP. An additional 8 acres private land will be acquired temporarily, for a period of four years, for the construction of camps, storage of construction equipment and materials.

About 34.39 acres of land will be acquired permanently for dumping sites and 10.64 acres will be acquired temporarily for four years. In total 2010 farm trees will be affected.

8.6.3. AFFECTED LAND AND INFRASTRUCTURE

It will be the responsibility of the contractor to protect and/or restore the affected infrastructure during the course of construction works, to their original condition and to the complete satisfaction of the affected persons or community, as the case may be. The access road needs to be improved before the start of the project implementation.

Compensation Parameters

All the PAPs due to the construction of the different components will be fully compensated for their respective losses. The compensation for different parameters will be as under;

The agricultural land will be compensated, based on DC/ current market/ replacement value to the land owners, plus 15% involuntary land acquisition charges, as provided in Land Acquisition Act (LAA). The crops compensation will be based on the market value of mature crops. If sown or standing crops are damaged or uprooted, the eligible persons will be compensated in cash for the loss of un- harvested crops, at the mature crop value to be assessed on the basis of current market prices, regardless of the title or tenurial status. Compensation for the loss of fruit trees will be based on the value of fruit up to 10 years, to be assessed at the rate of current market prices, regardless of the title or tenurial status. Compensation for the loss of different types of houses, building structures will be based on the cost estimates of the Building Department. The affected persons will also be provided shifting allowance (one time) and livelihood allowance (for three months).

8.6.4. LAND ACQUISITION

Overall, for the execution of the project, total 115.46 acres land will be affected for construction of project components. This land consists of 82.70 acres, 28.63 acres, 4.13 acres agriculture, plan barren and mountainous land, respectively. Additionally, 34.39 acres will be affected due to dumping sites. The details are provided in **Table 8-3**. The affected lands replacement values were computed on the basis of the most recent sale price in the project affected villages and in the adjacent valleys.

8.6.5. TEMPORARY LAND ACQUISITION

The temporarily acquired land will be used for the storage of construction material, parking of machinery, storage of equipment, Labour camps, and contractor offices during the execution of the work. However, additional temporary land will be needed at the powerhouse, weir and adit tunnel sites. Total area for temporary acquisition is estimated as 18.64 acres. This land will be taken on lease for a period of about four years. According to the local rates, the total rent for this land is computed as Rs. 3.58 million for 04 years **(Table 8-4).**

Table 8-3 Showing the Cost of Permanent Land Acquisition

C	Description	Unit	Quantity	Rate/unit (million PKR)	Total Cost (million PKR)
A	**Permanent Land Acquisition**				
i.	**Weir and Reservoir Area**				
1	Irrigation/ Cultivated	acre	11.21	10.40	116.58
2	Barren/ Plan	acre	28.17	7.41	208.63
3	Mountainous	acre	0.00	7.21	0.00
	Total	acre	**39.38**		**319.41**
ii.	**Free Flow Tunnel, Box Channel and Sandtrap**				
1	Irrigation/ Cultivated	acre	26.28	10.40	273.31
2	Barren/ Plan	acre	0.00	7.41	0.00
3	Mountainous	acre	4.13	7.41	30.59
	Total	acre	**30.41**		**303.90**
iv.	**Adit Tunnel**				
1	Agricultural Land	acre	5.75	10.40	59.80
2	Barren/ Plan	acre	0.00	7.41	0.00
3	Mountainous	acre	0.00	7.41	0.00
	Total	acre	**5.75**		**59.80**
v.	**Cut and Cover (Kotkay Khwar)**				
1	Agricultural Land	acre	4.42	10.40	45.97
2	Barren/ Plan	acre	0.46	7.41	3.41
3	Mountainous	acre	0.00	7.41	0.00
	Total	acre	**4.88**		**49.37**
vi.	**Powerhouse Area (including Residential colony)**				
1	Agricultural Land	acre	35.04	10.40	364.42
2	Barren/ Plan	acre	0.00	7.41	0.00
3	Mountainous	acre	0.00	7.41	0.00
	Total	acre	**35.04**		**364.42**
vii.	**Dumping Sites**				
1	Agriculture	acre	34.39	10.40	**357.70**
	Total (A)		**149.85**		**1,460.41**

B	TEMPORARY LAND ACQUISITION				
1	Contractor Camp, Contractor Labour Colony, Contractor Office for 4 years	acre	8.0	0.048/yr/acre	1.54
2	Dumping area required temporarily for 4 years	acre	10.64	0.048/yr/acre	2.04
Total (B)					**3.58**
Total (A+B)					**1,463.99**

Table 8-4 Showing the Cost of Temporary Land Acquisition

Sr. No	Description	Unit	Quantity	Rate/unit (million PKR)	Total Cost (million PKR)
1	Contractor Camp, Contractor Labour Colony, Contractor Office for 4 years	acre	8.0	0.048/yr/acre	1.54
2	Contractor Camp/ Labour Colony for Powerhouse, Power house Colony, etc.	acre	4.0	0.8/yr/acre	12.8
	Total (B)				**3.58**

8.6.6. Affected Trees

Total of 210 farm trees will have to be cut/ removed for clearing the proposed alignments/sites during the execution of different components of project. The plant species of farm trees are Bakin, Ailynthus, Mulberry, Eucalyptus and Robinia. The total numbers of affected trees are 210. **Table 8-5** provides details of the types of the affected trees and compensation will be paid on the basis of current market values of the trees.

Table 8-5 Fruit Trees Falling in Reservoir Area

Trees	Small	Medium	Large	Total
Bakine	55	-	20	**75**
Wild Anar	-	-	7	7
Ailynthus	30	-	27	57
Mulberry	-	-	17	17
Eucalyptus	4		9	13
Robinia	17	13	11	41
Total	**106**	**13**	**91**	**210**

8.6.7. RESIDENTIAL BUILDINGS

A total of 3 pacca houses are falling in the reservoir area on left side of the river which will be requiring resettlement or compensation. The details are provided in **Table 8-6.**

Table 8-6 Details of Residential Structures Falling in the Reservoir Area

Sr. No.	Construction Category	Location	Quantity	Unit Cost	Cost
1	Katcha	Right Bank of the River	0	0	
2	Semi Pacca		0	0	
3	Pacca		0	0	
	Sub-Total		0	0	
4	Katcha	Left Bank of the River	0	0	
5	Semi Pacca		0	0	
6	Pacca		3	2,187,500	6,562,500
	Sub-Total				***6,562,500***
GRAND TOTAL					**6,562,500**

* Construction cost is 1000/square ft, 1500/square ft and 2000/square ft for Katcha, Semi-Pacca and Pacca type of houses respectively

8.7. INSTITUTIONAL FRAMEWORK

8.7.1. GENERAL

PEDO will be responsible for the implementation of the RAP through its Project Director and the field offices, with the collaboration of district government departments. Project Director will make necessary arrangements for the implementation of tasks about environment, afforestation, land and social aspects (EALSA) and to coordinate and monitor the resettlement activities. The concerned government departments will assess the prices; undertake the process of land acquisition, compensation and livelihood rehabilitation. Grievance redress mechanism, internal and external monitoring mechanism will be established to ensure proper implementation of the RAP in an accountable and transparent manner.

8.7.2. IMPLEMENTATION ARRANGEMENTS

PEDO has overall responsibility for the program implementation and financing of all RAP development tasks and cross-agency coordination. The department will exercise its functions as under: There will be a *Program Management Unit (PMU*); The PMU shall be adequately staffed with competent professionals. The staff will be headed by a Project Manager, and include an Environment Specialist, a Resettlement Specialist, a Contract Administration Specialist and a Financial Management Specialist. The PMU will be responsible for the overall planning, management and monitoring of the environment and resettlement program. Environment and Resettlement Specialists: The Environment Specialist and Resettlement Expert/Specialist will provide technical guidance and support to the PMU and field offices on environmental and social issues during implementation. They will supervise the implementation of the RAP. Specific responsibilities will be as under:

i. Coordination for all land management related issues with the Project Director and ensure economic utilization of funds earmarked for land acquisition.

ii. Liaison with the field office on land management and project matters on permanent basis.

iii. Maintain complete record/data of land management and social issues including follow-up of land acquisition disputes and response to petitions/complaints received from general public regarding payment of compensation and other related issues.

iv. Assist the Legal section in court cases concerning land acquisition disputes.

v. Monitoring and reporting of social and environmental issues, compliance during the implementation of the project.

vi. Coordination with all relevant donor missions visiting various components of the project for social / environmental impact review and analysis.

Field Implementation Unit; Two Field Implementation Units (FIUs) shall be set up headed by an Environment and Resettlement Specialist. The units will be overall responsible for the implementation of all EIA and RAP development tasks and cross-agency coordination, and tasked with day-to-day related activities. The Specialists shall be assisted by a Social Safeguards, Health and Safety Supervisor and Dispenser. A Land Acquisition Collector (LAC) – one assigned to the project area– shall acquire land.

Specifically, the Unit will be responsible for Synchronization of resettlement activities with the project construction schedule; Ensure that all eligible APs are identified, provided with their respective entitlements according to the resettlement policy and are relocated/ compensated as per the implementation schedule and with minimum hardships;

Liaison with the Revenue Offices regarding timely acquisition of land required for the project and payment of compensation, and to ensure that these activities are completed as per schedule;

a. Negotiate with contractors for arranging employment for APs in the construction works.

b. Ensure all the environment related issues in the field during the construction works.

c. Ensure health and safety related issues in the field during the construction works.

d. Monitor the Labour camps, machinery, quarry sites and borrow areas.

8.7.3. DISTRICT AND PROVINCIAL GOVERNMENTS

District-based agencies have the jurisdiction for land administration and compensation and for the compensation/rehabilitation of other affected assets. DOR and several other staff members of the Revenue Department, most notably the Tehsildar, Patwari, and record keeper carry out specific roles such as title identification and verification of the ownership. The compensation rates will require approving by and in turn confirming by the Board of Revenue Office at state level.

DOR has a key role in the implementation process. He/she has the legal responsibility of acquiring land and paying compensation directly to the APs as per Land Acquisition Act. To facilitate PEDO as well as the APs in the project area, there will be a Land Evaluation Committee under the chairmanship of LAC/DOR. The other members of the committee are Project Director, Resettlement Specialist, District/Tehsil Council Chairman and at least three representatives of affectees. The Office of the District Council Chairman (the elected district head) is expected to play a coordinating role and will represent the rights of the local citizens. The affectees, representatives in each area will also be associated in implementation and monitoring of the RAP along with the government departments involved in the RAP development and implementation.

8.7.4. Contractors

The construction contractors will also nominate one liaison officer to coordinate with the project implementation unit (PIU) and other relevant offices on matters related to possible impacts occurring during the project implementation, and to coordinate on employment opportunities for the APs in the construction works. His key roles and responsibilities are to collaborate with the PIU and the Implementation Consultants in the following activities:

a. Verify the loss of infrastructures and other assets of APs due to project implementation and ensure their compensation;

b. Determine/review the replacement cost for all kinds of loss occurred;

c. Hold consultation meetings with the affected people.

8.8. LIVELIHOOD RESTORATION AND IMPROVEMENT PLAN

8.8.1. General

The objectives of livelihood restoration program are to restore the long term income generating capacity of affected households, improve the livelihoods of vulnerable households and to mitigate the short term income losses that may be experienced through subsistence support. Households experiencing severe impacts on their productive assets or livelihoods will be entitled to participate in the income restoration program. The forms and levels of income restoration assistance vary and will be commensurate with the duration, level and severity of impacts on livelihoods and productive assets as well as vulnerability of the affected persons. The project will also seek to maximize project related work opportunities to those affected by land acquisition. Opportunities to improve the livelihoods of women will also be mainstreamed in various project initiates, including in the income restoration program of the resettlement plan.

8.8.2. Rehabilitation of APs

Entitlement provisions for the PAPs losing their land, crops and income losses, rehabilitation include provisions of a livelihood disturbance allowance, and vulnerability allowance for the poor people whose income falls below the Poverty Line. In addition, to avoid the disturbance of livelihood, compensation will be given as per replacement cost of lost assets without deduction of any item salvaged and without any depreciation costs.

8.8.3. OWNERS OF PRIVATE LAND

The owners of private land are entitled to cash compensation for the loss of their land on replacement cost basis. The land will be acquired through the LAA, 1894. PEDO is responsible for disbursing all compensation payments, before the land is taken into custody. In addition, getting the vulnerability allowance (one-time cash allowance equal to Rs 15000 /-) in case their income is below the poverty line. The allowance is equal to per month minimum wage rate fixed by the government.

8.8.4. OWNERS OF STANDING CROPS

The damage caused to standing crops as a result of construction activities will be assessed and will be included in the land awards for payment to cultivator. The unit value of such compensation is assessed based on the current market value of the cultivated crop, i.e., their production and value at current prices. In addition, vulnerability/poverty allowance (one time cash allowance equal to Rs 15000 /-) as their income is below Poverty Line.

8.8.5. OWNERS OF TREES

The owners of timber trees will be compensated as per forest department nominated rate.

8.8.6. ADDITIONAL ASSISTANCE FOR IMPACT SEVERITY/VULNERABILITY

Affected households whose per capita income is below the poverty line will be provided Rs.15000/– (equal to 03 months amount of government fixed per month minimum wage rate).

8.8.7. LIVELIHOOD SUPPORT INTERVENTION MEASURES

The categories of affected livelihood are identified with appropriate income restoration measures based on client policy.

Following activities will be focused for the long-term strategy;

- Provision for the job opportunities that will be generated by the project on temporary or permanent basis.
- Provide the training on the use of latest agricultural practices to get the more agriculture product.
- Linking livelihood support for vulnerable affected households with income below poverty line.

However, for short term, all Affected Families whose livelihoods are affected will be supported for their income losses @ Rs. 15000/- onetime cash assistance equal to per capita household income of three months. In addition, there will be provision in the contract of civil works contractor to provide the job to affected families on priority basis,

8.8.8. SPECIAL MEASURES TO SUPPORT VULNERABLE GROUPS:

Vulnerable APs will be given priority for project–related employment opportunities as drivers, clearing and digging work, and if possible, as clerks or basic administration support staff. To this end, the PEDO will include clause in the contracts of the civil works contractor that they will give preference to vulnerable in recruiting personnel, skilled and unskilled labor for project related works. The compliance to this effect will be presented regularly in the internal monitoring reports.

8.9. INFORMATION DISCLOSURE, CONSULTATION AND PARTICIPATION

8.9.1. GENERAL

This chapter describes the project stakeholders and their views towards the Project and the process adopted in consulting affected households and communities on relocation and resettlement, impacts assessment, socio-economic and physical losses due to construction and compensation.

8.9.2. CONSULTATION WITH STAKEHOLDERS

Consultation and dialogue with stakeholders including PAPs is very critical for successful resettlement and/or compensation of the affected assets. The process of consultations will continue until implementation of the RP is completed. In the process of preparing this RP, extensive consultations were undertaken with the PAPs to update existing information. During these consultations the communities were encouraged to (i) be open and voice their concerns and claims; (ii) be free to access the formally established grievance process for lodging Complains; and (iii) allow and give the necessary assistance to the M&E team. In finalization and preparation of the payment schedules and actual payment, PEDO personnel will continue to conduct a series of consultations and counseling of the affected persons.

The processes and mechanisms of consultations project affected persons and other stakeholders are detailed in the RP, included an **Annexure 2** with the list of participants, the location, date and minutes of consultation meetings.

Table 8-7 Consultations with Stakeholders – Tasks and Purposes

Task	Purpose of Consultation with Stakeholders in Grid station Project
Why consultation with the stakeholders?	• To build trust to ensure sustained support for the Project and build resilience for times of crisis. • To learn about public concerns that need to be addressed and taken into account in designing of the project concept and preparation mitigation measures and programs • To learn about the strengths, skills and organizations that the stakeholders can bring to support project planning and implementation.
Modes and benefits of consultation	• Listening and dialogue with stakeholders to keep the project at tuned to public concerns early, to pre-empt breakdowns in public confidence • Engaging the public as advocates for the project construction and to support the implementation of social, resettlement, and environment and health programs.

8.9.3. STAKEHOLDERS IN PROJECT AREAS

Project stakeholders – both primary and secondary – include the project affected persons and beneficiaries in the project and other related government departments/agencies, district administration, the local governments, civil society members, consultants and project advisors.

Table 8-8 Primary and Secondary Stakeholders

Type of Stakeholder	Stakeholder's Profile
Primary Stakeholders	All project affected persons, households, communities, project beneficiaries; and project APs – for instance, residents of the project area.
Secondary stakeholders	Project owner/other related departments/agencies of the Government of Pakistan, civil society members, consultants and project advisors

8.9.4. CONSULTATION FRAMEWORK USED IN THE PROJECT

The guiding principle underlying consultations is that the social safeguards planning and implementation must follow a consultative and participatory process to ensure success of the project.

Table 8-9 Frameworks for Consultation

Legal/Policy Sources	Regulations/Safeguard Policy Requirements
Government of Pakistan	• Land Acquisition Act (LAA)1894 requires disclosures (i.e., under/4 – publication of preliminary notification; under Section /5A public purpose and hearing of objections • Pakistan Environmental Protection Agency (PEPA) Regulations, 2000 • Environmental Protection Agency (EPA) 1997 Guidelines for Public Consultation requires public consultation and involvement in project planning and implementation. The policy and procedures require proponents to consult with affected community and relevant NGO during preparation reports. The guidelines contain a number of references to the need for Public involvement.

The consultation and participation adopted include: (i) a public participation and consultation mechanism established in the early scoping stage for effective public participation (ii) fair compensation rates formulated through extensive consultations in transparent manner ensuring smooth implementation of relocation and income rehabilitation;

8.9.5. APPROACH ADOPTED FOR CONSULTATIONS

Public consultations and information disclosure sessions continued during different time periods in the affected village. The affectees were informed well in time regarding the time and venue, at least one day prior to meeting and successive follow up including telephonic calls to local people. Meetings were held in an open encouraging atmosphere where affectees expressed their concerns and views freely.

Meetings were held through scoping sessions, focused group discussions and individual interviews with men and woman. Specific objectives of the public consultation were to:

- Share information with affected persons about the Project, its activities, latest interventions in project development;
- Elicit the views of PAPs about land acquisition and compensation process.
- Disseminate the impacts of the project in terms of land acquisition, people affected and measures proposed to minimize the impacts, entitlements, eligibility and community access over the grievance redress mechanisms;
- Obtain the co-operation and participation of the affectees in the resettlement planning and implementation process;
- Ensure transparency in all the project activities through sharing information; and

- Increase public confidence about the Project proponent, reviewers and decision makers.

These meetings proved very useful in information sharing and group consultation and consensus building. Concerns raised during the village meetings were incorporated in the RAP.

8.9.6. PAP'S CONCERNS AND MITIGATION MEASURES

During the consultations, people were asked about their views regarding the proposed project. In general, people have positive thinking/ view and good hopes about this project to reduce the shortage of electricity and provision of jobs to local people of the area. However, some issues/ concerns and feedback were also highlighted during the process of consultations with the PAPs/ communities and general public, summarized in **Table 8-10.**

Table 8-10 Summary of PAPs Concerns and their Address

Sr. No.	Concerns	Responses Provided	Responsibility
1	Land price should be announced before land acquisition	PEDO is working with local government to finalize the compensation and rehabilitation package, once it is finalized, will be shared with all the APs. However, the compensation rates will be as per market basis.	Land Acquisition Collector (LAC), RO & PEDO
2	Without title of land would affect persons will be paid compensation	Non-titled affected persons will be compensated.	LAC, RO & PEDO
3	What rates will be adopted for compensation to the land owners.	Compensation will be given as per replacement cost basis.	LAC, RO & PEDO
4	From where will the labor/ workers be hired during the construction phase.	Local people will be provided employment during construction stage. For this purpose, contractor will be bound by a clause in contract documents to hire the local	PEDO & Construction Contractor

Sr. No.	Concerns	Responses Provided	Responsibility
		labor during construction phase. This will be monitored through internal monitors. However, in case of several candidates for a job, merit will be followed strictly.	
5	Fair compensation as per market price should be given to all the PAPs.	PEDO is working with local government to finalize the compensation and rehabilitation package, once it is finalized, it will be shared with all the PAPs.	PEDO, LAC & RO
6	Who should we contact in case of any complaint/ objection?	The GRC will be established for complaint resolution and PAPs will be given the representation in the GRC and they can contact to their representatives in case of any grievance.	PEDO
7	When will payments be made for the lost assets.	Payments will be initiated once the land revenue record and field measurements are completed.	LAC&PEDO
8	Electricity should be distributed to the Project Area	PAPs will get their share proportionately as compared to national level.	PEDO
9	Transparent and fair compensation procedures should be adopted	Effective monitoring mechanism will be introduced to make the compensation process more transparent and PAPs representative will be a part of this process. Monitoring report will be prepared periodically and in case of non-compliance, correction action will be proposed/implemented for immediate remedial measures.	PEDO
10	Consultation process should be	Meaningful consultation and informed consultation and	PEDO

Sr. No.	Concerns	Responses Provided	Responsibility
	continued throughout the project cycle	information disclosure will be carried out. The issues along with the proposed measures discussed during the meetings will be documented.	
11	Vocational Training especially on embroidery work should be provided to local women for income generating	PEDO will work with concerned department/NGOs for the provision of vocational training. In addition, a resource person will be hired for these trainings and will be provided periodically	PEDO
12	Chances of some environmental effects like noise/ vibration and dust emissions to the nearby community	The contractor will be bound to implement the measures in this regard by putting clause in his contract	Contractor & PEDO
13	Local people's movements should not be hindered during construction stage	Alternate routes will be adopted for smooth movement.	Contractor & PEDO
14	Basic necessities of life, Gas, school, health centers and roads should be provided by the project	PEDO will take up the issue with the concerned department including deputy commissioner	PEDO & concerned departments
15	Existing infrastructure like road, routes and water channels should not be disturbed	PEDO will ensure with the design consultant for the restoration of infrastructure	PEDO & design consultant

8.9.7. PAPs Feedback

PAPs were generally satisfied with the compensation rates provided these are based on market values of the land and other assets. However, their feedback is discussed below;

- They are happy if the compensation is made on market rates and PEDO should not deviate from market rates during compensation payment.
- PAPs representative in the RP implementation committee will provide them easy access to grievance redress.
- Educated males and females are jobless; it will be great help for them if they are recruited under the project.
- Alternates routes are important prior to the commencement of civil work, otherwise their routine activities will be severely affected.

8.9.8. Disclosure of RP

For transparency in RP implementation process and for further active involvement of PAPs and other stakeholders, information will be disseminated through disclosure of RP document. The RP will be available on the websites of PEDO for disclosure purpose.

The following steps will be undertaken for the disclosure of RP;

- The draft RP will be disclosed to PAPs.
- An information booklet containing a summary of PAPs and compensation will be prepared specifically for this purpose. This information booklet will be translated into Urdu and distributed to all Project Affected Persons. This will enable the PAPs to be aware of their entitlements, unit rates of compensation/income restoration and rehabilitation assistance and payment procedures available for various types of APs as given in the ‘entitlement matrix’. In addition, the information regarding the grievance redress mechanism will be reflected in the booklet.
- After approval, the RP will be translated into Urdu by PEDO and disclosed to PAPs and other stakeholders by the Project Office through PMO.
- RP will be disclosed to women through a meeting by female staff. Both version of RP (English and Urdu) will be available at the offices of Project Director, Contractor, and Revenue Department as an official public document.
- A schedule explaining the date, time and venue for disbursement of compensation through cheques will be prepared in Urdu and distributed to all PAPs.

8.9.9. GRIEVANCE REDRESSAL MECHANISM

A Grievance Redressal Committee (GRC) will be constituted, which will look into all the grievance cases. This GRC will be composed of the representatives of (i) District Revenue Officer; (ii) PEDO (iii) Management Consultants (iv) Contractor and the (v) Affectees' Representatives. The main objective of the grievance redressal mechanism shall be to investigate charges of irregularities and complaints received from the affectees and provide an early, transparent and fair resolution. The Environment and Resettlement specialist will be assigned to maintain a community complaints-management register to record grievances brought forward by the affected person/communities, and ensure that these are appropriately addressed. Main objective of the grievance redress procedure will be to provide a mechanism to mediate conflicts and cut down on lengthy litigation, which are often observed to be sources of delays of such projects. It will also provide a forum of people who might have objections or concerns about their assistance and address these issues adequately.

8.9.10. COMPLAINTS AND GRIEVANCES

A grievance redress mechanism (GRM) will be available to allow an AP appealing any disagreeable decision, practice or activity arising from land or other assets assessment, acquisition, compensation and other environment issues. APs will be fully informed of their rights and of the procedures for addressing complaints whether verbally or in writing during the consultation, assessment survey, at the time of compensation and during the construction phase. Care will always be taken to prevent grievances rather than going through a redress process. This can be obtained through careful Land Acquisition Resettlement (LAR) design and implementation, by ensuring full participation and consultation with the APs, and by establishing extensive communication and coordination between the community, the Project Management, the LAC and local governments in general.

8.10. RESETTLEMENT BUDGET AND FINANCING

8.10.1. GENERAL

This section provides the indicative compensation cost for land acquisition and rehabilitation of the affectees. Efforts were made to work out realistic cost estimates/values that lead to fair compensation based on current market rate to the PAPs. For this purpose, concerned Government Departments i.e. Forest, Revenue and Agriculture were consulted; subsequently, market surveys were carried out in order to reach the market-based unit rates to be paid to the APs for affected land and crops. Subsequently, the total resettlement and rehabilitation cost worked out is Rs 1,705.29 Million.

8.10.2. RESETTLEMENT FUNDS

LAR preparation and implementation costs, including cost of compensation and LAR administration, will be considered an integral part of Project cost. Each RAP will include a budget section indicating (i) unit compensation rates for all affected items and allowances, (ii) methodology followed for the computation of unit compensation rates, and (iii) a cost table for all compensation expenses including administrative costs and contingencies.

Finances for compensation, allowances, and administration of RP preparation and implementation will be provided by the Government as counterpart funds. Costs for external monitoring tasks can be allocated under the budget. In order to ensure that sufficient funds are available for LAR tasks, the local governments will have to allocate 100% of the cost of compensation at replacement cost and expected allowances estimated in RP plus 5% of contingencies before LARP implementation.

Being the project sponsor, M/S Artistic Hydro I (Pvt.) Ltd. is responsible for the timely allocation of the funds needed to implement the RP. Allocations will be reviewed twice a year based on the budget requirements indicated by the RP.

As per the flow of LAR finances, it is noted that the budget for land and crop compensation will be disbursed by PEDO to the District Collector Office which in turn, through the LAC will disburse the compensation to the APs. For what concerns compensation funds for other items such as documented structures (houses), employment, income loss, etc. will go from PEDO to the PMU which will disburse the funds to the APs with assistance from the PIU.

8.10.3. METHODOLOGY FOR DETERMINING UNIT RATES AND COMPENSATION AMOUNT OF AFFECTED LAND AND OTHER ASSETS

The general methodology of assessment of compensation rates of different items is as follows:

- Compensation for Land and Assets: The rate of compensation for acquired housing, land and other assets will be calculated at full replacement costs.
- The calculation of full replacement cost will be based on the following elements: (i) fair market value; (ii) transaction costs; (iii) interest accrued, (iv) transitional and restoration costs; and (v) other applicable payments, if any.
- Where market conditions are absent or in a formative stage, PEDO will consult with the displaced persons and host populations to obtain adequate information about recent land transactions, land value by types, land titles, land use, cropping patterns and crop production, availability of land in the project area and region, and other related information.

8.10.4. Unit Rates of Land

Land is acquired through private negotiation. The private negotiation committee of PEDO and the representatives of the project affected persons mutually agreed on the average rate of Rs. 1.3 million/kanal (agricultural land) and Rs 0.925 million/kanal (barren land). Total 936.8 kanals of agricultural land and 262.1 kanlas of barren land will be acquired permanently while 149.1 kanals will be aquired temporarily for four years at the rate of 0.006 million/year/kanal during construction period of the project. Hence, based on the unit cost, the total land compensation worked out at Rs 1,463.99 Million.

8.10.5. Unit Rates of Crops

The cropping pattern of the Project area is comprised of wheat and maize. Per acre net income from these crops obtained through the socio-economic survey, have been used for the compensation of affected crops in the Project Area. The rates of crops will be calculated by Agriculture department (if applicable).

Total 38.15 acres of wheat crop are cultivated in the affected land. Based on the unit cost for four years, the total crop compensation worked out is Rs 2.86 Million. The rates are obtained from the Agriculture department.

8.10.6. Tree compensation

A total of 210 farm trees will affected due to project and compensation payment will be paid as per market value. The rates of wood trees can also be obtained from the forest department.

8.10.7. Housing Compensation

A total of 3 residential structures will be dislocated due to proposed project and compensation worked out at PKR 2,187,500 per house. The rates of pucca and Kacha Structures were obtained from the market and verified by the Building and Repair department.

8.10.8. Livelihood Disturbance Allowance

There is provision of livelihood disturbance allowance for the affected households whose livelihood was entirely dependent of agriculture and no other source of income. There are total 3 affected households who have single source (Agriculture) of their livelihood. Hence, these APs will be paid one time cash allowance of Rs. 15000/- per household.

8.10.9. SHIFTING ALLOWANCE

There is a provision of PKR 6000/- allowance for shifting of each affected household in the project area.

8.10.10. TRAINING COST

A lump sum amount of PKR 2.86 million is placed in the resettlement budget to enhance the livelihood restoration program. The amount will be utilized to arrange the training events on periodic basis.

8.10.11. MONITORING AND EVALUATION

Monitoring and evaluation of the RP implementation process will be required through proper setup of internal and external monitoring. For this purpose a sum of Rs 74.84 Million @ of 5% of the total cost) is provided in the budget estimate.

8.10.12. ADMINISTRATIVE COST

Administrative cost for the implementation of the RP is also required and provision is made in the budget @ 1% of the total cost i.e. Rs 15.72 Million.

8.10.13. CONTINGENCIES

Contingencies cost amounting to Rs 117.88 Million @ 7.5% of the total cost has been added in the budget to cover unforeseen items that may be may required during implementation of RP.

8.10.14. TAXES

There is no taxable item in the compensation package for the affectees; therefore, no tax either from Provincial or Federal Government is applicable.

8.10.15. SUMMARY OF BUDGET

The total requirement of funds for compensation payments, restoration and rehabilitation measures amounting to Rs 1,705.29 Million is given in **Table 8-11.**

Table 8-11 Summary of Cost

S. No	Description	Quantity/Total Number	Unit	Unit/Rate (Rs.) million	Total Cost (Rs.) million
1	Permanent Land Acquisition				
1.1	Agriculture Land Compensation	117.09	acres	10.4	1,217.78
1.2	Baren Land Compensation	32.76	acres	7.41	242.63
2	Temporary Land Acquisition for camps, offices, dumping sites etc	1	L.S	3.58	3.58
3	Crop Compensation (Wheat Crop)	38.15	acres/yr	0.075	2.86
4	Pucca House	3	No	2.19	6.56
5	Corporate Social Responsibility (CSR)	4	year	5	20.00
6	Trees	210	No	0.002	0.42
	Plantation	2100	No	50	0.11
7	Livelihood Allowance	3	Family	0.015	0.05
9	Shifting	3	Family	0.006	0.02
10	Training Cost		Lump sum	-	2.86
11	Monitoring and Evaluation @ 5% of the Total Cost		Lump sum		74.84
	Subtotal				**1,571.70**
10	Administrative Cost @ 1% of the Total Cost		Lump sum		15.72
11	Contingencies @ 7.5% of the Total Cost		Lump sum		117.88
	Grand Total				**1,705.29**

8.11. MONITORING AND EVALUATION

This section aims to demonstrate how and why resettlement plans are monitored and evaluated. It defines the key terms and suggests methods for conducting resettlement monitoring and evaluation.

8.11.1. RESETTLEMENT MONITORING

Resettlement monitoring means the collection, analysis, reporting and use of resettlement monitoring information about the progress of resettlement, based on the Resettlement Action

Plan. Monitoring focuses on physical and financial targets and the delivery of entitlements to people affected. Monitoring is usually conducted internally by the executing agency, sometimes with assistance from external monitoring specialists. Reports are usually passed on to the client.

8.11.2. Resettlement reviews

Resettlement review take place regularly and at key points in the project cycle, for resettlement reviews example at mid-term. During review, project decision makers gather together with key stakeholders to assess resettlement progress. Reviews draw upon monitoring and evaluation reports and other data. On this basis the reviewers reach consensus and decide upon any action needed to improve resettlement performance or respond to changing circumstances. Client staff may participate in such reviews, especially for large-scale resettlement efforts.

8.11.3. Resettlement evaluation

Resettlement evaluation takes place during and after implementation. It assesses resettlement evaluation whether the resettlement objectives were appropriate and whether they were met, specifically, whether livelihoods and living standards have been restored or enhanced. Evaluation assesses resettlement efficiency, effectiveness, impact and sustainability, drawing lessons as a guide to future resettlement planning. Evaluation differs from monitoring because of its broader scope, its less frequent timing, and its involvement of independent specialists. It is usually conducted externally. Evaluation provides a golden opportunity for resettlement planners and policy makers to reflect more broadly on the success or otherwise of basic resettlement objectives, strategies and approaches.

8.11.4. The Resettlement Monitoring and Evaluation Plan:

PEDO for the project is responsible for organizing and resourcing monitoring and evaluation efforts. The RP will specify the details of the arrangements for M&E, including: i) Allocation of responsibilities for monitoring and evaluation within the resettlement unit or agency. For large-scale resettlement a special M&E unit or group is desirable. For resettlement involving different agencies or levels of government a coordination plan is necessary; ii) Responsibilities for specific tasks, including data collection, data analysis, verification, quality control, coordination with related agencies, preparation of reports, submission of reports to decision maker, responsibility to review and act on reports; Method to be used to collect and analyze data; iii) Resources required for field survey work and for record keeping, including the provision of specialists in sociology, social anthropology and resettlement as specified in the client policy; iv) Any requirements to build the capacity and skills in monitoring and evaluation, including a training plan and budget; v) Time frame for data collection efforts, report preparation, and submission; and vi) Budget for monitoring and evaluation.

8.11.5. NEED FOR MONITORING AND REPORTING

The RM tasks will be monitored internally and externally. The NDTC will carry out internal monitoring (IM) of RP through Resettlement Unit (RU). The external monitoring will be assigned to an Independent External Monitoring Consultant, hired by PEDO with the concurrence of Donor for monitoring of RP implementation. The Independent Monitoring Consultant will be mobilized prior to RP implementation. The extent of monitoring activities, including their scope and timing, will be commensurate with the project risks and impacts. The RU is required to carry out the safeguard measures and implement relevant plans as provided in the legal agreements. Internal Monitoring Reports will need to be prepared monthly, quarterly and annually for the project mentioned in the RP.

Establish and maintain the monitoring of the LAR tasks aim to:

i) procedures to monitor the progress of the implementation of safeguard plans.

ii) Verify their compliance with safeguard measures and their progress toward intended outcomes.

iii) Document and disclose monitoring results and identify necessary corrective and preventive actions in the periodic monitoring reports,

iv) Follow up on these actions to ensure progress toward the desired outcomes,

v) Retain qualified and experienced external experts or qualified NGOs to verify monitoring information for projects with significant impacts and risks,

vi) Submit periodic monitoring reports (monthly, quarterly and annually) on safeguard measures as agreed.

8.11.6. INTERNAL MONITORING

Internal monitoring (IM) will be carried out by the RU. IM indicators will relate to process, outputs and results, information will be collected directly from the field, and will be reported monthly to the PMU to assess the RP implementation progress and adjust the work plan if necessary. Specific IM benchmarks will be based on the approved RP and cover the following:

i) Information campaign and consultation with PAPs;

ii) Status of land acquisition and compensation payments

iii) Compensation for affected structures and other assets;

iv) Relocation of APs;

v) Payments for loss of income;

vi) Selection and distribution of replacement land areas;

vii) Income restoration activities;

viii) Grievance redress status and

ix) Ensure the gender mitigation measures in the RP are adhered to during the internal monitoring and reporting process.

The above gender disaggregated information will be collected by the PMU which will monitor the day-to-day resettlement activities of the project through the following instruments:

i) Review of project information for all PAPs;

ii) Consultation and informal interviews with PAPs;

iii) Key informant interviews; and,

iv) Community public meetings.

8.11.7. External Monitoring and Evaluation

PEDO will appoint an independent agency for external Monitoring to ensure complete and objective information. Post-evaluation of resettlement is an integral part of the project cycle. Independent evaluation can be done by an outside research or consulting agency, university department or development NGO. The tasks of the external agency are to:

i) Review and verify internal monitoring reports prepared by Resettlement Unit;

ii) Review of the socio-economic and census and inventory of losses baseline information of pre-displaced persons; update the baseline data if required;

iii) Identification and selection of impact indicators;

iv) Impact assessment through formal and informal surveys with the affected persons;

v) Consult PAPs, officials, community leaders for preparing review report;

vi) Assess the resettlement efficiency, effectiveness, impact and sustainability, drawing lessons for future resettlement policy formulation and planning;

vii) Ensure the gender mitigation measures in RPs are adhered to during monitoring.

The external monitoring will also assess the reporting of affected vulnerable groups such as, disabled/elderly, the landless and families below the poverty line. The following will be considered as the basis for indicators in monitoring and evaluation of the project:

i) Socio-economic conditions of the PAPs in the post-resettlement period;

ii) Communications and reactions from PAPs on entitlements, compensation, options, alternative developments and relocation time tables etc;

iii) Changes in housing and income levels;

iv) Rehabilitation of squatters, severely affected people, and different vulnerable groups;

v) Valuation of property;

vi) Ability to replace lost assets;

vii) Disbursement of compensation and other entitlements;

viii) Level of satisfaction of PAPs in the post resettlement period;

ix) Quality and frequency of consultation and disclosure; and

x) Grievance procedures.

Based on the external monitor's report, if significant issues are identified, a corrective measurement plan will be prepared, reviewed and approved by Client and disclosed to project affected persons. Internal and external monitoring and reporting will continue until all Resettlement activities have been completed.

8.11.8. REPORTING

The external expert will submit an external monitoring report to PEDO and directly to Donor on quarterly basis. The report should summarize the findings of External Monitor, including: (i) progress of resettlement plan updating and implementation; (ii) identification of problem issues and recommended solution so that implementing agencies are informed about the on-going situation and can resolve problems in a timely manner; (iii) identification of specific issues related to vulnerable displaced households, as relevant; and (iv) a report on progress of the follow-up of issues and problems identified in the previous report.

The monitoring reports will be discussed in a meeting between the Independent Monitor, the PEDO and PMU held after submission of the reports. Necessary remedial actions will be taken and documented.

8.11.9. DISCLOSURE

All the monitoring reports will be translated and disclosed as per Approved involuntary resettlement policy and monitoring reports will be publically open and placed on the PEDO and donor websites.

8.11.10. TORs OF INDEPENDENT MONITORING CONSULTANT

The Independent Monitoring Consultant will identify the field verification, any gaps in the resettlement baseline data and suggest steps to update the data. Review and verify the effective implementation of Resettlement Action Plan according to requirements of the Resettlement Framework and approved RP. Monitor and assess whether resettlement objectives, particularly livelihoods and living standards of the Affected Persons (APs) have been restored or enhanced. Overall objectives of the External Monitoring Consultant is to provide high level and professional independent advices and guidance to support PMU objectivity and ensure safe, economical, state-of-the-art construction/installation, and quality assurance/quality control procedures for successful implementation of the Project.

CHAPTER 9: CONCLUSION AND RECCOMENDATIONS

9.1. CONCLUSIONS

The Environmental Impact Assessment (EIA) of Artistic-I Hydropower Project has been prepared in the light of the Pakistan / KP EPA requirements and the project has been classified as a “Schedule II Project”. According to the World Bank (WB) and Asian Development Bank (ADB), it is also ‘A Category Project’ and requires the preparation of a full EIA. There are no environmentally sensitive or protected areas likely to be impacted by this project. Similarly, there are also no threatened or endangered flora and fauna species in the area. The cost of resettlement is based in accordance with the guidelines, objectives and policies made by Pakistan EPA, WB/ADB.

The Project will have no potential adverse impacts that cannot be managed by adopting appropriate and timely mitigation measures, as discussed in EIA. Most of the identified adverse impacts can be mitigated as per the proposed mitigation measures. It can be ensured that by adopting the proposed mitigation measures effectively and timely, out of the affected persons, no one is worse off due to the construction of the project than his pre-project situation.

The Study also reveals that some moderate to significant negative environmental impacts are likely to occur due to the construction activities with few minor impacts during operations after the proposed construction. Recommendations are made to mitigate expected negative impacts. Implementation of appropriate mitigation measures during the construction and operation phases will minimize the negative impacts of the Project to acceptable levels. The Project will have an overall beneficial impact and any negative environmental impacts will be carefully monitored and mitigated. Therefore, the completion of this EIA fully meets the EPA standards. The construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

The Project is environmentally feasible, economically beneficial particularly when it is compared with the other alternatives of power generations like thermal, nuclear, gas, coal, etc. These power plants use non renewable energy sources that emit greenhouse gases, which pollute the environment resulting in health hazards especially to the surrounding population. Alternative sources of power generation like solar and wind power are still technologically and economically not suitable for large scale power generation.

9.2. RECOMMENDATIONS

- Based on the data collected during the focus census survey, discussions with the stakeholders and public consultation, there are no potential adverse environmental impacts that cannot be mitigated including the environmental water requirement releases for the downstream population and ecology.
- By following appropriate and timely mitigation measures for the identified adverse impacts, there will be a major improvement in the socio-economic conditions of the residents of the project area.
- The project will assist the national economies of KP and Pakistan.
- The project should be implemented as planned for achieving the envisaged benefits and sustainable development of the country.
- To ensure that mitigation measures are implemented, the measures shall be included in the contract specification of the project.
- Site specific environmental management/monitoring plan should be prepared by the contractor using feasibility EMMP guidelines for better environmental compliance.
- During construction, a close consultation with the local stakeholders i.e. community is highly recommended for their cooperation and to resolve issues; if come under consideration.
- A fish ladder is recommended for passage of fish in the river and must ensure recommended ecological flow in the river.
- Watershed development in the up-land with the help of NGO’s and the community focusing on sustainable development approach and to enhance their livelihood is highly recommended.
- There should be a proper supervision for the environmental management, maintain health and safety with monitoring plans to enhance the project benefits.

Corporate Social Responsibility (CSR):

In the current project under the CSR umbrella, Artistic Hydro-I will provide medical facilities to the local community. The Artistic Hydro-I will establish a medical dispensary in the project area for their workers. In the same medical dispensary, medical service will be provided to the local community. However, for local community, these facilities will be available for five (5) days per week i.e. from Monday to Friday. While, for labours, 24 hours and 7 days a week (24/7) medical facility will be provided. Each year, a budget of Five (5) million Pakistani Rupees will be provided in the head of CSR. This budget will include the medicine and salary of the Medical staff as well. For the medicines, PKR 2 million will be provided every year, while PKR 3 million will be given to the Medical staff as salary which is tabulated in the following **Table 9-1**.

Table 9-1 Budget Allocated for the Medical Facility

Particulars	Amount (PKR)/year	Justification
Medicines	2,000,000	Life Saving & General Medicine
Medical Staff	3,000,000	Medical Staff Salary