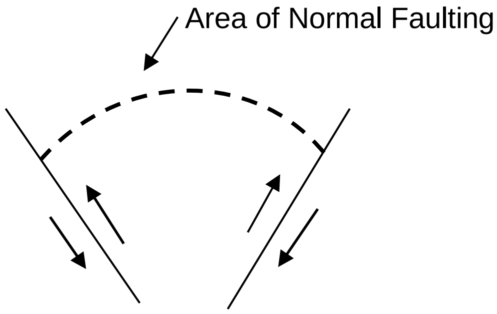


Figure 6-1 Development of Normal Faults under compressional regime.

6.4.2 Road section from Murradabad to Hussani Village:

Coordinate

N	4033080.557m
E	489417.275m
Ele.	2656.69 m a s l

Just upstream of Hussani village a large mass of ABGM and Brecciated rock is exposed along the road. It is present in the alignment of thrust fault where crushed marble is in contact with Passu Slates. The faulted contact between slate and marble is well exposed along road **(Photo 6-6)**.

Photo 6-6 View of Brecciated Rock Upstream of Passu Village.

In this area two faults are intersecting each other, one is striking N60°E and dipping 40°NW while other is striking NW and dipping NE **(Vol-2, DWG-1335)**. Due to these faults discrete hillocks have formed with thin overburden overlain by fault breccia. At few feet away from breccia, a slided material consist of ABGM is present along road. Apparently this material seems to be stable but in excavated portion, this material is folded. Compressional forces are responsible for this deformation exposed at slope **(Photo 6-7)**.

Photo 6-7 View of Folded ABGM Just Upstream of Passu Village.

Photo 6-8 Change of Dip along Shear joint.

Rock (Passu Slates) is locally folded, some shear joints along which the cleavage plane (originally bedding planes) across shear joint has different dip values. The overall strike of slates is NW and Dipping in NE. but along this shear joint some movement took place and the value of dip changes from SW to NE **(Photo 6-8)**. Change of sense of dip along the shear joint shows that some shear forces are active in the area. The development of such joints indicate the brittle deformational style.

6.4.3 At Sarat Village:

Coordinates:

N	4018254.850m
E	481549.816m
Ele.	2371.35m a s l

Due to Salmanabad slide in 1858, a large lake developed in upstream reaches. The depositional clayey silt can be seen on both bank of Hunza River. Due to operational neo-tectonic forces, deformation including folding, jointing, micro faulting has been developed in these deposits.

Both vertical and oblique joints can be seen in clayey silt at right side near Sarat suspension bridge. The strike and dip values of vertical and oblique joints are N38°W/87°NE and N32°E/63°SE respectively **(Photo 6-9)**.

Photo 6-9 View of Vertical and Oblique Joints in Clayey Silt at Sarat Village.

Clayey silt beds are striking N 80°E and dipping 18°NW at the left side of road to Sarat Village while at the right side of the road these beds have strike N 32°E and dipping 9°SE **(Photo 6-10 & 6-11)**.

Photo 6-10 Tiltness in Clayey Silt Beds, Left Side of Road at Sarat Village.

The strike of the beds is NE while the dip is in opposite direction, indicating that it forms some sort of antiform. Formation of antiform in recent deposits clearly indicates that lateral shear compressional force are operational in this area.

Photo 6-11 Tiltness in Clayey Silt Beds, Right Side of Road at Sarat Village.

Just downstream of Sarat village near the suspension Bridge, fault breccia is exposed along the river showing the alignment of fault.

Photo 6-12 Folded and Sheared Clayey Silt at Sarat Village.

Photo 6-13 Sheared and Smeared Clayey Silt at Sarat Village.

Photo 6-14 Fault Breccia just D/S of Suspension Bridge at Sarat Village.

Folding, jointing, smearing and shearing of clayey silt **(Photo 6-12, 6-13, 6-14)** deposit shows some lateral stresses are actively operating in this area. The active slides and rolling down of brecciated material from this slope indicate that it is tectonically active area.

6.4.4 Inside Tunnel 2:

Many cracks/joint are going to develop in the concrete specially in crown area in tunnel-2. The pattern of the cracks indicates stress release and shear oblique joints **(Photo 6-15)**.

Photo 6-15 View of Recently Generated Joints Tunnel-2.

As per geological conditions concerns, this portion of tunnel in is under influence of two faults **(Vol-2, DWG-1336)**. Rock is highly crushed, rolling down of boulders is quite common along these active faults. The active tectonic forces are responsible for the development of fractures in this terrane. The same features are also being noted in concrete area in between tunnel 2 and 3 **(Photo 6-16)**.

Photo 6-16 View of Recently Generated Joints Between Tunnel-2 & 3.

The concrete slab fractured between tunnel 2 and 3. It is evident that some tectonic forces are recently operative in this area.

6.4.5 Power House area:

In powerhouse area near helipad along old KKH, clayey silt is present where Chinese camp was established. The clayey silt was deposited after river choking due to Salmanabad slide.

Photo 6-17 Micro thrust fault in clayey silt beds near helipad.

Due to operational compressional stresses, some deformations including faulting, shearing, folding, and tiltness in clayey silt have been observed. The relative movement of both blocks against fault plane indicates compressional environment, moves the hanging wall block upward **(Photo 6-17)**.

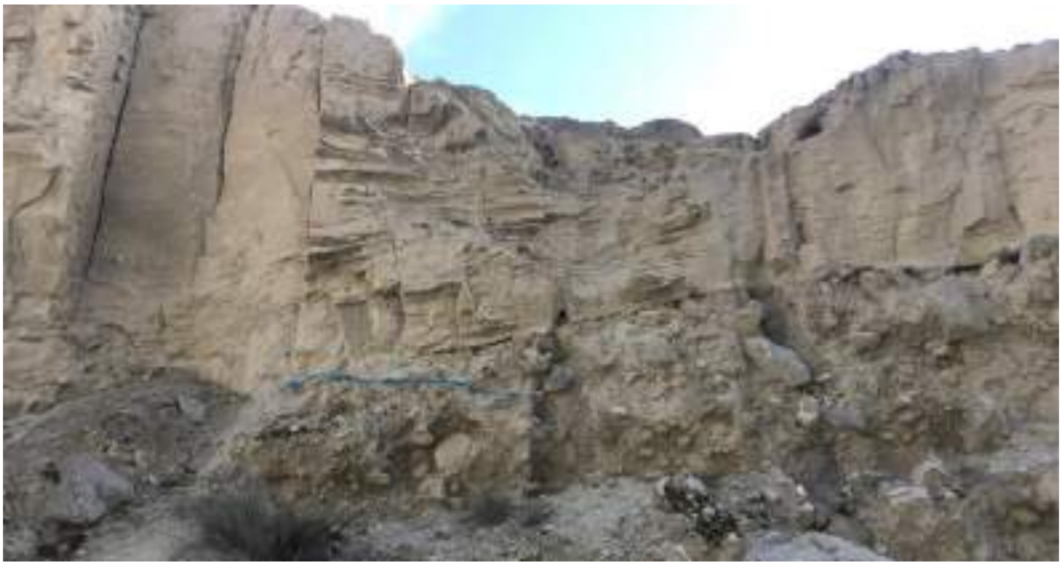


Photo 6-18 Inclination of Clayey Silt near Helipad.

The clayey Silt beds are well exposed at the left side of Hunza river near Sarat bridge. The clayey silt beds are well jointed and tilted upward at an angle ranging from 10° to 15° **(Photograph 6-18)**. The inclination of the beds is in recent soil is active tectonic feature.

Near old Chinese camp, at powerhouse area, the clayey silt is folded **(Photograph 6-19)**. Folding in recently deposited clayey silt may result of slipping along fault plane under regional compressional shear force, results in the formation of folding and faulting.

Photo 6-19 Folding in Clayey Silt near Helipad/Power House Area.

Near the SCO building, along old KKH, near tunnel-1, some cracks are going to develop in recently deposited material. The development of joints is mostly parallel in nature but occasional cross cutting joints also present **(Photo 6-20)**.

Photo 6-20 Development of Parallel Joints near SCO Building.

6.4.6 At Murtazabad- Shahyar Road:

Coordinates:

N	4016299.113m
E	465418.47m
Ele.	2095m a s l

Just crossing the Murtazabad to Shahyar bridge, a thick alluvial deposit consists of gravels, cobbles, pebbles interbedded with silty sand is exposed. This material moves upward against fault plane and form fault bend fold **(Photo 6-21)**.

Photo 6-21 Inclination in Clay Silt and Gravels.

The beds are tilted at an angle of 22° to 30°. Many micro fault in sand beds have been observed in hinge area of the fold. The ramp and flat geometry having NE striking and Dipping SE **(Photo 6-22)**.

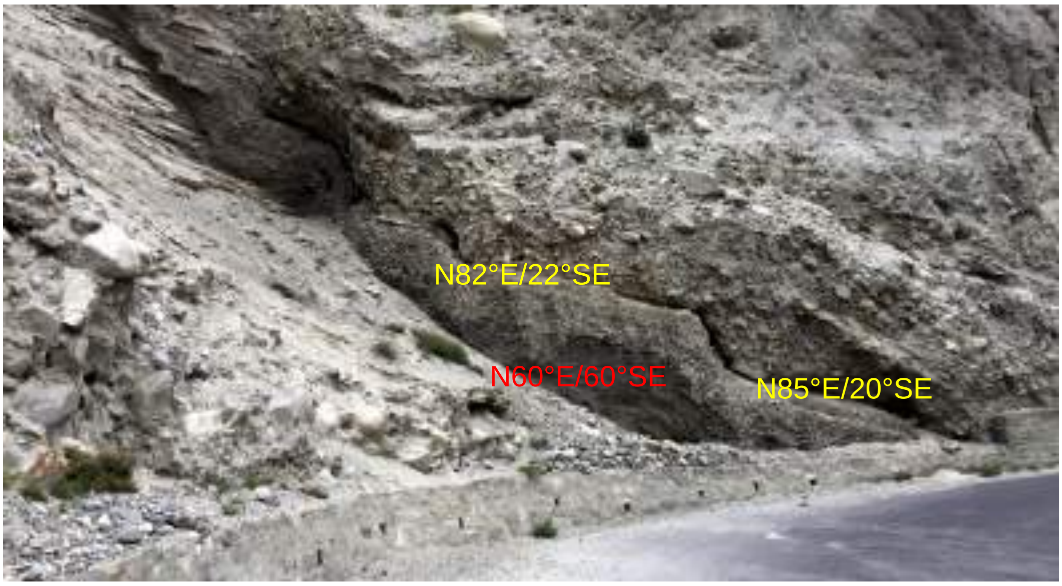


Photo 6-22 Ramp and Flat Geometry along Fault.

Some micro faults have been observed in this alluvium. Step faulting on micro level is well preserved in sandy material **(Photo 6-23)**. This alluvium is overlain by morainic material; same joint pattern is going to be develop in it. Some open joints ranging from 10cm to 150cm have been observed there. All these features indicate that the tectonic forces are active in this area.

Photo 6-23 Development of Micro Faults in Sand.

6.4.7 In Tashot Village:

Coordinates:

N	4012830.531m
E	462157.244m
Ele.	2111.0ma s l

After crossing suspension bridge near Tashot Bridge, a thick deposit of RBGM and Clayey silt is exposed along the road toward Phakhar village. Due to some recent activity, clayey silt is displace and smeared along micro fault.

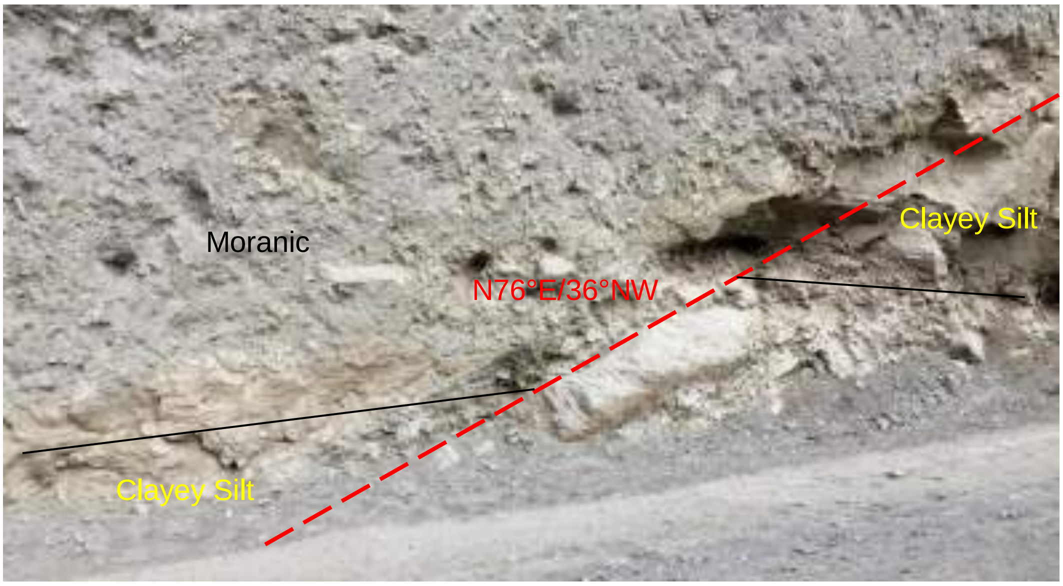


Photo 6-24 Development of Micro Faults in Clayey Silt.

Upward inclination of 6°in recent RBGM in measured along the road **(Photo 6-24, 6-25)**.

Photo 6-25 Inclination in RBGM in Tashot Village along Road.

6.5 SEISMIC HAZARD ANALYSIS

The quantitative and qualitative seismic hazard analyses presented in this study were preceded by a detailed appraisal of the structure, geodynamics and neotectonics, to characterize the on-site and regional tectonic scenario to assist in proposing a suitable earthquake resistant design. This study has used the seismic source characterization deduced in the accompanying Neotectonic studies and calculated the earthquake potential hazard and related ground motions as presented in this report.

6.5.1 Probabilistic Hazard Analysis

Both PSHA and DSHA were carried out using EZ-FRISK software Version 7.65 developed by Risk Engineering Inc. USA. The latest version of R-CRISIS Software version 21.1.1 developed by PEER, USA was also used during the current study. The purpose of using both software was to cross check the validation comparing the quality of the seismic hazard analysis of the two software for the project. During the study it was found that Ez-Frisk software is more standardized as compared to R-CRISIS software in quality of analysis as well as the smart outputs of the analyzed results. Therefore, Ez-Frisk software has been preferred and used in the in the final analysis.

Important input parameters for different seismic zones used in probabilistic approach are presented in **Table 6-1**. It is assumed that weir/dam foundation will mainly be placed on gravelly soil (alluvium) therefore the site condition was taken as gravelly soil with average shear wave velocity at 30 meters' depth (V_{s30}) of 450 m/sec for soil site (alluvium) and 760 m/s for rock sites. The mean total hazard curve was obtained by giving equal weighting to all the Five NGA W2 Ground Motion Prediction Equations.

The total hazard curve obtained for the project area is shown as **Figure 6-2** and the total mean Hazard Spectra showing combination of all used Ground Motion Prediction Equations for Attabad HPP is presented as **Figure 6-3**.

Table 6-1 Seismic Source Parameters for Probabilistic Analysis

Source Zone	Seismic Source Zone	Min. Magnitude Mw	Activity Rate / Year	β	Max. Magnitude Mw
1	Karakorum	4.0	1.929	1.120	7.3
2	Nanga Parbat	4.2	1.112	1.101	7.0
3	Western Himayan	4.1	5.339	1.44	7.0
4	Hindukush	4.2	59.107	1.20	8.0
5	Kashmir Himalaya	4.2	7.143	1.13	7.8
6	Kohistan	4.1	10.500	1.07	7.5

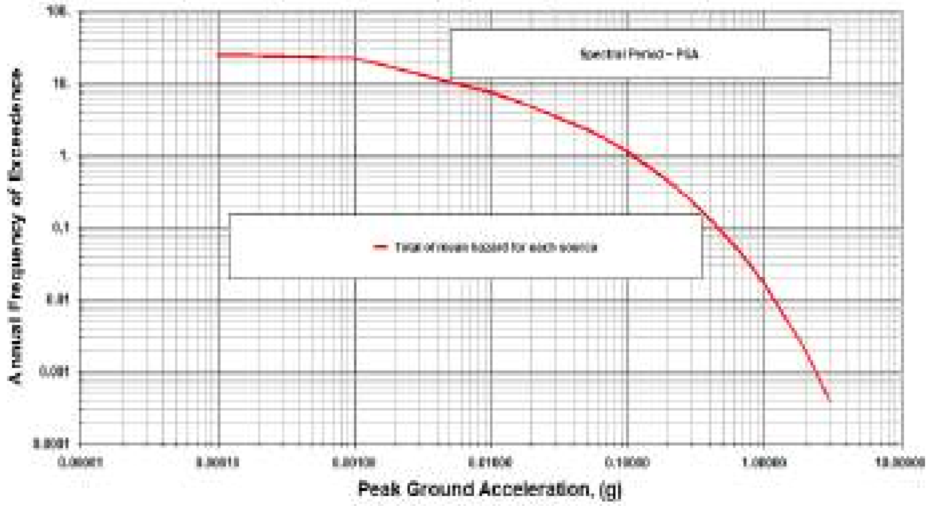


Figure 6-2 Total Hazard Curve for Attabad HPP

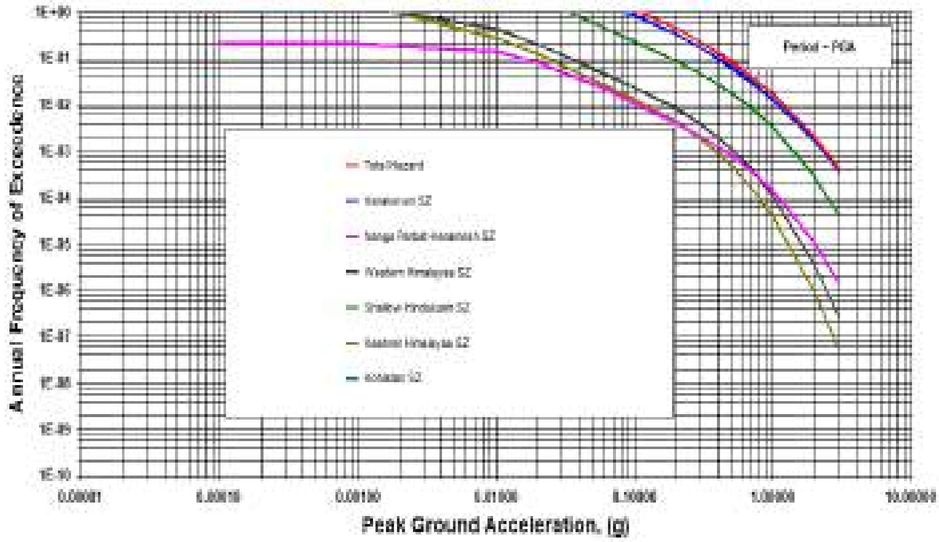


Figure 6-3 Earthquake Hazard by Seismic Sources, showing spectral response.

6.6 DETERMINISTIC SEISMIC HAZARD ANALYSIS (DSHA)

The capability of the faults to generate earthquakes is ascertained by means of analysis of historical and instrumental seismic data and geological criteria such as rupture length – magnitude relationship or fault movement – magnitude relationship.

The main tectonic features around the project site within a radius of 200 km which could be controlling the maximum earthquake hazard are as follows:

- Hunza Fault
- Main Karakoram Thrust (MKT)
- Main Mantle 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 Attabad Lake hydropower project site, the half rupture length of the faults has been taken for determination of maximum potential magnitude. The maximum earthquake magnitude (in moment magnitude M_W) of each of the fault was calculated using Wells & Coppersmith (1994) relationship between fault rupture length and magnitude and the input data given in **Table 6-2** has been used for deterministic approach.

Table 6-2 The Controlling Faults with Quantitative Features (input values of DSHA)

Controlling Faults	Fault Type	Fault Rupture Length (km)	Distance (km)	Maximum magnitude potential	
				Catalogue data	Conservatively Assigned
Hunza Fault	Thrust	5 inferred	1.4	6.1	6.7
MKT	Thrust	200	32	7.0	7.6
MMT	Thrust	260	71.69	6.9	7.6

Ground motion prediction equations developed under the Next Generation Attenuation (NGA) West 2 Project of PEER (Pacific Earthquake Engineering Research Center, University of California at Berkeley, USA) are used to obtain the median and median plus-one percentile levels of peak horizontal ground acceleration (PGA) in deterministic approach.

The NGA equations are developed using a large worldwide database of strong motion recording of earthquakes of magnitude 4-8 and distances ranging from 0-200 km in accordance with ICOLD Guidelines. The NGA equations are preferable over the older equations for the evaluation of seismic hazard particularly in the near field as these are based on a broad spectrum of data recorded in the near field. The same attenuation equations were used for the PSHA approach too.

For all the seismic sources, thrust rupture mechanism has been considered. It is assumed that dam foundation will mainly be placed on gravelly soil therefore the site condition for dam/weir was taken as gravelly soil with average shear wave velocity for top 30 meters (V_{s30}) of 760 m/sec. The depth to basement rocks (Z_{25}) is taken as 5 km. The Peak Horizontal Ground Acceleration (PGA) g values have been calculated using the latest Five sets of NGA West 2 Ground Motion Prediction Equations (GMPEs).

Input values in DSHA are given in **Table 6-2**. The analyzed results obtained through DSHA (Deterministic Seismic Hazard Analysis) are presented in Figures.

6.7 DETERMINISTIC RESPONSE SPECTRA

Deterministic response spectra for SEE at 50th percentile and 84th percentile levels over the Five NGA West 2 equations are shown in **Figure 6-4 & 6-5** respectively.

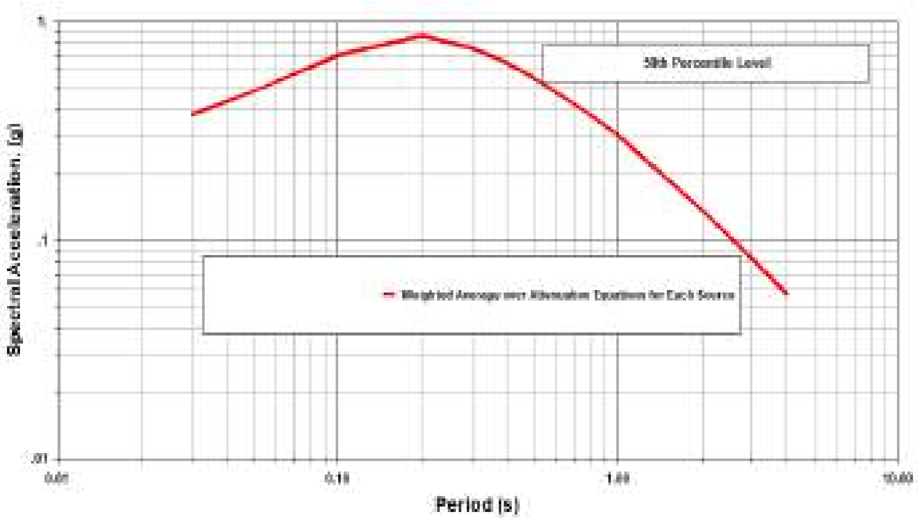


Figure 6-4 Deterministic Spectra at 50th percentile level weighted average

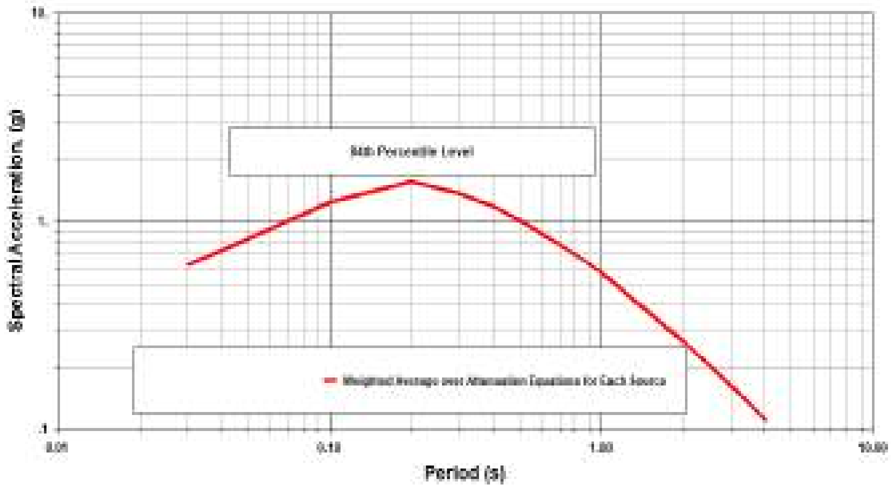


Figure 6-5 Deterministic Spectra at 84th percentile.

6.7.1 Deterministic Pseudo Spectral Acceleration (PSA)

Pseudo spectral acceleration has been worked out using the latest version of R-CRISIS software. Pseudo spectral acceleration Vs time is given in **Figure 6-6**.

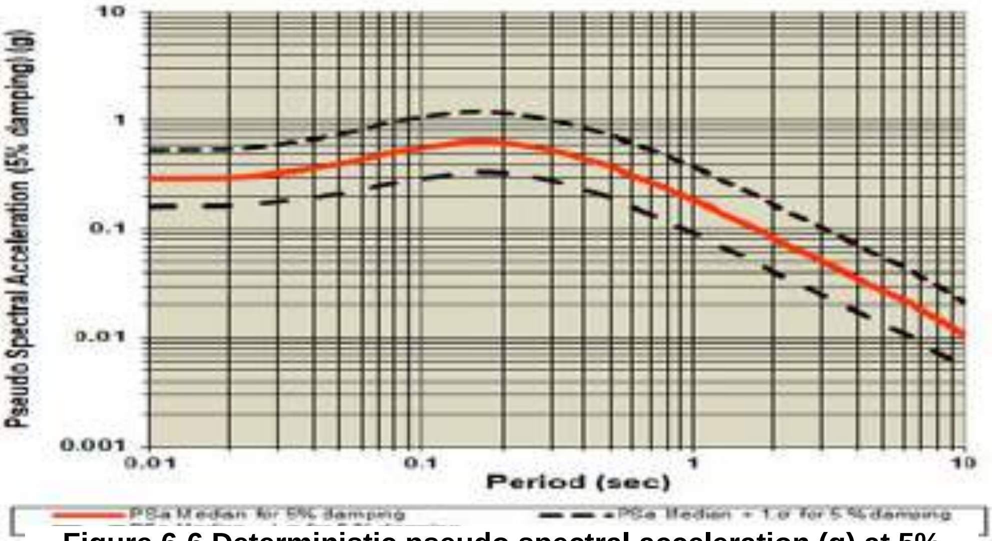


Figure 6-6 Deterministic pseudo spectral acceleration (g) at 5% Damping.

6.8 SELECTION OF SEISMIC DESIGN PARAMETERS

6.8.1 Safety Evaluation Earthquake (SEE)

As per ICOLD guidelines (2016) the Safety Evaluation Earthquake (SEE) will produce the maximum level of ground motion for which the dam should be designed or analyzed. For dams whose failure would present a great social hazard, the SEE will normally be characterized by a level of motion equal to that expected at the dam site from the occurrence of deterministically evaluated MCE or of the probabilistically-evaluated SEE earthquake ground motion with a very long return period, for example 10,000 years for high consequence large dams. Depending on the circumstances (e.g. the importance of the dam, the consequences of a dam failure, it is recommended to design safety-critical elements such as the bottom outlet and/or spillway gates for the SEE. It will be required at least that there is no uncontrolled release of water when the dam is subjected to the seismic load imposed by the SEE.

As per the latest ICOLD Guidelines, for medium consequence dams, median value (50th percentile level) is recommended whereas for high consequence dams, the SEE ground motion parameters should be estimated at median plus one (84th percentile level) if developed by a deterministic approach and need not have a mean annual exceedance probability (AEP) smaller than 1/10,000 if developed by a probabilistic approach. For a particular project of importance such as hydropower project, optimum percentile level may be any optimum percentile level between 50th percentile level to 95th percentile level. For Attabad Lake HPP, 66th percentile level has been worked out and the same is recommended.

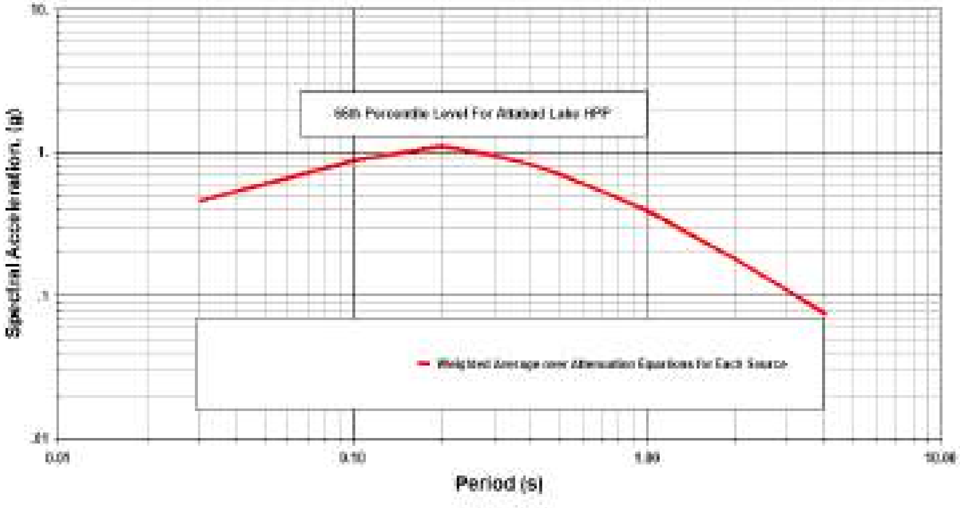


Figure 6-7 Deterministic Spectra at 66th percentile level of SEE.

6.8.2 Operating Basis Earthquake (OBE)

The Operating Basis Earthquake (OBE) represents the level of ground motion at the dam site at which only minor damage is acceptable. In theory the OBE can be determined from an economic analysis, but this is not always feasible and, in many cases, it will be appropriate to choose a return period of about 145 years (i.e. a 50 % probability of not being exceeded in 100 years). The dam, appurtenant structures and equipment should remain functional and damage easily repairable, from the occurrence of earthquake shaking not exceeding the OBE.

Since the consequences of exceeding the OBE are normally economic, the circumstances in a particular case may justify use of a more severe or less severe event for the OBE. The resulting return period depends on prevailing conditions.

Because of the above definition, the OBE is the best determined by using probabilistic procedure. OBE ground motions are significantly lower than those for SEE.

6.8.3 Uniform Hazard Spectra (UHS)

Uniform hazard spectra for Attabad Lake Hydropower Project for OBE (145 year return period), DBE (475 year and 2475 years return period) and SEE (10,000-years return period) are presented as **Figure 6-8.**

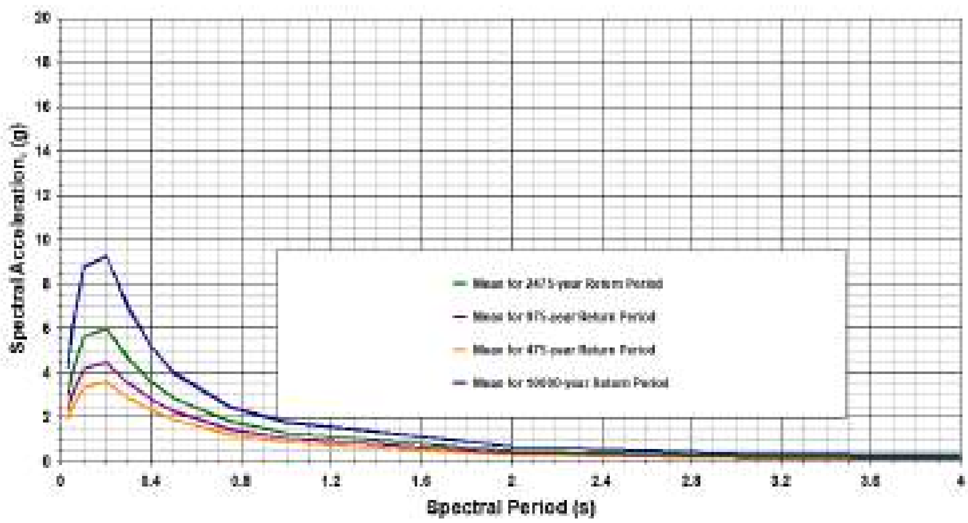


Figure 6-8 Uniform Hazard Spectra (UHS) showing mean hazard for various return periods.

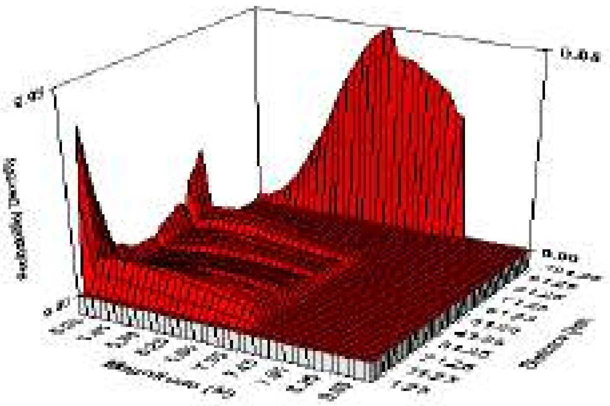


Figure 6-9 Deaggregation of Mean Hazard, Mean Magnitude and Mean Distance.

6.9 RESULTS

Based on the analysis results, the following earthquakes design parameters are concluded and recommended for Attabad Lake Hydropower project.

<u>Operation Basis Earthquakes (OBE):</u>

OBE at return period of 145 years is recommended as follows:

OBE Horizontal = 0.24 g

OBE Vertical = 0.17 g

<u>Safety Evaluation Earthquakes (SEE):</u>

For the design of dam / weir, the following PGA 'g' values for SEE (Safety Evaluation Earthquakes) are recommended:

SEE Horizontal = 0.44g

SEE Vertical = 0.29g

For the design of appurtinent structures including spillway gate betc. the following PGA 'g' values for SEE (Safety Evaluation Earthquakes) are recommended:

SEE Horizontal = 0.38g

SEE Vertical = 0.26

7 PROJECT LAYOUT

7.1 GENERAL

Attabad Lake Hydropower Project (ALHPP) has been identified on Hunza River downstream of Attabad Lake due to creation of dam because of land slide from right bank of Hunza River in January, 2010, 20 km upstream of Aliabad, Hunza Valley, Gilgit-Baltistan. ALHPP is proposed on Attabad Lake. Attabad Lake is about 15 km upstream of Ganish Bridge and about 111 km upstream from Gilgit.

The Dam due to landslide created a Lake behind it at Attabad not only possess a threat but at the same time an opportunity for making use of the head due to this Earthen Dam. Due to lake formation, there is potential drop of more than 100 m in 2.5 km river reach. The mean annual flow of Hunza River at Attabad Lake is 204 m^3/s. The Project Layout is to be configured considering the power demand and demand pattern of regional grid. Attabad Lake storage can be used for daily peaking. A design discharge with peaking storage facility is to be selected to generate the installed capacity 95% time of the year in peak hours. From the available flow data and estimated flow series at Project Area, a discharge of 60 m^3/s has been taken as design discharge.

The Project Layout options are to be studied with due consideration of topographic and geological features of the Area. In the Project Layout configuration, the existing natural dam treated will be used as diversion structure. The present river width has been narrowed due to land slide downstream of lake. The river width in the slided area is to be increased with proper control structure for design flood. In addition, sediment flushing arrangement is to be provided, so that a live storage of lake could be maintained. The water conveyance channel from reservoir to powerhouse is to be made that is technically sound and economical option. Considering the topography and geological features, surface powerhouse is viable at a site, 2.5 km downstream of the Lake. Alternative Project Layout are considered to arrive at the better option both technically and economically.

In this section, alternative Project Layouts have been discussed based on the investigations and studies. The selection of Project Layout has been made on the basis of technical soundness and economic viability.

7.2 ALTERNATIVE PROJECT LAYOUT

The Project layout has been considered on either bank with powerhouse near Attabad. Options for structures' location are limited due to land slided area, steep slope in reservoir area, and weak geological formation in the Project Area.

7.2.1 Alternative-I: Project Layout on the Left Bank

The left bank has been examined in detail to propose Project Layout with power intake, 2.3 km low pressure headrace tunnel, surge tank, embedded penstock and surface powerhouse near Hunza river, 2.5 km downstream of Attabad Lake.

The main access road to Project Area from down country is KKH passes on the left bank in Project Area leading to Chinese Boarder through Khunjerab Pass. After land slide, about 7 km highways tunnel has been constructed on the left bank because about 19 km was submerged in the lake. The access to the area and for construction activities, the left bank is the suitable bank to propose the Project Layout. Since the slide did not initiate from left bank the slopes are more stable. The geological conditions favour intake, headrace tunnel and surface powerhouse. The slided area of about 500 m is to be stabilized by excavating material on the left bank.

The following observation have been made

- An overflow weir is to be constructed to pass the 1000-year flood. The river diversion during construction is to be managed through a deep cut channel on the left bank. Later on the same deep channel is to be used for sediment flushing by installing gates.
- For power intake, there is sound rock formation on the left bank just upstream of weir site. The access to the area can be made through adit and headrace tunnel. Steep slopes and weak geology have been observed for the headrace, penstock and powerhouse area.
- Headrace tunnel can be constructed at lower elevation of highways tunnel in same geological formation upto surge tank. The access to surge tank and headrace tunnel is available through old KKH.
- From surge tank to powerhouse area, embedded penstock can be laid down over mild slope terraces. The anchor block can be placed over rock/boulders.
- At the proposed site, surface powerhouse can be constructed. Surface powerhouse, tailrace channel and bifurcated penstock can be placed at required elevation by excavating the alluvium.

The Project Layout on the left bank is presented in Figure 7-1. Topographic conditions to propose Project Layout on the left bank are found favorable and considered suitable to propose a Project Layout.

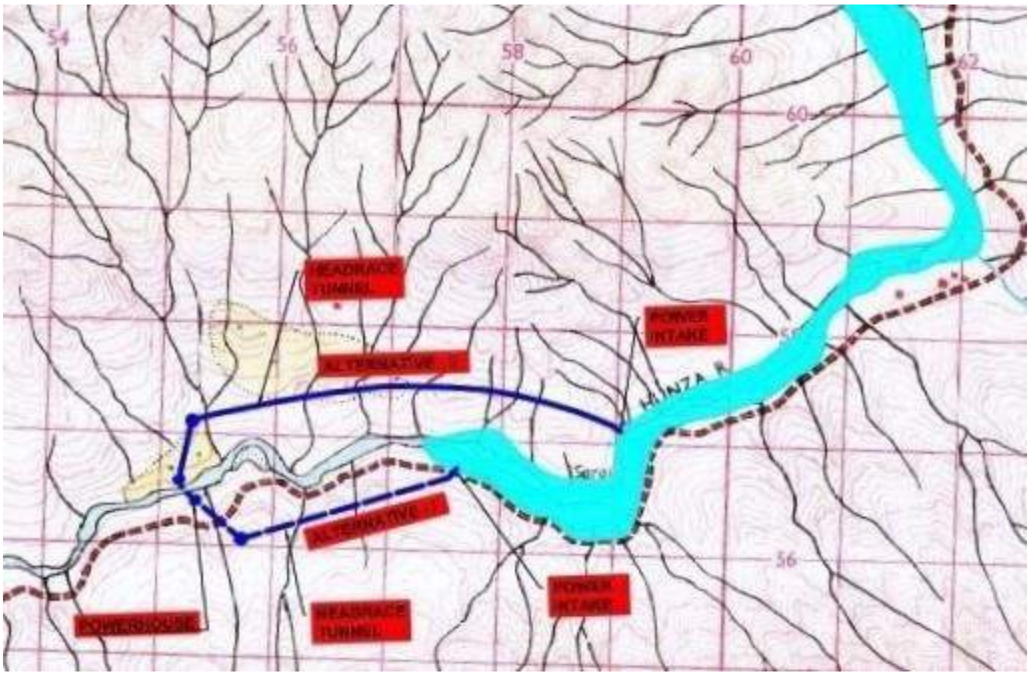


Figure 7-1 Alternative Project Layout on the Left and Right Bank

7.2.2 Alternative-II: Project Layout on the Right Bank

A Project Layout on the right bank have been studied with intake 1.6 km upstream and powerhouse 2.0 km downstream of weir site. A low pressure tunnel about 3.8 km length is to be constructed to utilize the available head at ALHPP.

The Project Layout on the right bank has geologically disturbed area and Attabad slide originated from the right bank and slided material fallen on the left bank. On the right bank of the River, there is excessive loose material present and it is considered susceptible to rock fall and minor slides due to its being fragmented. The accessibility to the right side is difficult and construction and operation of scheme on the right bank is technically unfeasible.

The right bank of the river is where the slide basically was initiated from, therefore, there is excessive loose material present and the mountain side is quite fragmented. Clearing the overburden to reach the rock face will not only require a lot of excavation, but also the site will remain susceptible to rock fall and minor slides due to its being fragmented. Operability of Project components on this bank will remain a challenge.

Considering the Project construction, operation and maintenance, environmental issues, stability of structures, the left bank layout has been preferred over that of the right bank and is selected for further studies.

7.3 FIELD INVESTIGATIONS FOR PROJECT LAYOUT

For Feasibility Study, field investigations like topographic survey, geological mapping, borehole drilling, test pits, environmental survey, flows and sediment observations have been carried out. For the identified dam / weir and the powerhouse site on the left bank of Hunza River near Attabad, topographic survey has been carried out, which is duly connected with Survey of Pakistan (SOP) Grid. The long term flow data of Hunza at Danyor Station has been used to estimate the daily flows and flow duration curves at the weir site. All the field data helped to finalize the structure locations and sizes for a technically feasible and economical layout.

Considering topographic and geological conditions at the weir and upstream valley, an overflow concrete weir at El. 2414 m a s l has been proposed with normal operating pond level as 2414 m a s l. The tailrace outlet of ALHPP has been planned at El. 2300 m a s l. Further 2 options have been studied on the left bank of Hunza River. i.e.

a. Alternative -I A Headrace Tunnel Option

b. Alternative -I B Headrace with Embedded Pressure Pipe T

7.3.1 Alternative-I A Headrace Tunnel Option

ALHPP has been envisaged with a 14 m high weir on Hunza River identified, 4 km downstream of Attabad Lake confluence with Hunza River and the powerhouse near Batakundi Village. The Project Layout includes power intake, sandtrap, headrace tunnel, surge shaft, in addition to ungated weir spillway and surface powerhouse on the right bank.

For the water ways from intake to surge shaft, two options have been considered; either headrace tunnel or pressure pipe. These two options have been studied with respect to powerhouse and preliminary cost estimates.

The salient features of Alternative Project Layout on the right bank are as under;

Salient Features Headrace Tunnel Option

The Salient Features of ALHPP layout for Alternative-IA are listed below.

a.	Weir/Dam Height	2.0 m
b.	Normal Reservoir Level	2414.0 m a s l
c.	Minimum Operating Level	2412.0 m a s l
d.	Live Storage	3.0 Million m^3
e.	Mean Annual Flow	209.0 m^3/s
f.	Design Discharge	60.0 m^3/s
g.	Turbine Level	2300.0 m a s l
h.	Maximum Net-Gross Head	108.1 m
i.	Minimum Net-Gross Head	105.6 m
j.	Headrace Tunnel Length	2300 m
k.	Penstock Length	550 m
l.	Type of Turbine	Francis
m.	Installed Capacity	54.0 MW
n.	Annual Energy Generated	374.0 GWh
o.	Plant Factor	79.0 %

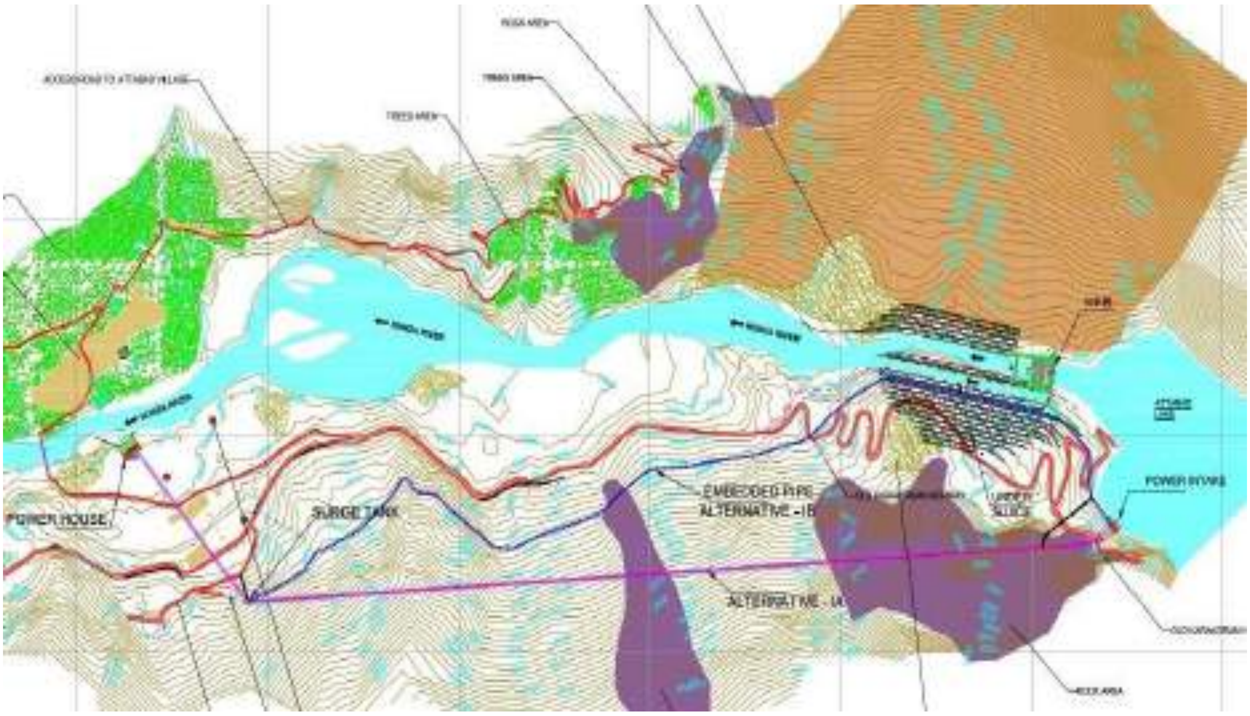


Figure 7-2 Project Layout on the Left bank with Tunnel and Penstock Options

7.3.2 Alternative-I B Headrace with Embedded Pressure Pipe.

The salient features of ALHPP layout for Alternative-IB are same except the following:

a.	Maximum Net-Head	102.1 m
b.	Minimum Net-Head	99.6 m
c.	Headrace pipe length	2.8 km
d.	Penstock Length	550 m
e.	Installed Capacity	51.7 MW
f.	Annual Energy Generated	357.8 GWh
g.	Plant Factor	79.0 %

7.4 EMBEDDED PENSTOCK VERSUS TUNNEL

Both the embedded penstock and tunnel options are considered for the conveyance of lake water for power generation along the left bank of the Attabad Lake. On the basis of field observations, on topographic survey, geological & geotechnical investigations, the embedded penstock route passes through overburden and its construction/installation will be quite hazardous as observed during geotechnical investigation. The cost comparison of tunnel and embedded penstock has also been carried out to check the suitability of conveyance of lake water. Cost comparison also shows that power tunnel option is more appropriate in view of least cost with less operation and maintenance issues that may encounter in case of embedded penstock alternative. Necessary geological studies, mapping and geotechnical studies including topographic surveys of cross drains along tunnel route and embedded penstock have also been carried out.

7.4.1 Geology along the Embedded Penstock Route

The scree, moraines, debris flow, creeps and landslides are common along the whole ridge from intake area to powerhouse. These deposits are the results of broken rock fragments at the toe of hill slopes, mountain cliffs, and valley shoulders that has accumulated through periodic rock fall from adjacent cliff faces. These rock spreads have been marked on the geological map of the Project Area.

7.4.2 Geology along the Tunnel Route

Gneisses of Baltit Group are well exposed along the proposed power tunnel. These rocks are mostly over run by very loose unconsolidated material. This overburden material is composed of boulders, cobbles, pebbles, gravels and with fine grained sand and clays. To ascertain the dimensions of the spread of overburden, electrical resistivity survey along the power tunnel has been conducted.

7.5 POWERHOUSE LOCATION

Powerhouse location is affected by factors primarily associated with availability of head, favorable geology, availability of land and accessibility besides impact of powerhouse construction on habitants in the area (locality). Issues relating to protection against land sliding and flooding have also been taken into account. Keeping the above in view, only one location has been considered for powerhouse for both the alternates.

A surface power house is being considered on the left bank of Hunza River about 300 m upstream of Sarat Bridge. The terrace is large enough space for powerhouse, switchyard, offices and/or staff residences in the close vicinity of the powerhouse. The river bed level at the site is 2306 m.a.s.l.

7.5.1 Geology of Powerhouse

The proposed powerhouse is located on alluvium deposits. The slope is gentle along penstock area which is covered by overburden material. The rocks of Baltit Group are exposed along the penstock. Quaternary alluvium has been recorded along slopes and in the river banks and along the main tributaries. Scree and unconsolidated colluvial debris have been recorded along slopes which are commonly loose and un-cemented in nature.

For confirmation of thickness and properties of overburden material; four boreholes drilled at powerhouse, tailrace, penstock and surge tank locations have been drilled the detail of locations is marked on topographic survey map.

7.6 COST ESTIMATES

For the identified Project Layouts, based on preliminary dimensions of structures, cost estimates have been prepared for Alternative-I A and – I B. The summary of cost of various project components and E&M equipment are presented in Table 7-1

Table 7-1 Estimated Project Base Cost

Sr. No.	Description	Total (Million Rs.)	
		Alter-IA	Alter-IB
A	**Preliminary Works and Environmental Cost**	1,161.40	1,161.40
B	**Civil Works**		
B-1	Main Weir	2,008.821	2,008.821
B-2	Sediment Flushing Channel	2,326.679	2,326.679
B-3	Power Intake	429.289	429.289
B-4	Low Pressure Headrace Tunnel	1,820.182	0.000
B-5	Surge Shaft	132.728	132.728
B-7	Penstocks	713.256	3242.063
B-8	Powerhouse	624.474	624.474
B-9	Tailrace Channel	84.318	84.318
B-10	Check Dams at Shimshal Nullah	392.500	392.500
	Sub Total B	8,532.247	9,240.872
	Total for Civil Works (A+B)	**9,693.642**	**10,402.267**
C	**HSS, Mechanical & Electrical Works**		
C-1	Hydraulic Steel Structures (HSS)	139.730	139.730
C-2	Power House Mechanical Works	1,690.890	1,690.890
C-3	Power House Electrical Works	2,249.339	2,249.339
C-4	Switchyard works	428.453	428.453
C-5	Transmission Line (Single Circuit Attabad to Sost & Double Circuit Attabad to Aliabad)	1,500.135	1,500.135
	Sub Total for C-1 to C-5	6,008.547	6,008.547
C-6	Transportation Charges of E&M Equipment @ 7%	420.598	420.598
C-7	Erection & Commissioning Charges @ 8%	480.684	480.684
C-8	Government Taxes on E&M Equipment @ 16%	961.368	961.368
	Sub Total C for E & M	**7,871.197**	**7,871.197**
D	**Project Construction CostSub Total A, B & C**	**17,564.84**	**18,273.46**
E	Indirect Cost	2464.076	2563.48
F	**PROJECT BASE COST**	**20,028.916**	**20,836.94**

For the two alternatives, power and energy have been computed for a design discharge of 60.0 m^3/s. The comparison of cost/kWh is presented in Table 7-2.

Table 7-2 Comparison of Alternatives

Project Components	**Alternative-I A** Headrace Tunnel	**Alternative-I B** Pressure Pipe
Project Base Cost (US$)	20,028.916	20,836.94
Power (MW)	54	51.7
Energy (GWh/year)	373.69	358
Energy Cost/ (USc/kWh)	3.61	3.93

The comparison of two alternative layouts indicate that Alternative IA has lower cost and will produce more energy/year, therefore cost/kWh is less as compared with that of Alternative-II B. Project layout with headrace channel is recommended for further studies.

7.7 SELECTED PROJECT LAYOUT

With favorable topographic and geological conditions for the Project Area. The Project Layout (Alternative-I A) with low pressure tunnel on the left bank is preferred over other available options. The availability of recorded flows of Hunza River at Attabad provide the basis to have design discharge of 60.0 m^3/s and installed capacity of 54 MW for ALHPP.

The Project Layout (Alternative-I A) on the left bank with identified weir site, 2.3 km long headrace tunnel, 550 m embedded penstock and surface powerhouse near Hunza River is considered the only technically sound and economical layout. Hence, it is recommended for further studies.

8 POWER POTENTIAL

8.1 GENERAL

The demand for electricity varies seasonally. In lower areas of the country demand reaches to its maximum in summer season and remains lower in winter. But in northern area of the country specially in Gilgit-Baltistan (GB) demand for power and energy is maximum in winter season and remains within lower ranges in summer. Electricity demands also vary during the same day, people use more power in the morning and in the evening. Therefore, many powerhouses are managed to tackle such peak times. For this purpose, temporary storage is done in the lake/pond/forebay and releases during peak hours. Such projects have small storage as compared to large dam's storage.

As the lake had already been developed so reservoir capacity has not been enhanced than present to avoid inundation of upstream areas due to increase of water levels, however, flushing will be carried out to retain the present capacity of the lake.

8.2 RESERVOIR OPERATION SYSTEM

ALHPP is located on Hunza River and there is no other considerable power project on main Hunza River which could influence the operation of ALHPP, further, there is no irrigation system which could be supplemented from Hunza River. Therefore, the Project is only for power generation.

The amount of hydropower generated depends upon the volume of water and the effective head. Reservoir operation and corresponding power potential has been studied for 50 years (1966 – 2015) in order to assess the true power potential of the Project.

It is proposed to operate the reservoir to provide diurnal storage in the low flow periods to enable peaking energy to be generated in preference to base energy when there is insufficient flow to generate continuously. The daily storage required for 4 hours peaking is 0.864 Mm3and storage required for 24 hours at full capacity is 5.18 Mm3, which is equivalent to all the volume available in the upper 1.25 m of the reservoir.

The following definitions of Peak Energy, Primary Energy and Secondary Energy were used:

- On-Peak Energy is defined as the energy that the plant can produce during four hours per day (peak demand hours) with at least 95% reliability. The On-Peak Energy is assumed to be the best remunerated.

- Off-Peak Energy is defined as the energy produced by the plant off the assumed 4 hours of daily peak demand.

- Firm Energy is defined as the energy that the plant can generate with 95% reliability, which is, deficits shall not occur for more than 5% of the time.

- Secondary Energy is the energy that the plant can produce in excess of the Firm Energy. Secondary Energy is produced only when the reservoir is full, and is limited by the capacity of the plant.

From power generation point of view, the primary target of the operation is to assure the highest possible peak generation: a general criterion considered was to assure at least 4 hours per day of operation at full capacity.

A second target of the operation is to maximize the firm energy production, which is the energy which can be guaranteed in each month with a sufficiently high level of reliability: in principle, a 95% reliability criterion for the firm energy has been considered.

8.3 ATTABAD RESERVOIR

As discussed earlier, reservoir capacity of the lake has been reduced from 250 Mm3 to 125 Mm3 which indicates that half lake capacity has been filled with sediments during the last 10 years. Therefore, in order to retain the lake capacity and utilize this hydro potential for the generation of electricity regular flushing would be carried out along with power generation. Under sluice Channels proposed for this purpose.

To study the power and energy potential of the Project, hydrographic survey is used to assess the lake's capacity with respect to the elevation. The present reservoir extends more than 12.5km, to actualize the present storage with respect to area and elevation in terms of Storage-Area-Elevation curve is given below

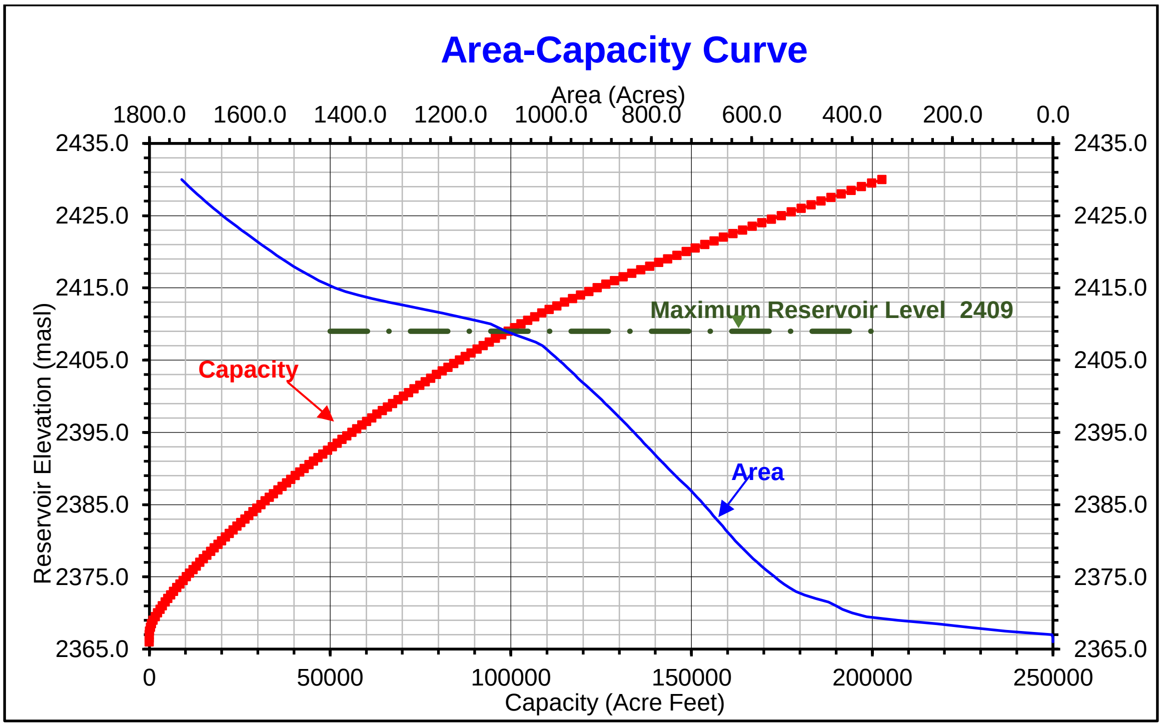


Figure 8-1 Area Capacity Curve

Table 8-1 : Area-Elevation-Capacity Data

Sr. No.	Reservoir Elevation (m.a.s.l)	Water Surface Area (Acres)	Storage Capacity (Acre Feet)	Storage Capacity Mm^3	Sr. No.	Reservoir Elevation (m.a.s.l)	Water Surface Area (Acres)	Storage Capacity (Acre Feet)	Storage Capacity Mm^3
1	2366.0	0.0	0	0.00	66	2398.5	884.4	65872	81.25
2	2366.5	0.0	0	0.00	67	2399.0	891.7	67329	83.05
3	2367.0	1.7	0	0.00	68	2399.5	899.1	68798	84.86
4	2367.5	94.5	87	0.11	69	2400.0	906.7	70279	86.69
5	2368.0	167.7	294	0.36	70	2400.5	914.4	71773	88.53
6	2368.5	231.0	624	0.77	71	2401.0	922.3	73279	90.39
7	2369.0	309.4	1065	1.31	72	2401.5	930.3	74799	92.26
8	2369.5	371.2	1626	2.01	73	2402.0	938.3	76331	94.15
9	2370.0	399.7	2261	2.79	74	2402.5	945.8	77877	96.06
10	2370.5	419.0	2933	3.62	75	2403.0	953.3	79435	97.98
11	2371.0	431.9	3631	4.48	76	2403.5	960.8	81005	99.92
12	2371.5	447.0	4351	5.37	77	2404.0	968.3	82587	101.87
13	2372.0	472.6	5103	6.30	78	2404.5	976.0	84181	103.84
14	2372.5	495.0	5898	7.28	79	2405.0	984.3	85789	105.82
15	2373.0	512.1	6725	8.30	80	2405.5	992.3	87410	107.82
16	2373.5	524.8	7576	9.34	81	2406.0	1000.4	89045	109.84
17	2374.0	535.7	8446	10.42	82	2406.5	1008.3	90693	111.87
18	2374.5	545.1	9332	11.51	83	2407.0	1016.6	92353	113.92
19	2375.0	554.2	10234	12.62	84	2407.5	1030.4	94031	115.99
20	2375.5	563.3	11151	13.75	85	2408.0	1051.4	95734	118.09
21	2376.0	571.9	12082	14.90	86	2408.5	1071.1	97478	120.24
22	2376.5	580.4	13027	16.07	87	2409.0	1088.7	99249	122.42
23	2377.0	588.8	13986	17.25	88	2409.5	1104.3	101048	124.64
24	2377.5	596.8	14959	18.45	89	2410.0	1120.1	102872	126.89
25	2378.0	604.3	15944	19.67	90	2410.5	1149.9	104733	129.19
26	2378.5	611.5	16941	20.90	91	2411.0	1182.0	106644	131.54
27	2379.0	618.6	17950	22.14	92	2411.5	1216.3	108612	133.97
28	2379.5	625.8	18971	23.40	93	2412.0	1251.6	110635	136.47
29	2380.0	632.7	20003	24.67	94	2412.5	1285.5	112716	139.03
30	2380.5	639.2	21046	25.96	95	2413.0	1323.4	114856	141.67
31	2381.0	645.5	22100	27.26	96	2413.5	1355.8	117055	144.39
32	2381.5	651.7	23164	28.57	97	2414.0	1383.6	119302	147.16
33	2382.0	657.9	24238	29.90	98	2414.5	1409.4	121593	149.98
34	2382.5	664.2	25323	31.23	99	2415.0	1430.8	123924	152.86
35	2383.0	670.4	26417	32.59	100	2415.5	1446.4	126284	155.77
36	2383.5	676.6	27522	33.95	101	2416.0	1462.3	128670	158.71
37	2384.0	682.8	28637	35.32	102	2416.5	1475.9	131080	161.68
38	2384.5	689.0	29762	36.71	103	2417.0	1488.5	133511	164.68
39	2385.0	695.4	30898	38.11	104	2417.5	1500.9	135963	167.71
40	2385.5	701.9	32044	39.53	105	2418.0	1513.0	138435	170.76
41	2386.0	708.5	33200	40.95	106	2418.5	1524.6	140927	173.83
42	2386.5	715.2	34368	42.39	107	2419.0	1535.7	143437	176.93
43	2387.0	722.0	35547	43.85	108	2419.5	1546.4	145965	180.05
44	2387.5	729.0	36737	45.31	109	2420.0	1556.8	148511	183.18

45	2388.0	736.6	37939	46.80	110	2420.5	1566.9	151073	186.35
46	2388.5	744.5	39154	48.30	111	2421.0	1576.9	153651	189.53
47	2389.0	752.0	40382	49.81	112	2421.5	1586.8	156246	192.73
48	2389.5	759.1	41621	51.34	113	2422.0	1596.7	158857	195.95
49	2390.0	766.3	42872	52.88	114	2422.5	1606.6	161485	199.19
50	2390.5	773.4	44135	54.44	115	2423.0	1616.4	164128	202.45
51	2391.0	780.3	45409	56.01	116	2423.5	1626.1	166788	205.73
52	2391.5	787.2	46695	57.60	117	2424.0	1635.7	169463	209.03
53	2392.0	793.9	47992	59.20	118	2424.5	1645.1	172154	212.35
54	2392.5	800.6	49300	60.81	119	2425.0	1654.3	174860	215.69
55	2393.0	807.4	50619	62.44	120	2425.5	1663.3	177581	219.04
56	2393.5	814.5	51949	64.08	121	2426.0	1672.0	180317	222.42
57	2394.0	821.2	53291	65.73	122	2426.5	1680.6	183067	225.81
58	2394.5	827.9	54643	67.40	123	2427.0	1689.0	185831	229.22
59	2395.0	834.6	56007	69.08	124	2427.5	1697.2	188608	232.64
60	2395.5	841.4	57382	70.78	125	2428.0	1705.3	191399	236.09
61	2396.0	848.3	58767	72.49	126	2428.5	1713.2	194203	239.55
62	2396.5	855.3	60165	74.21	127	2429.0	1720.9	197019	243.02
63	2397.0	862.5	61574	75.95	128	2429.5	1728.4	199849	246.51
64	2397.5	869.8	62995	77.70	129	2430.0	1735.7	202690	250.01
65	2398.0	877.1	64427	79.47					

8.4 WATER AVAILABILITY AT RESERVOIR

Mean annual flows are calculated for the period 1966-2015. Average value for mean annual flow has been calculated as 208.36 m^3/s. Flows are generally maximum in July and August almost touching 700 m^3/s. Whereas, flows are low from December to April each year when snow falls in the catchment. The graph shows that design discharge of 60 m^3/s is available for about half year (almost 6 months). Graph also shows that flows are exceeding the design discharge from June to mid-December which shows the potential of hydropower generation

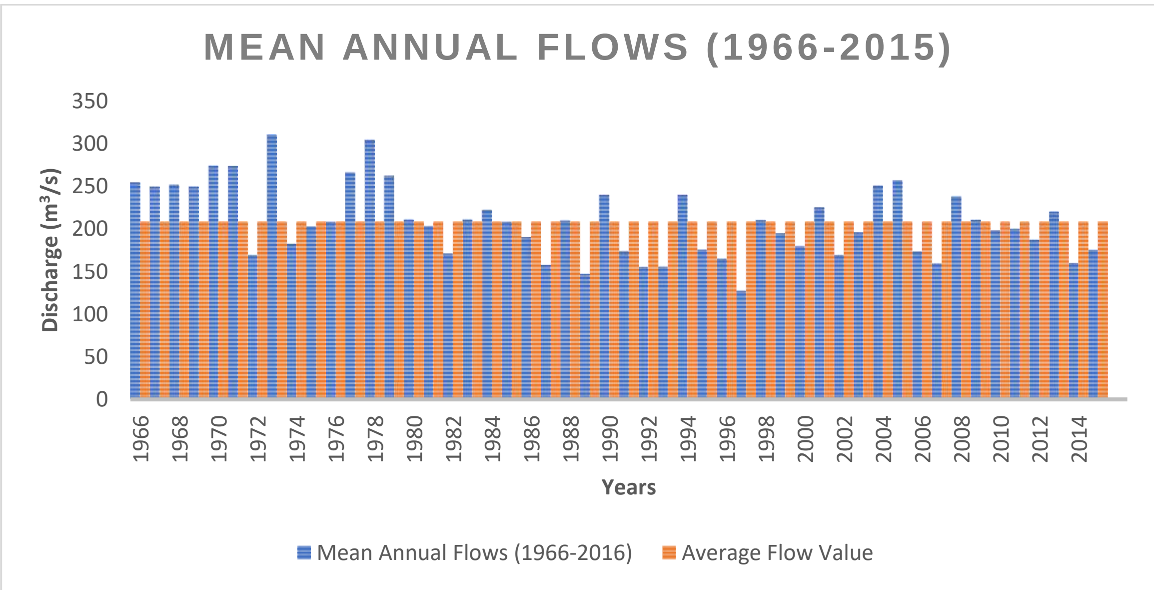


Figure 8-2 Mean Annual Flows

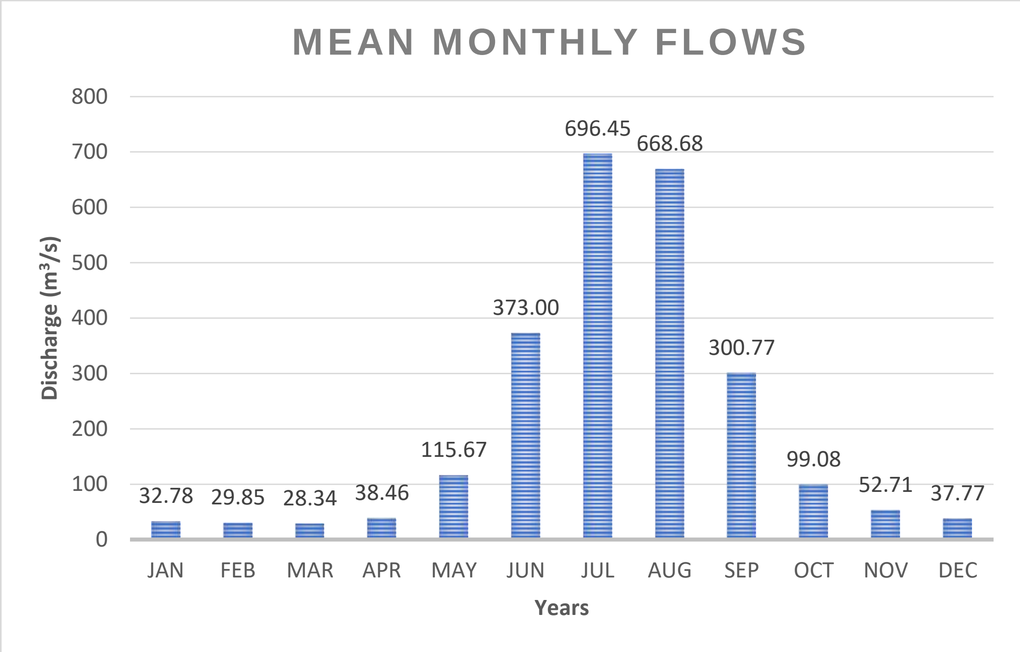


Figure 8-3 Mean Monthly Flows

Maximum, Mean and Minimum daily flows for the period 1966-2015 are also plotted in the Figure below to depict the flow pattern at Attabad Lake site.

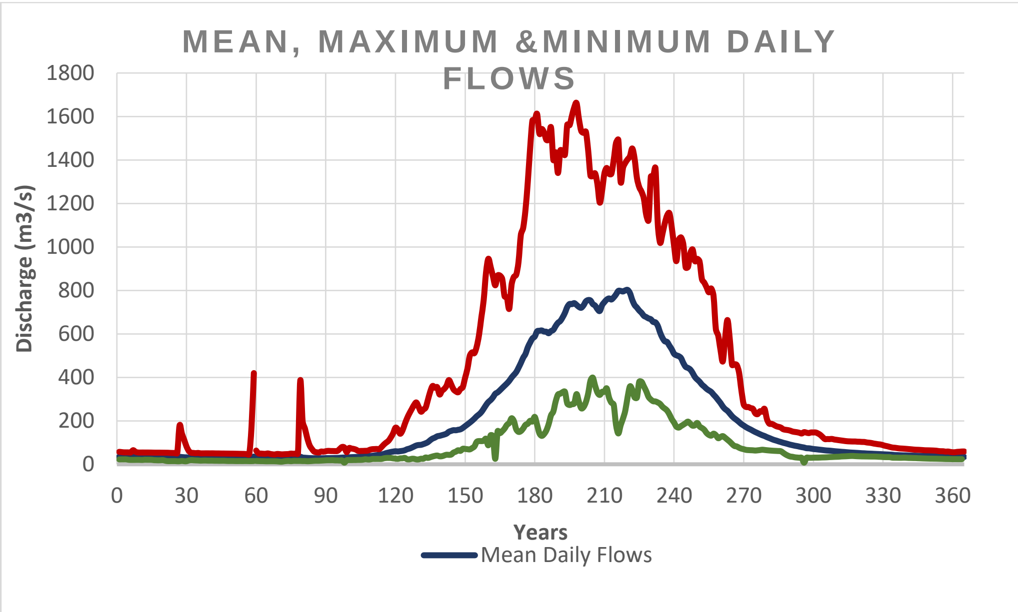


Figure 8-4 Mean, Maximum & Minimum Daily Flows

8.4.1 Flow Duration Curve (FDC)

Flow Duration Curve (FDC) for Attabad Lake HPPLHPP is plotted on the basis of almost 51 years (1966-2016). From FDC it is evident that design discharge of 60 m^3/s is available for almost 50% of the time. Therefore, design discharge of 60 m^3/s is justified for the generation of 54 MW power.

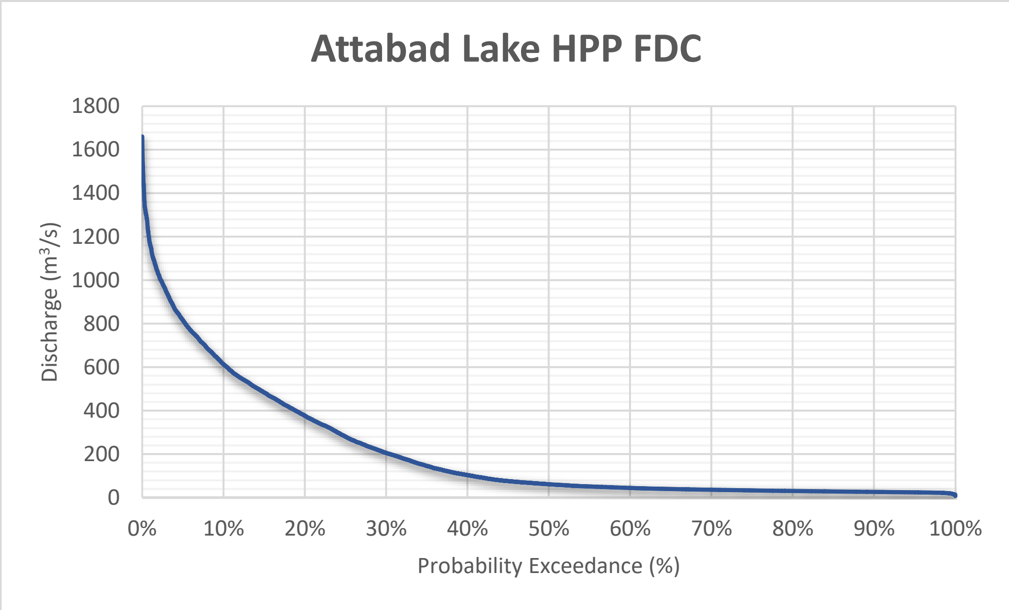


Figure 8-5 Attabad Lake Flow Duration Curve (FDC)

Table 8-2 Flow Duration Curve Results

Probability Exceedance (%)	Flow (m^3/s)	Probability Exceedance (%)	Flow (m^3/s)
10	613.4	60	44.3
20	376.6	70	36
30	205	80	30.3
40	103.3	90	26.2
50	61.3	99	20.5

8.5 WATER LEVELS

The available head for power generation has been determined from normal operative level and the water level where tailrace channel joins Hunza River.

8.5.1 Upstream Water Levels

Upstream water levels have been determined keeping in view the operation of the Attabad Lake. For power and energy estimates, the normal operative level varies from 2,412 m.a.s.l to 2,414 m.a.s.l.

8.5.2 Downstream Water Levels

The tail-water rating curve for downstream of the powerhouse at Hunza River is obtained using the water levels, historic discharges and cross section of Hunza River. Calculations are tabulated at Table 8-3 and the tailwater rating curve is plotted at Figure 8-6. The downstream tail water rating has been adopted for stage estimation downstream of power house. The head losses expected to occur in the power scheme have been calculated to determine the net head available for power generation.

Table 8-3 Tailwater Curve Analysis

Water Surface Elevation	Discharge (m^3/s)	Velocity (m/s)	Flow Area (m^2)	Wetted Perimeter (m)	Top Width (m)
2300.10	29.50	1.29	22.80	51.31	51.18
2300.35	98.27	1.87	52.53	68.02	67.77
2300.75	215.19	2.38	90.39	81.51	81.11
2301.35	394.73	3.00	131.40	83.59	82.93
2301.95	616.04	3.55	173.32	85.68	84.76
2302.55	876.00	4.05	216.15	87.76	86.58
2303.12	1172.50	4.51	259.90	89.85	88.40
2303.62	1503.99	4.94	304.55	91.93	90.23
2304.06	1869.31	5.34	350.12	94.02	92.05
2304.47	2267.56	5.72	396.61	96.10	93.88
2304.92	2698.06	6.08	444.00	98.19	95.70
2305.40	3049.87	6.17	494.07	106.72	104.05
2305.95	3525.16	6.44	547.06	110.79	107.93

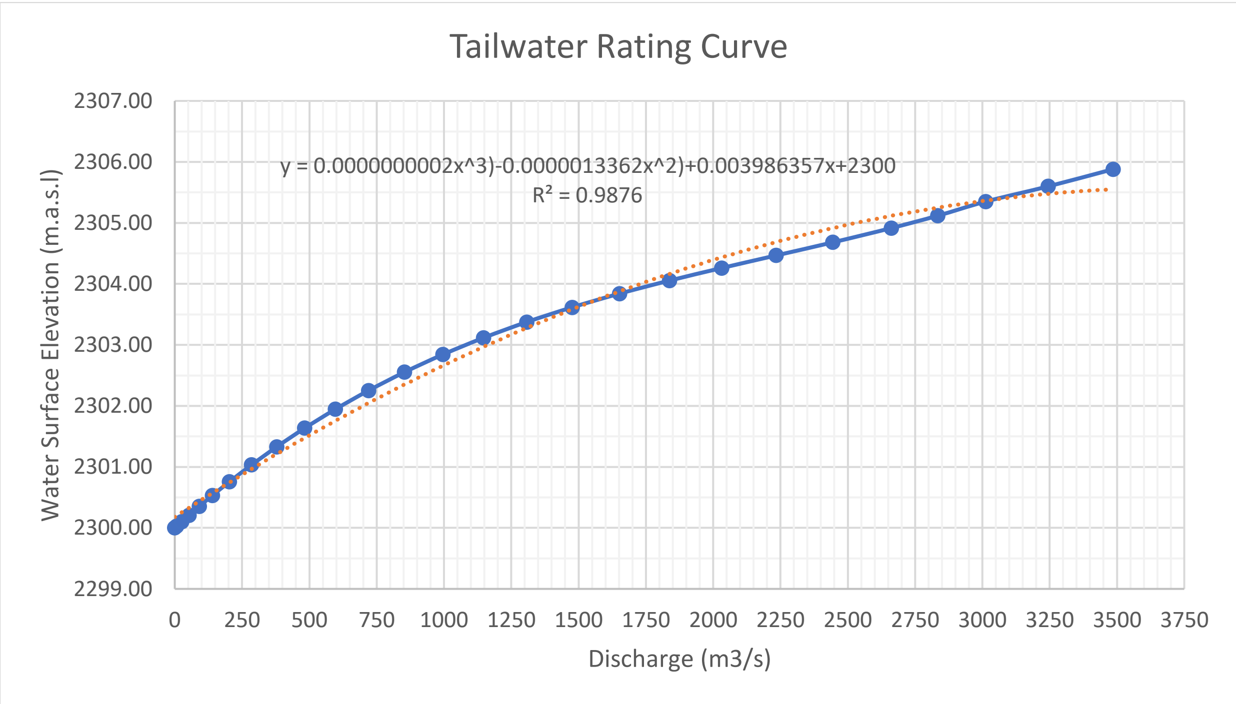


Figure 8-6 Tailwater Rating Curve

8.6 POWER AND ENERGY STUDIES

8.6.1 Power and Energy Potential

Power and energy potential at the site have been estimated on average 10-daily basis using time series data from 1966 to 2015. Available head across the hydropower facility has been computed keeping in view the minimum and maximum operation water levels i.e. 2,012 to 2,014 m.a.s.l. Tailwater rating curve has been used for estimating the tailwater levels on the downstream side for determining the head available for power generation.

The power estimates have been computed by using the following formula:

$$P = \frac{\gamma \, x \, n \, x \, g \, x \, H \, x \, Q}{1000}$$

where,

P	=	Power output, 54 MW
ρ	=	Density of water, 1,000 kg /m3
g	=	Gravity acceleration, 9.81 m/s2
η	=	Overall efficiency of the hydroelectric plant 88.32%
Q	=	Design discharge, 60m3/s
H	=	Net Head varies between 105 m to 107.5 m depending head wa ter levels

Table 8-4 Efficiency Coefficients of Various Power Plant Components

Component	**Efficiency**
Turbine & Speed Increaser	91.5%
Generator	97.5%
Transformer	99%
Overall	88.32%

The average daily energy has been calculated as follows:

$$E = \frac{P \, x \, h \, x \, d}{1000}$$

where,

E	=	Energy output (GWh)
P	=	Power output (MW)
h	=	Hours in a day
d	=	Number of days in each time step

8.6.2 Optimization of Power and Energy

In previous studies, 32.5 MW capacity plant had been proposed for this project, however, keeping in view the potential of the lake and availability of head, the power and energy optimization have been carried out to size the plant. Upstream water levels and tail water rating along with the average flow data for the period 1966 to 2015 have been used for calculating the power, energy and plant factor. Comparison of power and energy potential of this study with the previous study has been tabulated below:

Table 8-5 Summary of Power & Energy Potential

Power and Energy Parameters	As in Previous Studies Conducted through Consultants	As in this Study Conducted by WAPDA
Design Discharge (m^3/s)	40	60
Gross Head (m)	106	112
Power Capacity (MW)	32.5	54
Mean Annual Energy (GWh)	256.66	373.69
Plant Factor (%)	92.70	79

8.6.3 Plant Factor

The Plant Factor is the unit-less ratio of an actual electrical energy output over a given period of time to the maximum possible electrical energy output over that period.

The plant factor which provides the basis for the installed capacity of the project is calculated as follows:

$$pf = (E/(P*8.760))*100$$

Where as

pf = Plant factor (%)

E = Mean annual energy (GWh/annum)

P = Installed Capacity (MW)

Hydraulic Losses

The hydraulic losses have been calculated using Darcy' Weisbach equation for pipes and hydraulic losses for different discharges keeping all other parameters same given in Table 8-6.

$$h_L = \frac{fLV^2}{2gD}$$

Where

h_L = Friction head losses in meters (m)

f = Moody's Friction Factor

D = Diameter of conduit in meters (m)

G = Gravitational acceleration (m^2/s)

L = Length of conduit in meters (m)

The summary of head losses is given in the following table

Table 8-6 Total Hydraulic Loss at Different Discharges

Discharge (m^3/sec)	Total Loss (m)	Discharge (m^3/sec)	Total Loss (m)
10	0.22	**60**	**6.04**
20	0.71	80	10.69
40	2.71	100	16.67

Net Head

After establishing the gross head, it is important to allow for the losses arising from laying of conveyance system. The gross head minus the sum of all loses through conveyance of flow for entrance to exist equals the net head. The range of net head varies between 105 to 107.5 m.

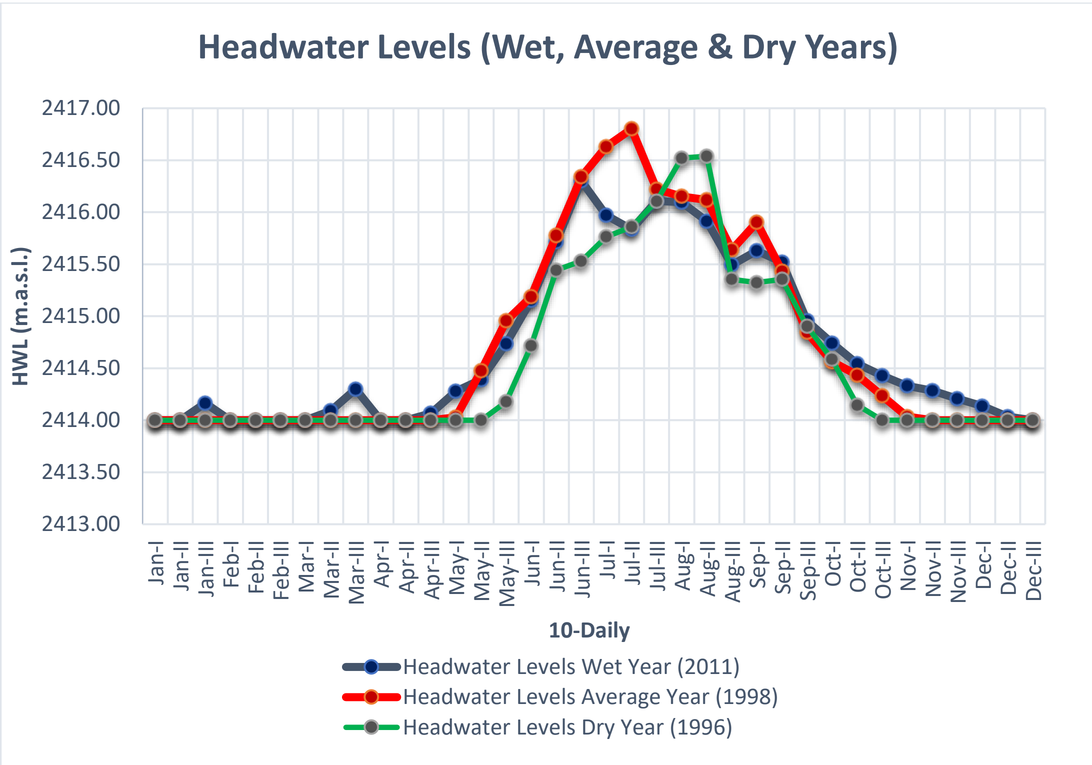


Figure 8-7 Headwater Level Variations (Wet, Average & Dry Years)

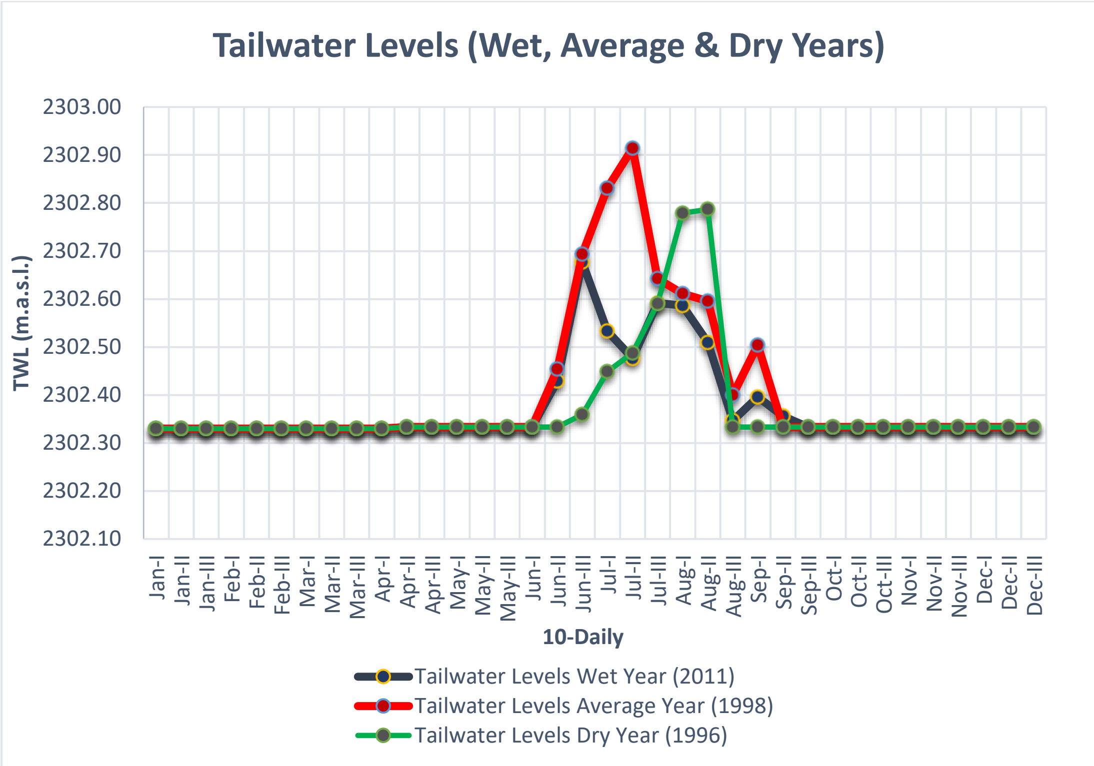


Figure 8-8 Tailwater Level Variations (Wet, Average & Dry Years)

Basic Assumptions in Calculations

The following basic assumptions have been made in estimating power and energy of the identified schemes.

- The residual water has been maintained in that 2 km reach i.e. weir to powerhouse site for ecological purposes and for calculations of power and energy.
- The variations in the efficiencies of generating units due to change of net heads have not been considered. For design discharges available to powerhouse, an efficiency of 91.5%, 97.5% and 99% have been used for the turbine, generator and transformers, respectively.

8.7 ESTIMATED POWER AND ENERGY

Keeping in view all the aspects, selected optimized design discharge is 60 m^3/s, the power and energy have been estimated on the basis of 10 day flows for all years from 1966 to 2015. For 10-Daily Power Curves, the optimum installed capacity would be 54.0 MW with environmental flow of 3 m^3/s having mean annual energy of 373.69 GWh. The plant factor will be taken as 79%.

The calculated annual energy, for years 1998 (average year), 2011 (wet year) and 1996 (dry year), is 375.75, 449.49 and 333.87 GWh respectively. The energy calculated based on 10 daily flows for 50 year ranges between 333.87 GWh to 449.49 GWh.A mean value of 373.69 GWh has been taken as mean annual energy. The 10 daily power and energy for average, wet and dryyears are presented in Table 8-7, 8 and 9 respectively, whereas power curves for these three scenarios are shown in Figure 8-9, Figure 8-10 and Figure 8-11 respectively.

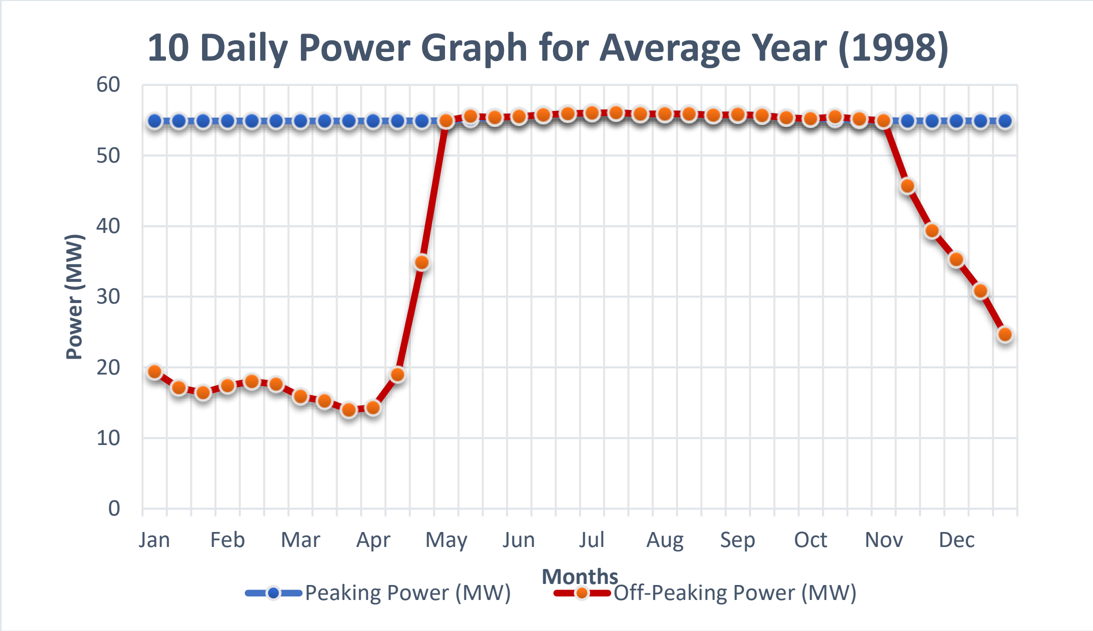


Figure 8-9 10-Daily Power Graph for Average Year (1998)

As in average year, the installed power of 54 MW would be available for 24 hours from May to October. Peaking power (4 hours) will be available throughout the year, however, off-peak power (20 hours) will vary from 14 MW to 54 MW and will remain full from May to October. When flow reduces due to winter in November, the power generation would also reduce, however, enough flows remain available to run one turbine unit during lowest flow period as indicated in Figure 8-9.

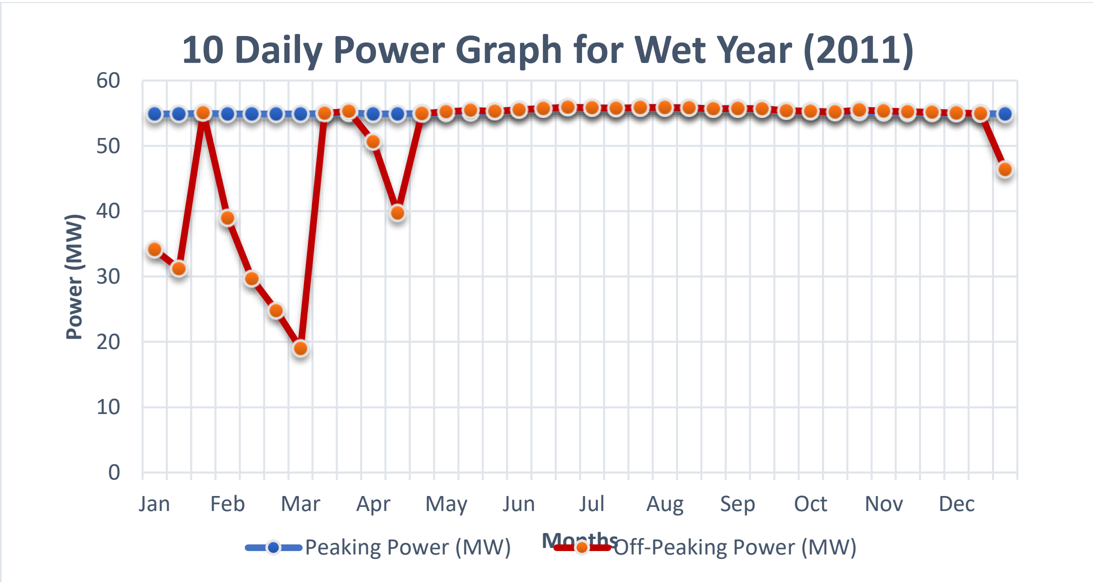


Figure 8-10 10-Daily Power Graph for Wet Year (2011)

In wet year, installed power of 54 MW would be available from May to mid-December. Power may reach to full capacity during high flows of wet year even in February and March. In low flow period, the minimum power is estimated to remain at 20 MW as indicated in Figure 8-10.

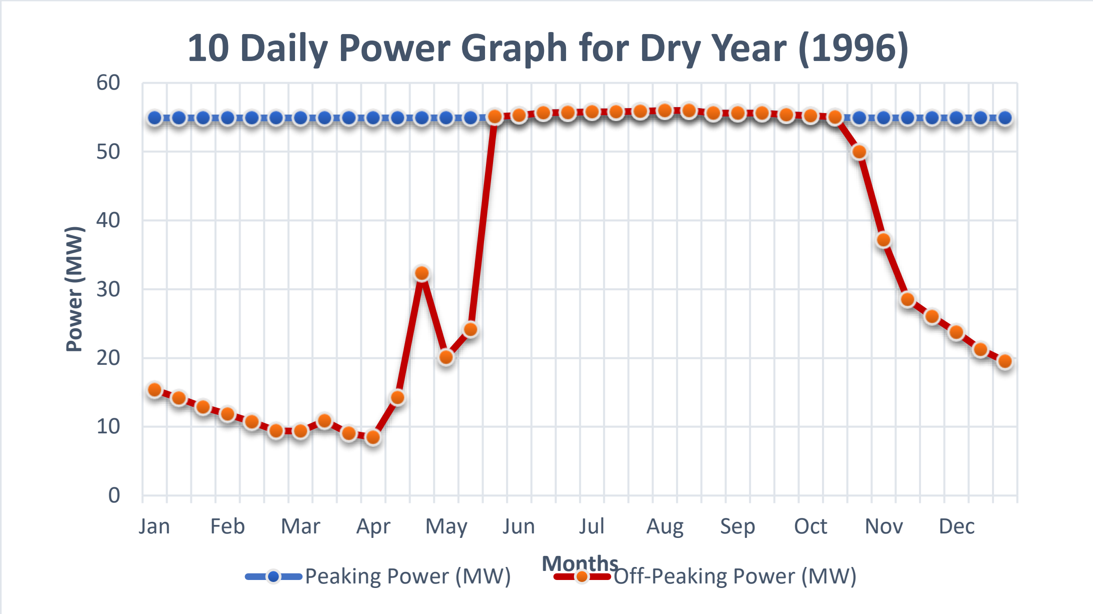


Figure 8-11 10-Daily Power Graph for Dry Year (1996)

In dry year, installed power of 54 MW will be available from June to mid-October and reduces as low as 9 MW when less flows are available. For dry year 1996, the power variation over the year is indicated in Figure 8-11.

The mean annual energy for the recorded period from 1966 to 2015 has been estimated and it is graphically presented in Figure 8-12. The graph indicates that the estimated annual energy over a period of 50 years doesn't vary much and remain quite consistent with little variation. It varies from 333.87 GWh to 449.49 GWh with mean value as 373.69 GWh. The plant factor for 54 MW power plant would be 79%. The low variation in mean annual energy and high plant factor indicate the reliability of hydropower from the lake.

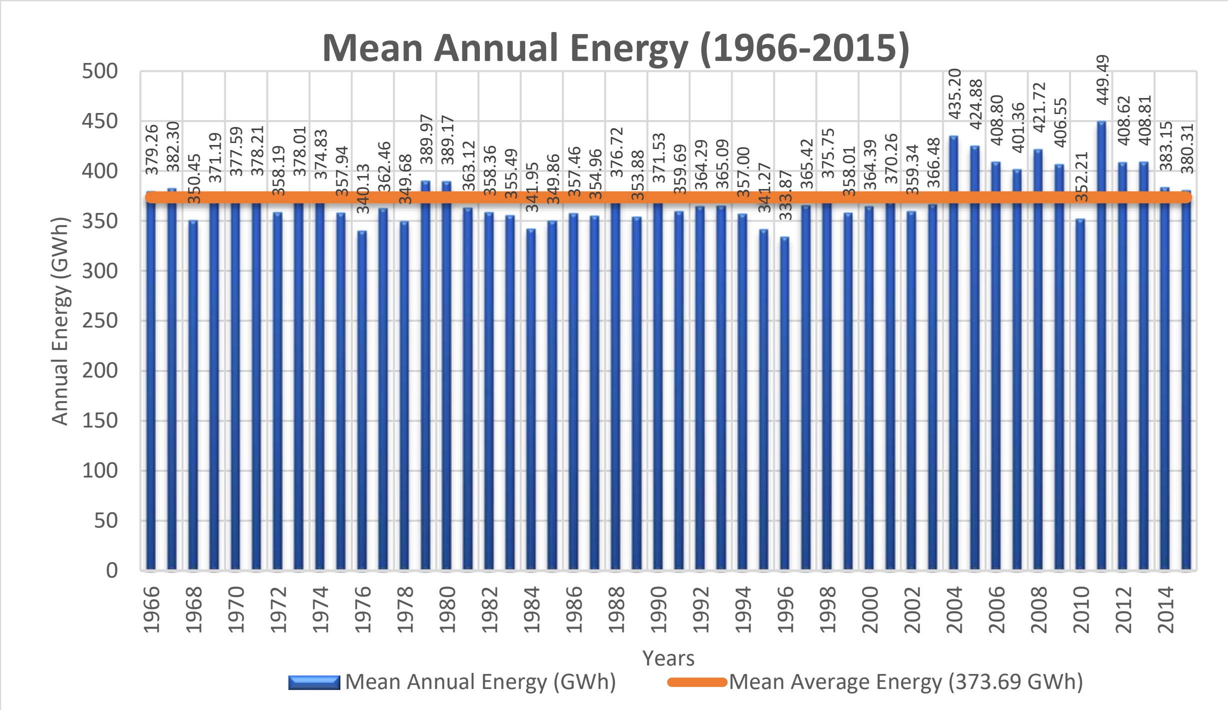


Figure 8-12 Mean Annual Energy Graph from 1966 to 2015

A comparison has also been plotted between monthly energy generations for Wet, Average and Dry years. Mean Annual Energy Curves indicate the trend of variations of monthly energies in GWh. The graph is shown at Figure 8-14.

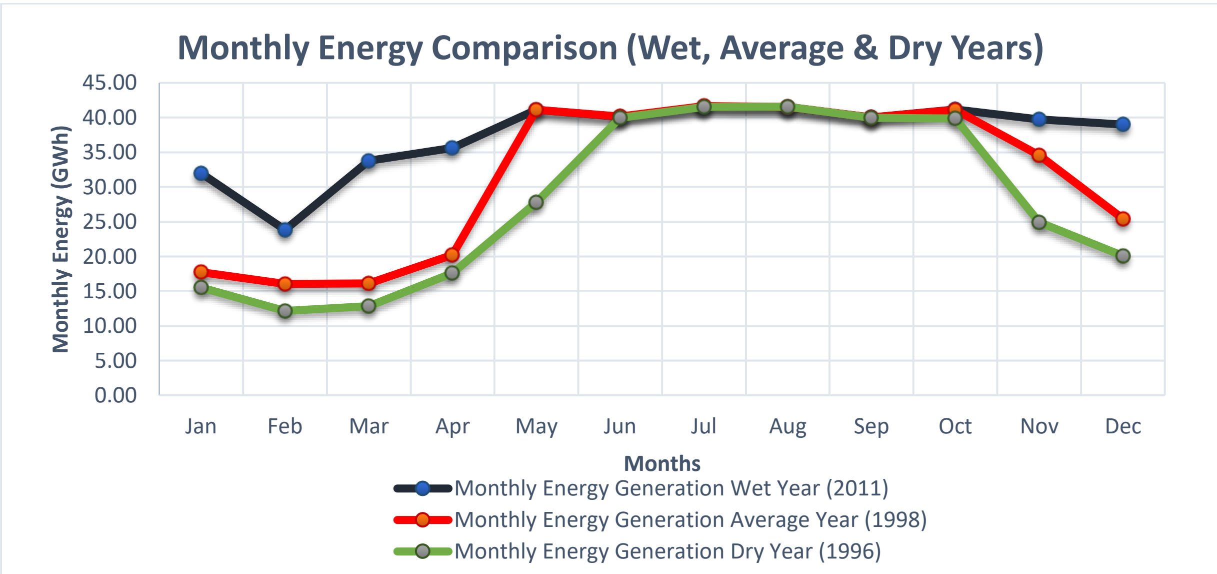


Figure 8-13 Monthly Energy Comparison (Wet, Average & Dry Years)

Power and energy calculations for Average, Wet and Dry years have been calculated and tabulated at Table 8-7, Table 8-8 & Table 8-9 respectively

Table 8-7 Power and Energy Calculations for Average Year (1998)

Month	Days	River Discharge (m^3/s)	Q_{pk} (m^3/s)	Q_{op} (m^3/s)	HWL m.a.s.l	TWL m.a.s.l	P_{pk} (MW)	P_{op} (MW)	Energy (GWh)
Jan	10	30.72	60.00	21.27	2414.00	2302.33	54.91	19.38	6.07
	10	28.65	60.00	18.78	2414.00	2302.33	54.91	17.11	5.62
	11	28.04	60.00	18.05	2414.00	2302.33	54.91	16.44	6.03
Feb	10	28.94	60.00	19.13	2414.00	2302.33	54.91	17.42	5.68
	10	29.47	60.00	19.76	2414.00	2302.33	54.91	18.00	5.80
	8	29.10	60.00	19.32	2414.00	2302.33	54.91	17.60	4.57
Mar	10	27.55	60.00	17.46	2414.00	2302.33	54.91	15.90	5.38
	10	26.95	60.00	16.74	2414.00	2302.33	54.91	15.25	5.25
	11	25.81	60.00	15.37	2414.00	2302.33	54.91	13.99	5.49
Apr	10	26.09	60.00	15.71	2414.00	2302.33	54.91	14.31	5.06
	10	30.33	60.00	20.80	2414.00	2302.33	54.91	18.95	5.99
	10	44.82	60.00	38.19	2414.00	2302.33	54.91	34.86	9.17
May	10	63.84	60.00	60.00	2414.03	2302.33	54.93	54.93	13.18
	10	116.70	60.00	60.00	2414.47	2302.33	55.16	55.56	13.32
	11	216.28	60.00	60.00	2414.96	2302.33	55.41	55.41	14.63
Jun	10	274.75	60.00	60.00	2415.19	2302.33	55.53	55.53	13.33
	10	451.22	60.00	60.00	2415.78	2302.45	55.77	55.77	13.39
	10	649.46	60.00	60.00	2416.34	2302.69	55.94	55.94	13.43
Jul	10	763.42	60.00	60.00	2416.63	2302.83	56.02	56.02	13.44
	10	832.02	60.00	60.00	2416.80	2302.91	56.06	56.06	13.46
	11	607.13	60.00	60.00	2416.22	2302.64	55.91	55.91	14.76
Aug	10	581.22	60.00	60.00	2416.15	2302.61	55.89	55.89	13.41
	10	568.59	60.00	60.00	2416.12	2302.60	55.87	55.87	13.41
	11	406.63	60.00	60.00	2415.64	2302.40	55.73	55.73	14.71
Sep	10	493.48	60.00	60.00	2415.90	2302.50	55.81	55.81	13.39
	10	345.06	60.00	60.00	2415.44	2302.33	55.66	55.66	13.36
	10	190.28	60.00	60.00	2414.84	2302.33	55.35	55.35	13.28
Oct	10	132.75	60.00	60.00	2414.57	2302.33	55.20	55.20	13.25
	10	110.03	60.00	60.00	2414.43	2302.33	55.14	55.49	13.30
	11	81.49	60.00	60.00	2414.23	2302.33	55.03	55.17	14.56
Nov	10	64.03	60.00	60.00	2414.03	2302.33	54.93	54.94	13.18
	10	54.65	60.00	49.98	2414.00	2302.33	54.91	45.69	11.33
	10	48.89	60.00	43.06	2414.00	2302.33	54.91	39.33	10.06
Dec	10	45.18	60.00	38.62	2414.00	2302.33	54.91	35.26	9.25
	10	41.18	60.00	33.81	2414.00	2302.33	54.91	30.85	8.37
	11	35.54	60.00	27.04	2414.00	2302.33	54.91	24.66	7.84
Average Year Annual Energy (1998) GWh									**375.75**

Table 8-8 Power and Energy Calculations for Wet Year (2011)

Month	Days	River Discharge (m^3/s)	Q_{pk} (m^3/s)	Q_{op} (m^3/s)	HWL m.a.s.l	TWL m.a.s.l	P_{pk} (MW)	P_{op} (MW)	Energy (GWh)
Jan	10	44.17	60.00	37.40	2414.00	2302.33	54.91	34.14	9.02
	10	41.46	60.00	34.15	2414.00	2302.33	54.91	31.17	8.43
	11	73.86	60.00	60.00	2414.16	2302.33	55.00	55.08	14.54
Feb	10	48.54	60.00	42.65	2414.00	2302.33	54.91	38.95	9.99
	10	40.09	60.00	32.51	2414.00	2302.33	54.91	29.66	8.13
	8	35.63	60.00	27.15	2414.00	2302.33	54.91	24.76	5.72
Mar	10	30.37	60.00	20.84	2414.00	2302.33	54.91	18.99	5.99
	10	67.54	60.00	60.00	2414.09	2302.33	54.96	54.99	13.20
	11	89.69	60.00	60.00	2414.30	2302.33	55.07	55.27	14.58
Apr	10	59.14	60.00	55.36	2414.00	2302.33	54.91	50.64	12.33
	10	49.22	60.00	43.46	2414.00	2302.33	54.91	39.70	10.14
	10	65.66	60.00	60.00	2414.06	2302.33	54.94	54.96	13.19
May	10	86.83	60.00	60.00	2414.28	2302.33	55.05	55.23	13.25
	10	103.14	60.00	60.00	2414.39	2302.33	55.11	55.41	13.29
	11	166.85	60.00	60.00	2414.74	2302.33	55.29	55.29	14.60
Jun	10	266.03	60.00	60.00	2415.15	2302.33	55.51	55.51	13.32
	10	431.15	60.00	60.00	2415.71	2302.43	55.75	55.75	13.38
	10	635.93	60.00	60.00	2416.30	2302.68	55.93	55.93	13.42
Jul	10	517.05	60.00	60.00	2415.97	2302.53	55.83	55.83	13.40
	10	470.43	60.00	60.00	2415.83	2302.48	55.79	55.79	13.39
	11	565.29	60.00	60.00	2416.11	2302.59	55.87	55.87	14.75
Aug	10	560.97	60.00	60.00	2416.10	2302.59	55.87	55.87	13.41
	10	497.46	60.00	60.00	2415.91	2302.51	55.81	55.81	13.40
	11	362.62	60.00	60.00	2415.49	2302.35	55.68	55.68	14.70
Sep	10	403.53	60.00	60.00	2415.63	2302.40	55.72	55.72	13.37
	10	370.33	60.00	60.00	2415.52	2302.36	55.69	55.69	13.37
	10	216.16	60.00	60.00	2414.96	2302.33	55.41	55.41	13.30
Oct	10	168.18	60.00	60.00	2414.74	2302.33	55.30	55.30	13.27
	10	128.43	60.00	60.00	2414.54	2302.33	55.19	55.19	13.25
	11	108.97	60.00	60.00	2414.43	2302.33	55.13	55.48	14.63
Nov	10	94.08	60.00	60.00	2414.33	2302.33	55.08	55.31	13.27
	10	87.67	60.00	60.00	2414.28	2302.33	55.06	55.24	13.25
	10	78.32	60.00	60.00	2414.21	2302.33	55.02	55.13	13.23
Dec	10	71.31	60.00	60.00	2414.14	2302.33	54.98	55.04	13.21
	10	64.06	60.00	60.00	2414.03	2302.33	54.93	54.94	13.18
	11	55.28	60.00	50.74	2414.00	2302.33	54.91	46.39	12.62
Wet Year Annual Energy (2011) GWh									**449.49**

Table 8-9 Power and Energy Calculations for Dry Year (1996)

Month	Days	River Discharge (m^3/s)	Q_{pk} (m^3/s)	Q_{op} (m^3/s)	HWL m.a.s.l	TWL m.a.s.l	P_{pk} (MW)	P_{op} (MW)	Energy (GWh)
Jan	10	27.06	60.00	16.87	2414.00	2302.33	54.91	15.36	5.27
	10	25.96	60.00	15.56	2414.00	2302.33	54.91	14.16	5.03
	11	24.77	60.00	14.12	2414.00	2302.33	54.91	12.85	5.24
Feb	10	23.83	60.00	13.00	2414.00	2302.33	54.91	11.83	4.56
	10	22.80	60.00	11.76	2414.00	2302.33	54.91	10.70	4.34
	8	21.61	60.00	10.33	2414.00	2302.33	54.91	9.40	3.26
Mar	10	21.56	60.00	10.27	2414.00	2302.33	54.91	9.34	4.07
	10	22.93	60.00	11.92	2414.00	2302.33	54.91	10.85	4.37
	11	21.27	60.00	9.93	2414.00	2302.33	54.91	9.03	4.40
Apr	10	20.75	60.00	9.30	2414.00	2302.33	54.91	8.46	3.89
	10	26.03	60.00	15.64	2414.00	2302.33	54.91	14.24	5.04
	10	42.51	60.00	35.41	2414.00	2302.33	54.91	32.32	8.66
May	10	31.39	60.00	22.07	2414.00	2302.33	54.91	20.11	6.22
	10	35.07	60.00	26.48	2414.00	2302.33	54.91	24.14	7.02
	11	75.25	60.00	60.00	2414.18	2302.33	55.00	55.09	14.54
Jun	10	162.25	60.00	60.00	2414.72	2302.33	55.28	55.28	13.27
	10	347.31	60.00	60.00	2415.44	2302.33	55.66	55.66	13.36
	10	373.33	60.00	60.00	2415.53	2302.36	55.69	55.69	13.37
Jul	10	446.88	60.00	60.00	2415.76	2302.45	55.77	55.77	13.38
	10	479.44	60.00	60.00	2415.86	2302.49	55.80	55.80	13.39
	11	564.28	60.00	60.00	2416.11	2302.59	55.87	55.87	14.75
Aug	10	720.09	60.00	60.00	2416.52	2302.78	55.99	55.99	13.44
	10	726.57	60.00	60.00	2416.54	2302.79	55.99	55.99	13.44
	11	322.03	60.00	60.00	2415.36	2302.33	55.62	55.62	14.68
Sep	10	313.09	60.00	60.00	2415.32	2302.33	55.60	55.60	13.34
	10	321.96	60.00	60.00	2415.36	2302.33	55.62	55.62	13.35
	10	203.88	60.00	60.00	2414.90	2302.33	55.38	55.38	13.29
Oct	10	136.56	60.00	60.00	2414.59	2302.33	55.22	55.21	13.25
	10	72.07	60.00	60.00	2414.15	2302.33	54.99	55.05	13.21
	11	58.52	60.00	54.63	2414.00	2302.33	54.91	49.96	13.41
Nov	10	46.90	60.00	40.68	2414.00	2302.33	54.91	37.15	9.63
	10	39.05	60.00	31.26	2414.00	2302.33	54.91	28.51	7.90
	10	36.80	60.00	28.57	2414.00	2302.33	54.91	26.05	7.41
Dec	10	34.72	60.00	26.07	2414.00	2302.33	54.91	23.76	6.95
	10	32.41	60.00	23.29	2414.00	2302.33	54.91	21.22	6.44
	11	30.83	60.00	21.40	2414.00	2302.33	54.91	19.50	6.71
Dry Year Annual Energy (1996) GWh									**333.87**

9 DESIGN OF STRUCTURES

9.1 INTRODUCTION

Attabad Lake Hydropower Project (ALHPP) is a Runoff River peaking scheme on Hunza River in Hunza Region. The Project is planned to develop the reach of river 2.5 km downstream of Attabad Lake to generate 54 MW power by proposing the following Civil Engineering Structures:

Natural dam of 45 m height from river bed to act as diversion structure with low level outlet and an overflow ungated spillway.

Power Intake structure is proposed on the left bank of river to take the design discharge of 60.0 m^3/s.

- Low pressure headrace tunnel having diameter of 5.5 m with total length of 2320 m.
- Vertical surge shaft of 10 m diameter with height of 49 m.
- Concrete lined pressure shaft of 3.6 m diameter having a length of 80 m.
- Steel penstock having a length of 470 m length and diameter of 3.5 m.
- Surface powerhouse with three (03) Francis units with an installed capacity of 54 MW and open switchyard.
- Tailrace channel of 18 m length.

The overflow weir/ungated spillway on existing dam created due to landslide at right side of Hunza River has been proposed with its crest level at elevation 2414.0 m.a.s.l. The structure has been designed to safely pass 1:10,000-year return period flood and Operating Basis Earthquake (OBE) and Safety Evaluation Earthquake (SEE) without damage. The overflow weir/spillway is ungated structure for flood discharge. The discharge to downstream stilling basin of overflow weir/spillway for energy dissipation before being released into channelized section of Hunza River in slide area. The care has been taken to provide protective design of the structures. Detail Drawings of over flow weir/ spillway are shown in AFS-WR-409 to AFS-411 Vol. 2 Drawings.

Three low level sediment flushing outlets serving the dual purpose of diversion during construction as well as sediment flushing have been provided on the left bank of overflow weir/ungated spillway. Considerable sediment inflow is expected into the reservoir during the glacier/snow melt runoff and also during rains. In order to maintain the power intakes free of sediment build up, it is located 2 m above the invert level of flushing outlets. The concrete spillway section and the three low level outlets will be used to flush the sediments from the reservoir.

Due to the high river bed gradient, it is expected that intensive sediment load would be entering in the reservoir. To prevent this occurring, provision has also been made to build a low “flow-through” rockfill boulder trap on Shimshal River upstream of the reservoir to trap any moving boulders or bed material.

Two boulder traps will be constructed on Shimshal River which is main sources of sediment load in Hunza River at Attabad. Each boulder trap will be 20 m high an estimated boulder/debris/sediment volume of 1.4 Million m^3. The diversion of Hunza River will be accomplished by the construction of upstream and downstream cofferdams with impervious cut off provided by intersecting columns of jet grouting.

Conventional ring cofferdams with sufficient space provision for construction activities and access will be used for construction of the diversion intakes and tunnels and the power intakes. The headrace commences at the twin intakes on the left bank connecting to the low pressure tunnel.

At the downstream end of the low pressure tunnel a surge shaft is provided to limit pressure rise in the waterway system and allow flexibility in power plant operation. From surge tank, first horizontal tunnel and the embedded penstock lead to three vertical shaft Francis Turbines arranged in on-ground powerhouse. Transformers are arranged in a GIS open switchyard. The switchyard is above ground located near the powerhouse. A 18m long tailrace releases generation flows back to the Hunza River about 2.5 km downstream of overflow weir. Feasibility Drawings are provided in Vol. 2 – Drawings of the Feasibility Report.

9.2 HYDRAULIC MODELLING OF RESERVOIR

The primary tools for simulating the flow phenomena in water resources structures are hydraulic/hydrodynamic models that describe the fluid motion and the dynamics of the flood wave by solving mathematical equations, which are based on the principles of the conservation of mass and momentum.

Hydraulic Model, the Hydrologic Engineering Center's River Analysis System (HEC-RAS 5.0.7) is used to assess the impact of design flood on the proposed weir, downstream as well as backwater effect at the upstream side of the lake. The software is developed by the US Army Corps of Engineers and it is widely used for performing 1D steady and unsteady flow, 2D unsteady flow river hydraulics calculations, sediment transport modeling, and water quality analysis.

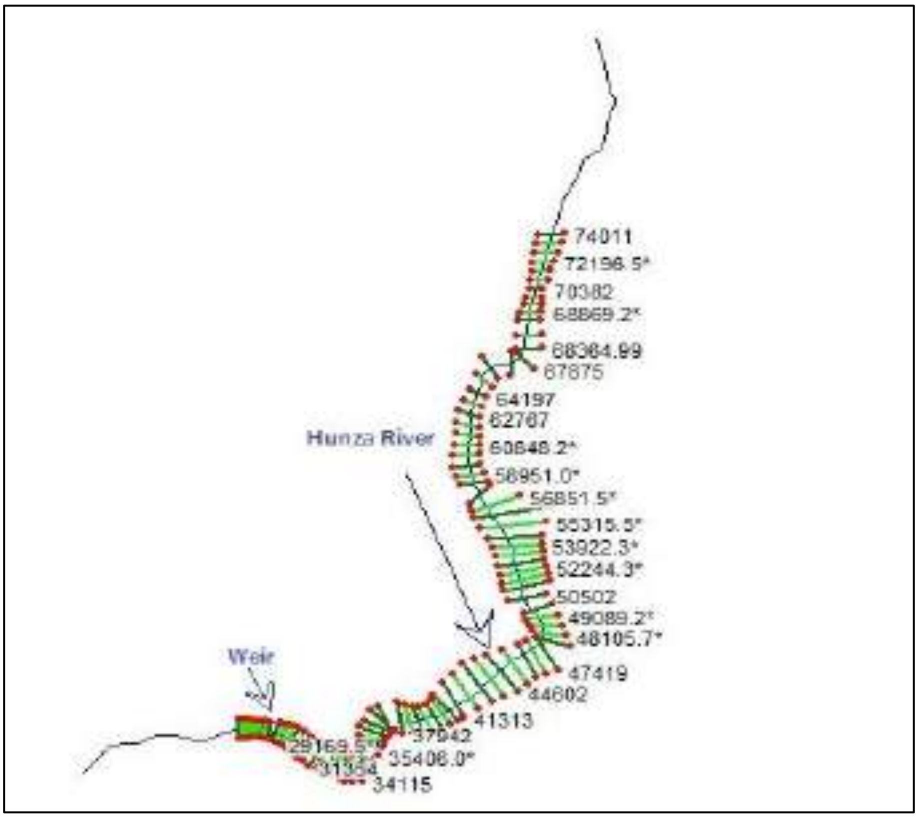


Figure 9-1 Reservoir Area showing River Cross Sections and Location of Weir

9.2.1 Input Data

Hydraulic Model is prepared to analyze the impact of flood of 3,250 m^3/s, 10,000 year return period flood, at upstream side of the project with proposed weir. A 1D-Unsteady numerical modeling approach is used in the analysis to study the impact of proposed weir having crest elevation of 2,014 m.a.s.l.

River cross section data has been taken from the hydrographic survey conducted for the project by ISRIP in Sep/Oct 2020. Forty Cross Sections in about 14 km reach has been used to prepare an input file for HEC-RAS. These surveyed cross sections are further used for interpolation of cross sections where required for true representation and model stability. A proposed 60 m long ungated ogee weir and about 400 m downstream reach covering stilling basin and stone apron have also been drawn. In most upstream part of the reach, Manning's 'n' value has been taken as 0.040, value changes just before the weir structure and at weir crest it has been taken as 0.013 and accordingly downstream, Coefficient of Discharge (Cd) is taken as 0.8. Further, boundary conditions are set as flood hydrograph for 3,250 m^3/s peak and normal depth at downstream.

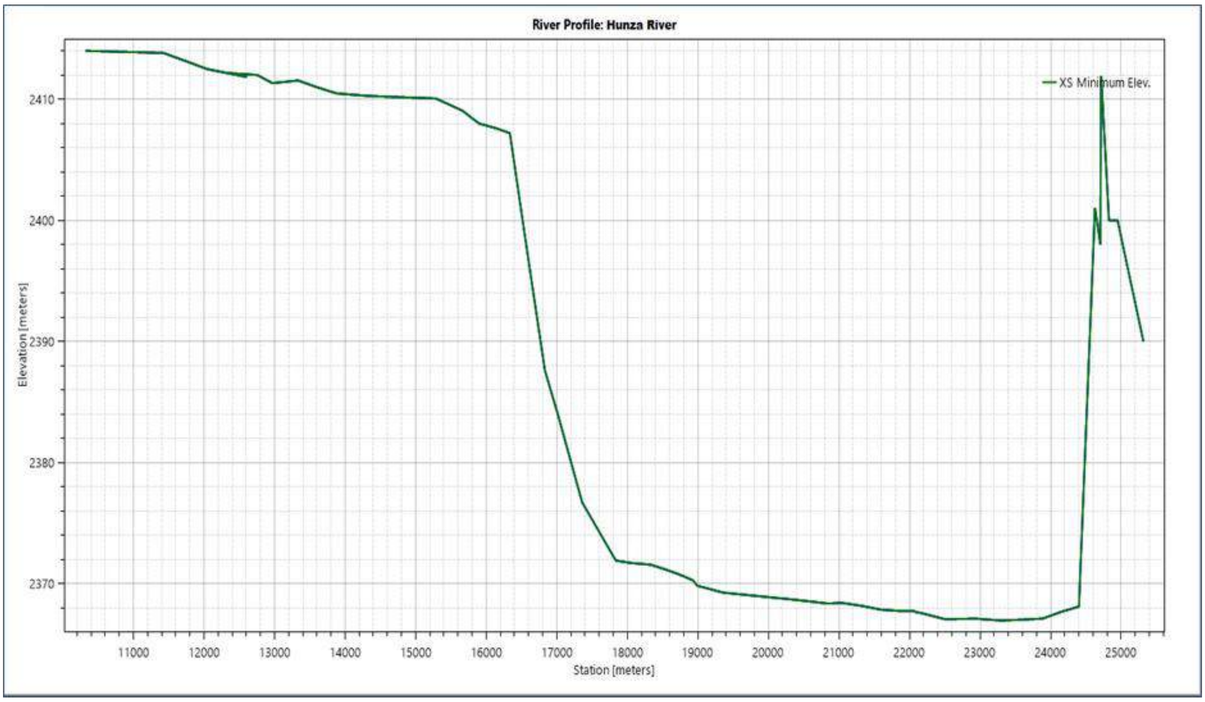


Figure 9-2 Hunza River Profile in Reservoir Area

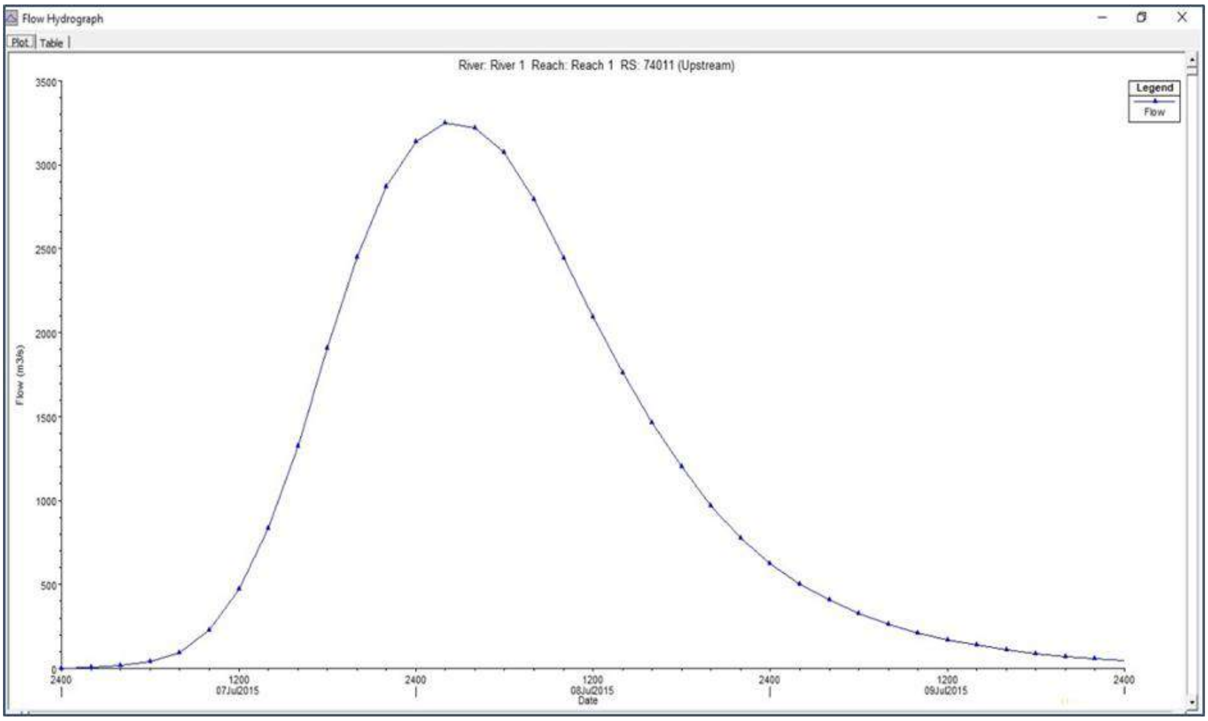


Figure 9-3 Extrapolated Flow Hydrograph

9.2.2 Analysis and Conclusions

The model has been run keeping a lesser time step for computations and accordingly results are computed. It can be viewed from the results that maximum Water Surface Elevation (WSE) at overflow Weir is 2,421.43 m.a.s.l. and about 14 km upstream it is 2,422.61 m.a.s.l. against design flood. This shows the impact of flood wave at upstream of the lake with 60 m long ungated weir having crest at 2,414 m.a.s.l. Flood mapping is drawn using RAS Mapper tool in HEC-RAS which shows the extent of maximum water surface elevation against the design flood. Rating Curve is also drawn at the weir. The model is calibrated using the flows measurements at Ganish Bridge and water surface level measurements at the lake during hydrographic survey.

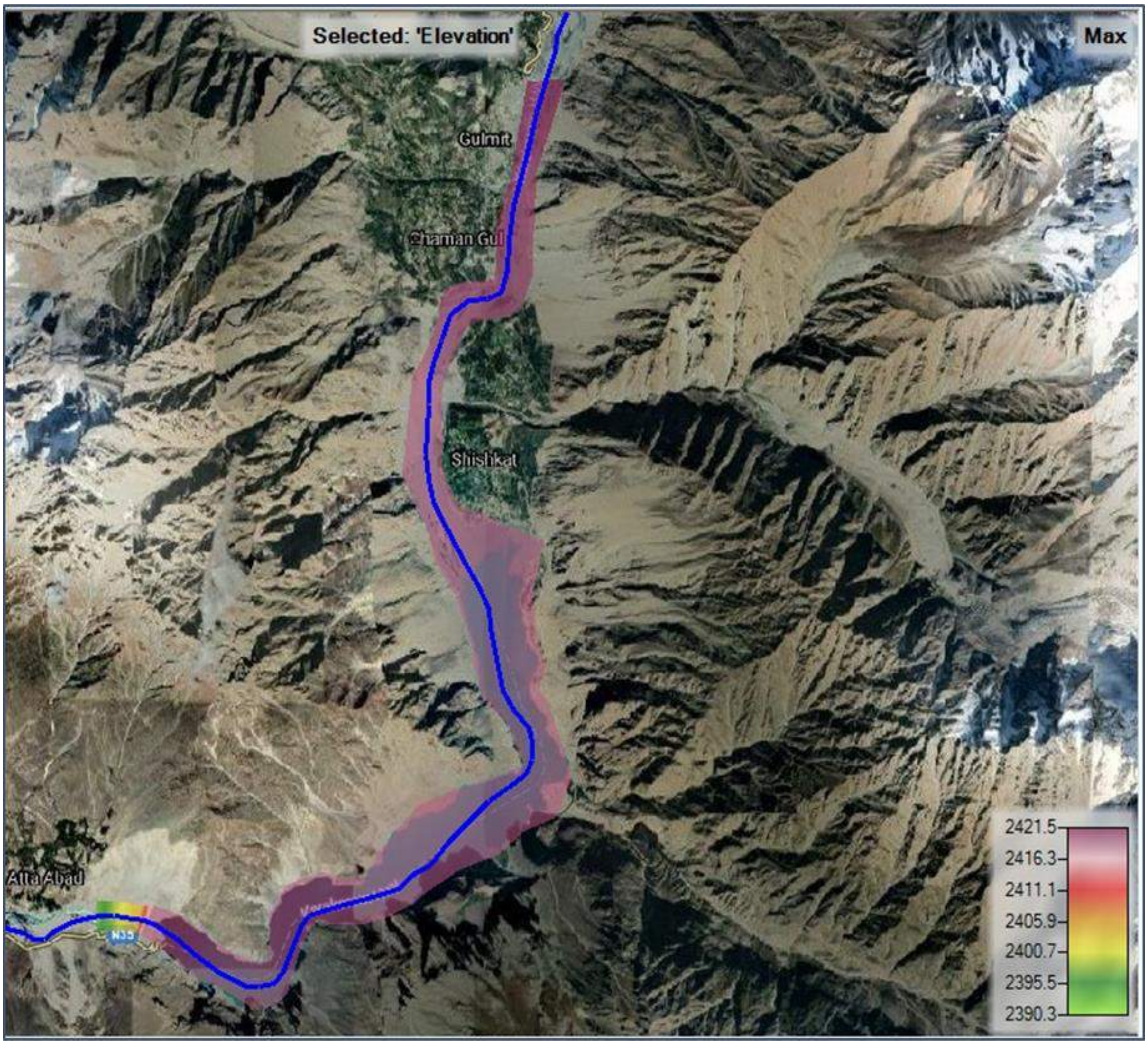


Figure 9-4 Maximum Water Surface Elevation (WSE) against Design Flood

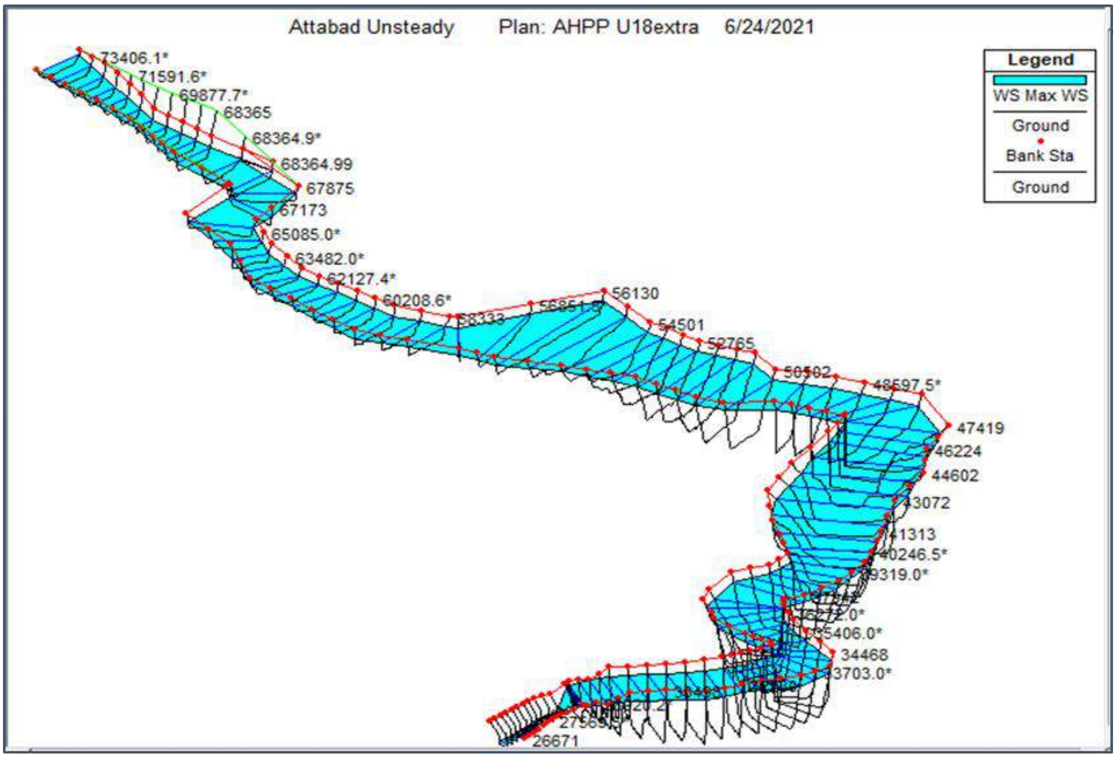


Figure 9-5 3D Perspective Plot against Max WSE

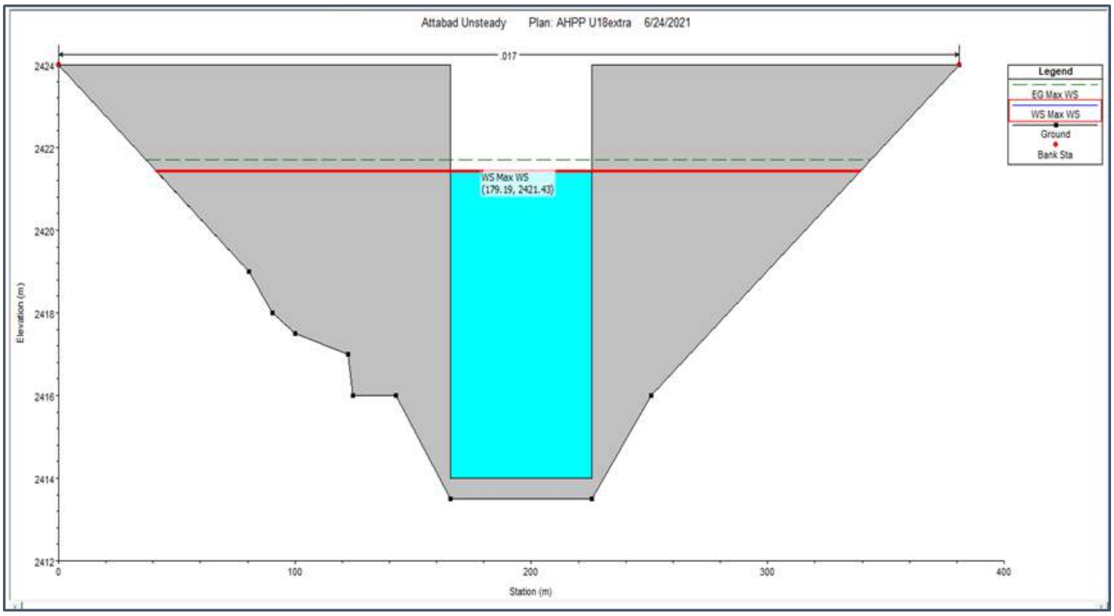


Figure 9-6 Weir Section with Maximum Water Surface Elevation

Detailed output table is tabulated below showing discharges, minimum river elevation, water surface elevation, energy grade line elevation, velocity, flow area and top width of each cross section from about 14 km upstream of the overflow weir / ungated spillway to about 500 m downstream. In conclusion, this shows that there would be no major impact on upstream settlements due to the overflow weir at 2,414 m.a.s.l and flood would remain within the river system.

Table 9-1 Maximum Water Surface Elevation at each Surveyed Cross Section

Sr. No.	River Station (u/s to d/s)	Distance from Weir (m)	Q Total (m^3/s	Min XS El. (m)	W.S. El. (m)	E.G. El. (m)	Velocity (m/s)	Flow Area (m^2)	Top Width (m)
1	74011	13,886	3169.	2414.00	2422.6	2422.6	1.05	3017.17	399.81
2	70382	12,780	3116.	2413.82	2421.9	2422.3	2.59	1200.87	170.55
3	68365	12,165	3119.	2412.50	2422.0	2422.1	1.06	2934.84	332.25
4	68365	12,165	3118.	2411.84	2422.0	2422.0	0.95	3291.69	413.04
5	67875	12,016	3118.	2412.01	2422.0	2422.0	0.82	3808.64	429.72
6	67173	11,802	3112.	2411.33	2421.9	2422.0	0.86	3603.62	428.07
7	65973	11,436	3113.	2411.55	2421.9	2421.9	0.88	3552.69	447.56
8	64197	10,895	3106.	2410.49	2421.8	2421.9	1.33	2334.18	246.01
9	62767	10,459	3095.	2410.28	2421.6	2421.8	2.02	1533.76	221.29
10	59569	9,485	3094.	2410.06	2421.6	2421.6	0.71	4383.47	452.61
11	58333	9,108	3091.	2409.06	2421.6	2421.6	0.70	4398.80	408.15
12	57573	8,876	3094.	2408.00	2421.6	2421.6	0.74	4171.30	420.15
13	56130	8,436	3092.	2407.20	2421.6	2421.6	0.21	15073.7	1252.65
14	54501	7,940	3092.	2387.60	2421.6	2421.6	0.17	18005.9	847.82
15	52765	7,411	3093.	2376.70	2421.6	2421.6	0.14	22744.4	698.40
16	51203	6,935	3093.	2371.90	2421.6	2421.6	0.11	28707.9	769.19
17	50502	6,721	3093.	2371.70	2421.6	2421.6	0.14	21636.6	573.80
18	49581	6,440	3094.	2371.56	2421.6	2421.6	0.18	17209.1	460.98
19	47614	5,841	3092.	2370.26	2421.6	2421.6	0.15	20547.6	553.60
20	47419	5,781	3092.	2369.82	2421.6	2421.6	0.14	21934.0	660.34
21	46224	5,417	3093.	2369.26	2421.6	2421.6	0.12	24782.0	703.79
22	44602	4,923	3092.	2368.97	2421.6	2421.6	0.10	31098.3	786.87
23	43072	4,457	3092.	2368.70	2421.6	2421.6	0.09	34793.8	814.98
24	41313	3,920	3092.	2368.35	2421.6	2421.6	0.11	28512.3	719.01
25	40714	3,738	3092.	2368.41	2421.6	2421.6	0.12	26649.7	603.33
26	39779	3,453	3092.	2368.16	2421.6	2421.6	0.14	22493.7	494.28
27	38859	3,173	3091.	2367.84	2421.6	2421.6	0.14	21662.4	470.46
28	37942	2,893	3091.	2367.73	2421.6	2421.6	0.12	25907.7	555.37
29	37328	2,706	3091.	2367.75	2421.6	2421.6	0.14	21329.6	491.89
30	37243	2,680	3091.	2367.63	2421.6	2421.6	0.14	22001.6	527.13
31	37079	2,630	3091.	2367.59	2421.6	2421.6	0.13	23213.2	496.64
32	36669	2,505	3091.	2367.41	2421.6	2421.6	0.13	23108.0	481.39
33	35875	2,263	3091.	2367.05	2421.6	2421.6	0.17	18406.1	374.54
34	34468	1,834	3091.	2367.11	2421.6	2421.6	0.15	20584.5	430.94
35	34115	1,727	3091.	2367.05	2421.6	2421.6	0.13	24623.9	503.81
36	33291	1,475	3091.	2366.95	2421.6	2421.6	0.13	23690.5	495.10
37	32230	1,152	3091.	2367.03	2421.6	2421.6	0.17	17716.2	398.85
38	31354	885	3091.	2367.11	2421.6	2421.6	0.14	22496.2	463.89
39	30498	624	3091.	2367.66	2421.6	2421.6	0.15	21319.7	436.76
40	29668	371	3091.	2368.10	2421.6	2421.6	0.20	15587.6	432.53
41	28671	67	3091.	2398.00	2421.5	2421.6	0.51	6086.59	363.33
42	28635	56	3091.	2413.50	2421.4	2421.7	2.29	1350.51	297.71
43	28450	0	**Weir**						
44	28269	(55)	3091.	2400.00	2404.0	2412.1	12.60	245.28	60.00
45	27869	(177)	3091.	2400.00	2402.6	2422.0	19.51	158.43	60.00
46	26671	(542)	3091.	2390.00	2392.7	2410.8	18.83	164.19	60.00

9.3 NATURAL DAMMING ON HUNZA RIVER

On January 4, 2010, a huge mass from the right bank of Hunza river slided down near Attabad village and blocked Hunza River for about 2 km. The inflow filled upstream valley created a 22 km long till reservoir the end of May 2010. The estimated lake initial storage was about 310 million m^3.

The deposited mass as a result of land slide is mainly composed of non-cohesive rock flour (fine dust, silt, silt gravels and cobbles) at the toe of the failed slope. Large boulders of granodioritic rocks with intrusions of granite, pegmatite and apatite were deposited close to the left bank of Hunza River. The deposit on the downstream side is composed of black clay with high plasticity and organic content. The upstream shoulder of the natural dam has mild slope and downstream slope is quite steep. With 2 km long dam, there is rare chance of piping failure.

A Dam brake study was conducted by NESPAK for National Disaster Mitigation Authority (NDMA) in March, 2010. For drainage of impounded flows through slided area, the excavation of material was proposed as 24 m deep and 45 m wide to form as spillway. The excavation works for the spillway was completed in the mid of May and the overflow began on May 29, 2010. The pattern of outflows was observed at downstream Ganish Bridge. The flows in summer 2010 were as a result of snow melt, no abrupt change in flows observed.

The recent deposits are the most widely spread soil units overlies the bed rocks. The slopes are covered with overburden having variable thickness. Terrace deposits comprise of mixtures of clay, sandy silt, boulders and gravel in various proportions. These units include Angular Boulder Gravel with Fines (ABGM), Rounded Boulder Gravel with Fines(RBGM), Terrace deposit and Moranic deposits. An overtopping concrete weir founded on slided mass is proposed after foundation treatment. Geological rock units with which weir has to be abut, includes Granodiorite, intruded by pegmatite veins at right side. On left side weir has to be abut with ABGM formed by slided mass.

The present bed level of Hunza River at start of narrow section downstream of reservoir is 2412 m.a.s.l. The river width is about 50 to 55 m in summer month. The water depth varies from 2 to 6 m depending upon the outflows. The existing water way would be remodeled to act as ungated spillway to pass the design flood. The river diversion during construction would be made through a low level open channel which would be used as sediment flushing channel during operation phase.

On the left bank of Hunza River, upstream of the weir, the river flows will be diverted at twin intakes into the power waterways system leading via desanders to the low pressure tunnel, surge tank, pressure pipe upto the power station from where the water ultimately discharges into the Hunza River. The roadway network exists at all important locations of proposed structures: weir, power intake, surge tank and powerhouse.

The maximum and minimum operating levels of the Attabad Lake Reservoir has been set by optimization and intake submergence requirements at 2414.0 m.a.s.l. and 2412.0 m.a.s.l. With normal poundage at 2414.0 m a s l, the length of reservoir is about 12 km and it has a gross capacity of 123 million m^3. The live storage with 2 m regulation from 2412 to 2414 m.a.s.l is 11 Million m^3.

The existing river course downstream of lake would be remodeled into channelized section. In the initial portion, a concrete structure of overflow weir / ungated spillway and stilling basin is proposed as control section for flood passage. Downstream of weir/spillway structure, trapezoidal section 50 m bed width. The overflow ungated weir/spillway crest is at 2414.0 m.a.s.l. On the left bank of main weir, a deep cut channel would be excavated to divert the river flows during construction for a discharge of 1750 m^3/s. The diversion channel later on would be used for sediment flushing. The width of flushing channel has been proposed as 25 m. Three low level bottom outlets 5 m x 5 m are proposed to be equipped with hydraulically operated radial gates. Taking account freeboard above maximum flood level and gate operating of low level outlets and clearance requirements to pass flood, plate form level has been set at 2424.0 m.a.s.l.

A deep cut channel has been proposed on the left bank for diversion during construction which later on can be used for sediment flushing. The low level outlets can be used to supplement spillway discharge for additional measure of safety. The spillway discharges onto a stilling basin on the downstream for energy dissipation to be released into Hunza River. Considerable sediment inflow is expected into the reservoir during the glacier/snow melt runoff and also during rains. In order to maintain the power intakes free of sediment build up these are placed 2 m below the power intake. During the high flow season, the spillway will also be operated to pass any suspended sediment.

9.4 HYDRAULIC DESIGN

9.4.1 Hydraulic Design of Weir/Spillway and Stilling Basin

The weir/spillway overflow structure provided on the ALHPP is located on the left abutment of the embankment dam and is designed to safely pass the 1:10,000 year returned period flood of 3250m^3/s. The weir/spillway will be supplemented by the capacity of the three low level diversion cum flushing outlets in case of mal-operation of one gate and in case of emergencies.

Maximum reservoir level	2414.0 m.a.s.l.
Spillway crest elevation	2414.0 m.a.s.l.

9.4.1.1 Weir/Spillway Discharge Capacity Overflow Ungated Structure:

The weir/spillway structure was designed with a crest elevation of 2414.0 m a s l and a design head of 12.0 m. The spillway discharge capacity is calculated for various design discharges. The effect of piers and abutments on the effective crest width as well as the variation of the discharge coefficient with head are considered in the calculation of the spillway discharge capacity. For the relevant design floods the calculation of the discharge capacity has been performed and the corresponding results are given in the tables and graphs below.

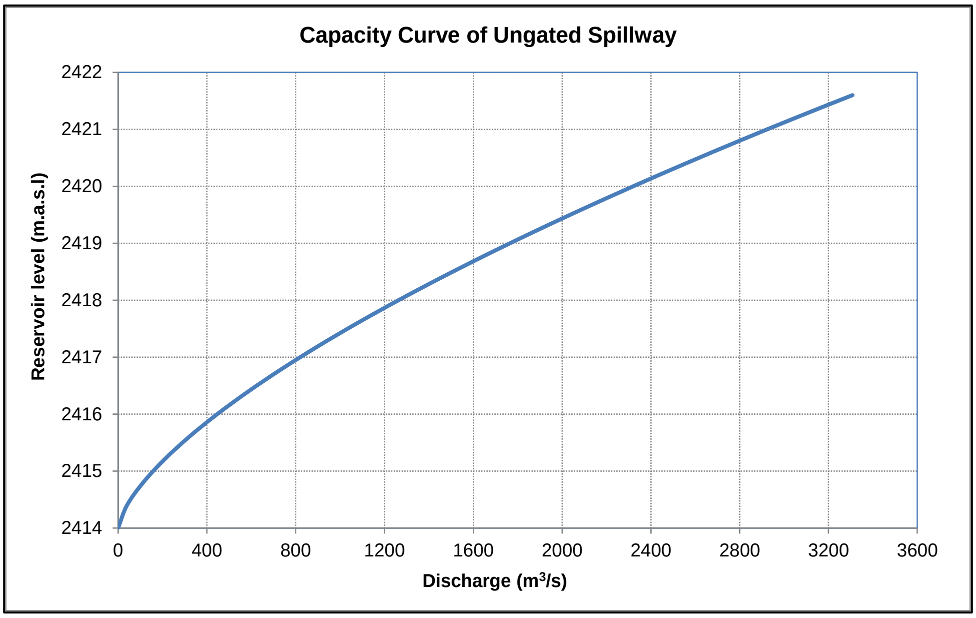


Figure 9-7 Discharge Capacity of Overflow Spillways

It is seen that the spillway discharge at elevation 2421.4 m a s l is 3,250 m^3/s. Along with overflow spillway, two low level flushing outlets would be in operation to discharge 600 m^3/s. The total discharge through overflow weir / ungated spillway is 3,250 m^3/s, which is 10,000 year return period. The spillway can therefore safely pass the PMF discharge with sufficient free board.

It is seen that the overflow weir/ungated spillway discharge capacity even at elevation 2414 m.a.s.l. is zero and spillage through power intake and sediment flushing outlet is possible which is only about 660 m^3/s when out of three, two under sluices are in operation. The discharge rating is shown in Figure 9-7 and indicates that the 1: 10,000 returned period flood can be passed safely in an emergency at an elevation of 2421.4 m.a.s.l.

9.4.1.2 Design of Spillway Stilling Basin

The riverbed downstream of the spillway consists of sandy gravels and boulders and would erode if the spillway discharges were released directly on to the bed. As such a stilling basin needs to be provided for energy dissipation.

The stilling basin is designed for the design flood of 1:10,000, (HQ 10,000 = 3,250 m^3/s). Proper functioning of the stilling basin is reconfirmed in addition for floods covering return periods from 1:10 to 1: 10,000 years AEP.

HQ_{10} = 2,040 m^3/s

HQ_{100} =2,910m^3/s

$HQ_{10,000}$ =3,250 m^3/s

The approach to hydraulic design of the stilling basin is as follows:

I. Determine the energy head at the spillway crest for the selected spillway design at maximum operation level of 2414.0 m.a.s.l.

II. Determine the hydraulic conditions along the ogee, in particular at the transition from ogee to stilling basin.

III. Calculate the conjugated depth h2 of the hydraulic jump and the required length of the stilling basin.

IV. Determine the relevant tailwater level and calculate the required elevation of the stilling basin floor.

The relation between conjugate depths for a hydraulic jump on a stilling basin is given by,

$$\frac{h_2}{h_1} = \frac{1}{2}\sqrt{1 + 8F_1^2} - 1$$

Where,

h1 and h2 are the depths before and after the jump.

F1 is the Froude number at the start of the jump.

Tailwater levels has been checked for the various design discharges using the tailwater rating curve developed for the river cross-cross section 50 m downstream of the weir.

The hydraulic conditions from spillway crest to the stilling basin has been determined for discharges between HQ_{10} and HQ_{1000} i.e. 2040 to 3250 m^3/s. As a result, a stilling basin with the following dimensions have been selected:

Invert of stilling basin	2397.0 m.a.s.l.
Width of stilling basin	60.0 m.
Elevation of river bed d/s	2400.0 m.a.s.l.
Length of stilling basin	55.0 m.

Attabad Hydropower Project
Design Calculations for Weir

1. Weir Dimensions

Discharge (estimated design flood)	Q =	**3130**	m^3/s
Crest Width (as per site conditions)	B =	**60.0**	m
	B1 =	**60.0**	m
Gravity	g =	9.81	m/s^2
Crest Coefficient	μ =	0.9	

Water height over weir has been calculated from the formula as :

$$Q = 2/3 \mu B (2g)^{0.5} h^{1.5}$$

Height of Water above crest (from formula	**h =**	**7.33**	m
Upstream Bed Level (as per site condition)		2412	m
Weir Crest Level (assumed to pass flood)		2414.0	m
Water level at Flood (crest Elev.+h)		2421.3	m
Side Wall Level		2422.0	m

2. Design of Stilling Basin

Assumed Stilling Basin Level		2397	
Upstream water depth	h_o	9.33	m
Inflow velocity	v_o	5.59	m/s
Total energy at stilling Basin	E_o	25.91	m
Height of weir	w	2.00	m
Depth of water at toe (assume)	h_1	2.555	m
Depth of water at toe (Calculated)	h_1	**2.539**	m
Velocity	v1	20.55	m/s
Froud's number	F1	4.12	
Sequent Depth	h_u	6.40	m
Velocity	V_u	8.15	m/s
Depth of water after Jump	h_2	13.57	m
Length of Stilling Basin	$5x(h_2-h_1)$	55.15	m
Downstream water depth	h_d	6.00	m
Level difference (e)	h_2-h_d	7.57	m

$$h_1 = E_o - \frac{1.10 \times (Q^2)}{(h_1)^2 \times (B)^2 \times 2g}$$

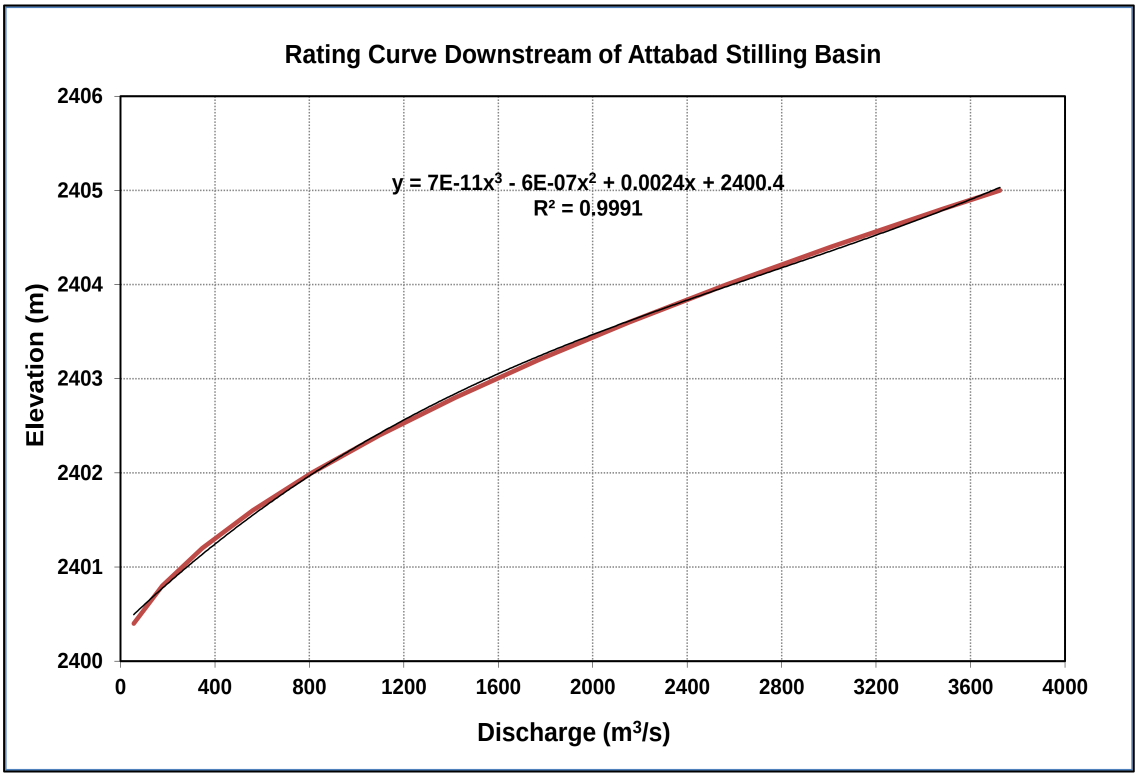


Figure 9-8 Tail Water Rating Curve Downstream of Stilling Basin

For the entire range of discharges considered in the present analysis, the criterion that the downstream water level exceeds the conjugated depth h_2 is maintained including a safety margin of 5 %.

Table 9-2 Variation of Stilling Basin Length with Flood Discharge

Discharge m³/s	Flood	Energ Head m	Depth h_1 m	Froude number	Conjugate depth h_2 m	Tailwater level m.a.s.l	Stilling Floor m.a.s.l	Basin Length m
2040	HQ10	22.83	1.496	5.06	9.98	2403.5	2397	42.44
2650	HQ50	24.25	1.965	4.54	11.67	2404.1	2397	48.54
2910	HQ100	24.82	2.165	4.36	12.31	2404.3	2397	50.72
3730	HQ1000	25.91	2.539	4.12	13.57	2405.0	2397	55.15

9.4.2 Flushing Outlets

Three low level sediment flushing cum diversion outlets have been provided on the left bank upstream of the embankment dam to enable flushing of sediment in front of the power intakes. Each flushing outlet is equipped with a hydraulically operated slide gate as the service gate. Provision has been also made for installation of stoplogs both at the upstream and downstream ends of the tunnels for use both during maintenance and repair.

The flushing outlets will be utilized for the following:

- Sediment flushing to keep the area upstream of the power intakes sediment free
- Reservoir (sediment) flushing in combination with reservoir draw down. The operational procedures for this need to be verified by physical model tests and also consider effects on reservoir periphery slope stability.
- For drawdown of the reservoir for maintenance and repair of structures as necessary.
- For use as an optional release facility for flood passage in the event of spillway gate problems.

The inverts of the flushing conduits have been set at riverbed level. The slide gates are located as upstream as possible in the conduits taking into consideration structural and operational requirements. Relatively high flow velocities will prevail and will prevent sediment load from depositing within the conduits. The design discharge capacity available at full reservoir supply level of 2414.0 m.a.s.l is 900 m^3/s with flushing outlets operating.

The flushing outlets are designed to be capable of removing fine and medium fractions of sediments (sand and gravel) that should not be allowed to accumulate in front of the power intake. During the high flow season 60 m^3/s will be diverted through the power intakes located upstream of the weir. The balance inflow may be released over the spillway and through the sediment flushing channel / undersluice, the latter being utilized to clear any sediment deposition in front of the intakes. This will ensure that coarse sediment fractions will not be drawn into the power intake at times of high river flow at normal operating level. No continuous flushing of the reservoir is envisaged. Discharge capacity of the two low level outlets which are also used as diversion tunnels during pre-commissioning stage for river diversion is provided in the details given under the sub-section on river diversion.

DESIGN OF UNDERSLUICES

ATTABAD HYDROPOWER PROJECT

Maximum upstream Water Level	2421.4	m.a.s.l.
Maximum downstream Water Level	2405.0	m.a.s.l.
Upstream Bed Level	2400.0	m.a.s.l.
Downstream Bed Level	2400.0	m.a.s.l.
Design Discharge	720	m^3/s
Width of Undersluice	5.0	m
Height of Undersluice	5.0	m
Gravitational Acceleration	9.81	m/s^2
Cross sectional Area	25	
Wetted Perimeter	20	
Hydraulic Radius	1.25	
(U/S water level) - (D/S water level) = h	16.40	m

CAPACITY OF UNDER SLUICE

X = $(1/1+f_i+f_o+f_c+f_{fr})$^1/2

where

Coefficient for intake losses (f_i)	0.06	
Coefficient for outlet losses (f_o)	1	
Coefficient for change in cross sec. (f_c)	0.04	
Coefficient for friction losses (f_{fr})		
Stickler's coefficient (k)	70	
f_{fr} =	0.13	
X =	0.67	
V = X (2gh)^0.5	12.00	m/s
Q = One Under Sluice	**300.0**	m^3/s
Discharge through three Undersluices	**900.1**	m^3/s

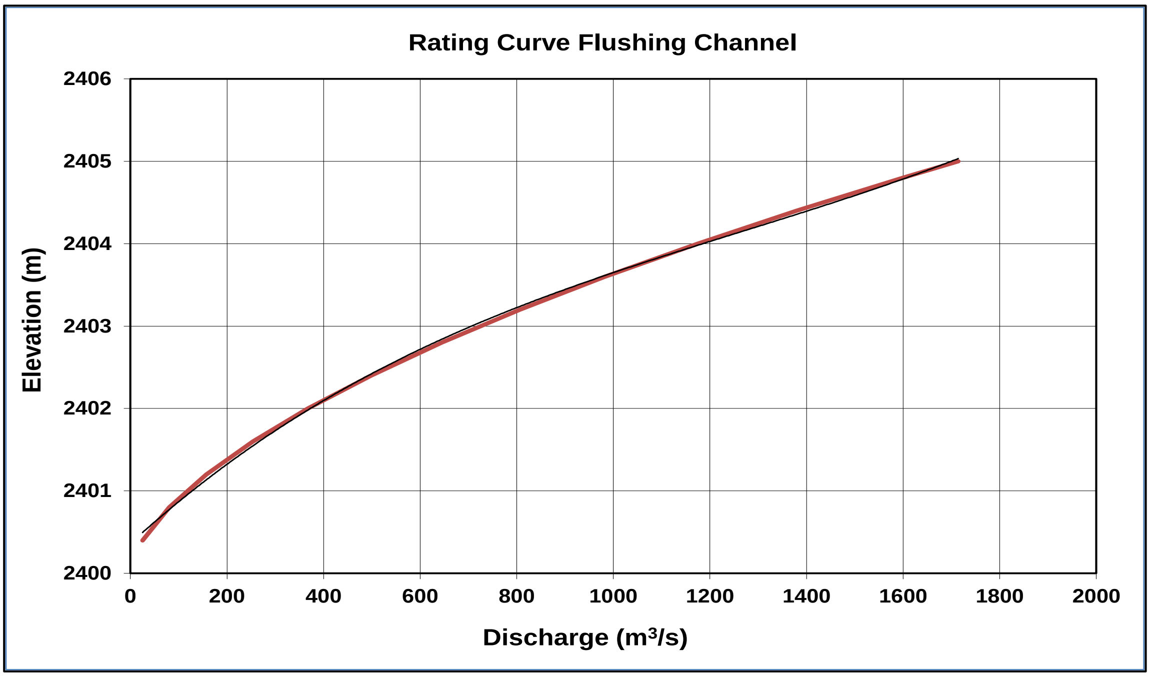


Figure 9-9 Tail Water Rating Curve at Flushing Channel

Reservoir drawdown can be achieved as when required through spillway and the low level outlets. However, it is necessary to ensure that the reservoir is not drawn down rapidly so as to provoke instability of the embankment dam or destabilize the reservoir periphery slopes. It is recommended that the hydraulic performance of the low level outlets be confirmed in combination with the spillway and power intake by hydraulic model tests at design stage.

9.4.3 Freeboard Calculations

Freeboard is provided on all dams to ensure that overtopping of the dam will not result from wind setup, wave action, uncertainties in analytical procedures and in operation in combination with high reservoir pool elevations.

Freeboard is the vertical distance between the crest of the dam and the reservoir water surface. Freeboard is further categorized into “normal freeboard” and “minimum freeboard”. Normal freeboard is the allowance between the crest of the dam and normal reservoir level as fixed by design. The normal freeboard should satisfy the dam safety needs for long term storage and must be adequate to prevent overtopping in case of abnormal and severe wind action of low probability that may result from unusual sustained winds of high velocity from a critical direction. Minimum freeboard is the difference in elevation between the crest of the dam and the maximum reservoir level that would result from the inflow design flood with normal spillway operation.

9.4.3.1 Wind Speed:

Wind speed at reservoir sites is best estimated from local measurements, although even these usually need to be carefully interpreted because of localized influences of surrounding topography. However, wind data was not available in the case of Attabad Lake weir stie. Therefore, in the absence of data, the per hour wind velocity over land has been assumed as per the recommendation of ACER Technical Memorandum No 2 (1992) which is 100 km/hr with all speed correction factors applied, for calculating minimum freeboard.

9.4.3.2 Design Wave Height and Duration

The wave heights and periods are associated with the fetch. Wind duration and adjusted wind speed are determined from the ACER Technical Memorandum referred to above. Taking fetch length = 0.25 miles and wind velocity as 100 miles / hr. the wave height is 4 ft. (1.21m) for 4.5 seconds wave period. The duration of wind is 5 hours

Wave Height by Molitor – Stevenson Formula:

$$H_s = 0.76+0.032\,(VF)^{0.5} - 0.26\,F^{0.25}$$

Where:

V = Wind velocity (km/h)	160
F = Fetch (km)	0.4
H_s	0.81 m

The maximum value of Hs = 1.21 m is adopted for design.

9.5 DESIGN OF RIVER DIVERSION WORKS

The riverbed at the weir site is about 60 m wide. On either bank, there is alluvium due to landslide and at rock is not found upto 68 m depth. The river diversion has been proposed in two stages. The river will flow through main weir section for constructing the left bank deep diversion channel regulated by gates after constructing a coffer dam in stage-I (shown in Dwg AFS-WE-412 in Vol.2) which will later used for sediment flushing channel. Afterwards a coffer dam has been constructed in stage-2 (detils shown in in Dwg AFS-WE-413 in Vol.2) and the river flow will be managed through diversion channel to construct the overflow weir/ spillway.

9.6 DISCHARGE CAPACITY OF RIVER DIVERSION WORKS

The magnitude of the construction flood is normally limited to flood return period of 1:20 to 1:50. However in the case of Attabad Lake, the diversion structures are designed for the average year flood of return period of 1:20 which is a flood of 1750 m^3/s magnitude. The risk of overtopping will be managed by strengthening of the coffer dam to tolerate overtopping during the construction period while the main embankment is still at lower levels.

The height of the upstream cofferdam has been estimated related to the discharge capacity of the diversion channel. The adopted crest elevation of the cofferdam is fixed at 2420.0 m.a.s.l. The channel will discharge in free flow condition.

Table 9-3 Diversion Channel Discharge Rating

Geometrical Input Data			Calculation of Downstream Rating Curve						
Length of Canal :	475.00	m	Wat. Dep.	Area	Wett.Par.	Hydr.Rad.	Discharge	Velocity	Froude No.
Slope Water Side : 1:	1.00	-	m	m^2	m	m	m^3/s	m/s	-
Hydraulic Bed Width :	25.00	m	0.00	0.00	25.00	0.00	0.00	0.00	0.00
Strickler Value (M)	45.00	-	0.40	10.16	26.13	0.39	27.37	2.69	1.36
Slope of Energy Line (S)	6 /475	-	0.80	20.64	27.26	0.76	86.71	4.20	1.50
			1.20	31.44	28.39	1.11	170.19	5.41	1.58
Water Depth : (Input)	5.00	m	1.60	42.56	29.53	1.44	274.67	6.45	1.63
Depth : (From rating curve)	**5.00**	**m**	2.00	54.00	30.66	1.76	398.33	7.38	1.67
$Q = MxR^{0.667}xS^{0.5}xA$			2.40	65.76	31.79	2.07	539.97	8.21	1.69
Discharge	**1857.79**	**m^3/s**	2.80	77.84	32.92	2.36	698.73	8.98	1.71
			3.20	90.24	34.05	2.65	874.02	9.69	1.73
WL Canal Start :	2403.00	m.a.s.l.	3.60	102.96	35.18	2.93	1065.38	10.35	1.74
WL Canal End :	**2397.00**	**m.a.s.l.**	4.00	116.00	36.31	3.19	1272.50	10.97	1.75
			4.40	129.36	37.45	3.45	1495.13	11.56	1.76
BL Canal Start :	2398.00	**m.a.s.l.**	4.80	143.04	38.58	3.71	1733.09	12.12	1.77
BL Canal End :	**2392.00**	**m.a.s.l.**	5.00	150.00	39.14	3.83	1857.79	12.39	1.77

The crest level of the coffer dam was set at elevation 2421.0 m.a.s.l. allowing about 2.0 m freeboard. The above results show that the adopted scale of the river diversion works accommodates reasonable risk from flooding during construction of the overflow weir / ungated spillway structure.

9.7 POWER INTAKE STRUCTURE

9.7.1 General

Twin intakes have been provided for intake of water into the power waterway system. The intakes are designed to be operated in such a manner as to ensure that the required turbine flow shall be conveyed within acceptable limit of head losses in accordance with the capacity requirements of the water conveyance systems and the power station in a safe and dynamically acceptable manner. The intakes will be capable of discharging the total design discharge for the generating units plus 20% of the design discharge for flushing the de-silting basin. The total design discharge of intakes is 60.0 m^3/s, that is, each intake will discharge 30.0 m^3/s. details of intake structure are shown in AFS-PI-424 to 426 in Vol.2.

On each structure, a trashrack has been provided at the entrance to prevent entry of debris into the power waterway system. The control gate in the gate passage is rectangular 4.5 m high by 3.6 m wide and is upstream sealing. This allows air passage downstream of the gate and does away with the need for special provision of an air vent. Provision has also been made for installation of stoplogs upstream of the control gates for maintenance and inspection. A trashrack cleaning machine has been provided for removal of debris from the trashracks. A gantry has been provided for placement and removal of the stoplogs.

9.7.1.1 Siting and Orientation

The intakes have been sited on the left bank as close as possible to the embankment dam for mitigation of blockage by sedimentation, maximization of submergence and ease of flushing of sediment at the entrances by the low level flushing outlets cum diversion channel located just upstream of the embankment dam. The intake is oriented so as to minimize tendency for flow separation which can render a portion of the intake ineffective. Higher intake flow rates are more conducive to flow separation than lower rates and as such velocities of entry have been kept low.

The invert of the intake is placed at elevation 2412.0 m.a.s.l. based on sediment control and submergence considerations. Deck and other operating levels have been set at 2422.0 m.a.s.l.so that the intake can perform over a range of operating water levels in the reservoir including maximum flood water levels.

9.7.1.2 Intake Geometry

ALHPP intakes are low head, horizontal intakes. To minimize head losses and the potential for flow separation, the configuration of the entrance area of the intake is such that the flow accelerates more or less uniformly from the trashrack to the gate area and downstream.

Boundaries of flow approximate those of flow issuing from an orifice to minimize the effects of the surfaces on flow and thus minimize head losses. The boundary curvature upstream of the gates including roof, floor and sidewalls and those downstream of the gates including transition shapes and lengths are defined in accordance with the above considerations.

The entrance shapes are designed in accordance with guidelines given in U.S. Army Corps of Engineers EM 1110-2-1620 and the U.S. Army Corps of Engineers, Waterways Experiment Station (WES) Hydraulic Design Charts, HDC 221-2 or HDC 211-1 as suited to site lateral space availability.

9.7.2 Hydraulic Design

9.7.2.1 Criteria for Design

The following basic criteria shall be complied with in the hydraulic design of the intakes:

- The hydraulic performance of the intakes shall be sustained so that the net flow area on the intakes is not reduced by adverse sediment build up.
- The intakes shall be designed for hydraulically efficient flow with bell mouthed intakes and entrance losses shall be accounted for in the design.
- The intake shall have sufficient water cover under MDDL conditions and no vortices shall form. The design shall be tested by hydraulic model study and modified as necessary to prevent formation of vortices at detailed design stage.

- Head losses in the waterway system shall be evaluated for hydraulic purposes and accounted for in design for all normal operating conditions.

- There shall be no settlement of sediment in the tunnel. Velocity in the tunnel shall be greater than the non-silting velocity at the design discharge of the tunnel.

- The water conductor system shall be designed to be emptied only by gravity.

- The intake gates shall operate only either in the fully open or fully closed position only. The gates shall be able to receive the command/signal from instruments and operate accordingly for this purpose.

- Provision will be made at the intake for instruments to collect and transfer information on gate positions, reservoir levels immediately upstream of the intakes, tunnel flows etc. for optimum operation of the Project.

9.7.2.2 Intake Submergence

Vortices can affect intake efficiency and also present a safety hazard. The intensity of the circulation phenomena set up around an intake is a function of the geometry. Design guidance provided by Gordon and others shall be used in preventing formation of undesirable vortices. Gordon's curve for unsymmetrical flow is used for design.

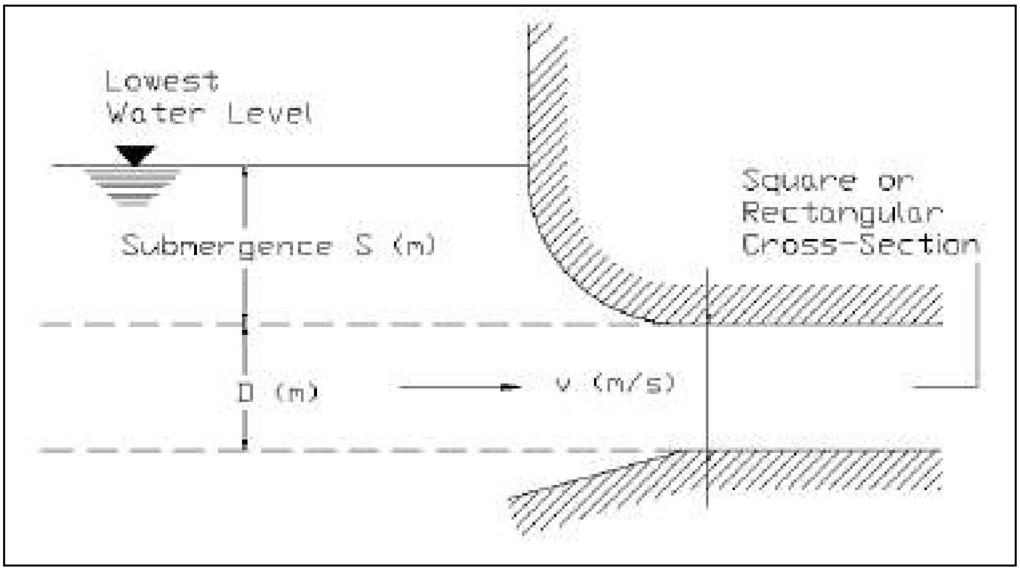
Gordon's relationship for asymmetrical flow is given by:

$$S_{min} = 2.3\ DF_r$$

where

Fr	= Froude number	$=V/\sqrt{gD}$
V	= velocity of flow in the conduit (m/s)	
D	= diameter or height of conduit (m)	
S_{min}	= required submergence from the opening soffit (m)	

The power intakes should have sufficient submergence to prevent air entrainment by vortex formation. For the selected intakes each connecting tunnel design discharge is 60.0 m³/s.



D = 4.5 m

V = 2.41 m/s

S_{min} = 2.3 x 4.5 x 0.36

S_{min} = 3.75 m

Take,

S_{min} = 3.75 m

9.7.3 Power Intake Settings

Maximum Operation Level	2414.0 m.a.s.l.
Minimum Operation Level	2412.0 m.a.s.l.
Required submergence	2.0 m
Intake waterway height	4.5 m
Required Invert level	2404.0 m.a.s.l.

The intake invert has been set at 2404.0 m.a.s.l.

Since vortex formation is dependent on many factors including orientation of the intake to flow and not only on submergence, hydraulic model studies are recommended at detailed design stage to confirm that vortices do not form at the intake.

9.7.4 Trashrack Cross-sectional Area

The gross cross-sectional area of the trashrack shall be selected for a flow velocity not exceeding 1.0 m/s. For the design discharge of 60 m^3/s, the required minimum trashrack area is determined as:

A_{min} required > Q / 1.0 m/s, giving Amin>60 m^2

Necessary trashrack area has been selected to comply with the above requirement with allowance for trashrack bar thicknesses etc.

9.8 LOW PRESSURE TUNNEL

9.8.1 Criteria for design

The hydraulic design criteria followed for tunnels were as follows:

(i) Head Loss Considerations

For discharge calculation conservative values of loss coefficients have been taken in accordance with intake geometry and geometry of the tunnel. The approaches and flow boundaries are designed for hydraulically efficient flow minimize head losses.

(ii) Boundary Pressures

Pressure gradients are developed for the headrace tunnels to show local average pressure changes resulting from velocity changes. These are examined in terms of conduit back pressures for the entire operating range.

(iii) Air Relief

Air that occupies a partially filled tunnel can become trapped and can lead to operational difficulties such as head loss, unsteady flow, transients and blowouts. Air can enter the tunnel system at the intakes and at hydraulic jumps. It can also form when pressure and temperature conditions cause dissolved air to be released. Engineering measures are taken to reduce air entrainment which includes elimination of hydraulic jumps and dissipation of flow vortices at intakes. Vents to the ground surface are also given.

(iv) Flow Velocity

Flow velocities are restricted so that turbulent conditions and the possibility of damage to the structures are limited. Velocities for shorcrete lining shall in general be less than 3 m/s. For velocities greater than 3 m/s the risk of cavitation increases and special precautions like provision of concrete lining may need to be taken.

(v) Energy Losses

Energy losses within conduits fall into two general classifications: (a) surface resistance (friction) caused by shear between the confining boundaries and the fluid and (b) form resistance resulting from boundary alignment changes

(vi) Surface Resistance (Friction)

Three basic equations are generally being used for computing energy losses in pressurized systems. The Manning equation which has been used extensively for both free surface and pressure flow is adopted in this analysis.

Use of Manning's Formula

The Manning's Formula is expressed as:

$$V = \frac{S^{1/2} R^{2/3}}{n}$$

Where

R = A/P = Area of flow / Wetted perimeter

n = Manning's coefficient

S_o = Energy gradient Bed slope in uniform flow

(vii) Design Roughness Values

U.S. Army Corps of Engineers (EM 1110-2-2901) recommends the following values of Manning's n roughness values for different types of excavation and lining of tunnels:

USACE Recommended Manning's k Values

Type of Excavation or Lining	Recommended Manning's k Value
Drill and blast excavation, unhand	0.038
Tunnel boring machine excavation, unlined	0.018
Lined with pre-cast concrete segments	0.016
Lined with cast-in-place concrete	0.013
Lined with steel with mortar coat	0.014
Lined with steel (dia> 3 m)	0.013
Lined with steel (dia< 3 m (10 ft.))	0.012

However, the water conduit system was designed for Manning's k value of 0.016

(viii) Form Resistance

General

Energy losses caused by entrances, bends, gates, valves, piers, etc., are conventionally called "local losses". In many situations they are more important than the losses due to conduit friction. A convenient way of expressing the local losses in flow is,

$$h_l = K (V^2/2g)$$

Where

h_l = head loss in m

K = dimensionless coefficient

V = designated reference velocity m/s

g = acceleration due to gravity m/s^2

The reference velocity in the energy loss equations corresponds to a local reference section of the conduit at or near the point where the loss occurs.

Sudden Expansion

In almost all cases the loss coefficient K is determined by experiment. However, one exception is the head loss for a sudden expansion. Designating the smaller upstream section as section one and the larger downstream conduit section as section two, the head loss equation may be written as:

$$h_l = (1 - A_1/A_2)^2 (V_1^2/2g) = K (V_1^2/2g)$$

In which

$$K = (1 - A_1/A_2)^2$$

Where A1 and A2 are the respective upstream and downstream conduit cross-sectional areas and the reference velocity is the upstream velocity V_1.

Sudden Contraction

The head loss h, due to a sudden contraction is subject to the same analysis as the sudden expansion, provided the amount of contraction of the jet is known. Using the downstream conduit velocity V_2 as the reference velocity, the head loss equation may be written as:

$$h_l = (1/C_c - 1)^2 (V_2^2/2g) = K (V_2^2/2g)$$

In which

$$K= (1/C_c - 1)^2$$

Where C_c is the contraction coefficient

(ix) Transitions

Head losses in transitions shall be calculated using the equation:

$$hl = K (V^2/2g)$$

where the value of the transition loss coefficient K must be obtained from published experimental literature or references.

(x) Bends

The bend loss, excluding friction loss, for a conduit is a function of the bend radius, conduit size and shape, and deflection angle of the bend. Bend loss coefficients K must be obtained from published experimental literature or references.

9.8.2 Low Pressure Headrace Tunnel

(i) Alignment of Headrace tunnel

Low pressure tunnel from intake to surge tank would be excavated in the left bank rock formation parallel and at lower elevation to existing Highway tunnel. The length of headrace tunnel is estimated about 2320 m.

(ii) Dimensioning of Headrace Tunnel

Headrace tunnel was optimized by considering different diameters for design discharge of 60 m^3/s with following parameters:

- Manning- Strickler coefficient 60
- Tunnel slope 0.4 %
- Shotcrete lining thickness 0.10 – 0.3 m (as per conditions)
- Length of headrace tunnel 2300 m
- Diameter of concrete lined section 5.5 m
- Concrete Lining 0.3 m

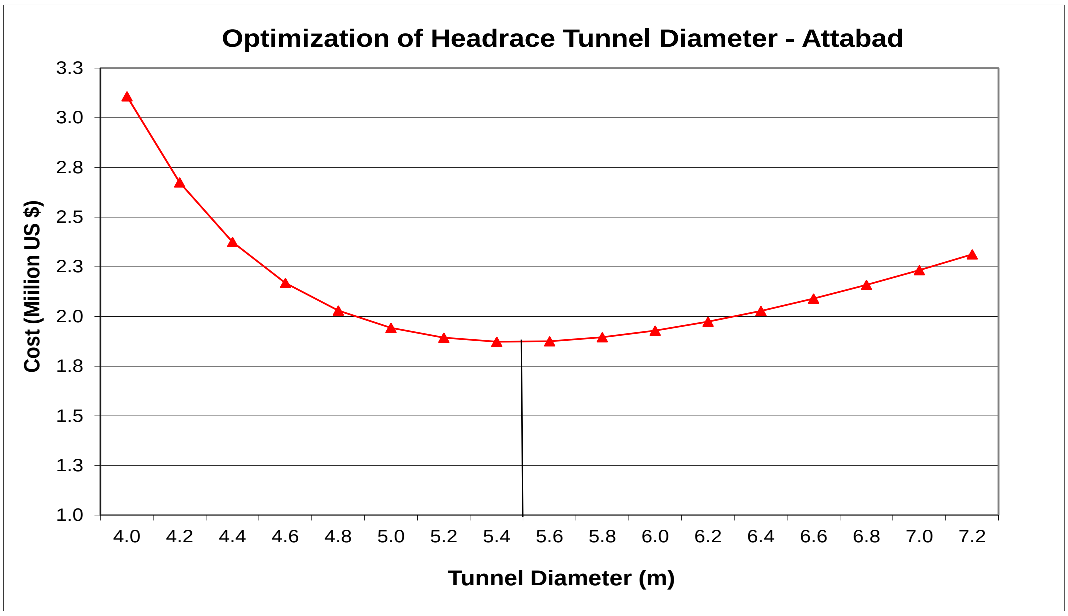


Figure 9-10 Optimization of Headrace Tunnel Diameter

The optimized diameter of low pressure headrace tunnel is 5.6 m and its length 2320 m. The alignment, layout and cross-sections drawings of low pressure headrace tunnel are given in AFS-WR-404 to 407 Vol. 2 Drawings.

9.9 SURGE TANK

The configuration of the waterway system has been generally given above and consists of two intakes with each intake connected to the low pressure headrace tunnel with an internal diameter of 5.5 m. The Surge tank is provided just before the start of pressure shaft. Downstream of the surge tank the headrace tunnel transitions from 5.5 m to 3.6 m diameter concrete lined section leading to embedded penstock. The penstock commences downstream of the surge tank with internal diameter of 3.5 m in the steel lined section.

9.9.1 Hydraulic Design of Surge Tank

The principal surge tank designs considered Throttled cylindrical surge tank. At the junction of the headrace tunnel and surge tank a throttle with a cross-section area of not less than 50 % of the pressure shaft is arranged in accordance with standard design practice to damp pressure fluctuations. In view of the expected high flow velocities at the throttle it will be steel lined.

In accordance with standard design practice and the hydraulic design criteria, the cross sectional area of the cylindrical surge tank is selected with a factor of safety of 2.5 times larger than the Thoma-Criterion to ensure adequate stability of plant operation. Based on the characteristics of the upstream waterways and the design water levels, the minimum surge tank dimensions have been determined as shown in Table 9-4.

Table 9-4 Surge Tank Dimensions

Minimum Cross Section for Surge Tank at Headrace Tunnel			
Total headrace discharge	Q	60	m^3/s
Length of headrace tunnel	L	2320	m
Diameter of Tunnel	D	5.50	m
Cross section area	A	24.62	m^2
Head loss	h	2.6	m
Velocity in tunnel	v	2.46	m/s
Velocity head	$v^2/2g$	0.31	m
Minimum reservoir level	W_L	2412.0	m.a.s.l
Minimum tailwater level	W_L	2302.0	m.a.s.l
Head difference	H_o	110.0	m
Net head	H_n	105.2	m
	A_S	63.16	m^2
	1.5 A_S	90.08	
	$D_{Srequired}$	10.7	m
	$D_{Sselected}$	10.0	m

For load acceptance of the turbine units and subsequent full load rejection the following scenarios are assumed.

LC-UP 1) Load acceptance from partial load, not exceeding 50 % total load increase; subsequent full load rejection;

LC-UP 2) Load acceptance of two units after synchronization; subsequent full load rejection;

LC-DN 1) Full load acceptance of two turbines followed by another turbine after a certain time interval

LC-DN 2) Load reduction by 50 per cent and subsequent complete load acceptance.

9.9.2 Load Case Maximum Upsurge

The load case is defined assuming that full load rejection occurs in the most unfavorable moment, i.e. when flow in the headrace tunnel is at its maximum (flow velocity) as the result of preceding partial load acceptance.

For the maximum upsurge analysis, the following assumptions are made:

Turbine load acceptance after synchronization	5.0 seconds (10 to100%)
Wicket gate closure at turbine load rejection :	5.0 seconds (100 to 0 %)
Maximum Reservoir Level :	2414.0 m.a.s.l.
Minimum tunnel roughness :	0.3 mm

The relevant load cases are defined assuming partial load acceptance following load rejection in the most unfavorable moment, i.e. when the flow in the headrace tunnel is at its maximum (reverse flow velocity) after full load rejection. A conservative approach is taken in the present feasibility design, full load acceptance of two units connected to the headrace tunnel will be assumed as extraordinary load case for which the surge tank design shall guarantee the specified minimum freeboard margins.

For the minimum down surge analysis the following assumptions are made:

Turbine load acceptance after synchronization	50 sec (10-100%)
Wicket gate closure at turbine load rejection	5.0 sec (100-0%)
Minimum reservoir water level	2412.0 m.a.s.l.
Maximum turbine discharge	20 m^3/s
Maximum tunnel roughness	0.3 mm

Minimum down surge was calculated for following scenarios:

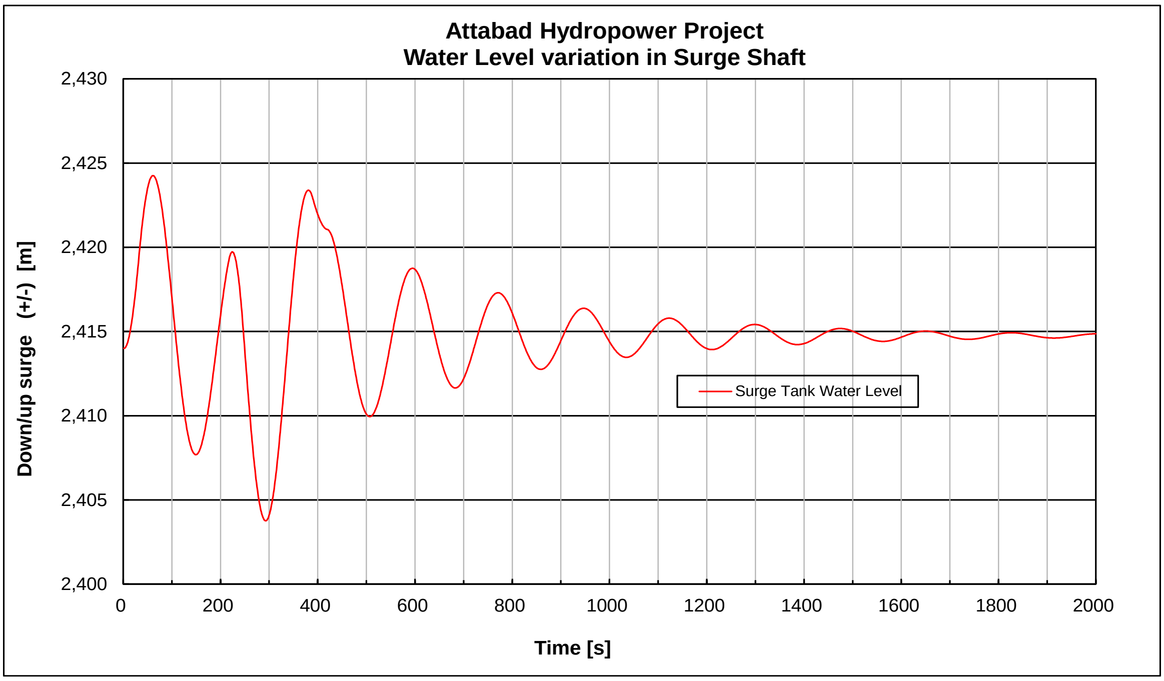


Figure 9-11 Surge Tank: Combined Load Case Maximum Upsurge

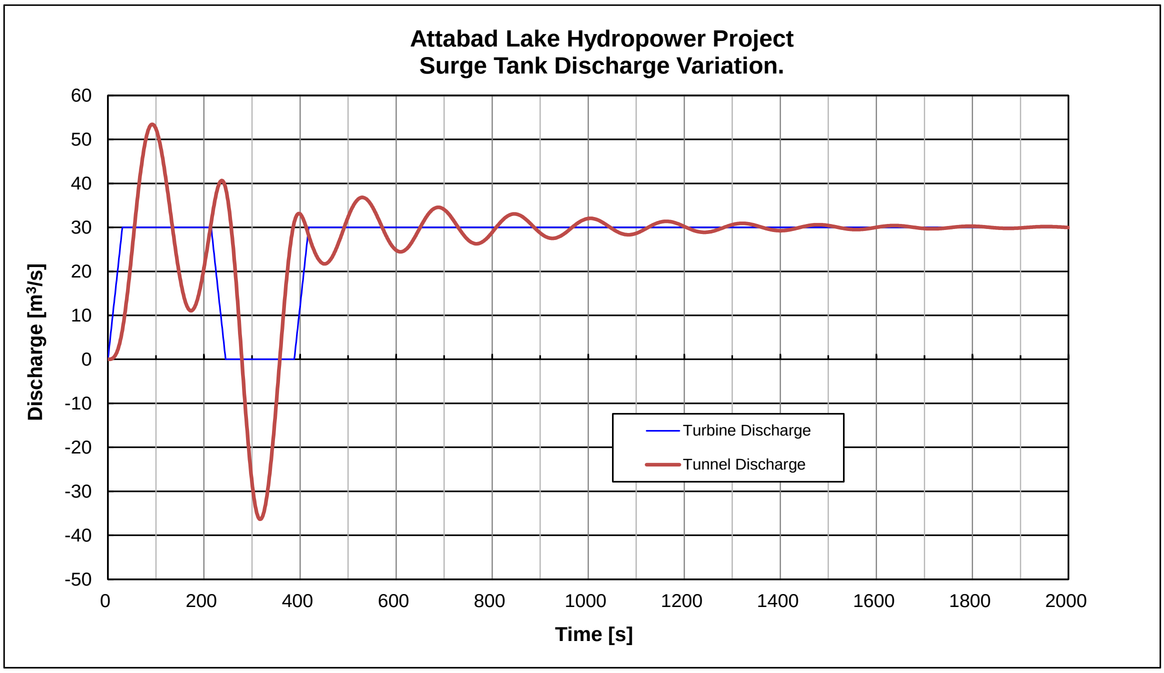


Figure 9-12 Surge Tank: Combined Load Maximum Upsurge and Downsurge

9.9.3 Results of Surge Tank Simulation

For the most critical load cases surge tank water level, flow into and out of surge tank and turbine discharge with time are shown in Figure 9-12.

For the load case resulting in the maximum down surge the corresponding variation of surge tank water level, is shown in Figure 9-13. The extreme surge tank water levels are given in Table 9-5 for all relevant load cases.

Table 9-5 Extreme Water Levels in Surge Tank

	Water Level
Upsurge	2424.2
Down surge	2403.8

9.10 WATER HAMMER ANALYSIS IN PENSTOCKS

For the calculation of pressure rise in the penstocks of Attabad Hydropower project water hammer analysis was carried out by applying the standard procedure based upon the following conditions:

Reservoir Level	2414.0 m.a.s.l.
Turbines centre line level	2300.0 m.a.s.l.
Operation Mode	Full Load Rejection within 5 seconds
QT for single unit	20.0 m³/s

9.10.1 Water hammer calculations for single Penstock

In Attabad Hydropower Project the power house has three turbine units. Each turbine unit is connecting with one penstock. To calculate water hammer pressure in the penstocks the longest penstock is considered because it will give the maximum rise in pressure when valve of turbine closed suddenly. The longest penstock is 35m long.

Total discharge for 3 units	Q	= 60.0 m^3/s
Discharge for single turbine	QT	= 20.0 m^3/s
Diameter of penstock	D	= 2.07 m
Velocity in the penstock	V	= 5.89 m/s
Length of penstock	L	= 35 m
Maximum Operation Level		= 2414.0 m.a.s.l.
Minimum Tail Water Level		= 2300.0 m.a.s.l.
Maximum Head		= 114 m
Steel liner Thickness	t	= 25 mm
D/t		= 82.8

9.10.2 Pressure wave velocity

Engineering analysis of water hammer required the term a which is the velocity of pressure wave. According to Parmakian (1955) the velocity of pressure wave is given by the following formula:

$$a = \sqrt{\frac{1}{\rho(\frac{1}{K} + \frac{DC_1}{Et})}}$$

Where

E = Elastic modulus for steel = $1x10^9$ N/m^2

K = Volume modulus of water = 2.1×10^{11} N/m^2

ρ = Mass of water = 1000 kg/m^3

$C_1 = 1 - u^2$

u = Poisson's ratio for steel = 0.3

a = 140 m/s

9.10.3 Water hammer Pressure (Allievi chart)

Neglecting hydraulic losses in the Penstock,

Pipe-line constant, $\rho = \dfrac{aV}{2gH_o}$ = 0.2267

For closure time t = 5sec

Time constant, $\theta = \dfrac{aT}{2L}$ = 10

From Allievi Chart,

Max. Pressure rise ratio, $Z = \dfrac{H_o + h_{max}}{H_o} = 1.025$

$H_O + h_{max} = 1.025 H_o = 107.6$ m

Hence pressure rise in penstocks for sudden closure of value (5s) the pressure rise in 35 m long penstock is 33.02 m.

9.11 POWER COMPLEX

9.11.1 General

At the powerhouse site mildly sloping terrace with good geological conditions is available to place a surface power complex. Hence a surface power complex is selected. The power complex comprises of mainly surface powerhouse, transformers bay and Gas Insulated Switchgears (GIS) building.

The powerhouse building houses three (03) Francis turbine units each comprising main inlet valve. The vertical axis Francis turbine is coupled directly to a generator, their auxiliary plant, the generator circuit breakers, isolators and unit transformers. The powerhouse also accommodates the main drainage sump, battery rooms, mechanical and electrical workshops.

The transformer bay houses 10 transformers (three each for a unit) and one spare transformer, a rail is provided beside the transformers for gantry crane to move along 6 m. wide roadway. The general arrangement of the power complex structures are shown in Dwgs. No. AFS-PH-431 to 436 in Vol. 2 Drawings

9.11.2 Sizing of Powerhouse

The powerhouse building was sized considering the turbine axis setting level and space required to house the electrical equipment, transformers and mechanical plant with adequate allowance for installation, operation and maintenance.

Floor levels in the machine hall are dictated by the level of the turbine centerline which is set at elevation 2308.0 m.a.s.l. The water after passing through Francis pressure turbine goes into elbow shaped draft tube and carried out to tail bay from where the open free flow tailrace channel starts. The outlet of the draft tube will always remain submerged to avoid suction. The submergence height with reference to turbine centreline is calculated as 4.5 m by Thoma criteria. With the submergence height the minimum tailwater level is fixed at elevation 2300.0 m.a.s.l. and the maximum Tailwater is at elevation 2307.0 m.a.s.l. A draft tube gate is provided at its outlet which is to be operated by a gantry crane to be placed at elevation 2308.2 m.a.s.l.

The turbine, electrical equipment, generator and operating floor levels are determined chiefly by the headroom required to access the turbine pit with the top cover suspended, the headroom to accommodate auxiliary equipment such as the generator circuit breakers, the structural depth of concrete to carry the bottom bracket, and the height of the generator.

Placing the crane rail level, the underside of the crane bridge beam and the main hook height around 5.80m from the operating floor which at elevation 2306.2m.a.s.l. should allow cranes in tandem, utilizing a lifting beam about 2m deep, to lift either the rotor or the stator to a height safely above the generator exciter housings, usually standing about 1 m above the floor. A sloping trussed roof is proposed to cater for the snow accumulation problem over the roof. Minimum of 2.5 m clear height is provided over the top of crane bridge beam which at the centre is 6.0 m which is sufficient for movement of operating and maintenance staff.

All levels will be confirmed or revised if necessary when turbine and generator manufacturer's data is received during detailed design. Manifold will be constructed for the trifurcating the 4.2 m dia. steel lined high pressure tunnel into three 1.85 m dia, penstock pipes that will be connected with spherical valve and further leading to turbine.

The surface powerhouse building is 63 m long, 20 m wide and 35 m high from the foundation level. At the draft tube end a draft tube gate is provided which will be lifted by a gantry crane moving on 3.2 m extended cantilevered deck along each unit bay.

9.11.3 Powerhouse Building

The powerhouse building comprises of the four main floors which are:

- Machine Hall floor at Elevation. 2306.2 m a s l
- Generator floor at Elevation. 2303.0 m a s l
- Turbine floor at Elevation. 2298.0 m a s l
- Valve floor at Elevation. 2300.0 m a s l

In addition to these floors the following are full width but shorter floors provided at different levels such as:

- Administration Floor at Elevation. 2306.2 m a s l
- Services and HVAC floor at Elevation. 2309.2 m a s l

Machine hall floor is divided into three sections i.e. Erection bay, Unit bays and powerhouse Operation bay. Erection bay is provided between the main access and the machine bay. The length of this bay is 11 m that will allow the assembly, erection and dismantling of one complete machine, providing adequate floor space for assembling the bottom cover, runner, top cover, shaft, bottom bracket, rotor and top bracket. The unit bays length is 10.0 m and it comprises of three units. The control room, store, lift, stairs and amenities are located in powerhouse operation bay. From machine hall floor three cable ways from generators lead to transformers bay which is of the same level of machine hall i.e. 2009.0 m. From transformers cable galley carries cables to GIS switchyard for further transmission.

On Generator floor, in addition to three generators, mechanical, electrical workshops, welding room and store are provided under the erection bay. Beyond the unit bays battery and charger rooms are placed along with lift and stairs. Turbine floor houses three turbine units and on one side there are compressor room with lift and stairs. On Valve floor spherical valves are placed on pedestals. The length of this floor is approx. 48 m. Stairs are terminated at this floor. Below this floor there are drainage and cooling water pits. The drainage sumps have emergency pumps.

On Administration floor meeting room, prayer room, offices, stairs and lift are provided. Services and HVAC floor contains potable water, service water, HVAC plant room with treatment, etc. Two overhead cranes run in the powerhouse building at Elevation. 2012.0 m. The powerhouse building floor plans and cross sections are given in Dwg. No. AFS-PH-431 to 436 in **Vol. 2 Drawings.**

9.12 TAILRACE CHANNEL

From each turbine the water will be carried through elbow shaped draft tube that will outflow into a tailrace bay from where the tailrace channel starts. The design parameters of the tailrace channel are as follows:

Type	Concrete lined
Manning Stickler’s coefficient	60
Total Length	18.0 m
Cross section type	Rectangular
Width	45.0 m
Height	13.0 m to 10.0 m

10 GEOTECHNICAL & STRUCTURAL STABILITY ANALYSIS

10.1 GENERAL

The overflow weir/ungated spillway and sediment flushing channel/undersluice of the Attabad Lake Hydropower Project (ALHPP) are in between sloping surfaces on both the left and right banks of existing spilling channel of Attabad Lake. Major focus of geotechnical and structural stability is carried out for an overflow weir/ungated spillway and sediment flushing channel/under sluices located on or near sloping ground, and thus are potentially subject to various kinds of slope instability such as slides, flows and falls. Slope failures can produce extensive damage to the structure. Therefore, it is necessary to evaluate the proposed slopes to assess their stability.

Slope geometry is an important factor which affects the slope stability. The basic geometrical slope design parameters are bench height, overall slope angle, and surface area Stability of slope decreases with the increase in its height and slope angle. In case of the ALHPP, for the sake of stability the slope is cut and is proceeded from top towards the edges of the structures in bench formation.

The cross sections showing benched slope stability options are shown from AFS-WR-414 to 423 Vol.2 Drawings. The cross section selected for analysis is the critical section at Chainage 0+50, where the main structure of the Project is placed in between the two slopes; the left slope will be benched from El 2490 to 2400 m.a.s.l, which needs analysis for its safety.

10.2 PROJECT NARRATIVE FOR USE OF GEOTECHNICAL SOFTWARE (SLOPE-W; GEOSTUDIO)

Manual procedures available for slope stability analysis are very laborious. These have limited application and based upon various assumptions. Quite often, the manual procedures for slope stability are very complex and less precise.

Over the last five decades, a lot of research has been carried out in the world for developing new techniques for planning, analysis and design. In this regard, various techniques have been developed to produce better quality of analysis in civil engineering projects. Besides, these techniques are being supplemented by computer software which save a lot of time and effort and thus provide better quality and cost effective design by incorporating actual conditions at the site. Use of computer software have made it possible to incorporate those analysis conditions which were limited in the past owing to tedious manual methods of analysis.

SLOPE/W provides less tedious and user-friendly operation and also reflects the existing conditions at the Project Site and operates in Windows Environment.

The analysis on geotechnical software is intended to provide guidance for the proper procedure and incorporation of modern techniques for stability analysis for sound design, saving the efforts involved in conventional analysis. The cross section showing slope under analysis is shown in **Figure 10.1.**

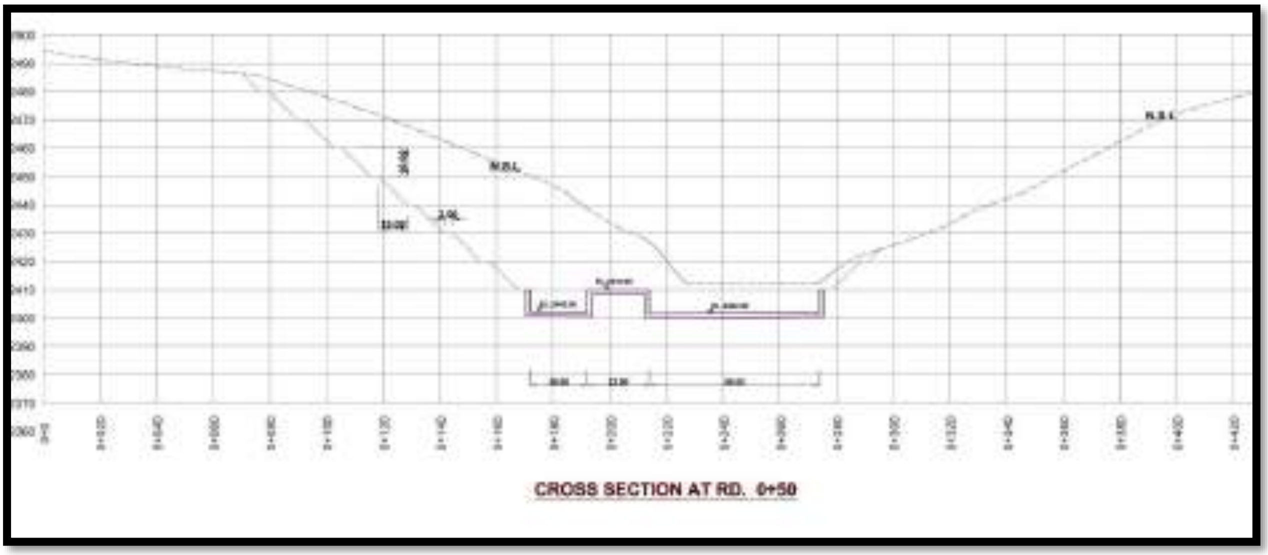


Figure 10-1: Cross Section at Chainage 0+50

10.3 GEOLOGY OF THE SLOPES

Slided mass covers huge volume and consisted of mixed boulders and gravels near the slope surface and beneath the proposed area of overflow weir/ungated spillway and sediment flushing channel/undersluice. One of the difficult and critical task is to stabilize the both side slopes along the weir and sediment flushing channel. Benching is one of the best solution for such type of slope to stabilize. At some place, mashing or gabion maybe helpful for slope stabilization.

10.4 SCOPE OF THE ANALYSIS

The intended scope of the design has been to analyze the critical slopes near ALHPP structures, using conventional (computer aided) methods of analysis. The comparison of results obtained by different analysis methods is presented in factors of safety.

10.5 DESCRIPTION OF THE SLOPE STABILITY ANALYSIS

The conventional methods of slope stability analysis used are based on limit design. In these methods a trial surface of sliding is assumed and a quantitative estimate of the factor of safety is obtained by considering the overall equilibrium of the sliding mass and comparing the strength necessary to maintain limit equilibrium with the available shear strength of the embankment material. Stability computations are performed along a number of sliding surfaces to obtain the minimum factor of safety. The sliding surface, along which the minimum factor of safety is obtained, is known as the critical sliding or slip surface.

The basic premise of all limit equilibrium methods of stability analysis is that the slope mass acts as a rigid body and the shear strength of the materials will be fully developed at all points simultaneously along a surface of incipient failure. Deformations of the slope mass and the relationships of the strain to the developed strength of the material are not accounted for in the analysis as customarily performed. Such assumptions are significant departures from reality and the magnitude of the error involved will depend on the stress-strain relationships of the materials involved. However, limit equilibrium methods are used because of their simplicity and the fact that experience has shown that if the factor of safety exceeds the recommended value, the slopes would be safe against shear failure and would not suffer excessive deformations.

The shape of sliding surface depends on the geometry of the problem and may be circular or non-circular. A shear failure in a steep slope of homogeneous soil will usually develop along circular surfaces; however, if weak layers or seams are present in the soil profile, the failure surface will have a tendency to follow these planes, insofar as kinematically possible, and adopt a non-circular shape. In most cases the sliding surfaces can be approximated by circular slip surfaces even for non-homogeneous (zoned) sections with moderate differences in the shear strength of constituent materials.

These methods are described in detail in the following sections:

10.5.1 Ordinary Method of Slices

In all the limit-equilibrium methods of stability analysis the factor of safety is determined by considering equilibrium of the potential sliding mass along assumed slip surfaces and locating by trial the slip surface that gives the lowest factor of safety. The method of analysis should be such as to accommodate conditions wherein the slip surface is curbed and the soil properties and pore pressures vary with location through the slope. For this reason, most of the equilibrium methods divide the free-body bound by the slip surface into a number of vertical slices. This procedure is known as the method of slices and is adaptable to any type of slip surface, circular or curbed. The method was pioneered by Fellenius and Taylor and has since been developed to improve its reliability and accuracy.

Equilibrium Requirements

In this method the potential sliding mass is subdivided into a number of vertical elements or slices. These slices need not be equal in width, e.g., slice widths may be selected in such a way that, as far as possible, the base of each slice falls within one type of soil in a non-homogeneous slope. The inclination of the base of each slice, the slice weight, the material properties and the pore pressures at the base of each slice should be known before an analysis can be carried out.

Figure 10.2 shows a potential sliding mass along a trial slip surface through an embankment slope. The sliding mass is subdivided into a number of imaginary vertical slices. Usually six to nine slices are adequate for all practical purposes. The ratio between slice height and slice width should usually be 1 to 2.5, or maximum 3.

Each slice is acted upon by its own weight W and by the boundary interslice or side forces, both of which have tangential or shear components X and normal components E. The forces acting on the base of the slice are the shear resistance S and the normal force P. A rigorous solution to the problem of stability involving the soil mass would require that:

- The forces on each slice must satisfy the conditions of equilibrium, and

- The forces acting on the sliding mass as a whole must satisfy conditions of equilibrium.

The following static equilibrium conditions should be satisfied:

- Sum of all vertical forces, $\sum F_V = 0$
- Sum of all horizontal forces, $\sum F_H = 0$
- Sum of moments of all forces about any point, $\sum M = 0$

These conditions should be satisfied both for the individual slices as well as for the overall equilibrium of the slope.

In addition, to enable computation of the factor of safety, the following equation relating the equilibrium shear stress to the shear strength of the material is introduced. A state of limiting equilibrium is said to exist when the equilibrium shear stress is express as:

$$\tau = \frac{\tau_f}{F}$$

Where,

F = Factor of safety;

τ_f =Shear strength at failure

$\tau =$ Equilibrium shear stress along the shear surface

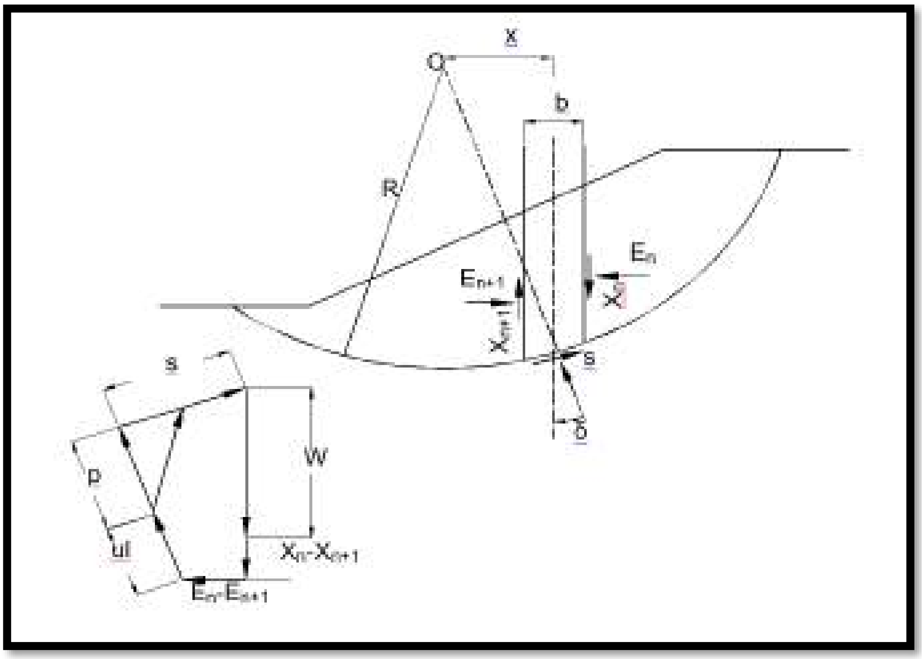


Figure 10-2: Sliding Mass – ordinary method of Slices

The shear strength of soils is usually expressed by Coulomb's equation:

$$\tau_f = c' + \sigma'_n \tan\phi'$$

Combining eqns. above,

$$\tau_f = \frac{c'}{F} + \frac{\sigma'_n \phi'}{F}$$

$$\tau = c_e + \sigma'_n \tan\phi_e$$

Where 'c' and 'phi' are the mobilized or developed values of shear parameters corresponding to equilibrium shear stress acting along the shear surface.

Limit equilibrium analysis is based on the assumption of ideal plastic behavior wherein stress-strain relationships do not exist (as for brittle soils) and the shear stress is defined by eqn. 2.3, the term 1/F giving the degree of mobilization. Implicit in the analysis is a constant value of F along the entire shear surface. Most soils lie somewhere between the ideal brittle and plastic materials.

By using the factor of safety to define the limit equilibrium, one can easily discriminate between the failure shear surface (F_{min} = 1) and the critical shear surface at equilibrium (F_{min} > 1).

Limitations of this method

The number of unknowns (interslice forces, normal and tangential forces, and F) are more than the number of equations. No explicit solution is therefore possible for the factor of safety, and it is necessary to make further simplifying assumptions to arrive at a solution. The various procedures of stability analysis differ principally in the equilibrium requirements they satisfy and the manner in which they handle the interslice forces.

10.5.2 Bishop method of Slices

The Simplified Bishop Method satisfies the following two equilibrium conditions:

XI. Overall moment equilibrium about the centre of the slip surface;

$$F = \frac{1}{\sum W \sin\alpha} \sum [c^{'} l + (P - ul) \tan\phi^{'}]$$

XII. Vertical equilibrium for each slice; thus resolving the forces acting on a typical slice vertically (Figure 10.2).

$$W + X_n - X_{n+1} = P\cos\alpha + S\sin\alpha$$

The factor of safety in this method is computed by the equation:

$$F = \frac{1}{\sum W \sin\alpha} \sum [c^{'} b + \tan\phi^{'} (W - bu + X_n - X_{n+1})] \frac{1}{m_\alpha}$$

It is assumed in the Simplified Bishop Method that the interslice forces are adequately defined by their horizontal components and their vertical components can be neglected. With this assumption, the final factor of safety equation will be:

$$F = \frac{1}{\sum W \sin\alpha} \left[\frac{c^{'} b + \tan\phi^{'} (W - bu)}{m_a} \right]$$

Limitations of this method

The main limitations of the Simplified Bishop Method are that it neglects the vertical component of the interslice forces and does not satisfy the horizontal force equilibrium. In practice, the Simplified Bishop Method has proved an accurate method for circular slip surfaces, including flat slopes with high pore pressures, and has gained wide acceptance. The justification for using the Simplified Bishop Method is largely empirical.

10.5.3 Spencer method

Keeping in view the limitations of the above methods used, spencer method is also used which produces accurate values of FOS keeping by considering also the following:

- Considers both shear and normal interslice forces,
- Satisfies both moment and force equilibrium, and
- Assumes a constant interslice force function.

The force-equilibrium factor of safety F_t can be obtained by the following:

$$F_t = \frac{\sum\left[\{c'b + \tan\phi'(W - bu + X_n - X_{n+1})\}\frac{1}{m_\alpha}\sec\alpha\right]}{\sum[W + X_n - X_{n+1}]\tan\alpha}$$

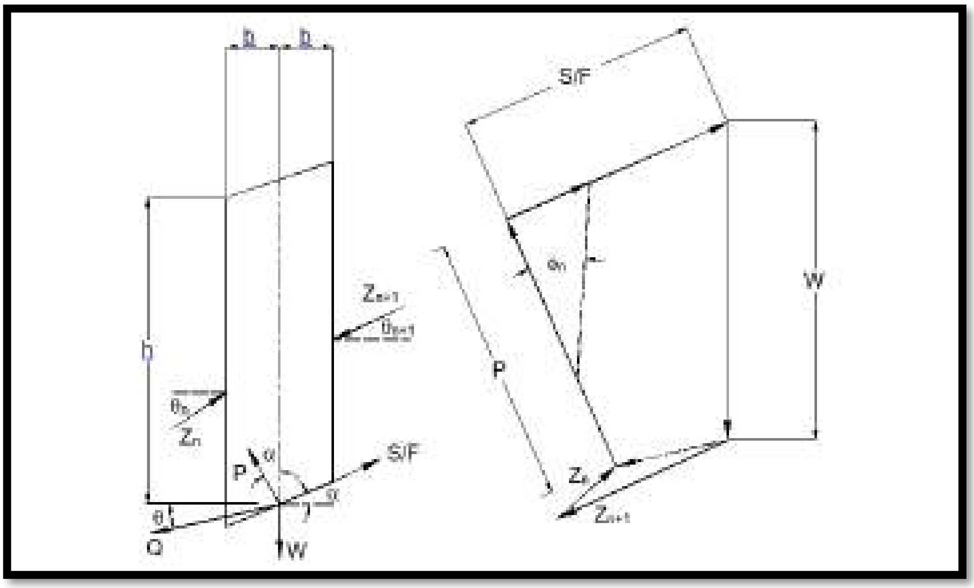


Figure 10-3: Slice Orientation – Spencer Method

When using Spencer's Method for analyzing slope stability for a non-circular sliding surface, the moment-equilibrium equation can be established by taking moments of the forces acting on the slices about some arbitrary center of rotation. The rest of the procedure remains unchanged.

10.5.4 Janbu Method

Janbu's Method of stability analysis, also known as the Generalised Procedure of Slices (GPS), can be used for solving stability problems involving a shear surface of any shape, circular or curved. Janbu considered the force and moment equilibrium of an individual slice as well as the equilibrium of the sliding mass as a whole. In view of the difficulty of obtaining a moment-equilibrium equation for the sliding mass as a whole for a non-circular sliding surface.

10.5.5 Morgenstern-Price method

Morgenstern and Price (1965) developed a method similar to the Spencer method, but they allowed for various user-specified interslice force functions. The interslice functions available in SLOPE/W for use with the Morgenstern-Price (M-P) method are:

- Constant
- Half-sine
- Clipped-sine
- Trapezoidal
- Data-point specified

Selecting the Constant function makes the M-P method identical to the Spencer method.

10.6 PROS AND CONS OF SLOPE STABILITY METHODS-SUMMARY

Many different solution techniques for the method of slices have been developed over the years. Basically, all are very similar. The differences between the methods are depending on: what equations of statics are included and satisfied and which interslice forces are included and what is the assumed relationship between the interslice shear and normal forces?

In the beginning, Ordinary, or Fellenius method was first developed. The method ignored all interslice forces and satisfied only moment equilibrium. These simplified assumptions made it possible to compute a factor of safety using hand calculations, which was important since there were no computers available.

Later Bishop (1955) devised a scheme that included interslice normal forces, but ignored the interslice shear forces. Again, Bishop's Simplified method satisfies only moment equilibrium. Of interest and significance with this method is the fact that by including the normal interslice forces, the factor of safety equation became nonlinear and an iterative procedure was required to calculate the factor of safety.

The Janbu's Simplified method is similar to the Bishop's Simplified method. It includes the normal interslice forces and ignores the interslice shear forces. The difference between the Bishop's Simplified and Janbu's Simplified methods is that the Janbu's Simplified method satisfies only horizontal force equilibrium, as opposed to moment equilibrium.

Later, computers made it possible to more readily handle the iterative procedures inherent in the limit equilibrium method, and this lead to mathematically more rigorous formulations which include all interslice forces and satisfy all equations of statics. Two such methods are the Morgenstern-Price and Spencer.

10.7 SLOPE STABILITY INPUT PARAMETERS

The parameters are used are as follows:

Above below Water Surface:

- c 100 KPa
- Phi 20
- Unit Weight 21 KN/m^3

Above Water Surface:

- c 120 KPa
- Phi 25
- Unit Weight 18 KN/m^3

Youngs Modulus of Elasticity is 1.29 e +4 and poisons ratio used is 0.15

10.8 METHODOLOGY ADOPTED FOR SLOPE STABILITY SLOPE/ W ANALYSIS

Slope stability analysis of critical slope at ALHPP is done by using aforementioned methods for the following two different slip surface arrangements within the Slope/ W software:

- Grid and radius Arrangement of Slip Surfaces
- Entry and Exit Slip Circle arrangement.

The Factor of Safety (FOS) has been calculated by introducing 2000 iterations and a Critical Slip Circle (the slip circle whose FOS is the minimum) has been found by analysis.

The shear strength & Normal Strengths and Interslice forces are drawn for each of the slice.

The Analysis are shown in **Figure 2-1 to Figure 2-10 (Volume 7 Appendices)**.

The Results from the analysis are tabulated in **Table 10-1 below**:

Table 10-1 Results of SLOPE/W Methods

Method	Grid & Radius arrangement for Slip Circle	Exit and Entry Arrangement for Slip Circle
Ordinary or Fellenius	**1.75**	**1.53**
Bishop's Simplified	**1.865**	**1.63**
Janbu	**1.725**	**1.51**
Spencer	**1.87**	**1.62**
Morgenstern-Price	**1.821**	**1.63**

10.9 CONCLUSIONS FOR SLOPE STABILITY SLOPE/ W ANALYSIS

The stability analyses of critical slope at Chainage 0+50 is analyzed under different loading conditions using conventional methods of analysis revealed that Spencer Method and Morgenstern-price Method (which satisfies only force and Moment equilibrium both) normally gives the highest factors of safety while Janbu Method (gives the lowest factor of safety). The variation among the methods is upto 9%.

Morgenstern Price method and spencer's method of analysis gave the identical results in the analyses this is owing to the fact that both the methods satisfy force as well as normal equilibrium.

FOS is inversely proportional to the height of the slope.

Material used on the facing with higher value of cohesion will increase the factor of safety.

Following general findings have been deduced for all the methods in terms of equilibriums:

Method	Moment Equilibrium	Force Equilibrium	Interslice Normal (E)	Interslice Shear (X)
Ordinary or Fellenius	Yes	No	No	No
Bishop's Simplified	Yes	No	Yes	No
Janbu's Simplified	No	Yes	Yes	No
Spencer	Yes	Yes	Yes	Yes
Morgenstern-Price	Yes	Yes	Yes	Yes

10.10 FUTURE RECOMMENDATION

For future, if there is possibility of water filled tension crack upstream of slopes, causing the slopes to be saturated it is proposed to carry out the study on same lines using dynamic deformations. In this way it will be possible to calculate pore pressure changes effecting FOS of the whole system/ slope. This may be carried out using another computer software QUAKE/W in association with SLOPE/W.

10.11 GEOTECHNICAL STABILITY OF OVERFLOW WEIR/UNGATED SPILLWAY STRUCTURE WITH RESPECT TO SEEPAGE FORCES

10.11.1 Seepage Analysis

The objective of the analysis in case of an overflow weir/ungated spillway structure is to determine the following parameters which will be used in various stability checks:

- Total head dissipation from u/s to d/s.
- The Pressure Head and Pressure Profiles.
- The Hydraulic xy- Gradient Profiles
- Computation of Critical Hydraulic Gradient at d/s.
- Safety against Uplift
- Safety Against Piping

Seepage analysis is done to analyze whether the structure is safe against uplift and piping with respect to highest flood level and normal level conditions.

Seepage analysis is done by using Finite Element Analysis technique. The SEEP/W in GEOSTUDIO software used for the analysis. SEEP/W basically obeys the flow law described hereafter.

10.11.2 Flow Law

SEEP/W is formulated on the basis that the flow of water through both saturated and unsaturated soil follows Darcy's Law which states that:

$$q = ki$$

Where;

$q =$ Specific discharge

$k =$ Hydraulic conductivity

$i =$ Gradient of fluid head or potential

Darcy's Law was originally derived for saturated soil, but later research has shown that it can also be applied to the flow of water through unsaturated soil. The only difference is that under conditions of unsaturated flow the hydraulic conductivity is no longer a constant but varies with changes in water content and indirectly varies with changes in pore water pressure.

Darcy's Law is often written as:

$$v = ki$$

Where v is known as the Darcian velocity. The actual average velocity at which water moves through the soil is the Darcian velocity divided by the porosity of the soil. SEEP/W computes and presents only the Darcian velocity.

10.11.3 Governing Equation of Seepage Analysis

$$\frac{\partial}{\partial x}\left[k_x \frac{\partial H}{\partial x}\right] + \frac{\partial}{\partial y}\left[k_y \frac{\partial H}{\partial y}\right] + Q = m_w \gamma_w \frac{\partial H}{\partial t}$$

Where;

$k_x =$ Hydraulic conductivity in the x-direction

$k_y =$ Hydraulic conductivity in the y-direction

$H =$ Total Hydraulic Head

$Q =$ Applied boundary flux

$m_w =$ Slope of the storage curve

$\gamma_w =$ Unit weight of water

10.11.4 Geology at Overflow Weir/Ungated Spillway

An overtopping concrete weir founded on slided mass is proposed after foundation treatment. Geological rock units with which weir has to be abut, includes granodiorite, intruded by pegmatite veins at right side. On left side, weir has to be abut with Angular Boulder Gravel and Fines (ABGM) formed by slided mass (Vol-2, AFS-GE-297). As described in Volume 3 Geology and geotechnical studies, some treatment / engineering solution have to be implemented for stability of the weir and its left abutment. The basic purpose is to provide seepage line of defenses which can lengthen the seepage path, minimize the uplift pressure at critical portions of the weir structure to make it safe against piping and uplift.

10.11.5 Drilling results at weir site

A borehole BH-1, has been drilled at left side slope to investigate the subsurface geological conditions. The location of the boreholes is presented (Vol-2, AFS-GE-316). No rock has been encountered in this borehole upto 90 m. The core recovery CR (%) and permeability test results are given in Table 10-2, and graphically presented in Figure 10-1. The permeability tests were conducted after every 3 m, in most of test head could not maintained due to cavities/ open works encounter in subsurface. The borehole has been stabilized with cement.

Table 10-2 core recovery CR (%) and permeability test results

ATTABAD LAKE HPP											
BH-01											
Depth(m)		CR (%)	K-Value (cm/sec)	Depth(m)		CR (%)	K-Value (cm/sec)	Depth(m)		CR (%)	K-Value(cm/sec)
From	To			From	To			From	To		
0.5	1	0		31	32	62		61	62	54	
1	2	0		32	33	88		62	63	44	Head Failure
2	3	40		33	34	83	Head Failure	63	64	55	
3	4	39	0.046178	34	35	100		64	65	31	
4	5	78		35	36	70		65	66	32	Head Failure
5	6	60		36	37	78	Head Failure	66	67	44	
6	7	17	Head Failure	37	38	58		67	68	45	
7	8	40		38	39	69		68	69	88	
8	9	29		39	40	45		69	70	61	Head Failure
9	10	31	Head Failure	40	41	46	Head Failure	70	71	56	
10	11	30		41	42	45		71	72	53	
11	12	32		42	43	53		72	73	65	Head Failure
12	13	12	Head Failure	43	44	68	Head Failure	73	74	65	
13	14	42		44	45	81		74	75	77	
14	15	90		45	46	56		75	76	87	Head Failure
15	16	49	0.002858	46	47	89	Head Failure	76	78	87	
16	17	43		47	48	65		78	79	64	Head Failure
17	18	16		48	49	58		79	80	37	
18	19	96	0.012294	49	50	63	Head Failure	80	81	89	
19	20	100		50	51	66		81	82	57	Head Failure
20	22	90		51	52	33		82	83	32	
22	23	65		52	53	28	Head Failure	83	84	45	
23	25	98	Head Failure	53	54	58		84	85	38	Head Failure
25	26	33		54	55	56		85	86	56	
26	27	45		55	56	100		86	87	66	
27	28	35	Head Failure	56	57	47	Head Failure	87	88	59	
28	29	55		57	58	50		88	89	55	Head Failure
29	30	99		58	59	23		89	90	59	
30	31	100	Head Failure	59	60	53	Head Failure	**End of Borehole.**			

It is noticed that head could not be maintained throughout the drilling of borehole. 100 % water loss has been observed. It indicates that slided mass is highly permeable with large cavities and open works required cementing for stabilization of bore holes during drilling.

10.11.6 Seepage Line of Defenses

If the Structure is to be placed on it, it requires treatment of strata with stabilized soil from 4 to 14 m from (El: 2412 to 2402 m.a.s.l). The stabilized portion is not needed in the stilling basin area. There is enough permeable layers present from (El: 2402 to 2396 m.a.s.l). Beneath is there is close to free draining.

To cater with the above problem following seepage line of defenses have been provided:

- Stabilized clayey soil
- Cement Slurry Cutoff/ Plastic Piles
- Clay Blanket to cover the upstream face of the Slide material

Trial analysis have been done on the above combinations and finally the cross section so selected for final analysis of all the parameters mentioned in 10.11.1 above. The final cross section so selected in shown in **Figure 2-1 (Volume 7, Appendices)** and in **Figure 10.4** below:

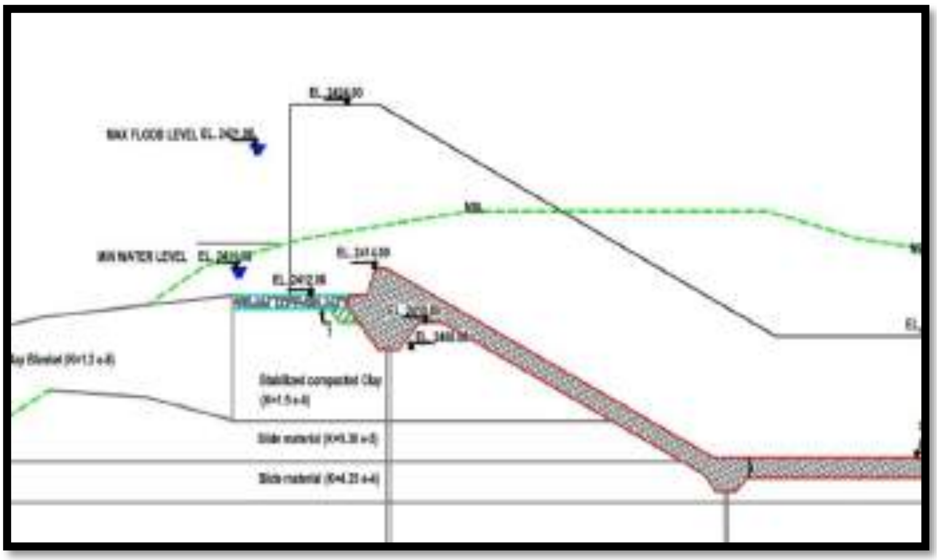


Figure 10-4: Selected weir cross section with all seepage line of Defenses

10.11.7 Selection of Stabilized Soil

The material for stabilized soil is taken from Power House Area and processed. The Soil classification done and processed soil is found to be silty clay material A-4 according to AASTHO after performance of sieve analysis, hydrometer analysis and Atterberg Limits. The results of the Sieve Analysis and Hydrometer are shown in **Figure 10.5** below:

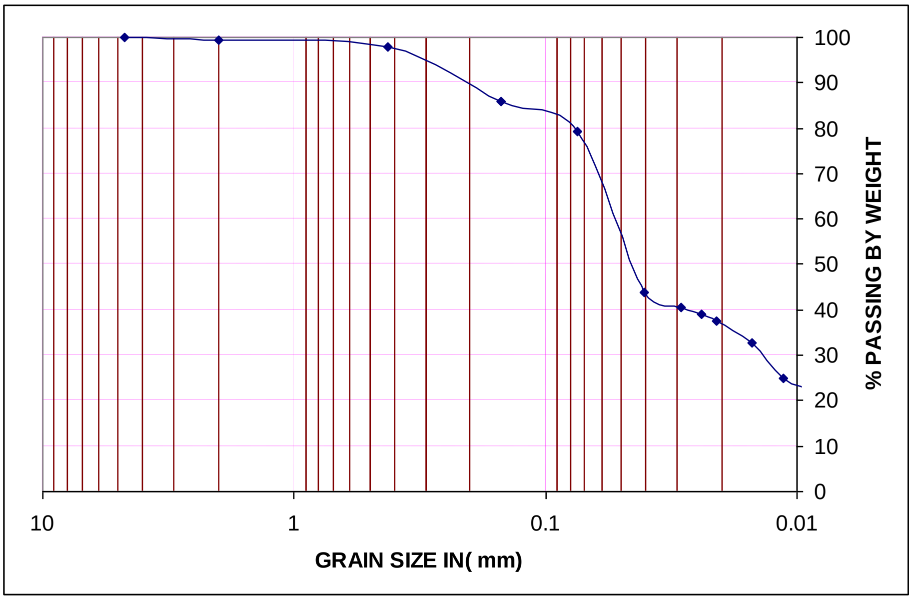


Figure 10-5: Sieve Analysis of Soil used for Stabilization

After classifying the soil, different samples were made with 0%, 2%, 4%, 6%, 8% and 10% of cement (3 samples for each %age). These samples were tested immediately and after 7, 14 days of casting by unconfined compression test. The results of the unconfined compression test are shown in **Figure 10.6 to 10.8** hereafter.

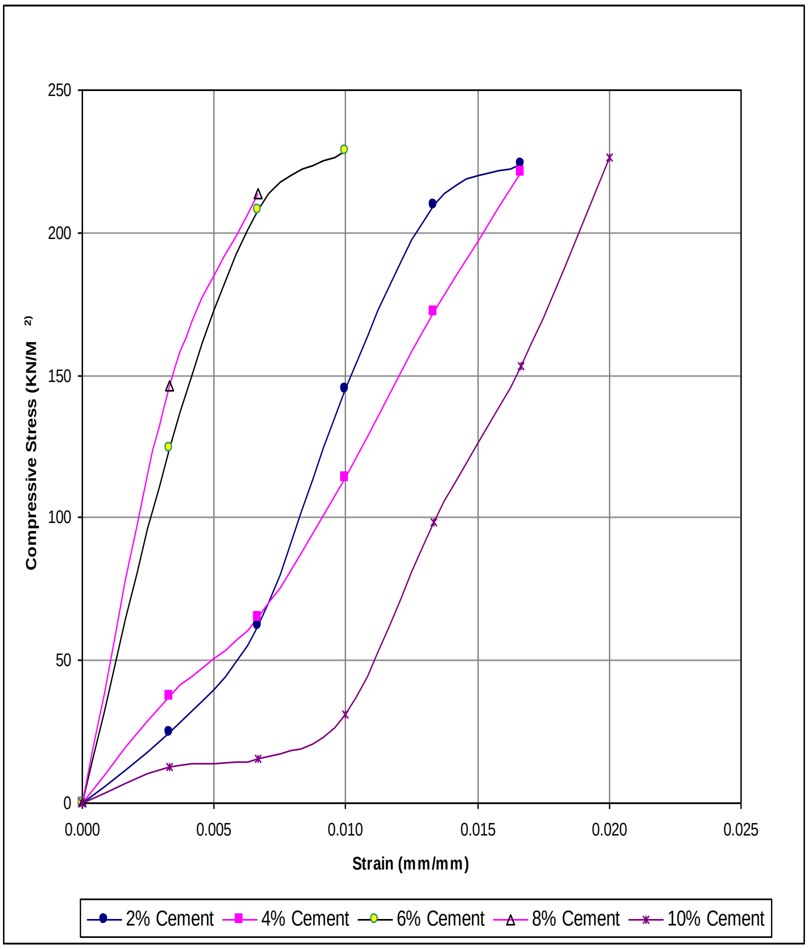


Figure 10-6: Stress Strain Results of the unconfined compression test immediately after mixing cement

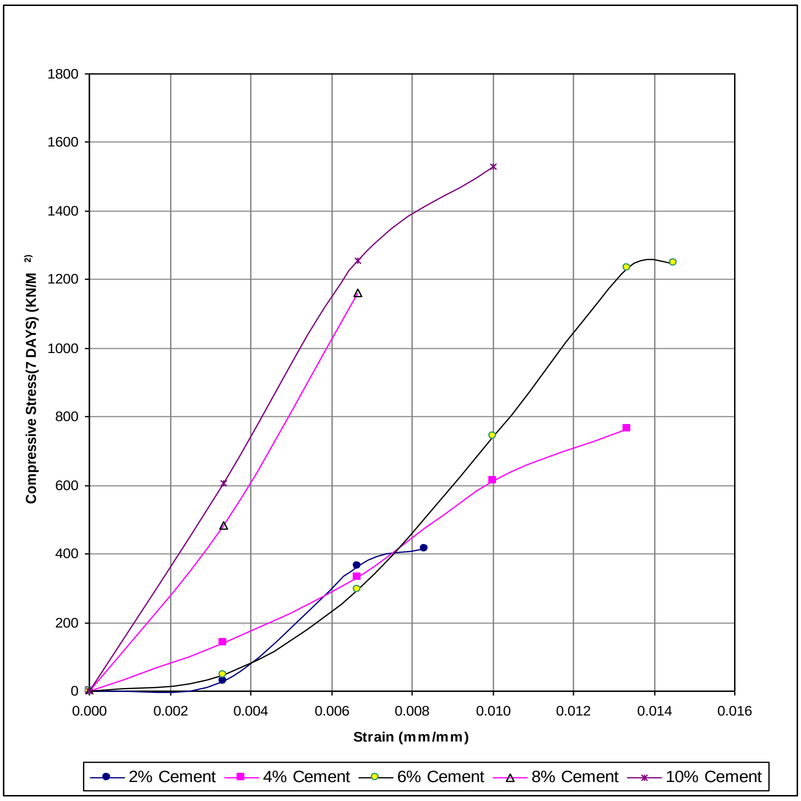


Figure 10-7: Stress Strain Results of the unconfined compression test immediately after 7 days of mixing cement

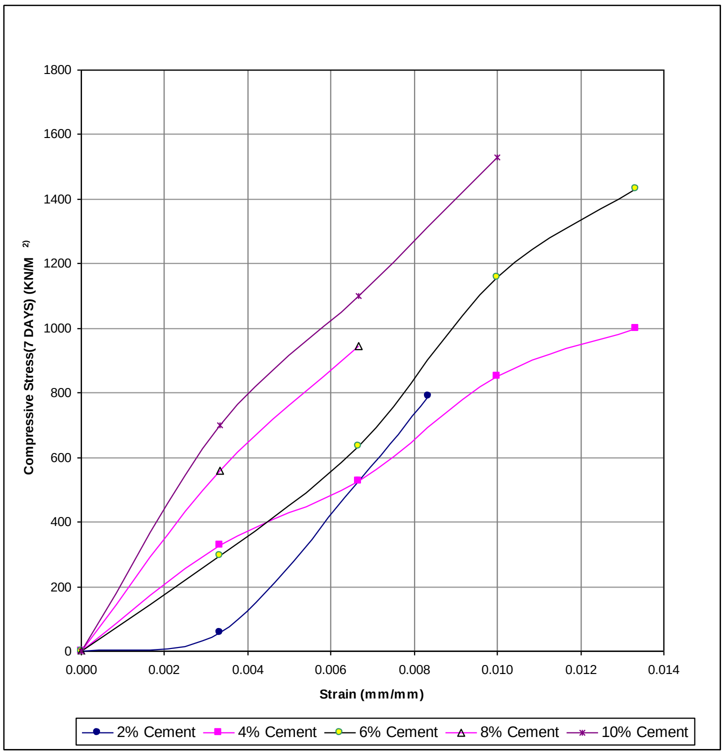


Figure 10-8: Stress Strain Results of the unconfined compression test immediately after 14 days of mixing cement

The Summary of the Stress Strain Results and reduction of Plasticity index are shown in **Table 10.3** below:

Table 10-3 Borehole Drilling Summary at Weir Site

Samples		0%	2%	4%	6%	8%	10%
"C" in kPa	0 days	82.79	112.035	110.5	114.34	107	113.185
	7 days	82.79	207.395	381.9	642.47	734	750+
	14 days	82.79	394.67	500.48	716	749.39	750+
P.I %		7.22	6.75	5.95	4.73	4.17	3.42
Reduction in P.I		-	6.50%	17.60%	34.48	42.20%	52.63%

For economical consideration the soil with 2 % cement stabilization has been selected for the analysis and placement below the weir section. Almost 4 times the stabilization is achieved in terms of cohesion while the Plasticity index is already not in danger zone.

10.11.8 Material Description and Input Parameters

The permeability for the dyke foundation is taken from the permeability tests performed during borehole drilling and the for stabilized soil it's determined in laboratory.

For Stabilized soil beneath weir

1.5×10^{-8} m/sec

For slide material (El: 2402 to 2399m.a.s.l):

9.38×10^{-5} m/sec

For slide material (El: 2402 to 2399m.a.s.l):

4.25×10^{-4} m/sec

10.11.9 Geostudio (SEEP/W Analysis)

The Analysis is performed in Seep/w, a sub program of Geostudio.

The Finite element model has been prepared with Steady Seepage conditions by inputting the proper structural sizes and material properties. Water head and flux (total and unit) boundary conditions have been applied at appropriate edges within the FEM model alongwith potential seepage review face on both of the right and left embankments of channelized section. The FEM Model prepared is shown in **Figure 2-13 (Volume 7, Appendices)**.

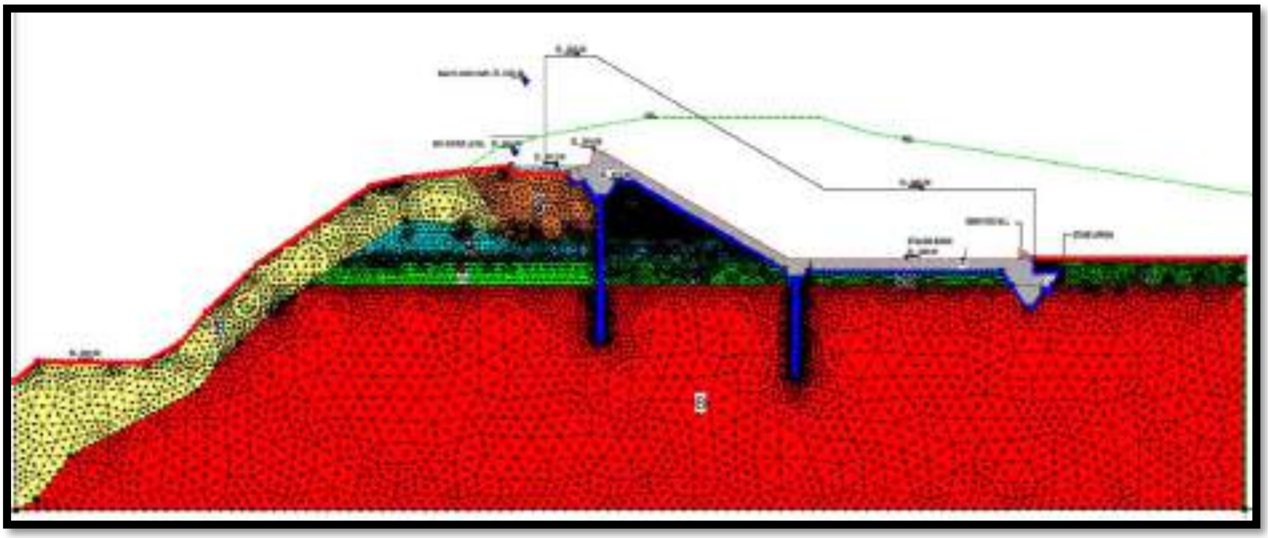
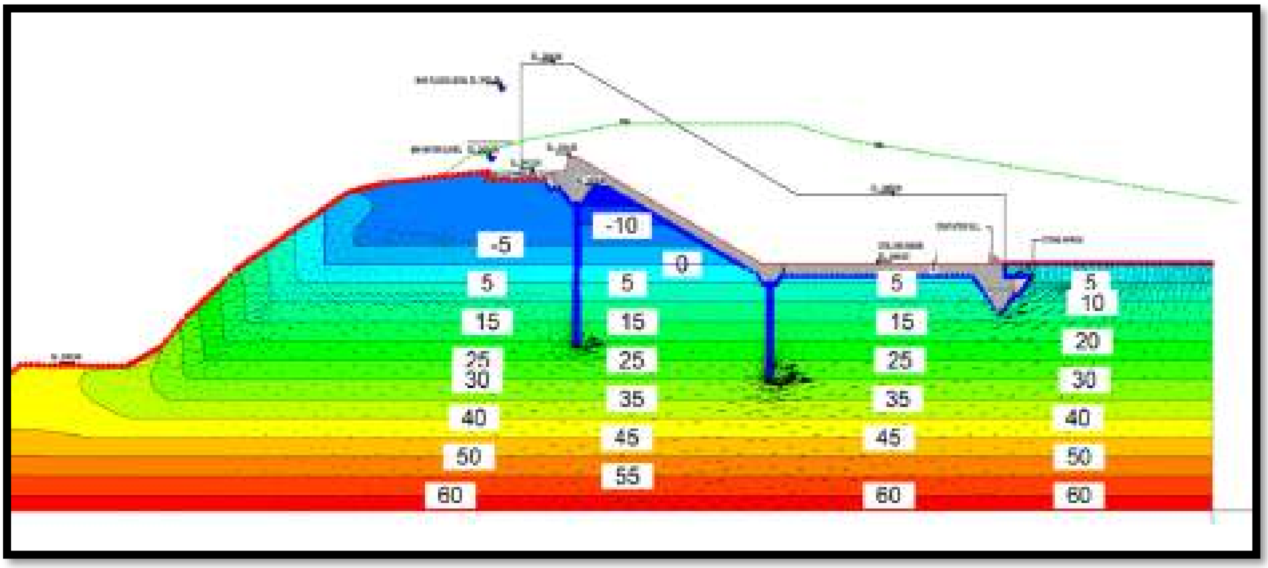


Figure 10-9 Weir Structure at Minimum Pond Level (El : 2414m.a.s.l)

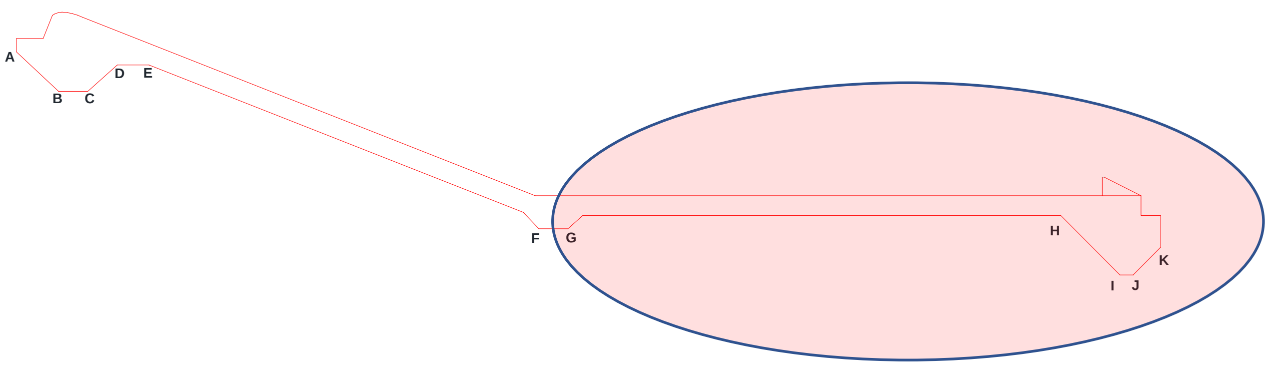
<u>Safety against Uplift:</u>

The Pressure head Profile is shown from **Figure 2-13 (Volume 7, Appendices)**.



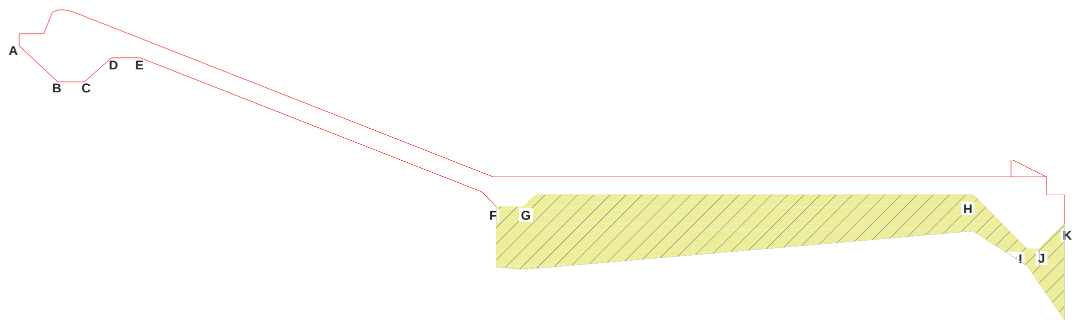
It is quite evident from the Pressure Head Profile and visualization of phreatic surface within the foundation, only the downstream portion is critical against any uplift to check.

Pressure heads have been found at nine Nos. already provided Pressure points beneath the Barrage Structure.



Pt #	Press Head (m)
F	5
G	5.2
H	3
I	1.4
J	1.6
K	8

Based on the Pressure Heads obtained from the SEEP/W, pressure head envelop has been plotted beneath the structure as follows:



The Hydraulic Force per unit length of the weir is calculated by the following equation:

- U= Unit Weight of water x Area of the Pressure head Diagram
- Area of pressure diagram between A & G= 201.3 m^2
- Unit weight of water = 9.81 KN/m^3
- U= (Total Hydraulic Force per Unit length) = 201.3 x 9.81= 1974.753 KN/m
- W=Weight of the Structure per unit length is calculated as = 2436 KN/m
- F.O.S against uplift= W/U= 1.24 (STRUCTURE IS SAFE AGAINST UPLIFT at WL EL: 2414 m.a.s.l)

Safety against Piping:

According to Lane's weighted creep Theory the safety against Piping is ensured if:

$$\boldsymbol{L_{req}} > CH$$

Where;

L_{req} = Required Seepage Length

$C =$ Coefficient taking into account the soil characteristics

$H =$ Maximum Head

According to lanes;

L available = L (vertical)+ 1/3*L(horizontal)

Where;

L available = Available Seepage length under the foundation

L (vertical) = Total vertical seepage length

L (horizontal) = Total Horizontal Seepage length

For Chashma Hydropower Project:

L available=79.8 + 1/3 (72.02) = 103.8 m

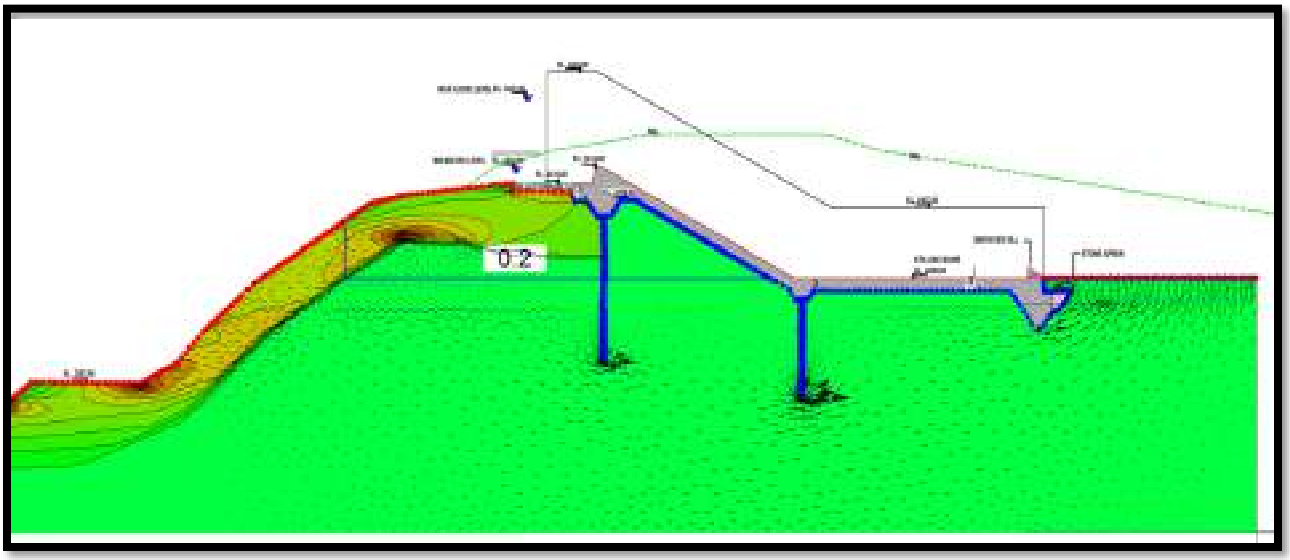
$L_{req} = CH$ = 14 X 3 = 42 m

L available >L_{req}, i.e. 103.8> 42

Hence, the weir structure is safe against piping forces.

Safety against piping d/s of weir through exit gradient criteria.

The Exit gradient profile computed from Geostudio SEEP/W Analysis is shown in **Figure 2-14 (Volume 7, Appendices)**



Exit gradient from Seep/W analysis= 0.2

Critical Hydraulic gradient= (Gs-1)/(1+e)

Where Gs= specific gravity

e= void ratio

Critical Hydraulic gradient= (2.66-1)/(1+0.95)=0.85

Factor of Safety against piping =i (critical)/ i exit=0.85/0.2= 4.25 > 1, hence the weir structure is safe against piping.

10.11.9.1 Weir Structure at Maximum Pond Level (El :2424m)

<u>Safety against Piping:</u>

According to Lane's weighted creep Theory the safety against Piping is ensured if:

$$\boldsymbol{L_{req}} > CH$$

Where;

$L_{req} =$ Required Seepage Length

$\mathrm{C} =$ Coefficient taking into account the soil characteristics

$\mathrm{H} =$ Maximum Head

According to lanes;

L available = L (vertical)+ 1/3*L(horizontal)

Where;

L available = Available Seepage length under the foundation

L (vertical) = Total vertical seepage length

L (horizontal) = Total Horizontal Seepage length

L available=79.8 + 1/3 (72.02) = 103.8 m

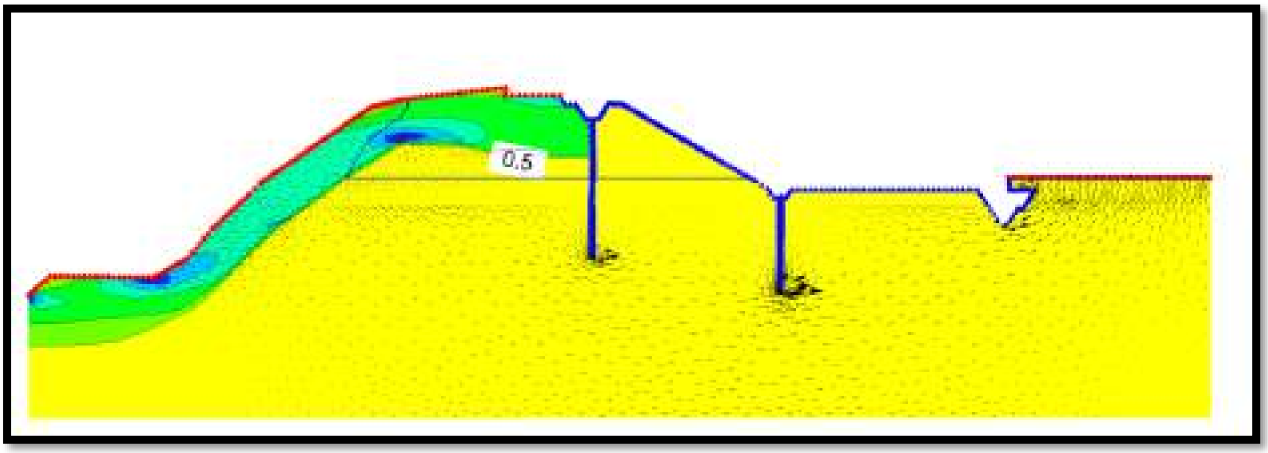
$\mathrm{L_{req}} = \mathrm{CH}$ = 24 X 3 = 72 m

L available >$\mathrm{L_{req}}$, i.e. 103.8> 72

Hence, the weir structure is safe against piping forces.

<u>Safety against piping d/s of weir through exit gradient criteria.</u>

The Exit gradient profile computed from Geostudio SEEP/W Analysis is shown in **Figure 2-15 (Volume 7, Appendices)**



Exit gradient from Seep/W analysis= 0.5

Critical Hydraulic gradient= (Gs-1)/(1+e)

Where

Gs= specific gravity

e= void ratio

Critical Hydraulic gradient= (2.66-1)/(1+0.95)=0.85

Factor of Safety against piping =i (critical)/ i exit=0.85/0.5= 1.7> 1, hence the weir structure is safe against piping.

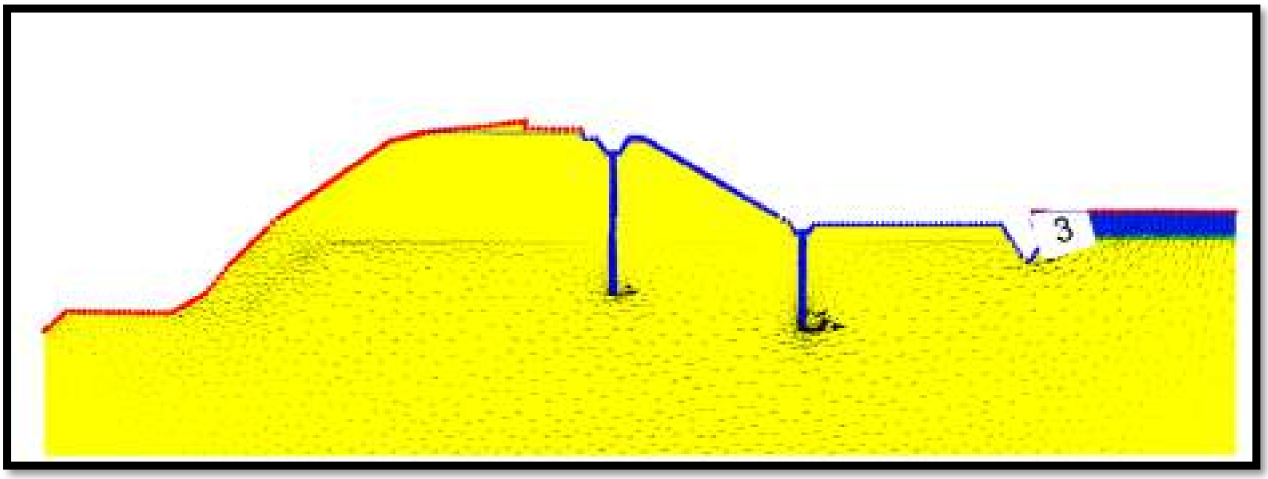
Due to proper seepage line of defences the phi and equipotential lines for max pond level are well below the weir foundation and follows almost same pattern at stilling basin area. The safety against piping was critical which has been checked above.

The clay blanket alongwith cement slurry cutoff and stabilized soil proved to be best in stabilizing the weir structure over the slided material.

For comparison the safety against piping has been checked for weir structure without clay blanket upstream, just to show that its presence upstream is so critical. The structure has been failed as shown below:

Safety against piping d/s of weir through exit gradient criteria at highest pond level 2424 m.a.s.l without clay blanket.

The Exit gradient profile computed from Geostudio SEEP/W Analysis is shown in **Figure 2-16 (Volume 7, Appendices)**



Exit gradient from Seep/W analysis= 3

Critical Hydraulic gradient= (Gs-1)/(1+e)

Where

Gs= specific gravity

e= void ratio

Critical Hydraulic gradient= (2.66-1)/(1+0.95)=0.85

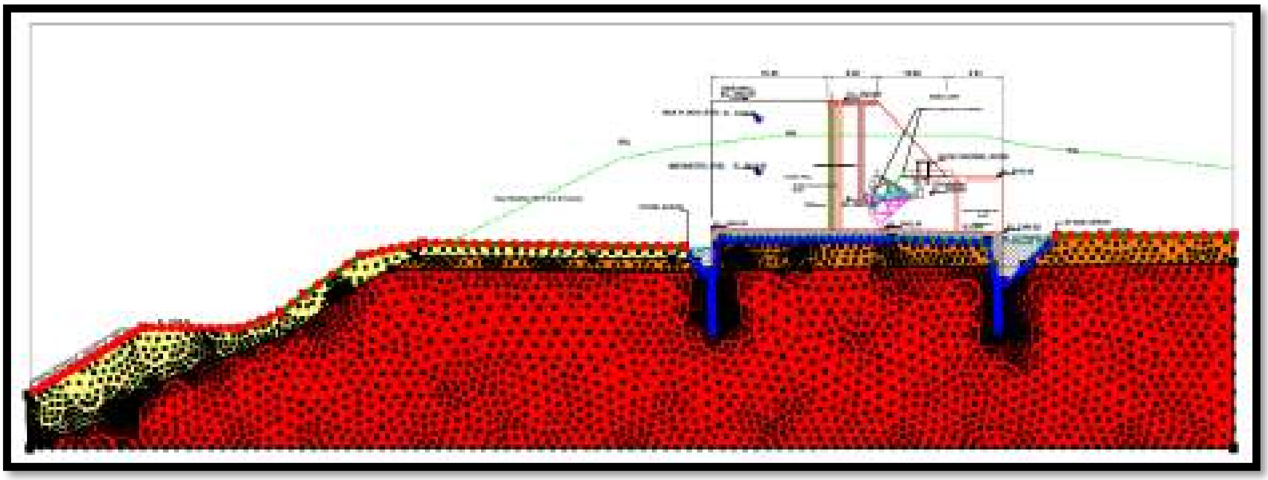
Factor of Safety against piping =i (critical)/ i exit=0.85/3= 0.28> 1, hence the weir structure is not safe against piping when clay blanket is removed.

Under sluice Structure at Maximum Pond Level (El: 2424m.a.s.l)

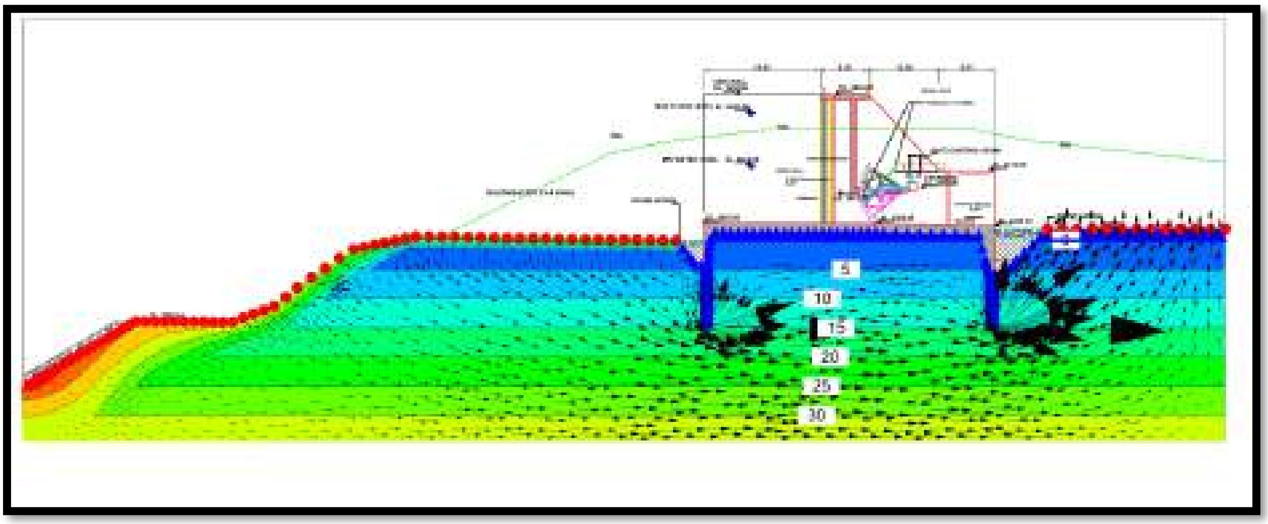
<u>Safety against Uplift:</u>

The Cross section finalized for analysis is shown in **Figure 2-17 (Volume 7, Appendices)**. Seepage line of defenses are upstream clay blanket and pile cutoffs.

The Finite Element model of under sluice section is shown in **Figure 2-18 (Volume 7, Appendices)**.

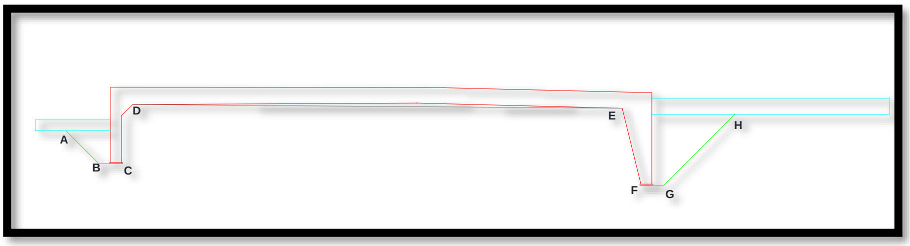


The Pressure head Profile is shown in **Figure 2-18 (Volume 7, Appendices)**.



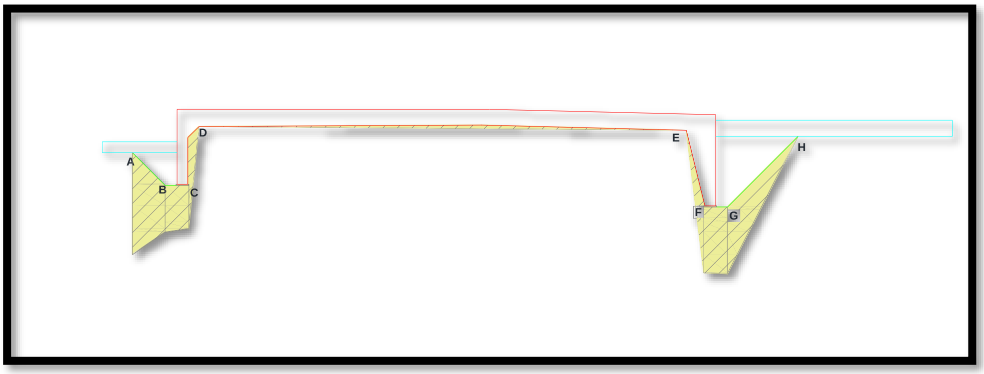
It is quite evident from the Pressure Head Profile and visualization of phreatic surface within the foundation, only the downstream portion is critical against any uplift to check.

Pressure heads have been found at nine Nos. already provided Pressure points beneath the Barrage Structure.



Pt #	Press Head (m)
A	9.4
B	4.33
C	4.1
D	0
E	0
F	6.08
G	6.18
H	0

Based on the pressure heads obtained from the SEEP/W, pressure head envelop has been plotted beneath the structure as follows:



The Hydraulic Force per unit length of the weir is calculated by the following equation:

- U= Unit Weight of water x Area of the Pressure head Diagram
- Area of pressure diagram between A & G 82.51 m^2
- Unit weight of water 9.81 KN/m^3
- U= (Total Hydraulic Force per Unit length) 82.51 x 9.81 = 809.42 KN/m
- W=Weight of the Structure per unit length is calculated as 3147 KN/m
- F.O.S against uplift W/U 3.88 **(STRUCTURE IS SAFE AGAINST UPLIFT at WL EL: 2424 m.a.s.l)**

Safety against Piping:

According to Lane's weighted creep Theory the safety against Piping is ensured if:

$$\boldsymbol{L_{req}} > CH$$

Where;

L_{req} = Required Seepage Length

C = Coefficient taking into account the soil characteristics

H = Maximum Head

According to lanes;

L available = L (vertical)+ 1/3*L(horizontal)

Where;

L available = Available Seepage length under the foundation

L (vertical) = Total vertical seepage length

L (horizontal) = Total Horizontal Seepage length

:

L available=64.648 + 1/3 (49.38) = 81 m

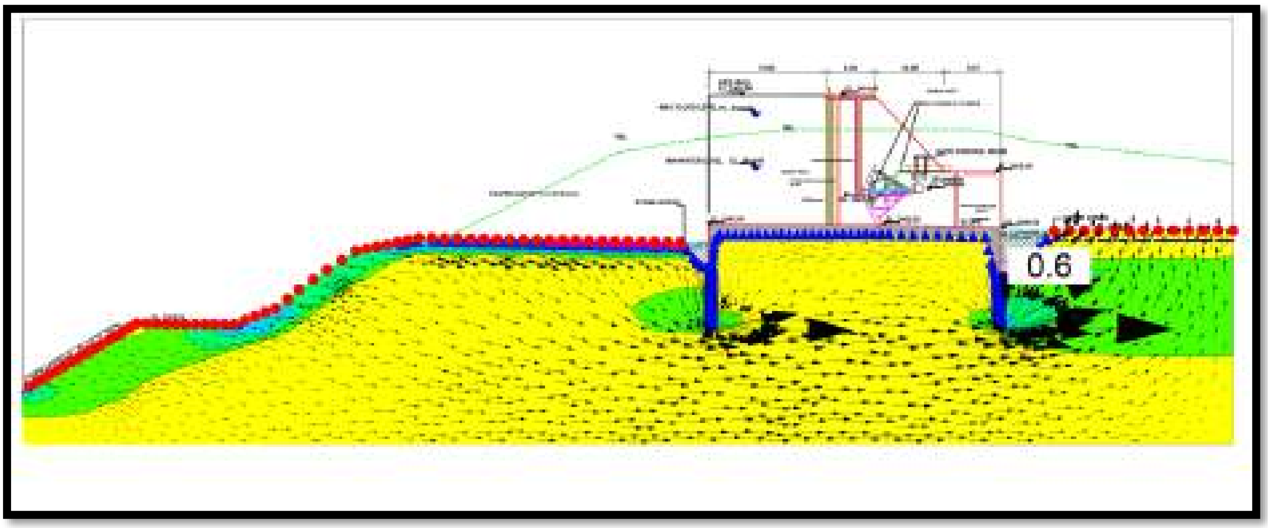
$L_{req} = CH$ = 24 X 3 = 72 m

L available >L_{req}, i.e. 81> 72

Hence, the weir structure is safe against piping forces.

Safety against piping d/s of barrage through exit gradient criteria.

The Exit gradient profile computed from Geostudio SEEP/W Analysis is shown in **Figure 2-20 (Volume 7, Appendices).**



Exit gradient from Seep/W analysis 0.6

Critical Hydraulic gradient (Gs-1)/(1+e)

Where Gs= specific gravity

e= void ratio

Critical Hydraulic gradient (2.66-1)/(1+0.95)=0.85

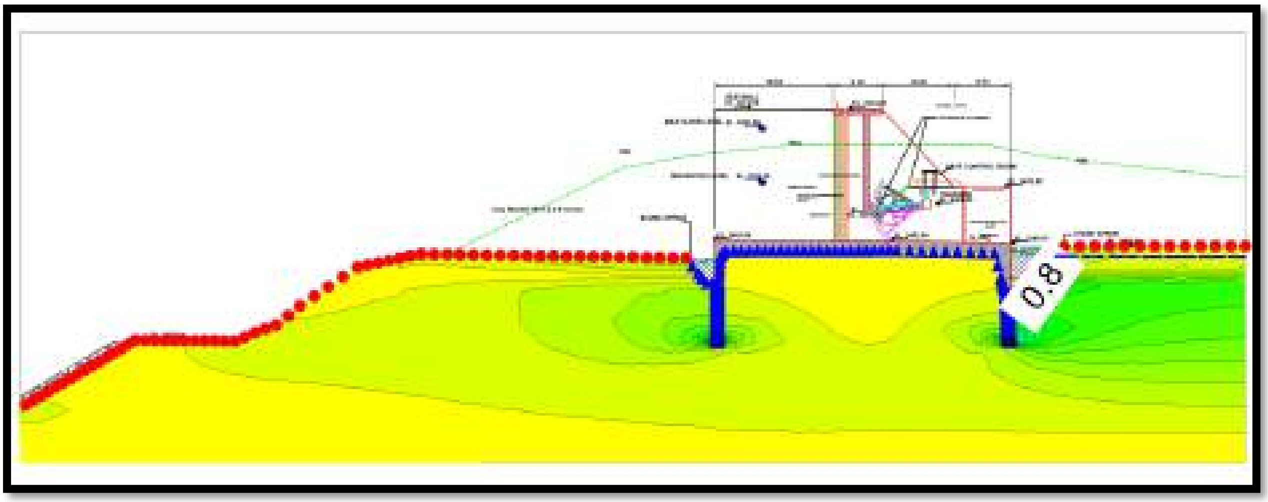
Factor of Safety against piping =i (critical)/ i exit=0.85/0.6= 1.41> 1, hence the weir structure is safe against piping.

10.11.9.2 Overflow Weir Structure at Max Pond Level without Blanket (El: 2424 m.a.s.l)

For comparison the safety against piping has been checked for overflow weir/ungated spillway structure without clay blanket upstream, just to show that its presence upstream is so critical. The structure has been failed details are given below:

Safety against piping d/s of sediment flushing channel /under sluice through exit gradient criteria at highest pond level 2424 m.a.s.l without clay blanket.

The Exit gradient profile computed from Geostudio SEEP/W Analysis is shown in **Figure 2-21 (Volume 7, Appendices)**



Exit gradient from Seep/W analysis= 0.8

Critical Hydraulic gradient= (Gs-1)/(1+e)

Where

Gs= specific gravity

e= void ratio

Critical Hydraulic gradient= (2.66-1)/(1+0.95)=0.85

Factor of Safety against piping =i (critical)/ i exit=0.85/0.8= say equal to 1, hence the sediment flushing channel/ undersluice structure is not safe against piping when clay blanket is removed.

10.12 MONITORING AND SURVILANCE OF SLOPES

Slope indicators are proposed on right side slope benching starting from overflow weir site at chainage 100+00 towards downstream @ 100m. They are really necessary to use to measure relative and absolute (total) horizontal (lateral) movement, and/or variation in inclination, with respect to a vertical or inclined reference axis.

Lateral movements in structures are measured by use of borehole slope indicators (Inclinometers). The slope indicator casing may be installed during construction of the dam, or, after in the event that excessive displacement is observed.

The instrumentation basically will be comprising of a specially designed access tube (duct), with incorporated guide tracks, which is embedded in the respective structure, embankment or foundation, aligned along the selected measurement reference axis. The access tubing is of segmental construction with telescoping joints to accommodate extension/compression movements.

The tilt of the sensor will be measured and recorded by servo-accelerometer located within the probe. Where two accelerometer are used they can sense the inclination of the tube in two directions at right angles to each other.

Portable electronic probes, with attached calibrated measurement/control cables, are provided for insertion and traversing along the access tube(s) for reading purposes. The probe readings are taken with special electronic readout units capable of storing the readings for subsequent direct downloading to a computer for purposes of analysis. Analysis of the readings is carried out by special computer software provided as part of the instrument package.

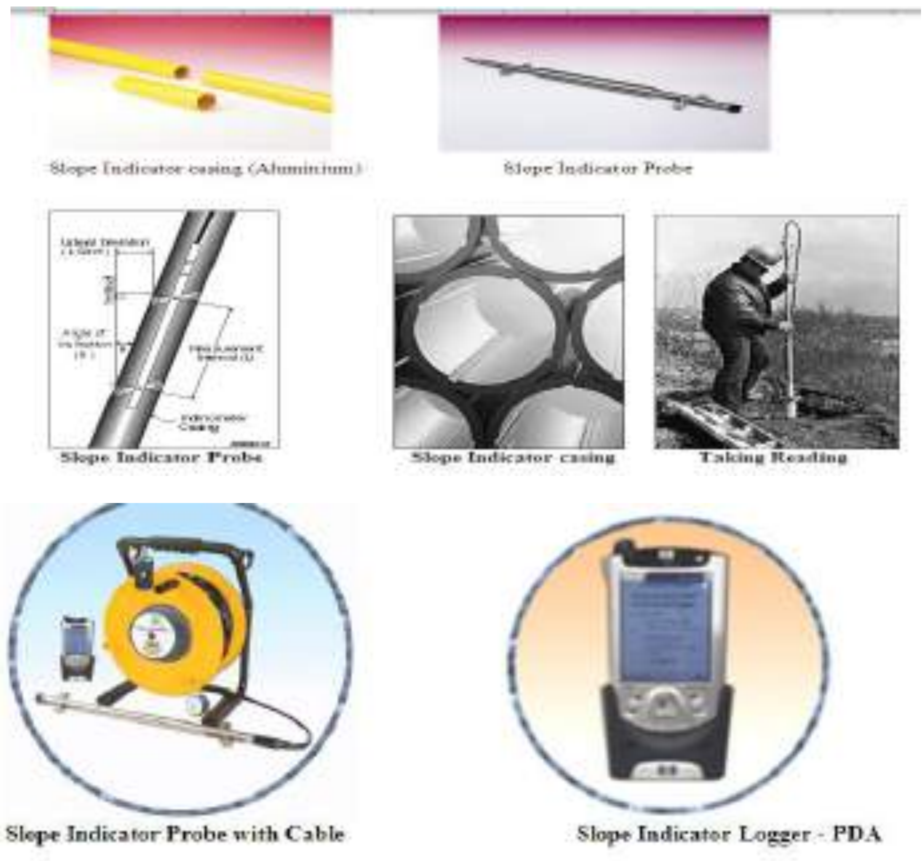
In the case of the inclinometer probes, readings of the inclination of the access tube at selected points are taken in two orthogonal directions (i.e. at 90^o to each other) over the fixed gauge length of the probe, and by taking a series of continuous readings a profile of the deflected shape of the access tube corresponding to the deflection within the structure, embankment, or foundation can be obtained.

Provision is made in the supplied computer software for the graphical plotting of the deflected shapes and the determination of both absolute (total) and relative (incremental) displacements with time.

The accuracy of measurement is 3 mm.

Inclinometer consists of;

- Aluminum access tube (in small lengths)
- Biaxial probe
- Inclinometer data logger



The cross section details of slope indicator are presented in **Figure 10.9 & 10.10** below:

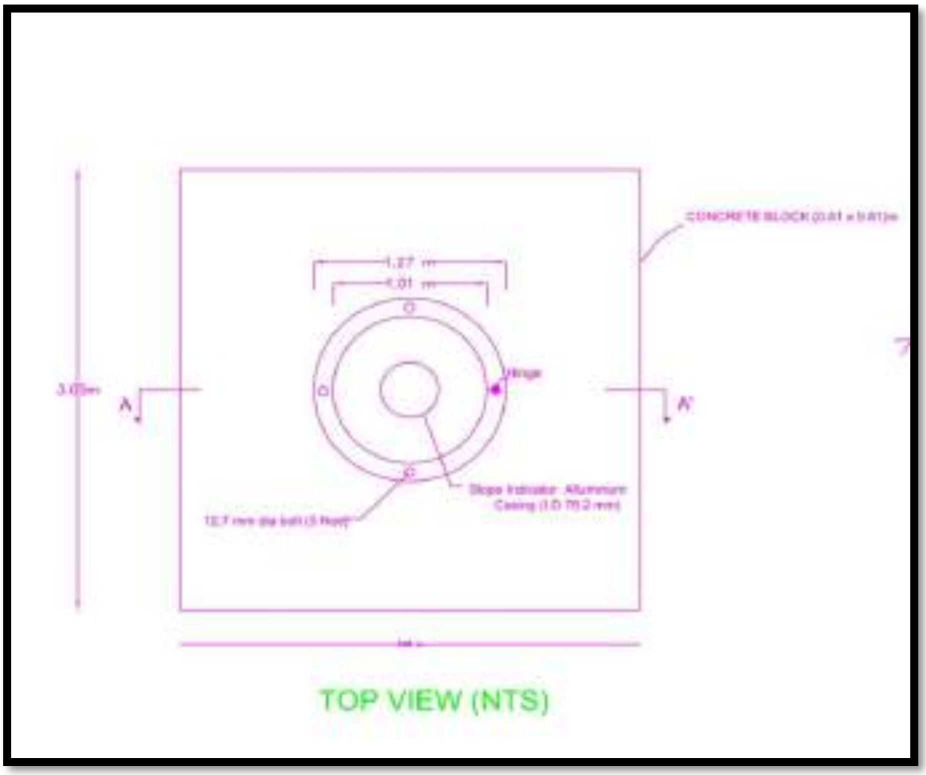


Figure 10-10: Cross Section details of Slope Indicator (Top view)

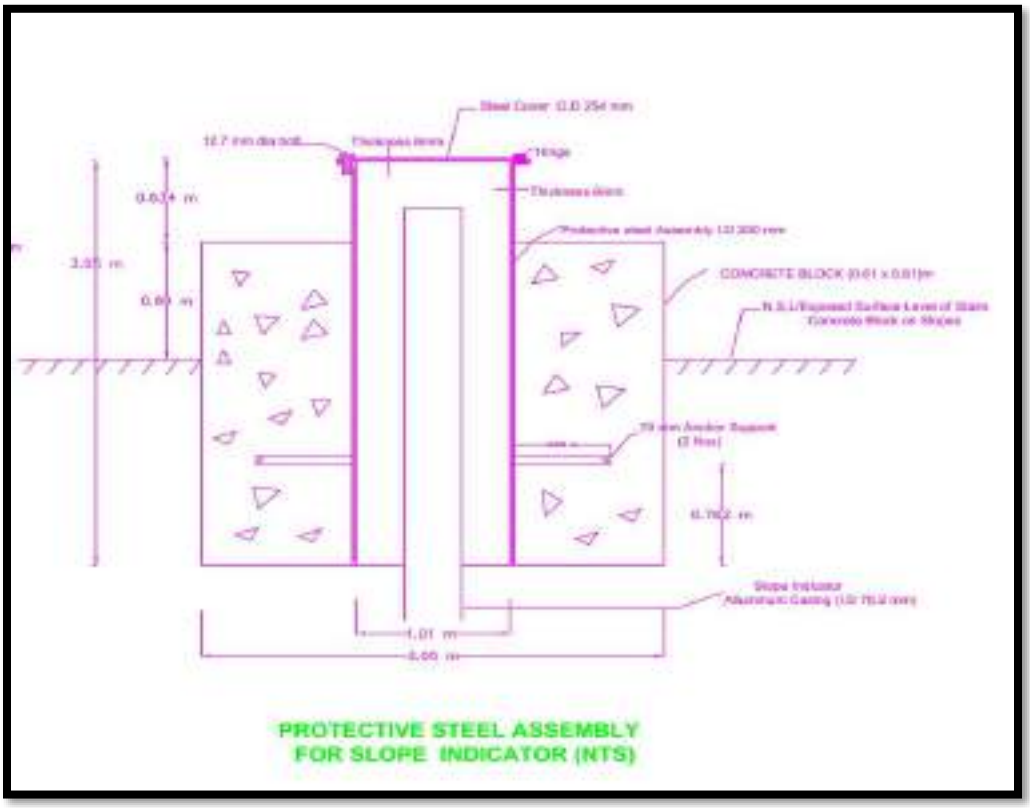


Figure 10-11: Cross Section details of Slope Indicator (cross section)

The depth of the slope indicator will be upto bottom of the final stepping/ bench and will start from one above the middle bench of the benched slope.

11 HYDRO MECHANICAL EQUIPMENT

11.1 INTRODUCTION

11.1.1 BACKGROUND

Energy is the indispensable force that drives all economic activity the greater the energy consumption, the more the economic activity, resulting in the emergence of growth. A steady growth in the economy is a prerequisite for any nation desirous of becoming a developed country. If Pakistan adequately utilizes its energy potential to meet growing demand, it will be better poised to achieve high levels of economic growth.

Hydropower is a clean, domestic, and renewable source of energy. It provides inexpensive electricity and produces no pollution. Unlike fossil fuels, hydropower does not destroy water during the production of electricity. Hydropower is the only renewable source of energy that can replace fossil fuels' electricity production while satisfying growing energy needs. According to some estimates, Pakistan is endowed with a potential of about 40,000 MW but only 11.0% of it is presently being utilized for generation of electricity leaving the remaining untapped.

Considering the electric industry that exists today, hydropower has a distinct advantage over fossil fueled generator plants: it is clean, green and renewable. Hydropower does not contribute to local air pollution. Other energy generators are an important source of air, water, and soil pollution and greenhouse gases, and provide fewer opportunities for economic spin-offs.

11.1.2 Location

Attabad is a town in the Gilgit-Baltistan region of northern Pakistan. It is located at 36°19'0N 74°48'0E with an altitude of 2559 meters (8398 feet) and is famous as home of the Attabad lake. The lake was formed when Attabad Village in Hunza Valley in Gilgit-Baltistan had a landslide, 14 kilometers (9 miles) upstream (east) of Karimabad that occurred on 4th January, 2010. Location for the Proposed Attabad Hunza Hydropower Project has been identified in the intermediate reach along Hunza River 29km upstream of Aliabad Village and 111km from Gilgit.

11.1.3 Parameters

To arrive at the optimum unit rating and parameters of the power plant detailed studies for the various possible alternates were carried out. From these studies it was concluded that installation of generating units of capacity 54 MW corresponding to 375 rpm synchronous speed would be the optimum solution. The key characteristics of the unit selected for Attabad Hydro Power Project, are given below.

Full Supply Level (FSL)	2414 m.a.s.l
Minimum Operating Level (MOL)	2412 m.a.s.l
Maximum Tail water Level	2307 m.a.s.l
Minimum Tail water Level	2302 m.a.s.l
Site Gross Head	112 m
Rated Net Head	106 m
Installed capacity	54 MW
No. of Generating Units	03
Units Rated Capacity	18 MW (Generator Output)
Turbine Rated Capacity	57 MW
Plant Overall Efficiency	90.28% (0.915(T)x0.98(G)x0.985(T_f))
Transformer Capacity	66 MVA (3 x 22)
Generator Voltage	11 kV
Power Factor	0.85
Powerhouse Cavern	45 m x 18 m x 22 m (L x W x H)
Transmission Voltage	132 KV

11.2 POWER HOUSE MECANICAL WORKS

11.2.1 General

This section provides general information and guidelines used for the feasibility design of the hydro-mechanical equipment for Attabad Hydro power project (AHPP). It also covers the characteristics of these equipment and various factors used to establish the size and configuration of such type of equipment. The key dimensions of turbine are also workout and given in this chapter.

11.2.2 Introduction

The mechanical equipment of Attabad Hydropower Project consists of the following main components:

- Vertical Shaft Francis Turbines
- Turbine governors
- Main Inlet Valves
- Powerhouse Main Crane
- Station Auxiliaries
- Cooling Water System

- Drainage and Dewatering System
- Compressed Air System
- Oil Handling System
- HVAC System
- Fire Fighting System
- Mechanical Workshop Equipment
- Elevator
- Potable Water Supply and Sanitation System

11.3 STANDARDS AND BASIC DESIGN CRITERIA

The mechanical equipment will be designed according to the well reputed international standards and codes like IEC, ISO, EN, ASTM, ASME, BSS, DIN, etc.

11.4 MAIN DESIGN PARAMETERS

11.4.1 Water Flow

Flow Duration Curve (FDC) for Attabad Lake HPP is plotted on the basis of almost 51 years (1966-2016). From FDC it us evident that design discharge of 60 m^3/s is available for almost 50% of the time. Therefore, design discharge of 60 m^3/s is justified for the generation of 54 MW power.

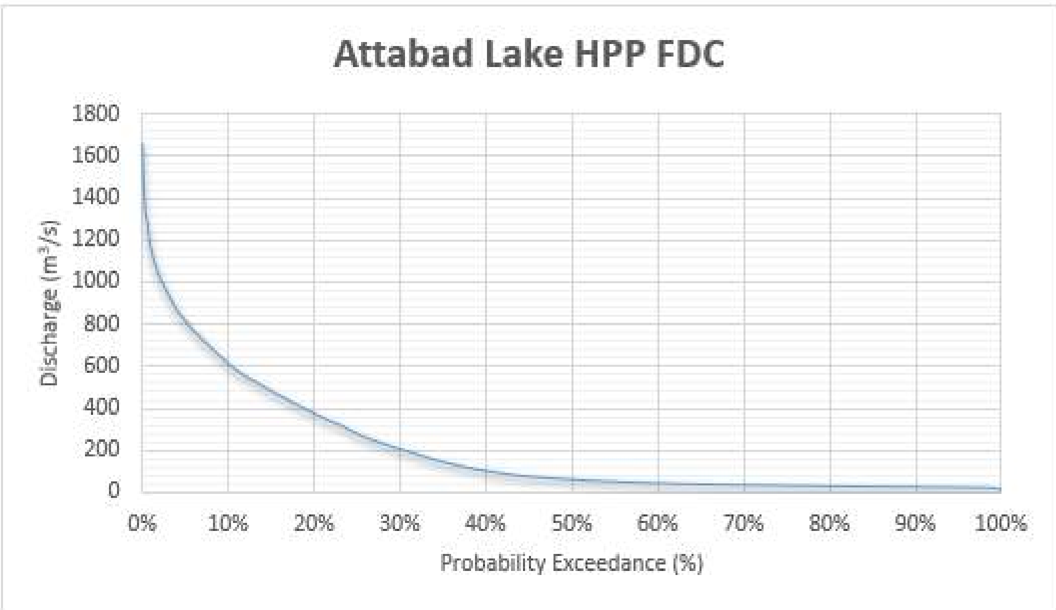


Figure 11-1 Attabad Lake Flow Duration Curve (FDC)

Table 11-1 Flow Duration Curve Results

Probability Exceedance (%)	Flow (m3/s)	Probability Exceedance (%)	Flow (m3/s)
10	613.4	60	44.3
20	376.6	70	36
30	205	80	30.3
40	103.3	90	26.2
50	61.3	99	20.5

11.4.2 Head Calculation

Head water Level

The Full Supply Level (FSL) of AHPP is 2414 m.a.s.l., while minimum Operation Level (MOL) is about 2412 m.a.s.l. depending upon the availability of flows.

Tail water Level

Since there is fluctuation of flow, thus tail water level will also be changing accordingly. Maximum tail water level has been recorded as 2307 m.a.s.l. and minimum tail water level is 2302 m.a.s.l.

11.4.3 Water Head

Gross head

On the basis of selected water levels calculated gross head will be:

Site Gross Head: 112 m

Rated net head

Considering the head variation, friction losses and turbine runner central line arrangement the selected rated net head for AHPP is as follows:

Maximum Net Head: 108 m

Rated Net Head: 106 m

Minimum Net Head: 100 m

11.4.4 Site Elevation

Site elevation of AHPP powerhouse is 2358 m

11.4.5 Water Temperature

Average water temperature at AHPP site is 10˚C

11.4.6 System frequency

System frequency of AHPP powerhouse equipment is 50 Hz

11.4.7 Plant Capacity

The Power has been carried out according to the following formula:

$$P = \rho \times g \times Q \times H \times \eta / 1000$$

Where,

P= Power (MW)
ρ = Density of water = 1 (ton/m^3)
Q = Discharge (m^3/sec)
H = Available head (m)
g = Acceleration due to gravity (9.81 m/sec^2)
η = overall Efficiency coefficient (%)

On the bases of selected rated discharge of 60 m^3/sec and rated net head of 106 m and overall efficiency of turbine, generator & transformer is around 0.90. The installed capacity of power house comes out to be 54 MW.

11.5 POWERHOUSE MECHANICAL EQUIPMENT

The powerhouse will be equipped with three Vertical Shaft Francis turbines. The total plant out capacity of AHPP powerhouse is 54 MW. The turbine shall be capable to operate within a wide range of head and discharge at maximum attributable efficiency.

No. of Units	= 03 (Vertical Francis)
Plant Discharge, Q_{Total}	= 60 m^3/s
Rated Net Head, H_n	=106 m
Plant Capacity, P_{Total}	= 54 MW

Followings are the main powerhouse mechanical equipment.

- Turbines
- Governors
- Cooling and Service Water Systems
- Dewatering and Drainage Systems
- Potable water system
- Sewage and water treatment
- Compressed air Systems
- Oil handling system

- Heating Ventilation & Air-conditioning System
- Fire protection system
- Powerhouse Crane
- Powerhouse elevator
- Workshop equipment etc.

11.6 TURBINES

In the power house, three (03) turbine-generating units, each consisting of a Francis turbine and a synchronous generator rigidly coupled by a vertical shaft. Each turbine will be equipped with a main inlet valve of butterfly type at the inlet of the manifold. On the downstream side of each turbine, draft tube gates can be set to isolate the turbine pit from the tailrace channel.

At the power intake (in Attabad Lake), fixed wheel gate will be installed, which will act as emergency gate.

The size of powerhouse totally depends upon type of turbine and number of units. Discharge and net head basic is the key parameter and basic criteria for selecting the type of hydel turbine. Other factor such as gates, stop logs, trash racks, dewatering and drainage pits, loading and service bay are also important.

Since, the layout and dimensions of a powerhouse are mainly influenced by the selected type of turbine, particularly by arrangement of turbine axis either in horizontal or in vertical direction and discussed as follows:

11.6.1 Turbine Selection Criteria

In case of AHPP with gross head of 112 m, rated net head of 106 m and rated discharge of 60 m^3/sec, figure 2.2 & 2.3 refer Francis turbines to be the most suitable ones.

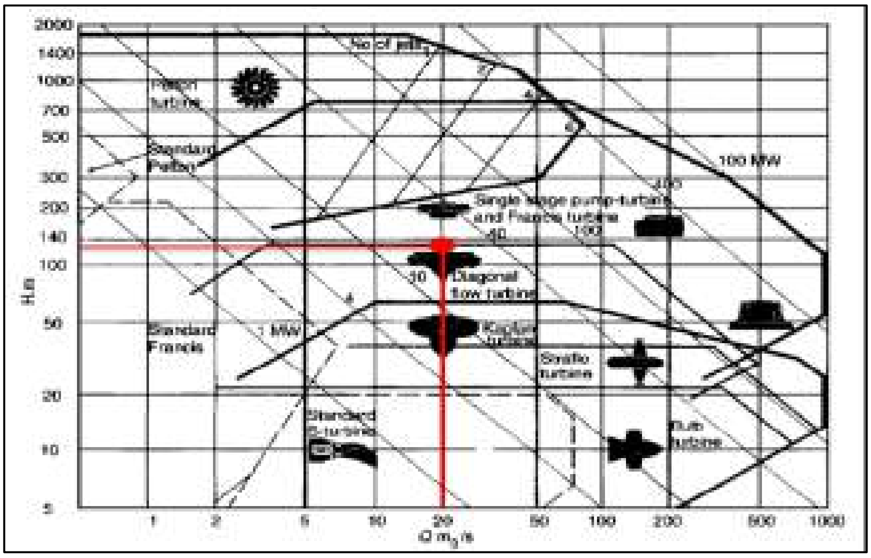


Figure 11-2 Generalized Turbine Operation Limits

(Courtesy Sulzer Hydro Ltd., Zurich)

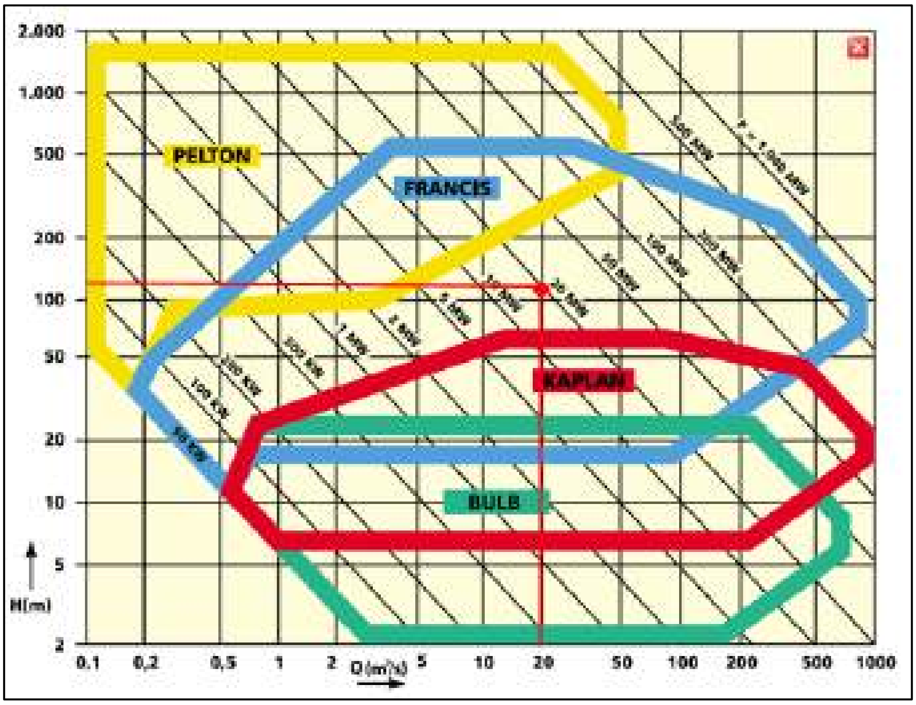


Figure 11-3 Turbine Operating Regimes

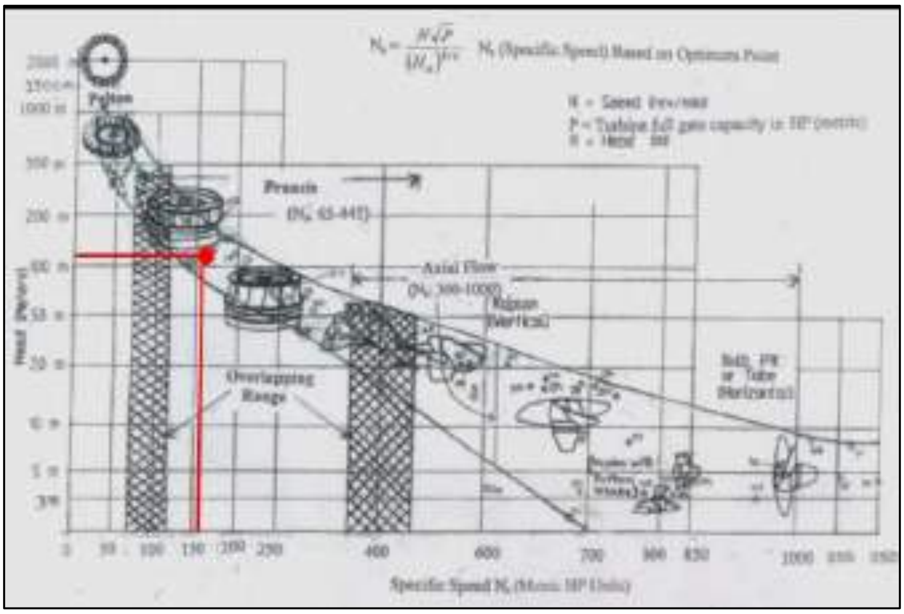


Figure 11-4 N_s Versus Head:

This figure shows the various turbine type as a function of specific speed (Ns) and head. This figure should be used a guideline, as there is overlap between the various turbine types with respect to their operating ranges (Based on ASME–Guide to Hydropower Mechanical Design Book)

Following standards and monographs are good guides for selection of hydraulic turbines.

- IS 12837 – 1989 – Hydraulic Turbines for Medium and Large Power Houses – Guidelines for Selection.

- IS 12800 (Part 3) 1991 – Guide lines for selection of hydraulic turbines, preliminary dimensioning and Layout of surface Hydro-Part 3 Small Mini and Micro Hydroelectric Power Houses.

Vertical Francis type turbine is best and appropriator solution for the rated discharge of 20 m^3/sec and rated net head of 106 m.

11.6.2 Specific Speed

The term specific speed used in classifying types of turbines and characteristics of turbines within types is generally the basis of selection procedure. This term is specified as the speed in revolution per minute at which the given turbine would rotate, if reduced homologically in size, so that it would develop one metric horse power at full gate opening under one-meter head. Low specific speeds are associated with high heads and high specific speeds are associated with low heads. Moreover, there is a wide range of specific speeds which may be suitable for a given head.

Flow based metric system for specific speed (N_q) is given by equation below.

$$\mathbf{N_q = \frac{NT^{0.5}}{H^{1.25}}}$$

Where,

N_q = Specific Speed

N = Speed in rpm

T = Turbine Power

H = Net Head in meters

$$N_q = \frac{375 * 19000^{0.5}}{106^{1.25}}$$

$$\mathbf{N_q = 152.0}$$

Specific speed (metric HP units) range of different types of turbines is as follows:

Fixed blade propeller turbines - 300 – 1000

Adjustable blade Kaplan turbines - 300 – 1000

Francis turbines - 65 – 445

Impulse turbines –

- Pelton Turbine per jet 16-20 per jet for multiple jets the power is proportionally increased.

- Cross flow turbine 12-80

Specific speed is calculated to be 152.0 which lies in range of Francis turbine (65 – 445). Hence, vertical Francis turbine is best suitable for the specific speed of 152.0.

11.6.3 Number of units

Normally, it is most cost effective to have a minimum number of units at a given installation; however multiple units may be necessary due to various reasons. Thus for selecting number of units following factors should be considered.

- Efficient water use
- Getting Max energy
- Space limitation for civil structure
- Transportation Problems
- Maintenance View point
- Cost effectiveness

Table 11-2 Power Output with Different no. of Units for Attabad HPP

Number of Units		**4**	**3**	**2**
Unit Discharge	m^3/sec	15	20	30
Rated Turbine capacity	MW	14	19	29
Over all Plant Capacity	MW	53	54	55
Efficiency at rated discharge	%	90.0	90.0	90.0
Turbine Speed	rpm	429	375	333.3
Runner outer diameter	m	1.457	1.676	1.988
Crane capacity	Ton	60	80	100

11.6.4 Efficient Water Use

Efficient use of available water and getting maximum energy from hydropower station is necessary to maximize the profitability.

Selection of number of units plays a bridge role to achieve this target. On the feasibility stage, two units of same capacity and one with less capacity are considered.

One major factor for evaluation of number of units is how the power station will anticipate in operation. Particularly for AHPP, with 03 units operational reliability and given optimum annual energy. This operational advantage will also contribute in the annual energy produced by the project.

11.6.5 Space Limitation for Civil Structure

Space limitation for geologic characteristic may dictate larger or smaller units. In case of AHPP, turbine capacity is 19 MW. From the Civil structure & Geologic viewpoint, no major hindrance found in power house side.

11.6.6 Maintenance View Point

More the number of units higher the operation and maintenance (O&M) cost, lesser the number of units less will be maintenance cost. But for the system stability and avoid the complete shutdown of powerhouse more than one unit is strongly recommended.

11.6.7 Transportation

The transportation of heavy construction and permanent equipment (turbine runner, generator rotor, stator, transformers) to the site is a matter which needs careful attention. In Case of AHPP, no transportation limitation is found.

11.6.8 Cost effectiveness

Higher the number of units more the E&M and total project cost. In case of 03 units, the difference in energy benefits is very less, however by increasing units from 03 to 04 cost will increase considerably. Thus 03 units are more suitable and cost effective.

11.6.9 Recommendation

Considering all above parameters/aspects, three (03) units are the most favorable solution from the technical and economical point of view. A summary of key turbine parameters are shown in Table-11.3 below.

Table 11-3 Key Turbine Parameters

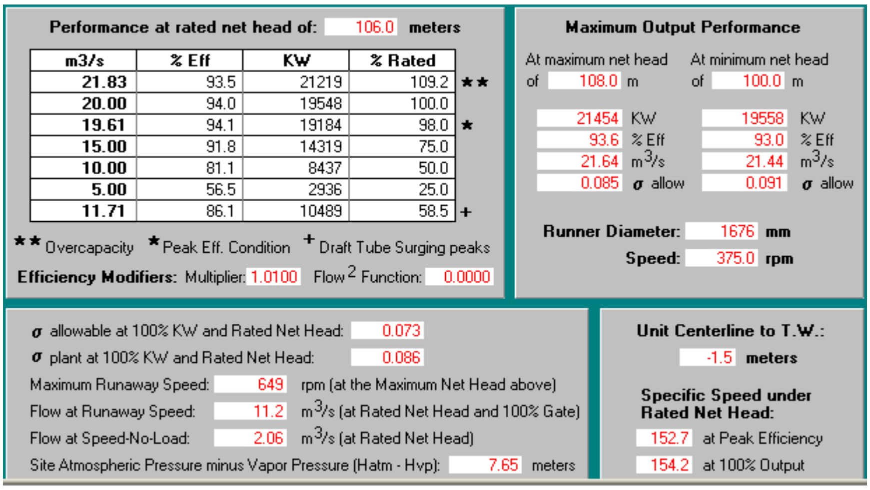
Name	Quantity	Unit
Number of Turbines	03	-
Turbine Type	Vertical Shaft Francis	-
Design net head	106	M
Minimum net head	100	M
Maximum net head	108	M
Maximum Turbine Efficiency	≥ 91.5	%
Design Unit Discharge	20	m^3/sec
Design Scheme Discharge	60	m^3/sec
Turbine Rated Output	19	MW
Rated Speed	375	Rpm
Runaway Speed	649	Rpm

All proposed turbines are of Vertical shaft Francis type. The turbines will be directly coupled to the generator rotor.

The direction of rotation shall be clock-wise when viewed from drive end. The turbines shall be capable of giving outputs higher than rated outputs to match the overload capability of the generators. Each turbine shall be designed to give a rated output at rated head at generator terminals with guide vane opening of about 80-85 %. The turbine shall have adequate capacity commensurate with the 10 % continuous overload capacity of the generators.

11.7 TURBINE LAYOUT AND SIZING

The layout and sizing of the AHPP turbine units have been carried out using the in house available computation programs, United States Bureau Reclamation (USBR) manual and computer software TURBNPRO. Details of computation and analysis on computer software TURBNPRO is shown below from Figure-11-5 till Figure 11-11 below:



Performance at rated net head of: 106.0 meters

m3/s	% Eff	KW	% Rated	
21.83	93.5	21219	109.2	**
20.00	94.0	19548	100.0	
19.61	94.1	19184	98.0	*
15.00	91.8	14319	75.0	
10.00	81.1	8437	50.0	
5.00	56.5	2936	25.0	
11.71	86.1	10489	58.5	+

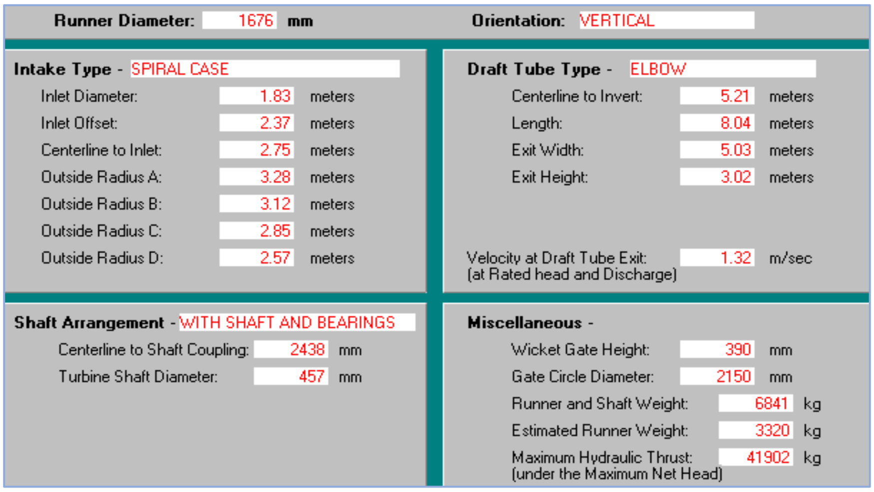
** Overcapacity * Peak Eff. Condition + Draft Tube Surging peaks
Efficiency Modifiers: Multiplier: 1.0100 Flow 2 Function: 0.0000

Maximum Output Performance
At maximum net head of 108.0 m: 21454 KW; 93.6 % Eff; 21.64 m3/s; 0.085 σ allow
At minimum net head of 100.0 m: 19558 KW; 93.0 % Eff; 21.44 m3/s; 0.091 σ allow
Runner Diameter: 1676 mm
Speed: 375.0 rpm

σ allowable at 100% KW and Rated Net Head: 0.073
σ plant at 100% KW and Rated Net Head: 0.086
Maximum Runaway Speed: 649 rpm (at the Maximum Net Head above)
Flow at Runaway Speed: 11.2 m3/s (at Rated Net Head and 100% Gate)
Flow at Speed-No-Load: 2.06 m3/s (at Rated Net Head)
Site Atmospheric Pressure minus Vapor Pressure (Hatm - Hvp): 7.65 meters

Unit Centerline to T.W.: -1.5 meters
Specific Speed under Rated Net Head: 152.7 at Peak Efficiency; 154.2 at 100% Output

Figure 11-5 Turbine Output Specifications



Runner Diameter: 1676 mm Orientation: VERTICAL

Intake Type - SPIRAL CASE
Inlet Diameter: 1.83 meters
Inlet Offset: 2.37 meters
Centerline to Inlet: 2.75 meters
Outside Radius A: 3.28 meters
Outside Radius B: 3.12 meters
Outside Radius C: 2.85 meters
Outside Radius D: 2.57 meters

Draft Tube Type - ELBOW
Centerline to Invert: 5.21 meters
Length: 8.04 meters
Exit Width: 5.03 meters
Exit Height: 3.02 meters
Velocity at Draft Tube Exit: 1.32 m/sec (at Rated head and Discharge)

Shaft Arrangement - WITH SHAFT AND BEARINGS
Centerline to Shaft Coupling: 2438 mm
Turbine Shaft Diameter: 457 mm

Miscellaneous -
Wicket Gate Height: 390 mm
Gate Circle Diameter: 2150 mm
Runner and Shaft Weight: 6841 kg
Estimated Runner Weight: 3320 kg
Maximum Hydraulic Thrust: 41902 kg (under the Maximum Net Head)

Figure 11-6 Intake, Draft tube and Shaft Arrangement

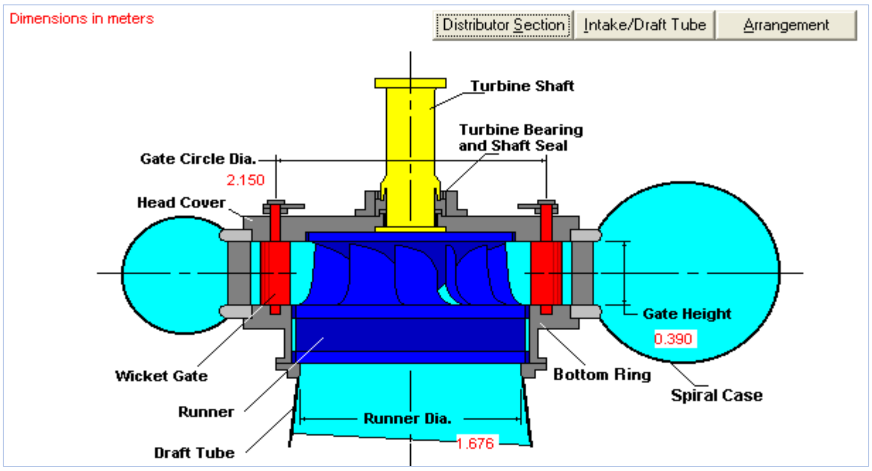


Figure 11-7 Distributor Section

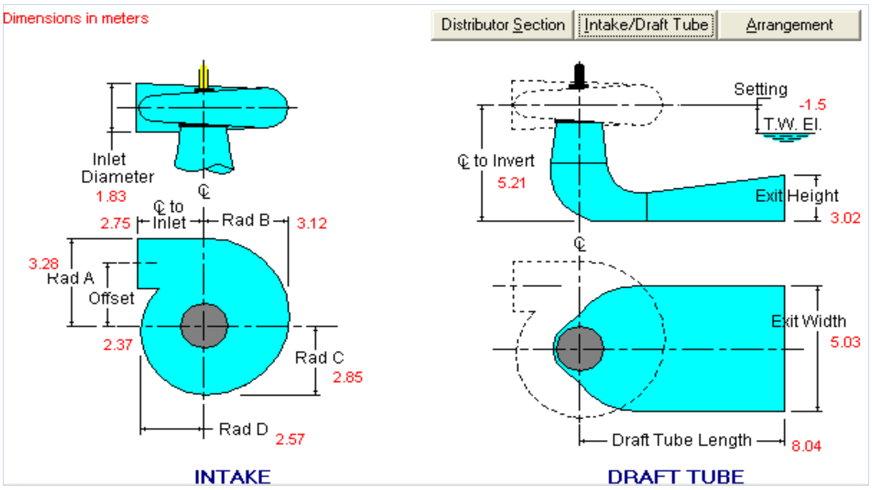


Figure 11-8 Figure 11-8 Intake and Draft tube Layout

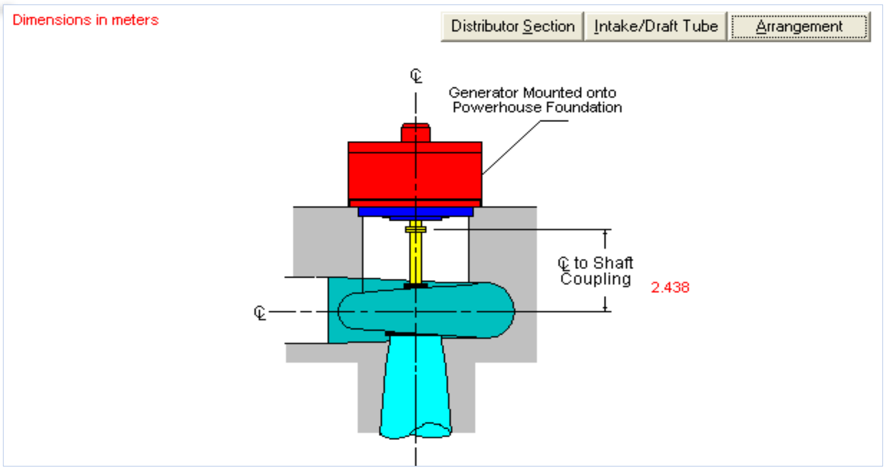


Figure 11-9 Generator to Shaft Coupling Layout

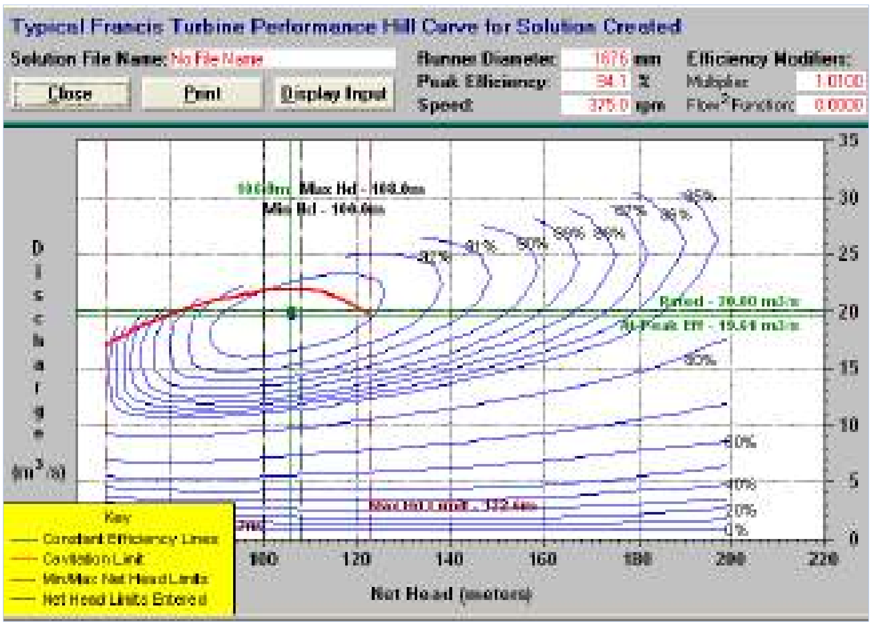


Figure 11-10 Performance Hill Curve

11.8 MAIN DATA

The turbine rated output is expressed by the following equation:

$$P_t = \rho \times 9.81 \times Q \times H_n \times \eta_t$$

Where,

P_t	=	Turbine out Power (KW)	
Q	=	Discharge (m^3/sec)	= 20 m^3/sec
H_n	=	Rated Net Head (m)	= 106 m
η_t	=	Efficiency of turbine	= 91.50 %

$$\mathbf{P_t = \rho \times 9.81 \times Q \times H_n \times \eta_t}$$

P_t = 1000*9.81*20*106*0.915

P_t = 19 MW

Rated Turbine Output at shaft, P = 19 MW

11.8.1 Turbine Speed

The main data for comparison of some turbine speeds is made as follows:

Turbine Speed	300 rpm	333 rpm	375 rpm
Runner outlet diameter	1.828 m	1.757 m	1.676 m
Runner weight	9.19 ton	7.91 ton	3.32 ton
Turbine setting approx.	- 2.0 m	- 2.0 m	- 1.5 m
Turbine efficiency	91.2 %	91.1%	91.5%
Turbine Generator weight	28 ton	23 ton	10 ton

Considering the technical and related advantages of high speed units, a turbine of 375 rpm is selected for this project.

Turbine speed = 375 rpm

11.8.2 Runner diameter

Runner diameter = 1676 mm

11.8.3 Runaway speed

The unit Maximum runaway speed as determine by TURBNPRO comes out to 649 rpm, however an accurate value is guaranteed by the turbine manufactures.

11.8.4 Setting

The turbine has to place sufficiently below the tailrace level to ensure that there is an adequate submergence. The proposed minimum setting for all turbines is about -1.5 m.

The turbine setting is determined as follows from the referenced Standards.

$$\mathbf{Z = H_s + b + HL_{tw}}$$

$$\mathbf{H_s = (H_b - H_V) - \sigma H_{cr}}$$

Where:

Z	=	Total draft head (m)
H_s	=	Static draft head (m)
b	=	Vertical distance from centerline of distributor to minimum runner diameter
H_b	=	Barometric pressure of water at station site (m)
H_{cr}	=	Maximum head at which turbine operates with full gate for maximum generator output
σ	=	Cavitation coefficient
H_v	=	Water Vapour pressure (m)
HL_{tw}	=	Tail water tunnel loss (one unit operating)

The cavitation coefficient σ, is normally quoted by the turbine manufacturer after undertaking a series of cavitation model tests.

11.8.5 Components Dimensions

The turbine major components dimension and layout have been workout by software TURBNPRO, moreover this data also compare with the similar installations in term of type and size, which have been built in the past. Components Dimensions are shown in Figure-11.4 till Figure-11.7.

11.8.6 Special design criteria

The turbine and its various components shall be designed to operate at a maximum load and to bear the stresses produced corresponding to maximum turbine shaft power output.

11.8.7 Overpressure

The maximum pressure in the spiral casing in the most unfavorable condition of head and sudden discharge, with or without wicket gate closing, will not exceed a pressure rise of about 25%.

11.8.8 Over-speed

The maximum momentary speed rise will not exceed 45% of the rated speed in the most unfavorable i.e. 544 rpm.

11.8.9 Runaway speed

The turbine will withstand the maximum runaway speed in the most unfavorable head and gate condition safely and without any abnormal reaction. Maximum runaway speed is 649 rpm.

11.8.10 Critical speed

The first critical speed of the combined turbine generator unit will be at least 25% higher than the maximum runaway speed.

11.9 TURBINE MAJOR COMPONENTS

The main parts of the turbine are described as follows:

- Runner
- Shaft
- Bearings
- Guide Vane Mechanism
- Operating Mechanism
- Throat Ring
- Draft Tube

11.9.1 Runner

The runner is the energy conversion element of turbine. Francis runners use stainless steel blades, bands and crowns. Special alloys are also used to minimize erosion. In this project the runner will be a cast or welded construction of 13% chrome, 4% nickel steel. The runner shall be designed and manufactured to operate at any load, head and speed within the limits given, as well as the runaway speed at maximum head with exceeding the allowable stresses and without undue cavitation's and vibration.

All surface of the runner exposed to the flow of water will be carefully machined and finished smooth to the templates.

11.9.2 Turbine shaft and Coupling

The turbine shaft shall be forged carbon steel or alloy steel conforming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should conform to American standard ANSI-49.1.

The turbine shaft shall be connected to the runner on one side and to the flywheel generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion. A renewable and removable sleeve of stainless steel shall be provided wherever the shaft passes through a shaft seal or a gland.

11.9.3 Bearings

The turbine bearings can be:

- The pad type or sleeve type or Babbitt lined, self-lubrication type.
- Anti-friction ball, roller bearings, oil or grease lubricated.

The turbine shall be provided with adequate number of bearings. The bearings shall be designed to withstand operation at maximum runaway conditions with cooling water supply on for a period of not less than 15 minutes and also for operation at normal speed without cooling water supply for 15 minutes. The bearings shall be provided with a dial type or resistance type thermometer and a pressure gauge with provision for alarm annunciation/shut down on excessive bearing temperatures.

11.9.4 Spiral casing

The spiral casing shall be fabricated from welded steel plate/mild steel plates and shall have suitable sections for ease of shipment and to be within transport limitation. The spiral case shall be designed to withstand maximum water pressure including water hammer and shall be complete with anchors, supports, sole plates, turn buckles, hold-down rods, all types of clamps, etc.

11.9.5 Guide Vanes

The guide vanes shall be made from stainless steel. Sleeves of stainless steel at the bearing and sealing surfaces shall be provided, if required. The guide vane bushes shall be of the self-lubricating type with protective seals or shall be suitable for grease lubrication.

11.9.6 Operating Mechanism

The operating mechanism shall have ample strength to withstand the maximum load that can be imposed on it by the most severe operating condition. All working points with relative motion shall be bronze bushed, grease lubricated/ self-lubricated. Means shall be provided for adjusting the position of the individual guide vanes to ensure close contact with adjacent guide vane in the closed position.

Each guide vane shall be individually connected to the regulating ring through suitable levers and links. Shear/ breaking link or some other suitable arrangements shall be provided on each guide vane to protect guide vane and to provide alarm on foreign body getting wedged between guide vanes.

The regulating ring shall be fabricated from welded steel plates. It shall be supported on the outer casing of top/side cover on bronze strips with provision for grease/ self-lubrication.

11.9.7 Guide Vane Servomotor

The guide vane shall be operated by two double acting oil operated servomotors of adequate capacity. The servomotors shall be capable of moving guide vanes smoothly during full opening and closing in required time. Standard available hydraulic cylinders of approved make, proven design and of suitable material can also be used as a servomotor.

11.9.8 Top Cover/ Side Cover

The top/side cover shall be of cast steel or welded plate construction. Suitable stainless steel labyrinth rings or similar sealing arrangements shall be provided in the covers.

11.9.9 Draft Tube

Each turbine shall be provided with a draft tube liner/suction bend of welded construction of structural steel. The draft tube cone shall have machined flange for bolting with the runner chamber. The design of the draft tube shall be such as to ensure the best overall efficiency for the turbine and stable and pulsation-free operations of the machines.

All components will have state-of-the-art design and conform to the relevant international standards. The turbine construction will enable all maintenance and repair work, which will require standstill of the turbine, within the shortest possible time. All turbine components to be dismantled will be equipped with eyebolts, lugs and / or other devices to facilitate handling, installation and removal. All tools and devices will be delivered, which are specially made and / or require for assembling, dismantling, adjustment and maintenance of the turbine. The scope of spare parts as well as the tests to be performed in the Works and at site will be specified in detail in tender documents.

11.10 TURBINE MODEL TESTS

Model tests are conducted to identify early the characteristics and problems of the prototype and to do the necessary modifications. The verification of the guarantees is more accurate at the test rig than at Site. From the manifold inlet to the discharge pit, the model turbine will be of vertical and fully homologous to the prototype. The model turbine chamber will include all baffles, dummy deflectors and operating rods, air vents and all other fixtures in the runner discharge pit, which will be installed in the prototype. The discharge passage will be included, together with means for measuring the runner chamber water levels.

The model acceptance tests will be performed according to IEC 60193. The preliminary model test report will be submitted by the Contractor latest 28 days prior to the start of the model acceptance witness tests. The turbine model tests will at least include the following items:

- Performance tests to determine the performance characteristics of the prototype for various needle openings and at net heads corresponding to the various flow rates.

- Runaway tests to determine the runaway speed under the operating heads.

11.11 GOVERNOR SYSTEM

Each turbine shall be equipped with suitable electro-hydraulic or electronic governor conforming to IEC No. 308, governor actuator, pressured oil unit and associated control and safety devices. The governor actuator and the pressured oil unit will be arranged on the Turbine Floor, whilst the cubicle containing the digital governor will be next to the unit control board on the Machine Hall Floor. The governor shall be of proven design capable of controlling speed / output under all operating conditions. The governing system shall comprise oil pressure system, governor actuator (Mechanical), governor electronic regulator, speed signal generator, oil pipe lines and deflector position restoring mechanism. The electronic regulating functions of governor i.e., speed / gate setting, deflector limit setting, start, stop, main circuit breaker position, shutdown etc. shall operate the unit in manual mode in case governor electronic regulator is non-operative. Local control unit have the indicators for deflector position, speed of the unit and power generated by the unit.

The control should be possible:

- Locally at the governor for the control of individual components and for maintenance purposes.

- From the main control board for starting, synchronizing, loading and stopping the unit.

- From the control room for supervising the function and operating the unit in connection with the main grid and for the local network.

11.11.1 Governor Head

Each governor head to be assembled in the main control board of the power station shall be equipped with

- Start and stop switches
- Quick shut down
- Speed setting
- Speed drop setting

All necessary buttons, indicators, instruments and limit switches and the control equipment for the automatic start, synchronizing and stopping sequence should be provided.

11.11.2 Electronic Equipment

In recent years the advent of the microprocessor has changed the design of the electronic governors from analogue to digital systems with much more effective man-machine interfaces. The electronic governor control provides functions such as turbine, start / stop, auto-frequency control and automatic load control, and provides interface connections to a main control and instrumentation system. Its monitoring functions include fault detection, alarm annunciation and unit shutdown. The governor also provides facilities for manual control of the turbine.

The electronic equipment is extremely reliable and the digital technology allows continuous self-checking of system operation. As the parameters for each turbine are stored within computer programs, there is no need for printed circuit boards to be pre-calibrated. With a digital system all the data is stored either within memory circuits (EPROMS) or is downloaded from a programming module or central computer. The governor is normally designed to allow circuit modules to be replaced whilst the unit remains connected to the grid. As the mean time between failures is usually a number of years, a large stock of spares is not usually required.

The following functions will be included in the governor:

- Speed control at no load operation.
- Automatic start and stop sequences, including automatic synchronization.
- Power output control; operation at output limitation with power feedback.
- Frequency regulation.
- Load sharing between the units in "joint control" mode.

- Quick shutdown in case of mechanical failures.

- Emergency shutdown on electrical failures.

11.11.3 Hydraulic Systems

The main development in hydraulic systems over recent years has been a steady increase in the operation pressure of the governor hydraulic systems. This change has been driven by two factors: cost and size. As the system pressure is increased the cost of the hydraulic system decreases due to reduction in its size. With increasing system pressure, the size of guide van servo-motors, oil pumps, oil piping and tanks decreases. The overall effect of an increase in system pressure is a reduction in the turbine cost although there is some increase in the governor cost. For very large turbines, the oil storage requirements at low system pressures are very large and this has also encouraged the adoption of higher pressures.

One further advantage of reducing the size of the hydraulic system is that more of the equipment can be assembled and tested within the manufacturer's works. This means that site work can be limited to simply connecting a skid-mounted package containing low and high pressure tanks, oil pumps, control valves, etc., to the turbine servomotors. The reduction of site work shortens the installation time and also increases the reliability as there is less opportunity for contamination of the system.

11.11.4 Water Hammer within High Pressure Conduit

Water hammer is a pressure change in a close pipe caused by water deceleration or acceleration for example due to opening / closing of the turbine wicket gate. The worst case for water column deceleration within the power conduit is the emergency shut down of the unit.

For the investigation of the worst case, a check according to the empirical formulae for rigid water column theory by Parmakian, Ray S Quick's water hammer chart and Allievi Chart for determining maximum pressure rise and also United States Bureau of Reclamation (USBR) Table and empirical formulae for determining speed rise due to load rejection must been applied. It shows the order of magnitude of the water hammer for linear closing characteristic of the turbine guide vanes.

11.12 TURBINE INSTRUMENTATION, CONTROL AND SAFETY DEVICES

Each turbine shall be provided with a complete set of instruments, gauges, controls and safety devices for unit control board for monitoring the conditions of the unit during normal running and emergencies. The instruments and gauges for the turbines include, inter alia, pressure gauges, level indicators, temperature and flow indicators, position indicator, indicating lamps for status indication etc. The safety devices shall comprise equipment and devices for sensing abnormal operating conditions, for giving visual and audible annunciation and shut down the unit.

11.13 INLET VALVE

A Butterfly type shut off valve will be required at the powerhouse end at upstream of each turbine. It will allow the penstock flow to be shut off in case of turbine malfunction, maintenance or an emergency.

The valve shall be suitable for all operating conditions of transient and maximum water hammer. The valves shall be operated by oil pressure and closed by oil pressure/counterweight, so that it is capable of being closed under all emergencies. All associated equipment such as servomotors, oil pressure units, counterweights, etc., shall be included in the offer. The valve shall close automatically under normal and emergency shut down conditions. The valve will be complete with inlet pipe, outlet pipe, with expansion joint, by-pass arrangement if required for equalization of pressure on either side of the valve, etc.

The main Data for these valves is as follows:

Valve type	Butterfly
No of valves	03
Diameter	1.83 m
Sealing system	Cast steel
Operating system	Pressure oil

11.13.1 Operating Mechanism

The valve rotor will be driven by an oil servomotor, which will be fixed on the valve body and supplied with pressured oil by its own hydraulic unit. In comparison with servomotor operated by headwater taken from the penstock and closing by weight and opening by pressured oil or water, opening and closing by pressured oil is the most economical solution and the easiest for maintenance. The seal rings will be moved by pressured water taken from the penstock, which will be filtered.

The service valve in the by-pass will be operated by the pressured oil provided by the same hydraulic unit as for the oil servomotor. Opening and closing of the butterfly valve will be possible at the minimum operating level in the reservoir and at the minimum operating oil pressure of the hydraulic unit.

11.13.2 Control and Safety Devices

The butterfly valve will be designed for both fully automatic remote control and manual control locally. Normally, the butterfly valve will be controlled by the automation and control system of the power plant. However, it is possible to operate locally each valve step by step.

The operation of the butterfly valve will be so interlocked hydraulically and mechanically that it will be impossible to move the sealing rings to the closed position, unless the valve rotor is in the “closed position”. On the other hand, it will be impossible, too, to turn the valve rotor towards the open position unless the seal rings are unsealed. A manual closing device will be installed on the Turbine Hall floor. For safety reason, the maintenance seal can be mechanically locked at the closed position. Furthermore, it will only be possible to open locally. At the fully open and close position, the valve rotor can be mechanically locked.

All components will have state-of-the-art design and conform to the relevant international standards. The valve construction will enable all maintenance and repair work, which will require standstill of the turbine, within the shortest possible time. All valve components to be dismantled will be equipped with eyebolts, lugs and / or other devices to facilitate handling, installation and removal.

All tools and devices will be delivered, which are specially made and / or required for assembling, dismantling, adjustment and maintenance of the valve. The scope of spare parts as well as the tests to be performed at the Works and at Site will be specified in detail in the tender documents.

11.14 AUXILIARY SYSTEMS

The auxiliary systems in a power plant have a vital role in the power plant's successful operation. Auxiliary systems shall include the various functions like plumbing works and fixtures, sewerage system, oil handling, drainage, detecting and suppressing fire, compressing air, Heating and ventilation of powerhouse, handling of various parts, workshop facilities etc.

To have a well-functioning, easy to operate, and easy to maintain power plant, all the auxiliary systems have to be carefully considered and conceived. A major design concern for auxiliary installations (such as compressors, strainers, and pumps) is their location, performance and maintenance access. The items requiring maintenance or monitoring shall be installed in easy-to-access areas for convenience

11.14.1 General

The sewage, sanitation and potable water system for Attabad powerhouse includes the following systems:

- Plumbing works and fixtures
- Water supply system
- Sewerage system

11.14.2 Plumbing Works

The plumbing works will include glazed earthenware water closets, wash hand basins, urinals, overhead showers, kitchen sinks, electric water heaters etc.

11.14.3 Water Supply System

The water supply system will include hot and cold water supply piping, pressure filtration unit and water treatment with ultraviolet disinfection tube having a capacity of 25 liters per minute, valves and other fittings.

Two pumps each of capacity 50 l/min at 1 bar to operate one as main and the other as standby, will pump treated water to the potable water storage tank for further distribution.

11.14.4 Waste and Sewerage water

Septic tank for lavatory disposal has been foreseen, the settled sludge will be periodically removed by using sludge pump or trolley and the sewage will be drained to downstream, away from the tail race pit through drain pipe. The sewerage and drainage system will include a network of C.I spun pipes, C.I fittings, C.I floor traps man hole frames and covers, gratings, glazed earthen ware, soil and waste pipes, etc., to be provided on the various floors of Control Block and a steel sewage septic tank of capacity approximately 6000 liters buried underground outside the powerhouse.

11.14.5 Dewatering and drainage system

Depending on the general layout, the station drainage system would be required to handle waters from the powerhouse and from several other equipment and accesses located below the maximum infrequent tail water level. These will include:

- Cooling water of minor mechanical systems, such as: compressors, governing systems and alike.
- Water leaking to the turbine pit through the shaft seals and wicket gate stem seals.
- Water used for cleaning the floors of caverns and galleries.
- Seepage of water to the caverns, galleries accesses and tunnels with the inflow to fulfill geotechnical requirements to be established at the design stage.
- Water from pressure relief perforations and systems to be established at the design stage.
- Any releases from the sprinklers of firefighting water system.

The dewatering and drainage system shall be provided, which shall include all structural components and equipment required for dewatering penstocks/ draft tube for maintenance purpose, and for dewatering all seepage of structures and equipment.

Dewatering of the units will be required during scheduled or unforeseen maintenance of any of the units and incase of leakages from valve on bypass line connecting upstream of inlet valve to draft tube.

A gravity drainage system consists of various equipment drains (like compressors, gland leakage etc.) and floor drain, condensate that drain to a main sump / pit, located at lowest elevation of the Power house. The water in the sump shall be pumped into the tailrace. Pumps shall be sized to meet the required estimated seepage and drain water. Two submersible pumps are recommended. One pump will work as standby. These pumps shall operate alternatively for equal wear and tear.

11.14.6 Compressed Air System

A compressed air system will be provided for the service and maintenance purpose. The capacity of the system shall be sufficient to cater to all the generating units. The compressed air system shall be of the automatic start-stop design operating under pressure switches control sensing the pressure in the receiver. The compressors will be electrically driven.

The whole system of compressed air supply shall comprise 03 systems, as follows:

- Compressed air for workshop equipment.

- Compressed air for governors pressure oil tanks.
- Service air (for generator brakes and operation of equipment etc.)

Each air system shall be supplied complete with all piping, valves, fittings and accessories for all required connections.

11.14.6.1 Design Criteria and Operation Conditions

Operation pressure will be about 0.8 MPa. Two (2) identical air-cooled compressors of screw type and two (2) identical air accumulators will be provided, one for service, and other as stand-by. They will be placed on the turbine floor.

- The compressed air system will have following main components:
- Two (2) identical air-cooled compressors of screw type, each with a delivery capacity of not less than 80 m^3/h of atmospheric air.
- Two (2) identical air accumulators, each with a capacity of 1.0 m^3.
- Distribution piping throughout the powerhouse with connecting taps, to the air receivers for the mechanical brake of the generators and to other services.
- Monitoring, control and safety devices.

All components will have state-of-the-art design and conform to the relevant international standards. The scope of spare parts as well as the tests to be performed in the Works and at Site will be specified in detail in tender documents.

11.14.7 Oil Handling System

Two oil handling systems will be provided at the power plant, which are:

- Turbine oil handling system.
- Transformer oil handling system.

11.14.8 Turbine Oil Handling System

For ease of handling and filtration of turbine and governor oil inside the powerhouse, the equipment is laid out on turbine floor, with oil storage tanks and the filtration plant located under the erection bay.

The oil handling system will have the following main components:

- One (1) oil filtration plant (Stationary type)
- One (1) oil filtration plant (Mobile type)
- One (1) clean oil transfer pump (Mobile type)
- One (1) dirty oil transfer pump (Mobile type)

- Two (2) clean oil storage tanks
- Two (2) dirty oil storage tanks
- Supply and return pipe work
- Control and safety device
- Oil testing device

The oil storage tanks will be sized to accommodate the oil of governor and all bearing of one unit. The oil treatment plant will be designed for carrying out degassing, dewatering, filtering and drying of the lubricating oil and pressure oil of the governor to prolong the life of plant. The capacity of the oil treatment plant will be 3 m^3/hr maximum. Mobile oil treatment plants will be provided with suitable rubber hose pipes and power cables. Each mobile unit will have a capacity to purify about 0.2 m^3/hr oil.

The steel pipe work will be designed for a working pressure, with supply and return headers connecting the filtration plants, oil storage tanks and the oil reservoirs of the unit.

11.14.9 Transformer Oil Handling System

The transformer oil handling system will have following main components:

- Two (2) oil purification and treatment plants (Mobile type).
- Two (2) oil transfer pumps (Mobile type).
- One (1) set of oil drums in enough quantities to drain one transformer completely.
- One pick-up to transport the oil drums and other equipment from and to the storage area and the powerhouse.
- One (1) fork lifter two (2) ton capacity.
- Controls and safety devices.
- Oil testing devices.
- Two (2) sets of rubber hose pipes about 15 m long, with connectors at both ends for connecting the purification plant / transformer pump with the transformer.
- The capacities of oil purification plants and transformer pumps will be approximately the same as those for the turbine oil handling system.

11.14.10 Heating, Ventilation and Air Conditioning System

Necessary arrangement for Ventilation, cooling and heating will be provided, according to powerhouse area requirements.

HVAC system will be designed in view of the following objective:

- To maintain indoor temperature at a pre-determined value by extracting heat from the indoor environment. The plant will have a capacity in terms of heat extraction rate equal to maximum anticipated heat input to indoor environment from electrical-mechanical equipment, lighting, people and conduction from fresh air.

- To maintain indoor relative humidity at a pre-determined value for areas such as control room, computer room, administration areas, electrical equipment rooms etc. by condensation of moisture in air stream.

- To provide clean air to conditioned apace by filtration of re-circulated and outside (fresh) air.

- To pressurize the building up-to 0.3 mbar to prevent infiltration of uncontrolled outside air.

- To provide winter heating in areas such as control room, administration areas, computer room etc. by adding heat to indoor environment. Relative humidity will simultaneously be controlled by adding moisture whenever required.

- To recover equipment heat dissipation in winter and to use it for space heating where possible.

The proposed air conditioning system for this project calls for providing year round air conditioning and ventilation to provide comfortable and required ambient conditions for people and sensitive equipment in the specified areas.

The design criteria are, to maintain indoor temperatures at 22 ~ 24^{o}C. In order to maintain that temperature in offices and control room, an independent air conditioning system shall be provided. Layout, dimensioning and arrangement of air-conditioning equipment will be defined during preparation of construction drawings of powerhouse building

11.14.11 Fire Protection System

The fire protection system is an important auxiliary system for any powerhouse. This system mainly consists of the equipment required for detecting and extinguishing fire in the powerhouse. The fire protection systems will be provided to extinguish fire of the following equipment and areas:

- Generators

- Transformers

- Oil storage rooms

- Computer and control rooms

- Remote computer control terminal units

- Office and miscellaneous-spaces, electrical and control equipment galleries

- Auxiliary and powerhouse equipment and maintenance workshops
- Diesel generator rooms located at head works.

There will be three common systems for fire protection:

- Water Spraying System
- CO2 Fire Protection System
- Potable Fire Fighting cylinders

In this system a group of Carbon dioxide (CO_2) filled cylinders are arranged in series at any suitable location and connected by a common piping system for spray through nozzles set in each generator. The system shall operate automatically with heat detecting elements. It is also possible to operate this system manually in case of failure of automatic system.

Moreover, Carbon dioxide (CO_2) filled fire extinguisher will also be placed at different floors to extinguish electrical fires. Oil storage rooms shall also be provided with CO_2 filled cylinders with auto release system initiated by smoke and fire detectors installed in the room.

Fire hydrants at different locations in control building, service area and administrative areas are to be provided. Mobile fire extinguishers shall be placed at most wanted locations in powerhouses. In addition, the power station will be provided with several taps for fire hoses. The water for the firefighting system shall be taken directly from upstream side.

Transformer fire is most common in hydro plants, thus special care and arrangement is required to overcome. Water deluge system seems to be the most successful, safest and from most aspects preferred method for fighting transformer fire. The water will be used from service water supply tank having desired water pressure with back up of fire / booster pump.

11.14.12 Standards and Regulations

All fire protection installations shall be designed, in accordance with the international NFPA-Codes and Standards, mainly NFPA 851, Recommended Practice for Fire Protection for Hydroelectric Generating Plants, (Latest Edition).

The design of fire protection installations shall also be in accordance with local regulations and requirements from the authority having jurisdiction.

11.14.13 Particular Requirements

11.14.14 Survey of systems

The firefighting systems to be provided are indicated in the following table as a minimum. Number and location of the various installations and systems shall be determined by the Contractor as per applicable code during detail design, subject to the Employer's / Engineer's approval. The Contractor shall, however, add and include any areas / items not listed in the table in order to cover fire protection for the entire plant.

Table 11-4 Survey of Fire Protection System to be Installed

Sr. No.	Building /Area / Equipment to be Protected	Fire Fighting Systems	Fire Detection Systems
1.	**Power House Building**		
1.1	Machine Hall	Portable Dry powder fire extinguishers & one mobile 30Kg clean agent extinguisher	Manual fire alarm stations
1.2	Generator	Automatic & electrically interlocked CO2 gas fire suppression systems	Smoke / Heat detectors, generator differential relay.
1.3	Turbine Floor	Portable Dry powder fire extinguishers	Manual fire alarm stations, Smoke detectors
1.4	Inlet valve Floor	Portable Dry powder fire extinguishers	Smoke detectors, Manual fire alarm stations
1.5	Unloading Bay Floor	Hydrant Hose stations, Dry powder Fire extinguishers	Manual fire alarm stations
1.6	Oil Handling & compressor Plant Room, Water treatment room, HVAC room, Mechanical store	Hydrant Hose stations, Portable dry powder Fire extinguishers	Smoke detectors, Manual fire alarm stations
1.7	Elevator Hoist Machine Room	Portable dry powder extinguishers	Smoke detectors, Manual fire alarm system
1.8	Maintenance Engineers, Conference room, Operational Manager room, document room and Prayer room	Portable clean agent fire suppression system	Smoke detectors, Manual fire alarm stations
1.9	Cable Tunnel	Automatic water spray system	Smoke / heat detectors
1.10	Control room, relay room, SCADA and telecommunication room	Portable clean agent fire suppression system	Smoke detectors, Manual fire alarm stations
1.11	Workshop, Battery Room & Switchgear room	Portable dry powder fire extinguisher.	Heat / Smoke detectors Manual fire alarm stations
1.12	Corridors and Lobbies	Portable dry powder fire extinguishers	Smoke detectors, Manual fire alarm system
2	**GIS Building**		
2.1	Switch yard	Portable fire extinguishers	Smoke detectors, Manual fire alarm system
2.2	Cable Spreading Room	Automatic water spray system	Smoke / Heat detectors
3	**Diesel Generator Room**	Portable dry powder fire extinguishers	Smoke / Heat detectors, Manual fire alarm system
4	**Penstock Valve House**	-do-	-do-
5	**Power Intake Control Room**	-do-	-do-
6	**Transformer Bays**		
6.1	Automatic water spray system and one mobile 30Kg portable dry powder extinguisher	Smoke / Heat detectors, Manual fire alarm system	Automatic water spray system and one mobile 30Kg portable dry powder extinguisher
7	**Water Storage tank Pump House**	Portable dry powder fire extinguishers	Smoke / Heat detectors manual fire alarm system

11.14.15 Structure Fire Protection

Fire Areas

In order to avoid an uncontrolled fire, spread inside a building or a tunnel, which would result in a considerable or total loss of the building and equipment, and to provide safe escape routes for the personnel, the building / tunnel shall be subdivided into various fire areas, separated by approved fire resistant barriers and elements.

Fire walls, ceilings and partitions shall have a fire resistance rate of not less than 2 hours.

All penetrations for electrical cables or pipes in fire resistant walls or ceilings shall be sealed with approved seals.

Firefighting Pump

One electric motor driven fire pump and one electric motor driven stand-by fire pump, located in a pump house adjacent to the water storage tank, shall draw fire fighting water from the tank and supply it through the fire service main to the hose stations and water spray fixed systems. One electric motor driven jockey pump with a capacity of approx. 3 l/s shall also be provided to keep the line pressure of 5 bars.

The fire pump shall have a capacity of approx. 40 l/s at a delivery head of approx. 6 bars. The final capacity of the firefighting pump shall be verified during detail design.

The firefighting pump unit shall be connected to the safe station power supply.

The pump shall start automatically upon water flow and / or pressure drop in the fire service main.

A fire service main system shall be provided, to serve outdoor hydrants, indoor hose stations and water spray fixed systems with firefighting water.

Next to each outdoor hydrant, a weather resistant, properly ventilated and red painted fire hose cabinet shall be provided, containing four (4) fire hoses DN 65 (21/2") with couplings and two (2) jet / spray branch pipes.

Each indoor hose station shall be housed in a wall mounted or self-standing cabinet, which shall contain a valve with reducer, instantaneous couplings, swiveling hose reel and one 30 m long non collapsible fire hose with readily attached branch pipe.

Water Spray Fixed Systems

The water spray fixed systems shall be designed, installed and tested in accordance with NFPA15.

Complete systems will be provided with all components required for automatic operation, normally released via the fire detection and fire alarm system. Manual release will also be possible.

The automatic operation for opening the deluge valves for the spray systems shall be initiated either by the detection of 2 heat or smoke detectors of 2 different detection lines (2 out of 2) or the transformer buchholz relay.

The deluge valve stations will be located adjacent to but not inside the same fire area they shall protect.

The following specifications shall be observed for the firefighting system of the transformers.

- The water shall be sprayed at a rate of not less than 10 l/min m2 of the projected area of rectangular prism envelope of the transformer.
- A pipe cage made of galvanized steel pipe with all necessary spray nozzles shall be installed around each transformer.

Total Flooding Carbon Dioxide Fire Extinguishing Systems

The total flooding carbon dioxide extinguishing systems shall be designed in accordance with NFPA 12, standard on carbon Dioxide extinguishing systems (latest edition) and will be adopted for the fire protection of Attabad HPP generators.

Complete system shall be designed, for automatic operations normally activated by the fire detection and alarm system.

In this system the CO_2 gas is stored in cylinders. It is delivered to distribution nozzle through a system piping network in the fire protection area. Critical to the functioning of system is the fire detection and control network. Smoke detectors sense the presence of fire in the protected facility. The detection and control panel then sounds and alarm, shuts down air handlers, disconnect power from the protected equipment and then release agent into the protected area.

Fire Extinguishers

The selection, installation and testing of portable fire extinguisher shall be in accordance with NFPA-10 for initial firefighting. Portable fire extinguishers with capacities of 6 kg chemical dry powder, for rooms containing electrical equipment with capacities of 5 kg clean agent, shall be provided and placed in the rooms and buildings at strategic locations and next to exits.

In addition to the portable extinguishers, two mobile 30 kg clean agent, and two mobile 50 kg dry powder extinguishers, mounted on wheeled hand carts and furnished with 6 m hoses, shall be provided and located in the machine hall of the powerhouse and GIS floor and diesel generator room.

Other equipment like fire blankets, first aid boxes and rescue tools will be provided as required.

11.14.16 Powerhouse Crane

The powerhouse crane will be a bridge crane with a main hoist, which can serve any requirements for lifting and moving of heavy components during installation, maintenance work and operation, the generator rotors being the heaviest components. AHPP is equipped with 03 Vertical Francis turbines.

The main crane hook shall be capable of lifting the tallest component of the transport vehicle and both the main and auxiliary hooks should be capable of reaching as far down as required to serve the inlet valve floor.

The hoist is mounted on a trolley of compact design enabling minimum operational hook distance from the walls and maximum lifting height. The main hoist is equipped with one hook, cable and drum, with possibility of changing the corresponding values of lifting capacity and hoisting speed with push- button from the crane driver's cabin.

Provision shall be made on the powerhouse roof above the erection bays for easy replacement of the trolleys.

Design Criteria and Operation Conditions

The overhead bridge crane will be designed according to the well reputed international standards likes EN, DIN, FEM, etc.

The overhead bridge crane will have a main hook and an auxiliary hook with a preliminary capacity of 80 t and 20 t, respectively. The main hook will be used for lifting heavy pieces like generator rotor and butterfly valve, whilst the auxiliary hook will be utilized for erection and maintenance work of small parts like rotor poles, servomotors, heat exchangers, etc.

Usually, the heaviest and the tallest piece to be handled by the main hoist is the generator rotor with shaft, and its weight and height will be finally fixed by the generator supplier. Thus, the capacity of the main hook and height between the powerhouse crane and the erection bay floor shall be optimized during the implementation stage.

The powerhouse crane will have the following main parameters:

Rated lifting capacity	main hook	80	t
	auxiliary hook	20	t
	Span	17.5	m
	Hook height	8.8	m
Lifting height (total)	main hook	17.5	m
	auxiliary hook	22	m
Bridge traveling speed	normal	20	m/min
	creeping	0.6	m/min
Trolley traveling speed	normal	15	m/min
	creeping	0.6	m/min
Main hook lifting speed	normal	1.2	m/min
	creeping	0.1	m/min
Auxiliary hook lifting speed	normal	40	m/min
	creeping	0.5	m/min

The crane will be controlled from an operator's cabin, provided at the upstream end of the bridge.

11.14.17 Mobile crane

In addition to powerhouse bridge crane, suitable capacity mobile crane is also provided for:

- Erection of the transformer
- Erection of the machine hall crane
- Loading and unloading the equipment

11.14.18 Power House Elevator

General

One elevator has been foreseen at power plant to be used for transportation of goods from service bay to the equipment gallery and for transporting the passengers from the control room to the inlet valve gallery with electrical equipment in the erection bay and with guide rails for cabins and counterweights complete with all anchorages, bumpers, etc., and all accessories necessary for the elevator to be complete.

Main Data for Powerhouse Elevator

Number of elevators	One (1)
Capacity	13 persons / 1000 kg
Lifting and lowering speed approx.	1.6 m/s

For the design aspects of the elevator, reference shall be made to EN 81, A.N.S.I A17, BS 5655 or other equivalent standards.

The design of the elevator shall meet the following requirements:

- Driven by electric hoisting machine including cable and counter weight.
- Power supply 3 phases 400 v, 50 Hz.
- Shaft doors of the automatic sliding type for access to the elevator.
- Electronic door detectors as safety device for cabin doors.
- Smooth acceleration of cabin.
- Accurate floor landing / leveling without jerking and jumping.
- Continuous operation and high start / stop frequency without overheating of hoisting machine.

The elevator shall be provided with control and safety devices, preventing operation:

- Under overload conditions.
- With open shaft doors.

The cabin control and panel shall be equipped with:

- Push button plates.
- Floor indicator and moving direction indicator.
- Safety push button for emergency stop and acoustic alarm in the central control room.
- Key locked switch for manual control of cabin position.

The panels at the shaft doors shall be provided with:

- Push button plates.
- Direction indicator.
- Gong signal indicating arrival of cabin.

11.14.19 Workshop Equipment and Tools

The complete maintenance workshops will be provided inside the powerhouse for preventive maintenance and repair of powerhouse equipment. The maintenance workshop will consist of followings:

- Electric shop
- Machine shop
- Portable equipment

Workshop equipment and tools should be sufficient to perform the day to day maintenance requirements such as:

Necessary tools for components repair or renewal which do not need specialized skill or experience like welding machine, portable drill machine, small lathe, electric grinder etc.

All special tools, slings, lifting devices, jacks, turn buckles, foundation plates/ bolts, etc. required for erection of the equipment shall be listed and supplied. First filling of oil and grease (if applicable) with 10% extra quantity (included in the overall scope) shall be supplied along with equipment. Welding electrodes as required for site welding and paint for finishing coat shall be supplied by the contractor.

A tentative list of the workshop machinery is as under:

- Gap bed heavy duty lathe
- Gap bed medium duty lathe
- High precision bench lathe
- Shaping machine

- Radial drilling machine
- Drill stand
- Pedestal grinder
- Bench mounted grinder
- Hydraulic press
- Black smith forge
- Machine hacksaw
- Portable electric welding machine
- Pipe bending machine
- Anvil
- Sheet metal sheer
- Dry acetylene welding equipment
- Quenching tank
- Tool cabinets
- Tool room racks
- Lockers
- Metal working benches
- Electrical working benches
- Hand tools
- Air operated tools
- Platform trucks
- Wood saw machine

11.15 HYDRAULIC STEEL STRUCTURE

11.15.1 General

This section introduces the function and / or performance criteria and the derivation of the key dimensions of main components of the hydraulic steel structures which will be installed in the various civil structures of the Attabad Hydropower Project, namely:

- The power intake gates
- The power intake trashracks and cleaning machines
- The power intake stoplogs
- The auxiliary hoisting equipment
- The pressure shaft
- The surge shaft and
- The draft tube gate equipment

11.15.2 Power Intake Gate Equipment

Intakes for power generation serve to provide hydraulically efficient water inlets to the water passages leading to the powerhouse. The passages may consist of conduits embedded in dams, excavated as tunnels, constructed as free-standing penstocks, or as short concrete passages between intakes constructed integrally with the powerhouses.

Power intakes must control the flow into the headrace tunnel during filling of the waterway and isolate the reservoir from the waterway for inspection and maintenance of the waterway and automatically close into and up to maximum flow to protect the waterway and power station in the event of a major breach in the waterway downstream of the power intake.

11.15.2.1 Selection of Gates:

The type of gate to be adopted depends mainly on the size of the opening, the head on the gate, and the operating conditions (corresponding to the following circumstances).

1. If the gate must open and close under full operating head conditions with flow through the intake.

2. If the gate is only required to operate as a guard gate under no flow balanced head conditions.

Generally, a fixed wheel gate or slide gate is used. However, a high pressure gate, caterpillar gate, or a high pressure radial gate is used when the water head is high. A general comparison of slide gate and fixed wheel gate is provided below:

11.15.2.2 Slide Gate

The slide gate is the simplest type of flat gate. It consists basically on a gate leaf that slides alongside guides embedded or fastened to the concrete. The leaf

is provided with sliding surfaces, usually metallic, which under tight contact at the bearing surfaces act as seals. Since it requires little maintenance, the slide gate is largely used as a control device in irrigation canals, sewage works, bottom outlets and small intakes and reservoir spillways.

Other distinguished characteristics of the slide gates are the uniform transmission of the hydrostatic load to the concrete and the absence of vibrations in partial openings due to the large friction forces developed between the sliding surfaces. This feature is highly desired for bottom outlet gates. On the other hand, the slide gate is not recommended for installations requiring closure by gravity, due to the large friction forces created which is a major drawback for an intake gate.

11.15.2.3 Fixed Wheel Gates

High-head fixed-wheel gates are installed in recesses built in intake structures or in the face of concrete dams, at the upstream ends of outlets or penstocks. Since the primary use of these gates is to provide emergency shutoff of water to protect the penstock and downstream equipment, the preferable location of such gates is near the entrance. Therefore, fixed wheel gates is a suitable option for intake gates of Attabad HPP.

11.15.2.4 Functional Requirements & General Arrangement

Two power intake conduits are proposed for tunnel. Immediately upstream of each intake gate is provision for a stop log. It will be lowered when inspection or maintenance of the intake gate is required. The stop log will be raised and lowered by a rail mounted gantry crane.

A trash rack will cover the entrance to each power intake. The bars of the trash racks will be spaced so as to block floating debris large enough to damage the turbines. This way floating debris is prevented from entering the waterway.

A trash rack cleaning machine mounted on rails on the intake structure deck will remove trash and debris collected by the trash racks.

The equipment at power intake will be designed to meet the following functional requirements:

- Two hydraulically operated fixed wheel gates will be installed, one on upstream of each intake tunnel.
- These will be capable to close under full flow in the tunnels in an emergency, if the penstocks fail or turbines over speed.
- These gates will be designed to self-lower under gravity and hydrodynamic forces (down pull). These gates will be used for emergency protection of turbines and penstocks (and will overtake the role of turbine shut-off valve).
- The gates hoisting system will be operable from local control panels as well as from power intake control room.
- Trash racks will be installed at power intake structure to prevent entry of large size trash into the tunnels and clog the turbines.
- A gantry crane operating on a runway spanning the entire structure will be provided for maintenance of the intake gates.

11.15.2.5 Fixed Wheel Intake Gate

Typically, a fixed wheel type gate is used, and it generally consists of the following assemblies:

- The gate leaf assembly, which includes the skin plate, supporting beams and girders, bracings and rubber seals.
- The wheel assembly includes the main and side rollers, lubrication provisions, and mounting brackets.
- The embedded seal path assemblies include the side seal, bottom sill, and anchors.
- The hoist tower and bridge assembly for supporting the gate hoist system.
- Hydraulic Hoist and wire rope hoist system.

11.15.2.6 Gate Leaf

The fixed-wheel gate is certainly the most common type of gate and basically consists of leaf, wheels, shaft and seals. In general, leaf is formed by a flat skin plate and stiffened by horizontal girders and ribs. On each side of the leaf, the ends of the horizontal girders are welded to a vertical girder. Wheels are mounted on shafts fixed laterally to the leaf on the vertical girders and have the double function of reducing the friction forces and the transmission of the water load to the embedded parts. Submerged fixed-wheel gates have seals on all four sides. Seals on dam face gates frequently surround the opening like a picture frame.

Upstream sealing gates have been chosen as they minimize down-pull during closure into flow and provide easy access for inspection of the downstream side of the gate when the gate is closed. The fixed wheel gate will be of welded steel construction with upstream skin plate reinforced by horizontal and vertical members/beams. If necessary, the skin plate assembly will be divided into sections for ease of transportation and handling at the site. These sections will be field assembled by bolting and seal welding.

The gate will be provided with downstream J-type double stem side and top rubber seals with fluorocarbon cladding. A flat bar type rubber seal will be mounted at the bottom of the skin plate on downstream side. Wheels will be with corrosion resisting steel rim mounted. Wheels will rotate on stainless steel spherical bearings (or self-lubricated bearings).

In the steel lined gate section, the guiding parts and sealing facilities of the gates will be integrated. Above the discharge openings, provisions will be made for continuing the guiding parts and sealing facilities in steel lined slots. The steel lined slots will extend up to the equipment room level. The slots will be closed with pressure cover plates or so-called bonnets.

Each gate will be operated by one oil-hydraulic servomotor. The servomotors will be mounted on the bonnets. For each set of maintenance and service gates a common oil pressure unit has been considered. In order to promote safety, the oil pressure units will be interconnected to each other. With this is arrangement it is possible to serve all gates by one oil pressure unit. The design and performance criteria of intake gate is summarized here below:

Table 11-5 Design and Performance Criteria of Intake Gates

Type of gate	Fixed wheel gate
No. of gate openings	2

No. of intake gates at the Power Intake	2
No. of embedded parts at the Power Intake	2
Gate operation	Hydraulic cylinder
Operating Speed	0.3 – 0.5 m/min

11.15.2.7 Gate Hoist

Each gate hoist will include a hydraulic cylinder, pipes, hoist support, servomotor, hydraulic power unit, piping, gate position indicator, electric control panel for command and signaling.

Each Fixed Wheel Gate will be provided with one hydraulic hoist. The hoist will be designed to have enough lifting force to lift the gate under any foreseeable operating conditions. Hydraulic oil for raising the gate will be supplied by motor driven oil pumps. Two oil pumps per gate will be provided to ensure reliability. Each oil pump will be rated to supply oil at the required pressure and rate to lift the gate at the maximum lifting speed selected for the gate. Lowering of the gate will be accomplished by gravity i.e. by weight of the gate itself. However, the hydraulic hoist would be able to push the gate down in case the closure resisting forces increase. Provision will be made for normal operation of the gate at all reservoir levels. The design and performance criteria of the Gate Hoist is summarized here below:

Table 11-6 Design and Performance Criteria of Gate Hoist

Type of hoist	Hydraulic
Power equipment for gate operation	415 V from Power Station
No. of hydraulic hoist cylinders per gate	1
Gate handling for repair and maintenance	By gantry crane or mobile crane

11.15.2.8 Gate Hoist Control System

A hoist control module will be provided with each gate, which will control the operation of the hoist. It will include hydraulic and electrical controls. A local control panel will be provided near each gate and a common remote control panel for all power intake fixed wheel gates will be installed in the local control room. The remote control panel will include one selector switch for each gate. The selector switch will provide two operating modes i.e. normal and maintenance.

Provision will also be made for emergency closure of the intake gate from the powerhouse central control room for the protection of turbine against sustained speed if the governor over malfunctions.

11.15.2.9 Embedded Parts

Embedded parts for the guard gate will include anchorages for hoist cylinder, side and top seal bearing plates and guide bars, rails and sill beams. The side and top sealing surfaces will consist of corrosion resisting steel plates embedded in concrete. The bottom sealing surface will also be corrosion resisting steel plate attached to a structural steel sill beam embedded in the concrete floor. The embedded parts will be installed in block outs and adjusted by means of erection studs attached to the welding pads embedded in first stage concrete.

11.15.2.10 Stop Logs

Two stop logs for the two intake gates will be provided. Stop log slots, guides and other embedded metal work will be installed in the piers upstream of each intake gate to guide and finally seal the stop log when it is in the closed position. Exposed parts of the embedded metal work will be cladded with corrosion resistant steel cover plate.

The stop log will be of welded construction with a downstream skin plate reinforced by vertical and horizontal girders. It will have wedge type bottom seals and 'J' type side seals. Guide shoes will be provided at the top and bottom of each side of the stop log to engage the guides embedded in the concrete. The stop log will be designed to be handled by a lifting beam and gantry crane. A filling valve activated by the lifting beam will facilitate balanced head conditions across the stop log before rising. The design and performance criteria of the stop logs is summarized here below:

Table 11-7 Design and Performance Criteria for Stop Logs

Type	Vertical lift
No. of Stop log	2
No. of stop log embedded parts	2 set
Handling	By lifting beam and gantry crane or mobile crane

11.15.2.11 Gantry Crane

One gantry crane will be provided at the power intake. The crane will be an electrically operated outdoor type, with an operator’s cab located on the upstream side and raised above the deck for ensuring good visibility of all crane operations. The gantry crane will operate on rails extending over the full length of the intake deck. The crane will be required to handle the service gates and for reparation and maintenance activities within the intake shafts.

A lifting beam equipped with two automatic grappling hooks for setting and removing the stop log will be provided. After the hooks have engaged the stop log, the lifting beam will activate the filling valve, allowing water to flow through the stop log, filling the cavity between the stop log and the closed intake gate so that the stop log can be raised by the gantry crane under balanced pressure condition. The design and performance criteria of the Gantry Crane are summarized in the following table:

Table 11-8 Gantry Crane and Lifting Beam

Type	Electrically operated
No. of gantry cranes	1
Hoist capacity	25 ton
No. of lifting beam	1

11.15.3 Trashracks

Trash racks and safety grates are a critical element of outlet structure design and serve several important functions. When properly designed, installed, and maintained trash racks.

Keep debris away from the entrance to the outlet works where the debris will not clog the critical portions of the structure;

Capture debris in such a way that relatively easy removal is possible;

Trash racks can serve these purposes without interfering significantly with the hydraulic capacity of the outlet (or inlet in the case of conveyance structures) (ASCE, 1985; Allred-Coonrod, 1991).

The trashracks will prevent the ingress of debris and floating matter into the power conduit, which could block or damage the generating units.

The trashracks will be of the non-withdrawal type, consisting of fixed trashrack panels supported by streamlined cross beams. The trashrack panels and the corresponding supporting structures will be designed to withstand the design pressure with a safety factor of 1.5.

For condition monitoring of the trashracks, the differential pressure across the panels will be measured. An alarm will be triggered when the trashracks are unduly clogged, requiring action by the trashrack cleaning machines.

11.15.4 Trashrack Cleaning Machines

One trashrack cleaning machine (TRCM) of the cable operated type have been foreseen for installation on the deck level 2424.00 m.a.s.l. of the power intakes.

TRCM will consist basically of a steel gantry structure including the rake carriage, the bucket and the revolving apron as well as the associated hoist and control mechanisms. In addition, an articulated hydraulically operated arm with grapping hook will be provided.

The TRCM will be suitable for all purpose cleaning of the trashracks while operating under flows of 100 m^3/s maximum. Moreover, the TRCM will be equipped for removing floating debris in the vicinity of the trashracks, i.e. the TRCM will be able of removing floating debris at water levels as low as the MOL = 2412 m.a.s.l. The debris will be collected either with the bucket or with the grappling hook.

The TRCM will operate in manual and semi-automatic modes, controlled from the inside of the operator’s cabin.

TRCM will include also a crane hook of adequate capacity for handling the intake stoplogs at the power intakes. The design and performance criteria of Trashracks and Trashracks cleaning machines are summarized in the following table:

Table 11-9 Trash racks & Trash rack Cleaning Machines

Trash racks		**Trash rack Cleaner**	
Type	Non withdrawal fixed type	Vertical Inclination	10 º

No. of trash racks	1 set	Rake “pay load”	1 ton
Handling	By mobile crane	-	-

11.15.5 Pressure Shaft

The lower, horizontal part of every pressure shaft will be steel lined, from the bifurcation onwards up to the spiral case inlets of the generating units.

For the feasibility design of the steel lining, safety factors of 2.0 and 1.5 were adopted to establish the required minimum plate thicknesses with regard to the prevailing internal and external pressures, respectively. Moreover, the steel lining was pre-dimensioned under the following assumptions:

- No load sharing with the surrounding rock, and
- Full external pressure with no pressure relief valves.

The material of the steel lining will be killed, fine grained steel with a yield strength of no less than 550 N/mm² for limiting the plate thickness so that no stress relieving after field welding is required.

11.15.6 Surge Shaft

Surge shaft is a structure provided at the end of pipe to account for water hammering effect in the pipe at its downstream. Surge shaft is considered to be an important component of power intake, especially for those involving headrace pressure tunnels.

When power house is suddenly shut down by closing the turbine valves the water in penstock stops suddenly and because of the inertia of incoming water from the back creates a resonance effect, which in a mean while causes water hammering effect. If no arrangement has been made to prevent this water hamming it may result in bursting of penstock pipe and may lead to serious stability issues of the hydropower project, the best solution is to provide a surge shat or surge tank depending upon the site constraints.

Design of Surge Shaft depends upon different parameters such as given below:

- Design discharge
- Headrace water level
- Headrace tunnel diameter
- Headrace tunnel length
- Headrace tunnel slope
- Headrace tunnel material

Design discharge is the amount of water to be carried by the headrace tunnel of specific diameter with a pre-defined longitudinal slope, greater the slope more will be the velocity of water through headrace tunnel and hence more will be head losses.

11.15.7 Draft Tube Gate Equipment

11.15.7.1 Functional Requirements and General Arrangement

For installation, maintenance, inspection and repair of turbines, it is necessary to dewater the turbines and their related waterways. Draft tube gates are required to act as bulkheads for preventing entry of surge chamber water into the waterways when the turbines and their waterways are emptied for maintenance and inspection. Draft tube gates will work under balanced head conditions.

The draft tube gates will be vertical lift bulkhead type designed for operation under balanced head conditions created through filling valves installed on the gates.

Draft tube gate equipment will consist of bulkhead gates, lifting beam and overhead travelling crane.

11.15.7.2 Draft Tube Gates

Gate Leaf

The draft tube gates will have upstream side seals and downstream bottom sealing. Skin plate will be on downstream side. This concept of sealing and skin plate position is to prevent any uplift effect during surge tank operation. Each section will be of welded steel construction. The top section will have wedge type bottom seal and caisson type side and top seals with fluorocarbon cladding while the lower sections will have sealing plate at the top on which the upper section will be seated to seal the water passage. Guide shoes will be provided at the top and bottom of each side of the gate sections to engage the guides embedded in the concrete. For alignment of draft tube gate sections, guide pins will be installed on the top of lower sections and guide sleeves in the bottom of upper sections. Lifting pins will be provided to handle the gate sections by a lifting beam.

Embedded Parts

A set of embedded parts will consist of a sill beam, a lintel beam, two side bearing plates, two guide rails for installation of draft tube gates along with two guide rails and bottom supports for storage of draft tube gate sections. Welding pads will be embedded in first stage concrete to facilitate the alignment of the parts embedded in the second stage concrete. The sill and lintel beams will provide sealing surfaces for bottom and top sections of the gates respectively. All sealing surfaces will be of corrosion resisting steel. The design and performance criteria of graft tube gates are summarized in the following table:

Table 11-10 Design and Performance Criteria of Draft Tube Gates

Type of gate	Vertical Lift Gate
No. of gate openings	3
No. of draft tube gates	4

No. of embedded parts	3 sets
Gate operation	Overhead Travelling Crane

Overhead Travelling Crane

One electrically operated overhead travelling crane will be provided for handling the draft tube gates and inlet stoplogs of tailrace tunnels with the help of lifting beams. The lifting beams will operate in the slots and guide rails provided for the draft tube gates and inlet stoplogs for tailrace tunnels. The crane will operate over the rails spanning all the draft tubes of the powerhouse.

11.16 MECHANICAL COST ESTIMATION

It is assumed that a major portion of the mechanical equipment will be imported from foreign sources. The prices include profit, overheads and the cost of designing, purchasing raw materials, manufacturing, painting, testing and packing the products, delivering to the port of export, ocean freight, insurance, landing cost, inland transportation in Pakistan and installation. A contingency amount of 2% of the total costs of all mechanical equipment has been added to cover the additional costs arising from increases in equipment dimensions due to unforeseen physical conditions at site. Unforeseen site conditions have the greatest impact on civil works, but they can also impact, to a lesser extent, on the dimensions and cost of mechanical equipment

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12 ELECTRICAL EQUIPMENT

12.1 GENERAL

This chapter is aimed to summarizing the feasibility design considerations for the electrical equipment and its installation in the powerhouse. The study shall provide the basis for the cost estimates and will form the background for the final design studies.

The main electric installation would consist of 03 nos. vertical shaft synchronous generators, 02 nos. GCBs and 03 nos. three-phase step-up power transformers. Medium Voltage, Low Voltage, DC Auxiliary power supply system and safety installations will provide adequate operational and personal safety.

Three power generating units having a total capacity of 54 MW with a generation voltage of 11kV will be located in the power house. The generators shall be connected to their respective unit transformers (three phase) through GCB to step-up the generation voltage for onwards transmission to the local grid. A GPS Clock synchronized time system for the common time basis of all the equipment, Lighting & small power services will be provided in the Power house along with earthing. All equipment shall operate without undue vibration and with the least practical amount of noise.

All equipment shall be designed to minimize corona or other electrical discharges, to comply with local electromagnetic compatibility (EMC) standards and IEC 60801 and IEC 61000.

All electrical components shall be adequately rated for their most onerous duty and the specified ambient temperature. When equipment is mounted in panels, cubicles etc., due account shall be taken of any heat generated by the equipment therein and the components shall be appropriately selected, rated or de-rated as necessary to suit the most onerous operating temperatures within the enclosure.

12.2 STANDARDS AND REGULATIONS

The works will comply with the relevant statutory requirements of Pakistan and WAPDA. The design, materials, manufacturing, testing, inspection and performance of the works will conform to the latest current ISO/IEC publications.

- IEC 60034 Rotating electrical machines
- IEC 60085 Thermal evaluation and classification of electrical insulation
- IP 44 Degree of protection

Other recognized national or international standards and codes that ensure substantial equivalent may be acceptable. For applications where no relevant standard exists, up-to date recognized practice will apply.

12.3 GENERATOR

All three generators shall be installed vertically & their rotors shall be solidly coupled with the turbine runner hydraulic driven with a combined thrust and guide bearings below the rotor upper guide bearing neutral grounding assembly. Automatic Voltage regulators, excitation cubicles and a closed circuit cooling system surface air cooler shall be installed. A flywheel of suitable inertia will also be mounted on the same shaft to keep the constant speed of the generator & avoiding the fluctuations/harmonics resulting from varying loads and switching surges. All the Generator parts shall safely withstand stresses resulting from over speed conditions at runaway. Generator terminals are connected by Isolated Phase Bus ducts (IPBs) to Generator Circuit Breaker (GCB).

Each generator shall be provided with a set of brakes arranged for pneumatic operation from station compressed air system. A rotor maintenance jacking system will be supplied to lift the turbine and generator rotating parts.

Each generator shall have a closed circuit air-cooling system in which the circulation of the air is achieved by the fan action of the rotor. The air leaving the generator will be cooled by a number of surface type air/water coolers. With one complete heat exchanger out of service, the maximum continuous output will be maintained without the stator and rotor winding temperatures exceeding Class B permissible temperature rise. Electric heaters shall be provided in all generator housing to prevent condensation when the generator is not working. The lower bearing bracket shall support the weight of the rotating parts and the hydraulic thrust of the turbine. The bearing arrangement shall be according to IEC60034-7. Stator and rotor insulation shall be rated for class F; however, the temperature rise of the stator and rotor windings shall not exceed the Class B limits specified in IEC 60034-1.

12.3.1 Type & Description

The three-phase synchronous generators shall be of the vertical shaft type, hydraulic driven, with a combined thrust and guide bearing below the rotor, upper guide bearing, neutral grounding assembly, CO_2 fire extinguishing system and a closed system of ventilation with surface air coolers. Generator terminals will be connected by Isolated Phase Bus ducts (IPBs) to Generator Circuit Breaker (GCB).

The Generator shall be suitable for direct connection to a Francis type vertical shaft turbine. The direction of rotation of the turbines will be clockwise when viewed from non-driven end. The stator bore shall be such that it allows lifting the largest turbine component through it. The neutral grounding of the generators shall be through a dry-type distribution transformer connected between the neutral of the generator and earth with resistor connected at the secondary winding.

The generators shall be designed to withstand all fault situations that can be experienced during operation without any displacement of its windings or mechanical damage to any of its parts or to the generator foundations, such as short circuit between two or three phases at its terminals, faulty synchronization, magnetic imbalance due to pole winding failure and runaway conditions etc.

The generator condition monitoring system shall comprise the following features:

- On-line Vibration Monitoring System
- On-line Partial Discharge (PD) Monitoring System
- Generator Air Gap Monitoring System

Table 12-1 Main Parameters of the Generators

Generator Shaft Orientation	Vertically Coupled
No. of Units	3
Nominal Capacity	21.2 MVA (18 MW)
Rated Speed	375 RPM
No. of Poles	16
Efficiency	98 %
Unit Output Voltage	11 kV
Frequency	50 Hz
Power Factor	0.85
Insulation Class	F
Limit of Thermal Utilization	B
Excitation	Static
Excitation Voltage	220 V DC
Runway speed	648 rpm
Connection	Y, Neutral Grounded through transformer resistance
Cooling System	Closed circuit Air-cooling system with surface type Air/Water Coolers

12.3.2 Design

The generator shall be of a standard construction according to the respective IEC-60034 standard. The design of the generator is determined by the construction, layout and speed of the turbine. The choice of a vertical shaft Francis turbine with 375 rpm defines a vertical generator with 16 poles with upper guide and thrust bearing and lower guide bearing. The design of the frame and the foundation will have to carry the weight of the turbine and the generator as well as to take over the stresses caused by the dynamic forces produced during short circuit conditions on the generator side as well as the stresses caused by seismic activities. CO2 fire extinguishing system and a closed system of ventilation with surface air coolers. Generator terminals are connected by Isolated Phase Bus ducts (IPBs) to Generator Circuit Breaker (GCB). The nominal voltage of the generator has been chosen 11 kV which is appropriate for this size of the Generators and standard WAPDA system. The generators are capable to run at 15% continuous overload without exceeding the temperature limits of class F insulation.

The generator is designed to withstand all fault situations that can be experienced during operation without any displacement of its windings or mechanical damage to any of its parts or to the generator foundations, such as short circuit between two or three phases at its terminals, faulty synchronization, magnetic imbalance due to pole winding failure and runaway conditions etc.

The power factor of the machines is proposed to be 0.90. The generator shall meet the specified temperature rise limits, based on an ambient temperature not exceeding 40C. The voltages withstand levels for the generator shall be in accordance with IEC 60071.

12.3.3 Rotor

The rotor structure supporting the pole pieces built up of steel laminations shall be of steel plates or with a central cast steel/fabricated spider, equipped with field windings as well as with collector rings. The poles shall be laminated and provided with a damper winding for the required operating stability. Any method of securing the poles to the rotor body shall depend on the stressing by the centrifugal force that is developed at the runaway speed. The poles shall be fully consolidated laminated assemblies fitted to the rim. The pole fixing shall be designed so as to limit stress concentrations, and ensure uniform load distribution between fixings.

The insulation class of the pole windings has to be "F" but for extended insulation life the generators would be rated at class "B" temperature rises. Damper bars of copper shall be braced into ring segments at both ends of the rotor. The rotor is provided with a continuous low resistance damper winding in the pole pieces to minimize over voltages due to unbalanced faults. The damper winding is designed to make the ratio of quadrature-axis sub-transient reactance (xq’’) to direct-axis sub-transient reactance (xd’’) nearly equal to 1.0 for stabilizing the power system transient swing.

A segmental brake ring shall be fitted to the rotor with provision for expansion and contraction due to repetitive normal braking. The design shall be such that the brake ring segments can be readily removed for resurfacing or replacement. The brake ring shall be sufficiently thick to prevent thermal distortion. It shall comprise bolted segments which shall present a smooth even surface to the brake pads. Bolts shall be well countersunk.

The Generators shall be efficiently cooled with closed air system. For proper cooling, the Generators shall be equipped with surface air water coolers having sufficient cooling capacity to maintain the air temperature at 40˚C or less, with the generator delivering continuously 100% rated output. The circulation of the air shall be by means of the fan action of the Generator rotor.

12.3.4 Stator

The stator should be framed by welded steel rings on both sides, which transmit all dynamic and static forces through thrust bearing to the plates laid in the concrete foundations. Stator bars shall be treated with anti-corona protection and wound in the slot with conducting materials designed to compensate for relaxation in service, in order to eliminate the possibility of slot discharge damage. Stator wedges shall be fitted in such a way that radial pressure is applied to the bars even after relaxation in service. The interval between wedge re-tightening, and the method adopted, shall be subject to the Engineer's approval. Stator bar joints shall be brazed, and bar to bar joints fully insulated with tape material.

For proper and effective cooling the generator core shall be divided by radial and axial air gaps for air flow through the generator core. The stator winding shall be designed so that a generator wave form as close as possible to the sine curve could be obtained. The stator winding is star connected and neutral point is grounded through a grounding transformer. The stator winding is provided with an online partial discharge measuring system with necessary partial discharge sensors to measure the partial discharge activities in such various plates of stator windings as external to the stator winding, slot surface, slot wall, insulation/copper interface and end turn

The stator winding shall be made of bar or coil winding system with an insulation of continuous tape impregnated with synthetic resin in vacuum and subsequently cured. The coil shall be provided with a necessary anti corona protection in the slot section and at the ends, if necessary. The insulation shall meet the requirements of the temperature class F. Grounding of generator neutral through grounding transformer is proposed. The Grounding resistors shall be installed in a separate housing with proper insulation provided.

The winding shall be designed to minimize temperature variation throughout the slot content. Bars shall be manufactured and wound to an agreed quality plan which shall be approved by the Engineer.

Stator bars shall be treated with anti-corona protection and wound in the slot with conducting materials designed to compensate for relaxation in service, in order to eliminate the possibility of slot discharge damage. Stator wedges shall be fitted in such a way that radial pressure is applied to the bars even after relaxation in service.

The interval between wedge re-tightening, and the method adopted, shall be subject to the Engineer's approval. Stator bar joints shall be brazed, and bar to bar joints fully insulated with tape material.

Windings shall be braced and supported so that they can withstand short circuit forces and accommodate thermal cycle movement without damage. Slot wedges shall be locked in position so that they cannot fall out of the slot. Bars shall be fixed, using conformable packing, to insulated non- metallic support rings. All bar clamping devices shall be locked by approved means. The method of winding support and wedging shall be shown in the drawings to be submitted by the Contractor.

Stator bar joint and connecting ring maximum temperature rises shall not exceed those allowed in the slot portion of the winding. The predicted maximum temperature rises, shall be validated by tests.

Air gap measuring probes shall be fitted in the slot wedges to monitor abnormal air gap changes. The probes shall be connected to a processor mounted outside the machine enclosure. The proposed system shall be complete with interface equipment to provide signals to the Distributed Control system (DCS) for alarm purposes and for deterioration analysis, required to plan preventative maintenance.

Suitable connections shall be installed in each phase of the winding to monitor "on line" discharge levels of the bars, without taking the unit out of service.

12.3.5 Generator Bearings

Guide bearings shall be of the segmented multiple pad design, oil lubricated self-pumping type. Their design shall permit vertical movement of the shaft system for adjustment and removal of the thrust bearing shoes. Bearing pads shall be individually adjustable and shall be lined with high grade white metal, no less than 5mm thick, securely bonded to the pads. The bond shall be ultrasonically examined. Bearing pads shall be easily removable without the removal of any other major component. A portion of the bearing shall be continually immersed in oil to provide initial lubrication during a unit start.

All bearings shall be equipped with water-in-oil sensors with alarms. Each generator bearing housing shall be sealed and ventilated to ensure that oil vapor does not enter the generator, slip-ring housing or turbine pit. Vapor pipe work from each bearing housing shall be terminated in a convenient location in the turbine gallery, by condensate containers equipped with drain and level indicator. If necessary to completely eliminate vapor release from the bearing housings, an external vapor extraction and condensation system shall be provided for each unit.

12.3.5.1 Generator Lower Guide Bearing

The lower guide bearing may share an oil reservoir with the thrust bearing. In this case oil supply to the lower guide bearing may be by the pumping action of the thrust bearing. Otherwise the guide bearing shall be self-pumping.

If a separate oil reservoir is used, the coolers of the lower generator guide bearing shall be external to the guide bearing housing and shall be easily isolated and removable for cleaning and maintenance.

Alternatively, if self-pumping is proven to be impractical with external coolers then coolers may be installed in flanged recesses in the bearing houses such that they can be removed without the necessity of dismantling any major component.

12.3.5.2 Generator Upper Guide Bearing

The bearing shall be of self-pumping design mounted in the upper bracket. Coolers shall be consistent with those on the lower guide. It shall be possible to remove the upper guide bearing pads without dismantling the brush gear or its enclosure.

12.3.5.3 Generator Thrust Bearing

The thrust bearing shall be self-pumping by rotation of the shaft. It shall be mounted in a lower bracket designed to transmit axial loads into the concrete foundations. The design shall be such as to limit thermal expansion forces whilst maintaining the bearing concentricity with the shaft. The thrust pads shall be supported so as to ensure uniform load distribution between pads and provide ease of adjustment for maintenance. The bearing shall be designed to accommodate repetitive restarts immediately after hot shut down. Removal of the pads shall be possible sideways by jacking the generator rotor. The Contractor shall supply all special tools and devices for this purpose.

The thrust bearing runner shall be a one-piece forging. Weld repair of the runner surface will not be accepted. The bond of the white metal to the bearing pads shall be inspected ultrasonically.

The thrust bearing shall be equipped with a high pressure oil lift system which shall normally be operative during start up and shut down. However, it shall be possible (and demonstrated during commissioning) that the unit can be stopped without the pumps in operation without any appreciable temperature rise and any damage to thrust bearing pads. The results of this demonstration shall be visually verified by inspecting two thrust bearing pads at random. Each pad shall be equipped with non-return valve integral with the pad. The high pressure system shall comprise two pumps (normal and standby) with all necessary starters and associated controls for automatic switching. The standby pump shall be dc motor driven which shall start automatically upon failure of ac motor driven main pump. The required oil film thickness shall be established in about five (5) seconds. Remote indication and local visual indication shall be provided for excess inlet and outlet filter pressure drop.

The high pressure lift system shall be located external to the unit so that it can be easily inspected and maintained without entering the unit. Automatic drainage of any leakage oil shall be provided. Bearing oil coolers shall be mounted outside the bearing housings with isolating valves so that they can be removed for cleaning. There shall be indicating devices or visual aids to observe foaming of oil in the bearing.

12.3.6 Condition Monitoring System

The generator condition monitoring system will comprise of the following features

On-line Vibration Monitoring System

The generators are provided with a vibration measuring system to monitor vibrations of radial and axial directions as well as shaft run-out at each bearing of the turbine and generator unit. The vibration measuring system is arranged to measure the following items.

a)	At upper guide bearing:	Vibrations of radial (X and Y) directions
		Shaft runout of radial (X and Y) directions
b)	At thrust bearing:	Vibrations of axial direction
c)	At lower guide bearing:	Vibrations of radial (X and Y) directions
		Shaft runout of radial (X and Y) directions
d)	At turbine guide bearing	Vibrations of radial (X and Y) directions
		Shaft runout of radial (X and Y) directions

The vibration indication units are mounted on the turbine control panel.

The vibration measuring system is designed to give alarm (1st stage) and unit trip (2nd stage) signals in the event of excessive vibration.

On-line Partial Discharge (PD) Monitoring System

In order to indicate the condition of winding insulation, a partial discharge analyzer (PDA) is provided to monitor the partial discharge activities of the stator windings. The system consists of permanently mounted partial discharge sensors (capacitive couplers) on the line and neutral windings.

Generator Air Gap Monitoring System

Air gap monitoring system consists of stator mounted probes to detect the deformation of rotor and stator concentricity. Data will be used for analysis of irregular behavior of rotor and stator due to effects of centrifugal force, magnetic force and thermal expansion on generator.

12.3.7 Excitation System

The generator excitation system will be of the static type comprising three-phase cast resin type excitation transformer, thyristor converter, field flashing and field discharge equipment, automatic voltage regulator and control circuitry. The excitation transformer will be installed in a self-supported steel plate cubicle to achieve personnel safety. The excitation transformer shall be AN cooled and of dry insulated type using non-flammable Class B insulating material.

Static excitation with excitation transformer, controlled rectifier and the automatic voltage controller has the advantage of providing quick response, being capable of reversing its output voltage in case of load rejection and unit over speed. Therefore, the proposed Power House shall have a static excitation system.

Excitation systems feed the field winding via slip rings and brushes allowing rapid response for voltage regulation. The automatic voltage regulator will be equipped with automatic and manual channels with follow-up control to allow change of mode without bumping. The excitation rectifier envisaged will be of solid-state type with controlled silicon power thyristor for both polarities. While considering forced ventilation, redundancy of the cooling system must be provided to avoid shutdown of the generator in the event of breakdown of the fan motors. Cooling fans must be self-powered from the excitation transformer so that loss of station service does not cause excitation failures.

The excitation system will be capable of providing sufficient margin of stability under all steady and transient load conditions. The voltage regulator will have a voltage variation range of ± 10 % of the rated generator voltage. The field current control will be used as the manual channel of the regulator. The excitation system shall have built-in protection and supervision equipment. All fault signals shall be displayed on the AVR front panel.

For excitation start-up / field flashing, an additional supply from the DC system will be provided. The excitation system will communicate with the distributed control system (DCS) via a standard bus system.

The static excitation systems will consist of:

- Digital type AVR’s
- Rectifier assemblies
- Excitation transformers
- Field cubicles with breakers, discharge, control & protection devices and cooling circuits
- Field flashing circuit/equipment
- Excitation leads between excitation cubicles and slip rings

The excitation system will be provided with the following features:

- Following of line voltage during synchronization
- Quadrature droop parallel operation compensation
- Under-excitation or load angle limitation with adjusting device
- Time graded limitation of the maximum excitation current

- Time graded limitation of the maximum stator currents (under-/ overexcited)
- Power system stabilizer

12.3.8 Generator Circuit Breaker

The Generator Circuit Breakers will be SF6 gas type as insulating and interrupting medium, high current type and complying with IEEE C37.013. For current interruption the self-blast interrupting principle is applied. The arc voltage of the circuit breaker is high enough to ensure current zeros in case of generator-source short-circuit currents with delayed current zeros. The Generator Circuit Breakers will be suitable for synchronizing duties and provided with interlocks to avoid incorrect operation of the disconnector or the earth switches. The Generator Circuit Breaker is capable of interrupting currents under out-of-phase conditions with out-of-phase angles up to 180 degrees.

The Generator Circuit Breakers will conform to IEC 60694 and suitable for the normal load current specified with natural cooling and with a temperature rise in accordance with IEEE C37.013.

12.4 OTHER ELECTRICAL EQUIPMENT

Generator protection comprising all the required relays according to the size and specifications of generator.

- Control and metering panels.
- Control and protection cables.
- MV/LV switchgears.
- 220V DC Battery Set & Battery Charger.
- Energy Hour Meters shall be used to monitor energy generation.

12.5 POWER TRANSFORMERS

Power transformers configuration have been considered to transmit the power from power house to local grid station.

Each generator connected to its own unit transformer.

It has advantages of being flexible in case of problems with the equipment. Each unit is independent so that availability of the generation is higher than the group transformer. Thus for this hydropower project, each generator is proposed to connect to its own step-up transformer. Off load tap changer is proposed on high voltage side. An allowance of 10% continuous over load is also proposed. Detailed parameters of the recommended transformer are as under:

Table 12-2 Recommended parameters of the Transformers

Description	For Generator I to III
No. of Transformers	03
Nominal Capacity	22 MVA
Cooling Type	ONAN/ONAF
% Impedance	12%
Primary Voltage	11 KV
Secondary Voltage	132 KV
Frequency	50 Hz
Type	3-Phase, 2 windings (HV/LV)
Tap Changer	OFF Load
Vector Group	Ynd11

A spare power transformer shall also be provided. As per standard practice, Buchholz Protection and all other necessary Protection will be provided. The delta connected winding on the low voltage side will provide short-circuit for possible third harmonics from the generator. The high voltage winding is star (Y) connected with the neutral taken out on a separate terminal for connection to earth.

12.6 STATION SERVICE TRANSFORMER

One transformers of 2 MVA, 132/11 KV rating will be installed for power supply to intake, auxiliary supply, control room, transformer bay, intake, crane, Lighting Load, DC supply and power house supply and as alternative supply in case of emergency.

The ratings of transformer are as under:

No. of Transformer	1
Capacity	2 MVA
Primary Voltage	132 kV
Secondary Voltage	11 KV
Frequency	50 Hz
Temperature rise	55˚C
Cooling	ONAN
Type	Dry/Oil

12.7 AUXILIARY TRANSFORMERS

Two nos. Unit Auxiliary Transformers (UAT's) will be installed for power house auxiliary supply. It is not necessary to install a unit auxiliary transformer with each unit. Here, It is considered economical to install 11/0.4 kV transformer only with two units. Another unit auxiliary transformer will be used to interconnect unit auxiliary supply with station supply to get the supply from station service transformer. The ratings of unit auxiliary transformers are mentioned below.

No. of transformers	3
Rated Capacity	630 kVA
Transformation voltage	11 kV / 0.4 KV
Insulation class	H
Cooling	ONAN
Type	Oil
Percentage Impedance	4 %

Two auxiliary transformers of capacity 400 kVA each shall supply the electrical power to the auxiliary equipment of intake and switch- yard control building. Oil filled distribution type transformer with a capacity of 400 KVA, 11KV/0.4kV, has been selected based on the required capacity of load in the plant. Natural air circulation cooling has been chosen due to the operational safety. The insulation material shall be self-extinguishing and varnish shall prevent any spreading of fire. The units shall be installed close to the space where the power is needed. The ratings and characteristics of the auxiliary transformer shall be as follows.

No. of transformers	2
Rated Capacity	400 kVA
Transformation voltage	11 kV / 0.4 KV
Insulation class	H
Cooling	ONAN
Type	Oil
Percentage Impedance	4 %

12.8 SWITCHGEAR SYSTEM

The generators shall be connected to 11kV switch gear, which consists of medium voltage circuit breakers, medium voltage disconnecting switches and the corresponding metering and protection equipment.

12.8.1 132kV Switchgear

Conventional air insulated type switchgear is applied for 132 kV switchyard for connection of the outgoing 132kV transmission line which includes voltage and current transformers for protection relays.

132kV switchgear is figured with one and a half circuit breakers system being generally applied for high voltage system in substation and power house.

12.8.2 11kV Switchgear

The primary purpose of the 11 kV switchgear is to provide auxiliary supply for the powerhouse, intake and also to support any adjoining areas. The switchgear has been planned to be located in a separate room in the 132kV switchyard.

The incoming 11 kV supply from 132/11 kV service supply transformer will be terminated in the 11 kV bus bar. Some 11kV feeders supply power to rural areas and will be finalized in the tender design stage.

The necessary 11 kV feeders and service supply transformer will be equipped with modern fuse disconnecting switches or circuit breaker of SF6 or vacuum type (to be decided at detailed design stage) enclosed in cubicles thus obtaining high personnel safety.

The main data for the circuit breaker shall be the following:

Nominal voltage	11 kV
Maximum voltage	12 kV
BIL	95 kV
Rated short circuit current	31.5 kA

12.8.3 400 Volt Switchgear

It is proposed to use a 400V switchgear scheme to supply power to station auxiliaries. The AC supply of 400V shall be obtained from the 630 KVA station service transformers. Miniature Circuit Breaker and Molded Case Circuit Breaker (MCB's & MCCB's) shall be used accordingly for the 400V supply.

The following LV switchgears are provided for Unit and Station Auxiliary power supply.

a) Unit Auxiliary service boards

b) Essential service boards

c) Common service boards

Switchgear assemblies will be comprised of low voltage power air circuit breakers, moulded case circuit breakers, buses, current transformers, voltage transformers, indicating instruments, relays, control devices, associated wiring and test blocks.

12.9 CONTROL, INSTRUMENTATION AND PROTECTION EQUIPMENT

12.9.1 Instrumentation & Control

1) One-Man Control System

The control system for each generating unit; hydraulic turbine, generator, unit transformer and 132kV circuit breaker will be designed for “one-man control system” in which any operation of the generating unit can be carried out remotely by an operator from the machine hall in the powerhouse as well as from the main control room of the central control building.

In the one-man control system, the unit start-up and stop operations will be made by automatic sequential control with the aid of the programmable logic controller for each unit. All auxiliary equipment of the unit will be actuated and stopped by automatic control sequence program loaded in the PLC.

2) Control Mode

Each generating unit will be operated under three (3) control modes of "Remote- Auto", "Local-Auto" or “Local-Manual” as follows:

a) Remote-Auto” Control Mode

The generating unit operation including unit start/stop, turbine speed adjustment, load adjustment and generator voltage adjustment will be carried out remotely from the control room of the main control building.

The unit start/stop operations will be carried out under the full-automatic mode. The remote-auto control mode will be used for ordinary start and stop operation.

a) Local-Auto” control mode

The generating unit operation will be carried out remotely from the machine hall floor level of the underground powerhouse.

Under the local-auto control mode, the unit start/stop operations will be made by full-automatic mode or step-by-step mode.

Under the full-automatic mode, the generating unit will start up automatically to the step of the generator synchronizing when the “Start” command is given, and the running unit will be automatically brought to the unit standstill when the “Stop” command is given.

The step-by-step mode is a semi-automatic control mode to start and stop the generating unit from the unit local control board with confirmation of each step operation. This local-auto control mode will be used when the SCADA system is out of service.

b) Local-Manual” Control Mode

The local-manual control mode is to operate the turbine and generator unit by manual control of their governor, excitation system and auxiliary equipment without using the automatic control function of the programmable logic controller.

This mode will be used only for testing and trial operation of the turbine and generator unit after maintenance and repair, or when the programmable logic controller is out of service.

Indicating, measuring and control instruments have been considered necessary for the major components of Power House. For monitoring and control of the overall power plant, Latest control system (DCS/SCADA) should be installed for plant control. The transducers shall be installed where necessary. All indications shall be visible in the main control room.

The control of the single unit shall be local and remote, able for auto or manual selection. It is necessary to provide a separate control desk and mimic panel that shall be located in the main control room and include the most important remote control functions.

12.9.2 Protection Equipment

Separate relay protection cubicles comprising modern electronic relays will be installed. All relays shall preferably be of the same make (manufacture) to build a uniform modular system.

The relays are to be organized in two groups so that one group provides back-up protection for the other group The outline of protection scheme for the Generators, Main Step-Up Transformers, is shown on the Design Drawing. The general principle for the protection is that all parts of the installation (Generator and Main Step-Up Transformers) are covered by two high speed protection schemes which are independent to avoid common-mode failures.

The protection equipment is provided with all relay panels, instruments, meters, interposing and auxiliary relays, control switches, interposing current and voltage transformers, transducers and all auxiliary equipment. The protection system aims at compliance with IEC 62351. Control supply will be taken from 220 VDC system. Separate circuits will serve the two groups of relays in order to obtain maximum reliability. Protection equipment is designed and supplied to provide maximum discrimination between faulty and healthy circuits. All equipment is to remain inoperative during transient phenomena which may arise during switching or other disturbances to the system.

Signals and data provided by the protection relays will be monitored by the DCS.

12.9.2.1 Generator Protection

- Under voltage protection (27)
- Reverse power protection (32)
- Loss of excitation protection (40)
- Negative sequence current protection (46)
- Generator winding thermal monitoring (49 G)
- Over current / short circuit protection (50; 51; 51 N)
- Over voltage protection (59)
- Rotor earth fault protection (64 R)
- Stator earth fault protection (95 % & 100%) (64 G)
- Under frequency protection (81)

- Three phase generator differential current protection (87 G)
- Shaft current protection
- Vibration and shaft movement supervision protection

12.9.2.2 Power Transformer Protection

The following transformer protections are recommended:

- Transformer Differential protection
- Restricted earth fault protection
- Back-up earth fault protection
- Buchholz protection
- 132 kV XLPE cable differential protection

And also over current protection for excitation transformer and unit auxiliary transformers will be provided.

It is also recommended that the numerical transformer protection system be combined with the main generator protection system and contained in one cubicle or in an adjacent cubicle.

The following devices, supplied as part of the unit transformer shall be integrated in the transformer protection and supervision scheme.

- Level of insulating oil, maximum and minimum (71T);
- Oil temperature (26);
- High voltage (HV) and low voltage (LV) windings temperature (49T);
- Gas release (63);
- Pressure relief valve (63VS)

12.9.2.3 132kV Transmission Line Protection

The 132kV transmission line protection shall be comprised by redundant multifunctional numeric IEDs, with exclusive hardware.

- Transmission line differential protection (87L)
- Transmission line distance protection (21)
- Breaker failure protection (50BF)

12.10 SYNCHRONIZING

12.10.1 Automatic Synchronizer

A solid-state automatic synchronizer for each unit, to automatically synchronize and connect the generators to the power system via the unit 132 kV circuit-breakers will be provided.

I. The automatic synchronizing equipment will be mounted on the unit control panel.

II. A check synchronizing relay for each unit, which will be arranged to prevent closing pulses from the auto-synchronizer reaching the circuit breaker if the phase angle difference at that time is greater than nominal 5 degrees will be provided. Operation of the auto -synchronizer circuit breaker closing pulse without the check synchronizing relay operating will lockout the auto-synchronizer and initiate an urgent alarm.

12.10.2 Manual Synchronizing Facilities

A manual synchronizing for each turbine generator unit in the power station control room will be provided.

All hardwired voltage and speed control signals of the Project Plant units on the above console, to enable the operators to adjust the voltage and speed of the unit during manual synchronizing, will be provided.

12.11 MEASURING EQUIPMENT

Each feeder will be equipped with current and voltage transformers between the power transformer and the circuit breaker. Measuring accuracy of the protection cores shall be as per IEC standard. CT's shall be designed to carry the same nominal and short circuit currents as the other switchgear equipment and shall have separate cores for measuring and protection purposes. All measuring transformers are assumed to be dimensioned to meet all the needs of the operation of the power plant.

12.11.1 Current Transformers (CT)

Current transformers shall comply with IEC 61869-2 as amended and supplemented by the following requirements. Separate current transformers shall be provided for protection, instrumentation and metering purposes. For measuring current transformers, the following accuracy classes shall apply;

a) For generator output for the purposes of acceptance testing, and for tariff metering of large supplies, unless otherwise specified

b) For plant record metering, and for other acceptance testing purposes

c) For automatic voltage regulators (AVRs)

d) For indicating instruments.

Current transformers used for indication/metering purposes shall be designed to saturate at a value of primary current sufficiently low enough to protect the secondary circuit from damage at all possible values of primary fault current up to the associated primary short time rating.

Current transformers for protective/indication purposes shall be designed to suit the particular requirements of the associated protection which, in general, shall be in accordance with the recommendation given in IEC 61869-2. Class 5P current transformers shall be used for combined over current and earth fault protection of the inverse time over current type.

The rated accuracy limit with actual burden connected shall be equivalent to the ultimate maximum symmetrical three phase fault current or earth fault current of the protected circuit. The current transformers shall be capable of meeting the 5P error classification at rated accuracy limit current over the full range of relay settings.

Current transformers for combined purposes e.g. inverse time relays and indicating meters, shall have a dual Class 5P/Class 1 performance and where necessary the secondary circuits shall have an approved means of protecting the meters and reducing their burden under system fault conditions. Current transformers for protection using high impedance relays shall be of the low reactance type and their performance shall be stated in terms of the Class TPS, TPX, TPY and TPZ parameters of IEC 61869-2 (low reactance current transformers are preferred for all forms of protection), or equivalent approved standard.

The rated volt-amp output of each current transformer shall not be less than the connected burden, as installed in service, the burden of cable connections being taken into account. Current transformers shall be capable of withstanding without damage the peak and rated short time currents of their associated equipment. The secondary windings of each set of current transformers shall be earthed at one point only, via a bolted disconnecting link.

The current transformer core, where accessible, shall be separately earthed. When multiple ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformer, indicating clearly the connections required for each tap. The connections and the ratio in use shall be indicated on all connection diagrams. Design magnetization curves and DC resistance values shall be submitted before manufacture for each current transformer used for protective purposes and shall be subsequently verified by works routine tests. For metal-clad switchgear, all current transformers shall be located on the outgoing circuit side of the circuit breaker. Current transformers may also be provided on the bus bar side of the circuit breaker to permit protection zone overlap.

The primary conductors of all current transformers shall be readily accessible for primary injection testing on site. Where current transformers have to be mounted on apparatus provided under other contracts, shall be responsible for ensuring compatibility with the other apparatus. Current transformers incorporated in equipment which are spare or for future use, shall (if not connected to associated relays, instruments etc.) be provided with a suitably rated shorting link mounted at a convenient terminal block to avoid the current transformer being energized with its secondary connections open circuited. Bushing type current transformers shall be provided with taps to measure capacitance and loss factor (tan delta).

12.11.2 Voltage Transformers (VT)

All voltage transformers shall comply with the requirements of IEC 61869-3 as amended and supplemented by this specification. They shall have outputs 50% in excess of the present requirements unless otherwise specified.

The voltage transformer secondary circuits shall be complete in themselves and shall be earthed at one point only. Metal cases shall be separately earthed. The transformer core, where accessible, shall be separately earthed. All voltage transformers at the same voltage level shall be earthed in the same manner. Where it is required to earth the primary neutral of a metal clad voltage transformer, the neutral earthing connection shall be insulated from the tank and brought out separately from the secondary earthing connection. Primary windings shall be connected through fuses with current limiting resistances or having current limiting features. However, such fuses may be omitted when the voltage transformer is located within the overall protection zone of the main circuit. Secondary main protection fuses or miniature circuit breakers shall be provided as close as possible to, and preferably mounted on, each voltage transformer, within a lockable or bolted enclosure.

Secondary main protection fuses or miniature circuit breakers shall be labeled to show their function and phase color. It shall not be necessary to de-energize the primary circuit or remove the voltage transformer of metal clad switchgear to gain access to the fuses or miniature circuit breaker. Auxiliary contacts shall be provided for alarm purposes in the event of loss of supply. Voltage transformers shall be so designed that saturation of their cores does not occur when 1.732 times normal voltage is applied to each winding.

Magnetization curves shall be submitted for approval for each type of voltage transformer prior to Works Tests. The standard secondary voltage between phases shall be 110 V unless special circumstances dictate otherwise. Secondary circuits of different voltage transformers shall not be connected in parallel. Voltage transformers shall preferably be mounted on the outgoing circuit side of circuit breakers. Three phase voltage transformers having an earthed - star primary winding shall have cores with five limbs, the outer two of which shall be unwound

12.12 SURGE ARRESTERS

On the outgoing transmission line surge arrester (SA) will be connected to each phase. In addition, one group of three SA will be included on each transformer bushing.

Surge arrestors shall be gapless non-linear metal-oxide resistors (Zinc oxide surge arrestor). The magnitude and duration of temporary power frequency switching over voltages are important design criteria and are to be defined during the final design stage.

12.13 DC POWER SUPPLY

220V DC Power shall be obtained by rectifying the AC Power. The DC supply shall also be supplemented by a DC Battery Set. Purpose of the battery system is to provide a safe and reliable DC power to all primary functions. The system is almost independent of all other power supply systems and ensures reliable execution of the control functions, both for selected normal operation and during possible fault conditions.

The DC battery system will mainly provide power to the complete Plant Control System. Some instruments, protection devices or computer interfaces will need 24 V or 48 V DC supply. In this case AC/DC converters should be used. The use of separate 24 V or 48 V batteries is not recommended. The Ah capacity of batteries shall be finalized at the final design stage on the basis of the actual DC load requirements of each powerhouse.

12.14 CABLES

The insulating, sheathing and non-metallic filler materials used in the cables shall be selected to ensure compliance with statutory and Section 16 for flame retardant or fire resistance, reduced propagation or low emission of smoke, acid gas and halogens free for the cable as a whole. Cables installed on or connected to equipment that is subject to vibration, movement and/or expansion shall have stranded copper conductors throughout. These cables shall have crimped connectors for the termination of the conductors. Only conductors carrying signals of the same category shall be contained within any one multi core cable. To reduce the risk of common mode failure all cabling associated with high integrity signals, such as data transmission signals, signals from fiscal metering systems or with protection and/or safety systems shall be segregated from control cabling over the entire length of the cable run.

This segregation shall also apply to junction boxes and terminations. A further segregation is required to ensure that conductors forming part of intrinsically safe circuits are contained in cables reserved solely for such circuits. A minimum of 20 % spare capacity shall be included in all cables carrying either binary or analogue signals.

12.14.1 Power Cables

The power cables to be used between the generators, transformers and their respective 11 kV switchgears shall be XLPE as per IEC/WAPDA standards. Actual quantity/Length of the respective cables shall be decided at the final design. The insulation is of extruded chemically cross-linked polyethylene (XLPE) with sheath of LSHF and either of fire retardant or of fire resistance characteristics. The cables will be armoured and will contain semi-conducting screens and any tapes, binders, separators or bedding required to manufacture reliable, technically proven, high quality cable

12.14.2 Control Cables

Control cables are used for protection, instrumentation, control and communications. These shall be of stranded copper conductors or armored cables. These cables shall be standard product of a reputed manufacturer with a proven track record. The construction of the cables will be in compliance with the specified requirements and the related IEC Standards. Control cables will be laid in perforated steel trays or at the bottom of concrete trenches. . The earthing and lightning protection system is designed in accordance with the IEC / IEEE standards. The cable trays shall be mounted on the floor underneath the local control area, to have short connections between the different control panels, distribution boards, equipment and other auxiliary installations.

12.14.3 Telecommunication Cables

The application of telecommunication type cables shall be restricted to voice and data communication purposes. These cables shall comprise multiple twisted pairs, triples or quads, with copper conductors, polyethylene or XLPE insulated, laid up and screened overall. Each pair/triple/quad may be individually screened, where required to minimize cross-talk or interference. Cables which are to be direct buried or installed in accessible areas without external mechanical protection shall be armoured, un-armoured cables shall have a braided screen. Minimum 20% spare capacity shall be included in all cables. The insulation of the cores shall be colour coded in accordance with an appropriate international standard. In addition, the colour , construction, marking, etc., of telephone cabling shall be subject to any requirements laid down by the local telephone company or authority. Telephone type cables laid in the ground alongside power cables shall be capable of withstanding induced voltages from the power cable.

12.14.4 Fiber Optics Cables

Fiber optic cable shall be made up cores sheathed in 125 µm cladding, coated and reinforced using strengthening fibers for protection against crushing forces and excessive tension during installation. All fiber optic cables shall comply with an appropriate international standard. The outer jacket shall be made of a flame retardant polymer. A loose tube with minimum strain configuration that provides protection from external forces shall be used in dry and indoor applications.

Specific measures shall be taken to protect the fibers from the ingress and propagation of moisture. The outer sheath shall be resistant to water and hydrocarbon contamination. Gel filled loose tubes shall not be used for vertical cable runs or in submerged applications. Tight buffered or ruggedized fiber optic cable type shall be used for long runs or where the cable is to be buried or submerged.

Each cladded core shall have two coatings, the first coat 250-900 µm plastic layer; the second coat 200-400 µm layer of waterproof acetate. Direct buried fiber optic cable shall be of a steel wire or steel tape armoured construction. Single-mode fiber optic cables shall be used when there is only one propagation mode (single wave length) or where there is a long transmission distance. The fiber optic cores shall be either 7.1 or 8.5 µm diameter.

The cable shall be suitable for transmission of laser light. The optical cable shall be of the single mode type equipped with at least 24 fibers and shall be suitable for direct burial underground. The fiber cladding diameter required is 125 micron, optimized for 1310 nm, but suitable for transmission at 1550 nm wavelength. Construction and type testing shall be in accordance with the appropriate international standard with a maximum cabled fiber attenuation not exceeding 0.4 dB/km at 1310 nm; and not exceeding 0.35 dB/km at 1550 nm Multi-mode fiber optic cables shall have a core diameter of 50, 62.5 or 100 µm, of all dielectric construction, with a graded index, suitable for use in the wavelength range 850 to 1300 nm. Construction and type testing shall be in accordance with the appropriate international standard. Multimode fibers shall be suitable for the transmission of infrared light produced by LEDs.

Simplex fiber optic cables consist of only one fiber link and should be used for applications that require only one-way data transfer. Simplex can be applied to both single and multi-mode type fiber optic cables. Preferably the fiber optic cable shall be installed in one length without joints, however where joints cannot be avoided shall complete all jointing as specified below. No intermediate joints are permitted in multimode fiber optic cable joints shall be housed in a weatherproof joint box. Joint boxes shall be provided with the cable.

The joint box shall be made of corrosion resistant aluminum alloy or similar material. The cover shall be provided with a long life neoprene gasket to provide a seal against moisture and dust in an ambient environment of 100% humidity and 55 ºC. The cable inlet shall be similarly sealed. If joint box locations will be exposed to the sun then sunshades are required and these shall be provided with the joint boxes. Intermediate cable joint boxes will be provided at approximately 2 km intervals, subject to the maximum fabrication/drumming requirements from the manufacturer. The joint box shall be placed in suitably accessible positions and be appropriately marked.

The fibers shall be spliced by fusion techniques for minimum signal loss. A heat shrink optical supporting sleeve with inner mechanical reinforcement shall protect the splice. Terminations at either end of the cable runs will be performed into patch panels using ceramic ST connectors supply the patch panels unless otherwise stated in the general technical requirements. A fan out kit to protect each fiber strand in its own buffer sheath shall be used when terminating loose-tube cables. Patch cords shall be used between patch panels and equipment cabinets within buildings. Patch cords shall be performed, tight buffered, single or duplex fiber cables, 62.5/125 micron, multi-mode type, provided in standard lengths complete with factory-installed ceramic ST connectors and with sheathing suitable for internal building use.

All patch cords shall be supplied and installed. All patch cord runs between cabinets shall be mechanically protected in conduit or closed trunking provided and installed. The conduit or trunking shall contain only fiber optic cables and fit fiber optic patch panels for all fiber optic cables in their supply.

The supply shall include any cabinet or enclosure necessary for their installation or protection. Patch panels shall be provided with sufficient ports to terminate all fibers entering the respective building, with 20 % spare installed connectors. Connector type shall be ST. Sufficient room shall be allowed within the patch panel for adequate cable and fiber management, allowing for bend radius control. Independent patch panels and splice trays shall be provided. Smooth fiber and tube management shall be provided. After cable installation and splicing the completed fibers shall be inspected and tested using an Optical Time Domain Reflectometer (OTDR). The OTDR traces generated shall provide as-built evidence of the actual losses on the installed cables.

12.15 ILLUMINATION AND SMALL POWER

An adequate indoor and outdoor lighting with illumination levels in accordance with recognized standards will be provided. Inside the powerhouse, an emergency lighting system powered from the station battery must be installed. The system will operate the instant when the normal power supply fails.

AC lighting and small power socket outlets, for 230 V, shall be single-phase, connected between phase and neutral of the 400 V system.

12.15.1 Lighting/Illumination System

A complete LED lighting system, with the individual components being of approved type and constructed of best quality materials shall be supplied, installed and commissioned. The scope of supply shall comprise, but is not limited to the following:

- Indoor and outdoor lighting for all equipment, structures, roads and outdoor operation areas as required for the plant
- Lighting main distribution
- Lighting sub-distributions
- Lighting fixtures with LED luminaries
- Power socket outlets
- Portable LED lamps

- Cabling, wiring, conduit system for the low voltage wiring, convenient outlets, lighting fixtures and lighting panel boards and lighting switches as well as all required installation material

- Specified spare parts and special tools

The average illumination levels, as measured at a height of 0.8 m above floor (above ground level), at any location, shall be as follows (minimum levels):

Turbine /Generator Floor	300 lux
Mechanical Floor and Rooms	300 lux
Unit Transformers and Outdoor transformers	200 lux
Street lighting	20 lux
Oil and water storage tank areas	50 lux
Outdoor operating areas, intake / spillway area	150 lux
Accessible cable trenches with fixed covers	60 lux
Indoor transformer rooms, corridors, stair cases, basements 200lux locker rooms, store rooms, toilets, machine rooms	200 lux
Switchgear rooms, battery rooms, day rooms foreman's rooms, dispensary	360 lux
Workshops, offices	500 lux
Control rooms, Relay rooms	800 lux

An aging factor of 20% shall be taken into account and therefore the lighting intensities of the fittings must be achieved as a minimum during the acceptance tests.

Throughout the installation the lighting intensity at local measuring and control points and instruments panels shall be at least 200 Lux. Additionally, all local push button stations, control stations, control panels, instrument racks, hand operated equipment like valves, etc., shall – if required due to the low surrounding illumination levels – be lit separately by means of suitable LED luminaries, mounted on poles or at adjacent structures, so as to obtain at least 200 lux illumination level.

The systems include light fixtures operating at 230 VAC (line to neutral connected). The power source for the internal lighting shall be derived from the 400V lighting switchboard.

The machine hall will be provided on both long walls with a chain of fluorescent lamps which are used for normal access. During maintenance and repair jobs on a unit, additional portable lamps will be used where necessary. The control room will have intensity controlled illumination, so that it might be adapted to special situations. Special attention will be paid to avoid reflections on monitor screens.

Fluorescent light fittings are preferred everywhere indoor where they are feasible. High pressure sodium vapour lamps with built in control gear which are economical and long lasting will be installed outdoors. In order to reduce the number of equipment types and sizes which have to be stocked as spares, there must be standardization of both lamps and fittings. This will result in relatively few varieties.

The illumination level for the emergency lighting will be at least 10 Lux in the entire powerhouse area except control room and unit control panel area. The illumination level of 30 Lux will be specified in those areas.

Portable battery handsets will be made available for additional lighting during maintenance works, e.g. in case of AC failure. These will be located at various important places in the powerhouse, switchyard and intake structures.

Exit lights will be installed above doors, staircases and floors along the emergency exit ways and those will be powered by the uninterruptible power system in the event of failure of auxiliary power supply.

12.15.2 Emergency Lighting:

In normal operation, it will be directly powered from the 400 VAC essential switchboards. When plant auxiliary supply fails following will occur,

The first 60 seconds, energy supply will be taken over by the uninterruptible power supply system. After 60 seconds, the supply will be obtained from the emergency diesel generator unit (Emergency load switchgear is separated from normal supply).

Both systems will have a main concept, common distributed “on / off” switches. Emergency lighting will therefore not come on automatically in vacant rooms where the lights are off. However, special consideration will be paid to areas containing “escape routes”.

12.16 EMERGENCY DIESEL GENERATORS

One no. 200kVA diesel generator set shall be provided to feed essential station load in case of outage of generating units. This will be connected to Low voltage switchgear board at P/H and will supply power to essential auxiliaries of the units, required for restart of units, a 75kVA DG Set at intake for emergency gate operation and selected emergency lights. The diesel generator will be standard 400volts, 4 wires, 50Hz, Auto start type. The diesel generators shall be supplied with a local control panel which shall include all facilities for remote, auto start and control by the station control system (SCS) as well as facilities for manual starting and loading.

The diesel generator sets will be installed in a properly ventilated room, equipped with fire detection and firefighting arrangements.

12.17 ELECTRICAL WORKSHOP

The power plant will be provided with an electrical workshop. It shall be consisting of essential equipment to perform the day to day maintenance of electrical equipment. The necessary electrical T&P and testing equipment i.e. voltmeter, ammeter, ohmmeter, odometer, megger meter, etc. with whole range of special and standard tools necessary to perform all electrical as well as the associated mechanical work for maintenance and repair of the power plant equipment shall be required in the workshop.

Sizes and technical data of equipment shall principally be maintained but may be adjusted to fit with vendor’s standard production program. Sizes of wrenches and other relevant tools shall be supplied according to the metric system.

12.18 GROUNDING SYSTEM

Metallic parts of all the electrical equipment in or around the powerhouse shall be connected to the grounding system for safety of the personnel and equipment. It shall use stranded bare copper conductor in the concrete floor slabs. Ground rods shall be driven in soil surrounding the powerhouses. The number of electrodes shall be determined during the final design stage, keeping in view the soil resistivity and touch/step voltage. The grounding grid shall be capable to sustain without damage heavy currents during short-circuits for specified time. The Engineer/contractor during detailed design study shall carryout the necessary measurements to determine the ground and ground water resistivity to be used for the calculations and the design.

The actual cross-section of the earthing conductors will be defined in the earthing system calculation. All equipment associated with the plant including reinforcement steel and embedded steelwork will be bonded to the earthing electrodes by adequately dimensioned conductors. Surge arresters and transformer neutrals will be directly connected to the main earthing conductor and /or particular earthing rods.

12.19 SCADA AND TELECOM SYSTEM

12.19.1 Functional Overview

The SCADA and Telecommunication system shall comprise three sub-systems:

- An In-plant Instrumentation and Control system allowing monitoring and control of the plant (referred hereafter as the station) including generators, all auxiliaries, the associated switchgear, and 132 kV switchyard.

- An interface to the existing NTDC SCADA system at the National Power Control Center (NPCC) Islamabad enabling system dispatchers partial control of the Attabad Lake Hydropower Plant from Islamabad.

- A Telecommunication System for the distribution of voice and data within the Power Plant and for exchange of voice and data with NPCC Islamabad.

12.19.2 Station Instrumentation and Control (I&C) System

An in-plant I&C system shall be deployed for the monitoring and control of the power house and auxiliary systems, including:

- Control of generators including output power and ALFC.

- The monitoring of rotor vibration and air gap for generators.

- The monitoring and limited control of spillway gates, power intake flows, water levels, and their auxiliaries.
- The operation of 132 kV Circuit Breakers (in association with NPCC).

The plant instrumentation and control functions can be performed by either a hierarchical SCADA or a distributed control system (DCS). In view of the modularity and superior fault tolerance capabilities of the DCS the latter is proposed for the in-plant or station I&C system. The DCS shall comprise smart transducers and instruments installed across the plant. The controllers, transducers and associated field devices shall communicate over a plant wide LAN. Internet Protocol (IP) and other open standard protocols shall be deployed with built in diagnostics to monitor device health and predict problems thereby avoiding downtime. Field transducers shall communicative with the controllers over industry standard protocols. The station operational staff shall be provided with a Human machine interface (HMI) set up in the station control room for control and routine operation of the power plant.

12.19.3 Interface with Existing NTDC SCADA System

Selective key parameters of the Attabad Lake power complex shall be remotely monitored by NPCC and key functions will be remotely controlled from the National Power Control Centre (NPCC), Islamabad in line with NTDC's standard operational practices. The generation of power and 132 kV transmission system at Attabad will be managed by NPCC and the DCS in control room of Powerhouse will be responsible for station control and instrumentation requirements.

NPCC will be responsible for the overall generation and transmission management associated with the Project, while the station DCS will be responsible for the overall station control and instrumentation requirements as well as interfacing with NPCC through appropriate hardware.

All the important plant parameters like active and reactive power of generators, and transmission lines, station frequency, busbar voltage, reactors disconnect switches and faults alarms will be monitored remotely.

The plant DCS shall monitor and display position of circuit breakers, isolators, all local/remote switches for generators and circuit breakers and indication of Automatic Load Frequency Control (ALFC) etc.

12.19.4 SCADA Facilities for Tele-Control by NPCC

To enable NPCC to control selective key parameters of the Attabad Lake Power Plant, the following two alternative methods have been considered:

Alternative-1

This alternative is an extension of the existing hierarchical SCADA system based on front end computers deployed at NPCC Islamabad. It deploys conventional Remote Terminal Units (RTUs) serving the NPCC SCADA System and is independent of the station DCS at Attabad.

The SCADA requirements will be handled by two separate RTUs, one for monitoring and control of the Powerhouse and one for monitoring and control of 132 kV Switchyard.

Inter RTU communication shall be provided, if required. The RTU in the powerhouse will be configured in the most effective manner, for example:

- As a separate RTU, or
- As a distributed input/output module from the AIS RTU, or
- As a “slave’ unit scanned by the AIS RTU.

The RTU equipment will be capable to cater for future requirements of Powerhouse and switchyard augmentation.

For the measurements of MW, MVAr, kV and frequency etc., separate transducers will be provided in the SCADA Interface.

Advantages

Since the RTUs would be obtaining their own information from the field mounted sensors and transducers, a breakdown in the station DCS would not hamper the flow of information from the field.

Alternative-2

This alternative comprises hardware establishing an inter-computer data communication link bridging the station DCS with front end computers hosting the NPCC SCADA applications. A redundant gateway controller/inter-center communication controller, for data inter-change between the station DCS and the SCADA master system at NPCC Islamabad will be installed in the station control room for monitoring and control of the station equipment under SCADA. Dual processors configured as online and hot standby with duplicated database and operating system will be employed in the gateway controller. The gateway will interface with DCS equipment through dual redundant communications infrastructure Gateway or Inter-center communication controller fulfilling all aspects of the communications between NPCC and Attabad Lake HPP Control Room.

In this alternative, no information shall be collected afresh by NPCC rather a subset of information already collected by the station DCS for station control shall be passed on through the Communications Gateway to NPCC.This would save duplication of transducer for data collection, thereby precluding additional interfacing. For reliability, both path and media redundancy shall be deployed for data communication between the station DCS and NPCC utilizing PLC, optical fiber or alternate telecommunication means.

The amount and type of information exchanged between the station DCS and NPCC shall be a software configurable parameter of the gateway controller. The authorization of 132 kV circuit breakers control will be from the NPCC and the station DCS will only monitor the status of circuit breakers. However, this authorization can be set to local control during emergencies or maintenance. The authorization of each 132 kV circuit breaker control will be set individually from the DCS operator console. The selectable authorization levels shall be SCADA, DCS, or local. Similarly, the assignment of ALFC authorization of each generator will also be done from DCS.

12.19.5 Local/Remote Switches

"Three position" (i.e. SCADA/DCS/Local) switches will be provided in the local control panels of 132 kV switchgear equipment and the generator/governor local control panels (LCP) for the 11 kV circuit breakers and generating units respectively.

12.19.6 SCADA Control Philosophy

Normally the operation of 132 kV circuit breakers will be from NPCC and the switchyard DCS will only be monitoring their status. However, during emergencies or maintenance, the control authorization of circuit breakers will be set on local control (either station DCS or local control panel). The authorization of each 132 kV circuit breaker control shall be set from the individual three position local/remote switch (SCADA/DCS/Local).

The assignment of each generator set point control or ALFC authorization to SCADA/DCS/Local will also be done from the respective generator local/remote switch. ALFC control from NPCC will be either in the form of a set point value or increase/decrease command to the unit's governor. Operation of the plant local/remote switches will be authorized from NPCC.

RTU communication with NPCC Front End Computers will be through duplicated data channels along the PLC/fiber optic links.

12.19.7 Telecommunication System

Dual play data transmission media for transmission of speech, facsimile, data (including energy metering) shall be set up between NPCC and Attabad Lake Powerhouse. Tele protection channels, provision of telecom equipment for power interface with existing NTDC operational telephone network for operational traffic between Attabad Lake HPP and NPCC/existing stations, along with the facilities to meet the administrative traffic for the Power Complex shall also be set up as part of the Telecommunication system.

12.19.7.1 Powerhouse Communication

A communication system consisting of Local Area Network (LAN), digital telephone system (PAX/PABX), VHF radio systems and station clocks will be provided for communicating the power house with intake, switchyard, and residential camp and outside.

A digital telephone network has been planned to be installed in the powerhouse to cover the entire plant (powerhouse, switchyard, intake, the residential camp and outside).

Each generating unit will include at least one noise cancelling telephone per floor. And also step up transformer area will be provided with noise cancelling telephone sets. The outside telephones will be weather proof and installed in the switchyard and other appropriate locations. All offices, workshops, ventilation rooms, battery charger rooms etc., in the power house will be provided with telephone extensions from the digital telephone system.

12.19.7.2 Power House Intake Communication

A fiber optic cable clamped to the 11 kV feeder from powerhouse to intake has been planned to be used for communication purpose. This will have advantages in reliability, quantity of information which can be transmitted and most important no problems with electro-magnetic compatibility which outweighs by far its higher price.

A backup digital radio communication link will be provided from powerhouse to intake for communication and protection purposes.

12.19.7.3 External Communication

WAPDA uses Power Line Carrier (PLC) for its communications between powerhouses and the load dispatch centre. The coupling is done between one phase and earth which makes it necessary to install for each communication line, one-line trap and one coupling capacitor at each terminal.

The location of the equipment will be partially in the switchyard and partially in the area of the control room. The 50 VDC communication supply will provide necessary power when there is a power failure in the normal auxiliary supply.

This system will give the possibility for voice and signal transmission on 132kV line between the remote powerhouse and the load dispatch center.

The control room will be additionally connected to the public telephone system to guarantee the communication with the power plant in case of failure of the PLC system.

12.19.8 Teleprotection

For 132 kV transmission lines emanating from the Powerhouse, duplicated teleprotection channels will be provided for high speed direct tripping (for breaker failure and reactor protection) and permissive tripping (for distance protection) of lines along with blocking of tripping. In order to achieve maximum security and redundancy, the direct tripping signaling will utilize different equipment to that used for permissive/blocking schemes. The teleprotection signals will not interfere with the speech signals. The equipment for teleprotection will have the flexibility for transmission over any communication medium i.e. PLC or OPGW.

12.19.9 Public Address System

For announcement and instructions to the staff in the Powerhouse area, a Public Address system shall be provided which consist of a central power amplifying unit/ and a number of microphones and loudspeakers.

Control consoles with microphones will be provided in the CCR and in each local control area. The complete system will be modular in structure. The system will be capable of selecting a single loudspeaker or a group of speakers.

12.19.10 Un-Interruptible Power Supplies (UPS)

A 48 V DC UPS system will be provided for SCADA & telecom equipment to remain functional and operative at all times. The UPS will supply the loads for PLC, Fiber Optic Terminal, RTU, Teleprotection, PABX, PAX and public address equipment. The UPS system will be fully redundant and will comprise duplicated battery chargers, battery banks and DC distributed boards to supply the loads.

12.19.11 Time Synchronization

A station clock system will be provided to ensure constant time keeping across the plant. A master clock will use local time and be synchronized using the Global Positioning System (GPS). The master clock will run slave clocks installed at key locations around the powerhouse especially on the generating unit panels. For tagging of events

satellite based Global Positioning System (GPS) with accurate time synchronization, will be utilized with time receivers at Powerhouse and NPCC. These receivers will communicate with Powerhouse and NPCC master clock system.

12.19.12 Video Surveillance System (CCTV)

The Video surveillance system shall comprise CCTV cameras, power supplies and video recording equipment enabling selected locations of the power house premises to be monitored remotely from the control building. The objective of video surveillance system shall be to monitor the entry/exit gates, boundaries, power house premises for security purposes.

The closed-circuit television (CCTV) system will be provided to monitor the condition and status of the project area remotely from the control room of the main control building. The following places

- Intake structure
- Powerhouse
- Entrance gate
- Erection bay (entrance of powerhouse)
- Machine bay
- Essential rooms
- Transformer and 132 kV AIS
- Unit transformer room
- Entrance gate of switchyard
- Entrance of main control building

Video archives for past seven days shall be maintained to facilitate post facto analyses of any untoward incidents. System design shall be flexible to permit future extension of the system. This subsystem shall comprise of the following major components:

a) Video cameras

b) A network video recorder capable of storing video bit streams generated by each camera of up to the last seven days.

The CCTV system shall be extended according to the requirements.

13 TRANSMISSION LINE STUDY

13.1 GENERAL

This chapter aims to summarize the interconnection of 54 MW Attabad Lake Hydropower Project (being proposed at Attabad Lake on Hunza River in Hunza District) to Regional grid through 132 kV transmission line network.

The main objective of the transmission system studies is to ensure that the power plant could be connected to the proposed 132kV regional grid at Aliabad and Sost, in a safe, cost effective and reliable manner.

The Northern Areas of Pakistan, located at the gateway to China, Central Asia, Afghanistan and India, are spread over mountainous regions with world's famous mountain ranges of Himalaya, Karakoram and Hindukush. It covers an area of more than 72300 km². The population settlement is normally near the confluence of small streams with main nullahs and the river. In some cases, it also exists inside the valleys where the nullahs have mild gradients with morainic deposits. Slopes of the streams and the tributary rivers, creates tremendous potential that can be harnessed to get cheaper renewable source of energy for feeding to the regional as well as the national grid.

Transmission system of an individual project can only be developed in an appropriate manner when the parameters and layout of existing system that will be needed to satisfy the production and demand of the area, for a certain planning horizon is available. Unfortunately, there exists no comprehensive and integrated transmission network in the entire northern areas, hence no proper data is available that can provide the basis for the planning of transmission system. However, Water & Power Dept. GILGIT BALTISTAN has made a plan to establish certain parameters for the future planning of transmission system in the area.

To cater with the growing energy needs of the area, transmission of power from the national grid to the northern areas can be considered as one of the possible options. But the most suitable option to meet the immediate energy needs of the area, is the rational exploitation of renewable energy sources in the area.

Attabad Lake Hydropower Project is one among these identified run of river schemes that can be developed for the regional grid. The project is located in Attabad area at Hunza river, at a distance of 27 km from Aliabad and 120 km from Gilgit. In order to evacuate the power generated by the project, and taking into account the technical and economical parameter, a regional transmission network shall be developed, to link effectively, the load centres that can efficiently absorb the energy. The surplus power shall be required to transmit to the regional grid in Gilgit through the interconnection network of 132 kV transmission lines.

Currently, entire region of Gilgit Baltistan is facing the shortage of electricity. Water & Power dept. of GILGIT BALTISTAN has prepared the plan to meet the demand by installing new hydropower projects with the commissioning and upgradation of transmission network. In this scenario, Attabad Lake HPP will help out to meet the energy demand in Hunza and other cascaded districts.

Following are the necessary activities to establish basic project parameters / information on which the whole transmission line project will be based.

- Identification of tentative transmission line route from Attabad to the nearest load centers.
- Study and analysis to select the main components e.g. conductor, tower's type, insulator' type & strength and related hardware.
- Quantification of different components of transmission line.
- Development of cost estimate.

13.2 EXISTING GILGIT BALTISTAN TRANSMISSION SYSTEM

Gilgit-Baltistan lies between longitude 73 degree and latitude 35 degree and the population of about 1.5 million people spread over an area of 72496 sq, km. Topographically the region is mountainous and hilly surrounded by the ranges of Karakorum, Himalayas and Hindukush with deep gorges and narrow valleys. The region is not connected with the national grid due to its mountainous terrain, non-availability of high-power transmission line system and extreme weather conditions. The electricity demand of the area is mostly met by developing isolated micro and small hydro power stations having capacity 0.4-18MW installed on various rivers and nullahs. Electric power so generated is transmitted through 66KV, 33KV and 11KV overhead transmission lines and distributed through 400V LV distribution system on off grid basis.

13.3 ESTABLISHMENT OF REGIONAL GRID

Presently Gilgit-Baltistan area grid of 140 MW capacity is operating in many islands and is not connected to any grid system. There was need of assembling the data and model the present grid system and plan the interconnection along with new incoming large hydro plants. Presently the power network is based on off grid and the aim of the project is to bring them on one-grid in the region and readiness for further connection to the National Grid.

The main objectives are as under:-

Reduction of the present power loses of over 35% to the allowable limits.

Efficient management of power supply in Gilgit-Baltistan due to interconnection of all the power stations and increase of diversity factor.

Development of HPPs at the most promising sites due to availability of high voltage transmission network.

Connection to the National Grid would be possible for evacuation of surplus power to the National Grid to meet the shortage at the National level.

Attraction to the private sector to invest in the hydro power sector on IPP & PPP modes to supplement the National Grid to overcome energy shortage and to minimize subsidy and circular debt.

The regional grid would further be connected to the National Grid for evacuation of surplus power and to attract private investors to develop HPPs at the most promising sites in the region to meet the energy shortage at the National level. High voltage transmission lines of 132 KV and 66 KV along with grid stations have been proposed according to the feasibility study conducted through an independent consultant.

13.4 PARAMETERS FOR TRANSMISSION LINE STUDY

Transmission system of an individual project can only be developed in an appropriate manner when the parameters and layout of existing system that will be needed to satisfy the production and demand of the area for a certain planning horizon is available. Unfortunately, there exists no comprehensive and integrated transmission network in the entire northern areas, hence no proper data is available that can provide the basis for the planning of transmission system. However Water & Power Dept. GB has made a plan to establish certain parameters for the future planning of transmission system in the area.

Following are the necessary activities to establish basic project parameters / information on which the whole transmission line project will be based.

In coordination with Water & Power Department Gilgit-Baltistan, identification of transmission line route from Attabad to the nearest load centers.

Quantification of different components of transmission line.

Study and select the main components e.g. conductor, towers, insulators and related hardware.

Development of cost estimate.

13.5 TRANSMISSION LINE FROM ATTABAD LAKE HPP

The power generated by the Attabad Lake Hydropower Project shall be mainly supplied to the load centers in the central Hunza, Aliabad and the upper Hunza (Sost) through 132 kV transmission lines. The transmission line from Attabad Lake HPP to Aliabad & Sost shall fulfill the transmission requirements keeping in view N-1 contingency and transmission of power generated by the expected future hydro power projects. A double circuit 132 kV transmission line of 27km will be connected to the proposed Aliabad Grid station to further disperse the power in the Regional Grid Network (RGN).

Alongwith double circuit 132 kV transmission line to Aliabd, a 132 kV single circuit of 70 km transmission line is also proposed upto the existing 33kV grid station Sost which is already in operation to cater for the domestic electricity demand and likely to be upgraded to 132/33/11 kV grid station. Govt. of GB is planning to make the Sost area industrialized and a dry port there in upcoming years. In the route of Aliabad to Sost, population is less and scattered therefore to meet the domestic electricity demand, already existing 33 kV line will be used to disperse the power from Sost to upper and lower nearby populated areas.

Aliabad is the commercial and administrative centre of Hunza district. Water and Power Dept. (GB) has proposed the 132/66/11 kV, 55 MVA capacity grid station in the Aliabad. There are 3 suitable sites located aside the bank of Hunza River passes near to Aliabad Town. The coordinates of these sites are listed below:

Alliabad Grid Station	Longitude	Latitude
Site 1	74°38'6.65611"/ 74.6241230583	36°18'8.71248"/ 36.3024201327561
Site 2	74°38'6.65611"/ 74.6351822536	36°18'34.36322"/ 36.309545339016
Site 3	74°38'7.22723"/ 74.6353408969	36°18'33.69423"/ 36.309359508971

All sites are located above the river water surface level. The studies regarding flood dangers will be carried out at design stage by Engineer. Large gravels are found at sites 1 & 2, while site 3 is located on plane ground. Final site to construct the Grid station will be selected by Water and Power Gilgit Baltistan.

13.6 TRANSMISSION VOLTAGE

As per Pakistan's Grid Code, the voltage of all the busses under normal operating condition should remain within the bandwidth of +8% to –5% of Nominal System Voltage. Under (N-1) contingency operating conditions, the voltage variation shall be in the range of +10% and –10% of Nominal System Voltage.

132 kV will be most suitable and economical to transmit power of 54 MW from Attabad-Lake Hydropower Project to Aliabad & Sost grid stations as the same voltage level (132 kv) has been selected for up-gradation of regional grid.

13.7 LOADABILITY CHARACTERISTICS

Load ability or transfer capability of transmission line depends upon the following:

- Voltage of the system
- Length of the transmission line
- It is represented as a percentage of its Surge Impedance loading (SIL) permissible with in the allowable voltage drop, thermal and stability limits.
- An increase in power (current) in a line will:
- Increase I^2R loss and hence temperature of the conductor denoted
- Cause increase sag of the conductor.
- Increasing sag decreases the clearance to the ground of conductor.
- Increase the voltage drop.
- increase the transmission line angle.
- All the above mentioned factors limit the maximum power transfer capacity of the transmission line. In fact, the governing limitations are different for different lines depending on:
- Line length
- Type and degree of compensation
- System characteristics / conditions

According to the universal load ability curve for overhead transmission lines, load ability for a transmission line of 80 km length is 3.0 times its SIL (Surge Impedance Loading) and increases exponentially for lines of length shorter than 80 km.

13.8 NUMBER OF CIRCUITS

Numbers of circuits for a power transmission line are determined by the power carrying capacity of a particular voltage level over the required distance. Transmission line loadings should not exceed 85% of their normal ratings under steady state operating (normal) conditions. Under outage/contingency conditions, the transmission lines may be loaded up to their short term or emergency ratings which are equal to their SIL (Surge Impedance Loading) or thermal ratings depending upon the line length involved.

A double circuit transmission line is envisaged from Attabad to proposed Aliabad grid station, which will further disperse the power in the Regional Grid Network (RGN).

The double circuit transmission line to Aliabad will be necessary keeping in view the 'N-1' criterion as well as possibility of induction of additional power from future power projects in the area, The option of single circuit is also otherwise not feasible because system voltage and stability will remain at stake even under normal operating conditions, if full capacity of about 130 MW on 132 kV line is utilized with future local generation.

A single circuit with N contingency is proposed to transmit the power Whereas, from Attabad Lake HPP to Sost.

13.9 TRANSMISSION LINE ROUTE

Detailed visits of the project area concludes that the possible transmission line route will be along KKH road/ Hunza River depending upon the accessibility to the transmission line route while no alternate route is available. The whole terrain is mountainous with steep gorges and tight bends on the road. The areas along the route may be subjected to snowfall on some sections from the project site to the load centers.

Access to the tower sites during execution phase will mainly be possible from the existing road. At some places the tracks / kacha roads exist which may require repairs, along with construction of new approaches for transportation of construction machinery and line materials. In order to overcome certain constraints, the line may have to be crossed to the other bank of Hunza River. Few locations may not be accessible; in such cases material will have to be transported to site through alternate means.

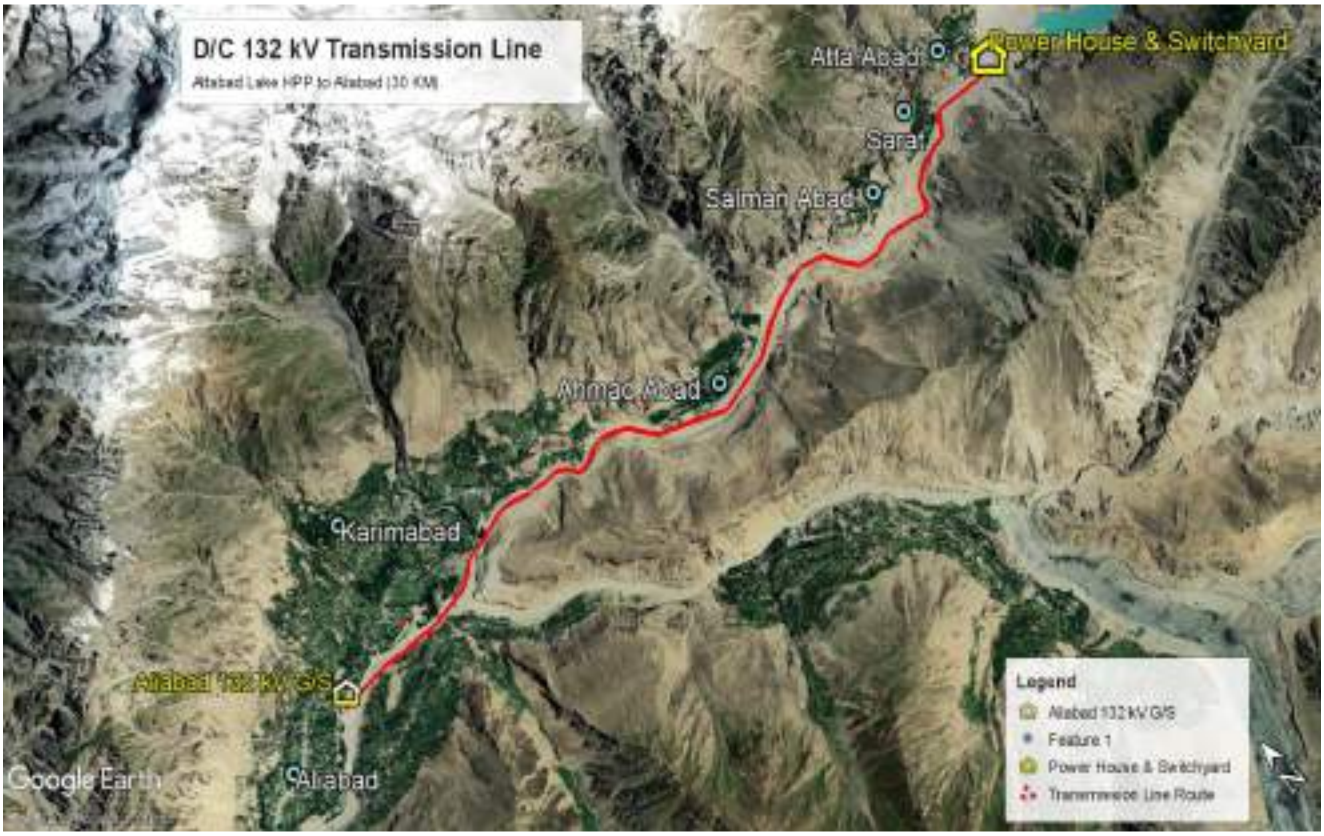


Figure 13-1 Transmission line route -Project Site to Aliabad G/S

The types of rock observed along the line route corridor are suitable for tower foundations on hill slopes. Controlled blasting will also be required both for making approaches and constructing tower foundations. In view of the prevailing terrain and environmental conditions along the proposed line route, careful design considerations such as providing higher ratio of angle towers to suspension towers along with its extent, shorter spans, insulators of suitable type and higher strength and related hardware of compatible strength are required.

Detailed survey followed by preparation of plan & profile drawings and spotting of towers will however be done separately during the detail design stage.

Figure 13-2 Transmission line route -Project Site to Sost G/S

13.10 CLIMATIC CONDITIONS

The Gilgit / Hunza River basin falls in the "subtropical continental high lands" climatic region. The weather of the area is characterized by moderate summer and severe winter. The winter season starts from November and extends up to April, and summer from May up to October. The temperature data of areas is presented in Table 13-1.

Table 13-1 Monthly Max. and Min. Temperatures

Location	Mean Monthly Max.	Mean Monthly Min.
Attabad	25° C	- 10° C
Hunza	30.6° C	- 8.0° C
Gilgit	36.1° C	- 2.7° C

13.11 SELECTION OF CONDUCTOR

As a normal rule, the conductor of a double circuit transmission line is selected on the following basis:

- The conductor should be capable of carrying the desired quantum of power under normal operating conditions, as well as under the situation of contingency outage of one of the two circuits.
- It should be strong enough to withstand extra loadings due to ice and wind pressure.

- It should be helpful in improving system operating conditions, including voltage profile, phase shift / stability, power losses etc.

Selection of conductor for the line has been done through comparison of Lynx, Panther and Rail conductors, which is presented in Table 13-2.

Table 13-2 Comparison of ACSR Lynx, Panther and Rail Conductors

Sr. No.	Description	ACSR LYNX Conductor	ACSR Panther Conductor	ACSR RAIL Conductor
1.	Number and diameter of each aluminum strand (mm)	30/2.79	30/3.00	45/3.70
2.	Number and diameter of each steel strand (mm)	7/2.79	7/3.00	7/2.47
3.	Overall diameter (mm)	19.53	21	29.61
4.	Area of cross section of aluminum (mm²)	183.4	212.10	483.43
5.	Area of cross section of steel (mm²)	42.77	49.40	33.43
6.	Total area of conductor (mm²)	226.17	261.50	516.86
7.	Weight (Kg / Km)	842.4	973.8	1600.2
8.	Ultimate tensile strength (Kg)	8483	9410	11749
9.	DC resistance (Ω/ Km)	0.1580	0.1363	0.0600
10.	Current carrying capacity at 40° C (min. at w nd vel. of (m/s) (Amp)	330	367	626
11.	Power loss (W/Km/Amp)	0.474	0.408	0.180

13.11.1 TENSILE STRENGTH

The above comparison shows that the ultimate tensile strength of Rail conductor is around 38% & 24% higher than that for Lynx & Panther conductors, respectively. Hence, Rail conductor will be more reliable and secure in difficult terrain encompassing high mountains, steep gorges, sharp bends & difficult crossings as well as high to low degree of snowfall & wind pressure along the proposed transmission line route.

13.11.2 POWER TRANSFER CAPABILITY

The current carrying capacity of Rail conductor is around 90% and 70% higher than that for Lynx and Panther conductors, respectively.

One circuit of Rail conductor will accommodate safely up to 130 MW with acceptable voltage and other system conditions. Hence, in case of outage of one circuit from Attabad Lake HPP to Aliabad, other circuit with rail conductor will not only accommodate full power of 54 MW from Attabad-Lake Hydropower Project but will also have provision of accommodating additional power of other possible future power projects in the area.

13.11.3 POWER LOSSES

Power loss through Rail conductor will be about 62% and 56% less compared to that for Lynx and Panther conductors, respectively.

13.11.4 RECOMMENDATION

Due to the above mentioned advantages, it is recommended to use Rail conductor for the subject. Rail conductor will be in accordance with WAPDA / NTDC Specification No. P-50:88.

13.12 TOWERS

13.12.1 TYPE AND BASIC DATA

Towers will be as per WAPDA / NTDC Standards and Specifications applicable to double circuit & single circuit 132kV transmission line using Rail conductor.

Types of these towers as designated in the Specifications are “ZM-1”, “ZM-30” and “ZM-60”. “ZM-1” is Suspension tower whereas “ZM-30” & “ZM-60” are Angle towers. Basic data of these towers is as follows:

ZM-1

Deflection Angle	30^0
Wind Span	230 m
Weight Span	260 m
Weight of the basic tower	4275 kg
Weight of 3 m Leg extension	708 kg
Weight of 6 m leg extension	1400 kg

ZM-30

Deflection Angle	30^0
Wind Span	230 m
Weight Span	260 m
Weight of the basic tower	6415 kg
Weight of 3 m Leg extension	1242 kg

ZM-60

Deflection Angle	60^0
Wind Span	230 m
Weight Span	260 m
Weight of the basic tower	8594 kg
Weight of 3 m Leg extension	1739 kg

13.12.2 TOWER CONFIGURATION

WAPDA/NTDC Standard configuration will be used as much as possible. This shall facilitate design, erection, maintenance, stock, etc. and shall also use the organizational experience in construction, operation and maintenance. Therefore the existing WAPDA/NTDC drawings for double circuit & single circuit 132kV are to be taken as base.

The new tower configuration has to consider the behavior of conductors and earth wires in different Zones under the conditions with and without ice, under wind acting on them and considers the movement of conductors due to dropping of ice.

To minimize stresses in earth wire peaks at suspension towers due to unequal span length or unequal additional loading. It is recommended to clamp the earth wires by V frame with approximately 0.7m length at the tension tower peaks. This would prevent grid mounting and allows balance of difference in tensions. For the new tower configuration it is assumed that sag and ground clearance shall be the same as for standard 132kV lines built so far.

It is assumed that towers will need increased internal clearance to consider different behavior of conductors under the no load and load conditions as well as the unequal dropping down of accretions.

13.12.3 MIX OF DIFFERENT TYPES OF TOWERS

The numbers of each type of tower shall be finalized as per site during the detail engineering design.

The ratio of suspension tower to angle tower come out to be 30: 70 as compared to the ratio of 80: 20 generally used in plain areas. The low ratio of suspension towers to angle towers will be one of the most important factors with respect to the reliability and security of the subject transmission line along the difficult route involving difficult, mountainous terrain, steep gorges and sharp bends. Provision of appropriate number of WAPDA / NTDC Standard 220 kV towers of types EA, ED & EG, respectively, is also recommended for use specially at locations involving crossings of steep gorges, river etc.

The average span shall be based on the site conditions during the detail engineering design stage. The important aspects for length of span are however are the acceptable margin of safety, additional estimated combined loading of up to 25 % on towers due to ice accretion. If required, the spans can be further reduced for line stretch in high ice zone and with longer spans in low ice areas, during project execution stage.

As mentioned earlier, the task of detailed survey, preparation of plan and profile drawings and spotting of towers will be undertaken during the project execution stage. Type of tower and span at each identified location throughout the line stretch will also be determined and finalized with the approval of the Engineer.

13.12.4 ADDITIONAL LOADINGS DUE TO ICE AND WIND

During extreme winters, additional combined load on towers due to ice accumulation on conductor, insulators and cross arms is expected to be up to 25 % of normal loading, ranging from maximum to minimum between project site to load centers.

The number and mix of angle to suspension towers with much reduced spans will help sustain the additional loading on towers due to ice and wind. However, larger foundation base may be essential requiring design of new towers and tower foundations to withstand simultaneous impact of ice and wind pressure especially in the high ice zone. This aspect should be got checked by NTDC, based on their experience of existing transmission lines in the similar areas.

If concerns about stability of towers against extreme ice and wind conditions could not be resolved, then employer should consider awarding this project on EPC basis wherein the contractor will also be responsible for design of new towers and associated foundations, if needed.

In any case, design and testing of new towers is highly specialized and an independent task which is not covered under the present scope of work.

13.12.5 WAPDA / NTDC SPECIFICATIONS

For proposed towers, the related WAPDA / NTDC Specifications are as under:

Fabrication of Steel Structure	P-139:80
Zinc Coatings	P-82:81
Steel Nuts and Bolts (Inch Series)	P-19:83
Barbed wire	P-162:81
Danger & Sign Plates	P-104:76
Steel Washers	P-20:68

13.12.6 FOUNDATIONS

Tower foundations will be in accordance with WAPDA / NTDC Standards and Specifications.

Foundation type and design will be corresponding to each type of Standard tower used.

Geotechnical investigations for construction of foundations will be carried out during the project execution stage. Foundations will be classified as normal, pile, rock-anchor, or any special foundation not covered in the WAPDA / NTDC Specifications.

For each foundation, each type of foundation will be identified during project execution stage which will be reviewed / approved by the Engineer. The design and method of construction for any special foundation not covered in the WAPDA / NTDC Standards will also be submitted to the Engineer for review / approval.

13.12.7 INSULATORS

In order to avoid flash-over due to ice and fog, Fog type porcelain insulators are recommended to be used. In normal areas, insulators of 80 kN strength are used on 132 kV transmission lines in NTDC system. However, because of difficult conditions associated with route of the subject transmission line, Fog type insulators of 100 kN strength have been considered to make the line completely reliable and secure. 8 numbers of insulators per string is recommended. The Fog type Insulators will be in accordance with WAPDA / NTDC Specification No. P-8:96.

The WAPDA / NTDC Specifications for insulator hardware will be as under:

Suspension Strings:	P-140:82
On Strings	P-143:82

13.12.8 MISCELLANEOUS ITEMS

Miscellaneous items of transmission lines will be according to the following WAPDA / NTDC Specifications:

Galvanized Steel Wires	P-12:80
Earth Wire Fittings	P-141:80
Mid Span Joints and Repair Sleeves	P-144:80
Stock Bridge Vibration Dampers	P-142:83
Grounding Material	
Earth Rod	P-116:81
Copper Wire for Earthing	P-16:68

13.13 OPTICAL OVERHEAD GROUND WIRE (OPGW)

In order to protect the transmission line and grid station equipment from lightning and to transmit the protection and communication signal optical ground wire will be provided.

The main features of the cable will be

OPGW size	70 mm2
Outer diameter	11.4mm
Breaking load	8000kg
DC resistance at 20ºC	1.02 ohm/km

Nominal weight	458kg/km
Number of fibers	at least12

13.14 ENVIRONMENTAL ASPECTS

In high voltage range, the conductor selection is based on

a) Corona losses
b) Radio interference (RI)
c) Television interference
d) Audible noise (AN)

13.14.1 CORONA LOSSES

The effect of increasing the operating voltage of a line as its critical surface gradient (21.2kV/cm) is approached, is producing power losses in the lines and causes the conduc tor to generate emanate higher frequencies causing radio and television interference.

For Attabad-Lake HPP transmission line, the conductor diameter will be higher than the permissible limit. In view of the rail conductor, there will be no problem of corona, radio interference and television interference.

13.14.2 AUDIBLE NOISE

Up to 220 kV level, the audible noise generated by transmission lines is usually no concern. The level of AN generation with conductor design which satisfies the RI requirements sufficiently low.

13.14.3 Surface Gradient

The clearance between overhead transmission lines and nearest objects are set primarily to avoid any possibility of flash over. The proposed design ensures that there will be no problem of surface gradients causing charging current through the human body or passing vehicle.

13.15 MINIMUN CLEARANCE OF 132 KV TRANSMISSION LINE

The minimum clearance of the proposed 132 kV overhead line is as follows:

i.	132 kV lines across country	6.71m
ii.	Over roads and highway	7.92m
iii.	Over rivers and canals	9.14m
iv.	Minimum clearance from building Vertical	5.18m
v.	Horizontal	6.10m

14 PROJECT QUANTITIES AND COST ESTIMATES

14.1 GENERAL

The cost estimates form the basis of the economic and financial evaluation of the Project. These have to be prepared on the basis of representative unit rates for the various construction activities and the respective quantities. The estimation of cost for Attabad Lake Hydropower Project (ALHPP) has been carried out on the basis of Feasibility Drawings.

The cost estimate for ALHPP covers quantities and costs for Preparatory works, Environmental Mitigation, Civil and Electrical & Mechanical (E&M) works. Civil Works items such as earthwork, concrete, reinforcement, shotcrete and grouting, etc. have been estimated based on Feasibility Drawings. Rates adapted are based on WAPDA Composite Schedule of Rates, Material based Survey Rates and recently tendered WAPDA Projects.

14.1.1 Basic Assumptions

Few assumptions are always made in cost estimation. For this costing, following assumptions and exceptions are considered:

- No allowance has been kept in the rate analysis for price escalation. All rates have been evaluated on March, 2021 prices.
- Project layout and alignment of structures will not change.
- The survey on which the whole study has been according to prevailing International Standards.
- Specifications for the construction would be according to prevailing International Standards.
- Land acquisition of the Project Area and other pre-construction activities will be completed before Contractor’s mobilization.

14.2 COST ESTIMATION

Cost estimation of any Project or its component is based on two factors; one is Quantity and the other is Unit Rate. The cost estimates for various works including Preparatory works, Civil and E&M works have been prepared by multiplying unit rates with the relevant quantities of different items.

14.2.1 Price Index

For Local & Foreign cost component the rate of 1 US$ = Pak Rs. 157 of March, 2021 price level has been adopted.

14.2.2 Development of Unit Rates

To develop the unit rates, the operating cost of the equipment, labour and material cost has been worked out from basic data.

Rental and Operating Cost

The operating cost of the equipment are worked out which includes the rental cost of machinery, operators' charges and fuel, lubricant and minor repair costs.

Labour Cost

The rates of wages for the skilled, un-skilled and operators for various construction equipment are required to work out operating cost. The selected rates are based on market wages in Hunza District. These rates are based on 8 hours of work per day.

i. Rental and Operating Cost

The operating cost of the equipment are worked out which includes the rental cost of machinery, operators' charges and fuel, lubricant and minor repair costs.

ii. Labour Cost

The rates of wages for the skilled, un-skilled and operators for various construction equipment are required to work out operating cost. The selected rates are based on market wages in Hunza District. These rates are based on 8 hours of work per day.

iii. Material Cost

These costs fall under two categories:

- Manufactured items: e.g. cement, POL, steel, etc. The unit rates taken for these items are ex-factory rates including transportation to the site.
- The other category includes concrete aggregates and riprap which are readily available at site. These materials will be processed in size as per requirement at site and used. Local market rate has been taken for these materials for rate analysis.

14.2.3 Rate Analysis

Rate analysis for each major item of work includes the rates for individual machines involved in a process, generating composite rates for each major item of works by combining the required number of different machines to develop a workable group and loading it with necessary operators/drivers and materials.

International price for the major equipment were used including its transportation from Karachi port to Project site. Duties and taxes are not included in the equipment cost as it is considered feasible by many foreign contractors to procure the machinery on import/re-export basis by submitting the guarantees against duties and taxes. Bank charges for these guarantees have been accounted for in the computation of Contractor's indirect cost.

Transportation of equipment from Karachi to Project site has been estimated on the basis of cargo handling charges through existing roads. On the basis of rates selected earlier for labour, material and operating equipment, the unit rates for each item is then derived. Specified field conditions are taken into consideration. Provision of overheads, idle hour, supervisions staff cost and contractors profit has been taken while working out the equipment and labour cost components. It has been assumed that:

- Work will be carried out for 8 hours per day and
- 26 working days per month

14.2.4 Basis for Unit Rates

The Project cost is sensitive to the unit rates. Thus, care has been exercised in deriving the unit rates. Unit rates for most of the items of Civil Works of ALHPP have been estimated using rates analysis method. The rate analysis for several items of Civil Works such as excavation, structural reinforced cement concrete, plain cement concrete and, shotcrete have been derived and applied to the quantities for cost estimation. For certain items, the unit rates have been compared and checked with the rates of recently WAPDA tendered projects. The WAPDA Composite Schedule of Rates, 2013 has also been consulted. For some of items related to Project, due escalation has been applied for price level of March, 2021 to arrive at most reasonable and realistic rates.

Cost of E & M equipment is based on budgetary prices from reputed manufactures, both local and foreign. The following factors have also been assumed during the development of Civil and E&M works cost estimate:

- Construction of major civil works and installation of majority of the E & M equipment will be performed using Pakistani or an equivalent cost competitive labor force; and
- Where feasible, equipment fabrication will be carried out locally. Locally produced items could include trashracks, stoplogs, embedded parts and the rolling & welding of steel manifold.

Unit rates adopted for different items are presented in Table-14.1.

14.2.5 Civil Works Quantities

Civil works quantities for cost estimate have been calculated using Feasibility Drawings consisting of plans and sections of all the Project components. These drawings are presented in Volume-2 of Feasibility Report. Efforts have been made to estimate the quantity of each major items of each Project component with accuracy.

Major portion of the Civil Works estimate includes calculations for earthwork, concrete and reinforcement etc. For the major structures such as Main Weir, Sediment Flushing Channel, Power Intake, Low Pressure Headrace Tunnel, Surge Tank, Penstock, Powerhouse, Switchyard and Tailrace Channel, the quantities of earthwork, concrete and reinforcement are presented in Table-14.2.

14.3 BREAKDOWN OF ESTIMATES

The basis for costing of different project components is briefly discussed as under:

14.3.1 Land Acquisition and Environmental Mitigation

Land Acquisition and Environmental Mitigation cost contains the cost of permanent land acquisition for project components, temporary land acquisition, building compensation, spoil disposal area rehabilitation, rehabilitation of villages, livelihood allowance for affectees, monitoring &evaluation and land conservation etc. The total cost of land acquisition and environmental mitigation is estimated as Rs. 208.450 Million (Ref: Table-14.4).

14.3.2 Preparatory Works

The items under this component includes construction of access roads within the Project area, site installations, Contractor camps, construction of camp/colony for Consultants' and WAPDA staff, construction of bridge near powerhouse. The cost for mobilization and demobilization and reservoir slope stabilization & construction risks costs are also included. The total cost for preparatory works is estimated as Rs. 952.945 Million (Ref: Table-14.5).

14.3.3 Main Weir

Estimate for Main Weir includes construction of Main Weir itself along with the construction of upstream and downstream coffer dams to facilitate the working of the main civil structures. The total cost is estimated as Rs. 2,008.821Million (Ref: Table-14.6).

14.3.4 Sediment Flushing Section

Cost of construction of Sediment Flushing Section consists of cost for clearing & grubbing, soil and rock material excavation, rock excavation, concreting, reinforcement, grouting etc. The total cost of Sediment Flushing Section is estimated as Rs. 2,326.679 Million (Ref: Table-14.7).

14.3.5 Power Intake

Cost of construction of Power Intake consists of cost for rock excavation, concreting, reinforcement etc. The total cost of power intake is estimated as Rs. 429,289 Million (Ref: Table-14.8).

14.3.6 Low Pressure Headrace Tunnel

Cost of construction of Low Pressure Headrace Tunnel consists of cost for rock excavation, shotcrete, rock bolts, concreting, reinforcement and access tunnel cost etc. The total cost of headrace tunnel is estimated as Rs. 1,820.182 Million (Ref: Table-14.9).

14.3.7 Surge Tank

Cost of construction of Surge Tank consists of cost for rock excavation, shotcrete, rock bolts, concreting, reinforcement etc. The total cost of surge tank is estimated as Rs. 132.727 Million (Ref: Table-14.10).

14.3.8 Penstock

Cost of construction of Penstock consists of cost for soil and rock excavation, shotcrete, rock bolts, concreting, reinforcement, penstock (steel liner) etc. The total cost of penstock is estimated as Rs. 713.256 Million (Ref: Table-14.11).

14.3.9 Powerhouse and Tailrace Channel

Estimate for Powerhouse and Tailrace Channel contains the cost of all the civil works for construction of Powerhouse. It covers the cost of soil excavation, earthen backfill, concreting, reinforcement etc. The total cost of powerhouse and tailrace channel construction is estimated as Rs. 708.792 Million (Ref: Table- 14.12 & 14.13).

14.3.10 Watershed Management at Shimshal Nullah

At Attabad Lake, most of the sediment load comes from Shimshal Nullah, therefore, check dams has been proposed in the Nullah for which survey and field investigation will be carried out during the detailed design. An amount of Rs. 392.500 Million has been kept for the construction of 03 check dams to control the rate of sediments entering in Attabad Lake.

14.3.11 Hydraulic Steel Structures

Estimate for Hydraulic Steel Structures include procurement of power intake main gate, intake trashracks, intake trashrack cleaning machine, draft tube gates and gantry cranes. The total cost of hydro-mechanical equipment is estimated as Rs.139.730 Million (Ref: Table -14.14).

14.3.12 Hydro-Mechanical Works

This section deals with the Hydro-Mechanical Equipment which includes procurement of turbines, governors, inlet valves, powerhouse bridge crane and mobile crane, cooling water system, drainage and dewatering system, compressed air system, firefighting system & powerhouse elevators and HVAC system etc. etc. The total cost of hydro mechanical equipment is estimated as Rs. 1,690.890 Million (Ref: Table-14.15).

14.3.13 Electrical Works

This section deals with the procurement of Electric Equipment and comprises of generators, transformers (main & auxiliary), MV/LV& DC equipment, grounding, telecommunication and lighting systems, spare parts etc. The total cost of electrical equipment is estimated as Rs. 2,249.339 Million (Ref: Table-14.16).

14.3.14 Switchyard Works

This section deals with the procurement of 132 kV Switchyard Equipment and comprises of circuit breakers, communication system, control equipment, spare parts etc. The total cost of Switchyard equipment is estimated as Rs. 428.453 Million (Ref: Table-14.17).

14.3.15 Transmission Lines

This section deals with the civil works and procurement of equipment for 132 kV Double Circuit Transmission Line from Powerhouse to Aliabad and 132 kV Single Circuit Transmission Line from Powerhouse to Sost. The total cost of transmission lines is estimated as Rs. 1,500.135 Million (Ref: Table -14.18).

14.3.16 Transportation Charges

The E&M equipment for the construction of Project including turbines and generators etc. are to be imported. These equipment are to be shipped from the country of its manufacturing to the Project Site. The transportation charges of equipment have been estimated as Rs. 420.598 Million which are 7% of the E&M equipment cost.

14.3.17 Erection & Commissioning

Erection & commissioning charges have been taken as 8% of the E&M equipment cost. The cost of erection and commissioning has been estimated as Rs. 480.684 Million.

14.3.18 Engineering and Supervision

This represents the cost of preparation of tender documents, pre-qualification of bidders, evaluation of bids, review of detailed design and submittals by the Contractor, administration of the construction contract and measuring of work. The cost for engineering and supervision has been taken as 7% of the Project cost and is estimated as Rs1,229.539 Million.

14.3.19 Physical and Numerical Modeling

The physical and numerical modeling plays a fundamental role in the analysis of the hydraulic structures behavior of a Project. A lump sum provision of Rs. 5.0 Million has been kept for model studies during detailed design.

14.3.20 Physical Contingencies

Contingencies have been included in the estimate. These need to be viewed as an integral part of the estimated construction cost. To cover some of the unforeseen that may occur over the period of construction, 3% of the costs of Civil, E&M and Preliminary works have been applied. Contingencies are estimated as Rs. 526.945 Million.

14.3.21 Admin, Audit, Accounts, Legal and Client's Expenses

Administration, audit, accounts, legal and client’s expenses have been taken as 2% of the Civil, E&M and Preliminary works costs. The cost of these expenses has been estimated as Rs. 351.297 Million.

14.3.22 Authority Overheads

Factor of 1.5% has been applied on the costs of Civil, E&M and Preliminary works to cover this head and Authority Overheads cost is estimated as Rs. 263.473 Million.

14.3.23 Insurance Cost

The cost of insurance has been taken as 0.5%of the costs of Civil, E&M and Preliminary works, estimates to Rs. 87.824 Million.

14.3.24 Local and Foreign Components

The cost estimates for various works including the preliminary works, civil works, hydraulic steel structures, hydro-mechanical and electrical equipment has been further subdivided into local and foreign cost components. This job has been accomplished by consulting recently tendered WAPDA projects and prepared by multiplying factor (percentage) to the whole cost of different components.

14.4 PROJECT COST

The total cost of the Project by summing up all the costs mentioned above is presented below:

- Total Base Cost Rs. 20,028.916 Million
- Total Base Cost US$ 127.573 Million

The summary of the Cost Estimate is presented in Table-14.3.

The Equipment, Material and Labor rates adopted are given in **Annexure – A.**

14.5 PROJECT PHASING

Estimated time for Project construction is 03 years. Accordingly, Project phasing plan has been designed to fulfill the Project needs as per requirement (Ref: Table-14.19).

Table 14-1 Unit Rates for different Items

Description	Unit	Rate (PKR)
Excavation in common material	m^3	958
Excavation in Rock	m^3	2,714
Tunnel Excavation	m^3	20,278
Shaft Excavation	m^3	22,608
Shotcrete with Fiber Reinforcement	m^3	45,080
PCC (1:2:4)	m^3	17,270
Concrete (1:1.5:3)	m^3	21,399
Steel Reinforcement Grade 60	Ton	204,524

Table 14-2 Quantities of Main Civil Works Items

Description	Unit	Quantity
Earthwork (Excavation)		
Main Weir	m^3	1,008,000
Undersluices	m^3	1,400,000
Power Intake, Low Pressure Headrace Tunnel, Surge Tank and Penstock	m^3	98,160
Powerhouse and Tailrace Channel	m^3	87,044
TOTAL	$\mathbf{m^3}$	**2,593,204**
Concrete		
Main Weir	m^3	12,570
Undersluices	m^3	11,028
Power Intake, Low Pressure Headrace Tunnel, Surge Tank and Penstock	m^3	29,728
Powerhouse and Tailrace Channel	m^3	13,584
TOTAL	$\mathbf{m^3}$	**66,910**
Reinforcement		
Main Weir	Ton	655.20
Undersluices	Ton	498.50
Power Intake, Low Pressure Headrace Tunnel, Surge Tank and Penstock	Ton	1,020
Powerhouse and Tailrace Channel	Ton	820.50
TOTAL	**Ton**	**2,944**

Table 14-3 Summary of the Cost Estimate

Price Index – March, 2021

US$ Exchange Rate = Rs. 157

Sr. No	Description	Local	Foreign	Cost		Reference
		Mill.PKR	Mill.PKR	Mill.PKR	Mill.US $	
A	**Preliminary Works**					
A-1	Land Acquisition & Environmental Mitigation	208.450	-	208.450	1.328	Table – 14.4
A-2	Preparatory Works					
-	Mobilization & De-mobilization	500.000	-	500.000	3.185	Table – 14.5
-	Project Colony and Contractor Camp	130.310	-	130.310	0.830	
-	Access Roads to Main Works sites	134.235	-	134.235	0.855	
-	Reservoir Slope Stabilization & Construction Risks	188.400	-	188.400	1.200	
	Sub Total A	**1,161.395**	**-**	**1,161.395**	**7.397**	
B	**Civil Works**					
B-1	Main Weir	2,008.821	-	2,008.821	12.795	Table – 14.6
B-2	Undersluices	2,326.679	-	2,326.679	14.820	Table – 14.7
B-3	Power Intake	429.289	-	429.289	2.734	Table – 14.8
B-4	Low Pressure Headrace Tunnel	1,820.182	-	1,820.182	11.594	Table – 14.9
B-5	Surge Tank	132.728	-	132.728	0.845	Table – 14.10
B-6	Penstock	713.256	-	713.256	4.543	Table – 14.11
B-7	Powerhouse	624.474	-	624.474	3.978	Table – 14.12
B-8	Tailrace Channel	84.318	-	84.318	0.537	Table – 14.13
B-9	Check Dams at Shimshal Nullah	392.500	-	392.500	2.500	
	Sub Total B	**8,532.247**	**-**	**8,532.247**	**54.346**	
	Sub Total (A+B)	**9,693.642**	**-**	**9,693.642**	**61.743**	
C	**Hydraulic Steel Structures, Mechanical & Electrical Works**					
C-1	Hydraulic Steel Structures (HSS)	104.798	34.933	139.730	0.890	Table – 14.14
C-2	Mechanical Works	33.818	1,657.072	1,690.890	10.770	Table – 14.15
C-3	Electrical Works	31.400	2,217.939	2,249.339	14.327	Table – 14.16
C-4	Switchyard Works	4.285	424.168	428.453	2.729	Table – 14.17
C-5	Transmission Line (Single Circuit Attabad to Sost & Double Circuit Attabad to Aliabad)	1,200.108	300.027	1,500.135	9.555	Table – 14.18
	Sub Total C-1 to C-5	**1,374.408**	**4,634.139**	**6,008.547**	**38.271**	
C-6	Transportation Charges of E&M Equipment @ 7% of Sub Total C1 to C-5	252.359	168.239	420.598	2.679	
C-7	Erection & Commissioning Charges @ 8% of Sub Total C1 to C-5	144.205	336.479	480.684	3.062	
C-8	Government Taxes on E&M Equipment @ 16% of Sub Total C1 to C-5	961.368	-	961.368	6.123	
	Sub Total C	**2,732.34**	**5,138.86**	**7,871.197**	**50.135**	
	Sub Total (A+B+C)	**12,425.98**	**5,138.86**	**17,564.839**	**111.878**	
D	Engineering and Supervision of Project and Review of Feasibility Study by Consultants @ 7%of Sub Total (A+B+C)	865.819	359.720	1,225.539	7.831	
	Generation Capacity Espansion Plan for GB	4.000	-	4.000	0.025	
E	Physical and Numerical Modeling (Lumpsum)	5.000	-	5.000	0.032	

Price Index – March, 2021

US$ Exchange Rate = Rs. 157

Sr. No	Description	Local	Foreign	Cost		Reference
		Mill.PKR	Mill.PKR	Mill.PKR	Mill.US $	
F	Physical Contingencies @ 3% of Sub Total (A+B+C)	372.779	154.166	526.945	3.356	
G	Admin, Audit, Accounts, Legal and Client's Expenses @ 2% of Sub Total (A+B+C)	351.297	-	351.297	2.238	
H	Authority Overheads @ 1.5% of Sub Total (A+B+C)	263.473	-	263.473	1.678	
I	Insurance Costs @ 0.5% of Sub Total (A+B+C)	62.130	25.694	87.824	0.559	
	PROJECT BASE COST	**14,350.479**	**5,678.437**	**20,028.916**	**127.573**	

COST ESTIMATES

(Preliminary & Civil Works)

Table 14-4 Cost Estimate for Land Acquisition and Environmental Mitigation

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Permanent Land Acquisition*					
-	Powerhouse Site	kanal	32	750,000	24,000,000	152,866
-	Weir & Associated Structures	kanal	120	750,000	90,000,000	573,248
-	Project Colony	kanal	20	750,000	15,000,000	57,325
-	Miscellaneous	LS	1	16,000,000	16,000,000	101,911
2	Temporary Land Acquisition	LS	1	1,000,000	1,000,000	6,369
3	Building Compensation	LS	1	15,000,000	15,000,000	95,541
4	Spoil Disposal Area Rehabilitation	LS	1	4,000,000	4,000,000	25,478
5	Rehabilitation of Villages	LS	1	2,000,000	2,000,000	12,739
6	Livelihood Allowance for Affectees	LS	1	2,000,000	2,000,000	12,739
7	Monitoring and Evaluation	LS	1	16,500,000	16,500,000	105,096
8	Capacity Building/training	LS	1	2,000,000	2,000,000	12,739
9	Land Conservation	LS	1	2,000,000	2,000,000	12,739
				Sub-Total	**189,500,000**	**1,207,006**
10	Contingencies 10%				18,950,000	120,701
				Total	**208,450,000**	**1,327,707**

Table 14-5 Cost Estimate for Preparatory Works

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
A	Mobilization & Demobilization	LS	1	500,000,000	500,000,000	3,184,713
B	Project Colony & Contractor's Camp					
1	Officer, Staff colony and Hostel	m^2	4,000	31,400	125,600,000	800,000
2	Contractor's Camp	LS	1	3,140,000	3,140,000	20,000
3	Equipment and material storage	LS	1	1,570,000	1,570,000	10,000
				Sub-Total (B)	**130,310,000**	**830,000**
C	Access Roads & Bridge					
1	Roads in Weir Area	m	1,200	39,250	47,100,000	300,000
2	Road to Power Intake	m	300	39,250	11,775,000	75,000
3	Road to Surge Tank	m	200	39,250	7,850,000	50,000
4	Road to Powerhouse	m	500	47,100	23,550,000	150,000
5	Road to Adit	m	200	31,400	6,280,000	40,000
6	Bridge on Hunza river near Powerhouse	m	80	471,000	37,680,000	240,000
				Sub-Total (C)	**134,235,000**	**855,000**
D	Reservoir Slope Stabilization & Construction Risks Costs	LS	1	188,400,000	188,400,000	1,200,000
				Total (A+B+C+D)	**952,945,000**	**6,069,713**

Table 14-6 Cost Estimate for Main Weir

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No	Description of Activities	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
A	**Main Weir**					
1	Excavation for Main Weir upto design depth in Medium Hard Soil removing of material from outside of the structure area	m^3	828,000	958	792,975,600	5,050,800
2	Excavation for Main Weir upto design depth in Rock material requiring blasting i/c removing of material from outside of the structure area	m^3	180,000	2,714	488,587,140	3,112,020
3	Free Draining Backfill	m^3	8,280	1,005	8,319,744	52,992
4	Lean Concrete 1:4:8	m^3	990	14,130	13,988,700	89,100
5	RCC 1:1.5:3 for Main Weir using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	10,920	21,399	233,678,172	1,488,396
6	Reinforcement Grade 60	Ton	655.20	204,524	134,004,059	853,529
7	Dewatering	LS	1	15,700,000	15,700,000	100,000
8	Riprap Protection	m^3	2,160	7,850	16,956,000	108,000
9	Protection with Gabions	m^3	1,000	11,323	11,322,840	72,120
	Sub-Total (A)				**1,715,532,255**	**10,926,957**
B	**Coffer Dams**					
B1	**Upstream**					
1	Excavation	m^3	7,200	958	6,895,440	43,920
2	Compacted Concrete	m^3	660	14,130	9,325,800	59,400
3	Jet Grout Cutoff	m^3	1,000	28,563	28,563,010	181,930
4	Riprap Face Protection u/s	m^3	2,500	7,850	19,625,000	125,000
5	Rock Fill	m^3	8,100	1,703	13,797,945	87,885
	Sub-Total (B1)				**78,207,195**	**498,135**
B2	**Downstream**					
1	Excavation	m^3	2,250	958	2,154,825	13,725
2	Jet Grout Cutoff	m^3	700	28,563	19,994,107	127,351
3	Riprap Face Protection u/s & d/s	m^3	500	7,850	3,925,000	25,000
4	Rock Fill	m^3	3,750	1,703	6,387,938	40,688
	Sub-Total (B2)				**32,461,870**	**206,764**
	Sub-Total (B)				**110,669,065**	**704,899**
C	Miscellaneous 10% for joints of all types, Drainage, Architectural details, finishes etc.				182,620,132	1,163,186
	Total (A+B+C)				**2,008,821,452**	**12,795,041**

Table 14-7 Cost Estimate for Undersluices

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Clearing and Grubbing of area 300m upstream of Weir	m^2	10,875	314	3,414,750	21,750
2	Excavation for Undersluices upto design depth in Medium Hard Soil removing of material from outside of the structure area	m^3	1,120,000	958	1,072,624,000	6,832,000
3	Excavation for Undersluices upto design depth in Rock material requiring blasting i/c removing of material from outside of the structure area	m^3	280,000	2,714	760,024,440	4,840,920
4	Compacted Concrete	m^3	413	23,110	9,533,040	60,720
5	Riprap face protection u/s	m^3	500	6,961	3,480,690	22,170
6	Lean Concrete 1:4:8	m^3	645	14,130	9,113,850	58,050
7	RCC in Undersluices using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	9,970	21,399	213,349,027	1,358,911
8	Reinforcement Grade 60	Ton	498.5	204,524	101,955,164	649,396
9	Grout Curtain	LS	1	10,990,000	10,990,000	70,000
10	Dewatering	LS	1	15,700,000	15,700,000	100,000
11	Consolidation Grouting	LS	1	15,700,000	15,700,000	100,000
12	Miscellaneous 5% for joints of all types, Drainage, Architectural details, finishes etc.				110,794,248	705,696
				Total	**2,326,679,209**	**14,819,613**

Table 14-8 Cost Estimate for Power Intake

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Excavation for Power Intake upto design depth in Medium Hard Rock requiring blasting i/c removing of material from outside of the structure area	m^3	17,150	2,714	46,551,497	296,506
2	PCC in overbreak section including placing, compacting, finishing & curing (Ratio 1:2:4)	m^3	172	17,270	2,961,805	18,865
3	Lean Concrete 1:4:8	m^3	271	14,130	3,824,744	24,361
4	RCC 1:1.5:3 for Linning using crushed stone aggregate (screening & ashing) and coarse sand i/c costof all labor and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	10,405	21,399	222,666,730	1,418,259
5	Reinforcement Grade 60 in Lining	Ton	520	204,524	106,407,905	677,757
6	Dewatering	LS	1	7,850,000	7,850,000	50,000
7	Miscellaneous 10% for joints of all types, Piles, Backfill, Drainage, Architectural details, finishes and Gate Control Building etc.				39,026,268	248,575
				Total	**429,288,949**	**2,734,325**

Table 14-9 Cost Estimate for Low Pressure Headrace Tunnel

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Excavation for Headrace Tunnel upto design depth in Medium Hard Rock requiring blasting i/c removing of material from outside of the structure area	m^3	60,737	20,278	1,231,655,089	7,844,937
2	PCC in overbreak section including placing, compacting, finishing & curing (Ratio 1:2:4)	m^3	4,191	17,270	72,376,562	460,997
3	Lean Concrete 1:4:8	m^3	1,030	14,130	14,559,552	92,736
4	Shotcrete 35mm thick-fiber reinforced	m^3	1,012	44,117	44,628,432	284,258
5	RCC 1:1.5:3 for Lining using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	9,935	21,399	212,605,151	1,354,179
6	Reinforcement Grade 60 in Lining	Ton	397	204,524	81,280,127	517,708
7	Rock Bolts 4m long with 4m spacing	No.	1,728	24,178	41,779,584	266,112
8	Adits (Access Tunnel)	LS	1	31,481,640	31,481,640	200,520
9	Dewatering	LS	1	3,140,000	3,140,000	20,000
10	Miscellaneous 5% for joints of all types, Drainage, Architectural details, finishes etc.				86,675,357	552,072
				Total	**1,820,182,493**	**11,593,519**

Table 14-10 Cost Estimate for Surge Tank

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Excavation for Surge Tank upto design depth in Medium Hard Rock requiring blasting i/c removing of material from outside of the structure area	m^3	3,291	22,608	74,392,161	473,835
2	PCC in overbreak section including placing, compacting, finishing & curing (Ratio 1:2:4)	m^3	329	17,270	5,682,735	36,196
3	Shotcrete 35mm thick-fiber reinforced	m^3	509	44,117	22,452,814	143,012
4	RCC 1:1.5:3 for Lining using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labor and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	360	21,399	7,714,326	49,136
5	Reinforcement Grade 60 in Lining	Ton	22	204,524	4,423,824	28,177
6	Rock Bolts 3m long with 2m spacing	No.	222	24,178	5,367,516	34,188
7	Dewatering	LS	1	628,000	628,000	4,000
8	Miscellaneous 10% for joints of all types, Drainage, Architectural details, finishes etc.				12,066,137	76,854
				Total	**132,727,512**	**845,398**

Table 14-11 Cost Estimate for Penstock

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Excavation for Penstock upto design depth in Medium Hard Rock requiring blasting i/c removing of material from outside of the structure area	m^3	1,382	22,608	31,235,213	198,950
2	Excavation for Penstock upto design depth in Medium Hard Soil removing of material from outside of the structure area	m^3	15,600	958	14,940,120	95,160
3	PCC in overbreak section including placing, compacting, finishing & curing (Ratio 1:2:4)	m^3	110	17,270	1,897,973	12,089
4	Shotcrete 35mm thick-fibre reinforced	m^3	51	44,117	2,231,422	14,213
5	Filter Material	m^3	1,400	7,850	10,990,000	70,000
6	RCC 1:1.5:3 for Linning using crushed stone aggregate (screening & ashing) and coarse sand i/c costof all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	1,354	21,399	28,971,539	184,532
7	Reinforcement Grade 60 in Lining	Ton	81	204,524	16,613,891	105,821
8	Rock Bolts 3m long with 2m spacing	No.	123	24,178	2,973,894	18,942
9	Dewatering	LS	1	603,846	603,846	3,846
10	Miscellaneous 10% for joints of all types, Drainage, Grouting, finishes etc.				11,045,790	70,355
11	Penstock	Ton	802	737,661	591,751,943	3,769,121
				Total	**713,255,631**	**4,543,029**

Table 14-12 Cost Estimate for Powerhouse

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate (PKR)	Cost (PKR)	Cost (US$)
1	Excavation for Powerhouse upto design depth in Medium Hard Soil removing of material from outside of the structure area	m^3	74,451	957	71,301,723	454,151
2	Backfilling	m^3	74,451	1,005	74,808,365	476,486
3	Lean Concrete 1:4:8	m^3	635	14,130	8,965,485	57,105.00
4	RCC for Sub structures and around Draft Tubes using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	7,774	21,399	166,353,180	1,059,574
5	RCC 1:1.5:3 for walls, columns, slabs and floors using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	3,426	21,399	73,303,636	466,902
6	Reinforcement Grade 60	Ton	715.45	204,524	146,325,843	932,012
7	Dewatering	LS	1	1,962,500	1,962,500	12,500
8	Miscellaneous 15% for joints of all types, Drainage, Architectural details, finishes etc.				81,453,110	518,810
				Total	**624,473,840**	**3,977,540**

Table 14-13 Cost Estimate for Tailrace Channel

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate (PKR)	Cost (PKR)	Cost (US$)
1	Excavation for Tailrace Channel upto design depth in Medium Hard Soil removing of material from outside of the structure area	m^3	12,593	958	12,059,837	76,814
2	RCC 1:1.5:3 using crushed stone aggregate (screening & ashing) and coarse sand i/c cost of all labour and material and all kinds of form works, moulds, shuttering lifting / pumping, curing, rendering and finishing the exposed surface excluding steel reinforcement	m^3	1,750	21,399	37,448,425	238,525
3	Reinforcement Grade 60	Ton	105	204,524	21,475,010	136,784
4	Backfill	m^3	1,440	1,021	1,469,520	9,360
5	Dewatering	LS	1	7,850,000	7,850,000	50,000
6	Miscellaneous 5% for joints of all types, Drainage, finishes etc.				4,015,140	25,574
				Total	**84,317,932**	**537,057**

COST ESTIMATES

(HSS, Hydro-Mechanical, Electrical, Switchyard & Transmission Line Equipment)

Table 14-14 Cost Estimate for Hydraulic Steel Structures

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Power Intake Main Gates	Set	2	11,775,000	23,550,000	150,000
2	Intake Trashrack	Set	1	18,840,000	18,840,000	120,000
3	Power Intake Trashrack Cleaning Machine	Set	1	15,700,000	15,700,000	100,000
4	Powerhouse Draft Tube Gates	Set	4	6,280,000	25,120,000	160,000
5	Gantry Crane	Set	2	28,260,000	56,520,000	360,000
				Total	**139,730,000**	**890,000**

Table 14-15 Cost Estimate for Hydro-Mechanical Equipment

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	Turbine	No.	3	335,980,000	1,007,940,000	6,420,000
2	Governor and Auxiliaries	No.	3	36,110,000	108,330,000	690,000
3	Main Inlet Valves	No.	3	67,510,000	202,530,000	1,290,000
4	Powerhouse Bridge crane (100 Ton) Mobile crane (20 Ton)	L.S	1	78,500,000	78,500,000	500,000
5	Cooling Water System	L.S	1	59,660,000	59,660,000	380,000
6	Drainage and Dewatering System	L.S	1	69,080,000	69,080,000	440,000
7	Compressed Air System	L.S	1	32,970,000	32,970,000	210,000
8	Fire Fighting System	L.S	1	25,120,000	25,120,000	160,000
9	Oil Handling Equipment	L.S	1	28,260,000	28,260,000	180,000
10	Powerhouse Elevators	No.	2	10,990,000	21,980,000	140,000
11	Heating, Ventilation and Air Conditioning (HVAC) System	L.S	1	32,970,000	32,970,000	210,000
12	Workshop Equipment	Lot.	1	17,270,000	17,270,000	110,000
13	Miscellaneous Equipment				6,280,000	40,000
				Total	**1,690,890,000**	**10,770,000**

Table 14-16 Cost Estimate for Electrical Equipment

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
A	**Generator**					
1	21.20 MVA Generator, complete with Excitation system, cooling system, Control and protection	Set	3	471,000,000	1,413,000,000	9,000,000
2	11 kV Generator Circuit Breaker	Set	2	39,250,000	78,500,000	500,000
3	Isolated Phase Bus System with associated components	Set	3	15,700,000	47,100,000	300,000
				Sub Total (A)	**1,538,600,000**	**9,800,000**
B	**Transformer**					
4	Power Transformer 22 MVA, 11/132 kV with off-load tap changer, control & protection and other associated components. (A spare transformer shall also be provided)	No.	3	78,500,000	314,000,000	2,000,000
5	Station Service Transformer 2 MVA, 132/11 kV with control and protection and associated components	No.	1	20,410,000	20,410,000	130,000
6	Main Auxiliary Transformer 630 KVA, 11/0.4 kV with control and protection and associated components	No.	3	2,355,000	7,065,000	45,000
7	Main Auxiliary Transformers 400 KVA, 11/0.4kV with control and protection and associated components	No.	3	1,884,000	3,768,000	24,000
				Sub Total (B)	**345,243,000**	**2,199,000**
C	**MV, LV & DC Equipment**					
8	11 kV switchgears with control & protection & associated components	No.	8	26,690,000	213,520,000	1,360,000
9	Station service Equipment, Low Voltage Installation, 220 V DC & UPS System including batteries, chargers and other associated equipment	LS	1	15,700,000	15,700,000	100,000
				Sub Total (C)	**229,220,000**	**1,460,000**
D	**Others Equipment**					
10	Control System & Protection	LS	1	34,540,000	34,540,000	220,000
11	Lighting and Small Power System	LS	1	2,355,000	2,355,000	15,000
12	Earthing & lightning Protection System	LS	1	5,495,000	5,495,000	35,000
13	Fire Detection & Alarm System	LS	1	3,140,000	3,140,000	20,000
14	Telecommunication(EPABX, PAS, CCTV)	LS	1	3,925,000	3,925,000	25,000
15	Cables(MV, LV, Control, P&I) and Cable trays	LS	1	14,915,000	14,915,000	95,000
16	D.G Set	LS	1	17,270,000	17,270,000	110,000
17	Electrical Workshop	LS	1	5,181,000	5,181,000	33,000
18	Spare Parts	LS	1	47,100,000	47,100,000	300,000
19	Maintenance Tools & Plants	LS	1	2,355,000	2,355,000	15,000
				Sub Total (D)	**136,276,000**	**868,000**
				Total (A+B+C+D)	**2,249,339,000**	**14,327,000**

Table 14-17 Cost Estimate for 132 kV Switchyard Equipment

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
1	132 kV SF6 Circuit Breakers, with associated components	Set	12	3,140,000	37,680,000	240,000
2	132 kV Disconnecting Switch, three pole, motor operated with associated components	No.	27	1,099,000	29,673,000	189,000
3	132 kV Communication System including Line Matching Units, Digital Power Line Carrier, SCADA equipment, etc.	LS	1	141,300,000	141,300,000	900,000
4	Other Switchyard Equipment required for complete functioning like Bus Bars, SA, CT, CVT, CCVT, earthing & Lightening system etc.	LS	1	94,200,000	94,200,000	600,000
5	Protection & Control Equipment	LS	1	86,350,000	86,350,000	550,000
6	Spare Parts	LS	1	39,250,000	39,250,000	250,000
				Sub Total	**428,453,000**	**2,729,000**

Table 14-18 Cost Estimate for 132 kV Transmission Line

Price Index – March, 2021
US$ Exchange Rate = Rs. 157

Sr. No.	Description	Unit	Qty	Rate	Cost	
				(PKR)	(PKR)	(US$)
A	**132 kV Transmission Line (Double Circuit from Powerhouse to Aliabad) - 27 km**					
1	Towers (ZM1, ZM30, ZM60)	No.	135	1,413,000	190,755,000	1,215,000
2	Conductor Twin Bundle (Rail)	Km	180	785,000	141,300,000	900,000
3	Optical Ground Wire (OPGW)	Km	30	314,000	9,420,000	60,000
4	Insulators	LS	1	34,540,000	34,540,000	220,000
5	Hardware	LS	1	34,540,000	34,540,000	220,000
6	Grounding Sets	LS	1	4,710,000	4,710,000	30,000
7	Protection Equipment	LS	1	15,700,000	15,700,000	100,000
8	Land & Right of Way	LS	1	21,980,000	21,980,000	140,000
9	Excavation & Foundation	LS	1	31,400,000	31,400,000	200,000
				Sub Total (A)	**484,345,000**	**3,085,000**
B	**132 kV Transmission Line (Single Circuit from Powerhouse to Sost) - 70 km**					
10	Towers(ZM1, ZM30, ZM60)	No.	350	1,413,000	494,550,000	3,150,000
11	Conductor Twin Bundle (Rail)	km	210	785,000	164,850,000	1,050,000
12	Optical Ground Wire (OPGW)	km	75	314,000	23,550,000	150,000
13	Insulators	LS	1	89,490,000	89,490,000	570,000
14	Hardware	LS	1	89,490,000	89,490,000	570,000
15	Grounding Sets	LS	1	7,850,000	7,850,000	50,000
16	Protection Equipment	LS	1	15,700,000	15,700,000	100,000
17	Land & Right of Way	LS	1	51,810,000	51,810,000	330,000
18	Excavation & Foundation	LS	1	78,500,000	78,500,000	500,000
				Sub Total (B)	**1,015,790,000**	**6,470,000**
				Total (A+B)	**1,500,135,000**	**9,555,000**

Table 14-19 Phasing of Cost Estimate

Sr. No.	Description	Total				1st Year		2nd Year		3rd Year	
		Local (Mill. PKR)	Foreign (Mill. PKR)	Total (Mill. PKR)	Total (Mill. US$)	Local (Mill. PKR)	Foreign (Mill. PKR)	Local (Mill. PKR)	Foreign (Mill. PKR)	Local (Mill. PKR)	Foreign (Mill. PKR)
A	**Preliminary Works**										
A-1	Land Acquisition & Environmental Mitigation Cost	208.450	-	208.450	1.328	156.338	-	20.845	-	31.268	-
A-2	Preparatory Works										
-	Mobilization & De-mobilization	500.000	-	500.000	3.185	350.000	-	-	-	150.000	-
-	Project Colony & Contractor's Camp	130.310	-	130.310	0.830	130.310	-	-	-	-	-
-	Access Roads to the Main Works Sites	134.235	-	134.235	0.855	134.235	-	-	-	-	-
-	Reservoir Slope Stabilization and Construction Risks	188.400	-	188.400	1.200	188.400	-	-	-	-	-
	Sub Total A	**1,161.395**	**-**	**1,161.395**	**7.397**	**959.283**	**-**	**20.845**	**-**	**181.268**	**-**
B	**Civil Works**										
B-1	Main Weir	2,008.821	-	2,008.821	12.795	1,519.856	-	651.367	-	-	-
B-2	Undersluices	2,326.679	-	2,326.679	14.820	2,548.564	-	-	-	-	-
B-3	Power Intake	429.289	-	429.289	2.734	-	-	436.692	-	-	-
B-4	Low Pressure Headrace Tunnel	1,820.182	-	1,820.182	11.594	398.062	-	1,194.187	-	398.062	-
B-5	Surge Tank	132.728	-	132.728	0.845	-	-	179.911	-	-	-
B-7	Penstock	713.256	-	713.256	4.543	-	-	89.692	-	-	-
B-8	Powerhouse	624.474	-	624.474	3.978	-	-	455.416	-	190.893	-
B-9	Tailrace Channel	84.318	-	84.318	0.537	-	-	34.817	-	52.226	-
B-10	Check Dams at Shimshal Nullah	392.500	-	392.500	2.500	78.500	-	235.500	-	78.500	-
	Sub Total B	**8,532.247**	**-**	**8,532.247**	**54.346**	**4,544.982**	**-**	**3,267.584**	**-**	**719.681**	**-**
	Total (A+B)	**9,693.642**	**-**	**9,693.642**	**61.743**	**5,504.265**	**-**	**3,288.429**	**-**	**900.949**	**-**
C	**Hydraulic Steel Structures, Mechanical & Electrical Works**										
C-1	Hydraulic Steel Structures (HSS)	104.798	34.933	139.730	0.890	20.960	6.987	62.879	20.960	20.960	6.987
C-2	Mechanical Works	33.818	1,657.072	1,690.890	10.770	-	-	6.764	331.414	27.054	1,325.658
C-3	Electrical Works	31.400	2,217.939	2,249.339	14.327	-	-	6.280	443.588	25.120	1,774.351
C-4	Switchyard works	4.285	424.168	428.453	2.729	-	-	-	-	4.285	424.168
C-5	Transmission Line (Single Circuit Attabad to Sost & Double Circuit Attabad to Aliabad)	1,200.108	300.027	1,500.135	9.555	-	-	-	-	1,200.108	300.027
	Sub Total for C-1 to C-5	**1,374.408**	**4,634.139**	**6,008.547**	**38.271**	**20.960**	**6.987**	**75.922**	**795.962**	**1,277.526**	**3,831.191**
C-6	Transportation Charges of E&M Equipment @ 7% of Sub Total C1-C5	252.359	168.239	420.598	2.679	1.174	0.782	36.619	24.413	214.566	143.040
C-7	Erection & Commissioning Charges @ 8% of Sub Total C1-C5	144.205	336.479	480.684	3.062	-	-	57.682	134.591	86.523	201.887
C-8	Government Taxes on E&M Equipment @ 16% of Sub Total C1-C5	961.368	-	961.368	6.123	4.471	-	139.501	-	817.395	-
	Sub Total C	**2,732.339**	**5,138.857**	**7,871.197**	**50.135**	**26.605**	**7.769**	**309.725**	**954.966**	**2,396.010**	**4,176.122**
	Sub Total (A + B + C)	**12,425.982**	**5,138.857**	**17,564.839**	**111.878**	**5,530.870**	**7.769**	**3,598.153**	**954.966**	**3,296.959**	**4,176.122**
D	Engineering and Supervision @ 7% of Sub Total (A+B+C)	865.819	359.720	1,225.539	7.806	383.161	0.540	251.871	66.848	230.787	292.329
	Generation Capacity Expansion Plan for GB	4.000	-	4.000	0.025	4.000	-	-	-	-	-
E	Physical and Numerical Modeling (Lumpsum)	5.000	-	5.000	0.032	3.500	-	1.500	-	-	-
F	Physical Contingencies @ 3% of Sub Total (A+B+C)	372.779	154.166	526.945	3.356	165.926	0.233	107.945	28.649	98.909	125.284
G	Admin, Audit, Accounts, Legal and Client's Expenses @ 2% of Sub Total (A+B+C)	351.297	-	351.297	2.238	110.773	-	91.062	-	149.462	-
H	Authority Overheads @ 1.5% of Sub Total(A+B+C)	263.473	-	263.473	1.678	83.080	-	68.297	-	112.096	-
I	Insurance Costs @ 0.5% of Sub Total (A+B+C)	62.130	25.694	87.824	0.559	27.654	-	17.991	4.775	16.485	20.881
	PROJECT BASE COST	**14,350.478**	**5,678.440**	**20,028.916**	**127.573**	**6,308.964**	**8.585**	**4,136.819**	**1,055.237**	**3,904.698**	**4,614.615**

Annexure-A

Equipment, Material & Labor Rates

Summary of Major Construction Equipment Operating Cost

Sr. No.	Description	Monthly Rent (PKR)	HourlyRent (PKR)
1	Bulldozer D6 / Equivalent	1,352,000	6,500.00
2	Dump Truck 10-Wheeler	1,040,000	5,000.00
3	Excavator CAT 220 / EX 100 / Equivalent	1,456,000	7,000.00
4	Excavator CAT 225 / EX 200 / Equivalent	1,560,000	7,500.00
5	Motor Grader 12 Ft Blade	1,352,000	6,500.00
6	Front End Loader CAT 950 / Equivalent	1,040,000	5,000.00
7	Roller Vibratory 12.5 Ton (Plane)	936,000	4,500.00
8	Roller Vibratory 12.5 Ton (Pad Foot)	1,040,000	5,000.00
9	Water Tank /Bouzar Water 10000 litre	728,000	3,500.00
10	Tractor 78 HP	520,000	2,500.00
11	Crane 28/33 Ton	1,248,000	6,000.00
12	Concrete Batching Plant, 30 Cum/hr	936,000	4,500.00
13	Concrete Batching Plant, 60 Cum/hr	1,560,000	7,500.00
14	Concrete Transit Mixer Mobile 2.5 Cum	312,000	1,500.00
15	Concrete Transit Mixer Mobile 6.0 Cum	624,000	3,000.00
16	Concrete Pump 60~110 Cum / hr	520,000	2,500.00
17	Placement Machinery	312,000	1,500.00
18	Vibrator	416,000	2,000.00
19	Power Generator 1MW	6,240,000	30,000.00
20	Bar Cutting Machine	62,400	300.00
21	Bar Bending Machine	31,200	150.00
22	Tractor trolly	249,600	1,200.00
23	Drilling Jumbo	6,240,000	30,000.00
24	Loader 2.5 cum	1,040,000	5,000.00
25	Dumper 20T	1,664,000	8,000.00
26	Jack hammer	108,160	520.00
27	Dozer 100HP	1,456,000	7,000.00
28	Ventilator Blowers	3,120,000	15,000.00
29	Tipper	1,248,000	6,000.00

Summary of Material Costs

Sr. No.	Description	Unit	Rate (PKR)
1	Ordinary Portland Cement (OPC)	Per Bag	950.00
2	Coarse Sand	Cum	2,600.00
3	Aggregate	Cum	4,000.00
4	Rubble Stone	Cum	2,600.00
4	Water	1000 litre	1,000.00
5	Admixture	litre	1,200.00
6	Formwork (average)	Sq. m	200.00
7	Reinforcing Steel Grade 60	Ton	150,000.00
8	Reinforcing Steel Grade 40	Ton	120,000.00
9	Cold steel wire AASHTO M-32	Kg	300.00
10	Explosives	Kg	1,800.00

Summary of Labour Wages

Sr. No.	Description	Monthly Wage (PKR)	Hourly Wage (PKR)	Daily Wage (PKR)
1	Foreman for Batch/Mix Plant	65,000	312.50	2,500
2	Plant Operator	58,501	281.26	2,250
3	Forman for Excavation / Concrete Placing / Rebar	65,000	312.50	2,500
4	Mechanics	65,000	312.50	2,500
5	Electrician	58,500	281.25	2,250
6	Masons	52,000	250.00	2,000
7	Carpenter	45,500	218.75	1,750
8	Dresser	32,499	156.25	1,250
9	Steel Binder Cutter	32,499	156.25	1,250
10	Helpers/Oilers/Muckers/Beldaar	26,000	125.00	1,000
11	Drivers	32,499	156.25	1,250
12	Labourers	26,000	125.00	1,000
13	Explosives Inspector	64,999	312.49	2,500
14	Explosives Chargeman	52,001	250.00	2,000
15	Drillers	52,000	250.00	2,000
16	Wireman	31,200	150.00	1,200

15 CONSTRUCTION PLANNING AND COST ESTIMATES

15.1 GENERAL

This section covers the construction planning aspects of Attabad Lake Hydropower Project (ALHPP) in detail. The implementation schedule for the Project has been prepared taking into account the anticipated construction methods and planning. Following areas are covered in the subject section of the report:

- Project geographic location and access to the Project Area.
- Availability of manpower.
- Planning of effective working periods.
- Required Construction Materials, Storage and Major Equipment.
- Detailed Construction Planning and Methodology for different Project components.
- Project Implementation Schedule.
- Mode of Construction Supervision.

15.2 PROJECT LOCATION

ALHPP is proposed on Attabad Lake along Karakuram Highway (N-35) in Hunza Valley. The Weir Site has been proposed at existing spillway of Attabad Lake. The Powerhouse site is about 2.5 km downstream of the Weir Site, along the left bank of Hunza River.

15.3 ACCESSIBILITY TO PROJECT AREA

15.3.1 Roads Access

The ALHPP is approachable from all major cites of Pakistan, primarily Islamabad and Gilgit along the existing N-35 Karakoram Highway (KKH). KKH is 806 km long and starts at Hassanabdal in province Punjab. It passes through Khyber Pakhtunkhwa and the Northern areas and terminates at Khunjerab Pass in the Karakoram Range on the Pakistan – China border. The maintenance of the Karakoram Highway now is the responsibility of the National Highways Authority (NHA) who operates and maintains this road through Frontier Works Organization (FWO). The KKH is two lane all-weathered mountainous road. Landslides on KKH are frequently experienced during the rainy seasons, blocking the vehicular traffic ranging from a few hours to a number of days and can even extend up to a few weeks occasionally.

No major rehabilitation or upgrading has been carried out on the KKH since its completion in 1978, although some maintenance has been undertaken and its condition from Gilgit to Chilas city is good however, the condition of road from Chilas to Besham is not satisfactory. It shall be necessary to rehabilitate the existing structure of KKH to serve the construction of ongoing Dasu Hydropower Project & Diamer Basha Dam Project and proposed upstream projects including Shyok Dam, Bunji Hydropower Project and ALHPP Lake Hydropower Project etc., to allow transport of construction materials, heavy construction equipment and the permanent plant and equipment.

The route from Islamabad to Thakot via KKH is through Mansehra via Haripur and Abbottabad. From Mansehra, KKH moves towards Shinkiari, Battal, Batgram and Thakot. With the construction of Motorways, Thakot can now easily be accessed through Motorways. From Thakot Bridge, the access onward to Gilgit and Hunza continues as a part of KKH:

- Islamabad to Burhan Interchange near Hassanabdal via M-1 (Islamabad-Peshawar Motorway):
- The transportation from Islamabad to Burhan Interchange near Hassanabdal via Islamabad-Peshawar Motorway (M-1) comprised of 6 lanes is 44 km.
- Burhan Interchange to Thakot via M-15 (Hazara Motorway):
- The transportation from Burhan Interchange to Thakot via Hazara Motorway (M-15) is also 6 lanes upto Haripur, 4 lanes upto Mansehra and 2 lanes upto Thakot with five Tunnels, two at Abbottabad & one each at Battal, Karmong & Mansehra, with route distance of 180 km.
- Thakot to Gilgit via N-35 (KKH);
- KKH (N-35) from Thakot to Dasu is in good condition whereas from Dasu to Chilas, the road condition is not good and requires improvements. From Chilas onwards to Gilgit, the road is in good condition. The route distance is 390 km.
- Gilgit to Project Area via N-35 (KKH) along Hunza River.
- KKH (N-35) from Gilgit to Project Site at Attabad Lake is good condition metaled road with 2 lanes. The route distance is 120 km.

There is another route from Islamabad to Gilgit and Project area via Babusar Pass, through National Highway (N-15). This route with good condition metaled road is although shortest than national highway to reach upto Chilas but due to high altitude mountains, many sharp turns and route closure for about six months in a year because of heavy snowfall during winter, the transportation through this route is not suitable for heavy vehicles.

The distances between Project Site and major landmarks are as follows;

Major Landmark	Distance (km)	Importance
Gilgit	120	Capital of Gilgit Baltistan and nearest airport
Khunjerab Pass	150	Pak-China border, trade route between the two countries
Islamabad	735	Capital of Pakistan
Lahore	1,100	Capital of Province Punjab
Karachi	2,300	Sea Port

15.3.2 Access by Air

Gilgit, the capital of Gilgit-Baltistan is the closest airport at a distance of 120 km from the Project Site. Air time to reach Gilgit from Islamabad is about 1 hour subject to weather. Helipads are also available which can be used in case of extreme urgency situations.

15.4 MANPOWER AVAILABILITY

15.4.1 Unskilled

Unskilled labour including drivers, guards, clerical staff, etc. will be all indigenous and mostly available from Gilgit Baltistan Region.

15.4.2 Unskilled

Adequate number and variety of skilled labour will be required for the Project. Skilled labour will mainly consist of masons, carpenters, mechanics, electricians and technicians for operating various construction equipment, batching plant, aggregate processing plant, surveying alongwith the execution of various construction activities including production and laying of concrete, rock blasting, quality control, testing of construction materials, welding, heavy equipment repair and installation of E&M equipment etc. The Project Area will not be able to provide significant number of skilled labours. However, sufficient number of manpower is available in other parts of Pakistan.

15.5 FACTORS AFFECTING PROGRESS OF CONSTRUCTION WORKS

15.5.1 Non-Productive Periods

The climate of the Project are is characterized by moderate summers and severe winters with maximum daily temperatures in summer often exceeding 30 °C and about −10 °C in winters. The Project Area receives precipitation in the form of rain in summers and snow in winters. During severe cold weather with temperature falling below freezing point, the cement and reinforcing bars cannot be stored for long periods due to deterioration in their quality. The storage of cement below freezing point will lead to its setting. Moreover, it would be difficult for supervisory and working staff to work in cold season and snowfall, therefore, the above ground construction works are expected to be suspended for about 60 days every year during January & February.

Sunday is a weekly holiday in Pakistan. Therefore, six days work in each week is expected at Project from Monday through Saturday but normally, Sundays are not observed as holiday at Projects in remote areas and the labours are allowed to avail more holidays on Eid festivals. It is traditional to close the Project Site for 7 to 10 days on Eid-ul Fitr and Eid-ul-Azha as most of the labour, who would be hailing from distant places visit their families to celebrate these festivals with them. There are 14 official public holidays in Pakistan, as shown on Table 15-1. Depending on the lunar calendar, dates of some are subject to variation.

Table 15-1 Public Holidays

Occasion	Date	No. of Days
Kashmir Day	05th February	1
Pakistan Day	23rd March	1
Labour Day	01st May	1
Independence Day	14th August	1
Eid-ul-Fitr*	1st to 3rd Shawal	3
Birthday of Quaid-e-Azam & Christmas	25th December	1
Eid-ul-Azha*	9th to11th Dhul-Hijjah	3
Youm-e-Ashur*	9 &10th of Muharram	2
Milad-un-Nabi*	12th Rabi Ul Awal	1
Total Official Holidays		14

(*) Dates of religious holidays are defined by the lunar calendar

15.5.2 Procurement and Storage of Materials

Cement

The Cement is abundantly available in Pakistan. During snowfall and rainy season, there is risk of supply hold-up due to inclement weather for 8 to 10 days. To ensure continuity of construction works, it is assumed that 02 to 03 weeks storage of cement at site in weatherproof warehouses will be essential. It has been estimated that about 31,485 tons cement would be required to meet the project construction activities. Mostly Ordinary Portland Cement (OPC) will be used. Sufficient production capacity of cement per day is available with the existing cement factories in Pakistan and cement can be transported to the project site using trucks or long trailers.

The Table – 15-3 indicates the present daily production of five factories in nearest locations to the project. It is evident from production rates of these factories that any of these factories can furnish the requisite quantity of cement for concrete works at the project site.

Table 15-2 Cement Production Capacities in various Factories

No.	Manufacturer	Production (tons/day) / Distance (km)
1	Bestway Cement (Farooqia)	8,155 / 675
2	Askari Cement (Wah)	3,020 / 685
3	Fauji Cement (Fateh Jhang)	9,407 / 710
4	Askari Cement (Nizampur)	4,662 / 755
5	Cherat Cement (Nowshera)	12,427 / 790

Coarse Aggregate

As mentioned in Volume-2 Geology and Geotechnical Investigations, rock quarries have been identified at Passu and Powerhouse area. The marble present in Passu area and Rounded Boulder Gravel Silt (RBGM) at Powerhouse Area can be used as coarse aggregate by certain amount of processing, i.e. crushing, washing, screening and blending. The muck material from underground excavations cannot be used as coarse aggregate with OPC due to potential of Alkali Silica Reaction.

Sand

High quality of large sand deposits are available in the tail end area of Attabad Lake near Shishkat Bridge for use in the ALHPP.

Reinforcing Steel

The quantity of reinforcing steel required for the Project will be about 3,300 tons, with a monthly average consumption of about 155 tons. Several factories in the country produce small quantities of reinforcing steel, in the form of both plain and deformed bars. There is no factory producing reinforcing steel bars in the vicinity of the Project Site. The nearest location from where the reinforcing steel bars of the desired specification are available is Islamabad. Both hot and cold rolled reinforcing steel bars are available in desired quantity from Islamabad, about 735 km from the Project Site. The storage of reinforcing steel sufficient for one month peak consumption 155 tons will not require large areas.

Explosive Materials

In the main weir and flushing channel areas, extensive volume of excavation is of slided materials having large size boulders, which may require blasting. There are certain areas, where rock excavation would also be involved like power intake, headrace tunnel and surge tank etc. The consumption of explosives and blasting consumables is generally difficult to assess. However, a sustainable inventory will have to be maintained for which adequate storage depot will be essentially required at Project Site. The Wah - Bofors factory in Wah (near Rawalpindi) is capable of supplying all the explosives and blasting consumables required for the Project.

Steel Plates and Steel Formwork

Steel sheets of various thicknesses are produced at the Steel Mills at Karachi, which can be used to fabricate steel formwork. These can also be used for fabricating steel liners and other miscellaneous items required in connection with the construction activities. Alternatively, steel items can be imported from abroad. Most likely source of steel plate could be nearby countries such as China and Iran.

Petroleum Products

Petroleum products will be mainly diesel with comparatively minor quantity of gasoline and lubricants, which can be procured directly from the source i.e. the oil refineries, spread in the country, for the operation of machinery and vehicles. The storage tanks would be established at the Project site with total capacity of around 40,000 litres, sufficient for around one month of operation, to cope with extraordinary conditions like land sliding on the KKH or fuel shortages, etc.

Water and Stone for Riprap and Fill Material

The Hunza River water will be used in the making of concrete at ALHPP. The results of water samples taken from Hunza River indicate that water is suitable for mixing & curing of concrete.

The large boulders with sufficient quantity present in the slided mass can be used as riprap material to control the erosion by water. Silty sand, sandy silt and gravelly sand available in the river bed and in slided mass (in ample quantities) can be used as fill material for the protection of slopes and construction of coffer dam etc.

15.5.3 General Construction Equipment

The economic life for most of the construction plant and equipment is five 5 to 7 years, therefore brand new equipment should be deployed on the Project. Most of the construction plant and equipment required for the execution of the works will have to be imported from international sources like excavators, dumpers, graders, crawlers, cutters, drilling jumbos, drilling and grouting equipment, batching and concrete plant, vibrators, mixers, graders, rollers, dump trucks, power generator etc.; the same applies to most of the spare parts and construction plant and equipment-related consumable supplies.

Due to the difficult KKH haulage conditions through mountainous terrain, the size of equipment will generally be smaller, with most units weighing less than 40 tons when prepared for transportation. Large items of equipment may be brought to the Project site in knock-down condition for assembling at the site.

15.6 PRE-CONSTRUCTION PHASE

Upon the completion of Feasibility Study, a number of preliminary works are required to be completed as pre-requisites for starting the construction phase of the Project including approval of PC-I, land acquisition, procurement of Consultant, preparation of EPC tender documents and the selection of EPC Contractor.

Immediately after the approval of PC-I of the Project, the Consultant will be hired for the review of Feasibility Study, preparation of EPC tender documents and construction supervision. Simultaneously, land would be acquired for project components and access roads. The Consultant, after the award of Consultancy Contract will immediately commence their pre-construction phase tasks; however the supervision period will proceed after the award of Main Contract. After the completion of tender documents by the Consultant, the EPC Contractor shall be hired to commence the preparatory works at project site. The Pre-construction activities are planned to be completed within 14 months.

15.6.1 Land Acquisition

Permanent Acquisition

No major problem is envisaged in acquisition of land. It is anticipated that land required for the Project on permanent basis will be acquired / purchased. To streamline the Project implementation and to avoid delays, it is desirable that the land acquisition process is accomplished and possession of the land for temporary and Project main structures is taken at least one month before start of construction work.

Temporary Acquisition

The land required for the establishment of contractor camps, stores and workshops will be acquired on temporary basis by direct negotiation and agreement with the owners. Temporary acquisition will principally be the responsibility of the Contractor.

15.6.2 Contract Award on EPC Basis

International Competitive Bidding (ICB) has been proposed for execution of the project works for award to the contractor on EPC basis detailed hereunder:

XIII. Detailed engineering design of the Project components.

Construction of infrastructure works, civil works, procurement & installation of electrical and mechanical equipment etc.

15.7 PREPARATORY WORKS

Preparatory works includes access roads, contractor's camps & site installations and, infrastructure works, etc. It is envisaged that the EPC Contractor will mobilize its personnel and equipment to the site within 60 days after signing of Contract. The main activities to be undertaken by the EPC Contractor under preparatory works are briefly outlined below:

- Establishment of Contractor's camp and other facilities.
- Construction of Residential Colony.
- Construction of access roads to main work sites.
- Additional survey and investigations required by the Contractor.

The detailed design of temporary works and permanent structures by EPC Contractor shall also be commenced in parallel with the preparatory works.

15.7.1 Contractor's Camp

About 300~350 work force together with the supervisory staff of the Contractor will be required for the Project construction. The workforce will be originated from Gilgit Baltistan and different regions of Pakistan and from oversees. The Contractor will be responsible for the construction of adequate accommodation and temporary facilities for his workforce before the start of the main works. The Contractor also will carry out proper and adequate maintenance of such facilities to provide neat, well-kept, pleasant, healthful surroundings and conditions for all occupants.

All utilities including electricity, water supply, sewerage system and approach roads will be provided by Contractor at construction camps & offices and in residential area. The Contractor will ensure that all these facilities fulfill the requirements for residential camps, site offices, yards, construction sites etc.

15.7.2 Construction Plant Facilities

The Contractor will require work areas for various functions including space for stockpiling aggregates, aggregate manufacturing, and concrete batching and mixing plants.

Aggregate Processing System

The Aggregate Processing System for preparation of coarse and fine aggregates is proposed at the Powerhouse site due to easy access and the availability of wide area of land. The estimated requirement of aggregates of different sizes is 63,790 m^3. In accordance with the demand of finished aggregates, consideration of the losses during transportation, processing and pouring and counting the non-uniform coefficient of production, the system's overall raw material processing capacity is assumed to be 50 m^3/h.

The Aggregate Processing System mainly consists of raw material stock yard, coarse screening plant, pre-screening plant, coarse crushing plant, storage area for the semi-finished products, intermediate crushing plant, main screening plant, fine crushing plant, sand making plant, storage area for the finished product, water processing system, power supply system and belt conveyor system, etc. Aggregate processing system shall adopt the three-stage crushing and closed production workmanship. Main equipment includes jaw crusher, cone crusher, vertical shaft impact crusher, vibrating feeder, vibrating screen classifier, screw sand washer, etc.

15.7.2.1 Concrete Production System

The estimated total quantity of concrete in this project is about 73,600 m^3. Two independent units are proposed to meet the requirement of concrete and shotcrete for the Project structures. One concrete mixing batching plant of 30 m^3/hr capacity is proposed on left bank side, downstream of the Weir site to cater for the needs of Main Weir, Undersluice / flushing channel, Power Intake and Access Tunnel / Adit to Headrace Tunnel near Power Intake.

Another Concrete Batch of 60 m^3/hr capacity is planned to be install at Powerhouse site as suitable area is available here. This batch plant will cater for the needs of Headrace Tunnel, Surge Tank, Powerhouse, Tailrace Channel, Access tunnel / Adit to Headrace Tunnel near Surge Tank. The Temporary roads may be constructed to transport concrete at desired site location from these batch plants.

Concrete system consists of automobile receiver bin, finished charging bucket, belt conveyor, concrete mixing plant, screw conveyer, cementing material tank, air compressor room, cooling system etc. This facility need not be on level ground and it can be installed on a series of cut benches with delivery access with bins, cooling system, batch and mix plant possibly on three separate levels.

15.7.3 Other Site Facilities

The other site facilities that will be required by the Contractor for the construction of ALHPP are described below. Most of these facilities are planned near Powerhouse site where suitable wide land is available.

- Materials Laboratory equipped with the equipment for test on soil, rock, concrete, aggregates, bricks, embankment materials and filter materials.

- Temporary facilities / buildings such as steelwork and carpenter's workshops, mechanical equipment repairing workshop, fabrication workshop, storage yards for storing equipment, machinery, aggregate, sand, cement, steel reinforcement, scaffolding, bricks, chemicals, explosives to be used during blasting operations and fuel tanks etc.

- Temporary roads connecting camp & other temporary facilities with the sites of main structures in the project area, other than the access roads.

- Religious facilities within the camp areas for performing religious activities.

- Health facilities including portable First Aid Station equipped to provide primary care for emergencies relating to injuries, burns, broken bones etc. Arrangements shall be made with the closest major hospital to cater for accident and hospitalization cases.

- Emergency fire protection facilities in all offices and buildings to cater for any fire hazard including hose, fire extinguishers, pails and shovels etc.

- Wireless communication system for communication between site personnel, site offices and the working areas.

- Security facilities including security check posts at main entrance of camp/site. All the work areas, storage areas and such other area where construction activity is proceeding shall be guarded by the security guards and watchmen for security.

Spares and standby equipment to ensure continuity and proper completion of operations, including diesel power generating sets, earthwork plant, concrete mixing and transportation plant, grouting equipment, dewatering plant and other key plant and equipment required to ensure work progress.

15.7.4 Residential Colony

Residential accommodation for the Project Executing Agency and Consultant's staff is also an important requirement, which must be made available prior to the start of the main works. The construction of Residential Colony will be started simultaneously with the construction of access roads.
An area of 2.5 Acres will be required for the construction of office, residential block for O&M Staff including Engineers, supervisory and lower staff, rest house, mosque, basic health unit, shops and other allied services including roads, water supply / sewage disposal system and the electricity arrangement etc. The Colony once completed will be utilized for the management personnel of the Employer and Consultant till the project construction completes, to facilitate the communication and management. After the completion of the project the colony will be utilized by Operation & Maintenance (O&M) staff.

Area for both the Residential Colony & Contractor's Camp are planned at one place near Powerhouse Site as a wide area of land is available here and also other plants / workshops are to be installed here.

15.7.5 Access Roads to Main Work Sites

Access road is the most important structure to effectively start the construction activities; therefore, the construction of access roads to the Project structure's sites shall be taken up immediately after the mobilization of Contractor at Project site.

From transportation tunnel - 1 inlet of existing KKH, a stretch of old KKH first slopes down from El. 2400 masl to El. 2360 masl and then slopes up to El. 2500 masl with few sharp turns to approach existing spillway of Attabad lake. This stretch of old KKH within the Project Area will be improved / upgraded to provide access to the various Project structures and to serve as carriage for material and equipment required for the Project structures.

From El. 2360 masl, the old KKH path branch off to a track which slopes down to El. 2310 to approach Sarat and Salmanabad Villages through a bridge on Hunza River near proposed Powerhouse site. The track will be improved alongwith the construction of access roads to approach Powerhouse, Residential Colony, Construction camp and utilities to be established. Another track branch off from old KKH which slopes down from El. 2480 masl to El. 2420 masl near existing spillway. This track was developed at the time of creation of existing spillway of Attabad Lake and requires improvement to access Weir and Power Intake sites.

Besides the improvement / upgradation of old KKH and tracks, the access roads to access tunnels / adits for Headrace Tunnel and Surge Tank will also require to be constructed.

15.7.6 Additional Survey & Investigations

Based on review of existing survey and investigations, the requirements for additional field investigations will be identified by EPC Contractor and then be carried out as required for Detailed Engineering Design by the EPC Contractor.

15.7.7 Detailed Engineering Design

The EPC Contractor will be responsible for the Detailed Engineering Design and will be approved by Project Consultants engaged for construction supervision. Its objective is to achieve an effective design to enable the construction of hydropower plant that meets Project requirements for safety, availability & operability / maintainability with no adverse environmental impact and within the agreed cost and schedule. The EPC Contractor will design all Permanent works and all necessary Temporary works.

The design of access roads, Contractor’s camp & related facilities, Civil and E&M design of all the Project components will be commenced in parallel with the preparatory works. The design of access roads, Contractor’s camp & related facilities will be completed within one month for early construction of access road and Contractor camp & facilities. However, detailed Civil and E&M design of the Project will be presented by the EPC Contractor step by step for later work execution.

15.8 CONSTRUCTION PLANNING AND METHODOLOGY

The ALHPP involves execution of considerable quantities of excavation and concreting for structures. Considering the magnitude and nature of construction activities, mechanized construction has been considered for all type of construction job so as to achieve consistent quality at a faster rate for timely completion of the Project.

The Project involves overflow weir, sediment flushing channel / undersluice, power intake, low pressure headrace tunnel, surge tank, penstock, powerhouse and tailrace channel. The location arrangement and structural details of the above components are shown in Volume-5 (Drawings). The work on all these components can be carried out simultaneously.

The construction of low pressure headrace tunnel is very significant item in order to have early completion of the ALHPP. Diversion works are mandatory for the commencement of the works on sediment flushing channel and overflow weir. The construction of the access tunnels to the headrace tunnel near power intake and surge tank areas will help to make an early start on excavation of headrace tunnel which lies on the critical path. Rock mechanics tests of tunnel and surge tank will also help in determining the kind of support system required in the crowns and walls of these underground structures. Timely rock geology identification will facilitate in design, procurement and manufacturing of support systems and will help in timely completion of the Project.

The construction methodology described in this section of Feasibility Report show techniques for main structural units of ALHPP and is based on the assumption that the construction work will be executed by an experienced EPC Contractor selected through competitive bidding, who will be fully capable of employing modern construction methods, managing proper / sufficient manpower and equipment for timely completion of the Project. However, these construction methods should not restrict the EPC Contractor using other acceptable approaches and methods to achieve desired quantity & quality of works in scheduled time and cost.

15.8.1 Care and Handling of Water

It is envisaged that two temporary coffer dams will be constructed in 02 stages. Stockpiling of adequate material and mobilization of suitable equipment will be made well in time before the construction of coffer dams. The construction of Stage-I coffer dam at upstream of sediment flushing channel / undersluice with crest level at El. 2422 masl, will be initiated as soon as possible after the improvement / upgrading the access path to Weir Site. On the completion of the Stage-I coffer dam, the excavation of sediment flushing channel / undersluice will be commenced and the Hunza River / Attabad Lake water will continue flowing through the existing spillway.

The construction of Stage-II coffer dam at upstream of overflow weir section with crest level at El. 2422 masl, will be initiated after the completion of works of sediment flushing channel / undersluice. On the completion of Stage-II coffer dam, the Hunza River / Attabad Lake water will be diverted through sediment flushing channel. The Stage-II coffer dam is envisaged to prevent entry of water into the working area for construction of overflow weir in dry portion.

15.8.2 Sediment Flushing Channel / Undersluice

The suspended sediments transported by Hunza River and entering the power intake will unavoidably result in a certain wear and tear. The extent of the abrasion depends largely on the concentration, size and mineralogical characteristics of the sediment particles on one hand and the turbine type and runner speed on the other. This abrasion and the resulting need for overhaul and replacement of runners cannot be avoided; however, the frequency of repair works can be reduced by arrangement of flushing facilities.

For this purpose, the sediment flushing channel will be constructed at the left side of overflow weir section, consisting of low level outlets with gated arrangement (three bays each having 05 m width) and during construction of overflow weir will be used as diversion channel. The invert level of sediment flushing / undersluice section is planned at El. 2402 masl.

The sediment flushing channel would be founded on overburden / slided mass. The excavation work of sediment flushing channel will begin after the slope stabilization of left bank slopes. During its excavation, water will be diverted through existing spillway. Upon the completion of coffer dam (Stage-I), the sediment flushing channel will be excavated below its planned invert level. The occurrence of large size boulders within the sediment flushing channel area must be anticipated by the Contractor, for which proper methodology needs to be applied for removal of such boulders.

During the excavation, high moisture content materials can be encountered. The Contractor must ensure that his excavation methods ensure for the additional and unseen difficulties associated with removing this material, such as efficient transport of high moisture content material and complex care of water issues. The excavated material will be disposed-off at spoil areas planned near the Powerhouse site.

After the completion of excavation, vertical concrete cut off walls upto the required depth will be provided on upstream and downstream edge of sediment flushing section, followed by the concrete works of channel. Concrete will be poured up to the invert level, at which point where gate will be rested. Concrete placements will be temporarily diverted to flushing channel, until the completion of grouting and drainage curtain works in each bay. When the concrete works have been sufficiently progressed, the gate guides will be installed, aligned, and measured for tolerance. When the survey of these guides will confirm their position, second stage concrete will be placed. It is anticipated that the radial gates will be fabricated offsite in manageable sections. A test assembly of the gates would be undertaken at the fabrication yard, following which the gates would be dismantled to their transportable sections for mobilization to site.

At site, the gates would be preassembled into larger sections, such as trunnion arms and full height skin plate sections. These gate components would then be hoisted into place and fixed into final position. The exact process for undertaken this complex task would need to be developed in detail by the Contractor, in collaboration with the gate supplier. Once the flushing section gates are installed, the remainder of the M&E equipment i.e. gate hoists would be installed. Stop logs would also be fabricated and brought to site in full width segments. Dry commissioning of both the radial gates and stop logs would occur. Wet commissioning will follow when an appropriate level of lake is reached.

The stone apron will provided at the upstream side. Before placing stone apron, the ground will be properly adjusted and compacted and if required covered by a filter fabric. The sediment flushing channel is envisaged to be completed in 8 months period.

Upon the completion of sediment flushing channel, lake water will be diverted through this structure, to commence construction activities on power intake and overflow weir section.

15.8.3 Power Intake

A two bay intake structure shall be constructed on left bank of Attabad Lake upstream of main weir for passing the design discharge. The Intake level will be 4m above the invert level of sediment flushing channel section to keep the area upstream of the intake sediment free. It shall be equipped with a trashrack to prevent intrusion of debris (like timber, leaves, trees etc.)

into the waterways and with a hydraulically operated gate for emergency closure and for isolating the waterways for inspection and maintenance.

After the completion of sediment flushing channel in all respects and drawdown of water level in Lake below El. 2400 masl, the construction work on intake structure will commence. The excavation of intake has to be made at El. 2404 masl. To access the power intake area, access road has to be constructed first and after the construction of intake structure, it will be removed. Concrete and other materials will be brought to the structure via the same route.

The excavation for the power intake shall be open cut rock excavation and will be done from top to bottom. The slope protection and support measures will be installed after each excavation step and prior to the next excavation step. The excavation will be done in a manner that the remaining rock slopes are not damaged, rock properties are maintained and rock is not loosened. The rock strengths shall be maintained by using adequate blasting techniques. The excavation beyond the theoretical rock contour shall be backfilled with concrete or shotcrete.

After completion of excavation works at intake, the erection of formwork of suitable length for pouring concrete will be done with concrete pumps to expedite the work. The excavation and concreting activities at intake structure are envisaged to be completed in 12 months period. After the completion of intake structure, a trashrack cleaning machine (TRCM) will be installed for removal of debris infront of trashracks. A gantry will be installed for placement and removal of the stoplogs.

15.8.4 Overflow Weir / Ungated Spillway

The overflow weir is a concrete gravity type, un-gated section (60 m wide) with downstream stilling basin. The weir would be founded on overburden / slided mass. The weir crest (El. 2414 masl) will be of ogee type which will transfer the water from Attabad Lake reservoir in a smooth decline to the downstream. A stilling basin downstream of weir will dissipate the energy by creating a hydraulic jump and shall prevent downstream erosion.

Once the construction of coffer dam (stage-II) will be completed, the work on the overflow weir section will be commenced with its excavation to required level with excavators. The occurrence of large size boulders within the main weir area must be anticipated by the Contractor, for which proper methodology needs to be applied for removal of such boulders.

During the excavation of overflow weir section, high moisture content materials can be encountered. The Contractor must ensure that his excavation methods ensure for the additional and unseen difficulties associated with removing this material, such as efficient transport of high moisture content material and complex care of water issues. The muck generated from the excavation of main weir will be disposed-off along right bank downstream of the weir site

After the completion of excavation, vertical concrete cut off walls upto the required depth will be provided on upstream edge and center of weir.

For overflow portion, the crest of the weir will be 2412.0 masl and downstream basin at El. 2400.10 masl. After completion of the excavation up to the required level, the construction of weir will be commenced in form of monoliths by erecting formwork. The concrete hauling trucks with vibrating drum will be used for pouring concrete. The specified strength of concrete in lifts usually one meter in height will be poured into formwork of the various monoliths. After pouring the concrete, chipping or green cutting with water and air pressure on the top of the laid concrete lift will be carried out for preparation of a proper bond required for placing the next lift of the concreting. PVC water-stop will be provided between the two monoliths at u/s of contraction joints to stop the seepage, if any. In this way, concreting up to the crest level 2412.0 masl will be completed.

The stone apron will be provided at the upstream and downstream side. Before placing stone apron, the ground will be properly adjusted and compacted and if required covered by a filter fabric. The overflow weir is envisaged to be completed in 9-month period. Upon completion of overflow weir, the working area will be re-flooded to match the lake water level.

15.8.5 Access Tunnels / Adits for Headrace Tunnel

The biggest portion of the underground works is the excavation of the headrace tunnel, which is approximately 2.3 km long. The headrace tunnel covers about 95% of the total underground works excavation volume. Since the main objective of the project planning is time and cost minimization, the total of these works have to be split up into reasonable portions to enable simultaneous work at several sections. In accordance with the study of local geographical and environmental conditions, the provision of 02 access tunnels has been proposed. Nevertheless, the tunneling will remain the critical path for the civil works. The following access tunnels will be constructed to access the headrace tunnel:

Access Tunnel Adit	Length
Near Power Intake	450 m
Near Surge Tank	202 m

The excavation of these access tunnels will be done using the drill and blast technique as explained below for the low pressure headrace tunnel.

15.8.6 Low Pressure Headrace Tunnel

From power intake, approximately 2,300 m long low pressure headrace tunnel (horseshoe shape), having 5.5 m width & 5.5 m height would run along the left bank of Hunza River leading to surge tank. The upstream level of tunnel is El. 2,402.5 masl whereas downstream level is El. 2,385 masl.

After the completion of access tunnels / adits, the underground works for the headrace tunnel will be commenced immediately because the construction of headrace tunnel is connected with the dependent works of surge tank structure. Taking into account the geological and execution conditions, the “Drill and Blast method” is proposed for the excavation of the headrace tunnel. The underground works of headrace tunnel are assumed to be the most critical part of the Project.

The headrace tunnel will be sub-divided into two sections. With this division in construction sections, it will be possible to work simultaneously at two fronts basically independently from each other. However, due to limitations of space for spoil areas near the power intake site, major excavation will be executed through the section near surge tank for disposal of muck at spoil areas near Powerhouse site. Accordingly, the headrace section # 01 will be from its start at power intake upto about 700 m length. The headrace section # 02 will be from 700 m to 2300 m (1600 m long)

The surface geological mapping of the tunnel area has been carried out. A good to poor quality rocks are present in headrace tunnel area. The tunnel length for each rock classification and its quantity are used for tunnel progress rate calculation & for establishing the tunnel scheduling.

The headrace tunnel will be constructed in three main phases; the top heading, benching and invert. The drill and blast method using a jumbo drill will be used for the top heading excavation, and the front-end loaders and articulated trucks for mucking out the excavated material. The benching will be carried out by drilling a pattern of vertical charge holes through the floor of the top heading. The holes will be charged and shot as the excavation of the bench proceeds. The rock shot will be removed with front end loaders and trucks. Similarly, invert will be excavated at the end of tunnel excavation.

Depending on the type of rock, the advance rate for the top headings is assumed as 2 to 3 m per day based on two 10-hour shifts. This advance rate is adopted after reviewing data derived from standard guides as well as ongoing projects of similar nature within Pakistan, and is used for establishing the tunnel scheduling. It has been estimated that the excavation of tunnel will be carried out in 533 days.

Support measures comprising rock bolts, shotcrete, wire mesh, steel sets and drainage holes will be adopted depending on the condition of the rock strata. After completing the excavation and temporary supports in whole length of headrace tunnel, the erection of steel sliding forms of suitable length will be applied for pouring concrete with concrete pumps to expedite the concrete lining. A standard progress assumes at 120 m/month for arch and wall applying steel sliding form and 500 m/month for inverts. The backfill grout will follow the concrete lining.

After the completion of construction activities of headrace tunnel, the access tunnels/adits will be plug with the concrete. Total time of around 25 months has been estimated for the excavation, rock support measures and concrete lining of headrace tunnel.

15.8.7 Surge Tank

A circular surge tank having 10 m diameter and 45 m high will be constructed at the intersection of the headrace tunnel and penstock to prevent the adverse effect of water hammer pressure or flow variation due to turbine load fluctuation on the headrace and other structures.

For approaching surge tank, an access road and access tunnel / adit will be constructed upto its crown. The construction of access road will be commenced simultaneously with the other access roads to the work sites. The excavation work for access tunnel will be started from its outlet and mucking of excavated material will also be done from the same end. Rock bolting and shotcreting on excavated faces of access tunnel shall be done depending on the condition of the rock strata.

The work for surge tank will be done more or less independently from the other works. Dependence exists to the construction of 2nd section of the headrace tunnel because it will be used for mucking of excavated material from the surge tank structure.

After the completion of access tunnel / adit, the manpower and equipment shall be mobilized and downward excavation shall be done by raise boring to the full diameter of the surge tank.

Prior to raise boring activities, the excavation will be done to prepare the staging area and platform for the surge tank. Once the boring machine is set, drilling of pilot hole will commence. Drilling of pilot hole will be done until breakthrough with the tank bottom at headrace tunnel. After breakthrough, widening the pilot hole by raise boring will be done. The spoil generated shall be mucked out from the tank bottom off the headrace tunnel using wheeled loader that will load the spoil to dump trucks for transport to spoil areas near powerhouse site. Upon completion of raise bore, the boring equipment will be dismantled and removed from the site.

The raise bore will then be widened to the full diameter of the tank. After initial excavation, collaring of the tank will be done by applying the support measures. Suitable hoisting equipment and related accessories will be installed to transport equipment, supplies and personnel from the tank collar to the work area. After advancing downwards, the sinking platform will be installed to facilitate the work of the tank construction.

Main excavation will be by drill and blast method, starting from the top and progressing downward. The explosives charge will be limited to ensure that the pilot raise bore is not deteriorated or damaged by the blasting operations. After each blast, spoil will be dropped to the tank bottom through the pilot raise bore which shall then be loaded by a wheeled loader into dump trucks that will transport the spoil to the spoil area through the access tunnel / adit to headrace tunnel near surge tank.

After completion of excavation, the concrete lining in this structure will be taken up immediately by starting from its bottom to top with slip forms moving in an upward direction towards the tank collar. A total of 12 months have been allocated for completion of the underground excavation and concrete works of the surge tank.

15.8.8 Penstock

A Penstock of 3.6 m dia will be laid under the left bank slopes for conveying water from headrace tunnel to 03 Vertical Shaft Francis Turbines to be housed in Powerhouse. At the end, the penstock shall be trifurcated into penstock manifolds with reduced dia. In the first section upto 80 m, the penstock will cross horizontally the rock starting from the bottom of surge tank. This section can be considered as an extension of headrace tunnel, lined with an embedded steel lining. The second section, 455 m long will be the embedded penstock descending towards the powerhouse.

For the excavation of first section, the similar method of excavation as for headrace tunnel i.e. drill and blast method will be applied. For the second section, the alluvium will be excavated upto the required depth over which concrete will be placed for penstock to be laid. Excavation from the penstock trench will be stockpiled in the area near to the powerhouse site.

The penstock steel liner will be manufactured in the workshop at the Project site from the steel plates and welded into 4 to 6 m long sections, which after testing will be transported to their places of installation using trailers. The installation of penstock will be started from the upstream side moving downwards towards the powerhouse. The penstock will be placed on a bedding of blinding concrete. After laying in final position, the penstock sections will be welded, followed by the concreting of 8 no. anchor blocks and backfilling. The construction of penstock will be taken up alongwith the powerhouse construction. Total time envisaged for the construction of penstock is 10 months.

15.8.9 Powerhouse Civil Works

The Powerhouse is proposed 63 m long, 20 m wide and 35 m high with four floors at different levels. Machine Hall floor would be at El. 2306.2 masl and powerhouse top shall be at El.2314.5 masl. The main hall would accommodate three vertical Francis units, each of 18 MW, alongwith generators, switch cabinets, trifurcation of penstock pipe and erection bay.

The construction of powerhouse structure will be taken up independently after the construction of access road to powerhouse site. The powerhouse will be excavated upto the lowest El 2292 masl of the powerhouse pit. The muck generated from the excavation will be disposed off at the spoil areas near powerhouse site.

Upon completion of powerhouse excavation, the steel reinforced base concrete will be poured and subsequent concrete works for sub-structure and super-structure of powerhouse will be commenced in accordance with the planned sequence. The sloping trussed roof will be constructed along with the installation of powerhouse crane. Backfilling around powerhouse will be done upon the completion of powerhouse substructure. All these activities related to powerhouse construction will be completed in 15.5 months. The powerhouse architectural works will be completed parallel to testing and commissioning of units.

15.8.10 Unit Erection

The three generating units will be housed in the powerhouse, with the operating floor at El. 2,306.2 masl. A large erection bay is provided to maximize the ability to work on multiple units at a time to save time. Each turbine is connected via a main inlet valve to a steel penstock.

It is intended that the EPC Contractor will have three complete teams of workers on site, enabling the erection of three units in parallel. In addition, the workforce will be divided so that a team that installs and welds embedded components, such as the draft tube and spiral casing, will be separate from a team that installs the rotating plant (head cover, guide vanes etc.). There will also be separate generator teams, able to work on stators and rotors in parallel. The main inlet valves (MIV) for 03 turbines will be installed for commissioning of units when headrace tunnel is watered.

In draft tube construction, civil and mechanical teams will work continuously without impeding the each other. Once the draft tube liner has been installed for a particular unit, the mechanical team will move on to the next unit while the civil team undertakes draft tube embedment. Once the next draft tube liner is installed, and the concrete of the current unit is sufficiently cured, the team will move back to the initial unit to install and weld the spiral casing, and so on. In this way the mechanical and civil teams will be continuously employed without hindering each other.

15.8.11 Mechanical & Electrical Installations

The installation of the mechanical and electrical equipment can be broken down into the following major stages, excluding the civil works that are required to support these works, such as pouring the floor columns, beams, floors and plinths:

- Installation and embedment of the turbine embedded parts, comprising the draft tube liner, spiral casing, stay ring, and turbine pit liner.
- Installation and alignment of the turbine and covers to the stage where work can commence on the generators such as head cover, regulating ring, servomotors, runner

and turbine shaft. These items are large and heavy and need to be lowered into the turbine pit using the powerhouse crane, and hence no work in the generator enclosure can take place before these works are complete.

- Installation of the generator lower bracket (which is then covered over and used as a working platform) to allow generator stator building in parallel with installation of the remaining turbine components, which will need to be taken into the turbine pit via the pit entrance on the turbine floor.

- Installation of 03 spherical Main Inlet Valves (MIV). Each valve will be taken to its plinth and aligned with the penstock stub and spiral inlet, a potentially time consuming process depending on the accuracy of alignment of those components. The upstream stub pipe of the MIV will be welded to the penstock manifold stub. A stub piece will be welded to the spiral end, and the remaining gap filled with an adjustable make-up ring. The servomotor(s) will be installed as well as control pipework and fittings to enable the valve to be dry commissioned.

- Generator stator building. The stator frame will be brought to the erection bay in three sections. They can then either be assembled on the erection bay and taken as one assembly to the generator enclosure or taken as separate items and assembled in the enclosure. The method used would be that preferred by the manufacturer. Once in position and aligned the stator core will be built. The core will consist of layers of punched magnetic sheets of steel lowered over retaining rods to form a complete ring with no vertical joints. The layers will be built up and clamped to predetermined pressures at a number of stages to ensure the build is progressing satisfactorily. Care will be required to ensure the stator core is completely circular. Resistance temperature detectors will be embedded within the core to provide temperature information during unit operation. Once the core layers are complete the competed core will be clamped to ensure it does not move during operation. Upon tests to ensure the core is satisfactory, the stator winding will commence. There will be two layers of windings in each slot, but the exact dimensions and construction arrangements will be to the manufacturer's standard design.

- Generator rotor building. This work will be undertaken on the erection bay and as such can take place in parallel with the stator building. The rotor spider (the frame upon which the rotor pole rim is mounted) will be of forged construction and brought into the powerhouse as one item. It will be lowered over the generator shaft, and then the rim and brake track will be fitted, followed by the rotor poles.

- The upper bracket, bearings and slip-rings will be installed once the fully assembled and tested rotor has been lowered into the generator onto the thrust bearing (which will be mounted on the lower bracket). The rotor will be the heaviest single item to be lifted within a powerhouse, and will require two overhead cranes to operate in tandem (i.e. controlled as a single device) using a specially designed lifting beam.

- The generator transformers will be installed in transformer bays outside powerhouse at its back. During the erection stage, the transformers will be delivered directly to the transformer bays. The transformers will be delivered as complete tanks (that is, the core will be installed in the tank and the assembly sealed), but the internal voids will be filled with nitrogen rather than oil and most other items will be sent separately (such as the conservator) to reduce transportation weight. The transformers will have to be drained on the nitrogen, fitted out with all the remaining components and then filled with oil and tested. Upon completion of generating units, the transformers will be connected to Insulated Bus Pipes (IPBs) and HV switchgear for on-line commissioning.

- Main electrical equipment comprising excitation system, control boards, isolated phase busbars, gas insulated busbars (GIB) and the switchyard electrical equipment. All these items can be installed as civil works are finished and time allows.

- The turbine and generator auxiliary systems, comprising the cooling water system, lubrication system, compressed air system, braking and jacking system, shaft seal system, drainage and dewatering system and others can be installed in parallel with the main installation works, timed to finish at the same time.

- Lighting and small power equipment will need to be installed on a unit basis to provide the required amenities for the station operations and maintenance personnel once each unit is commissioned.

The total time for excavation, concreting in powerhouse and installation of vertical Francis turbines, generators, transformers and auxiliary systems is estimated to be 21 months.

15.8.12 Tailrace Channel

The draft tube of each turbine unit will drain water in the 20 m long tailrace channel and it finally will be discharged into Hunza river. The tail water level is therefore maintained to retain the minimum setting for turbines. The excavation of tailrace channel can be started and completed independent of the other activities in parallel with the excavation of Powerhouse starts.

15.8.13 Switchyard

A surface 132 kV switchyard will be located near Powerhouse. The civil works of the switchyard area will be started after the construction of powerhouse superstructure. The switchyard equipment will be transported to its location through access road to Powerhouse. The erection of switchyard equipment will be done using the 5 ton mobile crane. Cabling for instrumentation, monitoring and controls alongwith cable terminations will be completed before the start of unit testing. It is envisaged that the construction and installation of the equipment in switchyard will take 07 months.

15.8.14 Transmission Lines

The two double circuit 132 kV transmission line will be erected, each between ALHPP and grid station at Aliabad (70 km) and Sost (27 km) for transfer of power generated at Attabad to the local grids. The construction of transmission lines is critical for commissioning and commercial operation of the powerhouse units. This activity can proceed independently and does not have any link with the other project construction activities. But it is important that transmission line construction should be planned in such a way that at least one circuit must be available before commissioning of first generating unit, so that the energy generated can be transmitted to the local grid.

The construction activities include construction of foundations, fixing of towers, installation of equipment, stringing, etc., and other activities include transportation of construction materials and equipment. It is estimated that construction of transmission lines will take 23 months.

Another significant aspect for on time completion of the transmission lines is the marking of route corridors and acquisition of land prior to commencement of the construction activities.

Diligent planning will be required to complete the geotechnical and other investigations, route alignment, acquisition of right of way, identification of access road routes and crossings over the Hunza River etc., before the actual start of construction of the transmission lines.

15.8.15 Transportation, Assembly of Electro-Mechanical Equipment

All the Electrical & Mechanical equipment, which includes main inlet valve, turbine and generator parts, transformers, gate equipment, HV & LV switchgear, crane and other auxiliaries, will be transported from port to site on trailers and containers via National highway / Motorway and KKH. The largest pieces of equipment will be transported to site in parts and will be assembled at site. This equipment will be stored at site in the work yards / storage areas, with sensitive parts stored in covered areas for protection against rain, dust and weather action.

The first item of equipment to be installed in the powerhouse is the crane, for which the EPC Contractor will complete the civil works in erection bay and complete the erection of crane rails. The crane will be tested for travelling and carrying of the designed load with all protections in place, after completing installations of all parts.

15.8.16 Testing and Commissioning

After installation of all electro-mechanical equipment, two months will be required for testing and commissioning of the installed equipment before the start of commercial operation.

15.9 PROJECT IMPLEMENTATION SCHEDULE

The proposed implementation schedule takes account of the preliminary design of each structure and facilities, work quantities and site conditions. It is prepared on the basis of the construction plan, estimated construction progress, rate of each activity and work sequence. The Project Implementation Schedule spans over a period of 50 months, which includes 36 months for construction activities and 14 months for pre-construction activities. It is anticipated that the construction of the entire project shall be completed within this time frame. The Project Implementation Schedule is presented as Annexure-A.

During detailed design and execution of actual works, EPC Contractor may develop his own schedule in such a way that most of the work can be taken up simultaneously on various project components in order to complete the project in the shortest possible time.

15.10 CONSTRUCTION MANAGEMENT

15.10.1 Project Executing Agency

Pakistan Water and Power Development Authority (WAPDA) will execute the Project as Project Executing Agency. WAPDA in close liaison with the Consultants will provide supervision of all the Project works by EPC Contractor and will facilitate all staff permits, authorizations, licenses, customs clearance of imported equipment, materials & personal effects required for the execution of the Project. WAPDA will also coordinate with Gilgit Baltistan's authorities and departments for any issues arising about the project, which require resolution by inter-departmental interaction.

15.10.2 Consultants

The supervision of construction activities by EPC Contractor will be carried out by independent Consultants, comprised of a Joint Venture of local and international engineering firms with proven track records on such projects. The Consultants will be reporting to the Project Executing Authority.

During the Pre-Construction phase, the Consultants will prepare EPC Tender Documents of the Project. After approval of the Tender Documents, the Consultants will assist Project Executing Agency in the procurement of EPC Contractor.

During the Construction Phase of the Project, the Consultants will in general review & monitor the detailed design, construction, manufacturing, procurement, installation, commissioning & testing of works by the EPC Contractor. The Consultant's services will be in close coordination with the Project Executing Agency. The Consultant's major tasks for EPC implementation of the Project will be:

- To monitor additional field investigations, review of procedures adopted and types of tests performed by the Contractor.
- To examine the basis of design by the Contractor and review of design reports, detailed construction drawings, specifications, construction schedules, quality assurance / quality control manuals and health, safety & environmental manuals by the Contractor.
- To monitor the manufacturing and procurement of equipment by the Contractor for timely delivery and supervision of all quality control tests at manufacturer's workshops.
- To monitor Contractor's progress of work and coordination of construction activities of various civil and E&M works to ensure execution of the project within time and according to applicable standards.
- To monitor Contractor's compliance with construction management & environmental management plans.
- To verify the works executed by the Contractor for the purposes of making interim payments and the final payment.
- To review variations and claims by the Contractor and provide assistance to Project Executing Agency in processing the claims.
- To review Contractor's As-Built documentation / drawings, operation & maintenance manuals and project completion reports.

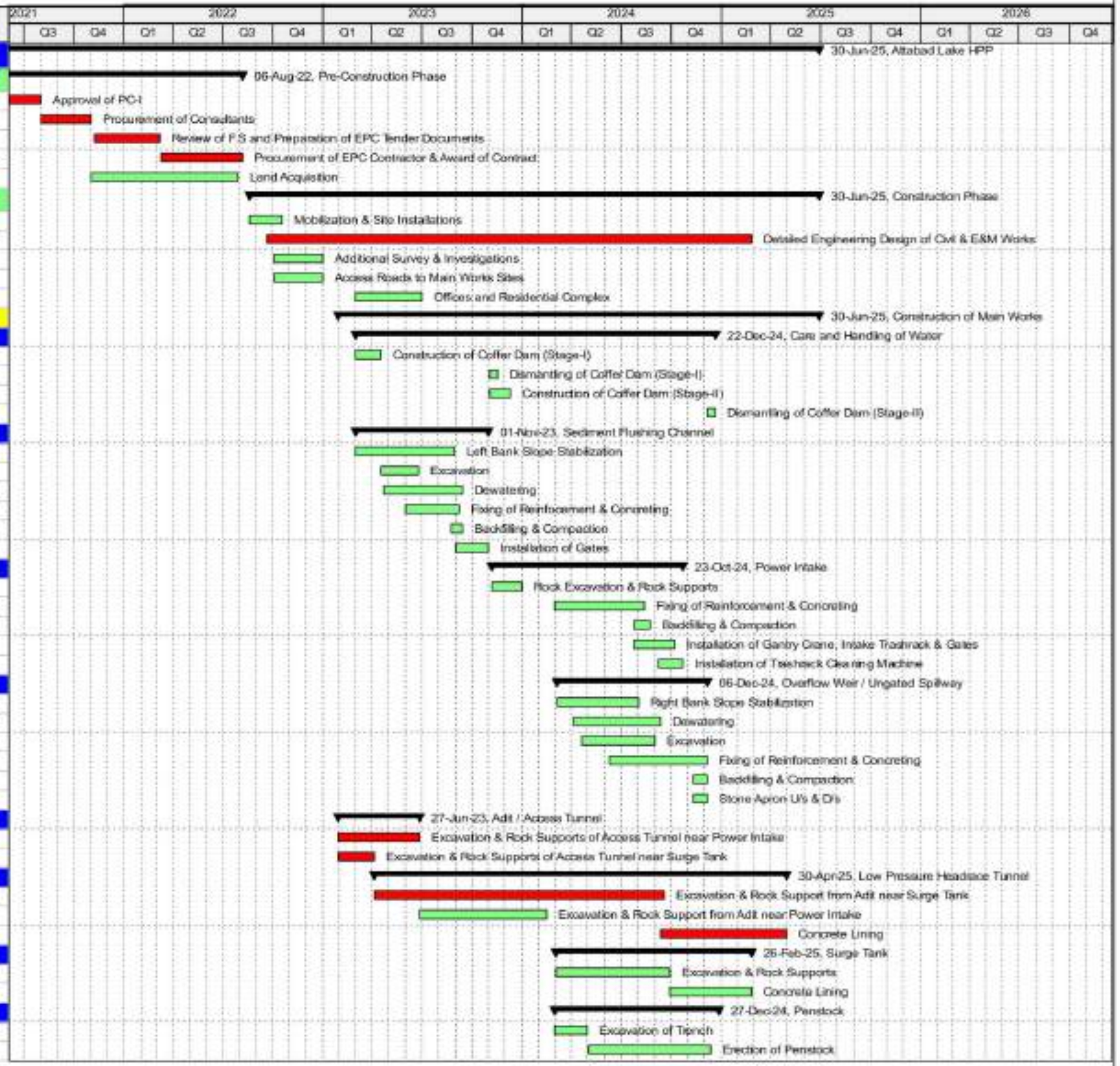
ANNEXURE - A

IMPLEMENTATION SCHEDULE

ATTABAD LAKE HYDROPOWER PROJECT

IMPLEMENTATION SCHEDULE

Activity ID	Activity Name	Original Duration	Start	Finish
Attabad Lake HPP		1519	03-May-21	30-Jun-25
Pre-Construction Phase		400	03-May-21	06-Aug-22
A1000	Approval of PC-I	90	03-May-21	01-Aug-21
A1010	Procurement of Consultants	90	03-Aug-21	01-Nov-21
A1020	Review of F.S and Preparation of EPC Tender Documents	120	08-Nov-21	08-Mar-22
A1030	Procurement of EPC Contractor & Award of Contract	150	09-Mar-22	06-Aug-22
A1040	Land Acquisition	270	01-Nov-21	29-Jul-22
Construction Phase		1045	20-Aug-22	30-Jun-25
A1050	Mobilization & Site Installations	60	20-Aug-22	19-Oct-22
A1060	Detailed Engineering Design of Civil & E&M Works	890	20-Sep-22	26-Feb-25
A1070	Additional Survey & Investigations	90	04-Oct-22	02-Jan-23
A1080	Access Roads to Main Works Sites	90	04-Oct-22	02-Jan-23
A1160	Offices and Residential Complex	120	03-Mar-23	01-Jul-23
Construction of Main Works		884	28-Jan-23	30-Jun-25
Care and Handling of Water		660	03-Mar-23	22-Dec-24
A1700	Construction of Coffer Dam (Stage-I)	45	03-Mar-23	17-Apr-23
A1710	Dismantling of Coffer Dam (Stage-I)	15	02-Nov-23	17-Nov-23
A1720	Construction of Coffer Dam (Stage-II)	40	02-Nov-23	12-Dec-23
A1730	Dismantling of Coffer Dam (Stage-II)	15	07-Dec-24	22-Dec-24
Sediment Flushing Channel		243	03-Mar-23	01-Nov-23
A1090	Left Bank Slope Stabilization	180	03-Mar-23	30-Aug-23
A1100	Excavation	70	17-Apr-23	26-Jun-23
A1110	Dewatering	145	22-Apr-23	14-Sep-23
A1130	Fixing of Reinforcement & Concreting	100	01-Jun-23	09-Sep-23
A1140	Backfilling & Compaction	20	25-Aug-23	14-Sep-23
A1150	Installation of Gates	60	02-Sep-23	01-Nov-23
Power Intake		350	08-Nov-23	23-Oct-24
A1260	Rock Excavation & Rock Supports	55	08-Nov-23	02-Jan-24
A1280	Fixing of Reinforcement & Concreting	165	02-Mar-24	14-Aug-24
A1290	Backfilling & Compaction	30	25-Jul-24	24-Aug-24
A1300	Installation of Gantry Crane, Intake Trashrack & Gates	75	25-Jul-24	08-Oct-24
A1500	Installation of Trashrack Cleaning Machine	45	08-Sep-24	23-Oct-24
Overflow Weir / Ungated Spillway		275	06-Mar-24	06-Dec-24
A1190	Right Bank Slope Stabilization	150	06-Mar-24	03-Aug-24
A1200	Dewatering	160	05-Apr-24	12-Sep-24
A1210	Excavation	135	20-Apr-24	02-Sep-24
A1230	Fixing of Reinforcement & Concreting	180	09-Jun-24	06-Dec-24
A1240	Backfilling & Compaction	25	11-Nov-24	06-Dec-24
A1370	Stone Apron U/s & D/s	25	11-Nov-24	06-Dec-24
Adit / Access Tunnel		150	28-Jan-23	27-Jun-23
A1310	Excavation & Rock Supports of Access Tunnel near Power Intake	150	28-Jan-23	27-Jun-23
A1320	Excavation & Rock Supports of Access Tunnel near Surge Tank	67	28-Jan-23	05-Apr-23
Low Pressure Headrace Tunnel		756	05-Apr-23	30-Apr-25
A1330	Excavation & Rock Support from Adit near Surge Tank	533	05-Apr-23	19-Sep-24
A1340	Excavation & Rock Support from Adit near Power Intake	234	27-Jun-23	16-Feb-24
A1660	Concrete Lining	230	12-Sep-24	30-Apr-25
Surge Tank		360	03-Mar-24	26-Feb-25
A1350	Excavation & Rock Supports	210	03-Mar-24	29-Sep-24
A1360	Concrete Lining	150	29-Sep-24	26-Feb-25
Penstock		300	02-Mar-24	27-Dec-24
A1380	Excavation of Trench	60	02-Mar-24	01-May-24
A1390	Erection of Penstock	225	02-May-24	13-Dec-24



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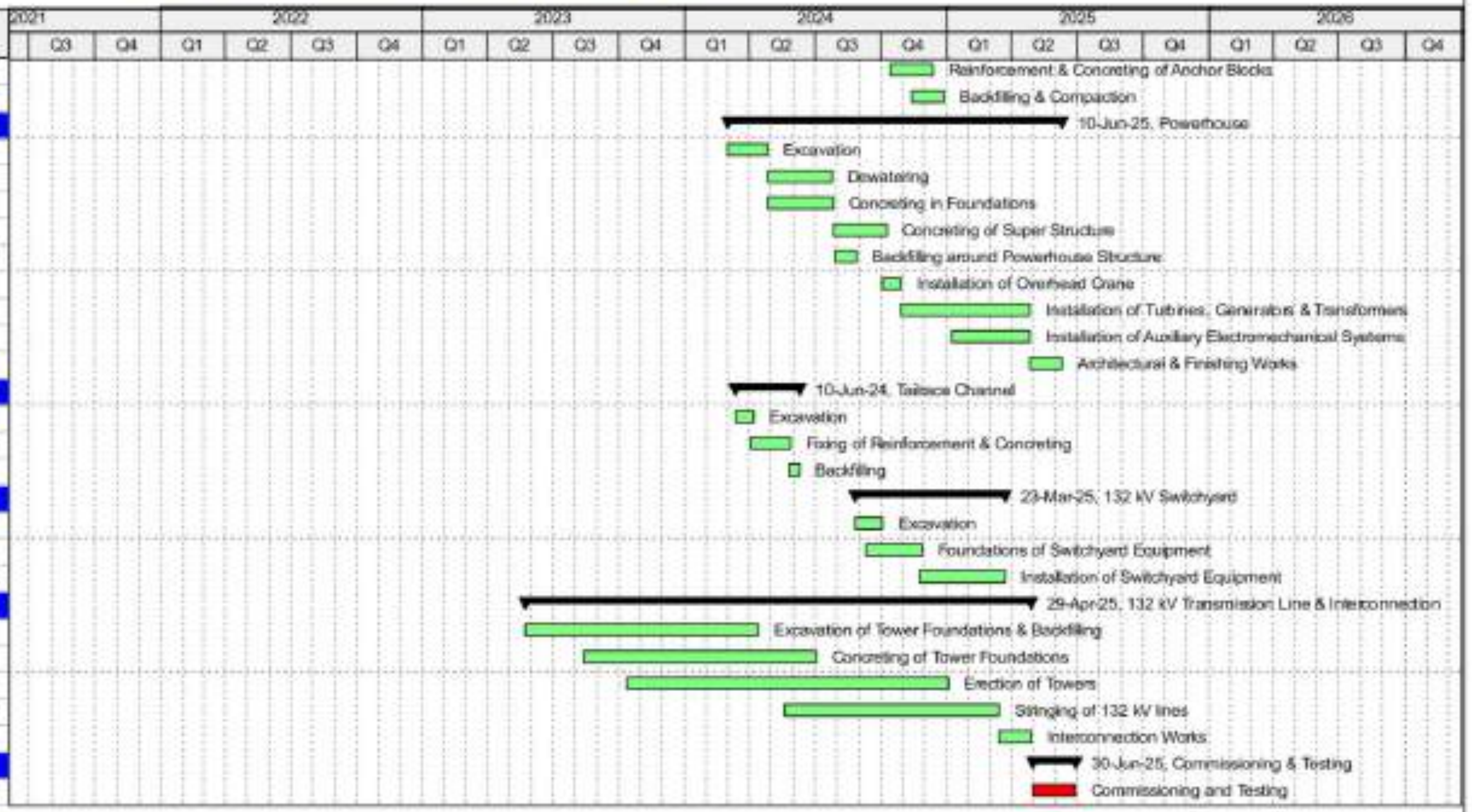
Annex - A

ATTABAD LAKE HYDROPOWER PROJECT

IMPLEMENTATION SCHEDULE

Activity ID	Activity Name	Original Duration	Start	Finish
A1400	Reinforcement & Concreting of Anchor Blocks	60	14-Oct-24	13-Dec-24
A1410	Backfilling & Compaction	45	12-Nov-24	27-Dec-24
Powerhouse		**465**	**02-Mar-24**	**10-Jun-25**
A1420	Excavation	55	02-Mar-24	26-Apr-24
A1430	Dewatering	90	26-Apr-24	25-Jul-24
A1440	Concreting in Foundations	90	27-Apr-24	26-Jul-24
A1450	Concreting of Super Structure	75	26-Jul-24	09-Oct-24
A1460	Backfilling around Powerhouse Structure	30	29-Jul-24	28-Aug-24
A1470	Installation of Overhead Crane	25	03-Oct-24	28-Oct-24
A1480	Installation of Turbines, Generators & Transformers	180	29-Oct-24	27-Apr-25
A1490	Installation of Auxiliary Electromechanical Syetems	110	07-Jan-25	27-Apr-25
A1520	Architectural & Finishing Works	45	26-Apr-25	10-Jun-25
Tailrace Channel		**90**	**12-Mar-24**	**10-Jun-24**
A1530	Excavation	25	12-Mar-24	06-Apr-24
A1550	Fixing of Reinforcement & Concreting	55	03-Apr-24	28-May-24
A1560	Backfilling	15	26-May-24	10-Jun-24
132 kV Switchyard		**210**	**25-Aug-24**	**23-Mar-25**
A1570	Excavation	40	25-Aug-24	04-Oct-24
A1580	Foundations of Switchyard Equipment	80	09-Sep-24	28-Nov-24
A1590	Installation of Switchyard Equipment	120	23-Nov-24	23-Mar-25
132 kV Transmission Line & Interconnection		**705**	**25-May-23**	**29-Apr-25**
A1600	Excavation of Tower Foundations & Backfilling	325	25-May-23	14-Apr-24
A1620	Concreting of Tower Foundations	325	13-Aug-23	03-Jul-24
A1630	Erection of Towers	450	12-Oct-23	04-Jan-25
A1640	Stringing of 132 kV lines	300	19-May-24	15-Mar-25
A1650	Interconnection Works	45	15-Mar-25	29-Apr-25
Commissioning & Testing		**60**	**01-May-25**	**30-Jun-25**
A1670	Commissioning and Testing	60	01-May-25	30-Jun-25



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16 ENVIRONOMENTAL IMPACT ASSESSMENT

16.1 GENERAL

Administratively, the Gilgit-Baltistan (Gilgit-Baltistan) is divided into 10 districts: Gilgit, Ghizer, Hunza, Nagar, Skardu, Ghanche, Shigar, Kharmang, Diamer and Astore. Previously there were seven districts in the Region. In 2016, the number of districts increased from seven to ten after the addition of 2 districts in Baltistan Region and the bifurcation of the Hunza-Nagar to 2 districts. in 2021, there are 10 districts in the entire region, 4 in the Baltistan Division, 4 in the Gilgit Division and two in the Diamer Division. In 2019, Darel, Tangir, GupisYasin and Roundu has been announced as new districts by the Gilgit-Baltistan Cabinet, but so far these are not notified officially

Figure 16-1 District and Tehsil Boundaries of Gilgit-Baltistan

Hunza Valley was composed of two independent kingdoms: Hunza and Nagar in the early 1600s. Hunza is located on the branch of the ancient Silk Route from Kashgar to Kashmir and is linked to Turkistan/western China since ancient times.

Attabad Lake was created due to a massive land slide in January, 2010. Water and Power Department (W&P Dept.) of Gilgit-Baltistan intends to utilize this storage as an opportunity to develop Hydropower Project of appropriate capacity utilizing this potential in order to meet the ever increasing demand of Hunza District and its suburbs.

16.2 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA)

The ESIA is the planning tool developed in recent years to foresee the environmental and social impacts of human intervention in nature arising from development projects. Major hydropower and storage dam projects invariably result in many far-reaching environmental, ecological and socio-cultural changes. Some of these changes benefit human population, while others threaten the natural resource base on a short or long term basis.

The negative environmental and social impacts of a development project are avoided or minimized through the ESIA and where adverse impacts cannot be avoided, the mitigation measures and resettlement activities are conceived and executed as part of the project.

The overall objectives of an ESIA in accordance with the Pakistan Environment Protection Act (PEPA 1997), and the World Bank guidelines (OP 4.0) include the following:

- Help to ensure the environmental and social soundness and sustainability of projects.
- Support integration of environmental and social aspects of projects into the decision making process.
- Promote environmentally sustainable development by supporting the protection, conservation, maintenance, and rehabilitation of natural habitats and their functions.
- Avoid or minimize involuntary resettlement and if not feasible, to assist displaced persons in improving or at least restoring their livelihoods and standards of living in real terms relative to pre-displacement levels or to levels prevailing prior to the beginning of project implementation, whichever is higher.
- Design and implement projects in a way that fosters full respect for indigenous peoples' dignity, human rights, and cultural uniqueness and so that they: (a) receive culturally compatible social and economic benefits; and (b) do not suffer adverse effects during the development process.
- Assist in preserving physical cultural resources and avoiding their destruction or damage.
- Assure quality, health and safety in the design and construction of new dams and the rehabilitation of existing dams, and in carrying out activities that may be affected by an existing dam.
- Enable vulnerable and disadvantaged stakeholder groups to participate in an informed manner.

16.3 PROJECT CATEGORIZATION

According to Pakistan Environment Protection Agency (PEPA) regulations for review of IEE and EIA, hydroelectric projects with a generation capacity of over 50 MW and power transmission lines with a capacity more than 11 kV fall into Schedule-II, i.e. projects requiring EIA. Similarly, in accordance with the guidelines of the World Bank, the Asian Development Bank and the Japan Bank for International Cooperation Environmental guidelines, the AALHPP (with a planned generating capacity of 54 MW and 132 kV power transmission lines) would fall within the category 'A' projects could be having significant impacts on the environment and requiring a full scale EIA.

16.4 SCOPE AND LIMITATIONS OF ESIA

16.4.1 Scope

The scope of the study includes this ESIA which only covers the dam site, reservoir, powerhouse areas and transmission systems. Resettlement Action Plan (RAP) is not under consideration as there is no displacement of people involved. Team of Engineers from Hydro Planning Organization (HPO) have envisaged the following statement of work related to environmental studies:

a. Review of national and local guidelines, laws and policies;

b. Review of all relevant existing data, studies, reports and drawings;

c. Avoid, minimize, mitigate and the potential significant environmental and social impacts due to the proposed intervention;

d. Collection of baseline data related to physical, ecological and social environmental aspects;

e. Identification, evaluation and categorization of the potentially significant adverse physical, ecological and socio-economic impacts on the local environment during the construction and operational stages of the proposed Hydropower Project;

f. Recommend appropriate environmental and social mitigation measures for the identified adverse impacts and monitoring plans to address them;

g. Preparation of Environment Monitoring Management Plan (EMMP);

h. Cost estimate for environmental setup;

i. Public consultation and disclosure;

16.4.2 Limitations

The baseline information documented in the present report reflects the prevailing physical, biological and socio-economic conditions of the Project Area. The Project is at Feasibility Stage and the detailed design and tender documents preparation stages will follow during the execution. If the Project is implemented after two years of completion of the Feasibility Stage then certain variables such as development of infrastructure, population growth, increase or decrease in the forest, land use, cropping patterns and economic conditions could be changed significantly.

16.5 APPROACH AND METHODOLOGY

16.5.1 Review of Previous Studies

ALHPP was conceived by W&P. Dept. of Gilgit-Baltistan. Consequently, a Feasibility Study was conducted by the W&P. Dept. of Gilgit-Baltistan through Consultants with a designed capacity of Project for 32.5 MW. Therefore, only IEE was carried out to fulfill the requirement of the PEPA by the consultants engaged by govt. of GILGIT-BALTISTAN because ESIA was not required for projects less than 50 MW. Later on the request of govt. of Gilgit-Baltistan, HPO, WAPDA updated the Feasibility Study of the Project with enhanced capacity of 54 MW and therefore, detailed ESIA was required.

The following earlier project reports have been reviewed to assess their applicability in the prevailing environmental conditions specially in GILGIT-BALTISTAN Region:

- Bunji Hydropower Project: Feasibility Study Report (Vol-III), Environmental Impact Assessment by Bunji Hydropower Consultants (March, 2005).
- Detailed Engineering Design Report of Phander Hydropower Project.
- Feasibility Study Report of Shyok Dam Project, Environmental Impact Assessment Study.
- And Various Other Reports Related to Gilgit-Baltistan.

16.5.2 Acquisition of Secondary Data

The secondary data have been collected from various offices and published reports of different organizations in the Gilgit-Baltistan. These organizations included W & P Dept., Education, Forest, Agriculture, Fisheries, Sanitation, Wildlife, Environmental Protection Agency, District Administration, Tehsil Offices, Local Councils and others. The studies are carried out on the information received during field visits of Project Area, data received from some NGOs, water samples collected from Project Area at various places and tested in Environmental Protection Agency Laboratory, Gilgit, climate data received from Metrological Department, and other data taken from earlier conducted Feasibility Study and other reports of projects.

16.5.3 Collection of Primary Data

The primary data have been collected and assessed with reference to different project components, i.e. dam site, reservoir area, powerhouse, construction camps etc. The data regarding climate, hydrology, geology, seismology, neo-tectonics and other physical features of the Project Area has also been obtained as part of the preparation of this Feasibility Study

I. Vegetation and Wildlife Fauna Studies

The assessment area for terrestrial flora and fauna encompasses the terrestrial environments upstream and downstream of the dam and adjacent areas that may be affected by the project activities, specifically from the dam to the upper end of the reservoir impoundment and from the dam to the powerhouse.

Since the lake was formed in January 2010 and no new area would be submerged with the Project except the powerhouse site, therefore, there would be no new threat to plants with the construction of hydropower project. However, concentration has been given to study the rare species and special emphasis has given to the economic species such as medicinal plants.

Information on wildlife fauna species (mammals, amphibians, reptiles, birds etc.) in the assessment area has compiled based on opportunistic observation, gathering the existing information and consultation with local experts, community members and government and non-government organizations.

II. Aquatic Ecology and Environmental Flow Study

Generally Northern Area is blessed with great water resources comprised of rivers, streams, and alpine lakes fed by the snowmelt and glacier waters. These freshwater resources harbor several fish species, which are the important component of the biological diversity. The fish fauna in Hunza Valley is relatively poor due to high turbidity, low water temperature and high water speed.

An environmental flow study has been carried out to determine the optimum environmental flow downstream of the proposed dam for sustainability of the aquatic ecosystem.

III. Social Surveys

The purpose of social survey is to record the present conditions of the people living in the Project Area and to assess the expected Project impacts on their life, subsistence systems, and social and cultural conditions. Prior to conducting the field surveys, the following steps have been taken:

- Geographic boundaries of the Project Area has been identified and listed existing villages and settlements.
- Decided the sampling procedure in order to draw a representative sample size of the target population and households.
- Developed the tools for data collection i.e. questionnaires for household sample survey, village profile, women sample survey, community participation and water use.

In order to obtain comprehensive and detailed information, the following techniques and tools of data collection has been used.

IV. Sampling Design

A stratified proportionate random sampling technique has been applied to select adequate and representative samples to generalize survey findings at the Project level. The stratification variables have been taken into consideration for enhancing the representation level for adopting appropriate sampling design.

V. Stratification Variables

The major objective of the study has to establish baseline socio-economic conditions for the inhabitants near the existing reservoir upto original extent of lake formed in 2010, powerhouse and adjacent areas of the Project. The following factors have been taken into consideration for enhancing the probability of every household being selected in the sample size:

Each village has been included in the sampling frame because of the heterogeneity of socio-economic characteristics between villages and relatively homogeneity within a village.

VI. Sampling Unit

The primary sampling unit for the socio-economic survey is the head (male or female) of the household falling within the nine sample villages of proposed ALHPP Area.

VII. Basic Unit of Study

The basic unit of study and analysis for the purpose of socio-economic investigation is nine villages of Project Area for ALHPP.

VIII. Questionnaires

In order to test the validity and reliability of the proposed questionnaires, interviewing guides have been pre-tested in the area and then the questionnaires have reviewed to assess whether questions needed to be clarified, changed or re-sequenced and then a final editing of questionnaires has been conducted prior to their subsequent application in the real sample areas.

List of Respondents of socio-economic survey is attached at **Appendix-A** of **Volume-6** of Feasibility Study. The different questionnaires used for the social survey are included in **Appendix-B** of **Volume-6** of Feasibility Report.

IX. Field Investigators

A team of experts of Hydro Planning Organization (HPO) moved to Project Area for field investigations. The team hired services of one local graduate female and one local graduate man for questioning and answering with local people in their language. Additionally, the services of a local well educated female hired for the interviews and data collection covers the subjects of gender and women empowerment. The team spent more than three weeks to visit seven villages of upstream and two villages of downstream side of the Project Area. In this exercise both genders have been covered in field visits of Project Area. The field investigators (team) with interviewing skills minimize the sampling error and wrongly asked or interpreted or recorded answers to finalize a report with the respondents.

X. Interviewing Guide for Community Participation

Well informed persons in the village has been interviewed by using a questionnaire to obtain information about village and their perceptions about the Project.

XI. Household Sample Survey

Household heads of total sample size from each sample village of the Project Area have been interviewed by using structured questionnaires. Detailed information about the socio-economic status of the family and household has been obtained from the respondents.

XII. Village Profile

A comprehensive village profile has been prepared to document the socio-economic and demographic data of each sample village in Project Area.

XIII. Gender Survey

The experts developed a separate questionnaire covering various aspects and issues of women in the area. The services of a qualified local female hired for this survey. Women from all the villages have been interviewed. Respondent women have been selected by applying the technique used for socioeconomic survey.

XIV. Data Editing

The filled-in questionnaires and interviewing guides have been edited by the same field investigators, who are involved in the data collection. This has been done immediately after completing the field investigations.

XV. Data Analysis

Data sets have been processed after the completion of the field survey and editing of socio-economic information. Analysis of this diversified data and preparation of conclusions in the minimum possible time has achieved using statistical techniques of data analysis.

All questionnaires sample are included in **Appendix-B** of **Volume-6** of Feasibility Report.

16.6 BASELINE CONDITIONS

This section provides baseline data (physical, biological and socio-economic parameters) related to the Project Area. Information provided is both quantitative and qualitative and is based on secondary and primary data collected, site field visits and desk studies. A baseline consists of the existing environmental and socio-economic and cultural status of the Project Area. The baseline information and indigenous knowledge is required for scoping potential environmental issues associated with the implementation of the Project. On the basis of baseline information, the Project interventions are assessed and mitigation measures are proposed. The baseline information also helps to indicate the specific issues to be monitored during Project execution as well as during operational phase.

16.7 PHYSICAL ENVIRONMENT

16.7.1 Physiography.

The site of the Project is located on Hunza River at Attabad Lake about 15 km upstream from Ganish Bridge of Hunza. Its distance is about 20 km from Hunza and 115 km from Gilgit. The powerhouse location is on the left bank of river and easily accessible from KKH. The intake weir/dam site is selected at current exit point of Attabad Lake which was formed in the year 2010 due to a huge slide from right bank mountain, however, some left bank mountain portion was also damaged.

16.7.2 Demography

Hunza Valley is mainly divided in three parts with different tribal structure. The people living in Gojal had migrated to this part of Hunza from Wakhan, Pamir and Badakhshan before the end of 18th century. They are mostly Wakhis (from Wakhan, a strip of land between Central Asia and Pakistan), an ethic group staying in the mountainous areas of the Karakoram and the

Pamirs in the border land of Pakistan, China and Afghanistan. The language and culture distinguish them from Brush and Shina speaking people, who live in central and lower Hunza.

16.7.3 Climate

The climatic parameters that influence the climate of an area include temperature, precipitation, humidity and evaporation. Situated in the western most arm of Karakoram Range, Hunza is found within semi-arid and rugged mountain landscape (mountain desert). The climate varies widely from monsoon-influenced moist temperate to arid and semi-arid cold deserts in the North. In general, two seasons prevail in the Project Area: winter (October to March) and summer (April to September).

16.7.4 Precipitation

Rarefied air, intense solar radiation, strong winds, and vast ranges of temperature are the characteristic climate of the Area. Below 3000 m a s l, precipitation is less than 200 mm per annum while there is a sharp precipitation gradient along the altitude, and over 2,000 mm annual snow fall above 6000 m.a.s.l. Average Monthly and annual rainfall recorded at WAPDA High Altitude Weather Station has been given in Table 16-1

The Hunza River catchment upstream of the dam site is highly mountainous generally with low precipitation. The low precipitation particularly during the hot (monsoon) season coupled with less catchment area likely to experience rainfall are the factors responsible for low runoff or poor contribution to flood producing mechanism source. Hunza like other areas in extreme North-West of Pakistan receives only 136 mm precipitation of which 40% occurs in Winter and Spring.

16.7.5 Temperature

Temperatures in the valley bottoms can vary from extremes of 35°C in summer to less than –15°C in winter. The summer season in Hunza Valley is cool while winter is chilly. Wide spread snow fall occurs in winter. During winter the northern winds blow constantly bringing the temperature down considerably. At Hunza, the mean maximum temperature is 23.8°C in July, the hottest month and the coldest month is January with an mean minimum average temperature of -1.9°C. The Gilgit Meteorological Station is the nearest station to Hunza Valley that has a sound historical record covering more than five decades

Table 16-1 Average Max & Min Monthly Temperature and Mean Precipitation at Gilgit

Month	Mean Min Temp (^{o}C)	Mean Max Temp (^{o}C)	Mean Prec. (mm)
Jan	2.4	9.4	4
Feb	0.7	12.6	6.8
Mar	5.7	18.2	0.14
Apr	9.5	24.1	23.8
May	12.1	28.6	24.5
Jun	15.1	34	8.8
Jul	18.4	36.1	14.6
Aug	17.8	35.3	14.6
Sep	12.7	31.7	7.6
Oct	6.8	25.5	6.9
Nov	0.9	18.2	2.4
Dec	-1.9	11.5	5.1
Annual Mean	**7.9**	**23.8**	**133.1**

16.7.6 Geology

Tectonically, Project Area lies in the Karakoram Block towards the North of the Main Karakoram Thrust (MKT) and Main Mantle Thrust (MMT) which are considered to be the manifestation of the tectonic collision between Indian Plate (Continent) with the Kohistan Island Arc and then with the Eurasian Plate (Continent). This continent to continent collision has given rise to three most famous orogenies in the world. The Himalaya, Karakorum and Hindukush are considered to be the highest mountainous ranges in the world.

The Glacio fluvial deposits forming the site of Attabad Village consist of boulders, cobbles and gravels with some silt and sand as cementing material. The rocks exposed at the crown and toe; are highly fractured, sheared, jointed and weathered. A fault on the eastern side of the village is passing through Hunza River trending almost North-South. The re- sediment till deposits flank both sides of Hunza River in the powerhouse area. These tills comprise extremely fine grained (powder) soapy-touch clays.

16.7.7 Seismology

The Project Area lies in the Northern Region of Pakistan which has high frequency of earthquakes especially in the Himalayan orogenic belt. This belt represents the contact between Indo-Pak and Eurasian plates, which has always been the source of moderate to large earthquakes including Kangra (1905), Bihar-Nepal (1934), Assam (1897) and 2005 Kashmir earthquakes with significance consequences.

In October 2005, an earthquake of very high intensity (7.8) hit the area near Muzaffarabad and disturbed the ground to a significant extent in that area. The geological, tectonic and geodynamic conditions of the Project Area have been assessed and detailed mapping of the ground surface has been done to define the geology and tectonic features of the Area.

16.7.8 Landslides, Erosion and Sedimentation

Landslides are very common features in the Project Area because of the high steep terrain. Erosion and sediment input to the river is a function of landslides and riparian erosion processes. There are frequent talus accumulations along the side slopes of the river. These are typically in a state of stable equilibrium at their current slope angle and environment but become unstable when the equilibrium is disturbed. Excess water and earthquakes often trigger landslides.

16.7.9 Land Use

There are nine villages located on alluvial fans and terraces on both sides of the Hunza River and its tributaries where water is available for human consumption and agriculture. The nallahs span out near the confluence of the river, forming some cultivable land masses as can be witnessed near Passu Village. The available flat land is used for residential purposes as well as for agriculture, orchards and grazing for cattle, goats and sheep etc. The total geographic area of the Hunza Valley is about 8,920 km2. Summary of land use in the Gilgit-Baltistan is shown in Table 16-2

Table 16-2 Summary of Land Use in Gilgit-Baltistan

S.No.	Type of land	Area Million (Hectares)	Percentage (%)
1	Mountain/Lakes/Rivers/Glaciers	4.810	66.3
2	Protective Forests	0.065	0.89
3	Private Forests	0.219	1.78
4	Social/Agricuture Forests	0.368	5.07
5	Range lands	1.626	22.4
6	Cultivable Area	0.078	1.1
7	Cultivable Waste	0.090	1.2
Total		7.250	100%

Source: Statistical Unit GILGIT-BALTISTANP & DD 2013

16.7.10 Mining

Mining is one of the common professions in small parts of the Project Area. The area near the lake is rich in mineral resources however their exploitation as commercial use is still not being done. People use to explore the mines by their own resources without any support of Government.

16.7.11 Agriculture

The area under agriculture is approximately 112,688 ha or 1.6% of the total area Gilgit-Baltistan. Because the climate is arid, agriculture depends on irrigation through water channels locally known as (kuhls) - that bring water through gravity flow from streams fed by glacier or snow melt. Agricultural in Gilgit-Baltistan can be divided into two broad cropping zones depending on the elevation. At elevations between 1200 and 2000 m a s l both summer and winter crops are grown, however, in areas situated in between 2000 and 3000 m a s l a single summer crop can be grown.

In Hunza District, the general combination of crops, livestock and other farm related activities are more or less the same. Wheat, barley and vegetables are the main Rabi crops. Whereas

Maize, potato, millet and pulses are Kharif crops. Shaft all and Lucerne or Alfalfa is grown as a perennial crop which is the most popular fodder for livestock throughout the year. District wise Agriculture Land of Gilgit-Baltistan is shown in table 16-3.

Table 16-3 District Wise Agriculture Land of Gilgit-Baltistan

District	Agriculture Land (ha)	Percentage Cover
Astore	8133.43	1.51%
Diamer	9058.52	1.26%
Ghanche	11966.75	1.35%
Ghizer	16431.94	1.34%
Gilgit	10167.94	2.44%
Hunza-Nagar	12013.87	0.8%
Skardu	30589.88	1.56%
Total	**98362.33**	**10.26%**

16.7.12 Fruits

Gilgit-Baltistan is producing many fruits like apple, cheery, walnut, and apricot. But apricot is more famous for its test and quality. Pakistan produces approximately 300,000 tons of fresh apricot, making it the world’s fourth largest producer. Gilgit-Baltistan and Baluchistan are the two main apricot growing regions in Pakistan, with Gilgit-Baltistan alone producing 114,286 tons in 2007. Planting density is only 230 trees/ha, which is much less than the recommended 750 trees/ha, due to apricots being planted around field edges, rather than orchards. Average yields of fresh fruit are 38 kg/ tree which are good considering the limited use of inputs, although yields of 50 kg/tree can be achieved through improved management.

At higher altitudes there are no fruit trees, but in lower portion of Hunza Valley several types of fruit are grown. Major fruits are apricot, apple, mulberry, grapes, almond and walnut. It has been calculated on average that every household has 22 trees out of which 15 are fruit bearing trees. The average production of fruit by each tree is 50 kg.

16.7.13 Livestock

The people of entire Hunza River the livestock reared by almost all households. Usually with the snow melt, goat, sheep and cows giving no milk are taken to the Alpine Pastures for grazing. They stay there during the summer season and are brought back with the onset of snow on the top of the hills. When the animals are brought to the village they are grazed in the agricultural fields of maize crop residues. All the milking animals are kept in the houses and stall fed.

Livestock contributes a great deal to the local economy. However, physical condition and general health of the animals is not satisfactory, especially in winter due to the shortage of fodder. Bullocks are the main source of farm power, but they are hardly capable of drawing plough due to poor health. Cows, sheep and goats are also lean and thin. Animal diseases cause considerable losses to the livestock. Productivity of cattle is generally low because of severe winter and lack of proper feed. Meat, milk, butter and eggs are the main animal /poultry products but most of these are consumed at the household level. At some places milk, meat, animal hides, wool and poultry are sold.

16.7.14 Hydrology

The main tributaries of Hunza River are; Chapursan, Kilik, Bola Das joining the Hunza River from the west and Khunjerab along with Ghujerab, Simshal and Hispar Rivers joining river from the east of the valley. The river flows of Hunza are usually maximum in the month of July when snow and glacier melt is at its peak while these are minimum in the month of March when snow and ice melting is insignificant.

There is only one hydrological gauging station on Hunza River at Danyor Bridge being operated by SWHP-WAPDA. This station is located at about 107 km downstream of Attabad Landslide Dam. The catchment area of Hunza River upto Danyor gauging station is 13,157 km2, whereas it is 14,083 km2 upto its confluence with Gilgit River. Hunza River catchment area is 8,901 km2 upto Attabad Landslide Dam. Therefore, river flows are transposed and estimated from documented discharge data from hydrological station at Danyor. Daily discharge data from 1966 to 2015 is available and processed for the calculations. Data for year 2016 was incomplete, missing the values of high flow months, and there was no record of hydrological data for the period 2017 to 2018 at SWHP therefore, it was not used in the calculations. Mean annual flows are calculated and drawn in the figure below for the period 1966-2015. Average value for mean annual flow has been calculated as 208.36 m^3/s.

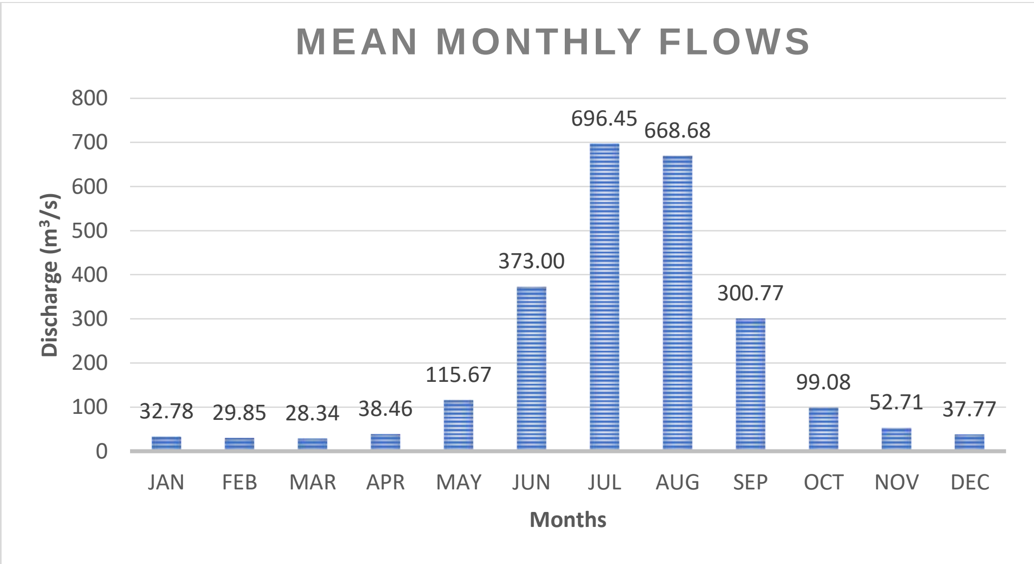

Figure 16-2 Mean Monthly Flows

Flows are generally maximum in July and August almost reaching 700 m^3/s. Whereas, flows are low from December to April each year when snow falls in the catchment. The record shows that design discharge of 60 m^3/s is available for about half year (almost 6 months). Graph shows that flows are exceeding the design discharge from June to mid-December which shows the potential of hydropower generation.

The maximum peak discharges of mean daily for every year recorded. The instantaneous peaks will definitely be higher than the measured daily flows and can be enhanced while execution accordingly. Instantaneous peak flows for the period 1966 to 2015 has been calculated and plotted as well.

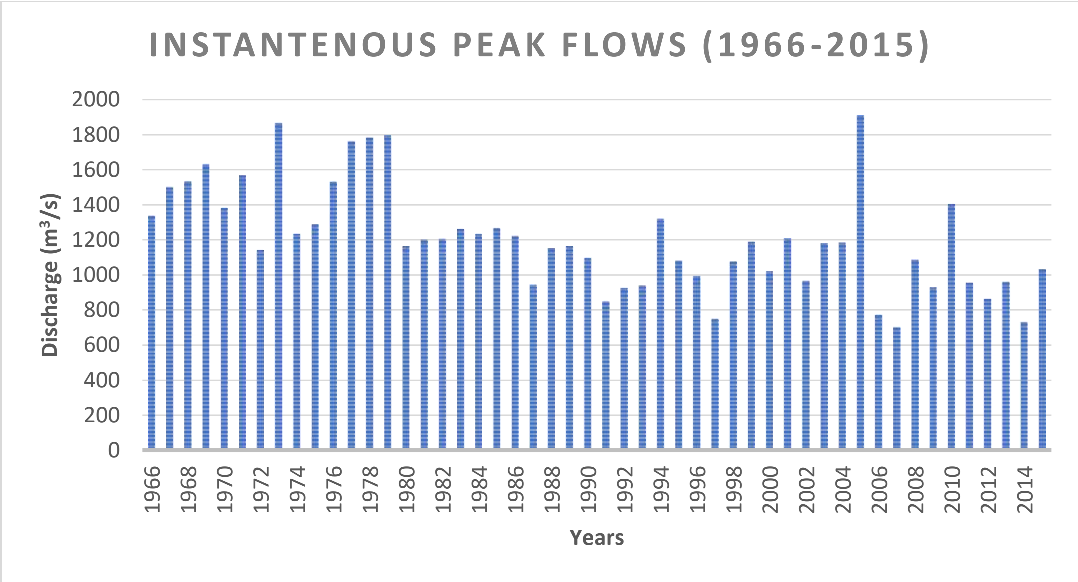

Figure 16-3 Instantaneous Peak Flows at ALHPP

16.7.15 Surface Water Availability & Quality

In the Project Area, the Hunza River carries water of various streams (nallahs)of snowmelt, and rainwater fall. The people use the water of these nallahs for drinking, household and agriculture purposes. Generally, there is no shortage of clean potable water in the Project Area as it is very difficult to fetch the water of river and nallahs due to the very steep slopes. People mostly use water from nallahs for drinking, washing and other domestic purposes. During the socio-cultural survey of the Project Area, many of the respondents from the villages reported stomach, skin, bones, diseases. Initially, rainwater as well as snowmelt water do not contain significant impurities. As these waters flow over land they pick up sediments, salts, toxic elements, pulverized organic matter and bacteria from the surface. Water samples were taken in November, 2020 covering the complete affected area within the project area. The laboratory results of these samples summarized in Tables given in volume 6and detail at Appendix-C reveal that all the parameters are within the permissible limits when compared with drinking water quality standards of WHO, except the presence of Escherichia Coli Pathogenic Bacteria which causes gastroenteritis in human beings.

Piped water supply that covers only 40% of the total population of the Gilgit-Baltistan does not provide safe/ clean drinking water to urban and rural settlements in the Region. In upper Hunza Region, drinking water is obtained from glacier melt and piped water only in summer season.

16.7.16 Groundwater

The Project Area consists of rocky mountainous terrain. The water originated from rainfall and snowmelt flows through streams and enters into river. Only a small quantity of water has the chance to percolate and form a groundwater reservoir.

16.7.17 Air Quality and Noise

The air quality of the Project Area and its vicinity is very fresh and clear under normal condition. Air and noise pollution has not yet emerged as an environmental issue owing to operation of a small number of vehicles increasing by a fair degree during the tourist season. Based on a number of observations on ambient air quality in rural areas the following range of concentration of gaseous pollutants is estimated on the roadside at Gulmit

Table 16-4 Range of Gaseous Pollutant Concentration & Noise Emission Level

Range of Variation	CO ppm	SO_2 ppb	NO_x ppb	SPM $\mu g/m^3$	Noise dB(A)
Minimum	0.65	05	05	45	40
Maximum	0.9	10	12	90	70
Average	0.7	07	07	70	55

The noise level near the river is fairly high and range between 50 to 65 dB without traffic, mainly due to the flowing water colliding against rocks and boulders. There is normal traffic on the KKH which runs through the Hunza Valley. So traffic noise has negligible contribution to the noise level in the Project Area.

16.7.18 Greenhouse gases

Greenhouse gases are those gases (CO2, CH4, O2, CFCs and NO) which contribute to global warming. The main sources of these gases are industries and vehicles using fossil fuel as fuel. At present there is no industry in the Project Area that emits greenhouse gasses (GHG) and vehicles intensity is also very low. The main sources of carbon and nitrogen oxide emissions are due to automobiles in the Project Area.

16.7.19 Waste

The villages within the Project Area do not have any drainage, sewerage or treatment system for sewerage collection and disposal. More than 50 percent of the houses have improvised pour flush pit latrines. The remaining 50 percent of the house hold use locally made toilets. Waste water(sludge) from kitchen, bathing and washing is discharged into small drains/water courses leading to the nallah or directly to small fields outside the houses. Animal waste especially cow dung is used for farm manure or used for burning after drying (though rarely).

16.8 BIOLOGICAL ENVIRONMENT

Habitat loss is considered as the leading cause of loss of world’s biodiversity. Most species need undisturbed habitat to find food, water, shelter, and mates. But people are altering habitats all over the world. In such areas, the activities causing habitat loss include commercial logging (not based on technical and sustainable basis), land development, over-grazing, fuel wood collection, construction of roads, and building new settlements. All these actions change landscapes, natural water flows, and the species composition in the area. Moreover, changes in climate and land use patterns also reducing the amount of snowfall and rain upon which the habitat depends.

16.8.1 Flora

A study was carried out on the Biodiversity of Khunjerab National Park (KNP) during May and June, 2006 to establish baseline information about existing plant wealth and wildlife including flora, reptiles, bird, sand mammals in order to make some vantage points for future monitoring of key wildlife species. Using different direct and indirect investigation techniques, 14 different valleys and Nullahs of KNP were surveyed and observations on various habitats were recorded.

Four types of vegetation zones were identified including Dry Alpine Scrub, Moist Alpine Pastures, Dry Alpine Plateau Pastures and Sub Alpine Scrub and Birch Forests. So far, 62 plant species belonging to 45 genera and 25 families were identified. Of them, 4 grasses and one species of Liliaceae were determined. Details of flora zones and further types are described in the **Volume-6** of this report.

16.8.2 Forestry

Forestry is important for fuel, timber, in addition to control of the soil erosion and reduction silt load in lakes and rivers. In the Gilgit-Baltistan only Diamer district is rich in forest while the other five districts including Hunza have nominal forest of Juniper. The forests consist of blue pine, spruce, willows and shrub consist of rosa species.

16.8.3 Fauna

This diverse range of vegetation and ecological zones also supports a rich faunal diversity, including an estimated 54 species of mammals and 230 species of birds. About 23 species of reptiles and 6 of amphibians have been reported from Gilgit-Baltistan. Among reptiles 9 species are of lizards and 14 of snakes, while among amphibians 2 species of frogs and 4 of toads. Very little information is available on insect diversity in Gilgit-Baltistan, however, about100 species of butterflies have been reported from Gilgit-Baltistan.

Several globally threatened species – including the snow leopard and Markhor – continue to survive in Gilgit-Baltistan in significant numbers. The flora and fauna belong to Palearctic region. Fifty-four species of mammals have been reported in Gilgit-Baltistan, which comprise 1 shrew, 10 bats, 18 carnivores, 6 artiodactyls, 3 lagomorphs, and 16 rodents. The region is also home to a few globally threatened species like Snow Leopard, Himalayan lynx, Marco polo sheep, Blue sheep, Ladakhurial, Markhor, Musk deer, and Woolly Flying Squirrel. The resident avifauna includes Monal pheasant, Snow Partridge, Himalayan Snow Cock, and several birds of prey species.

Occurrence of some rare species has been reported in Gilgit-Baltistan. These include species like Lammergeyer and Golden eagle. Few sightings of Lesser Kestrel have also been reported in lower Hunza near Hunza river. The main diverse group of birds in NA is the Passeriformes species. These are mostly Warblers, Tits, Flycatchers, and Buntings. Some of the restricted range species like Snow Partridge and Himalayan Monal pheasant are extremely rare and may be at the verge of extinction from many of their earlier strongholds. According to Birdlife International (2001) report there are 27 species of Pakistan, which are threatened internationally out of which 7 species are found in Gilgit-Baltistan.

Hunza is very scattered settlement with meager population. Considering its wildlife resources to be protected and preserved. Shooting, trapping of wild animals is not allowed except with a special permit. The number of animals or birds killed or captured is also restricted and specified in the permit. Snow leopard and Ibex are already declared as endangered and other species of mammal are also scarce. But trophy hunting is allowed which is beneficial to the local community as the 70% of the funds go to local community which is used for the development of the local area.

Table 16-5 Fauna available in Gilgit-Baltistan

English Name	Urdu Name	Scientific Name
Ibex	Kill or Kil	Capra ibex sibirica
Snow Leopard	Cheeta	Pantherauncia
Red fox	Lombrei	Vulpesvulpes
Lynx	Seaa gosh	Felis lynx
Wolf	Bharia or Bahdia	Canis lupus
Maramot	Barfanichoh Tershoon	MaramotaCandata
Alpine weasel	Gilhari	Mustelaaltacia
Musk rat	Chachondar	Mustelaaltacia
Himalayan snowcock	Ramchakur	Mustelaaltacia Tetraogallushimalayencis
Chukor	Chukor	AlectorisChukor
Eagle	Shaheen	Aquila Chrysaetos
Hawk	Gid	-
Falcon	OoqaaborOoqabaa	-
Pie	Jample	UrocissaEryphrohyncha
Hopoe	Hodhodh	Upepaepaps
Pigeon	Kabutar	-

16.8.4 Insects

The Project Areas is rich in biodiversity of insects including butterflies found in the Project Area, particularly during the humid months of July and August. In addition, caterpillars, bugs, beetles, black bees, weevils, mosquitoes, ants, green aphids, codling moths, leaf miners, mitts, fruit flies, woody aphids, stray grass hoppers, leaf hoppers, mealy and woolly bugs, peach leaf curling aphids, scale insects, walnut weevils, blister mites, and dusky veined aphides are all found in the Northern Areas including the Project sites.

16.8.5 Protected Area

In order to safeguard the biodiversity of key ecological systems, Government of Gilgit-Baltistan has declared four National Parks to protect and conserve bio-diversity of Gilgit-Baltistan. These include Handarb National Park, KNP, Deosai National Park and Central Karakorum National Park. In the protected forest, the forest owned by Government as per Forest Act-1927, all activities are prohibited until and unless permitted by the government. Usually, removal of fallen, dying, and dead trees is not banned, however, grazing, sometimes, is regulated to ensure regeneration. In GILGIT-BALTISTAN, designated protected forests cover an area of 445,712 ha and are mostly found in Ghizer, Astore, Skardu and Gilgit Districts. Out of that 64,512 ha is conifer forests while 3, 81,200 ha are scrub forests (IUCN, 2003).

Aga Khan Rural Support Programme (AKRSP), International Union for Conservation of Nature (IUCN), Wildlife Conservation Society (WCS) and World Wide Fund (WWF) are the main international organizations who over the last two decades have played a crucial role in creating awareness among communities for sustainable management of biodiversity resources. The then Ministry of Environment also implemented a Program for Mountain Areas Conservation (PMAC) to promote biodiversity conservation in Gilgit-Baltistan through community participation. This program was completed in 2011. As a result of these efforts the GILGIT-BALTISTAN offers a model for community based management of forestry resources.

Despite of all these conservation initiatives and efforts by government and international organization, fast depletion of forest ecosystems has been observed in the last two decades. The following strategies and actions will be taken to achieve the objectives of conservation, sustainable use and equitable sharing of benefits.

16.8.6 Aquatic Ecology

GILGIT-BALTISTAN is blessed with highest potential of cold and clean water resources in shape of lakes, canal, reservoirs, rivers, and water logged areas that offer ideal habitat for trout and other cold water fish species. There is dire need to get maximum benefit from these resources through technological advancement in production, processing and marketing. Both the public and private sector are fully involved in order to judicially exploit this potential both in natural waters as well as its development in culture conditions. The fish fauna in Hunza Valley is relatively poor due to high turbidity, low water temperature and high water speed.

16.8.7 Fisheries

Fisheries department Hunza was established in the year 2012 with the core aim to develop and promote Fisheries and aquaculture activities in newly created district. District Hunza has very rich aquatic resources of aquaculture and fisheries in forms of bluish lakes, gashing rivers, torrential streams, seasonal and perennial springs etc. Fisheries department Hunza has come up with novel approach and ideas to get maximum benefit from wise use and sustainable exploitation of natural resources in multiple ways with special focus on introduction and installation of cage culture system in Attabad Lake under controlled environment to enhance production with stocking and multiplication of fine verities of fish in nature. At the same time, it has also been planned to promote sport fishery providing enabling environment and other related facilities for tourists and fish anglers.

For this the Attabad Lake having crystal clear water offers as natural gene pool reserve, ideal for excessive multiplication and better growth of many indigenous and exotic fish species

Table 16-6 Potential Fisheries Resources in District Hunza

S.No	Name of River	Name of Lakes	Name of Nallas
1	Hunza River	Attabad Lake	MisgarNallah
2		Borith Lake Gojal	KhunjarabNallah
3		Shimshal Lake I	Dee Nallah
4		Shimshal Lake II	ChoporsunNallah
5		Bathora lake Gojal	GojarabNallah
6		Pasho Lake	Khyber Nallah
7			Shimshal Nallah
			Hassan Abad Nallah
Total	01	06	08

16.8.7.1 EXOTIC FISH SPECIES OF HUNZA

I. Salmo TruttaFario (Brown Trout)

II. Onchorynchus Mykiss (Rainbow Trout)

16.8.7.2 INDEGENOUS FISH SPECIES

Among the 15 identified indigenous fish species in Gilgit-Baltistan the following six fish species found in District Hunza:

I. Shizothoraxplagiostomus

II. ShizothoraxNasus

III. PtychobarbusConirostris

IV. TriplophysaTerwasae

V. TriplophysaYasinensis

VI. DiptychusMaculatus

16.9 SOCIAL AND ECONOMIC ENVIRONMENT

16.9.1 Population

The population in Gojal consists of 51% male and 49 % female; it has a population density of 17 persons/acre. The child-women ratio of the study area is 345 children per 1000 women. The dependency ratio is 142 % in Hunza Valley, which shows that there are about 3 dependents on every two earning members. The average size of household is 7.26 persons. The average size of family is 7 persons per household, while the density of room is 4 rooms per household.

In the study area of Gulmit, Shishkat and Passu total number of households according to the census 2017 is 8697 people, these are the areas surrounding the Attabad Village. The detail of population is shown in table

Table 16-7 Population of the Area (2017)

Name of Jamatkhana	No. of household registered	Actual Population
Gulmit central	142	963
Kamaris	42	319
Odver	42	320
Dalgiram	44	307
Chamangul	131	858
Ghulkin	158	1178
Hussaini	89	670
Passu	89	771
Janabad	24	169
Muradabad	4	49
Nazimabad central	117	989
Nazimabad-I- Bala	76	638
Nazimabad II Darmiyan	142	1417
Borithpayeen	6	49
Borithbala	2	1
Total	**1108**	**8697**

Source: Gulmit Local Council

16.9.2 Languages

Burushasky and Wakhi are the main languages of Hunza Valley. There are some other languages in the region are

- Shina.
- Burushasky.
- Khowar.
- Balti.
- Domaaki.
- Wakhi.
- Gojri.

16.9.3 Ethnic Groups and Religions

Almost, 95% of the people living in Hunza Valley and 100% in Upper Hunza belong to Ismaili faction with his highness Prince Karim Aga Khan as their spiritual leader. 5% in Hunza Valley are members of Shia Imami faction which is concentrated in the village Ganish and surrounding settlements.

16.9.4 Administrative Setup

Hunza remained an independent state after 1947 while still staying under the control of the Islamic Republic of Pakistan. The last Mir (Jamal Khan) and his family were retired and the Mirdom was abolished, and Hunza became a subdivision of the Northern Area in 1974. The government tried to establish administrative structure in the valley. The abolition of the traditional institutions left a gap that was partly filled by institutions established under projects of the Aga Khan Development Net Work (AKDN), which started operation in 1979.

16.9.5 Health Facilities and Common Diseases

The villages in the Hunza Valley have somewhat better healthcare facilities than rest of the Gilgit-Baltistan except Gilgit and Skardu. Aga Khan Health Service (AKHS) and Government health workers are providing health facilities in the area. They provide first aid facilities and also give family planning guidance to the people. Gulmit Government hospital was established in 1980.

16.9.6 Education and Literacy

Almost all the settlements in Hunza Valley have a high literacy rate. There was no school before 1946 in the villages of Gojal. Diamond Jubilee School for Boys was established in the Gulmit on the occasion of the Diamond Jubilee Ceremony of Sir Sultan Mohammad Shah, Aga Khan III in 1946. At present there is one Government High School for Boys and one D. J. High School for Girls, besides one public high school: Al-Amin Model School for boys and girls. There are two primary schools in Hussaini village. Literacy rate in Hunza is almost 95% which is higher than other districts of Gilgit-Baltistan. Girls in Hunza are enthusiastic about their future so they prefer to have higher education. For higher education students go to KIU Hunza Campus in central Hunza; a number of boys and girls are studying in Gilgit, Islamabad, Peshawar, Lahore, and Karachi for higher studies.

16.9.7 Infrastructure and Recreation

Infrastructure facilities including health, education and transportation are available in Hunza Valley to those near the KKH. Construction of Karakoram Highway (KKH), the Silk route or Pak China Friendship Highway, was started in 1965 and was completed in 1986. The KKH starts from Thakotin KPK and continues up to Khunjerab Pass; it has over one hundred bridges. The length of KKH is 1300 km and width is two lanes. KKH has played an important role in the development of Hunza Valley. Buses and vans are used for traveling in Gojal from and to Gilgit and down areas of the country. Public transport is provided by both Private vans and Government buses (NATCO). The impact of the KKH is very conspicuous on the socio-economic condition of the villages. KKH provides an important link between Pakistan and China. This road serves the tourist traffic and acts as supply route for the mountaineers to the down country and other neighboring countries.

Recreation and tourism has grown in the area rapidly, which in future can become an important source of income.

16.9.8 Professions and Source of Income

The people of the area are linked with different professions like tourism sector, business, livestock, dry fruits, trade and government jobs.

16.9.9 Tourism and Cultural Heritage

Hunza is the tourism and business hub of Gilgit-Baltistan thus a large number of residents from this area directly or indirectly involves either in business or work in tourism sector

16.10 ESIA AND MITIGATION MEASURES

Determining the significance of impacts identified is one of the main purposes of an ESIA and it enables the identification of necessary mitigation and a determination of environmental and social costs associated with the Project. Environmental and social impacts of any Project are identified taking into account all phases of the project cycle, including planning, construction, operation and decommissioning. The environmental issues and impacts of a project depend upon the nature of the project activities, and the types and extent of interventions involved. It is not easy to predict the future and assign a relative value or overall significance to an impact, since every impact has a different and multi-dimensional nature, and also because it involves personal and subjective judgment for many attributes. An environmental or social impact can be either beneficial or adverse and is assessed by comparing the quality of the existing environment with the predicted quality of the environment once the project is in place. This ESIA identifies the impacts likely to arise as a result of construction and operational activities and assesses the likely magnitude of the impact in order to provide some indication as to which impacts are likely to be most significant. The impact assessment has been based on that environmental checklist developed by the Asian Development Bank (ADB).

16.11 IMPACT ASSESSMENT PROCEDURE

In order to describe the significance of an impact it is important to distinguish between two concepts: sensitivity and magnitude. As far as possible the sensitivity and magnitude of the impact are described with reference to legal requirements, accepted scientific standards or accepted impact assessment practice, and/or social acceptability. Where no known published ‘standard’ criteria exist for determining the magnitude of effects, established professional criteria and best practice techniques are used and clearly described.

16.11.1 Sensitivity

Sensitivity is generally sites pacific and criteria are developed from baseline conditions. The sensitivity of are captor is determined based on review of the population (proximity/ numbers/vulnerability), presence of biological features of the site or the surrounding area, soil, agricultural suitability, geology and geomorphology, existing air quality, presence of any architectural and historic heritage, landscape etc. Sensitivity, relates to the value, importance and tolerance of an environmental resource or receptor and should take into account where possible stake holders views and public acceptability. Sensitivity can be categorized as high, medium, low, and negligible to the assessment of receptor sensitivity.

16.11.2 Magnitude

The assessment of magnitude is undertaken in two steps. Firstly, the key issues associated with the Project are categorized as being either adverse or beneficial. Secondly, beneficial and adverse impacts are then further sub divided into major, moderate, minor or negligible based on consideration of the parameters listed below:

- Duration of the impact
- Spatial extent of the impact
- Reversibility
- Likelihood; and
- Legal standards and established professional criteria.

In order to make the report as meaningful and useful as possible, an attempt has been made to describe each impact in the following terms: positive impacts refer to beneficial effects and negative impacts refer to harmful effects on e.g. natural resources, human beings and economy

16.12 IMPACTS DURING CONSTRUCTION AND OPERATIONAL STAGE

During the construction phase of the project most of the impacts identified are of a negative nature but some of them will be temporary and will vanish with the completion of Project.

16.12.1 Impacts on Topography

The interventions of the ALHPP are not likely to impact the topography of the area on a large scale except for those areas where the physical activities of excavation, digging and movement of the heavy machinery will take place Similarly, areas where excavated material from tunnels will be disposed, dumped or stored will be negatively affected. This impact can be considered as a negative impact with moderate magnitude during construction while there will be no impact on topography during operational stage.

Mitigation

To reduce the negative impacts of excavated material: firstly, the emphasis should be to reduce the volume of material requiring disposal and secondly, to dispose it in environmental friendly way. The following measures are proposed in this respect:

- As far as disposal on the dam site area is concerned, some of the spoil can be used for construction project related structures.
- Some of the spoil can be used for widening of the roads. Part of the excavated material on the powerhouse site can be used for making aggregate required for project construction and for the development of infrastructure such as roads and filling of natural depressions.

16.12.2 Impact on Seismicity

The area is well known to consist of active landslide zones as more than 33 damaging events have occurred in the region during the period from the year 1830 till January 2010 (Kreutzmann,1994). In addition to this, according to the Geological Survey of Pakistan (GSP) a fault line also passes through the area. During the devastating 2002 earthquake in Astore that hit Attabad, the process of crack evolution in the mountains of Attabad Region was observed, which worsened during the subsequent strong earthquake (7.5 on Richter scale) in 2005. With the passage of time, cracks began to widen slowly and gradually on January 4, 2010, slope failure occurred in the Attabad Region resulting in the establishment of a natural dam that completely blocked the Hunza River. According to the initial estimates, a slide mass of approximately 30 million m^3 fell from the northern valley wall.

Mitigation

All structures to be built must be designed giving maximum allowance to seismic factors. A very careful analysis of the situation will be required during the design stage of the project by specialist consultants.

Continuous monitoring of the behavior of faults will be required during the operation stage and contingency plans to deal with such a situation must be part of the project management. Instruments to monitor seismic activity must be installed at the time of construction

16.12.3 Impact on Geology

Almost all project interventions involve excavation of natural rocks, cutting of formations, moving and dumping of spoil. During tunnel excavation and some other operations, blasting of the formation will be required. All these activities will disturb the existing geological formations and consequently physical features of the local geological formations of the project area will be damaged at some places, which is a negative impact of moderate magnitude.

During operation of the Project the seepage from the reservoir will significantly impact the geology of the area. The seepage water will saturate the formation below and along the reservoir and soluble minerals from the rocks will dissolve in the water. Some solution channels may develop in the formation making the formation more pervious.

Mitigation

All these activities are an integral part of the project interventions and cannot be avoided. Blasting should be minimized where possible (near the surface) and, if unavoidable low power explosive should be used and a greater number of blasts with low power material may be preferred instead of high intensity single blasting.

It is difficult to check or reduce the seepage from the reservoir. A continuous monitoring system will be required during operation of the project to monitor the changes in groundwater level and chemistry of ground water.

16.12.4 Impacts on Landslides

As the natural dam had been a result of a major landslide, therefore, special emphasis should be given to this aspect. Landslides are common in the project area due to the high steepness, unstable geological formations on both sides of the river and common seismic activities. Due to the Project activities, especially blasting of rocks in some areas, the formation will become loose and the risk of landslides will increase in the immediate vicinity of the construction sites specially at the right bank of Hunza River, which may be considered as a moderate negative impact of the Project.

Mitigation

To avoid the major risks, all structures are proposed on the left bank of Hunza River. Further, to minimize blasting of formations and, if unavoidable, then use low intensity explosive if possible.

It is expected that landslides could increase due to construction activities. Further the seepage of water will make the formation loose and unstable and the chances of sliding due to rainfall, abnormally high and low temperatures and due to seismic activities will increase. The sloughing and slippage of saturated formation during regular flushing of the reservoir may also enhance the sliding potential of the area. This impact may be considered as a major negative impact.

As no mitigation is possible to check either the seepage or any resulting landslide, however, as after a few years of Project operation most of the rocks along the weir site will become stable.

16.12.5 Impacts on Land Use

There will be no major impacts on the land use of the area as the lake has already been formed and changes has already been taken place long before this Project. However, new infrastructure will be built in the area which would have positive impacts on the land use.

16.12.6 Impacts on Infrastructure

As there would be no resettlement involved in the project, therefore, impacts on infrastructure would be rather positive.

16.12.7 Impact on Climate

Project construction involves large scale activities including the movement of different types of light and heavy traffic, working of heavy machinery, blasting of rocks, operation of batching and mixing plants and the presence of large numbers of people in the area. Due to all these activities, it is expected that the microclimate of the project area (surrounding the dam site and powerhouse site) will suffer significantly. However, no impact on climate of the whole project area is expected, either positive or negative, during the construction phase.

The lake has already been there since 2010, therefore no major changes would occur to the climate after Project has been completed.

Mitigation

The deterioration in the local climate during the construction phase will be of a temporary nature and will disappear with the completion of the project.

16.12.8 Impacts on Hydrology

During the construction and operational, stage there will be no change in the hydrology of the river. The flow from the reservoir will be diverted to downstream of the weir through diversion channel.

Mitigation

To conserve the aquatic life (flora and fauna) of the river downstream of the weir (2 km patch), minimum flow of 3 m^3/s has been calculated as the environmental flow. It will be obligatory for Project Operating Agency to release 3 m^3/s in the river throughout the year as environmental flow.

16.12.9 Impacts on Sedimentation

During the construction stage, the overall sedimentation rate will remain almost the same upto the dam site, but it may change because of movement of heavy traffic, dumping of the excavated material and other Project related activities. The impact is considered as negative but of short duration and of minor magnitude.

The Hunza River water always contains huge sediments of around 20-21 Million Tons annually on average. Diversion Channel will be used for flushing of sediments during high flow months. It is expected that release of sediments in moderate quantity could change the morphology of the river d/s of dam. However, as sediments will be released during high flow months with relatively high velocity of water and the river in this section has a high gradient, it is expected that sediment will move far away from the downstream of the weir site.

Mitigation

The silt clearance (flushing) mechanism has been provided in the Project design through channel/sluices. It is proposed to flush the reservoir regularly during high flow months.

16.12.10 Impacts on Flooding

Flooding of the river at the dam site is not a common feature although some floods of high intensity are recorded in the past e.g. the glacial lake outburst floods of 1929. As river water from the upper cofferdam will be passed through diversion channels, there is chance that these tunnels could not accommodate the flows in any abnormal year. In such cases, floodwater can overtop or breach the cofferdam and damage the partially constructed civil works and lower cofferdam. Thehas significant positive impact.

Mitigation

The design of the weir has considered the design flood of 1 in10,000- year flood of 3,250 m^3/s

16.12.11 Impacts on Groundwater

During construction stage, no impact on groundwater is envisaged as the flow of water will continue as such without any storage. The lake has already been formed, therefore, there will be no change to the groundwater.

16.12.12 Impacts on Air Quality

The project activities during construction at both weir and powerhouse sites will involve large movements of heavy diesel operated machinery and vehicles which produce more noise and emit more smoke. Similarly, various levels of noise and air pollution are expected to be generated from construction machinery and equipment, working of heavy earth moving machinery, drilling, blasting operations, concrete mixing, pouring equipment and stone crushers etc. The impact on air quality is considered as short duration negative impact of moderate magnitude.

Mitigation

The contractors and sub-contractors must be held responsible through special clauses in the tender documents to strictly follow precautionary measures.

16.12.13 Impacts on Terrestrial Flora and Fauna

The Project Area has very thin vegetation cover due to the special features of the terrain i.e. poor rainfall and steep mountains with very little soil cover. During construction stage, the damages to flora can be done by vehicles and machinery, establishment of camps and permanent structures etc. The construction activities will generate impacts of negative nature on all types of fauna but of moderate magnitude.

Mitigation

Dumping of construction materials should be avoided where large number of terrestrial trees, shrubs, herbs, grasses and fruit trees are found. where mammals, amphibians, reptiles and birds settle.

There would be no significant impacts on Flora and Fauna of the micro environment of the Area during operation stage.

16.12.14 Impacts on Employment Opportunities

At present employment opportunities in the Project Area are limited to few fields which would increase with the construction and operational activities. Majority of local employees will be engaged in the unskilled and semi-skilled sectors. Employment generation is a major positive impact of the Project.

Enhancement

The contractors of the project components shall be bound legally through contract agreements to engage 100% unskilled labor from Project Area of Hunza Region. Preference should also be given to local skilled and semi-skilled manpower if available.

16.12.15 Impacts on Regional Safety and Health

People of Hunza used to interact with people from different areas, cultures and communities. However, when there is sudden influx and congestion of people at any place from other areas for a longer period of time, it may contribute to adverse effects on the community health, safety and security of locals. There is always potential for such social impacts as incidences of accidents, social conflicts, theft and spread of communicable diseases.

Mitigation

The contractors must be bound to establish workers camps sufficiently away from the settlements of local people. During construction, the Project working sites need to be bordered by a fence to safeguard life and property. As appropriate, any warning signs related to safety and security should be displayed in local languages. An appropriate security system must be in place to control all access routes to the site.

16.12.16 Impacts on Occupational Health and Safety

There is a tendency for the construction sector to be unregulated with respect to occupational health and safety. Additionally, unskilled and even some skilled construction workers may be illiterate and not necessarily informed or familiar with the protective measures to be adopted during work.

Mitigation

The contractors will need to carry out risk assessments and then develop site and Project specific Health and Safety Management Plans to prevent accidents, injuries and work-related diseases.

16.12.17 Impacts on Resources

Construction workers will need their daily supplies in the Project Area. This could potentially negatively affect the existing resource base and cost for firewood, food, goods, water and fish as well as create considerable amounts of waste. Both community members and construction workers will be affected by resource constraints and changing prices and are considered sensitive socio-economic receptors, because of their limited purchasing power and state of poverty which could be affected by these impacts. These impacts are considered to be negative and of minor magnitude.

Mitigation

Mitigation measures will be needed to ensure that the Project site is managed in a manner that is socially responsible and reflect sound environmental management practices. With respect to resource use, the Contractors will be expected to develop a plan and budget for providing workers with fuel for cooking and heating, water for cooking and cleaning, food supplies, and hygienic sanitation facilities for collecting and disposing rubbish, including construction waste.

16.12.18 Impacts on Cultural Heritage and Archaeology

No site of archaeological and historical importance has been identified in the Project Site. Some carving on stones were found near the powerhouse site regarding the incident of 2010 landslide but these carvings are outside the Project construction area.

Mitigation

Appropriate community relations have to be maintained for social respect between the local people and labor coming from other parts of the country.

16.12.18.1 Water Pollution

Heavy machinery and equipment will be used during construction and operational phases of the project with huge quantity of explosives for blasting of rocks. Resultantly heaps of leftovers of explosives, grease, chemicals, lubricants, and other harmful materials will be produced on daily basis. These pollutants through run off rain water enter into the lake and river course increase toxicity of water causing rapid destruction of fish population and riverin ecology.

16.12.18.2 Fish Migration

Fish usually migrate from one place to another for search of food, shelter and spawning/breeding. Due to construction of the Project fish migration might be affect up to some extent.

Mitigation

Rapid mechanism of dispose-off of such kinds of hazardous materials will be required on urgency basis by dumping the extracted hazardous materials selecting safe landfill areas away from the main river course and its watershed, so that contaminated water in form of runoff could not enter directly into the main course.

Land sliding and soil erosion are also the main factor to contribute silt load on river bed manifold causing damage to resting and nesting grounds of fishes. Construction of protective walls and gabions at certain points to make sure the stoppage of sliding debris. Plantation and vegetation cover can also be helpful for slope stabilization. Plants, herbs and shrubs reduce the level of pollution and toxicity at a great extent as bio-filter and carbon suckers.

- Fish screening system should be developed so that fish may not be trap at intake, penstock pipe or channel.
- Sewage water treatment discharged from all labour camps and toilet facilities must be treated before disposal into the river.
- Tanks of fuel, oil and other liquids to be placed quite distant from any water body.
- Washing of vehicles or other machinery in the river or nullah is to be strictly prohibited.
- Oil changes for engines and other machinery to be only allowed in workshops.
- All vehicle and machinery to be maintained properly in order to avoid any leakages

16.12.18.3 Impacts on Power

The most significant impact of the Project will be the power generation as the Region is presently facing acute shortage of power. The power generating capacity of the Project is estimated as 54 MW, which is enough to remove the power shortage from the area. The power generated will help to establish new industries to boost commercial activities and to enhance job opportunities in the valley. Electricity generation impacts are considered to be most significant positive impact of the Project.

16.13 CONFIDENCE BUILDING MEASURES (CBM)

People of Hunza are well educated and support development of projects, especially when it comes to power projects. However, in addition to satisfying the needs and requirements of locals, certain measures shall be taken in the form of CBM. During the social survey of the region, it was desired by the local communities to provide facilities where they could play sports and organize sporting events. For the said facility. Land would be acquired by the amount kept near Karimabad and Ganish for CBM, further infrastructure development can be developed with the help of involvement of NGOs.

16.14 ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

This section of the ESIA report provides an overall approach for managing and monitoring the environmental and social issues raised by the construction and operation of the ALHPP .The objective is to provide an overall frame work for implementing the mitigation measures that adequately address the identified adverse impacts and also the enhancements for predicted positive impacts. In addition, the items that require monitoring of the environment are also identified. All of these measures are to be put into a coherent Environmental Management and Monitoring Plan (EMMP), complete with the institutional arrangements and resources required to successfully implement the required actions.

The main objectives of an EMMP areas under:

- Provide the details of the Project impacts, along with the proposed mitigation and enhancement measures.
- Define the roles and responsibilities of the Project stakeholders, including the Project proponent, contractor, supervisory consultants and other key players.
- Identify the training requirements needed for the key role players in order for them to effectively implement the EMMP.
- Provide a mechanism in the form of an environmental monitoring program, that outlines which key parameters (both for the natural and social environment) will need to be monitored and the frequency that each of these has to be carried out.
- The objective is to ensure that mitigation measures are being effective in keeping environmental conditions within prescribed limits and if they are not, then making sure that there is an effective response mechanism that allows corrective action to be implemented.

16.15 MITIGATION MANAGEMENT MATRIX

The Mitigation Management Matrix (MMM), a preliminary out line is considered to be one of the main elements of the EMMP. The MMM shall be prepared during detailed design keeping in view the required functions and responsibilities and is to be used as the management tool for the implementation of mitigation measures. The mitigation management matrix should include:

- The required mitigation measures recommended in the ESIA Report.

- Identification of the person or institution/organization directly responsible for adhering to or executing the required mitigation measures.
- The person or institution/organization responsible for ensuring and monitoring adherence to the mitigation measures.
- The parameters that will be monitored to ensure compliance with environmental standards and also with the requirements and objectives of the mitigation measures.
- The timing at which the mitigation or monitoring has to be carried out.

16.16 MANAGEMENT OF DIRECT CONSTRUCTION IMPACTS

Construction programs and management of construction impacts shall be included by drafting appropriate environmental management clauses into the construction contracts. Once a master check list of direct construction impact issues has been finalized then a monitoring checklist can be created for use by the supervising engineers during the construction period. It is crucial to clearly define the responsibilities of each of the parties in the construction works (contractors, supervisors and the Project Proponent).

16.17 SITE RESTORATION PLAN

The main areas that will require site restoration include the main construction site area, workers' accommodation sites, land used for vehicle and material workshops and stores along with material excavation and storage areas and temporary access roads and tracks. These areas will need to be restored to their original condition as far as possible and where there has been significant change then landscaped to fit with the surrounding area. The restoration work includes the removal of all temporary construction works and materials, followed by the landscaping and planting of the areas, including provision of adequate surface drainage to ensure that there will be no erosion and particularly sedimentation into the reservoir. The following procedures will be adopted for the restoration of the site:

- All temporary constructions built for the site development will be removed.
- Areas used for construction camps will be restored to their previous condition as far as is possible and where this is not then appropriately landscaped and planted to an agreed plan.
- All toxic and hazardous chemicals and materials will be totally removed from the site followed by treatment and environmentally appropriate disposal.
- During the construction program efforts will be made to minimize the risk of oil and chemical spills and an effective clean-up program should be in place to remove these as soon as they happen.
- All debris from construction activities should be removed from the site and appropriately separated, reused, recycled and composted with the residual material appropriately incinerated.

- All redundant fencing and gates will be removed and excavated pits will be appropriately backfilled.

16.18 RESERVOIR MANAGEMENT PLAN

Reservoir area will need to be managed during both the construction and operation of the project. The risk of debris entering the intakes also has to be considered. Once a clear idea of the construction program has been agreed then an appropriate reservoir management plan can be drawn up. This should also include the fisheries development plan for the reservoir, along with a recreation and tourism management program for the area.

The reservoir management plan will also have to consider the need for upstream catch management measures in the watercourses that directly discharge into the reservoir, based upon the results of water quality monitoring that will be carried out. The quality of the reservoir water will also need to be monitored to ensure that there is not a buildup of nutrients that could cause problems with algal growth. If this should start to occur, then adequate measures will needtobetakentopreventnutrientloadedwaterfromflowingintothereservoir.

16.19 IMPACT MONITORING PROGRAM

16.19.1 Objectives of the Impact Monitoring Plan

The objective of the environmental monitoring activities to be carried out during the construction and operation stages of the project will be as follows:

- To monitor the actual project environmental impact on the physical, biological and socioeconomic indicators that will be selected to be appropriate for such work in order to compare appropriate indicators with the situation before the start of the Project.

- To provide information that will allow recommend mitigation measures to be drawn up for any unforeseen impact or where the adverse impact level exceeds that anticipated.

- Ensure compliance with legal regulatory requirements and also community obligations, including health and safety at both the construction and operational stages of the Project.

- Ensure the safe and environmentally sound disposal of excess construction materials, solid waste and effluents, along with the adequate management of noise and dust emissions.

The main objectives of environmental monitoring during the operation phase will be to:

- Appraise the adequacy of the ESIA with respect to the predicted long-term impacts of the project on the physical, biological and socio-economic environment of the area.

- Evaluate the effectiveness of the mitigation measures proposed in the EMMP and recommend any improvements in the EMMP if they are found to be required.

- Compile periodic incident and accident data to support analyses that will help to minimize future risks.

- Monitor the survival rate of the proposed vegetation planting program and make appropriate proposals to ensure that balanced mixed age and species stands develop in the area that provide sustainable supplies of fruit, fuel- wood and fodder for the local population.

16.19.2 Monitoring Strategy

All the compliance monitoring will be executed by the Contractor during the construction stage of the Project to ensure that they operate according to the regulatory framework. Supervision of the compliance environmental monitoring work during the construction stage will be carried out by the Supervisory/Management Consultants(SC).

16.19.3 Monitoring Parameters and Frequency

I. Natural Environment

For the physical environment the following parameters will need to be regularly monitored both before and during construction:

- Ambient air quality (mainly NOx, Sox and CO)
- Batching and crushing plant emissions (smoke, dusted.) during operation
- Ambient noise levels
- Water quality (drinking, surface and groundwater), for both chemical composition and also sediment

II. Socio-Economic Environment

The impacts on the socio-economic environment will be monitored by the SC using changes in house hold economic livelihoods as a major indicator in the longer term. Other key aspects that will need to be monitored include environmental and community health, safety issues, employment availability and generation, along with physical mobility and access, especially for women. At the construction stage of the Project the Supervisory Consultant will maintain a Social Complaints Register. This is an open public document that allows anybody to register a complaint which must then be thoroughly investigated and a judgment made as to its justification and the action need to address the issue.

16.20 CONSTITUTION OFPROJECTENVIRONMENT MANAGEMENT COMMITTEE

Sr. No.	Agency	Representative	Status
1	WAPDA	Project Director	Chairman
2	Government of Gilgit-Baltistan	DC/ AC (Concerned)	Member
3	Consultant	Resident Engineer	Member
4	Main Contractor	Designated Engineer	Member
5	Environment Department	Director, EPA Gilgit-Baltistan Representative	Member
6	Local Government	Chairman District Council	Member
7	NGO	Representatives of two functional NGOs of the Region	Member

16.21 LAND REQUIREMENTS FOR THE PROJECT

Resettlement, land requirements and acquisition for any Mega Project is a sensitive task, however, for this Project these issues are not as critical as in other projects. Attabad Lake was formed in 2010 as a result of a natural disaster and it still recovers about 4.5 km2 of land which includes lands of Ainabad, Shishkat, Gulmit and Gulkin. Shishkat, Gulmit and Gulkin were partly damaged but Ainabad was completely submerged.

Land will be acquired for mostly powerhouse site which includes land powerhouse, switchyard, Project colony and Project offices. Land at weir site is mostly riverine land and will be acquired from the government. Land required for the ALHPP is mentioned in the Table 16-8.

Table 16-8 Land Requirements for ALHPP

Sr. No.	Description	Town / Village	Land in Acres	Land in Kanals	Land Cost per Kanal (DC Rates)	Remarks
1	Powerhouse Side	Sarat	4	32	750,000	Community Land of Ganish Village
2	Weir and Associated Structures	Attabad	15	120	500,000	Mostly it is riverine land. Left Side of Hunza River is Community Land of Ganish Village and Right Side is Community Land of Attabad Village.
3	Access Roads to Sites	-	-	-	-	Old KKH will be repaired where available and new will be constructed where not available
4	Permanent Project Colony	Sarat	2.5	20	1,500,000	Community Land of Ganish Village
5	Transmission Line	Throughout the T.L route	As per site	As per site	Varies	Land for T.L will be acquired along the route
	Total		**21.5**	**172**		

17 ECONOMIC AND FINANCIAL ANALYSIS

17.1 INTRODUCTION

Electricity is imperative to social, agriculture, industrial development and growth of any Region. Electricity and energy consumption is an important indicator of economic growth. While 83% of the population of Pakistan presently has access to electricity, per capita energy consumption is about 516 KWh/year in the year 2020 (IGCEP-2021,2030)

Pakistan is endowed with a hydro potential of about 60,159 MW, most of which located in the provinces of Khyber Pakhtunkhwa (KPK), Northern Areas (NA) and Azad Jammu and Kashmir (AJK).

This section deals with quantitative analysis of the economic and financial aspects of ALHPP

17.2 ECONOMIC ANALYSIS

17.2.1 Introduction

Economic justification of investment in capital intensive project depends upon three factors, firstly the need of the project, secondly technological options available and the most economic choice (least cost option) for the project and thirdly the project will provide an acceptable return to the national economy and fulfills the debt obligation. The process involved the assessment of project benefits and identification of project cost over the economic life of the project. The basic technique for comparing costs and benefits occurring in different periods is discounted to express them in a common value in one point taking into account time value of money. Economic viability of the project has been checked under two approaches i.e. Equivalent Thermal Approach and Consumer Surplus to Pay (WTP).

17.3 CUSTOM DUTY

No import charges and sales tax has been added. However, custom duty @ 5% on import of plant and equipment not manufactured locally on foreign exchange component of E&M equipment are added to the project. (Refer Hydel policy for Power Generation Projects, 2015).

17.4 INTEREST DURING CONSTRUCTION (IDC)

The interest during construction has been calculated @12.20% per annum on both local and foreign cost components.

17.5 EXCHANGE RATE

Since 1982, the value of the Pakistani Rupee has been worked out with the help a "managed float" linking it to a basket of currencies. It is recognized that conversion factors are sometimes used even when a currency is floating especially if restrictions exist on currency exchange. Based on the facts it is concluded that conversion factor should not be applied to the exchange rate. Prevailing interbank exchange rate of US$= Rs 157 has therefore been applied.

17.6 OPERATION AND MAINTENANCE COST

The operation and maintenance cost of the Project has been assessed @ 1% per annum of the base cost during its 30 years of useful life.

17.7 AUTHORITY OVERHEADS

The authority overhead has been fixed @ 1.5% on Civil, E&M and Preliminary Cost.

17.8 ANNUAL RECURRING COST

Recurring costs refer to expenses that reappear over a period. The annual O&M cost and annual amortization costs have been taken in the annual recurring cost.

17.9 LOCAL ESCALATION

There are three measures to compute escalation. These are GDP deflator, consumer price index (CPI) and wholesale price Index (WPI). The GDP deflator is the ratio of nominal gross domestic product (GDP) in a given year to real GDP of the year. Since the GDP deflator is based on all goods produced in the economy and is used to measure inflation and escalating project costs, hence the same is proposed for escalation purpose. The future projections of inflation rate are made on the basis of historical trends and government policies to curtail inflation.

The State Bank of Pakistan is taking hard decision to control the inflation by tightening the monetary policy. The government of Pakistan has also taken measures like reducing the budget deficit and effective management of domestic food supplies to curtail the inflation in Pakistan. During the last two years GDP rates were abnormal which cannot be applied for up-dating of costs. Taking a realistic value in a real term inflation rate of 6.5% has been used in this project.

17.10 FOREIGN ESCALATION

The major share of project cost shall be incurred on importing hydro-mechanical equipment's. The foreign cost shall also be required to be escalated during the construction. Two indices are available to escalate foreign cost components during construction. The manufacturing unit value index (MUV) represent the escalation rate of seven industrialized countries. For foreign cost updating escalation rate of 2% has been used (World Bank web site).

17.11 ERECTION & COMMISSIONING, LC, INSURANCE & SECURITY COST

These items have been charged @ 5% on Civil, E&M and Preliminary cost.

Base Cost (Million Rs.)

Local	14350.480
Foreign	5678.440
Total Base Cost	**20028.920**
Price Escalation of Local and Foreign	1000.537
Custom Duties	216.706
Total Financial Cost	**21246.163**

17.12 ANNUAL O&M COSTS

The annual operation and maintenance cost has been estimated keeping in view the recent years, expenditures and salaries of the staff. The O&M cost @1% of the base cost comes to Rs. 200.289 million with transmission line which will be met through selling of energy of power plant

17.13 PROJECT BENEFITS AND ANALYSIS

The economic and financial analyses have been carried on the following two scenarios:

1. Financial Internal Rate of Interest (FIRR) with transmission line without Capital Development mechanism (CDM)

2. FIRR with transmission line with CDM benefits

17.14 FINANCIAL BENEFITS

- The Hydro Power Project is highly beneficial due to less unit cost and providing inexpensive electricity. It will also help in saving foreign exchange on import of fuel.

- The financial benefits over the project life of 30 years calculated on certain assumptions depict an (FIRR) as 19.27%, and 19.17% with and without CDM benefits respectively which makes the Project significantly viable.

- The generation cost is worked out to be Rs 5.67/kWh (3.61 US Cents) over the useful life of the project and cost per MW of installed capacity being Rs 393.447 Mill (US $ 2.506 Million) with transmission line is also very attractive to reflect the financial benefits of the Project.

17.15 ECONOMIC BENEFITS

The economic analysis of the Project has been carried out on the basis of benefits to the overall economy as a consequence of least cost optimal development of the hydropower potential in the country. For this purpose, the benefits from the proposed steam unit/combustion turbine plant with (CDM) have been evaluated in term of costs foregone for providing an equivalent thermal generation.

The project will yield Internal Economic Rates of Return (IERR) of 22.54% & 22.36% with and without CDM benefits respectively. The benefit cost ratios come to 1.56:1, and 1.55:1, at 12% discount rate with and without CDM benefits respectively which also reflect the economic viability of the proposed Project.

17.16 SOCIAL BENEFITS

The Project with an installed capacity of 54 MW will generate 373.69 GWh of electricity annually which will assist in meeting power demand of the Hunza Region. The project will implement several programs that are designed to improve living standard of the area. These programs will provide improved health, education and infrastructure facilities while other programs will provide alternative source of income and create improved employment opportunities.

Moreover, the Project will avoid annual releases of about 149,476 tons of CO^2 from an equivalent thermal plant which have a corresponding reduction in atmospheric pollution.

The revenues of would increase due to direct and indirect taxation, duties and levies on the production of goods and services that will arise from the power generation within the Project Area as well as from the electricity duty collected by the Federal Government, Government of Baluchistan or any other Government agency.

The hydel generation plays an important role in the country's economy due to utilization of indigenous energy resources, in reducing load shedding and saving of foreign exchange required to import furnace oil.

17.17 BENEFITS OF THE PROJECT

17.17.1 Quantifiable Benefits

ALHPP would be constructed at Attabad using existing infrastructure. It will provide inexpensive electricity of about 373.69 GWh annually to the National Grid. The total installed capacity of the Project is 54 MW. It has no adverse impacts on the local environment, on the other hand it will help to reduce emissions as compared to a thermal Project. There are many benefits associated with the construction of hydroelectric power generating facility. These benefits include:

- Power will be produced from a renewable resource instead of depleting reserves of the country.
- Harmful by-products such as SO_2, NO_2, and CO_2, etc. are not produced by hydropower as with other fossil fuel sources.
- It will increase the regional power grid stability, reliability and availability.
- Local socio- economic benefits as a result of the construction, operation and maintenance of the facility.
- Multi-use of the water resource thus maximizing the intrinsic value of the overall facility.

17.17.2 Non-Quantifiable Benefits

The hydel project needs extensive civil works and can create significant number of job opportunities for engineers, technicians, skilled and unskilled labour during execution and operation of the project. The project is envisaged to bring economic uplift activities of far-reaching effects in the project area particularly electrification. Construction of ALHPP will have direct and indirect benefits for the local area. It will create new employment and job opportunities during construction and operation stages.

The Project will provide incentive for the establishment of small and medium size industry based on local raw material, creating gainful employment opportunities to the increasing work force. This will further help in alleviating disguised unemployment in agriculture sector. Providing basic infrastructural facility of electricity in rural areas goes a long way in checking large scale migration of rural labour force to urban centers.

Higher per capita disposable income would create more opportunities, improved health and education facilities. It would provide incentives to the work force to live near their homes and tendency to migrate to main urban centers would be reduced. In brief, it is envisaged that providing one of the basic infrastructure facilities of electricity at a suitable scale would usher in a continuous prosperity as well as economic emancipation by utilization of indigenous resources of land, labour and capital.

The revenues of the government would increase due to levies and taxes on the production of goods and services which would be a consequence of the electrification of the area as well as from electricity duty due to additional sale of power. Besides, the annual payment of interest charges to the federal government / loaning agency would be a substantial amount.

17.18 CLEAN DEVELOPMENT MECHANISM (CDM) BENEFITS

The CDM is an emission reduction (ER) trading agreement under the Kyoto Protocol between two countries, where greenhouse gas emission is reduced in a non-annex country and transferred to another country. Under the Kyoto Protocol

Pakistan deposited its intent of accession to the Kyoto Protocol in the UN Secretariat on 11 January 2005.To become eligible for CDM Projects, an operational strategy was developed to fulfill requirements of establishing a designated national authority (DNA) and ensuring transparent, participatory and effective management of CDM process in the country. Carbon Credits are applicable in certain cases of hydroelectric projects, where a demonstrable reduction in greenhouse gas emissions can be claimed as result of the project.

In order to qualify a project has to cross a number of barriers; in particular, by providing additionally measure of benefits that the project brings that would not have been available in its absence and quantifying the benefits in terms of a voided emissions. Once credits are confirmed, it is necessary to trade them through one of the carbon funds to convert into hard currency revenue from the start of the operation.

Recently a number of international organizations such as Asian Development Bank (ADB) have established a means of purchasing (CERs) units. The ADB also offer technical support to prospective developments for taking the necessary steps to be able to benefit from CDM. Unit can be traded in the open market on exchanging.

For the purposes of this analysis it is assumed that 373.69 GWh generated annually by this project will displace about 149,476 ton of CO^2 at 0.40 kg/kWh. One ton of CO2 corresponds to CER which is currently valued about 1.5 US$. Therefore, the CDM benefits worth will be 29.921 million Pak Rs per annum:

Table 17-1 Estimate of Annual CDM Benefits

Description	Unit	Value
Energy	GWh	373.69
CO_2 emission per kWh	Kg	0.4
CO_2 emission per GWh	Tons	400
Project CO_2 Emission	Million Tons	0.149476
CO_2 emission per Ton	US$	1.5
Project CDM Benefits	US$	0.2242
Project CDM Benefits	M.Rs	35.20
Benefits attributed to the Project	M.Rs	29.921

17.19 FINANCIAL ANALYSIS

The Project with an installed capacity of 54 MW will generate 373.69 GWh of electricity annually which will assist in meeting power demand of the country and will help in reduction of load shedding though insignificant. The project will generate revenue of Rs 5037.462 million and Rs 5007.541 million with and without CDM benefits annually at full operation. The Internal Financial Rates of Return (IFRR) 19.27% and 19.17% with and without CDM benefits respectively are shown in Tables-17-2 to 17-3.

Table 17-2 Attabad Lake Hydropower Project
Financial Analysis With CDM Benefits

YEAR	PROJECT COST	O&M	TOTAL COST	ENERGY GWh	REVENUES	CDM BENEFITS	TOTAL BENEFITS	NET BENEFITS
1	6317.890		6317.890					-6317.890
2	5521.856		5521.856					-5521.856
3	9406.417		9406.417					-9406.417
4		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
5		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
6		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
7		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
8		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
9		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
10		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
11		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
12		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
13		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
14		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
15		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
16		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
17		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
18		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
19		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
20		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
21		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
22		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
23		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
24		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
25		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
26		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
27		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
28		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
29		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
30		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
31		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
32		200.289	200.289	373.69	5007.541	29.921	5037.462	4837.173
33	-	200.289	-	373.69	5007.541	29.921	5037.462	6593.657
TOTAL	**21246.16**	**6008.67**	**25498.35**	**11210.70**	**150226.217**	**897.641**	**151123.857**	**125625.503**

INTERNAL RATE OF **19.27%**

Table 17-3 Attabad Lake Hydropower Project Financial Analysis Without CDM Benefits

MILL.Rs

YEAR	PROJECT COST	O&M	TOTAL COST	ENERGY GWH	TOTAL REVENUES	NET BENEFITS
1	6317.890		6317.890			-6317.890
2	5521.856		5521.856			-5521.856
3	9406.417		9406.417			-9406.417
4		200.289	200.289	373.69	5007.541	4807.251
5		200.289	200.289	373.69	5007.541	4807.251
6		200.289	200.289	373.69	5007.541	4807.251
7		200.289	200.289	373.69	5007.541	4807.251
8		200.289	200.289	373.69	5007.541	4807.251
9		200.289	200.289	373.69	5007.541	4807.251
10		200.289	200.289	373.69	5007.541	4807.251
11		200.289	200.289	373.69	5007.541	4807.251
12		200.289	200.289	373.69	5007.541	4807.251
13		200.289	200.289	373.69	5007.541	4807.251
14		200.289	200.289	373.69	5007.541	4807.251
15		200.289	200.289	373.69	5007.541	4807.251
16		200.289	200.289	373.69	5007.541	4807.251
17		200.289	200.289	373.69	5007.541	4807.251
18		200.289	200.289	373.69	5007.541	4807.251
19		200.289	200.289	373.69	5007.541	4807.251
20		200.289	200.289	373.69	5007.541	4807.251
21		200.289	200.289	373.69	5007.541	4807.251
22		200.289	200.289	373.69	5007.541	4807.251
23		200.289	200.289	373.69	5007.541	4807.251
24		200.289	200.289	373.69	5007.541	4807.251
25		200.289	200.289	373.69	5007.541	4807.251
26		200.289	200.289	373.69	5007.541	4807.251
27		200.289	200.289	373.69	5007.541	4807.251
28		200.289	200.289	373.69	5007.541	4807.251
29		200.289	200.289	373.69	5007.541	4807.251
30		200.289	200.289	373.69	5007.541	4807.251
31		200.289	200.289	373.69	5007.541	4807.251
32		200.289	200.289	373.69	5007.541	4807.251
33	-1756.484	200.289	-1556.195	373.69	5007.541	6563.735
TOTAL	**21246.163**	**6008.676**	**25498.355**	**11210.70**	**150226.217**	**124727.862**

INTERNAL RATE OF RETURN = 19.17%

17.19.1 Unit Cost Analysis

The cost per kWh of energy generated has been estimated by dividing average annual recurring cost with annual generation of the Project. The average annual recurring cost is arrived at by amortizing the total financial cost of Rs 21246.163 Million (Local Rs 15360.187 million and foreign Rs. 5885.975 million) inclusive of escalation, custom duty and IDC at an interest rate of 12.20% for both local and foreign components for 20 years and levelized over 30 years. Annual O&M costs with transmission line of Rs 200.289 Million has also been included. The Project generation cost with transmission line per kWh and cost per MW of installed capacity are shown in Table-17-4.

Table 17-4 Cost Per KWh and MW

Sr. No	Description	Million Rs.
1	BASE COST	20028.920
	a) Local	14350.480
	b) F.E.C	5678.440
2	ESCALATION	1000.537
	a) Local@ 6.5%	793.002
	b) Forgien @ 2%	207.535
3	Import Charges @ 5%	216.706
4	Interest During Construction	0.000
	a) Local	0.000
	b) F.E.C	0.000
5	**Financial Cost**	21246.163
	a) Local	15360.187
	b) F.E.C	5885.975
6	Amortization of Financial Cost @ 12.20% For	
	20 Year & Levelised 30 year of:	
	a) Local	1388.162
	b) F.E.C	531.939
7	Operation & Maintenance Cost @ 1% of Base Cost	200.289
8	Annual Recurring Cost	2120.390
9	Annual Energy (GWh)	373.69
10	Cost Per KWh - Rs	5.67
	US $ Cents	3.61
11	Installed Capacity (MW)	54.00
12	Installed Cost Per MW- MRs	393.447
	Mill US $	2.506
	NOTE :- Exchange Rate: I US $ = Rs.157.00 .	

17.19.2 Breakeven Point (BEP)

BEP required to recover the recurring expenditure (Operating costs + Debt + Interest obligations). The breakeven production BEP is a production which determines the number of unit of energy volume of the project is 136.45 GWh of energy which is considerably less than the annual production of 373.69 GWh.

17.19.3 Payback Period

The payback period of the project are 5 years

17.19.4 Fuel Price

The scarcity of fossil, i.e. oil and gas for power generation demanded the development of renewable energy resources. Natural gas resources are depleting in Pakistan, which require from other countries, such as Dubai, Qatar, and Iran. The estimation of natural gas price to calculate the fuel cost per kWh of OCGT is cumbersome due to uncertainties in its availability. The price estimation further becomes complex with the depletion of indigenous natural gas reserves. Alternatively, re-gasification carryout from import of Liquefied Natural Gas (LNG) from Qatar is underway. Energy cost of thermal equivalent plants will be used.

The price of Qatar LNG has not yet been decided as such, LNG Price indicated in World Bank Commodities Data will be used to calculate the fuel price of the thermal plants. Average monthly price of LNG Japan is 5.98 $/mm Btu and after including shipping and re-gasification charges of 1.5 $/mm Btu, its comes to 7.48 $/mm Btu.AS per calculation depicted in Table 17-5

Table 17-5 Fuel Price kWh

Sr.	Description	Unit	
1	LNG Cost	$ mm btu	5.98
2	Shipping and Regasification	$ mm btu	1.50
3	LNG Cost (Fob)	$ mm btu	7.48
4	Heat Rate	btu kWh	6824
5	Fuel Cost	Cent/kWh	5.10
6	Fuel Cost	Rs.	8.42

17.20 ECONOMIC ANALYSIS

The economic analysis of the Project has been carried out on the basis of benefits to the overall economy as a consequence of least cost optimal development of the hydropower potential in the country. For this purpose, the benefits from the proposed steam unit/combustion turbine plant have been evaluated in terms of costs foregone for providing an equivalent generation.

The economic analysis is based on the following assumptions and summarized below:

DESCRIPTION		UNIT	OIL-FIRED
1.	Capital Cost/KW*	Rs	157000
2.	Plant Factor	%	80
3	O&M Cost @operated)	%	3.0
4.	Fuel Cost/KWh** Financial	Rs	8.42
5	Fuel cost / KWh: Economic	Rs	7.58

Source: Commodity price data world bank.

Results of economic analysis i.e. IERR with and without CDM benefits are calculated as 22.54%, & 22.36%. Detailed economic analyses are given in Tables-17-8 to 17.-9.

17.21 SHADOW PRICING

The economic analysis of the project requires that all costs and benefits must be evaluated at prices within the economy which reflect their real worth. Major inputs into the scheme of economic analysis do not necessarily reflect their true opportunity cost to the economy because of distortions in market prices. Like many other developing countries, the prices of goods and services are distorted by subsidies and taxes in Pakistan too.

The rate of foreign exchange has differed from its true opportunity cost., the price of labour in most of sector has generally been higher than its true opportunity cost. Shadow pricing has, therefore, been used to find out true opportunity cost of capital as well as other inputs to determine the economic cost of this project to the national economy.

17.22 COST OF CAPITAL

Shadow price of capital is defined as the opportunity cost of funds withdrawn from other uses and is considered equal to marginal cost of capital in the economy of Pakistan. The World Bank has used 10% discount rate for rural electrification projects and 12% by Planning Commission of Pakistan for economic evaluation of public sector projects followed by a study of Harvard Advisory Group on opportunity cost of capital. Accordingly, costs and benefits have been discounted @ 12% for the assessment of economic feasibility of the project.

17.23 COST OF LABOUR

In cases where there is significant unemployment and under-employment in a local economy shadow wage rates for labour should be used which are considerably lower than actual wages paid. The objective in economic analysis is to use the opportunity cost as an alternative application. In Pakistan the situation is one of under-employment for unskilled labour rather than full employment since there is labour shortages in rural areas in sowing and harvesting seasons. There is no employment problem for skilled labour as there are sufficient opportunities locally and in nearby oil producing countries.

Therefore, shadow wage rates of 1.00 and 0.75 for skilled and unskilled labour respectively, have been used for deriving the economic cost The economic cost of labour has been determined by applying shadow wage factors to the total labour cost which is equivalent to 38%

of the local cost of the project with 40% & 60% as skilled and unskilled labour components, respectively.

17.24 COST OF MATERIAL

Most of the material inputs for the project, i.e., steel, cement etc, are transported to the project site involving high freight expenditures. It is, therefore, assumed that shadow rate for material may be used as 0.91.

The results of shadow conversion factors have been applied to various components of project costs to derive adjusted economic costs

Table 17-6 Derivation of Standard Conversion Factor

Rs.(Million)

No.	Description/Years	2014-15	2015-16	2016-17	2017-18	2018-19	Average
1	Total Imports*	4644152	4658749	5540921	6694897	5,371,142	5381972
2	Total Exports*	2397513	2166846	2138186	2555043	2,263,648	2304247
3	Import Duties**	254360	255160	303476	366680	294177	294771
4	Sales Tax on Imports**	459492	460937	548219	662393	531421	532492
5	Subsidies on Imports***	52525	52690	62668	75719	60748	60870
6	Export Duties**	5826	5265	5196	6209	5501	5599

Standard Conversion Factor (SCF) = M + X $\dfrac{(M+X)}{(M+Tm)+(X-Tx)}$ = **0.91**

Source:-
* Economic Survey 2018-19

** FBR Year Book 2016-17 & 2018-19

*** Ministry of Finance, Islamabad

M = CIF Value of Imports

X = FOB value of Exports

TM= Net Value of Taxes on Imports

TX= Net Value of Taxes on Exports

17.25 ECONOMIC COST

The economic costs are derived by converting financial cost with adjustments for direct transfer payments like taxes, subsidies and interest (transfer payments) during construction, besides adjustments for distortions in the market prices of traded and untraded goods used in the project works. For this study also economic costs of the project have been derived by removing transfer payments in addition to adjustment of cost of labour and material with appropriate shadow conversion factors. The economic costs of the project thus derived have been used in economic evaluation and given in detailed calculations are as follows:

Table 17-7 Comparison of Economic Cost of the Project

Description	**Million Rupees**
Base Cost	**20028.920**
Local Cost	14350.480
Foreign Cost	5678.440
Labour Component	**5453.182**
- Skilled	2181.273
- Unskilled	3271.909
Material Component	**8897.298**
Labour Component	**4635.205**
- Skilled	2181.273
- Unskilled	2453.932
Material Component	8096.541
Local cost	12731.746
Foreign Cost	5678.440
TOTAL	**18410.186**

17.26 DERIVATION OF THERMAL EQUIVALENCE

The Feasibility has been assessed on the assumption that in the absence of hydel generation, an equivalent thermal generation plant would be required to produce equivalent amount of energy per annum. A comparative study has, therefore, been made and costs calculated on the basis of providing an equivalent quantum of generation from the steam plant using furnace oil described as economic benefits

Table 17-8 Economic Analysis with CDM benefits

MILL.RS

YEAR	COSTS			THERMAL EQUIVALENT				CDM BENEFITS	TOTAL BENEFITS	NET BENEFITS
	CAPITAL	O & M	TOTAL	CAPITAL	O & M	FUEL	TOTAL			
1	5806.57		5806.57	0.00			0.00	0.00	0.00	-5806.57
2	4771.92		4771.92	4185.62			4185.62	0.00	4185.62	-586.30
3	7831.69		7831.69	4285.62			4285.62	0.00	4285.62	-3546.07
4		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
5		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
6		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
7		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
8		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
9		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
10		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
11		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
12		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
13		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
14		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
15		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
16		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
17		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
18		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
19		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
20		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
21		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
22		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
23		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
24		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
25		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
26		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
27		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
28		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
29		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
30		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
31		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
32		180.26	180.26		251.14	2831.82	3082.96	29.92	3112.88	2932.62
33	-	180.26	-		251.14	2831.82	3082.96	29.92	3112.88	4689.10
TOTAL	**18410.19**	**5407.81**	**22061.51**	**8471.24**	**7534.11**	**84954.69**	**100960.04**	**897.64**	**101857.68**	**79796.17**

PW OF BENEFITS @ 12%; MILL.Rs = 24234.94

PW OF COSTS @ 12%; MILL.Rs = 15554.83

NET PRESENT WORTH; MILL.Rs = 8680.11

BENEFIT COST RATIO = 1.56

I.E.R.R = 22.54%

Table 17-9 Economic Analysis Without CDM Benefits

MILL RS.

YEAR	COSTS			THERMAL EQUIVALENT				NET BENEFITS
	CAPITAL	O & M	TOTAL	CAPITAL	O & M	FUEL	TOTAL	
1	5806.573		5806.573	0.00			0.00	-5806.573
2	4771.920		4771.920	4185.62			4185.62	-586.300
3	7831.693		7831.693	4285.62			4285.62	-3546.073
4		180.260	180.260		251.14	2831.82	3082.96	2902.700
5		180.260	180.260		251.14	2831.82	3082.96	2902.700
6		180.260	180.260		251.14	2831.82	3082.96	2902.700
7		180.260	180.260		251.14	2831.82	3082.96	2902.700
8		180.260	180.260		251.14	2831.82	3082.96	2902.700
9		180.260	180.260		251.14	2831.82	3082.96	2902.700
10		180.260	180.260		251.14	2831.82	3082.96	2902.700
11		180.260	180.260		251.14	2831.82	3082.96	2902.700
12		180.260	180.260		251.14	2831.82	3082.96	2902.700
13		180.260	180.260		251.14	2831.82	3082.96	2902.700
14		180.260	180.260		251.14	2831.82	3082.96	2902.700
15		180.260	180.260		251.14	2831.82	3082.96	2902.700
16		180.260	180.260		251.14	2831.82	3082.96	2902.700
17		180.260	180.260		251.14	2831.82	3082.96	2902.700
18		180.260	180.260		251.14	2831.82	3082.96	2902.700
19		180.260	180.260		251.14	2831.82	3082.96	2902.700
20		180.260	180.260		251.14	2831.82	3082.96	2902.700
21		180.260	180.260		251.14	2831.82	3082.96	2902.700
22		180.260	180.260		251.14	2831.82	3082.96	2902.700
23		180.260	180.260		251.14	2831.82	3082.96	2902.700
24		180.260	180.260		251.14	2831.82	3082.96	2902.700
25		180.260	180.260		251.14	2831.82	3082.96	2902.700
26		180.260	180.260		251.14	2831.82	3082.96	2902.700
27		180.260	180.260		251.14	2831.82	3082.96	2902.700
28		180.260	180.260		251.14	2831.82	3082.96	2902.700
29		180.260	180.260		251.14	2831.82	3082.96	2902.700
30		180.260	180.260		251.14	2831.82	3082.96	2902.700
31		180.260	180.260		251.14	2831.82	3082.96	2902.700
32		180.260	180.260		251.14	2831.82	3082.96	2902.700
33	-1756.484	180.260	-1576.224		251.14	2831.82	3082.96	4659.184
TOTAL	**18410.186**	**5407.808**	**22061.510**	**8471.24**	**7534.11**	**84954.69**	**100960.04**	**78898.530**

PW OF BENEFITS @ 12%; MILL.Rs	**=**	**24063.39**
PW OF COSTS @ 12%; MILL.Rs	**=**	**15554.83**
NET PRESENT WORTH; MILL.Rs	**=**	**8508.56**
BENEFIT COST RATIO	**=**	**1.55**
I.E.R.R	**=**	**22.36%**

17.27 EMPLOYMENT ANALYSIS

The project will help in providing employment to the inhabitants of the local area and play an important role in the country's economy. The project will also help in improving/enhance the socio-economic settings of the area.

17.28 SENSITIVITY ANALYSIS

Although the project has shown financial viability with higher rates of return than the weighted cost of capital even then the project is susceptible to different kind of adverse circumstances like cost over-run, delay in construction and decrease in benefits. The financially viability of the project has, therefore, been assessed against 10% decrease in benefits, 20% cost overrun, as well as combined impact of both the variations to see if the project remains financially viable.

Tables-17-10 to 17-11 give risk/sensitivity analysis on the following assumptions:

I. 10% reduction in sale price.

II. 20% cost over-run.

III. Combined effect of above

Table 17-10 Risk / Sensitivity Analysis With CDM Benefits

MILL.Rs

YEAR	TOTAL COST	BENEFITS	10% LESS RED.IN S.P	NET BENEFITS	20% COST OVER-RUN	NET BENEFITS	COMBINED IMPACT
1	5806.573	0.000	0.000	-5806.573	6967.887	-6967.887	-6967.887
2	4771.920	4185.620	3767.058	-1004.862	5726.304	-1540.684	-1959.246
3	7831.693	4285.620	3857.058	-3974.635	9398.032	-5112.412	-5540.974
4	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
5	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
6	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
7	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
8	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
9	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
10	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
11	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
12	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
13	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
14	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
15	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
16	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
17	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
18	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
19	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
20	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
21	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
22	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
23	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
24	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
25	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
26	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
27	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
28	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
29	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
30	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
31	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
32	180.260	3112.881	2801.593	2621.333	216.312	2896.569	2585.281
33	-1576.224	3112.881	2801.593	4377.817	-1891.468	5004.350	4693.062
TOTAL	**22061.510**	**101857.681**	**91671.913**	**69610.402**	**26473.812**	**75383.868**	**65198.100**

INTERNAL RATE OF RETURN = 22.54% 19.40% 17.40% 15.00%

Table 17-11 Risk / Sensitivity Analysis With CDM Benefits

MILL.Rs

YEAR	TOTAL COST	BENEFITS	10% LESS RED.IN S.P	NET BENEFITS	20% COST OVER-RUN	NET BENEFITS	COMBINED IMPACT
1	5806.573	0.000	0.000	-5806.573	6967.887	-6967.887	-6967.887
2	4771.920	4185.620	3767.058	-1004.862	5726.304	-1540.684	-1959.246
3	7831.693	4285.620	3857.058	-3974.635	9398.032	-5112.412	-5540.974
4	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
5	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
6	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
7	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
8	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
9	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
10	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
11	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
12	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
13	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
14	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
15	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
16	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
17	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
18	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
19	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
20	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
21	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
22	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
23	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
24	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
25	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
26	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
27	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
28	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
29	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
30	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
31	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
32	180.260	3082.960	2774.664	2594.404	216.312	2866.648	2558.352
33	-1576.224	3082.960	2774.664	4350.888	-1891.468	4974.428	4666.132
TOTAL	**22061.510**	**100960.040**	**90864.036**	**68802.526**	**26473.812**	**74486.228**	**64390.224**

INTERNAL RATE OF RETURN = 22.36% 19.24% 17.25% 14.86%

17.29 CONCLUSION

The Project is economically, financially and socially viable in addition to its technology viability hence recommended for implementation.

18 CONCLUSIONS AND RECOMMENDATION

Attabad Lake Hydropower Project (ALHPP) is a Run off River peaking scheme on Hunza River in Hunza Region at Attabad Lake. Attabad Lake is located about 120 km from Gilgit on the Hunza River along Karakorum Highway and 735 km from Federal Capital Islamabad. The Project is planned to develop the reach of river 2.5 km downstream of Attabad Lake with an installed capacity of 54 MW to generate mean annual electricity of 374 GWh.

The Feasibility Study of ALHPP has been carried out with due consideration of intensive field investigations (topographic and hydrographic survey, subsoil investigations and geological mapping), Socio-Economic and Environmental Survey.

With landslide on Hunza River on January 4, 2010, Attabad Lake was created. The natural head available from Lake to 2.5 km downstream and perennial flows of Hunza River attract to develop the indigenous hydroelectric resource. The slided mass have been investigated to propose the overflow weir/sediment flushing channel for flood evacuation, sediment flushing and desing discharge through headrace tunnel.

Detailed topographic survey and geological mapping have been carried for all major structures like overflow weir/ungated spillway, sediment flushing channel, intake, low pressure tunnel, and power house area. For reservoir area, hydrographic survey have been carried out six (6) borehole have been drilled at important sturctures location with total drilling depth of 400m.

For social and environmental aspects, detail survey has been conducted in the field and maps with DEM have been prepared to cover the Project Area details.

Power and energy potential at the site have been estimated on average 10-daily basis using time series data from 1966 to 2015. Keeping in view historic data, optimized design discharge of 60 m^3/s has been selected that could be made available during peak hours throughout the year . The available head across the hydropower facility has been estimated as 106 m with the consideration of upstream and downstream water level variation. The estimated mean annual energy is 374 Gwh and plant factor is 79.0%.

Overflow weir/ ungated spillway, sediment flushing channel/under sluices, intake, low pressure tunnel, surge tank and powerhouse, main dam and dykes / embankments have been designed based on field investigations to accommodate the flood and reservoir variation from 2014 m a.s.l to 2021 m a.s.l.

The cost estimate for the Project has been prepared using bill of quantities (BOQ) and costs for Infrastructure development, Preliminaries and Environmental Mitigation, Civil, Hydro-mechanical, Electrical, etc. Major Civil Works items such as rock excavation quantities, slope stability by benching concrete and grouting works, etc. have been estimated as Rs.21.246 million (US$ 135.32 million).

The Project is found economically and financially feasible. The calculated economic internal rate of return (EIRR) is above 22.36% (the assumed opportunity cost of capital in Pakistan) and the financial internal rate of return (FIRR) comes out to be 19.17%.

ALHPP is found to be technically feasible, economically viable and environmentally acceptable and will fulfill electricity needs particularly for Hunza City and in general for Hunza, Gilgit and Ghizar Regions. Therefore recommended for implementation at earliest.