1878 MW Oju Hydro-Electric Project, Arunachal Pradesh

Feasibility Study Report

Volume I - Main Report

Oju Subansiri Hydro Power Corporation Pvt. Ltd., New Delhi
New Delhi | India

RESTRICTED

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REPORT
Rev. A

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FEASIBILITY STUDY REPORT

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Subject : **Feasibility Study Report**

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EXECUTIVE SUMMARY

1. INTRODUCTION

Oju Hydroelectric Project is located in upper reaches of Subansiri River (called Si Nigit in upper reaches) in Upper Subansiri district of Arunachal Pradesh and envisages utilization of water of Subansiri River for hydropower generation. The project was identified as an attractive hydropower schemes by the Central Electricity Authority (CEA). Pre-Feasibility Report of the project was prepared by NHPC in 2004 and has subsequently been accepted / approved by CEA. Development rights of the projects have since been accorded to Navayuga Engineering Company Limited (NECL).

NECL has appointed Tractebel Engineering Pvt. Ltd. (TEPL) as its consultant for the preparation of the DPR. At this stage of the project, Feasibility Study Report has been prepared to facilitate NECL to submit the same to the Govt. of Arunachal Pradesh and Central Government Authorities to obtain necessary statutory clearances.

Salient aspects of the project are briefly described in the following sections.

2. LOCATION AND ACCESS TO THE PROJECT SITE

The above project site (Dam site) is located about 220km from Daporijo, district head quarter of Upper Subansiri district in Arunachal Pradesh. The project area including dam and powerhouse site can be accessed by a newly constructed BRO road from Limeking. The dam site is located at about 60km upstream of Limeking and powerhouse site is located at about 40km upstream of Limeking on the right bank of Subansiri river. Single lane metalled road connects Limeking with Daporijo which is about 150km.

Daporijo can be accessed from North Lakhimpur using either Pahumara-Kimin-Ziro-Daporijo road (300km) or Silapathar-Likabali-Basar-Daporizo Road (275km). Silapathar is accessible from North Lakhimpur and Dibrugarh in Assam. Please refer Figure-1 for location of project site and Figure-2 for the tentative road network to project site.

Figure 0-1: Project Location – Arunachal Pradesh

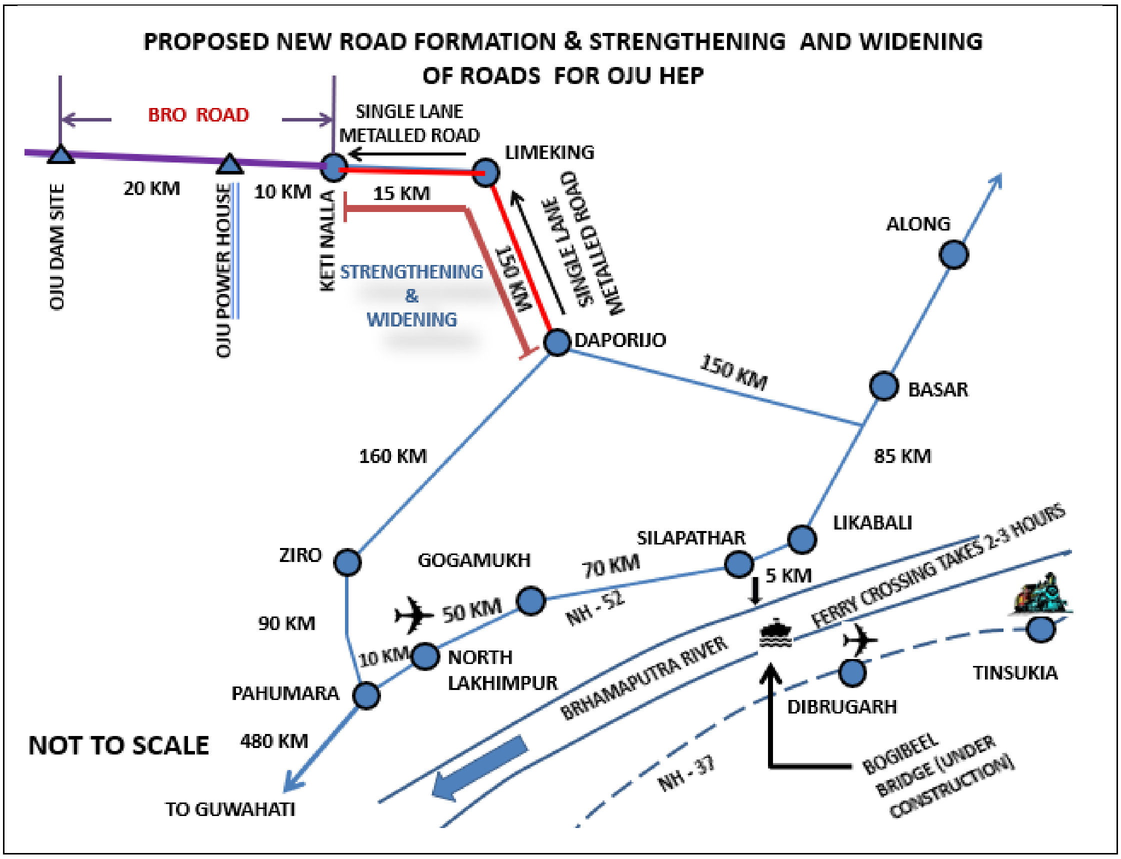

Figure 0-2: Tentative Road Network to Project Site

3. PROJECT AREA

Arunachal Pradesh is the easternmost state of India. Arunachal Pradesh shares its border with the states of Assam to the south and Nagaland to the southeast. Burma/Myanmar lies towards the east, Bhutan towards the west, and Tibet to the north.

The weather and the climate of Arunachal Pradesh are quite unique from the rest of India. The climate of Arunachal is governed by the Himalayan system and the altitudinal differences. The climate here is highly hot and humid at the lower altitudes and in the valleys wrapped by marshy thick forest particularly in the eastern region, while it becomes too cold in the higher altitudes.

The project is in Upper Subansiri district; this district was formed when Subansiri district was bifurcated into Upper and Lower Subansiri in 1987. The district headquarters are located at Daporijo. Upper Subansiri district occupies an area of 7032 sq.km. The important towns are Daporijo, Dumporijo, Taliha, Nacho, Siyum, and Maro.

3.1 Inter State / International Aspects

The project headwater and tailwater areas both lie well within the state of Arunachal Pradesh. Subansiri is a tributary of river Brahmaputra and there are larger projects like Lower Subansiri and Upper Subansiri, downstream on the same river, as such the Oju project does not entail any inter-state aspects. Part of the catchment area of the project lies in Tibet (China).

3.2 Defence Related Aspects

There are no defence-related establishments in the project's submergence or general development area. Military presence is all upstream, closer to the border with China.

4. NEED FOR THE PROJECT

Hydro power potential of the country has been estimated by CEA to be about 150,000 MW out of which 50,328 MW is assessed to exist in Arunachal Pradesh. Most of this potential remains unharnessed. Presently, the total installed hydropower capacity in the country is 46722 MW, of which only 544.55 MW is contributed by Arunachal Pradesh (as on April, 2022; source CEA web site).

As per India's National Determined Contribution (NDC) for Climate change submitted to the United Nations Framework Convention for Climate change, India has committed to increase its generation capacity from non-fossil resources to 40% of the total generation capacity and reduce the carbon intensity of its GDP by 30-35% by the year 2030 as compared to that in 2005. The commitment regarding non-fossil fuel capacity is proposed to be met mainly from installation of Solar and Wind power capacities, which are infirm sources of power i.e. the generation from these sources varies significantly with the change in the weather conditions. The targets are to add 160 GW of solar and wind power by 2022 and 440 GW by the year 2030. Integrating such large scale intermittent solar and wind power would cause problem in maintaining grid stability because generation from the other major source of power i.e. thermal power plants can be varied within a limited range only. Thus hydropower, which has unique features like quick ramping, black start capability etc. can play a very useful role in contemplating renewable source of power in stabilizing / balancing the grid. While there is increasing need for hydropower, the share of hydropower generation capacity in total electricity generation capacity has been steadily declining from a high of 50.32% in 1962-63 to about 11.6% in 20-22.

Comparing the projected growth of peak power demand, energy requirement anticipated and increase in the generating capacity on the basis of new projects proposed and/or under construction/consideration, it is evident that there is a dire need to provide additional power to the National Grid to meet the objective of power on demand by 2030. New schemes have to be taken up immediately and implemented to derive timely benefits. The most important source of power development in the Northern Eastern region is hydroelectric power located in Arunachal Pradesh and other sister states.

Implementation of the Oju hydroelectric project with a capacity of 1878 MW would contribute substantially to meeting the power demand in the country. The project was acknowledged as one of the attractive projects in the ranking studies carried out by CEA and techno-economic viability of the project has been further established in the present Feasibility Study Report.

5. SURVEY AND INVESTIGATIONS

Topographical survey and all required field investigations have been planned and shall be executed as per the work plan.

The scope of work for the topographic survey at this stage includes the following areas:

- Transfer of project benchmark
- Establishment of control points
- Topographic survey of dam and reservoir areas
- Cross-sections and longitudinal section of the river
- Topographic survey of the entire corridor of the water conductor system
- Topographic survey of the powerhouse complex covering surge shaft, pressure shaft switchyard, tailrace, and access roads etc.
- Borrow areas, construction plant areas, muck disposal sites, colony and office complex, access, and project roads

The sub-surface investigations of the project would mainly include the following:

- Rotary drilling (to retrieve undisturbed samples and rock cores) of size not less than Nx.
    - Vertical, horizontal or angled drill holes are envisaged
- In-situ tests in drill holes:
    - Water pressure / Permeability Test
    - Standard Penetration Test (SPT), if required
    - Uniaxial Jacking Test for Modulus of Deformation of Rock
    - Direct Shear Test for Determination of Rock Parameters
    - Hydro Fracturing Test
    - Any other test required by the Client

- Investigation through exploratory adit (Drift)
- Laboratory test of rock core samples
- Groutability Test

6. PROJECT HYDROLOGY

The total catchment area up to project dam site is about 9827 sq.km; out of which about 3128 sq.km. lies below the permanent snow elevation line of El. 4500m. The project catchment is formed by numerous streams which are perennial in nature. Nye Chu, Laru Chu and Yume Chu are three main streams contributing to the project catchment.

The submergence area at pond level is estimated as 43.2 Ha having a live pondage volume of 2.065 MCM.

6.1 Water Availability

Water Availability Studies are based on the following 10-daily discharge data available at different sites:

Table 0-1:Period of data availability at different sites

S.No.	Name of Site	Total Catchment Area (sq.km.)	Period of Data Availability
1	Chouldhawoghat	27269	1973-2002
2	Gerukamukh	26387	1973-2009 (With gaps)
3	Menga (Diversion site)	14665	2002-2008

The computed monthly inflow series and 10-daily inflow series are developed based on 10-daily discharge data available at the above G&D sites. The computed inflow series has been utilized for assessing water availability and for carrying out power potential studies.

CWC vide letter No.2/ARP/55/CEA/2012-PAC/4982-84 has examined the flow series and reduced the flow series by an additional correction factor of specific yield apart from catchment area correction factor. The series at Oju has also been made consistent with the Subansiri Upper and Nalo HEP by CWC. The final approved flow series for the Oju project has been used for further studies.

6.2 Design Floods

Design flood computations are done using the hydro meteorological as well as statistical approach. Guidelines of relevant Indian Standards are used. Design flood for sizing the spillway is established as the Probable Maximum Flood (PMF). The project PMF is estimated to be 6031 cumec.

Considering the period of construction and type of diversion structure, observed flood peak of 3603 cumec, which is approved by CWC, has been proposed as the temporary river diversion flood. Relevant guidelines of Indian Standards are used in establishing this value.

7. POWER POTENTIAL & INSTALLED CAPACITY

The 90% and 50% dependable years are determined from the derived flow series. Annual energies are calculated for different installed capacities, and the optimum installed capacity is determined as 1850 MW. Keeping in view the maximum net head which is 620.83m, Pelton turbine has been proposed for Oju hydroelectric project. Eight generating units of 231.25 MW each are proposed. The installed capacity of 1850 MW is as finalized by Central Electricity Authority (CEA).

The annual and lean season energy availability from the project in 90% dependable flows is given below:

7.1 Annual Energy Generation

Design Energy for 90% Dependable Flows with 95% machine availability	7856 MU
Annual Load Factor	49.87%
Lean Season Load Factor	12.89%

It is proposed to utilize the riparian flow for power generation by constructing a mini dam toe powerhouse of appropriate capacity just downstream of the dam with a by-pass arrangement to ensure release of riparian discharge in case of shutdown of generating unit(s). An installed capacity of 28MW has also been finalized by CEA.

8. GEOLOGY

Proposed Oju hydroelectric Project on the river Subansiri is located in Higher Himalaya in Upper Subansiri district of Arunachal Pradesh. The project area located in Higher Himalaya is characterized by highly rugged topography with precipitous hill slopes and deeply incised narrow valleys with steep abutment slopes. In general, altitude in the area varies between 800m near Taliha in the south and 2550m at Maza in the north. However, topography around Taksing is relatively less rugged. The river Subansiri, trunk river in the area flows through a narrow V-shaped valley in general. However, same is comparatively wider near Taksing where it is characterized by unpaired aggradational fluvial terraces.

The area around the proposed Oju hydroelectric projects exposes the metasedimantaries belonging to Gelensiniak formation of Subansiri or Sela Group. These are intruded by Maja Granite which is light grey in colour, fine grained and profusely jointed. It is characterized by roundish concentrations of tourmaline and associated biotite gneiss into which it has intruded. It is exposed on the left bank of the river near Redi. Rocks predominantly exposed in the area include biotite gneiss, garnetiferous biotite gneiss belonging to Gelensiniak Formation of Subansiri or Sela Group of Higher Himalaya. Biotite gneiss exposed in the area is light grey in colour, medium to fine grained and well foliated. Biotite gneiss imperceptibly grades into garnetiferous biotite gneiss, garnets measure up to a few milimetres and are randomly distributed in the gneiss. These are wrapped by foliation planes which in turn are defined by preferred orientation of biotite and felsic minerals

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Various litho-units exposed in the area exhibit polyphase deformation and structural elements produced due to several phases of deformation are folds, lineations and puckers and joints etc.

It is also observed that the bedrock exposed in the upstream reaches around the site for diversion dam for Oju is more intensely jointed particularly on the left bank where Maja granite is exposed at higher elevations. The site appears to be suitable for about 110m high concrete gravity dam. However, surface and subsurface explorations comprising detailed surface geological mapping, exploratory drilling and exploratory drifting would be required to be conducted at the site to determine the size and type of structure at the site.

The underground powerhouse is located on the right bank of Subansiri just upstream of confluence of Kuo/Keru Siko with the river. The right bank valley slopes at the site are moderately steep to steep and support moderately dense vegetation. The rocks exposed in the area comprise silimanite-kyanite-garnet gneiss with migmatite belonging to Sela Group. The bedrock is foliated and moderately jointed. Foliation in general strikes in NE-SW direction and dips at moderate angles towards NW. Prima-facie the site appears to be suitable for locating underground powerhouse and other appurtenant.

9. CIVIL ENGINEERING STRUCTURES

The project envisages construction of a concrete gravity dam including a dam toe powerhouse for generation of 28MW power utilizing environmental flow. The maximum height of the dam is about 123m above the deepest foundation level. The diverted water shall be carried through a water conductor system planned on the right bank of Subansiri River to an underground powerhouse. The water conductor system comprises a power intake, a 14171m long headrace tunnel, an open to sky surge shaft, two pressure shafts bifurcating into four intermediate pressure shafts which further bifurcated into two branches each, and a tailrace system to bring the water back into the Subansiri River. The underground powerhouse, housing eight units of 231.25 MW each, is proposed on the right bank of the river Subansiri.

9.1 Project Design Data

The following data is pertinent for layout and design of project components:

Full Reservoir Level	El. 1950m	Allotted Level

Maximum Tailwater Level	El. 1300m	Allotted Level
PMF	6031 cumec	
GLOF	2512 cumec	
Design flood for river diversion	3603 cumec	1 in 25 yrs flood for monsoon period

9.2 Layout and Civil Design Aspects

A brief description of project components is given in the following paragraphs:

9.2.1 River Diversion

The temporary diversion works have been designed for a design flood of 3603 cumec, corresponding to 1 in 25-year monsoon period flood.

Given the relatively large diversion discharge, two 12.7m diameter circular shaped diversion tunnels are proposed on the right bank. The riverbed level near the entrance of the diversion tunnels is 1870m. The approximate lengths of the two tunnels varies from about 1048m to 882m, respectively.

The proposed upstream cofferdam is a colcrete structure of 27m height. The downstream cofferdam is 11m high and is proposed of random fill material.

9.2.2 Headworks - Dam, Spillway, and Intake

Since the head-works area of the project is characterized by abundant rock exposures, a concrete gravity dam has been proposed.

The dam comprises a spillway section in the middle which is flanked by non-overflow sections on both banks. The spillway is so designed that the water way is largely confined to the natural river width.

The spillway is designed to pass the PMF of 6031 cumec along with GLOF of 2512 cumec. Four spillway bays are provided with crest level at El. 900m. Each bay is 8m (W) x 10.8m (H) and adjacent bays are separated by twin piers, each 4.5m thick at dam axis.

Energy dissipation is through flip/trajectory bucket. A pre-formed plunge pool is provided based on scour depth considerations.

In addition to the low-level sluice spillway, one chute type overflow spillways (6m wide) has also been provided adjacent to the left edge of the sluice spillway.

The proposed dam section has been checked to satisfy all stability criteria under different load combinations.

Adequate number of drainage and inspection galleries has been provided within the dam body. The dam foundation treatment comprises consolidation grouting of the entire base. A grout curtain is proposed to minimize seepage under the dam. It is proposed that one overflow block and one non-overflow block be provided with standard set of instruments for monitoring the performance of the dam during construction and operation.

The power intakes have been designed for a total discharge of 334 cumec. One set of two power intakes are proposed in the right bank of the river. Each intake is 6.8m wide and is provided with a trash rack. The crest level of trash rack is kept at El. 1929m.

In order to draw only the top, relatively sediment free layer of water into the water conductor system, the intake sill has been kept sufficiently high (almost 29m above the spillway crest). In this regard, it may also be noted that no de-sanding chambers are proposed in the project in view of a high dam with reservoir extending to almost 3.13km.

9.2.3 Water Conductor System

The water conductor system comprises a power intake, a 14171m long headrace tunnel (HRT), an open to sky surge shaft, two pressure shafts bifurcating into four intermediate pressure shafts which further bifurcated into two branches each, and a tailrace system to bring the water back into the Subansiri River.

A 10.4m finished diameter (circular shaped) HRT, with the objective of conveying 334 cumec of design discharge from diversion site to powerhouse is proposed on the right bank of river Subansiri.

Keeping in view the construction schedule of the project, five modified D-shaped construction adits of size 6.0m (W) x 7.0m (H) have been proposed along the length of the tunnel.

A 20m diameter orifice type surge tank of height 118.29m is proposed to accommodate surge levels. Resulting from the topography of the area, the tank will be open to sky.

An orifice slab has been provided to separate surge tank and HRT. The slab is 2m (average) thick and has a 4.2m diameter circular orifice concentric with the surge tank.

Water from the downstream of surge shaft wall is brought to the generating machines through two pressure shafts of 5.7m diameter, four intermediate pressure shafts each 4m diameter and after that through eight penstocks, each 2.85m diameter. Penstocks erection chambers are provided to facilitate erection at the top, intermediate and bottom most levels.

To bring back the water into the river from downstream wall of powerhouse cavern, a tailwater conductor system has been proposed. And it comprises of the following sub-components:

- Eight numbers unit TRT's of size 5.0m (W) x 7.25m (H) modified D-shaped
- Two numbers intermediate TRT's of size 7.5m (W) x 7.25m (H) modified D-shaped
- Two numbers main TRT's of size 9.5m (W) x 8.0m (H) modified D-shaped

Water, from powerhouse cavern, move to unit TRT's and then to intermediate TRT's and finally meet into the river through main TRT's.

9.2.4 Powerhouse Complex

One underground powerhouse, on right bank of the river, has been planned to accommodate eight units of 231.25 MW (Pelton) each. The powerhouse building is 251.5m (L) x 22.0m (W) x 46.5m (H). Units are spaced at 22.5m c/c. A 40m long Erection Bay is located at the right end and a 25m wide Control Block is located at the left end of the machine hall cavern. The centerline of distributor is set at El. 1307.5m.

The structural framework inside the machine hall and the control block is proposed as reinforced concrete frame.

The transformer hall cavern, of size 269.85m (L) x 16.5m (W) x 25.5(H), is located 45m downstream of the machine hall. It accommodates 26 single phase GSU (Generator Step-up) transformers (24 main+2 spares). Rails will be embedded in the floor of the transformer areas and in the passage joining the Erection Bay and the transformer area to allow handling of the transformers by the powerhouse EOT crane.

One common Gas Insulated Switchgear is also proposed to be installed inside the transformer hall. A 3m x 3m D-shaped cable duct connects this floor to the powerhouse.

A 158m x 50m surface pothead yard is proposed on right bank of the river at suitable level. It accommodates an open switchyard, a DG set, station service transformers and other electrical equipment.

The cables from the GIS of the transformer cavern to pothead Yard will be taken from a cable tunnel.

One 28MW surface powerhouse housing 2 units of vertical axis Francis turbine is also considered at the toe of the dam on right bank. The powerhouse building is 42m (L) x 18.0m (W) x 32.33m (H). Units are spaced at 14.0m c/c.

10. HYDROMECHANICAL EQUIPMENT

Hydro-mechanical equipment at the project comprises the spillway radial gates, auxiliary spillway gate, stoplogs, gates for the diversion tunnels, the intake, HRT adits, and TRT outlets. Trash racks and trash rack cleaning machine comprise the other hydro-mechanical equipment.

Four (4) nos. of spillway radial gates of size 8000 mm wide x 10800 mm high are provided to control the discharge through the spillway. Each gate will be operated by means of twin hydraulic hoist. The sill of the gate will be located at El. 1900m. The radial gate shall be designed for the head corresponding to FRL i.e. El. 1950m and would operate under any water head between the sill level and the FRL.

One (1) set of sliding type stoplogs is proposed to cater to the maintenance requirement of five spillway radial gates. Stop-logs units will have downstream skin plate and downstream sealing. The stoplogs will be required to be raised and lowered under balanced head condition. The balanced head condition will be achieved with the provision of bye-pass piping & manually operated valve arrangement.

One (1) no. vertical lift fixed wheel type Auxiliary Spillway gate and one (1) no. vertical lift fixed wheel type bulkhead gate are proposed to be provided in the auxiliary spillway section. Auxiliary Spillway gate shall be used to pass trash and floating material from the reservoir and bulkhead gate shall be used to cater to the maintenance requirement of Auxiliary Spillway gate.

Four (4) nos. vertical lift fixed wheel type gates for opening size of 5100mm x 12700mm are provided to close the diversion tunnel after construction of the dam. The sill of the gates will be located at El. 1870.00m. The gate will have downstream skin plate and downstream sealing. The lowering of all gates shall be done in lean season. All gates shall be lowered by individual fixed rope drum hoist of adequate capacity mounted on steel trestle.

The trash racks are proposed to be provided on the upstream face of the intake to prevent entry of extraneous material into the water conductor system. Trash collected on the trash rack panels during operation shall be removed by a trash rack cleaning machine.

Two (2) nos. vertical lift slide type bulkhead gates and two (2) nos. vertical lift fixed wheel type gates are provided in the intake. The sill of the gates is located at El. 1929m.

One (1) set of vertical lift slide type stop logs are proposed in unit TRT's to cater for maintenance requirement of eight (8) nos. of generating units. The gate will be required to be raised and lowered under balanced head condition.

Three (3) nos. hinged type gates for opening size 2200 mm wide x 2200 mm high have been proposed to be provided in the concrete plug at construction adit nos. 1, 3 & 5 to give access for vehicle to the headrace tunnel in the event of any inspection, repair and maintenance in future.

11. POWER PLANT EQUIPMENT

Principal electromechanical equipments of the project are located in the underground powerhouse and transformer cavern. As mentioned earlier, project's installed capacity has been fixed at 1850 MW and correspondingly, eight generating units of 231.25 MW, each, are proposed in the powerhouse.

Pelton turbines are provided in a vertical axis configuration. The turbines are directly coupled to synchronous generators which are connected to single phase step-up transformers through isolated phase bus ducts. These transformers shall be located in a separate transformer cavern adjacent to the main powerhouse cavity. Further evacuation of power shall be made through Gas Insulated Switchgear (GIS) located in GIS gallery on top of the transformer cavern. Outgoing bays of GIS will be connected to outdoor pothead yard equipment through XLPE cables laid on racks mounted on the side wall of the cable tunnel.

- Energy generated from the project will be evacuated through 400 kV double circuit line to the nearest pooling station.

- Principal electromechanical equipment of the project include

- Pelton turbines along with their governors and oil pressure system

- Synchronous generators along with their excitation system and isolated phase bus ducts

- Step-up transformers

- GIS equipment

- XLPE cables

- Outdoor pothead yard equipment

Mechanical auxiliaries, such as Cooling water system; Drainage and dewatering system; Low pressure Compressed air system; Oil handling system; Heating, Ventilation and Air Conditioning system; Fire fighting system; Electric overhead traveling cranes; Elevators; DG Sets; Mechanical workshops;

Electrical auxiliaries such as Station Auxiliary AC Supply system; Station DC Supply system; Digital distributed control system and SCADA; Protection system; Cabling system; Communication system; Illumination system; Grounding system; Electrical workshop.

The Pelton turbines are designed corresponding to generator output of 231.25 MW at rated net head of 620.8m and rated speed of 300 rpm. Each turbine shall comprise of runner, shaft, distributor, turbine housing, nozzle & deflector assemblies, nozzle servomotors, deflector servomotors, guide bearing etc.

Each turbine will be equipped with electro hydraulic governor of digital type and compatible with station SCADA system. The governor shall be provided with necessary controls to enable accurate speed / power regulation. The governor shall be suitable for peaking as well as base load operation.

The generators shall be vertical shaft, salient pole and semi umbrella type. The generator shall be directly coupled to the turbine shaft and rated for 256.95 MVA with 0.9 PF lag, 300 rpm, 50 Hz with an output voltage of 15.75 kV. The static excitation system shall match the field requirements of the 282.64 MVA hydro generators with 10% continuous overload capability. The connection between generator terminals and the generator step-up transformer will be achieved through Isolated Phase Bus duct with taps for connecting excitation transformer, unit auxiliary transformer and LAVT.

26 (24 in service and two as spares) indoor type, single phase transformers with rated capacity of 94.22 MVA, 15.75 kV, 400/ √3 kV, 50 Hz are provided. The gas-insulated switchgear (GIS) will be installed on the floor above the transformers hall.

Two 250/32/10 MT EOT cranes are provided in powerhouse. The two cranes would be used in tandem for lifting the generator rotor, stator, and other heavy components. One 10 MT pendant operated EOT crane is provided for handling the GIS equipment.

Power Evacuation

The entire power is proposed to be evacuated through two double circuit lines to the nearest pooling station.

12. INFRASTRUCTURE WORKS

Elaborate infrastructure works are required for constructing a project of the size of Oju Hydroelectric Project. Large components size requires extensive quantities of construction material as well as large areas for dumping of the generated muck. Sizeable dimensions of equipment, such as transformers and penstock liners, necessitate wide carriageways, which are usually difficult to lay in a hilly terrain like Oju project area. Taking the above factors into consideration a comprehensive infrastructure will be required to be developed.

12.1 Project Roads and Bridges

To execute the various civil works, roads would be made for linking the work site to other sites and to job facility areas. They would be constructed at a workable gradient so that loaded construction equipment does not have to toil hard to go up slope. An average gradient of 1:15 has been contemplated. These roads would be connected to the existing roads in the area or to other project roads.

12.2 Requirement of Land

Land would be required for locating permanent works as well as for setting up the infrastructural facilities necessary for constructing the project.

It is estimated that about 760 Ha of land would be required for development of the Project. Of this, part would be acquired permanently while the balance can be obtained on lease from the owners for a definite time period and returned to them after the project is completed. In the latter case, it would be restored to its original condition as far as possible.

12.3 Construction Power

Power required during construction of the project will have to be supplied using diesel generating sets as reliable grid power of adequate capacity is not available in the project area. The tentative power requirement for construction activities is estimated to about 25 MVA taking into consideration capacity of electric driven equipments which are to work during the construction period in addition to the lighting load.

13. CONSTRUCTION PLANNING

The construction methodology shall be developed for each structure and accordingly overall planning for construction of the project shall be developed. Appropriate type and size of equipment to be used shall be considered while preparing the construction methodology. The number of machines required for construction of the project and total requirement for each type and size of the major equipment has been worked out. Although a project of such a magnitude does require several different types of equipment to cater to the progress rates as required by the construction schedule, the proposed methodology has been developed keeping in view the objective that variety of equipment is minimized.

The Project lies in heavy rainfall belt of the State. The working season is therefore taken as 8 months in a year for all project works in the open. For underground project works, 50% of the normal progress has been taken during the monsoon months. Planning for all works has been done considering three shifts-working.

The project has been planned to be commissioned in a period of 72 months from the start of construction of river diversion works. A period of about 24 months has been provided for completion of all pre-construction activities such as development of infrastructure facilities, obtaining requisite clearances, financial approvals, land acquisition, tendering and award of work, design, and engineering.

14. COST ESTIMATION - HARD COST AND COMPLETION COST

The estimate of cost has been prepared based on the preliminary design and layout to arrive at the total capital cost of the project. The unit rates for different items have been taken as per the present-day rates for these items of works for ongoing projects of almost of the same magnitude in the North-Eastern region. Interest charges during construction period have been worked out separately.

In addition to the component costs, provision for sub-head wise expenditure has also been made. The cost provision for these items (mentioned below) has been made on lump sum basis of C-works / J-Power Plant / I-Works, generally as per the latest guidelines for formulation of DPRs for hydroelectric projects issued by CWC/CEA.

Item	Provision as % of Civil Works
A-Preliminary	2% (I-Works)
B-Land	2% (I-Works)
K-Buildings	4% (I-Works)
O-Miscellaneous	3% (I-Works)
P- Maintenance	1% (C+J+K)
R- Communication	4% (I-Works) + Cost of Approach Road to Project
X-Environment & Ecology	5% (I-Works)
Y-Losses on Stock	0.25% (C+J+K)
Establishment	As per CEA guideline norms

Q-Special T & P and T&P	1% (I-WORKS) Max. 200 lacs each
Receipts & Recoveries	(-) 15% (Q+K)
Capitalized Value of abatement of Land Revenue	5% (B-Land)
Audit & Accounts Charges & H.O. Establishment	0.25% (I-Works) as per CEA guidelines

The present-day tentative cost estimation of Oju Hydro Project has accordingly been worked out and is summarised in the table given below. However, detailed rate analysis will be carried out at the DPR preparation stage.

Table 0-2: Present Day Tentative Cost

Particulars	Present day Estimated Cost (₹ in Core)
Diversion Tunnels and Cofferdams	391.15
Dam including Spillway and associated works	1690.53
HRT, TRT and associated structures	1920.90
Powerhouse, Penstock, Pot Head Yard and associated structures	1062.55
Other Direct charges like Roads, land, buildings etc. and indirect charges	1586.85
Total Civil Works	6651.98
E&M works	2817.80
TOTAL Hard Cost	**9468.00**

15. FINANCIAL EVALUATION

15.1 Power Benefits

Oju Hydroelectric Project would yield Design Energy generation i.e., energy generation in 90% dependable year with 95% machine availability of 7856 MU from 1850MW power plant and 159MU from 28MW dam toe powerhouse. It has been presumed that the energy from the project could be fully absorbed in the Northern and Western regions which are facing huge power shortages, with proper co-ordination and scheduling of coal/gas/diesel-based power stations.

15.2 Project Cost

The completed cost of the project works out to be ₹ 17113.04 Crores as given in **Table-0-3**.

Table-0-3: Summary of Cost

	Items	(₹ Crores)
A.	**Hard cost of the Project**	
	Civil Works including HM works	6651.98
	E&M Works	2817.80
	Sub Total	**9468.0**
B.	**Escalation**	
	Civil Works including HM works	2775.78
	E&M Works	1214.83
	Sub Total	**3990.61**
C.	**IDC and Financing Costs**	**3653.45**
	Total Project Cost (A+B)	**13459.59**
	Total Project Completion Cost (A+B+C)	**17113.04**

15.2.1 Financing

The project will be financed at a Debt: Equity ratio of 70:30. The interest rate for debt is considered to be 12% p.a. The interest rate on working capital has been considered as 13.5%.

15.2.2 Phasing of Expenditure

Oju Hydropower Project is envisaged to be completed in 6 years, after 1 year of preconstruction activities. Another period of about 1 year is likely to be taken for jobs connected with the preparation of DPR and its TEC from CEA/CWC. In other words, full project benefits are considered to be available 8 years from now.

15.2.3 Escalation

Escalation of 6.0 % p.a. in Civil Works and 5% p.a. for Electromechanical Works over the estimated cost has been considered for working out the completed cost of the project.

15.3 Tariff Calculation

The tariff has been calculated in line with the Central Electricity Regulatory Commission (Terms and Conditions of Tariff) Regulations for period 2019-24 and is given in below Table. The salient points are:

1	Construction Period	=	6 years after 1 year pre-construction and another 1 year for TEC approval
2	Plant useful life	=	35 years

3	Debt-Equity Ratio	=	70:30
4	Interest Rate on Term Loan during construction	=	12.00%
5	Interest Rate on working capital	=	12.00%
6	Return on Equity	=	16.5%
7	O & M charges	=	2% of total cost
8	O & M escalation rate	=	5.72% p.a.
9	Escalation during construction for civil works	=	6% p.a.
10	Escalation during construction for E & M works	=	5% p.a.
11	Auxiliary consumption including Transformation losses	=	1.2% of total energy
12	Free Power to Home state	=	12%+1%
13	Financing Charges	=	1.0% of loan amount
14	Min. Alternate Tax (For 1st 10 Years)	=	20.96%
15	Rate of Income Tax (After 10 Years)	=	33.99%
17	Levellised Tariff / kWh (with free power to the State), ₹/kWh	=	5.65
18	1st Year Tariff (with free power to the State), ₹/kWh	=	5.79
19	Levellised Tariff / kWh (without free power to the State), ₹/kWh	=	4.92

16. CONCLUSION AND RECOMMENDATION

Oju Project involves civil works which are envisaged to be completed in 66 months with another six months provided for testing and commissioning of eight units. The project would yield energy of 8015 MU in 90% dependable year flows and 9871 MU in 50% dependable year flows with 95% machine availability (energy from main plant and dam toe powerhouse).

From the analysis carried out as part of the feasibility studies, it is concluded that Oju Hydroelectric Project is a techno-economically viable project. Being a run-of-river scheme, it also merits consideration for earning the carbon credit.

Salient Features

A. GENERAL	
• Installed Capacity	1878 MW
○ Main powerhouse	1850MW (8 x 231.25MW)
○ Dam toe powerhouse	28MW (2 x 14MW)
• State	Arunachal Pradesh
• District	Upper Subansiri
• River	Subansiri/Si Nigit
• **Allotted Water Levels**	**FRL= 1950.0m, TWL= 1300.0m**
• Location of Dam	Latitude 28º25'51.6"N Longitude 93º21'23.71"E
• Location of Powerhouse	Latitude 28º22'11.73"N Longitude 93º28'9.97"E
B. HYDROLOGY	
• Catchment area	9827 sq.km.
• Submergence Area	43.2 ha
• Design flood (PMF)	6031 cumec
• GLOF	2512 cumec
• Gross Capacity	15.588 MCM
• Live Storage	2.065 MCM
C. EARTHQUAKE PARAMETERS	
○ PGA value for MCE condition	0.47g horizontal 0.31g vertical
○ PGA value for DBE condition	0.27g horizontal 0.18g vertical
○ Design Seismic co-efficient	0.24g horizontal 0.16g vertical
D. CIVIL WORKS	
• **Dam (Concrete Gravity)**	
○ FRL	El 1950.0m
○ MDDL	El 1945.0m

○ Dam Top	El 1953.0m
○ Height of dam above riverbed	93m
○ Length at top	355m
○ Number of Blocks	24
• **Main Spillway**	
○ Crest elevation	El 1900.0m
○ Type	Breast Wall
○ Number and size of spillway opening	4 nos., 8.0m (W) x 10.8m (H)
• **Log Bay Spillway**	
○ Crest elevation	El 1946.0m
○ Number and size of spillway opening	1 no., 6.0m (W) x 7m (H)
• **Diversion Tunnel**	
○ Number, size and shape tunnel	2 nos., 12.7m Φ Circular
○ Length of diversion tunnels	DT-I: 1048m, DT-II: 882m
○ 25 year return period non-monsoon flood for construction season (Oct-May)	1603 cumec
○ 25 year return period monsoon/annual flood	3603 cumec
○ 100 year return period annual flood	4253 cumec
• **Cofferdam**	
○ Height of upstream cofferdam above riverbed	27.5m
○ Type	Concrete/colcrete
○ Height of downstream cofferdam above riverbed	11m
○ Type	Rock fill
• **Intake**	
○ Numbers and size	2 nos., 6.8m (W) x 6.9m (D).
○ Crest Elevation	El 1929.0m

• **Headrace Tunnel (HRT)**		
○	Length	14171m (approx.)
○	Number, size and shape tunnel	1no, 10.4m Φ, Circular
○	Design Discharge	334 cumec
• **Surge Shaft**		
○	Type	Open to Sky (Semi Underground)
○	Number, size and shape tunnel	1, 20m Φ, Circular
○	Height	118.29m
• **Valve House at Top**		
○	Type	Underground, RCC Building
○	Size	10m (W) x 25m (H) x 64m (L)
• **Underground Main Penstocks**		
○	Length (total)	995.085m
○	Number, size and shape tunnel	2nos, 5.7m Φ circular
• **Underground Intermediate Penstocks**		
○	Length (total)	1669.561m
○	Number, size and shape tunnel	4nos, 4m Φ circular
• **Underground Unit Pressure Penstocks**		
○	Length (total)	273.6m
○	Number, size and shape tunnel	8nos, 2.85m Φ circular
• **Penstock Erection Chamber at top (PEC-1)**		
○	Type	Underground
○	Number, size and shape tunnel	1, 9mx9m, Modified D-shape
○	Length	60m
• **Bifurcation Erection Chamber at intermediate level (PEC-2)**		
○	Type	Underground
○	Number, size and shape tunnel	1, 10mx9m, Modified D-shape
○	Length	70m

• **Penstock Erection Chamber at intermediate level (PEC-3)**	
○ Type	Underground
○ Number, size and shape tunnel	1, 8mx8m, Modified D-shape
○ Length	105m
• **Bifurcation Erection Chamber at Bottom (PEC-4)**	
○ Type	Underground
○ Number, size and shape tunnel	1, 8mx8m, Modified D-shape
○ Length	155
• **Main Powerhouse**	
○ Type	Underground
○ Size	22m (W) x 46.5m (H) x 251.5m (L)
○ Installed Capacity & Number of units	1850MW / 8 units (231.25MW each)
○ Type of turbine	Pelton
○ MIV	Inside the Powerhouse
• **Transformer Hall**	
○ Type	Underground
○ Size	16.5m(W) x 25.5m(H) x 269.85m(L)
• **Main TRT**	
○ Number, Size(WxH) and shape	2 nos., 9.5 (m)(W) x 8m(H) Modified D-shape
○ Length	TRT-1=1148.8m, TRT-2=1152.65m
• **Pothead Yard**	
○ Type and size	Outdoor / 50.0m(B) x 158.0m(L)
• **Main Access Tunnel**	
○ Size (WxH) and Shape	8.0mx8.0m Modified D-Shape
○ Length	706.2m
• **Access Tunnel to HRT**	

○ Numbers, Size (WxH) and Shape	5 nos, 6.0mx7.0m, Modified D-Shape
• **Dam Toe Powerhouse**	
○ Type	Surface powerhouse on left bank
○ Size	18.0m (W) x 32.33 (H) x 42.0m (L)
○ Installed Capacity & Number of units	28MW / 2 units (14MW each)
○ Type of turbine	Vertical Axis Francis
○ Penstock	Main, 1 no. - 3.0mϕ
○	Unit, 2 Nos. - 2.15mϕ

1. INTRODUCTION

1.1. General

The project is located in the remote area of Upper Subansiri district in the State of Arunachal Pradesh. It envisages utilization of the flow of Subansiri River (known as Si Nigit River in the upper reaches of the basin) for generation of electrical power.

Development rights for the project have been given to Navayuga Engineering Company Ltd. (NECL), Hyderabad by the Government of Arunachal Pradesh. As per the license, the projects are to be developed to harness power potential of river Subansiri between FRL 1950m and TWL El. 1670m for Oju-I (700 MW) and FRL 1650m and TWL 1300m for Oju-II (1000MW). Total length of the river reach between allotted levels is about 10.6km and 8km, respectively. Subsequently, based on the further techno-economical studies, the project is proposed to be developed as a Single Composite Scheme named Oju Hydroelectric Project within the allotted river reach.

The location of the project is shown in **Figure 1-1**.

Figure 1-1 : Project Location

1.2. Previous Studies

The project was originally conceived by Central Electricity Authority (CEA). Out of twenty-two schemes identified by CEA during Preliminary Ranking Studies in Subansiri basin in Arunachal Pradesh, the eight hydroelectric schemes (Oju-I : 1925 MW, Oju-II : 2580 MW, Niare : 1405 MW, Naba : 1290 MW, Duimukh : 170 MW, Kurung-I : 200 MW, Kurung-II : 115 MW and Hegio : 250 MW) with an aggregate probable installed capacity of 7935 MW were included in the preparation of PFRs and were allotted to National Hydroelectric Power Corporation (NHPC).

During PFR studies, NHPC suggested that it would be beneficial to combine Kurung-I & Kurung-II as single project and the same was agreed to, by CEA. Accordingly, one PFR combining Kurung–I & Kurung–II was prepared. Further studies indicated that the Hegio project would fall under the submergence of Subansiri Middle Project which is under DPR stage investigation. Thus, out of the eight projects, PFR for six projects could be prepared. Subsequently, NHPC identified two new projects namely Nalo & Dengser in Subansiri basin as replacement schemes against combination of Kurung-I & II projects and Hegio project. Finally, PFR for eight schemes (Oju-I : 700 MW, Oju-II : 1000 MW, Niare : 800 MW, Naba : 1000 MW, Nalo : 360 MW, Dengser : 552 MW, Duimukh : 150MW and Kurung –I&II : 330 MW) were prepared in Subansiri basin with aggregate installed capacity of 4892MW.

In the following paragraphs, evolution of conceptual layout of Oju HEP has been described.

1.2.1. CEA Proposal

1.2.1.1. OJU-I HEP

CEA assessed Oju-I HEP with 1925MW installed capacity, harnessing a head of about 275m for power generation. The Oju-I HEP entailed a diversion structure at riverbed elevation of +1875m, a 8km long headrace tunnel and a powerhouse with tailrace level at El. +1600m. The annual energy generation from Oju-I in 90% and 50% dependable year was estimated to be 8150 MU and 9790 MU, respectively.

1.2.1.2. OJU-II HEP

In case of Oju-II HEP, CEA assessed the project with installed capacity of 1925MW harnessing a head of about 275m for power generation. The Oju-II HEP entailed a diversion structure at riverbed elevation of +1615m, a 6.5km long headrace tunnel and a powerhouse with tailrace level at El. +1250m. The annual energy generation from Oju-II in 90% and 50% dependable year was estimated to be 10,930 MU and 13,120 MU, respectively.

The **Figure 1-2** below shows the general layout of Oju-I and Oju-II HEPs as conceived by CEA.

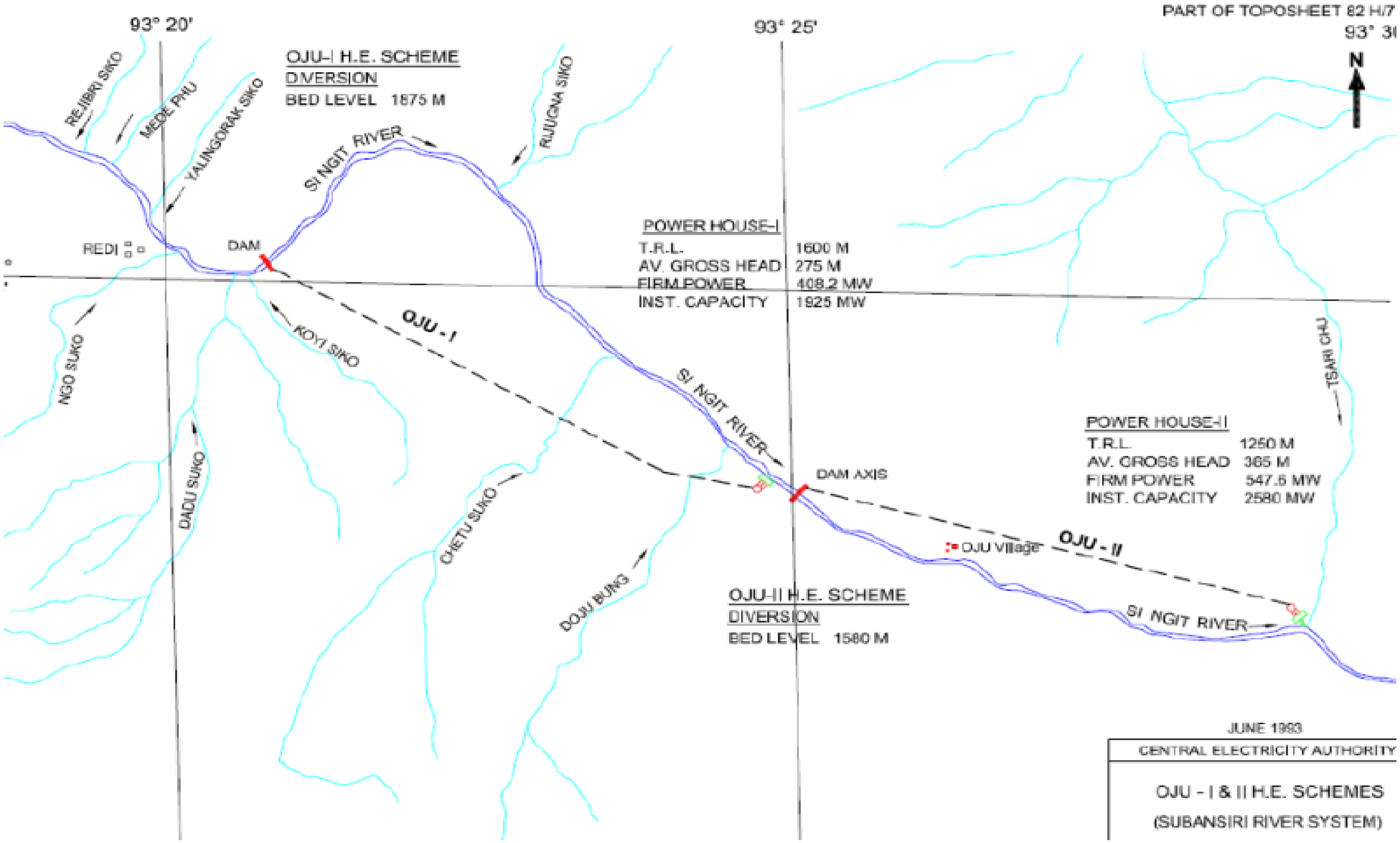


Figure 1-2 : General Layout of Oju-I and Oju-II HEPs

1.2.2. NHPC Proposal

1.2.2.1. OJU-I HEP

NHPC in the Pre-Feasibility Study of Oju-I HEP reviewed the parameters of the project. The project diversion site was shifted downstream at a location 0.9km downstream of Koyi Siko nallah at riverbed level +1860m and the tailrace outfall of the powerhouse was proposed at riverbed level +1660m. The FRL was proposed at El 1950m. The length of the water conductor system was reduced to 5.25km and the installed capacity to 700MW.

Various components of the proposed project are as under:

1. 2 numbers of 9.5m diameter horseshoe shaped diversion tunnels each 700m and 800m long with upstream and downstream cofferdams.
2. 110m high concrete gravity dam from deepest foundation level with FRL as EL 1950 m.
3. Water conductor system consisting of:
   - 2 nos intake structure
   - 4 nos. 300m (L) x 15m (W) x21m (H) desilting chamber
   - 9.6m diameter horseshoe shaped headrace tunnel 5.25km long.
   - 20m diameter surge shaft having 95m height.
   - One number 7.75m diameter, 232m vertical height steel lined pressure shaft further dividing into 4 nos. penstocks of 3.8m diameter to feed four units.
   - 9.6m diameter horseshoe shaped 200m long tailrace tunnel meeting the river at a location where riverbed elevation is at 1660m.
4. An underground powerhouse consisting of
   - 122m (L) x 22m (W) x 48m (H) powerhouse cavern
   - 96m (L) x 20m (W) x 25m (H) transformer-cum-draft tube gate cavern
   - 96m (L) x 12m (W) x 16m (H) MIV cavern
5. Pot head yard 50m x80m.

1.2.2.2. OJU-II HEP

NHPC proposed Oju-II hydroelectric project with diversion structure at a location 1.5km downstream of Jakina Siko nallah with FRL at EL 1650m and tailwater level as +1300m.

As per the proposed layout various components of the project are as under:

1. 2 numbers of 10m diameter horseshoe shaped diversion tunnels each 800m and 925m long with upstream and downstream cofferdams.
2. 90m high concrete gravity dam from deepest foundation level with FRL at EL 1650m.
3. Water conductor system consisting of:
   - 2 nos. intake structure
   - 4 nos 300m (L) x 17m (W) x 23m (H) de-silting chamber.
   - 10.25m diameter horseshoe shaped headrace tunnel 5.0km long.
   - 20m diameter surge shaft having 85m height.

- One number 8m diameter, 308m height steel lined pressure shaft further dividing into 4 nos. penstocks to feed four units
- 10.25m dia horseshoe shaped tailrace tunnel 200m long meeting the river at a location where riverbed elevation is 1290 m

4. An underground powerhouse consisting of
   - 124m (L) x 22m (W) x 48m (H) powerhouse cavern
   - 96m (L) x 20m (W) x 25m (H) transformer-cum-draft tube gate cavern
   - 96m (L) x 12m (W) x 16m (H) MIV cavern
5. Pot head yard 50m x80m

The layout of Oju-I and Oju-II HEP as proposed by NHPC is shown in **Figure 1-3** and **Figure 1-4**, respectively.

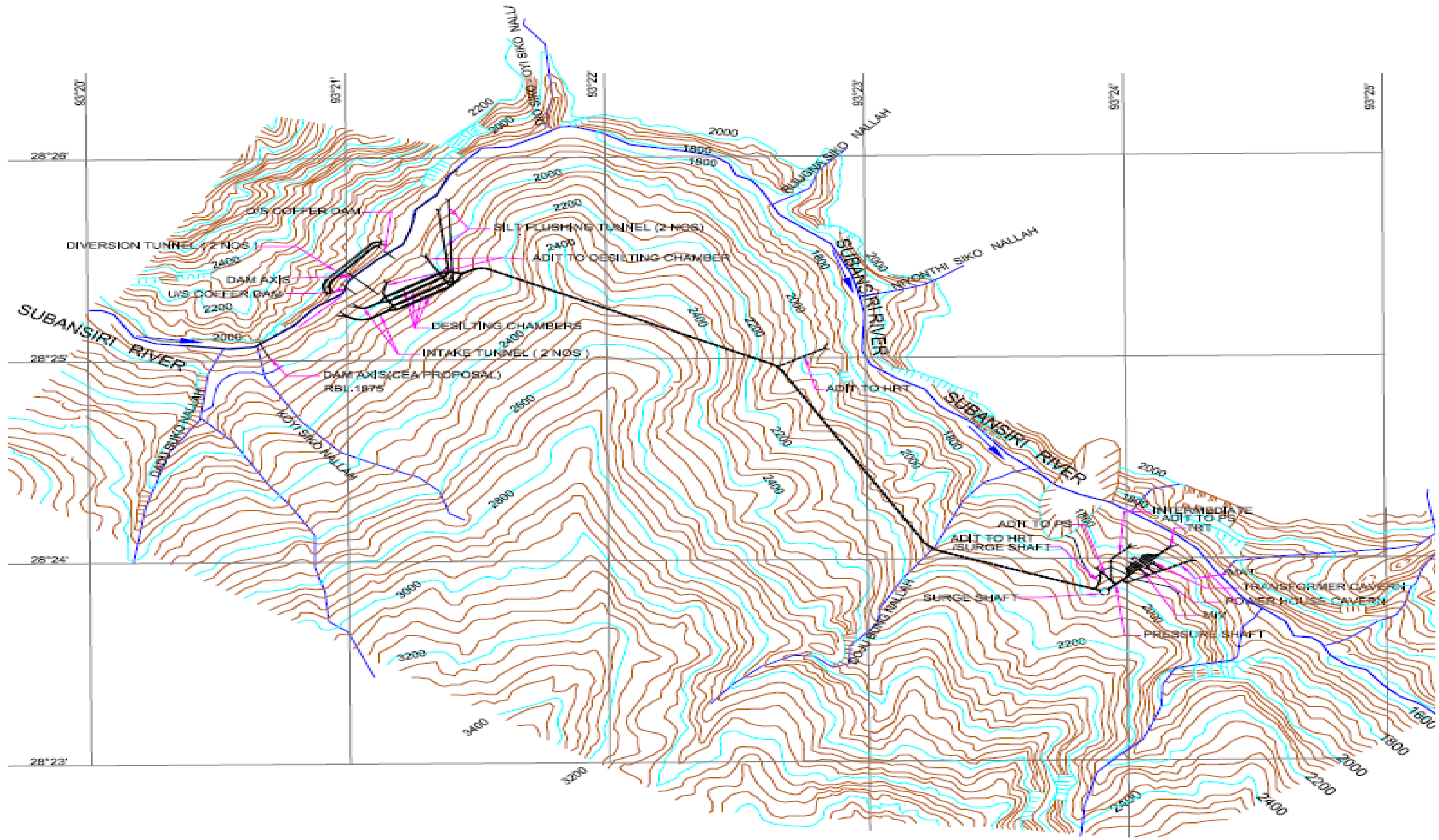


Figure 1-3 : Project Layout – Oju - I

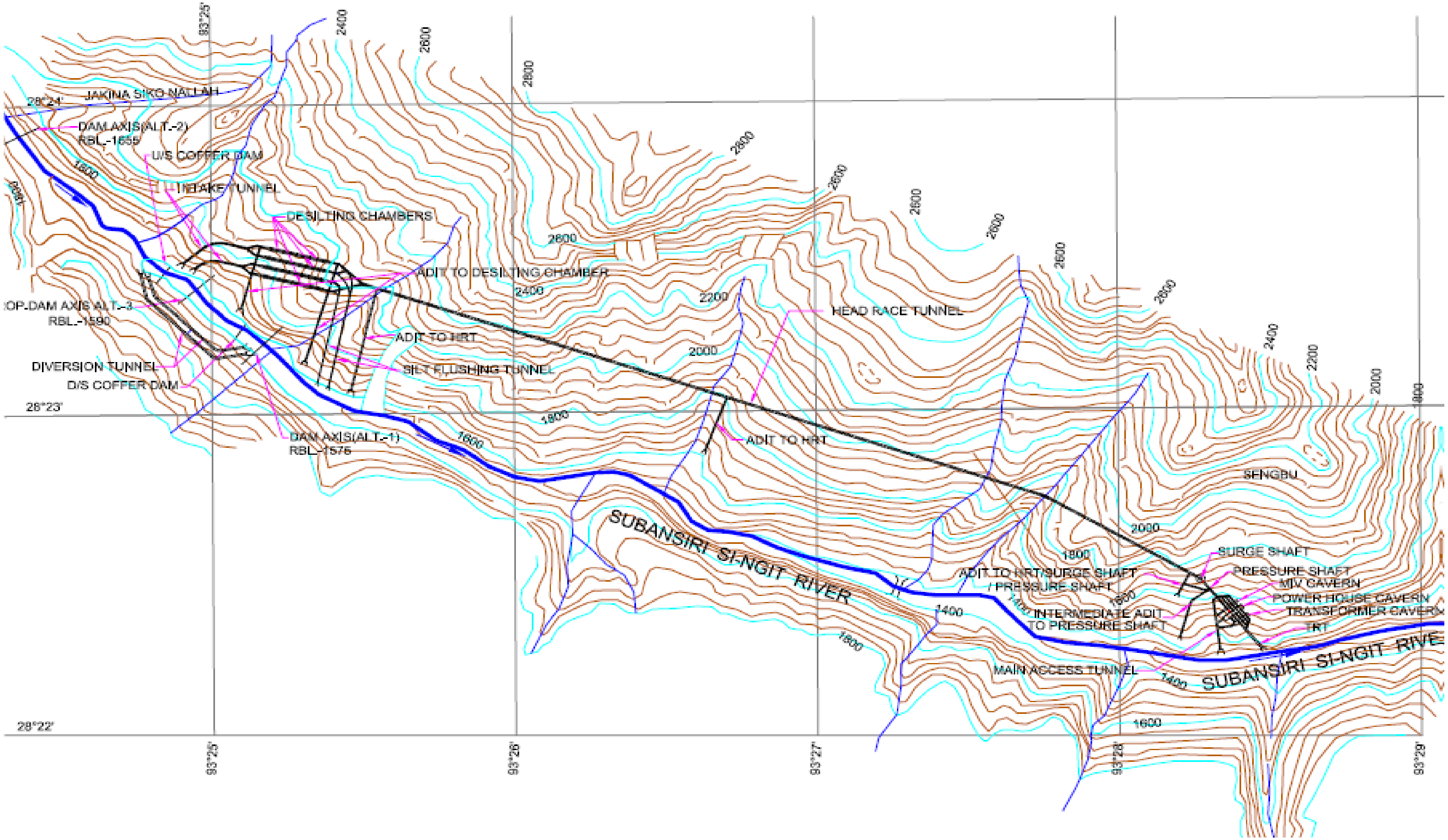


Figure 1-4 Project Layout – Oju - II

1.3. Present Proposal

After thorough review of all the previous studies done on the project and visit to the project site, the following major issues came up:

- The left bank of the river at proposed dam site for Oju-II is almost inaccessible due to dense forest cover and steep rocky escarpment. At present, there is no road or foot track on the left bank of Si Ngit River in this stretch.
- The left bank in Oju-II project stretch being very steep, development of infrastructure and approach roads in the area would be very difficult apart from being time consuming and costly.
- There is no significant difference in the catchment areas of Oju-I (9827 sq.km) and Oju-II (9975 sq.km). Thus, additional water available at Oju-II dam is only about 1.5% higher than that available at Oju-I dam site.
- In view of the above, it will be prudent to explore the possibility of combining both the schemes in to one composite and aligning water conductor and powerhouse along the right bank. The development of composite scheme will lead to reduction in construction of a surge shaft and powerhouse infrastructure for Oju-I project, a 90m high dam, diversion works comprising diversion tunnels and cofferdams, de-silting chambers and infrastructural development on left bank and bridges on Subansiri for Oju-II project as against about 3km additional stretch of HRT.
- The added advantages of locating the composite scheme on the right bank is that the under construction BRO road alignment also runs along this bank and ecology on left bank will remain largely undisturbed. Further, loss in generation from the contribution from the intermediate catchment between Oju-I and Oju-II will get offset to a great extent by additional generation due to gain in head because of the difference in the maximum tail-water level of Oju-I and FRL of Oju-II dam.

Hence, it was finally decided to submit a report to Government of Arunachal Pradesh on Development of Oju-I and Oju-II HEPs as Oju Composite HEP.

1.3.1. Report on Development of Oju-I and Oju-II HEPs as Oju Composite Scheme

The study carried out for evaluating the Oju HEP to be developed as a composite project on the right bank to harness full allotted head of Oju-I and Oju-II between FRL El.1950m and TWL El.1300m vis-a-vis two independent schemes proposed by NHPC reveals that:

- The left bank of the river at proposed dam site for Oju-II is almost inaccessible due to dense forest cover and steep rocky escarpment. At present, there is no road or even foot track on the left bank of Si Ngit River in this stretch. The left bank in Oju-II project stretch being very steep, development of infrastructure and approach roads in the area would be very difficult apart from being time consuming and costly and it will involve development of infrastructure and bridges/approach roads on both banks.

Further, there are no geological compulsions for development of one project on the right bank and the second on the left bank. As such, it is techno-economically prudent to develop a composite scheme on one bank instead of two independent schemes on either bank of the river.

- As per tentative cost estimates, the completion cost of Oju Composite HEP is about 30% lesser (about ₹ 17113.04 crores) than that of total cost of Oju-I and Oju-II as independent schemes (₹ 22297.0 crores).
- The total installed capacity for both Oju-I and Oju-II developed as independent projects works out to 1700 MW against the installed capacity of composite scheme is about 1878MW (1850 MW + 28 MW) with annual design energy of 8461 MU and 8015 MU, respectively.
- The composite scheme is environmentally attractive as it will have submergence for a single reservoir only against the submergence for two reservoirs. There would be significant saving in land requirement for the composite scheme against the two independent schemes.
- The added advantages of locating the composite scheme on the right bank is that the newly constructed BRO road also runs along this bank and ecology on left bank will remain largely undisturbed.

As the development of composite scheme has been found techno-economically more attractive and environment friendly as compared to the two independent schemes, adoption of a single composite scheme for harnessing the power potential has been proposed.

1.4. Accessibility

The project area can be accessed by newly constructed BRO road from Limeking. An all-weather single lane metalled road connects Limeking with Daporijo, the district headquarter of Upper Subansiri district. Dam site of the NHPC proposed Oju-I HE Project is located at about 60km and powerhouse site is located at about 53km upstream of Limeking on the right bank of Si Ngit River. Dam site of the NHPC proposed Oju-II HEP is located at about 50km upstream of Limeking and Powerhouse site is located at about 40km upstream of Limeking on the left bank of Si Ngit River.

Limeking is about 150km from Daporijo and is accessible by all-weather single lane Limeking - Daporijo road. Extension of this road upto Oju dam site location is under progress and formation cutting and gravel surfacing has been carried out by Border Road Organization (BRO) beyond Limeking. This road is passing along the right bank of the river and connects powerhouse as well as dam locations.

Major villages/towns present along the Daporijo-Limeking road are Taliha, Kodak, Siyum, Ayingmoring, Nacho and Limeking. Beyond Limeking, on way to Oju dam site the road passes through Niare, TCC, Orak, Redi and Oju villages. The nearest meter gauge and broad gauge railhead is North Lakhimpur and Nagaon, respectively. Nearest airport is at North Lakhimpur (Lilabari) in Assam.

1.5. River System

Subansiri River is a major tributary of river Brahmaputra. It contributes about 10% to the total discharge of Brahmaputra. Origin of Subansiri is in the Central Himalayas in Tibet. After traversing through the snow-clad mountains of Great Himalayas, it enters India in Arunachal Pradesh. The riverbed level drops from more than 4000m height in the mountainous region to less than 100m in the foothills before it enters the plains of Assam promising enormous hydropower potential with snowmelt combining with heavy rainfall it receives in its catchment ensuring significant discharge in the river throughout the year.

The river Subansiri is one of the major right bank tributary of mighty Brahmaputra River system. The Brahmaputra basin has a total drainage area of about 5, 80,000 sq.km out of which about 2, 65,260 sq.km lies in India. The Brahmaputra basin is spread in Tibet, India, Bhutan, and Bangladesh. In India, the basin drains almost all the North-Eastern states viz. Arunachal Pradesh, Assam, Meghalaya, Manipur, Nagaland, Sikkim and a substantial part of Tripura, Mizoram, and West Bengal. The Brahmaputra is one of the six major river systems of the country.

The Subansiri river has a total length of 360km and is joined by a number of streams. The major tributaries of the Subansiri River are Charchu, Lorochu, Tsarichu, Chayul Chu, Singit Siu, Kamla and Jiyadhol. The river together with its tributaries drains a total of 34400 sq.km of catchment area. Out of this, about 24000 sq.km lies within Indian territory. The Subansiri River has on its East, the Siang Valley and on the West the Kameng basin. The confluence of Subansiri and Brahmaputra is about 20km downstream of Jorhat township. The Subansiri originates beyond the Great Himalayan Range (Central Himalaya) at an altitude of around 5340m. Near its source, several mountain torrents and a family of streams, drain into main valley.

The principal stream is the Nye Chu which may be considered as the main source of the river Subansiri originating from the snow-clad peaks of Krakang, Shabota, Baru and Mata falling within 92º and 93º E longitudes and 28° and 29° N latitudes.

The region may be divided into four parts; the distant Tibetan mountains beyond the international border, the reach lying between the international boundary and Miri hills of Arunachal Pradesh, the area between the outskirt of Miri hills and the interstate boundary of Assam and Arunachal Pradesh and lastly the plains of Assam. The first two belong to the Great Himalayan, Lesser Himalayan range, the third is in the Siwaliks (Outer Himalaya) and the fourth lies in the fertile plains of Assam. The **Figure 1-5** shows the basin map of river Subansiri.

1.6. Location

The proposed Oju HEP dam site is located on Lower Subansiri River between Redi and Oju village. Diversion area is downstream of confluence point of Koyi Siko nallah with Lower Subansiri River. The powerhouse area is located upstream of the confluence of Tsari Chu nallah and Keru nallah with Si Ngit River. The Latitude and Longitude of the Dam and the Powerhouse sites are as given below:

	Dam	Powerhouse
Latitude:	28º25’51.6” N	28º22'11.73" N
Longitude:	93º21’23.71” E	93º28'9.97" E

The location of the project vis-a-vis other hydroelectric projects in cascade is shown in the **Figure 1-6**.

1.7. The Project

Earlier the road link to the project was upto Limeking only, which is about 60km away from the Dam site and about 40km from the powerhouse site. Presently, BRO has constructed new road beyond Limeking upto dam site and both powerhouse and dam locations are accessible by vehicle. The road connecting Limeking is a single lane metalled road coming from Daporijo. The distance between Daporijo and Limeking is about 150km. Daporijo is the district headquarter of Upper Subansiri. Daporijo can be accessed from either Pahumara-Kimin-Ziro-Daporijo road route or Silapanthar-Likabali-Basar-Daporizo Road route. Silapathar is accessible from North Lakhimpur and Dibrugarh in Assasm.

The nearest meter gauge and broad gauge railhead is at North Lakhimpur and Nagaon respectively. Nearest airport is at North Lakhimpur (Lilabari) in Assam. Besides, there are helipads at Daporijo, Nacho, Limeking, Reddi, Taksing and Tamachungchung.

The Oju Hydroelectric Project envisages utilization of water of river Subansiri by constructing a dam near Redi village. The water conductor system is envisaged on the right bank of the river. The intake is located at El 1925.0m and it leads to a headrace tunnel of length 14.82km (including 57m of RCC conduit), ending in a surge shaft.

2 numbers of pressure shafts off takes from the surge shaft, each further bifurcating and leading to eight units of 231.25 MW to underground powerhouse. One dam toe powerhouse housing two units of 14MW each, is also proposed on the right bank. Detailed layout and design aspects of the project are described in subsequent sections of this report.

1.8. Organization of the Report

This Feasibility Study Report describes the Oju Hydroelectric Project. The report is organized in two volumes.

Volume I Main Report

Volume II Drawings

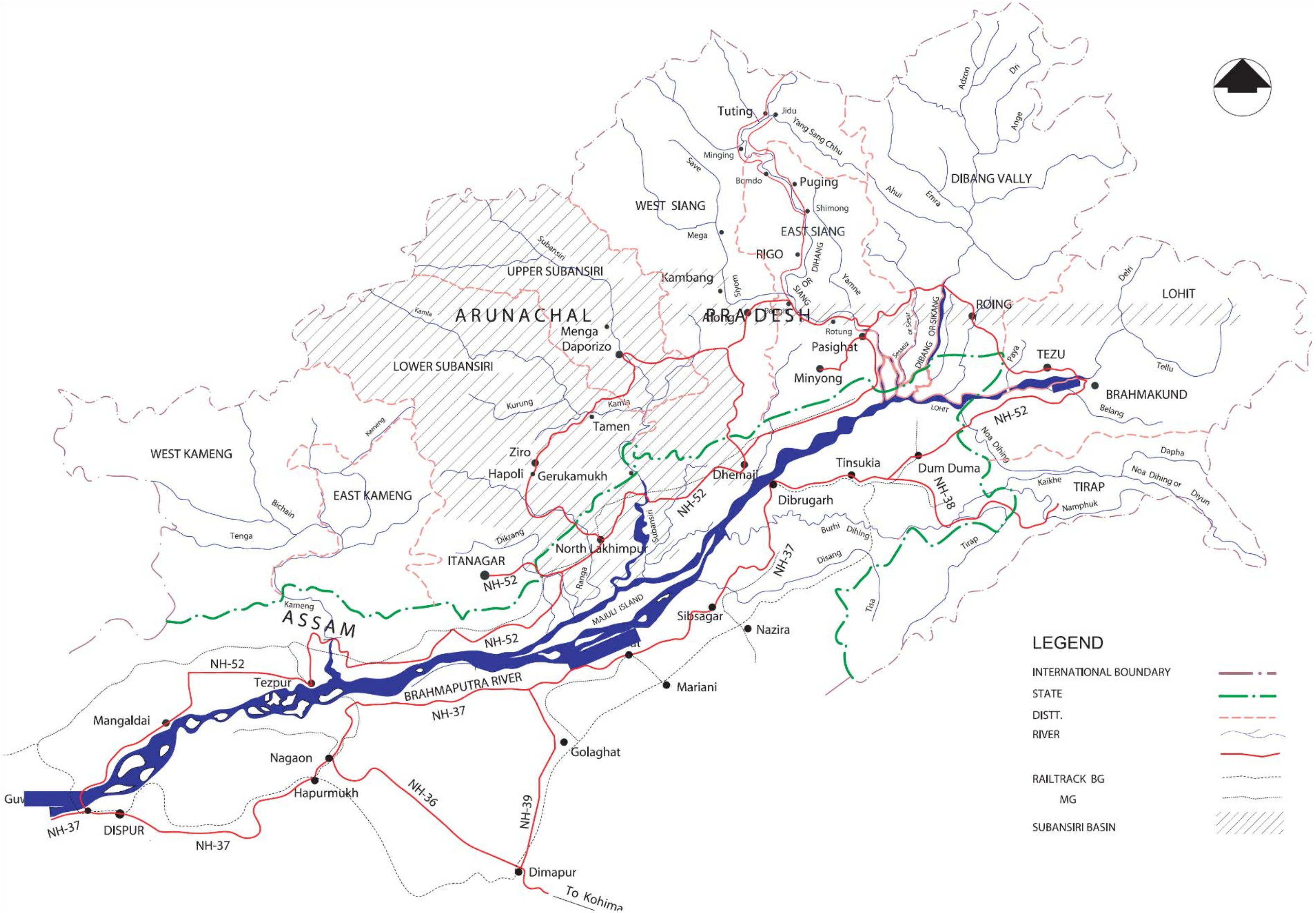


Figure 1-5 : Basin Map of Subansiri River

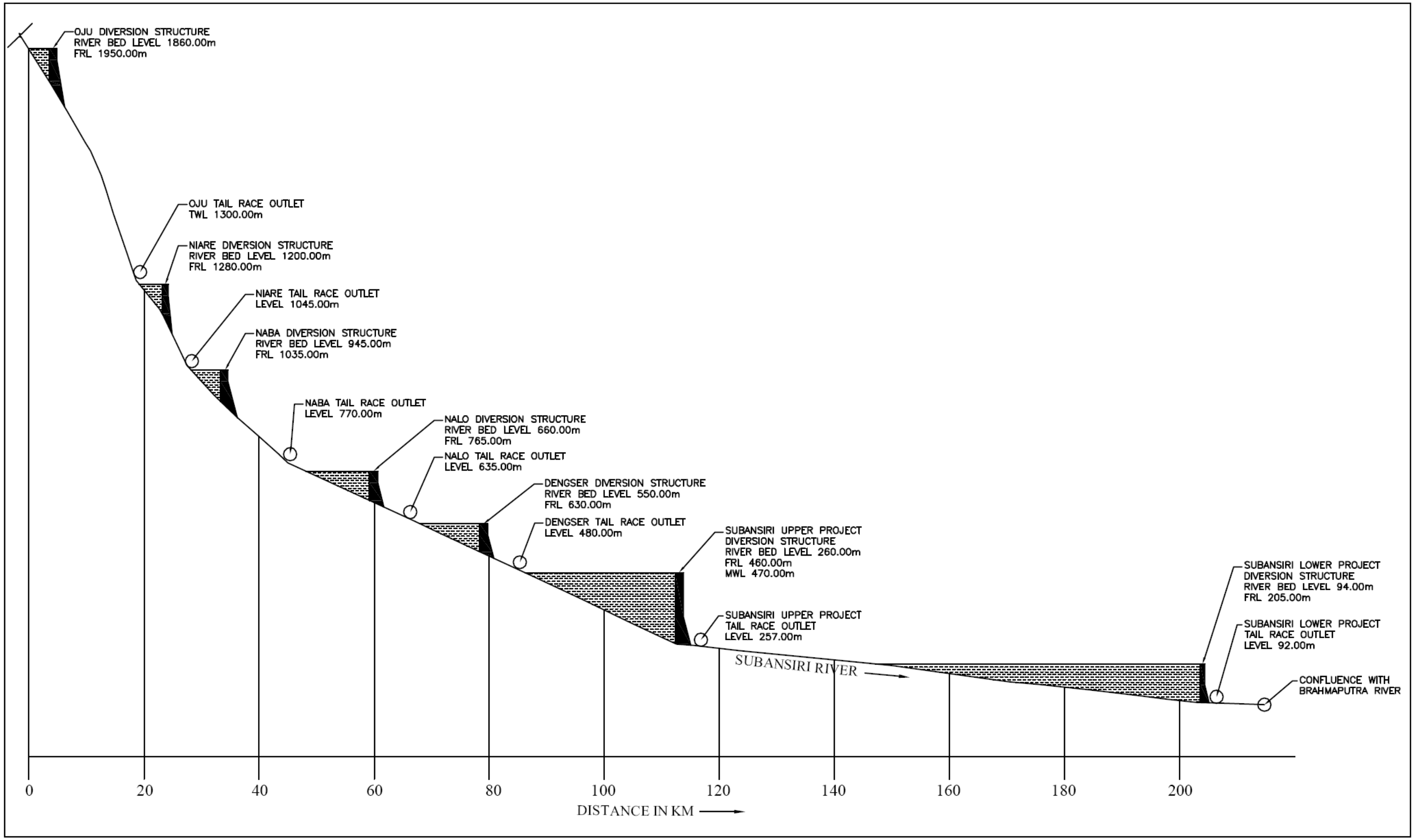


Figure 1-6 : Cascade Development of Subansiri River

1.9. The Consultant

Navayuga Engineering Company Ltd. (NECL) has appointed Tractebel Engineering Pvt. Ltd. (TEPL) as its consultant for the preparation of the DPR. At this stage of the project, Feasibility Study Report has been prepared to facilitate NECL to submit the same to the Govt. of Arunachal Pradesh and other government authorities to obtain necessary statutory clearances. **TRACTEBEL** is a global engineering consultancy company with more than 150 years of expertise in **ENERGY, WATER and INFRASTRUCTURE PROJECTS.**

TRACTEBEL Engineering pvt. ltd., India, started its Indian operations in March 2000, since then, it has established itself as the most preferred engineering consultant in India, in both public and private sectors for hydro power projects and other sectors. TRACTEBEL India is one of the few companies that can offer the whole spectrum of technical services with all associated disciplines by drawing on the expertise of its own professional staff. Around 600 professionals working as domain experts having the know-how and experience at all stages of a project: from the conception to the management, implementation and operation. **TRACTEBEL** India has executed many successful projects in various sectors for public and private clients including developers, investors, utilities, banks, multinational institutions (ADB, WB, AFD, KfW, JICA, GIZ, USAID, etc), EPC contractors, Government agencies and organisations

TRACTEBEL's key strength lies in providing services for complex multi-disciplinary water resources projects and multi-purpose development projects worldwide, working with international donors such as Asian Development Bank, World Bank, KfW, JICA, AfD, African Development Bank as well as with local donors, stage / central government organizations such as Water and Irrigation Ministries, State Water Resources Departments, large corporations including municipality etc.

TRACTEBEL has acquired broad expertise in Design, Project / Program Management, Implementation and Supervision of small size, mid-size and large size complex hydro power projects in preparation of pre-feasibility report, feasibility report, detailed project report, tender document, detailed design and construction drawings. From the initial stage of a project, Tractebel can offer: detailed assessments of available resources, analysis of present and projected demands, identification of constraints and implementation of the development plans, on-site investigations, design reviews as well as supervision and implementation.

1.10. Acknowledgement

Tractebel sincerely acknowledges the support provided by NECL during the preparation of this report. Cooperation extended by NECL in providing all the pertinent information required for completion of this report is also gratefully acknowledged

2. PROJECT AREA

2.1. General

Arunachal Pradesh is the easternmost state of India. Arunachal Pradesh shares its border with the states of Assam to the south and Nagaland to the southeast. Burma/Myanmar lies towards the east, Bhutan towards the west, and Tibet to the north. The State of Arunachal Pradesh Bill was passed by the Parliament in 1986 and with effect from 20 February 1987, Arunachal Pradesh became the 24th state of Indian Union. Arunachal Pradesh is divided into sixteen districts. The state is mostly mountainous with the Himalayan range along the northern borders criss-crossed with ranges running north south. These divide the state into five river valleys: the Kameng, the Subansiri, the Siang, the Lohit and the Tirap. All these are fed by snow from the Himalayas and countless rivers and rivulets.

2.2. Access to the Project

The project area can be accessed by newly constructed single lane road of BRO from Limeking. An all-weather metalled road connects Limeking with Daporijo, the district headquarter of Upper Subansiri district. Dam site of the project is located at about 60km and powerhouse site is located at about 40km upstream of Limeking on the right bank of Si Ngit River. Limeking is about 150km from Daporijo and is accessible by all-weather single lane Limeking - Daporijo road. Extension of this road beyond Limeking up to proposed dam site is under progress by Boarder Road Organization (BRO) and formation cutting and gravel surfacing have been done. Dam and power house locations can be accessed by vehicle through this road. Major villages/towns present along the Daporijo-Limeking road are Taliha, Kodak, Siyum, Ayingmoring, Nacho and Limeking. Beyond Limeking, on way to the project dam site the road passes through Niare,TCC, Orak, Redi and Oju villages. The nearest meter gauge and broadgauge railhead is North Lakhimpur and Nagaon, respectively. Nearest airport is at North Lakhimpur (Lilabari) in Assam.

2.3. Topography and Physiography

Arunachal Pradesh covers an area of 83743 km^2. Itanagar, the capital is about 530m above mean sea level. Arunachal Pradesh has a long international border with Bhutan to the west (160km), China to the north and north-east (1,080km) and Myanmar to the east (440km). It stretches from snow-capped mountains in the north to the plains of Brahmaputra valley in the south. The Himalayan ranges that extend up to the eastern Arunachal separate it from China. The ranges extend toward Nagaland and form a boundary between India and Burma in Changlang and Tirap district, acting as a natural barrier called Patkai Bum Hills. They are low mountains compared to the Greater Himalayas.

2.4. Geology of the Project Area

Proposed Oju Hydroelectric Project on the river Subansiri is located in Higher Himalaya in Upper Subansiri district of Arunachal Pradesh. The project area located in Higher Himalaya is characterized by highly rugged topography with precipitous hill slopes and deeply incised narrow valleys with steep abutment slopes. In general, altitude in the area varies between 800m near Taliha in the south and 2550m at Maza in the north. However, topography around Taksing is relatively less rugged. The river Subansiri, Trunk River in the area flows through a narrow V-shaped valley in general. However, same is comparatively wider near Taksing and Redi where it is characterized by unpaired aggradational fluvial terraces.

The area around the proposed Oju hydroelectric project exposes the metasedimantaries belonging to Gelensiniak formation of Subansiri or Sela Group. These are intruded by Maja Granite, which is light grey in colour, fine grained and profusely jointed. It is characterized by roundish concentrations of tourmaline and associated biotite gneiss into which it has intruded. It is exposed on the left bank of the river near Redi. Rocks predominantly exposed in the area include biotite gneiss, garnetiferous biotite gneiss belonging to Gelensiniak Formation of Subansiri or Sela Group of Higher Himalaya. Biotite gneiss exposed in the area is light grey in colour, medium to fine grained and well foliated. Biotite gneiss imperceptibly grades into garnetiferous biotite gneiss, garnets measure up to a few milimetres and are randomly distributed in the gneiss. These are wrapped by foliation planes which in turn are defined by preferred orientation of biotite and felsic minerals.

Various litho-units exposed in the area exhibit polyphase deformation and structural elements produced due to several phases of deformation are folds, lineations and puckers and joints etc.

It is also observed that the bedrock exposed in the upstream reaches around the site for diversion dam for Oju is more intensely jointed particularly on the left bank where Maja granite is exposed at higher elevations. The site appears to be suitable for about 110m high concrete gravity dam. However, surface and subsurface explorations comprising detailed surface geological mapping, exploratory drilling and exploratory drifting would be required to be conducted at the site to determine the size and type of structure at the site.

The underground powerhouse is located on the right bank of Subansiri just upstream of confluence of Keru/kuo Siko with the river. The right bank valley slopes at the site are moderately steep to steep and support moderately dense vegetation. The rocks exposed in the area comprise silimanite-kyanite-garnet gneiss with migmatite belonging to Sela Group. The bedrock is foliated and moderately jointed. Foliation in general strikes in NE-SW direction and dips at moderate angles towards NW. Prima-facie the site appears to be suitable for locating underground powerhouse and other appurtenant structures.

2.5. General Climatic Conditions

The weather and the climate of Arunachal Pradesh are quite unique from the rest of India. The climate of Arunachal is governed by the Himalayan system and the altitudinal differences. The climate here is highly hot and humid at the lower altitudes and in the valleys wrapped by marshy thick forest particularly in the eastern region, while it becomes too cold in the higher altitudes. Average temperature during the winter months range from 15ºC to 21ºC and 22ºC to 30ºC during monsoon. Between June and August, the temperature sometimes go up to 40 to 42 degree celsius. The rainfall of Arunachal Pradesh is amongst the heaviest in the country. Arunachal Pradesh receives about 80 to 160 inches (2,000 to 4,000mm) annually, most of it between May and September.

2.6. Socio-Economic Aspects

2.6.1. Demographic Features

The population of Arunachal Pradesh is 1.38 million according to 2011 census and is scattered over 16 towns and 4065 villages. The State has the lowest density of 17 persons/km2. The total population growth in this decade was 25.92% while in previous decade it was 26.21%. The population of Arunachal Pradesh forms 0.11% of India in 2011. - The sex ratio of Arunachal Pradesh at 920 females to 1000 males is lower than the national average of 940. Total literacy of the State rose to 66.95% from 54.34% in 2001. There are 20 major tribes and a number of sub-tribes inhabiting the area. Most of these communities are ethnically similar, having derived from and original common stock but their geographical isolation from each other has brought amongst them certain distinctive characteristics in language, dress, and customs.

2.6.2. Ethnographic Details and Religion

Broadly the people may be divided into three cultural groups on the basis of their socio-religious affinities.

The Monpas and Sherdukpens of Tawang and West Kameng districts follow the lamaistic tradition of Mahayana Buddhism. Noted for their religious fervour, the villages of these communities have richly decorated Buddhist temples, locally called 'Gompas'. Though largely agriculturists practising terrace cultivation, many of these people are also pastoral and breed herds of yak and mountain sheep. Culturally similar to them are Membas and Khambas who live in the high mountains along the northern borders. Khamptis and Singphos inhabiting the eastern part of the State are Buddhists of Hinayana sect. They are said to have migrated from Thailand and Burma long ago and still using ancient scripts derived from their original homeland.

The second group of the people are Adis, Akas, Apatanis, Bangnis, Nishis, Mishmis, Mijis, Thongsas etc., who worship Sun and Moon God namely, Donyi-Polo and Abo-Tani, the original ancestors for most of these tribes. Their religious rituals, largely coincide with phases of agricultural cycles. They invoke nature deities and make animal scarifices. They traditionally practice jhumming or shifting cultivation. Adis and Apatanis extensively practice wet rice cultivation and have a considerable agricultural economy. Apatanis are also famous for their paddy-cum-pisciculture. They are specialised over centuries in harvesting two crops of fish along with each crop of the paddy.

The third group comprises Noctes and Wanchos, adjoining Nagaland in the Tirap District. These are hardy people known for their strictly structured village society in which hereditary village chief still plays a vital role. The Noctes also practise elementary form of Vaishnavism.

2.6.3. Health and Education

In addition to the few general hospitals spread among the larger towns of Arunachal Pradesh, nearly every district has its own hospital. In more remote areas, health services are provided by 31 community health centers and 379 sub-centers. Tuberculosis remains a major concern in the state, with hospital facilities specifically designated as tuberculosis treatment centres. The Total Fertility Rate of the State is 3.0. The Infant Mortality Rate is 37 and Maternal Mortality Ratio is NA (SRS 2001-03). The Sex Ratio in the State is 920 (as compared to 940 for the country).

School Education in Arunachal Pradesh follows uniform structure of 10+2 system. The primary stage of schooling consists of Standard I to V, the middle stage from Standard VI to VIII and the Secondary Stage comprises Standard IX to X. Classes XI-XII falls under the higher secondary education stage. In order to universalize elementary education in Arunachal Pradesh, state government offers free education to students up to the age of 14. The state is home to a number of Pre-Primary Schools, Primary School, Middle Schools, High Schools and Higher Secondary Schools.

Arunachal Pradesh has a few renowned institutes that offer higher education in the state. Among them North-eastern Regional Institute of Science And Technology (NERIST) play a very significant role in raising the technical and management education in the state. Another premier educational institution in the state of Arunachal Pradesh is Rajiv Gandhi University. Institutes offering higher education in Arunachal Pradesh consist of two universities one deemed university and several recognized professional colleges.

2.6.4. Trade & Industry

The state's manufacturing sector consists primarily of medium and small-scale industries. Basketry, weaving, and carpets are the main handicraft manufactures. Smaller-scale industries include rice and oil milling, fruit processing, manufacture of forest-based products, and steel fabrication. Sericulture (raw silk production) also is important, and the state produces many varieties of silk yarns. Industrial expansion has been encouraged by the state's economic development policies, and industrial estates have been established at Itanagar, Naharlagun (formerly Old Itanagar), Pasighat, and Deomali.

Arunachal Pradesh has significant, though largely unutilized, resource potential. Among its resources for generating energy are rivers, coal, and petroleum; most of the state's power is provided by hydroelectric plants. In addition to hydrocarbons, other mineral resources of Arunachal Pradesh include dolomite, quartzite, limestone, and marble.

For conservation and explorations of vast minerals, the Arunachal Pradesh Mineral Development and Trading Corporation Limited (APMDTCL) were set up in 1991. Namchik-Namphuk coal fields are taken up by APMDTCL. To provide training to craftsmen in different trades, there are two Industrial Training Institutes at Roing and Daporijo.

2.6.5. Natural Resources

Bio-geographically, Arunachal is situated in the Eastern Himalayan province, the richest biogeographical province of the Himalayan zone. The entire territory forms a complex hill system with varying elevations ranging from 50m in the foothills and gradually ascending to about 7000m, traversed throughout by a number of rivers and rivulets. Rainfall varies from 1000mm in higher reaches to 5750mm in the foot-hill areas, spread over 8-9 months excepting the drier days in winter. This diversity of topographical and climatic conditions has favoured the growth of luxuriant forests which are home to myriad plant and animal forms adding beauty to the landscape. Nature has been exceedingly kind and has endowed this beautiful State of Arunachal Pradesh with diverse forests and magnificent wildlife.

The richness of life forms i.e., the flora & fauna that occur in these forests presents a panorama of biological diversity with over 5000 plants, about 85 terrestrial mammals, over 500 birds and a large number of butterflies, insects and reptiles. Such an unparalleled occurrence of life forms can be attributed to the peculiar location of the State, which is at the junction of the Paleoarctic, indo-Chinese, and Indo-Malayan bio-geographic regions, Biotic elements from all these regions occur in this state making it very rich in floral & faunal resources. The vegetation of Arunachal Pradesh falls under four broad climatic categories and can be classified in five broad forest types with a sixth type of secondary forests. These are tropical forests, sub-tropical forests, pine forests, temperate forests and alpine forests. In the degraded forests, bamboos and other grasses are of common occurrence.

2.6.6. Upper Subansiri District

The district was formed when Subansiri district was bifurcated into Upper and Lower Subansiri districts in 1987. The district headquarters are located at Daporijo. Upper Subansiri district occupies an area of 7,032km2. The important towns are Daporijo, Dumporijo, Taliha, Nacho, Siyum, and Maro.

In 2006 the government named Upper Subansiri one of the country's 250 most backward districts (out of a total of 640). It is the only district in Arunachal Pradesh currently receiving funds from the Backward Regions Grant Fund Programme (BRGF).

There are five Arunachal Pradesh Legislative Assembly constituencies in this district: Nacho, Taliha, Daporijo, Raga, and Dumporijo. All of these are part of Arunachal West Lok Sabha constituency.

According to the 2011 census Upper Subansiri district has a population of 83,205. This gives it a ranking of 621st in India (out of a total of 640). The district has a population density of 12 inhabitants/km2 (31/sq.mi.). Its population growth rate over the decade 2001-2011 was 50.34%. Upper Subansiri has a sex ratio of 982 females for every 1000 males, and a literacy rate of 63.96%.

Members of the Tagin, Hill Miri and Galo are found in the district. Languages spoken include Tagin, the dominant language, Hills Miri (now Nyishi) and Galo, also in the Sino-Tibetan language family and spoken in the western part of the district.

2.7. Hydropower Potential

Arunachal Pradesh, with more than 55000 MW hydropower potential, will be known as the Powerhouse of the country in few years' time. In fact, the experts say that the identified potential of 55000 MW is a conservative estimate, and the actual potential may run into 70000 MW. Since past few years the State has taken up concerted efforts to harness this potential by inviting the central public sector undertakings as well as private players to participate in the process. The State has its own Hydro Power Policy which guides the Government in the process of harnessing the power potential. It is worth mentioning that though the State is a late starter as far as harnessing the mega potential, but for micro hydel the process started way back in 1972.

2.8. Inter State / International Aspects

The project headwater and tailwater areas both lie well within the state of Arunachal Pradesh. Subansiri is a tributary of river Brahmaputra and there are larger projects like Lower Subansiri and Upper Subansiri, downstream on the same river, as such the Oju project does not entail any inter-state aspects.

Part of the catchment area of the project lies in Tibet (China).

2.9. Defence Related Aspects

There are no defence-related establishments in the project's submergence or general development area. Military presence is all upstream of dam site, closer to the border with China.

3. NEED FOR THE PROJECT

3.1. General

The re-assessment studies of hydroelectric potential of the country, completed by Central Electricity Authority in 1987 have assessed the economically exploitable hydropower potential in terms of installed capacity as 148701 MW out of which 145320 MW of capacity is from schemes having capacity above 25 MW. About 32% hydro potential has been harnessed so far and another 10% is under various stages of development.

The total installed capacity in the country is 401,010 MW as on April 30, 2022, out of which hydro capacity contributes 46,722 MW. From Renewable Energy Sources (R.E.S) the installed capacity is 111,399 MW including 4850 MW from small hydro power projects (< 25 MW). The Government has set a target of 70000 MW capacity from hydro power by 2030 considering the unique advantage of hydro power and the increasing need of hydropower for grid stability / balancing (source – Ministry of Power Annual Report 2020-21).

Hydropower is the richest renewable and environmentally benign source of energy. Hydropower stations have the inherent ability for instantaneous starting, stopping and managing load variations which helps in improving reliability of the power system. Hydro stations are the natural choice for meeting the peak demand. The generation cost is inflation free and in fact reduces over time. A hydroelectric project has a useful life extending to well over 35 years and helps in conserving scarce fossil fuels.

Development of hydropower projects also provides the added advantage of opening up avenues for development of remote and backward area of the state. Despite being recognized as a relatively benign and renewable source of energy, the share of hydropower in the overall generating capacity in the country has been steadily declining since 1963. The hydro share has declined from 44% in 1970 to about 11.7% in 2022.

Several constraints have affected the pace of hydropower development. These have been non availability of long-term financing and viability of tariff. Many hydro projects have been adversely affected by geological surprises especially during underground excavation. Other problems arising out of the inaccessible and remote location of the site, delays in land acquisitions and in resettlement of project affected families have also slowed down the pace of hydropower development in the country.

Now the government has accorded a high priority to the development of hydro potential and has taken a number of policy initiatives to address the issues impeding the hydropower development. Substantial private investment in hydropower development has been encouraged by the Central Government in accordance with latest hydro power policy 2008 of Government of India.

In order to speed up the progress of hydroelectric generation, various projects have been identified and preparation of feasibility reports of these projects are in progress.

Oju Hydroelectric Project is located in upper reaches of Subansiri River (called Si Nigit in upper reaches) in Upper Subansiri district of Arunachal Pradesh and envisages utilization of water of Subansiri River for hydropower generation. This project will be supplementing power generation in the North-Eastern region (structured on geographical congruity) which comprises the states of Arunachal Pradesh, Assam, Manipur, Nagaland, Meghalaya, Tripura and Mizoram. Power system in the region is mainly controlled by various central government/state government utilities.

The project belongs to a series of hydro projects that have been planned for development in cascade on the Subansiri River. Starting from the upstream, these projects are Oju, Niare, Naba, Nalo, Dengser, Upper Subansiri and Lower Subansiri projects. All these projects are being developed by independent power producers.

3.2. Country's Power Demand and Supply Scenario

The power demand and supply scenario in the country is as follows:

Table 3-1 : All India Installed Capacity as on 30-04-2022

Sector	Thermal				Nuclear	Hydro	R.E.S	Total
	Coal+Lignite	Gas	Diesel	Total				
State	67981.50	7087.36	236.01	75304.86	0.00	27126.80	2425.31	104856.98
Private	75028.00	10574.24	273.70	85875.95	0.00	3931.00	107341.38	197148.33
Central	67690.00	7237.91	0.00	74927.91	6780.00	15664.72	17297.02	99004.93
Total	**210699.50**	**24899.51**	**509.71**	**236108.72**	**6780.00**	**46722.52**	**111399.00**	**401010.23**

Table 3-2 : All India Region-wise Generating Installed Capacity (MW) of Power Utilities as on 30-04-2022

Region	Thermal				Nuclear	Hydro	R.E.S	Total
	Coal	Gas	Diesel	Total				
Northern	57000.47	5781.26	0.00	62781.73	1620.00	20631.77	27562.67	112596.17
Western	75973.14	10806.49	0.00	86779.63	1840.00	7562.50	34227.75	130409.88
Southern	49845.30	6491.80	433.66	56770.76	3320.00	11819.83	47313.95	119224.54
Eastern	27249.70	100.00	0.00	27349.70	0.00	4764.42	1755.51	33869.63
N-Eastern	630.90	1719.96	36.00	2386.86	0.00	1944.00	500.69	4831.54
Islands	0.00	0.00	40.05	40.05	0.00	0.00	38.43	78.43
All India	**210699.50**	**24899.51**	**509.71**	**236108.72**	**6780.00**	**46722.52**	**111399.0**	**401010.23**

Table 3-3: Actual Power Supply Position

	Peak Demand	Peak availability	Surplus/Deficit		Energy Requirement	Energy Availability	Surplus/ Deficit
	(MW)	(MW)	(MW)	(%)	(MU)	(MU)	(MU)
At the end of 7th Plan (1989-90)	40385	33658	-6727	-16.7	247762	228151	-19611
At the end of 8th Plan (1996-97)	63853	52376	-11477	-18.0	413490	365900	-47590
At the end of 9th Plan (2001-02)	78441	69189	-9252	-11.8	522537	483350	-39187
2002-03	81492	71547	- 9945	- 12.2	545983	497890	- 48093
2003-04	84574	75066	- 9508	- 1.2	559264	519398	- 39866
2004-05	87906	77652	-10254	- 11.7	591373	548115	- 43258
2005-06	93255	81792	- 11463	-12.3	631757	578819	- 52938
2006-07	100715	86818	-13897	-13.8	690587	624495	-66092
2007-08	108866	90793	-18073	-16.6	705724	628016	-77708
2008-09	109809	96685	-13124	-12.0	774324	689021	-85303
2009-10	119166	104009	-15157	-13.8	830594	746644	-83950
2010-11	122287	110256	-12031	-9.8	861591	788355	-73236
2011-12	130250	115847	-14403	-11.1	936568	857239	-79329
2012-13	135453	123294	-12159	-9.0	995557	908652	-86905
2013-14	135918	129815	-6103	-4.5	1002257	959829	-42428
2014-15	148166	141160	-7006	-4.7	1068923	1030785	-38138
2015-16	153366	148463	-4903	-3.2	1114408	1090850	-23558
2016-17	159542	156934	-2608	-1.6	1142928	1135332	-7596
2017-18	164066	160752	-3314	-2.0	1213326	1204697	-8629
2018-19	177022	175528	-1494	-0.8	1274595	1267526	-7070
2019-20	183804	182533	-1271	-0.7	1291010	1284444	-6566
2020-21	190198	189395	-802	-0.4	1275534	1270663	-4871

Table 3-4 : Targeted Installed Capacity at the end of 2021-22 & 2026-27 (MW)

Year	Hydro	Thermal			Nuclear	RES	Total
		Coal+ Lignite	Gas	Total			
2021-22	51301	217302	25735	243037	10080	175000	**479418**
2026-27	63301	238150	25735	263885	16880	275000	**619066**

3.3. Hydropower Potential of the North-East

The North-Eastern Region (NER), comprising the seven Indian states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura, is endowed with bountiful water resources carried by its numerous rivers originating mainly from the Himalayan region.

The Brahmaputra in the northern part and the Barak (Meghna) flowing through the southern margins along with their numerous tributaries are the two main river systems that have created a very dynamic and powerful hydrologic regime in the region.

As per Re-assessment Studies carried out by CEA, hydro potential of the North-Eastern Region in terms of installed capacity has been estimated as 58971 MW (58356 MW above 25 MW capacity) i.e., almost 40% of the country's total hydro potential. Out of the above, 2027 MW (above 25 MW capacity) have been harnessed, while projects amounting to **2000** MW are under construction as on 31 March 2021.

The State-wise estimated hydroelectric potential of North-Eastern Region and its status of development is given below as on 31 March 2021. *(Source: CEA website):*

Table 3-5 : The State-wise estimated Hydroelectric Potential of North-Eastern Region and its Status

State	Identified Potential as per Re-assessment Study (MW)		Capacity Developed (above 25 MW Capacity) (MW)	Capacity Under Construction (Above 25 MW Capacity (MW)
	Total	Above 25 MW		
Meghalaya	2394	2298	322	0
Tripura	15	0	0	0
Manipur	1784	1761	105	0
Assam	680	650	375	0
Nagaland	1574	1452	75	0
Arunachal Pradesh	50328	50064	1115	2000
Mizoram	2196	2131	60	0
Total	**58971**	**58356**	**2027**	**2000**

Additionally, the Region also has abundant resource of coal, oil and gas for thermal power generation. In spite of such huge potential the Region ranks lowest in the country in terms of per capita energy consumption. This has been mainly due to inhospitable climatic conditions, remote location and inaccessibility of geographical locations.

However, with continual improvement of infrastructure and communication facilities, the Northeast region stands to become the powerhouse of India by utilizing its surplus power potential especially in the hydropower sector.

There is no denying the fact that generating power from the utilizable water resources of the Northeast for augmenting development efforts for the country as well as the region is a legitimate pursuit. At the same time the ecological and social costs of such large projects in an environmentally and socio-politically vulnerable region need to be assessed properly before going all out to change the landscape of the region forever.

3.4. Power Scenario of North-Eastern Region

The power scenario of the North-Eastern region is described in the tables below:

Table 3-6 : State-wise Installed Capacity in NE Region as on 30.04.2022

Sector	Hydro	Thermal				Nuclear	R.E.S	Total
		Coal	Gas	Diesel	Total			
Arunachal Pradesh	544.55	37.05	46.82	0.00	83.87	0.00	144.34	772.76
Assam	522.08	402.52	764.92	0.00	1167.44	0.00	179.05	1868.57
Manipur	95.34	15.68	81.58	36.00	133.26	0.00	17.69	246.29
Meghalaya	409.27	0.00	109.69	0.00	109.69	0.00	50.49	569.45
Mizoram	97.94	31.05	60.46	0.00	91.51	0.00	44.48	233.93
Nagaland	66.33	32.10	73.93	2.00	106.03	0.00	33.71	206.07
Tripura	68.49	0.00	518.94	0.00	518.94	0.00	30.93	618.36
Central	140.00	112.50	63.62	0.00	176.12	0.00	0.00	316.12
TOTAL	**1944.00**	**630.90**	**1719.96**	**36.00**	**2386.86**	**0.00**	**500.69**	**4831.54**

(Figures in MW)

Table 3-7 : Total Installed Capacity in NE Region as on 30.04.2022

Sector	Hydro	Thermal				Nuclear	R.E.S	Total
		Coal	Gas	Diesel	Total			
Central	1522.00	630.90	1253.60	0.00	1884.50	0.00	30.00	3436.50
State	422.00	0.00	466.36	36.00	502.36	0.00	235.25	1159.60
Private	0.00	0.00	0.00	0.00	0.00	0.00	235.44	235.44
Total	**1944.00**	**630.90**	**1719.96**	**36.00**	**2386.86**	**0.00**	**500.69**	**4831.54**

(Figures in MW)

Table 3-8 : Power Supply Position in North-Eastern Region for 2020-21

State	Energy Required (MU)	Energy Supplied (MU)	Deficit (MU)	Deficit (%)	Peak Demand (MW)	Peak Met (MW)	Deficit (MW)	Deficit (%)
Arunachal Pradesh	719	714	-5	-0.7	158	149	-9	-5.6
Assam	10192	9815	-377	-3.7	2072	1987	-85	-4.1

State	Energy Required (MU)	Energy Supplied (MU)	Deficit (MU)	Deficit (%)	Peak Demand (MW)	Peak Met (MW)	Deficit (MW)	Deficit (%)
Manipur	974	969	-5	-0.5	252	249	-3	-1.1
Meghalaya	2031	2005	-26	-1.3	384	384	-0	-0
Mizoram	728	723	-5	-0.6	132	132	-0	-0
Nagaland	826	822	-4	-0.5	160	155	-5	-2.9
Tripura	1484	1481	-3	-0.2	317	315	-2	-0.5
NE Region	**16955**	**16531**	**-424**	**-2.5**	**3294**	**3107**	**-187**	**-5.7**

Table 3-9 : Status of report preparation of hydro power schemes in North-Eastern Region on 31 March 2021

State	HE Schemes concurred by CEA (MW)	HE Schemes under examination by CEA (MW)	HE Schemes returned to Project Authorities (MW)	HE Schemes under S&I (MW)	HE Schemes for which S&I is held up (MW)	HE Schemes dropped (MW)	HE Schemes yet to be allotted for development (MW)
Meghalaya	270	85	0	210	620	210	1312
Tripura	0	0	0	0	0	0	0
Manipur	66	0	0	0	0	1500	936
Assam	120	0	60	0	0	0	185
Nagaland	186	0	0	0	0	0	1272
Arunachal Pradesh	15,978	0	6403	588	9980	3998	14999
Mizoram	0	0	0	0	0	460	2076
Total (NER)	**16620**	**85**	6403	798	10600	**6168**	**20780**

(Figures in MW)

3.5. Hydropower Potential of Arunachal Pradesh

The topography of the State provides for very ideal conditions for development of hydroelectric power projects. There are five major river basins in the State, namely Kameng River basin, Subansiri River basin, Siang River basin, Dibang River basin and Lohit River basin. There are many smaller river systems in the State which also offer very attractive sites for hydropower projects. Almost all the major river systems flow in the North-South direction and ultimately drain into the Brahmaputra. Apart from the major rivers, the State has many small rivulets which are perennial in nature and providing ideal conditions for developing projects in the category of micro/mini and small Hydroelectric Project.

As per the preliminary ranking study done by the Central Electricity Authority (CEA), the total power potential from hydro projects in North-Eastern Region is estimated to be about 58971 MW

3.6. Power Situation in Arunachal Pradesh

Despite availability of such huge potential, the State has so far developed only 1115 MW till 31 March 2021. One project Lower Subansiri Hydroelectric project of 2000 MW is under construction by NHPC and is likely to be commissioned in year 2023-24. During the year 2020-21 peak demand was 158 MW but only 149 MW was met. Thus, the state Govt. has to resort to power cuts/ load shedding (source CEA Website).

Table 3-10 : Capacity addition target in hydro sector during 2022-27 for Arunachal Pradesh

Project name	Installed Capacity	Capacity addition	Share of the state
Subansiri Lower	2000 MW	2000 MW	281.90 MW

3.7. Development of Hydropower Demand

3.7.1. Present Status

The National Electricity Policy (NEP) entailed provision of adequate reliable power access to all citizens. The installed power generation capacity in country at the end of 11th plan about 200 GW. The capacity addition programme during the 12th plan period was targeted at 88.537 GW excluding 30 GW of RES against which capacity addition of 99.209 GW was achieved. Beyond 12th plan, capacity addition of 44.47 GW excluding power from RES upto year 2020-21 was targeted against which capacity addition of 27.93 GW was achieved till March 2021.

Table 3-11 : Total Generation and Growth in Energy Generation during period from 2009-10 to 2021-22

Year	Total Generation (BU)	Growth in Energy Generation (%)
2009-10	808.498	7.56
2010-11	850.387	5.59
2011-12	928.113	9.14
2012-13	969.506	4.46
2013-14	1020.200	5.23
2014-15	1110.392	8.84
2015-16	1173.603	5.69
2016-17	1241.689	5.80
2017-18	1308.146	5.35
2018-19	1376.095	5.19

Year	Total Generation (BU)	Growth in Energy Generation (%)
2019-20	1389.102	0.95
2020-21	1381.827	-2.49
2021-22	1490.277	7.85

The 19th Electric Power Survey (EPS) Report covering electricity demand projection of Distribution Companies, States / UTs, Regions and the All-India electricity demand projection has been brought out by CEA. As per 19th EPS, the electricity consumption on All-India basis during the year 2016-17, 2020-21 and 2026-27 has been assessed as 921 BU, 1300 BU and 1743 BU respectively. The electrical energy requirement on All-India basis during the year 2016-17, 2021-22 and 2026-27 has been assessed as 1160 BU, 1566 BU and 2047 BU respectively. The peak electricity demand has been assessed as 162 GW during the year 2016-17, 226 GW during 2021-22 and 299 GW during the year 2026-27.

The electricity consumption on all-India basis during the year 2031-32 and 2036-37 has been assessed as 2192 BU and 2672 BU respectively. The electrical energy requirement on all-India basis during the year 2031-32 and 2036-37 has been assessed as 2531 BU and 3049 BU respectively. The peak electricity demand has been estimated as 370 GW during the year 2031-32 and 448 GW during the year 2036-37.

Considering the electrical energy demand projection of 19th EPS, the power sector has to gear up for long term capacity addition and steps need to be taken to exploit the identified potential at an accelerated pace commensurate with the growing demand.

3.7.2. 50,000 MW Hydroelectric Initiative

Under the 50,000 MW initiative, 162 hydroelectric projects spreading in 16 states for the purpose of preparation of preliminary feasibility reports (PFRs) were taken up by CEA as nodal agency with CPSUs/ State Agencies as consultants. The PFRs were completed in September 2004 for all these projects with installed capacity of 47,930 MW.

As a follow up of preparation of PFRs, it was decided to take up implementation/ preparation of DPRs for attractive schemes. Based on preliminary techno-economic analysis 78 schemes (34020 MW) out of 162 schemes whose first-year tariff works out below Rs 2.50 /kWh were considered as low tariff hydroelectric schemes and were selected for taking up of detailed survey and investigations and preparation of DPR.

Out of 78 schemes, 19 are in Arunachal Pradesh (21,800 MW), 7 in Meghalaya (651 MW) and 4 are in Sikkim (835 MW) (Source CEA Website).

Oju Hydroelectric Project of 1850 MW capacity is covered in 19 schemes of Arunachal Pradesh. These projects are expected to yield benefits during 12th Plan and beyond.

3.7.3. Long Term Plan for Hydropower Development

As per the re-assessment of the hydroelectric potential carried out by CEA, the hydro potential of the country has been estimated about 150,000 MW. The hydro installed capacity as on 30 April 2022 is 46722 MW. Considering the unique advantages of hydropower and the increasing need of hydropower for grid stability / balancing, the Government has targeted to add 30000 MW by year 2030. CEA has also conducted a study to determine the optimal energy mix till the year 2030, considering about 70000 MW of hydropower by year 2030.

3.8. Necessity and Justification for Implementing the Project

As per India's National Determined Contribution (NDC) for Climate change submitted to the United Nations Framework Convention for Climate change, India has committed to increase its generation capacity from non-fossil resources to 40% of the total generation capacity and reduce the carbon intensity of its GDP by 30-35% by the year 2030 as compared to that in 2005. The commitment regarding non-fossil fuel capacity is proposed to be met mainly from installation of Solar and Wind power capacities, which are infirm sources of power i.e. the generation from these sources varies significantly with the change in the weather conditions. The targets are to add 160 GW of solar and wind power by 2022 and 440 GW by the year 2030. Integrating such large scale intermittent solar and wind power would cause problem in maintaining grid stability because generation from the other major source of power i.e. thermal power plants can be varied within a limited range only. Thus hydropower, which has unique features like quick ramping, black start capability etc. can play a very useful role in contemplating renewable source of power in stabilizing / balancing the grid. While there is increasing need for hydropower, the share of hydropower generation capacity in total electricity generation capacity has been steadily declining from a high of 50.32% in 1962-63 to about 11.6% in 20-22.

The gross annual per capita power consumption of Arunachal Pradesh is 514 kWh (for the year as 2020-21) compared to the national average of about 1200 kWh. The State plans to harness its enormous natural resources like forests and hydropower and exploit its mineral wealth to usher in an era of economic development and raise the per capita electricity consumption.

The State's generating capacity has increased substantially with the completion of 405 MW Ranganadi hydropower project, Kameng hydroelectric project (600 MW) and Pare hydroelectric project (110 MW). Subansiri hydroelectric project (2000 MW) is under construction and this project will provide electricity not only to Arunachal Pradesh and other states in the north-eastern region but also to other power-starved regions of the country.

Comparing the projected growth of peak power demand, energy requirement anticipated and increase in the generating capacity on the basis of new projects proposed and/or under construction/consideration, it is evident that there is a dire need to provide additional power to the National Grid to meet the objective of power on demand by 2030. New schemes have to be taken up immediately and implemented to derive timely benefits. The most important source of power development in the Northern Eastern region is hydroelectric power located in Arunachal Pradesh and other sister states.

The power from hydro projects in the North-Eastern region would be in excess of the demand in the region and would have to be exported for utilization in other regions of the country. Presently there is no problem in the availability of transmission systems beyond the North-Eastern power region for dispersal of power as the five power regions of the country are in the process of greater integration within a national grid.

Thus, implementing Oju Hydroelectric Project of 1878 MW capacity will not only meet the power requirement of Arunachal Pradesh but also can export excess power to other states and earn additional revenue for the state.

4. PROJECT HYDROLOGY

4.1. Introduction

The hydrological inputs are very important for the planning, execution and operation of any water resources development project. The hydrological studies are carried out at all the stages of project development starting from the pre-feasibility stage, detailed investigation and are continued even during the operation of the project. Hydrological studies usually carried out for the assessment of quantities of available water at project site and its time variation, estimation of expected flood (usually required for the hydraulic design as well as for safety of the structure) and sedimentation studies which are important from life point view of the project as well as its effect on the live storage.

The catchment of Oju Project lies in the state of Arunachal Pradesh, a mountainous state in India. The state is situated in North-Eastern part of India. This state is enriched with several rivers like Brahmaputra, Siang, Lohit, Dibang, Subansiri Kameng etc., which originate from mighty Himalayas in Tibet. They are mostly snow fed and perennial in nature and carry with them floods almost every year during monsoon and have huge hydro potential.

4.1.1. The Subansiri Basin

The Subansiri river basin is one of the largest sub-basins in the Brahmaputra valley. The study of the drainage basin of the Subansiri river and its tributaries in the Himalayan regime shows that the river system drains an area of about 30,000 sq.km. of the mountainous terrain ranging in height from 5591m (above m.s.l.) in the central Himalaya to about 152m near the foot hills. The drainage area up to the confluence with the Brahmaputra lies between latitude 27º(N) and 29º(N) and longitude 91º45' (E) and 94º45' (E).

The snow line or limit of perpetual snow in the Himalayas varies widely depending upon various local factors. The present snow line varies in altitude from about 4267m in the eastern part to about 5182m in the Western Himalayas.

Index map of Subansiri catchment showing the location of Dam site and Gauge and Discharge sites is given in Plate 4-1.

4.1.2. The River Profile

The Subansiri river originates beyond the Great Himalayan Range (Central Himalaya) at an altitude of 5340m above m.s.l. and after traversing about 375km joins the Brahmaputra River. The river flows through narrow gorges in most parts of its length and generally follows an easterly direction up to Siyum, and thereafter, it takes south-easterly course up to its confluence with its right-hand tributary named Kamla. Then, it flows in southernly direction up to Kherkatiasuti and after flowing for another 60km in south-westerly direction it joins mighty Brahmaputra River.

The river cuts across the Central Himalayan ridge in which occur a series of high peaks of 5486m and above. It follows a south easterly course along the Lesser Himalayan zone with an average height of 3048m and takes the name Subansiri. After traversing through the Miri hills of the outer Himalaya (Siwalik foothills), the Subansiri debouches into the plains of Assam near Dulangmukh. Before entering the plains, Subansiri cuts a steep gorge of unique beauty through the Siwalik rocks of Arunachal Himalayas. The total length of the river in the mountainous terrain is about 208km. The riverbed falls from a height of 4206m to 80m near Dulangmukh in the foothills.

Throughout its journey from the Central Himalayas to Arunachal foothills, the Subansiri receives the discharges of numerous mountainous streams big and small. The numbers of its tributaries are more in the Siwalik foothills than in other zones.

The longitudinal profile of Subansiri after it emerges from the hills into plains depicts the moderate fall in the riverbed. The first slope corresponds to the braided reach of the river. Thereafter, the river starts flowing in a highly winding fashion, followed by a small sector of straight course. Afterwards the meandering nature is continued though with varying degree depending on the variation of discharge affected by the joining of one tributary or the other. There is no abrupt drop in gradient close to the confluence with the Brahmaputra.

4.1.3. Project Catchment

The dam site for the Oju HE Project is located in the upper reaches of the Subansiri between the Redi and Oju villages at a Longitude of 93º21’ E and Latitude of 28º25’N, about 60 km up stream of Limeking town. The total catchment area up to project site is about 9827 sq.km. Out of which about 3128 sq.km. lies below the permanent snow elevation line of El. 4500m. The project catchment is formed by numerous streams which are perennial in nature. Nye Chu, Laru Chu and Yume Chu are three main streams contributing to the project catchment. Tsari Chu, another major stream joins the Subansiri just downstream of the project catchment. In the upper reaches of the basin, the Subansiri and its tributaries are fed by the melting of snow and in the lower reaches these are fed by ground water and rain water.

The project catchment is depicted below:

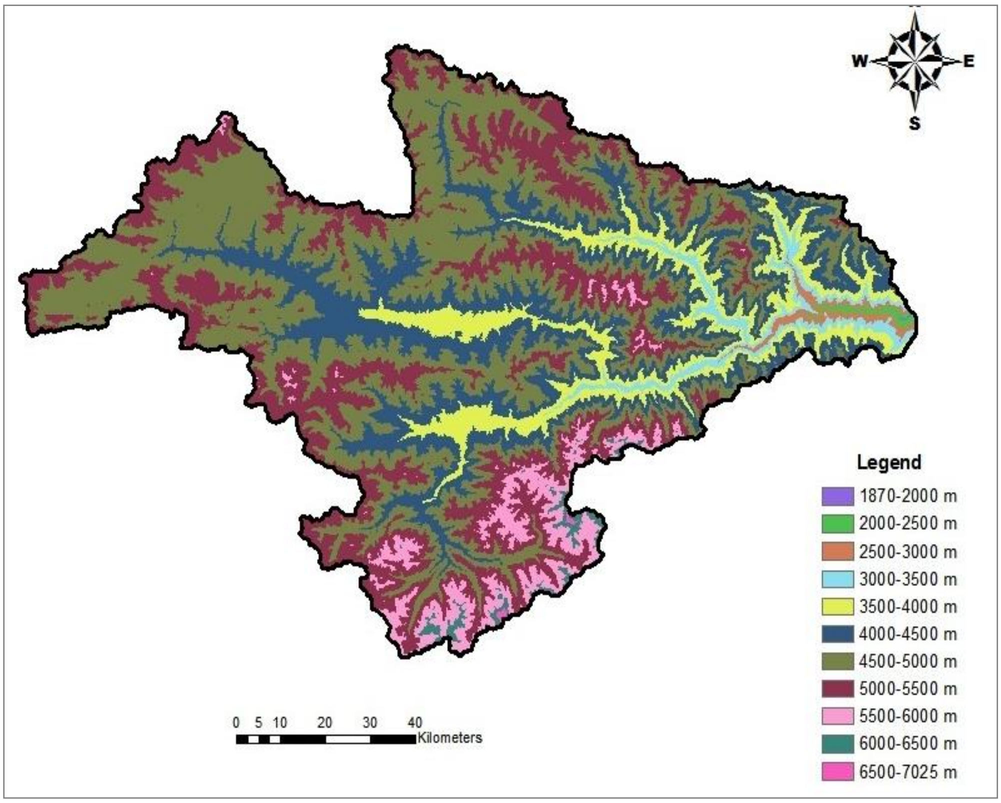


Figure 4-1: Catchment Map of Oju Project

Hypsometric details of the project catchment are shown below:

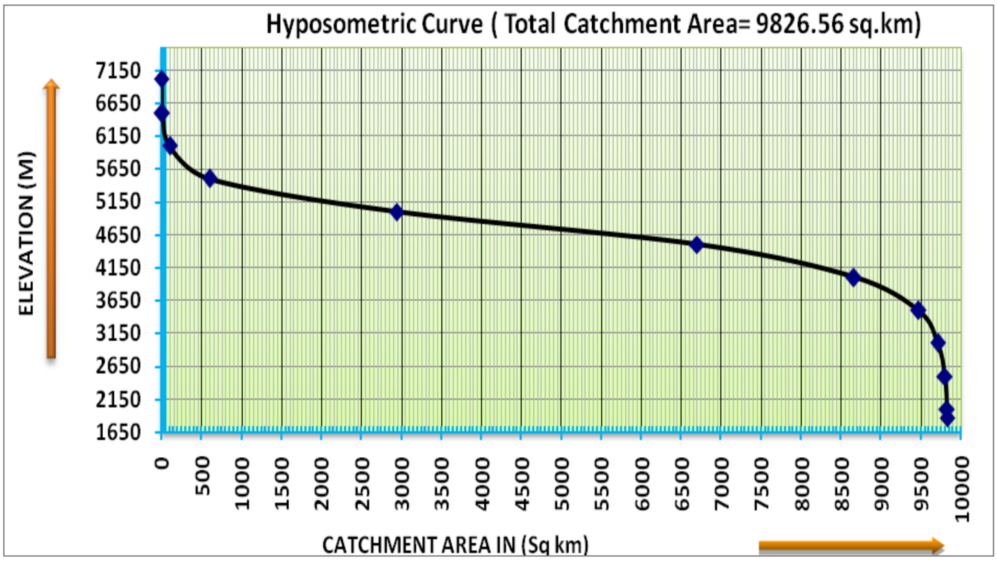


Figure 4-2: Hypsometric Curve for Oju Project

4.1.4. Meteorological Aspects

The Eastern and Central Himalayas function as a great climate divide. In winter, it serves as a barrier to the intense cold continental air flowing southwards and in monsoon months, the moist rain-bearing winds are forced up the mountains to deposit their moisture.

The south west monsoon, which enters Assam and adjoining area around the end of May and beginning of June, gets established firmly over the entire North East India by June end. During the monsoon season a low pressure region extends from the Rajasthan to the Bay of Bengal. This monsoon axis oscillates about it normal position to the North and south during the season. When it moves north towards the foothills of Himalayas the rainfall over Assam increases and this is one of the primary causes of flood in the Brahmaputra valley. Sometimes a minor East-West oriented trough over Assam and West Bengal, while the primary trough is along its normal position, can also give rise to increased precipitation over the Brahmaputra catchment.

The other features that normally cause increased precipitation over the Brahmaputra basin are passage of upper air trough in the monsoon westerlies and sometimes by the appearance of the remnants of mid latitude western disturbances over extreme north Arunachal Pradesh in conjunction with other precipitation causing features.

The above is an overall simplified account of weather and precipitation distribution, which is influenced by local orographic effects with minor ranges, spurns, valleys of different width and narrow gaps permitting winds to enter from particular direction, in the sheltered valleys. The orography of the catchment is so complex that a detailed study would be possible only with a dense network of observatories.

The other meteorological situations causing very heavy rainfall are the passage of cyclonic storms, originating in Bay of Bengal, over the area. This is generally noted in late May or June and in the late Sept. or October, when the cyclonic storm developing over the Bay initially moves towards North-West re-curves towards North-East and when it moves to the North of about 20º(N).

Study of rainfall from May to October is thus important for design storms study for finding flood potential of big structures like dam and spillways.

4.1.5. Hydro Meteorological Network

Background of the Setup

The design of a proper network of meteorological stations maintained for a sufficiently long time is necessary for various objectives like water resource assessment, flood forecasting, design storm, estimation of water balance etc. This requires detailed examination of the various sub-basins, the spatial variation of rainfall in the catchment, the topography, and the orography etc.

Temperature and Humidity

The climate in the entire region is humid and fairly uniform. Thick mist formation from early morning every day, which completely envelope the area and blocks out the sun is generally the climatic feature during winter. The temperature varies from at higher altitude to at lower altitude. The maximum temperature at Ziro is 27.3ºC and minimum (-)8ºC, at Dibrugarh maximum 30.9ºC, minimum 10.2ºC and at Tezpur maximum 32.2ºC and minimum 11.4ºC. The basin experiences extreme cold temperatures during the winter months. The relative humidity at these stations ranges from maximum 94% to minimum 62%.

Precipitation

Subansiri basin extends from tropical to temperate zones and therefore the area exhibits a great diversity in rainfall characteristics.

In the Northern and Central Himalayan tracts precipitation is scarce on account of high altitudes. Showers during monsoon period occur in the deep valleys and during winter months occurrence of heavy snowfall on the mountains is a general feature. South-East part of the Subansiri basin comprising the Sub Himalayan and the plain tract in Arunachal Pradesh and Assam, lies in the tropics. Precipitation occurs in this region in copious quantities due to North - East as well as South - West monsoon. Particularly the South-West monsoon causes very heavy precipitation in the whole of this region during May to October. July and August are generally the wettest month of the year.

Major portion of rainfall in Arunachal Pradesh occurs in monsoon season of June to September and heavy precipitation is generally limited to South-Western parts. The southern part receives a seasonal rainfall of 50mm to 3000mm with pockets of high rainfall of over 3000mm. Some rainfall occurs in the post monsoon months and in winter season also.

Long term rainfall is available at Limeking, Siyum and Taliha stations in the upper catchment of Subansiri for varying periods from 1966 to 2007. The average annual rainfall at these three stations works out to about 2735 mm. Annual Rainfall Normals at these stations are depicted in the plot and tables given below:

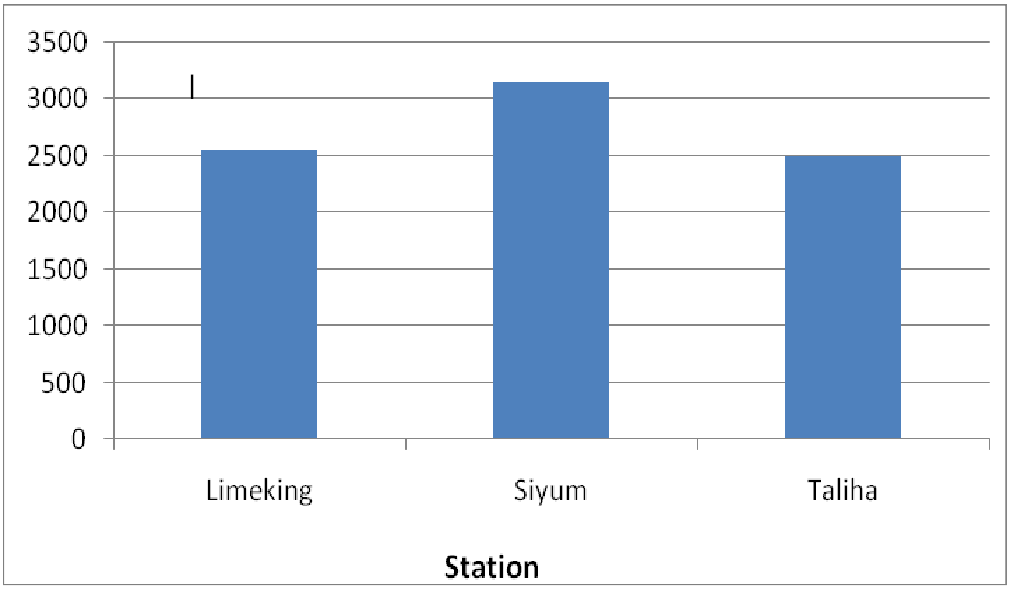


Figure 4-3: Normal Rainfall in the Upper Subansiri Basin

Table 4-1: Monthly Rainfall (mm) at Limeking

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1966				169.6	209.0	516.6	558.6		385.2		
1968	25.0	69.0	149.0	98.0	332.0	448.1	449.0	399.0	362.0	134.0	
1969		48.2	100.0	166.1	330.0	503.1	502.0	394.5	331.0		
1977						55.7	519.8	458.0	334.1	134.3	

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1978	19.1	55.7	33.8	111.4	381.6	548.6	461.4	206.0	456.3	139.0	67.7
1979	296.9	140.2	227.2	325.3	540.2	733.0	511.6	599.2	525.0	380.6	64.0
1980	183.9	123.0	416.0	464.2	588.6	955.3	663.8	548.1	339.0	153.2	18.2
2001							241.4	503.0	345.7	177.8	28.6
2002	33.9	37.9	120.7	64.8	306.6						
2003									56.7	41.0	21.0
2004	82.0	62.0	59.6	277.0	93	40.4	41.7	48.9	104.9	54.3	0
2005	4.8	40.5	78.4	64	53.4	63.2	57.6	79	164	62	7
2006	103	218									
Average	**93.6**	**88.3**	**148.1**	**193.4**	**314.9**	**429.3**	**400.7**	**359.5**	**309.4**	**141.8**	**29.5**

Table 4-2: Monthly Rainfall (mm) at Siyum

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1966	11.4	122.0	200.0	293.0	217.0	604.0	372.0		356.0		129.4
1968	69.0	90.1	187.0	188.0	383.0	511.0	615.0	284.1	406.0	319.0	80.0
1969		37.0	193.0	216.0	292.0	604.0	567.0	418.0	132.0	4.0	88.0
2001							381.0	475.3	540.7	244.2	93.4
2002	92.2	44.0	281.6	316.7	391.1	495.0	766.7	354.3	333.5	95.5	15.0
2003	83.5	187	240.8	215	349	511.70	212.4	502.4	654.9	367.5	47.7
2004	38.7	64.6	243.4			505.7	519.2	352.8	472.0	185.3	8
2005		147.7	537.1	356.4	365.8	333.3	307.2	806.1	207	273.9	31.2
2006	13	173.2	217.9	310.4	523.5	482.2	408.3	285.1	301.9	235	105.6
2007	30.7		184.6								
Average	**48.4**	**108.2**	**253.9**	**270.8**	**360.2**	**505.9**	**461.0**	**434.8**	**378.2**	**215.6**	**66.5**

Table 4-3: Monthly Rainfall (mm) at Taliha

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1968	83.0	167.9	183.4	169.1	353.1	258.0	530.1	346.6	113.0	128.0	
1969		75.0	164.1	348.1	221.3		347.2	333.6	488.2	41.3	
1976			99.1	181.9	215.7	417.7	504.0	341.2	211.8	220.1	124.2
1977	58.9	124.4	141.1	450.1	357.7	357.4	344.2	319.2	310.6	165.3	60.0
1978	37.3	71.1	174.4	458.1	318.8	437.0	342.1	161.2	422.4	108.4	76.6
1979	40.8	144.1	182.4	272.4	155.7	333.0	471.4	339.3	315.4	145.8	36.8
1980		139.5	219.9	241.8	251.4	69.7	287.4	268.0			29.6
1981	128.4	126.5	189.2	127.5	569.7	488.7	724.4	130.7	65.7	68.7	45.6
1997		36.7	170.0	99.8	293.4	280.4	146.8	269.6	118.2	126.8	123.2
2000								498.4	400.0	161.4	96.8
2001	38.2	83.6	141.0	610.0	275.8	358.2	305.5	376.0	486.7	245.7	132.9
2002	184.5	69.5	184.0	464.4	98.6	270.7	475.8	363.3	335.0	46.6	34.0

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
2003	40.8	104.2	171.6	267.1	279.8	417.0					
2006	13.9	37.5	129.4	186	118.2	246.2	292.8			227	28.2
2007	91	94.4	78.6								
Average	**71.7**	**98.0**	**159.2**	**298.2**	**269.9**	**327.8**	**397.6**	**312.3**	**297.0**	**140.4**	**71.6**

Stream flow and river gauges

River gauges have been established since 1956 on Subansiri river system. There are at present three main gauge stations. Daily flow at Chouldhowaghat, Gerukamukh (Lower Subansiri Dam Site) and Menga (Upper Subansiri Dam Site) are available for varying period. Period of availability of 10-daily flows at these sites is shown in the following Table.

Table 4-4: Period of Data Availability

S.No.	Name of Site	Rain-fed Catchment Area (sq.km.)	Snow-fed Catchment Area (sq.km.)	Total Catchment Area (sq.km.)	Period of Data Availability
1	Chouldhowaghat	19376	7893	27269	1973 - 2002
2	Gerukamukh	18494	7893	26387	1973 - 2009 (With gaps)
3	Menga	7546	7119	14665	2003 - 2008

4.2. Water Availability

The assessment of water availability at the diversion site of any hydro-electric project is a very important study. Due care should be taken while computing the flow series at the project site. Long-term observed flows data at any hydro-electric project site are rarely available. The flow series at the diversion of the project may be computed by transferring the long-term observed flow data from nearby G&D site on the same river. The flow data of the G&D site used for the study is required to be validated and any inconsistency in the data may be corrected before transferring it to project site.

4.2.1. Previous Studies

National Hydro Power Corporation (NHPC) had prepared a Hydrology Chapter on Upper Subansiri Project in 2004. Three hydroelectric projects namely Subansiri Upper, Subansiri Middle, and Subansiri Lower were proposed in Subansiri basin. Water availability study at Menga (Upper Subansiri Dam site) was performed considering entire Subansiri river system as one, so as to maintain consistency in the flow series at all the three project sites.

Water availability series for the Oju-I project was worked based on 20 years synthetic flow series generated at Menga by transferring it to the Oju-I project site on catchment area proportion basis.

4.2.2. Present Water Availability Study:

Long term 10-daily discharge data is available at Chouldhowaghat for the period from 1973 - 2002. 10-daily discharge data for the period from 1973-1997 is also available at Gerukamukh G&D site with some gaps. Both the sites were being managed by the CWC/ Brahmaputra Board. Gerukamukh G&D site is located near the dam site of the under construction Lower Subansiri Project of NHPC. In addition, 10-daily discharge data is also available at Gerukamukh G&D site and Menga (Upper Subansiri Project Site) for the concurrent period of 2003-08. Present Water Availability Studies are based on the following 10-daily discharge data available at different sites.

Table 4-5: Period of data availability at different sites

S.No.	Name of Site	Total Catchment Area (sq.km.)	Period of Data Availability
1	Chouldhawaghat	27269	1973-2002
2	Gerukamukh	26387	1973-2009 (With gaps)
3	Menga (Diversion site)	14665	2003-2008

Observed discharge data at Menga G&D site is available only for limited period i.e., from 2002 to 2008. The discharge series at Menga has been extended based on the long-term flow series available at Gerukamukh G&D site. For doing so, monthly correlation between the monsoon periods (May to October) discharge for the two sites for the concurrent period (2003-08) has been established. Missing data at Gerukamukh has been filled up with help of the data observed at Chouldhawaghat site located downstream.

4.2.3. Flow data observed at Different sites:

Observed 10-daily discharge pattern is shown in the following plots:

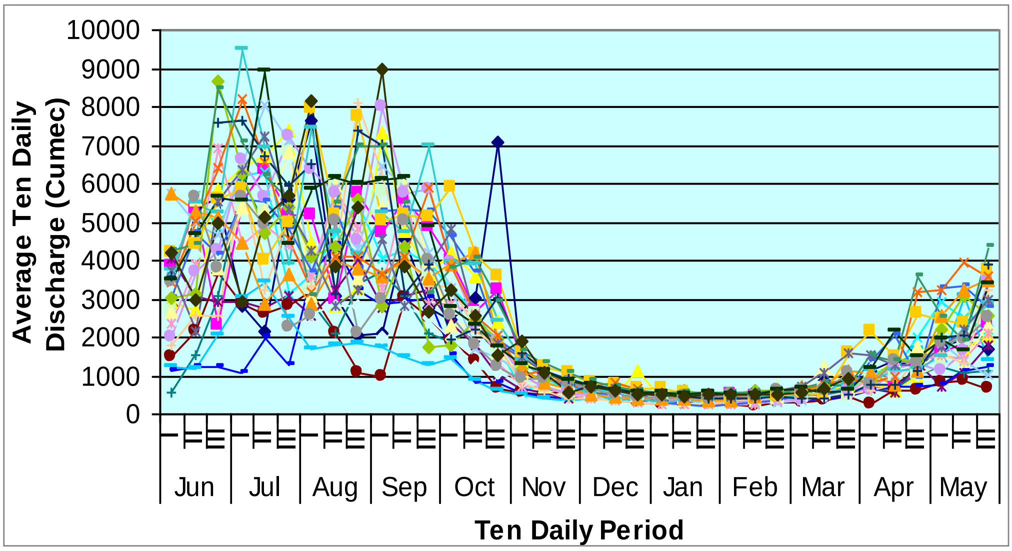


Figure 4-4: 10-daily Observed Flows at Chouldhawaghat

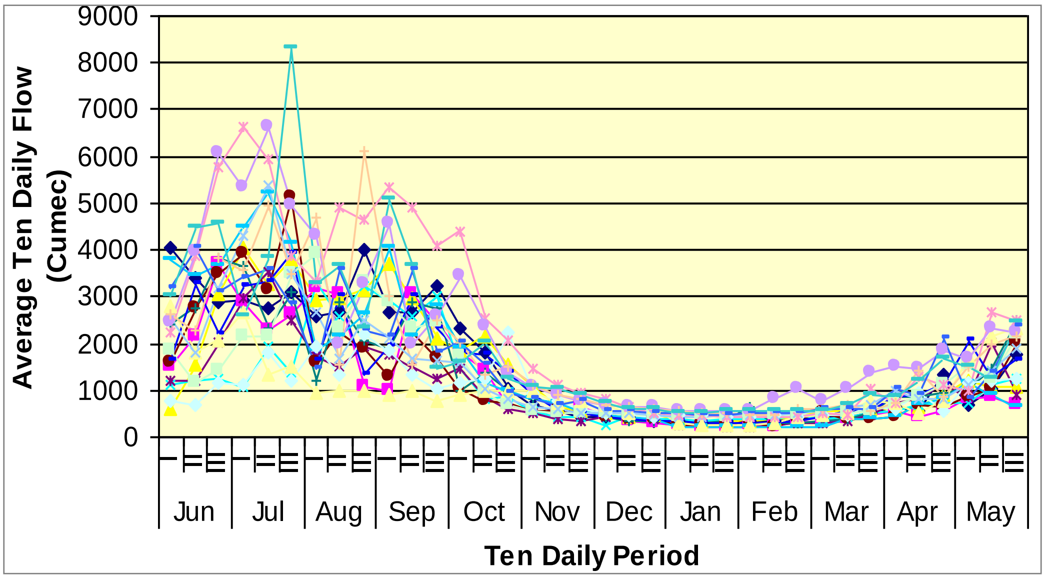


Figure 4-5: 10-daily Observed Flows at Gerukamukh

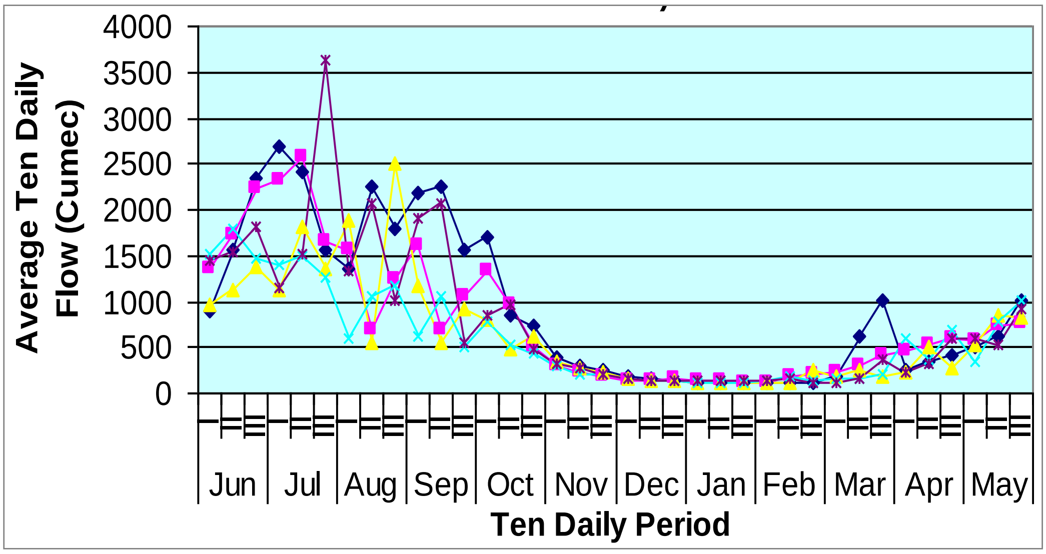


Figure 4-6: 10-daily Observed Flows at Menga

4.2.4. Completion of Series at Gerukamukh

Flow series at Gerukamukh is available for the period from 1973 to 1997 with many data gaps. As observed from comparison of flow data at Chouldhawaghat and Gerukamukh it appears that data observed at Chouldhawaghat is about 1.506 times that of observed at Gerukamukh for the concurrent period. The gaps in Gerukamukh data have been filled up based on the ratios of flow at Chouldhawaghat and Gerukamukh data for the concurrent period for Monsoon (May to October) and Non-Monsoon (November to April). Reduction factors of 1.60 and 1.227 have been applied for the monsoon season and non-monsoon season, respectively. Thus, a long-term series have been derived at Gerukamukh for the period from 1973 to 2002.

4.2.5. Derivation of Long-Term Flow Series at Menga Site

Site specific observed discharge data (at Menga G&D site) is available only for limited period i.e., from 2002 to 2008. The discharge series at Menga has been extended based on the long-term flow series available at Gerukamukh G&D site. For doing so correlation between the monsoon period (May to October) discharge for the two sites has been established as shown below:

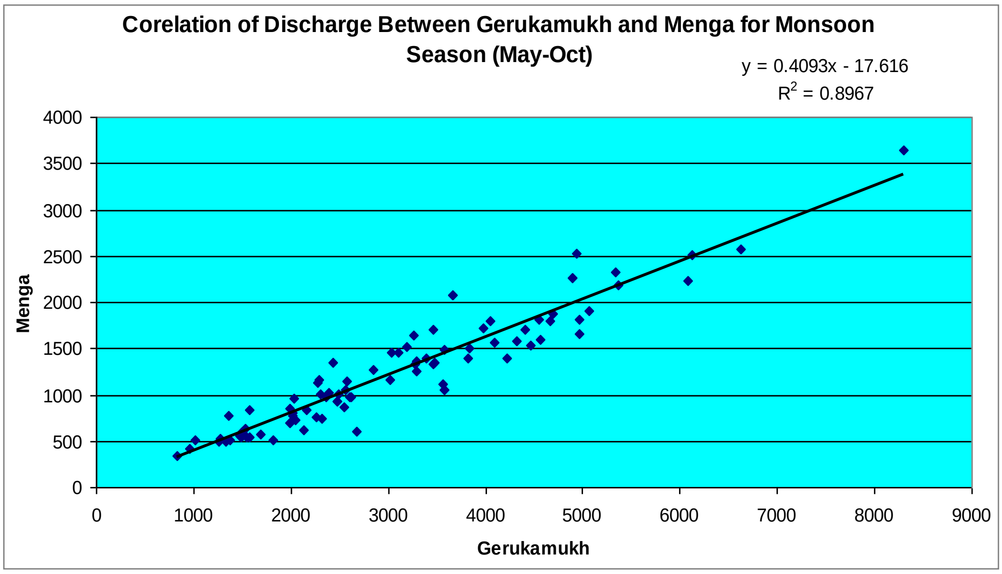


Figure 4-7: Monsoon Correlation between observed Flow at Gerukamukh and Menga

The monsoon period data for the extended period at Menga has been worked out based on the above relationship. The 10-daily flow data during the non-monsoon period (i.e., November to April) has been filled up based on the ratio of individual 10-daily average of the observed data at Menga to the average total flow observed during the entire monsoon period (i.e., May to October) as shown below:

Table 4-6: Ratio of 10-daily Flows to total Monsoon Flow at Menga (2003 to 2008)

Month	10-daily	Ratio of avg. 10-daily flow / Total avg. monsoon flow
Nov	I	0.014
	II	0.011
	III	0.009
Dec	I	0.007
	II	0.006
	III	0.007
Jan	I	0.005
	II	0.005
	III	0.006
Feb	I	0.005
	II	0.006

Month	10-daily	Ratio of avg. 10-daily flow / Total avg. monsoon flow
	III	0.006
Mar	I	0.007
	II	0.013
	III	0.021
Apr	I	0.015
	II	0.018
	III	0.022

Derivation of Flow Series at Oju Project site

Long term 10-daily series worked out at Menga has been transferred to Oju project site based on the catchment area proportion (9827 / 14665 sq.km).

Approval of CWC of Flow Series at Oju Project Site

CWC vide letter No.2/ARP/55/CEA/2012-PAC/4982-84 has examined the flow series and reduced the flow series by an additional correction factor of specific yield apart from catchment area correction factor (of Menga). The series at Oju has also been made consistent with the Subansiri Upper and Nalo HEP by CWC. The final approved flow series for the Oju project for the period from 1973-74 to 2001-02 and 2003-04 to 2008-09 has been given in the Table 4-8. The average annual yield of the approved series at Oju HEP works out to 11314 MCM (1151 mm). Annual yield in 50% and 90% dependable years works out to 11659 MCM and 7465 MCM, respectively.

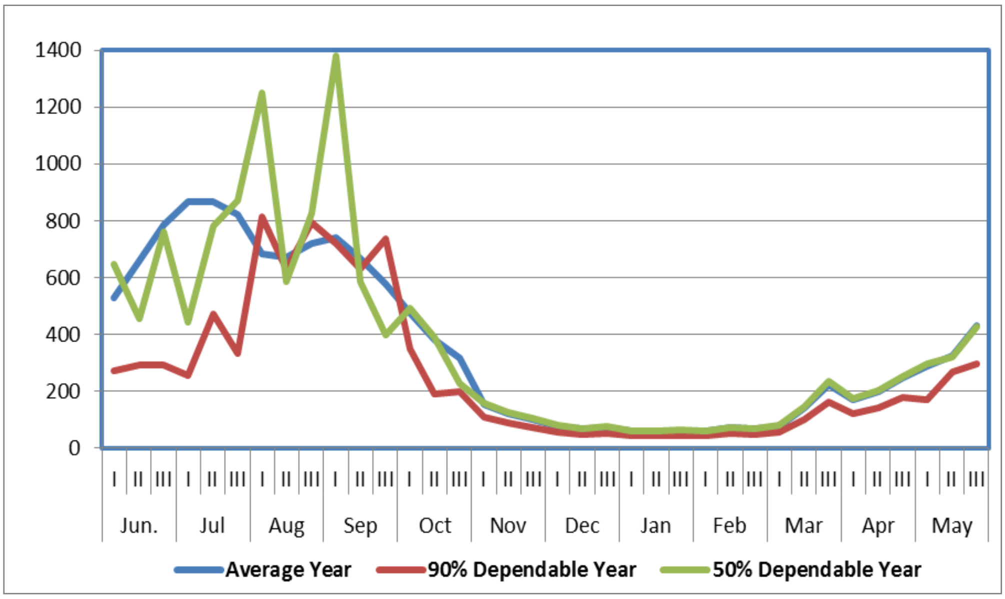


Figure 4-8: Ten Daily Flow (m^3/s) in Average, 90% Dependable and 50% Dependable Years

It is also pertinent to mention that there are numerous perennial streams which join the main river between the dam and powerhouse at regular intervals. These streams are originating near an elevation of about 4000m-5000m and have flow throughout the year.

Table 4-7: Streams Joining Subansiri River Between Oju Dam & Powerhouse

Location	Notation	Name of the stream nala	Catchment area (sq km)	Max elevation (m)
Streams joining **Left Side** to Mainstream of Subansiri	**L 1**	Dio Siko - Oyi Siko	73.00	5063
	L 2	Rijugna Siko	10.14	4365
	L 3	Niyonthi Siko	7.40	4264
	L 4		5.86	3802
	L 5		3.87	3509
	L 6		3.41	3527
Streams joining **Right Side** to Mainstream of Subansiri	**R 1**	Chetu Suko	17.51	4391
	R 2	Doju Bung Nalla	16.98	4389
	R 3	Oju Siko	41.77	4870
	R 4	Yang Siko	3.52	3486
Subansiri Catchment Area Between Dam and Powerhouse			**222.79**	

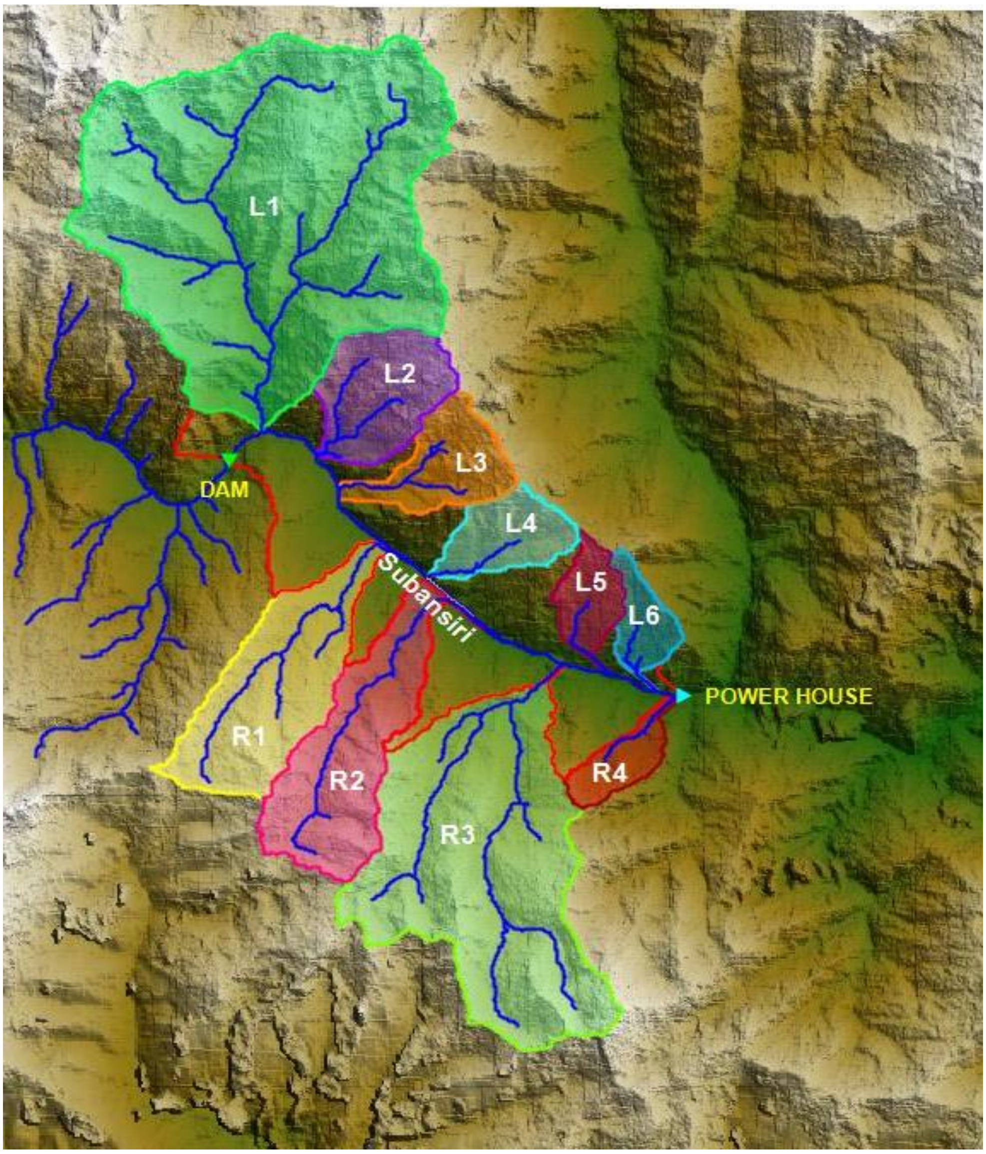


Figure 4-9: Streams Joining Subansiri River between Oju Dam & Powerhouse

4.3. Design Flood

4.3.1. General

Estimation of design flood for the design of different type of structures is a very significant component of a hydrological study. Proper estimation of the design flood value is very important. The underestimation of design flood may risk the safety of the dam structure as well as the population and otsher resources in the downstream of the dam. On the other hand, overestimation of the design flood may result in increase in the cost of structure and wastage of valuable resources.

4.3.2. Design Flood Criteria

As per the Manual on Estimation of Design Flood (CWC, 2001) as well as BIS: 11223-1985, "Guidelines for Fixing Spillway Capacity", the following criteria applies to determine the design flood of a spillway for a particular category of dam:

Table 4-8: Design Flood Criteria

Classification	Gross Storage ($x10^6$ m^3)	Hydraulic Head (m)	Inflow Design Flood
Small	0.5 - 10	7.5 –12	100 year return period
Intermediate	10 - 60	12 –30	SPF
Large	> 60	> 30	PMF

Oju Project falls under the category of Large Dam and consequently inflow Design Flood for the project is Probable Maximum Flood (PMF).

4.3.3. Present Study

The design flood study for the project has been carried out using following two approaches.

- Hydro-Meteorological Approach.
- Probabilistic approach (i.e., flood frequency analysis)

Hydro-meteorological approach is the most rational method for flood estimation and generally recommended. The short-term rainfall-runoff records at project site as well as of upper catchment along with physiographic characteristics are required for this study.

The Probabilistic approach is the most common procedure for the analysis of annual flood peak data of sufficiently longer duration at a gauged location. This approach can be applied to any type of hydro-meteorological data, but it is widely used with flood data. Therefore, it is sometimes designated as flood frequency analysis.

4.3.4. Hydro-Meteorological Approach

This approach has been widely used for the estimation of design flood for the medium and large project. The design flood study by this approach take in to account all the vital physiographic as well as hydro-meteorological parameters of the project basin. The main advantage of this approach as compared to Probabilistic approach is that it gives a complete flood hydrograph which allows making a realistic determination of its moderating effect while passing through a reservoir or a river reach.

The hydro-meteorological approach needs two basic inputs i.e., unit hydrograph and the design storm to arrive at the required flood. The unit hydrograph is the discharge hydrograph resulting from the 1 cm excess rainfall experienced uniformly over the basin at a uniform rate during a specific period of time. The unit hydrograph may be computed from the project specific observed hydrograph for few higher flood events. In absence of the essentially required hydro-meteorological data, a synthetic unit hydrograph is developed using catchment physiographic characteristics.

The design storm input in the present case is Probable Maximum Precipitation (PMP). PMP is defined as theoretical greatest depth of precipitation for a given duration that is never expected to be exceeded over a particular drainage area.

In absence of site specific short interval rainfall runoff records, the procedure for estimation of unit hydrograph given in "Flood Estimation Report for Sub Zone 2(a)" has been adopted.

The River flood in the Himalayan catchment are constituted by two basic component i.e. runoff contribution from the rain fed part and snow melt contribution snow/ glaciers. Therefore in the present study, the design flood has two components i.e. flood due to rainfall from the rain fed catchment and flood contribution from snow fed area.

The Oju catchment lies between Longitude 91º30′E to 93º21′E and Latitude 27º50′N to 29ºN. A concrete gravity dam of 90m height is proposed to be constructed on Subansiri River upstream of Oju village with gross storage capacity of 31.8 MCM. The longitude and latitude of proposed dam site are 93º21'E and 28º25'N, respectively. As the height of the dam is more than 30m, as per Central Water Commission's criteria and IS-11223-1985, the spillway of the Oju project qualifies to be designed to negotiate probable maximum flood. The design flood for the project has been estimated by adopting the deterministic approach using unit hydrograph analysis and developing the distributed hydrological model for the basin.

Rain-fed and Snow-fed Catchment Area

For the present study the catchment area pertaining to Subansiri HE Project has been computed by GIS processing of SRTM digital elevation model. These DEM are available in 5 degree x 5 degree tiles. The entire catchment of Subansiri upper HE project lies in SRTM tile namely srtm_55_07 available in WGS 84 co-ordinate system. The same has been converted to UTM-46 co-ordinate system through co-ordinate transformation. There is no data available about permanent snow line which may be varying from 4000m to 5000m. For the present study, the permanent snow line has been assumed at El. 4500m. For distributed hydrological analysis the entire catchment (basin) up to the project site has been divided into 3 sub-basins, SB-1, SB-2 and SB-3. The total catchment area up to Oju project site as obtained by GIS processing of STRM DEM is 9827 sq.km, comprising of 3128 sq.km as rain-fed and 6699 sq.km as snow-fed. The catchment area plan of the project showing the sub-basins is given in Figure 4-10. The sub-basin wise rain-fed and snow-fed catchment area is given in Table 4-10.

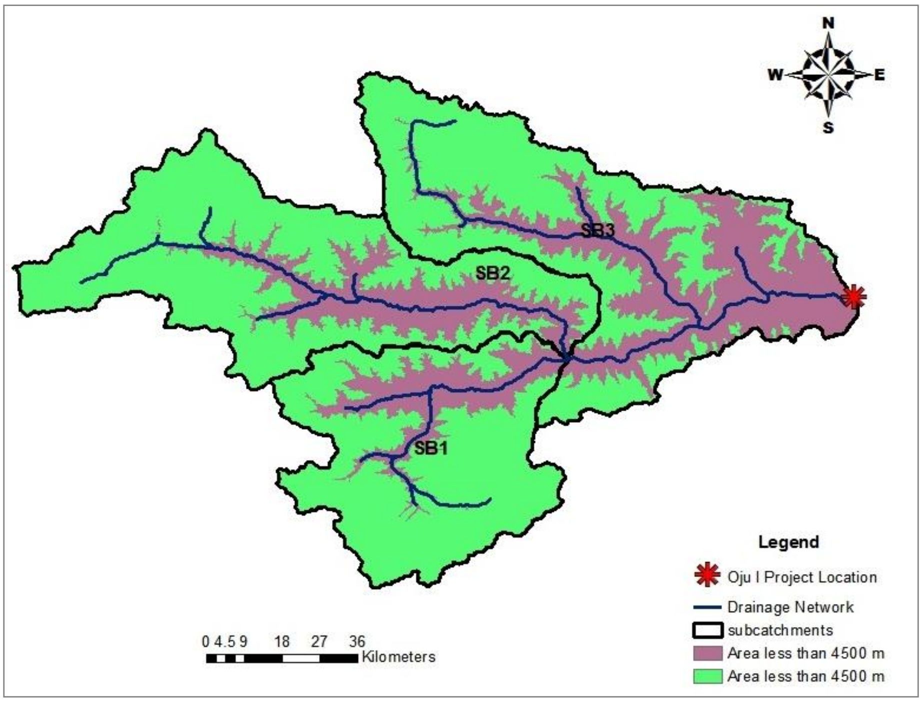


Figure 4-10: Catchment Area Plan of Oju Project showing Sub-basins

Table 4-9: Rain-fed and Snow-fed Catchment Area of Sub-basins of Oju Project

Sub-basin	Total area (sq.km)	Rain-fed Area (sq.km)	Snow-fed Area (sq.km)
SB1	**2631**	**596**	**2035**
SB2	**3421**	**890**	**2531**
SB3	**3775**	**1642**	**2133**
Grand-Total	*9827*	*3128*	*6699*

Design Storm

Design Storm studies of the Upper Subansiri Project located downstream of the proposed Oju Project were carried out by IMD, Delhi in 2011. IMD has given 2-day PMP value as 24.5cm for the Upper Subansiri Catchment vide letter no. HS-32/1/2011-DSU dated 23-05-2011. The same has been adopted for the present study. The 2-day SPS and PMP estimates for the Upper Subansiri Catchment furnished by IMD are 21.3cm and 24.5cm, respectively.

Temporal Distribution

IMD, Delhi has supplied the time distribution for 1-day and 2-day rainfall as given in Table 4-10. The same has been adopted to estimate design flood.

Table 4-10: Time Distribution of Rainfall for Upper Subansiri Catchment

Duration (Hour)	1-day	2-days
0	0	0
3	35	25
6	53	38
9	65	46
12	74	52
15	82	58
18	89	63
21	95	68
24	100	73
27		77
30		81
33		85
36		88
39		91
42		94
45		97
48		100

The hourly distribution of rainfall has been worked out by plotting the 2-day rainfall distribution supplied by IMD, Delhi. The plot is given in Figure 4-11.

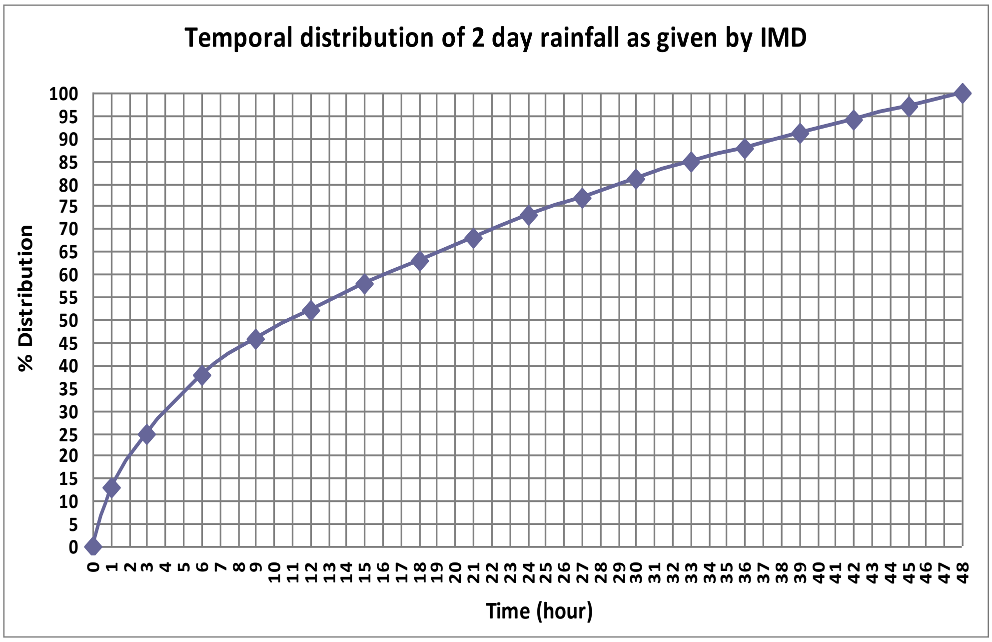


Figure 4-11: Temporal Distribution

The hourly temporal time distribution coefficient and normalized temporal time distribution coefficient used for 12 hour bell is given in Table 4-11.

Table 4-11: Hourly Temporal Distribution of 2-day Rainfall for 12 Hour Bell

Time (hour)	Temporal Distribution (%)	Normalised temporal distribution (%) for bells of 12-hour each
1	13	25
2	20	38
3	25	48
4	30	58
5	34	65
6	38	73
7	41	79
8	44	85
9	46	88
10	48	92
11	50	96
12	52	100

Unit Hydrograph

In the absence of concurrent rainfall-runoff data of short interval the unit hydrograph for all the three sub-basins have been worked out based on CWC's Flood Estimation Report for Sub-Zone-2(a). The sub-basin parameters as well as the UG parameters of SB-1, SB-2 and SB-3 are given in Annexure 4-1. The unit hydrographs of SB-1, SB-2 and SB-3 as used for the distributed hydrological model and their plots are also appended in Annexure 4-1.

Snowmelt Contribution

Snowmelt contribution has been estimated based on the formula Guide to Hydrological Practices (WMO No. 168-1994) taking the mean daily temperature as 3º centigrade. The formula used to estimate the snowmelt contribution is given below:

h= (0.30+0.012P)*Tavg+1.0 mm

where,

h = Daily snowmelt in mm

P = Daily rainfall in mm

Tavg = Mean daily temperature in (ºC)

Loss rate

The loss rate for rainfall has been assumed as 2.4 mm/hour as per FER-2(a).

Base Flow

The base flow has been adopted as 0.05 Cumec /sq.km as applicable for FER-2(a).

Design Flood (PMF) Computations

The total catchment area at Oju project site is about 9827sq.km. Hence, the PMF computations for the project have been carried out by distributed hydrological approach comprising of three sub-basins and one routing reaches as shown in Figure-10. As discussed previously, a uniform 2-day areal PMP depth of 24.5 cm has been taken for all the sub-basins. The hourly incremental rainfall has been worked out taking 4 bells of 12 hour each and normalized temporal distribution of Table 4-12 for each bell. The hydrographs of each sub-basin has been computed by convoluting the critically sequenced hourly effective incremental rainfall on the respective unit hydrograph.

The channel routing has been carried out by Muskingum method. The combined flood hydrograph of SB-1 and SB-2 has been channel routed through reach between confluence of SB-1 and SB-2 and project site. The sub-basin SB-3 flood hydrograph has been added to routed flood hydrograph to get the design flood (PMF) at Oju Project site. The Muskingum routing parameters used for channel routing are given in Table 4-12.

Table 4-12: Muskinghum Routing Parameters

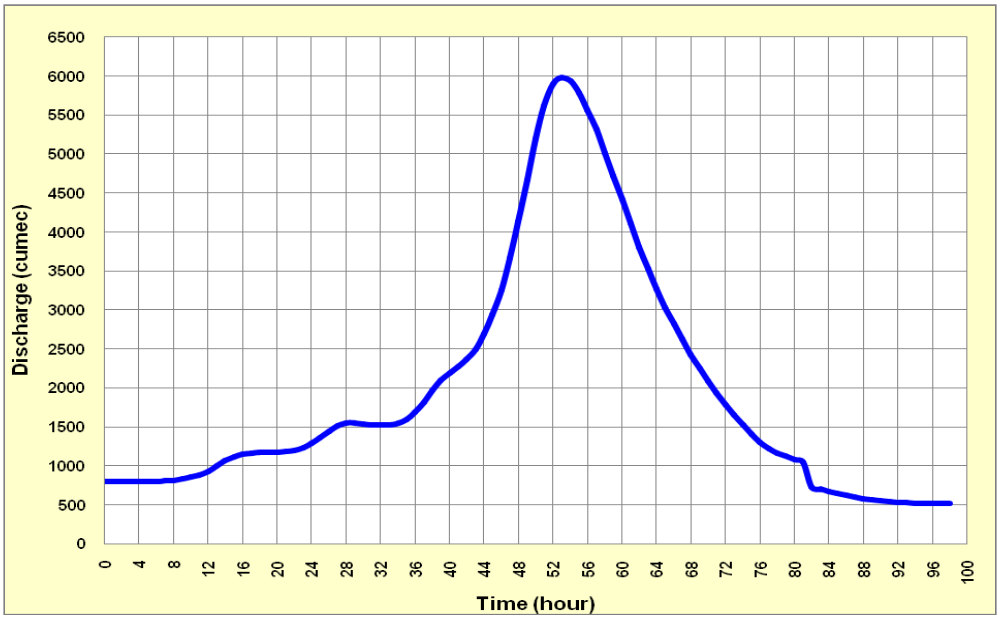
Routing Reach	**Reach length (km)**	**Number of Routing Steps**	**Muskingum "K" (hour)**	**Muskingum "X"**
Reach between confluence point of SB-1 &SB-2 and the project site	77.77	3	2.5	0.2

The design flood (PMF) hydrograph for Oju Project is given in Table 4-13. The plot of the same is given in Figure-12. Based on the results of distributed hydrological approach the design flood (PMF) with a value of 6031 Cumec is recommended for Oju project.

Table 4-13: Design flood (PMF) hydrograph for Oju Project

Time (hour)	Discharge (Cumec)	Time (hour)	Discharge (Cumec)	Time (hour)	Discharge (Cumec)
0	803	38	1968	76	1307
1	803	39	2095	77	1225
2	803	40	2197	78	1168
3	803	41	2274	79	1122
4	803	42	2368	80	1084

Time (hour)	Discharge (Cumec)	Time (hour)	Discharge (Cumec)	Time (hour)	Discharge (Cumec)
5	803	43	2496	81	1051
6	804	44	2691	82	731
7	807	45	2946	83	702
8	817	46	3261	84	674
9	833	47	3665	85	649
10	854	48	4130	86	624
11	887	49	4672	87	602
12	932	50	5203	88	581
13	996	51	5625	89	564
14	1065	52	5903	90	550
15	1120	53	**6031**	91	539
16	1156	54	5934	92	532
17	1168	55	5785	93	526
18	1170	56	5568	94	523
19	1170	57	5315	95	520
20	1175	58	5019	96	518
21	1185	59	4723	97	517
22	1199	60	4419	98	517
23	1234	61	4112		
24	1286	62	3812		
25	1364	63	3527		
26	1447	64	3274		
27	1510	65	3037		
28	1548	66	2823		
29	1551	67	2623		
30	1539	68	2430		
31	1526	69	2253		
32	1521	70	2089		
33	1529	71	1934		
34	1547	72	1789		
35	1599	73	1652		
36	1688	74	1523		
37	1820	75	1407		



Frequency Analysis of Annual Flood Peaks

Flood frequency analyses are used to predict design floods for sites along a river. The technique involves using observed annual peak flow discharge series to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability. The reliability of outcome based on this approach depends upon the accuracy and length of observed flood peak series. Flood frequency distributions can take on many forms according to the equations used to carry out the statistical analyses. Four of the common forms are:

Normal Distribution

Log-Normal Distribution

Gumble Distribution

Log-Pearson Type III Distribution

Each distribution can be used to predict design floods; however, there are advantages and disadvantages of each technique. In the present case, frequency analysis has been done for annual maxima flood peak series available at Gerukamukh G&D observation site for 24 years keeping in view availability of long term annual flood peaks and its location on the downstream of the project site on the same river. The detail of annual flood peak series is given below:

Table 4-14: Annual Flood Peaks at Gerukamukh Site.

Year	Observed Flood Peaks (Cumec)	Instantaneous Flood Peaks (Observed Peaks increased by 25%) (Cumec)
1973	6200	7750
1974	10700	13375
1975	8300	10375
1976	6300	7875
1977	7319	9149
1978	6011	7514
1979	12024	15030
1980	6169	7711
1981	4752	5940
1982	7787	9734
1983	7109	8886
1984	7585	9481
1985	7536	9420
1986	5380	6725
1987	9919	12399
1988	5702	7128
1991	3921	4901
1992	3470	4338
1993	5025	6281
1994	4994	6243
1995	4199	5249
1996	6728	8410
1997	3747	4684
1998	6341	7926

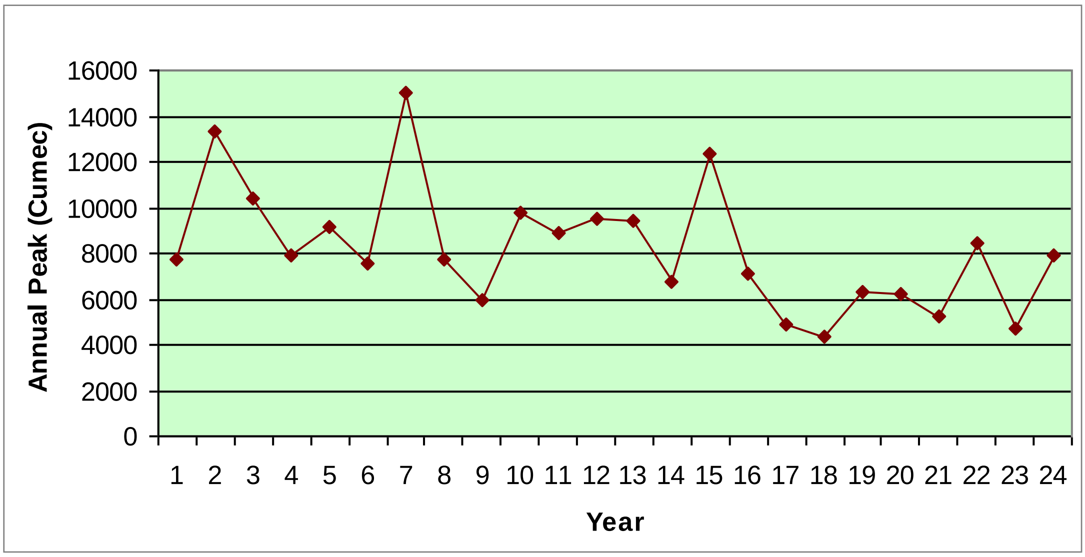


Figure 4-12: Annual Instantaneous Peaks at Gerukamukh

4.3.4.1. STATISTICAL PARAMETERS OF OBSERVED SERIES

The statistical parameters of the observed annual flood peak series such as mean, standard deviation, coefficient of variance, skewness and kurtosis are important parameters to judge the behavior of a given extreme event series. These parameters are helpful in finding the fitness of the time series to different probability distributions. The values of these estimated parameters are shown in table below:

Table 4-15: Values of Statistical Parameters

S.No	Statistical Parameter	Value
1.	Mean	8189
2.	Standard deviation	2691
3.	Variance	7243096
4.	Skewness	0.93
5.	Kurtosis	4.37

4.3.4.2. PROBABILITY DISTRIBUTION

In order to model the extreme hydrological flood event, the following distributions are very common applications. In the present analysis also, these distributions have been used for modeling to assess the extreme flood events.

i. Normal Distribution

ii. Log-Normal Distribution

iii. Gumbel Distribution

iv. Log-Pearson Type III Distribution

The outcome of these distributions is shown in the table below:

Table 4-16: Result of Flood Frequency of Annual Instantaneous Flood Peaks at Gerukamukh

Probability Distribution	25-Yr Return Period Flood Value (m^3/s)	50-Yr Return Period Flood Value (m^3/s)	100-Yr Return Period Flood Value (m^3/s)	500-Yr Return Period Flood Value (m^3/s)	1000-Yr Return Period Flood Value (m^3/s)	10000-Yr Return Period Flood Value (m^3/s)
Normal	12901	13716	14450	15935	16506	18198
2-Par Lognormal	13629	15018	16388	19556	20932	25601
Log Pearson Type-III	13834	15354	16880	20505	22121	27789
Gumbel Type I	13651	15119	16576	19942	21389	26193

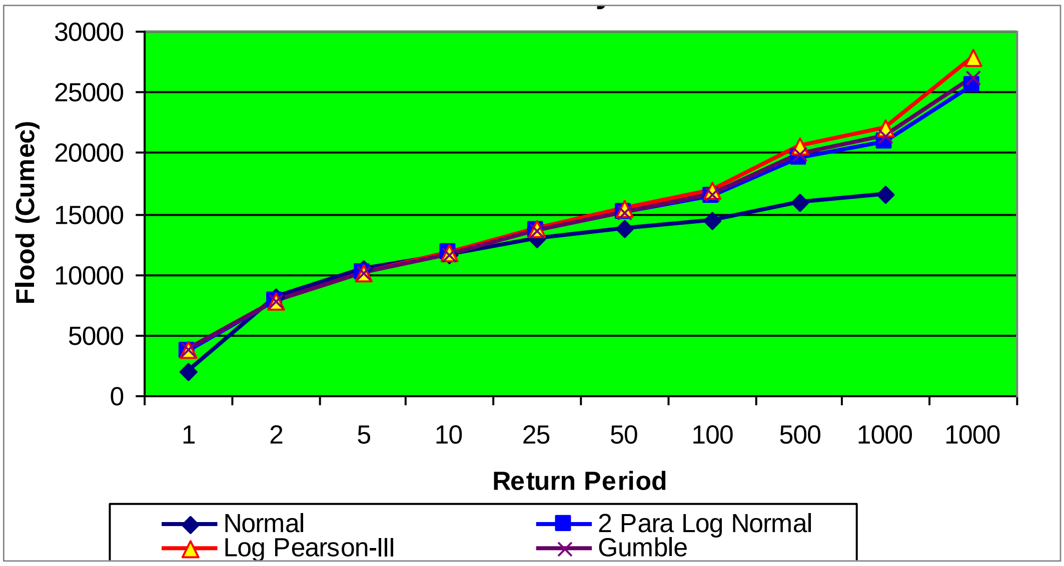


Figure 4-13: Various Return Period Floods by Different Distributions

The flood peaks for different return periods at Gerukamukh have been transposed to Oju diversion site by giving due consideration to variation in the rain-fed catchment area. The Dickens's formula $Q_P = CA^{3/4}$ has been used for transposition of flood values. The detail is shown below:

$$Q_{Menga} = (A_{Oju} / A_{Gerukamukh})^{0.75} * Q_{Gerukamukh}$$

Where:

A_{Oju} = $3128 km^2$, Rain-fed catchment area for Oju diversion site

$A_{Gerukamukh}$ = $18494 km^2$, Rain-fed catchment area for Gerukamukh site

$Q_{Gerukamukh}$ = Flood discharges at Gerukamukh site

The transposed flood peaks at Oju Project diversion site is shown in the table below:

Table 4-17: Different Return Period Floods at Oju Project Diversion Site

Probability Distribution	500-Yr Return Period Flood Value (m^3/s)	1000-Yr Return Period Flood Value (m^3/s)	10000-Yr Return Period Flood Value (m^3/s)
Normal	4203	4353	4800
2-Par Lognormal	5158	5521	6752
Log Pearson Type-III	5408	5834	7329
Gumbel Type I	5260	5641	6908

The variation in the 500-yr. 1000-yr and 10000-yr return period floods computed by different probability distribution at Oju Project diversion site are in the close range. The maximum values are computed by Log Pearson Type-III.

4.3.5. Comparison of Flood by different Approaches

The design flood at Oju Project diversion site has been estimated by flood frequency analysis of annual observed flood peaks of 24 years and hydro-meteorological approach. A comparison of flood peaks assessed by different approaches is given below:

Table 4-18: Comparison of Flood by Different Approaches

S.No.	Return Period (Year)	Flood peak (Cumec)	
		Hydro-Met. Approach	Frequency Approach
1	500	-	5408
2	1000	-	5834
3	10000	-	7329
4.	PMF	6031	-

4.3.6. Conclusions

The flood peak results shown in **Table 4-20** are having some difference in their magnitudes derived by both the approaches. Generally, flood values worked out by hydro-meteorological approach are preferred over the flood values obtained by frequency approach. Further, there is a vast difference between the rain-fed catchment area of Oju site and Gerukamukh site, where the flood frequency Analysis has been carried out. Thus, it is recommended that a design flood value of **6031 Cumec** as worked out by hydro-meteorological approach may be considered for planning of the project. The design flood of the project is currently under finalisation of CWC.

4.3.7. Design Flood for River Diversion Works

The river diversion works during construction are planned based on the construction season. In cases where heavy rainfall is experienced during monsoon (Jun-Sept), construction in the river- bed is generally carried out during low flows (from October to May). However, in some projects constructions have to be carried out during the monsoon period also, when the construction activities cannot be carried out during the entire non monsoon period because of very harsh winters. Thus, the construction season for a hydro project is decided keeping in view the type of dam structure proposed, safety of the man and resources, cost of operation and convenience. Design Flood for diversion works is worked out based on the construction season adopted (only non-monsoon or entire year).

The Oju Project is located in Arunachal Pradesh where rain fall occurs throughout the year and heavy rainfall observed during the monsoon period (June to September). Winters become quite harsh during December and January. Therefore, the diversion flood for the project has been worked out for non-monsoon period (from 15th October to 15th May) as well as for the entire year including monsoon season as working season. The appropriate working season would be adopted based on the construction schedule finalized for the project in the DPR.

4.3.7.1. DESIGN FLOOD CRITERIA

Since the headwork structure is a Dam, as per BIS: 14815-2000, "Design Flood for River Diversion Works – Guidelines," the diversion capacity has to be the higher of the two following values and shall be used as design flood for diversion works:

- Maximum monsoon/non-monsoon flow observed at the diversion site; (OR)
- 25 years return period flow, calculated on the basis of monsoon/non-monsoon yearly peaks

4.3.7.2. DATA AVAILABLE FOR NON-MONSOON PEAKS

The observed non-monsoon flood peaks for 24 years are available on river Subansiri at Gerukamukh G&D site located Downstream of the project. The non-monsoon flood peaks are given in the table below:

Table 4-19: Annual Non-Monson Flood Peaks at Gerukamukh (15th October to 15th May)

Year	Observed Non-Monsoon Flood Peaks (Cumec)
1973-74	3400
1974-75	2900
1975-76	4100
1976-77	2500
1977-78	2669
1978-79	1413
1979-80	2105

1980-81	1170
1981-82	2837
1982-83	1040
1983-84	2370
1984-85	2399
1985-86	2733
1986-87	1989
1987-88	1912
1988-89	1428
1990-91	1071
1991-92	2142
1992-93	1503
1993-94	1932
1994-95	1834
1995-96	2313
1996-97	1512
1997-98	2179

4.3.7.3. STATISTICAL PARAMETERS

The detail of important statistical parameters for the observed non-monsoon flood peaks is given in the table below:

Table 4-20: Statistical Parameters, Non-monsoon

S.No.	Statistical Parameter	Value
1.	Mean	2680
3.	Standard deviation	930.5
4.	Variance	865800
5.	Skewness	0.715
6.	Kurtosis	4.326

4.3.7.4. PROBABILITY DISTRIBUTION

The 25 year and 100 year monsoon flood for Gerukamukh has been worked out based on observed monsoon peaks as described previously. The 25-yr return period flood for the non-monsoon have been computed by various distributions including Extreme Value-I distribution also known as Gumbel, 2 Parameter Log Normal distribution and Log Pearson Type-III distributions. The results are shown in table below:

Table 4-21: Results of Flood Distribution in 25 year and 100 year Monsoon Flood

Distribution	25 years return period flood based on observed peaks at Gerukamukh (Cumec)		100 years return period flood based on Observed peaks at Gerukamukh (Cumec)		Highest Observed (Cumec)
	Monsoon	Non-monsoon	Monsoon	Non-monsoon	
Normal	10321	3446	11560	3876	12024 (Monsoon)
2 Parameter Log Normal	10903	3656	13110	4440	
Log Pearson Type-III	11067	3625	13504	4274	4100 (Non-monsoon)
Gumbels	10921	3750	13261	4606	

The results of the flood frequency analysis shown in above table show that flood discharges by different methods are very close to each other. The maximum value arrived by frequency analysis for 25-year return period is slightly less than the maximum observed as monsoon/non-monsoon flood peaks at Gerukamukh site. Therefore, as per the BIS criteria, the maximum value has been used to transpose the flood peaks at the diversion site by giving due weightage to variation in catchment areas of G&D site as well as project catchment area. Dickens's formula $Q_P = CA^{3/4}$ is being used for transposition of flood values at Gerukamukh to diversion site. The detail is given below:

Table 4-22: Results of Transposition of Flood Values at Gerukamukh to Diversion Site

Distribution	25 years return period flood at Oju (Transferred from Gerukamukh) (Cumec)		100 years return period at Oju (Transferred from Gerukamukh) flood (Cumec)		Highest Observed (Transferred from Gerukamukh) flood (Cumec)
	Monsoon	Non-monsoon	Monsoon	Non-monsoon	
Normal	2722	909	3049	1022	**3218**

2 Parameter Log Normal	8723	2925	10488	3552	
Log Pearson Type-III	8854	2900	10803	3419	**1081**
Gumbels	8737	3000	10609	3684	

The diversion flood for the entire year and non-monsoon period (15th Oct to 15th May) may be adopted as 3218 (say 3200) cumec and 1081 (say 1100) cumec respectively as per BIS criteria.

4.3.7.5. CONCLUSIONS

The design flood for river diversion works for Oju HEP is based on the flow data of Subansiri river observed at Gerukamukh site, having long term observed flow data for 24 years. Therefore, the arrived value of 3200 cumec considering entire year as working season and 1100 cumec considering only the non-monsoon season (15th Oct to 15th May) as construction season appear to be rational and proposed for planning of diversion works.

However, CWC vide letter No.2/ARP/55/CEA/2012-PAC/4982-84 has examined diversion flood and the following conclusions has been recommended. The excerpts of the observations of CWC are as follows:

"The catchment area at Oju-I project site is about 9827 sq.km. and for such a large catchment area observed flood peaks may be increased by 15% to convert those into instantaneous peaks. Based on the flood peak data of Gerukamukh and Menga available in this Directorate, the flood frequency analysis has been carried out by this Directorate."

CWC has worked out the flood of different return period by Gumbel distribution and the results so obtained have been presented below:

Table 4-23: Results of Flood Frequency Analysis

S.No.	Particular	Value (cumec)
1	25 year return period non-monsoon flood for construction season (Oct-May)	1603
2	25 year return period monsoon/annual flood	3603

3	100 year return period annual flood	4253

4.4. Sedimentation Studies

The Oju Project is a run of the river scheme with insignificant Gross Storage of 31.8 MCM and Live Storage of 2.065 MCM as diurnal storage for peaking purpose. The proposed structure is a concrete gravity dam of about 95m height above the riverbed level. As the Oju Project is a run of the river scheme with insignificant Gross Storage and very small C/I ratio and it is proposed to keep the crest elevation of orifice type spillway considerably lower than the MDDL, there is no danger of siltation of reservoir so as to affect the operation of the project during its life time.

5. PROJECT GEOLOGY

5.1. Introduction

Based on the alternative studies and techno-economic considerations, it is proposed to construct a 95m high concrete gravity diversion dam from riverbed at the site proposed for erstwhile Oju-I hydroelectric Project with FRL at El. 1950m, a 10.6m diameter and 14820m long horseshoe shaped headrace tunnel on right bank of Subansiri River with the objective to convey 333.39 cumec of design discharge to 1850MW installed capacity underground powerhouse located on the right bank just upstream of confluence of Kuo Siko with Subansiri. A dam toe powerhouse of 28 MW capacity is also proposed on the right bank.

5.2. Geomorphology and Regional Geology

5.2.1. Geomorphology

Physiographically, Arunachal Pradesh has been divided into four distinct physiographic and geotectonic divisions, each characterized by distinct geological history and separated from each other by major tectonic lineament (**Figure 5-1**). These are Arunachal Himalaya, Mishmi Hills, Naga - Patkoi Ranges and Brahmaputra Plains proposed projects located in Arunachal Himalaya.

Figure 5-1 : Map showing Physiographic Divisions of Arunachal Pradesh

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Arunachal Himalaya forms the easternmost part of the Himalaya. The Himalayan Ranges rise abruptly from the Brahmaputra plains at around 100m elevation above msl to dizzy heights of more than 7000m above msl and merge with the Tibetan Plateau in the north. The southern boundary of the Himalayan Ranges in the region is defined by Himalayan Foothill Thrust (HFT) or Himalayan Frontal thrust that separates Himalaya from Brahmaputra Plains. The Arunachal Himalaya in the east abuts against Mishmi Hills belonging to Arakan Youma ranges of Myanmar along Tiding Suture zone. Arunachal Himalaya, in the west passes into Bhutan. The Himalaya consists of rocks ranging in age from Proterozoic to Quaternary and has attained the present heights during different phases of orogenic movements. Broadly, based on orographically features, as elsewhere, Arunachal Himalaya has been sub-divided into four parallel NE-SW trending linear zones. These from south to north are: Outer or Sub Himalaya, Lesser Himalaya, Higher or Great Himalaya and Tethys or Trans Himalaya. The proposed project is located in Higher or Great Himalaya.

The Higher or Great Himalaya forming a NE-SW trending linear zone lies between Tethys Himalaya in the north and Lesser Himalaya in the south. The southern limit of this zone is defined by Main Central Thrust (MCT). Higher or Great Himalaya, in general, has high relief above 6000m with precipitous slopes and deep gorges. This zone, in the east of Subansiri is less prominent and merges with Tethys Himalaya in the north. Vegetation in this zone is either absent or sparse. Higher Himalaya consists of high-grade metamorphic rock of Paleo -Proterozoic age intruded by Tertiary granites.

Present day landscape of the Himalayan Mountain system has been shaped in Quaternary period, especially by physical activities in glacial and post glacial fluvial periods. Many terrain features diagnostic of giving structural control and lithological significance must have since been obliterated/ modified in response to exogenic processes to give rise to present day terrain. Himalayan mountain terrain at present is a conspicuous landmass characterized by its unique crescent shape, high orography, varied lithology, and complex structure. The geomorphic regime is in a geodynamically active stage, though the rock masses have undergone a long history of sedimentation, metamorphism and magmatism from Proterozoic to Quaternary age. In broad geomorphic classification, the area around the Project lies in Lesser Himalayan physiographic unit (S1) wherein Mountain ranges are characterized by moderately dissected, fine drainage textured, sharp crested ridges and is defined as S1e geomorphic unit of structural origin (Ghosh et.al., 1989). The conspicuous geomorphic features observed in the area are that the rivers flow mostly transverse to the NW-SE, E-W and NE- SW regional trend. This unit is frequently traversed by strong transverse lineaments which often appear to offset the ridges. The southern boundary of this geomorphic unit with Siwalik Hills is very sharp and often marked by local longitudinal lineaments of prominence, indicative of faults/thrusts. The western boundary of this unit is gradational, and the eastern boundary is marked by a syntaxial bend along the river Dihang or Siang, and also by the NW- SE lineament representing Lohit Thrust.

The Subansiri River, in the basin of which Oju HEP is located is a prominent north bank tributary of Brahmaputra. It originates in Tethys Himalaya in Tibet and cutting through Higher Himalaya, it drains about 30,000 sq.km. area in Lesser and Sub-Himalayan parts of Miri and western parts of Abor Hills. It debouches into Brahmaputra Plains near Dulangmukh in Assam (El. 152m above msl). The river in Himalayan sector has a length of about 208km and riverbed falls from an altitude of 4206m to 152m in this reach. The Subansiri River and its tributaries in the plains flow along a straight braided to highly meandering course with sinuosity ratio varying from 1:10 close to foothills to 1:90 near the confluence with Brahmaputra.

5.2.2. Regional Geology

The Arunachal Himalaya mainly encompasses – Proterozoic crystallines, the Proterozoic folded covers, Paleozoic cover sequence and volcanics tectonically reworked during Himalayan fold thrust movements. Northern part of this terrain is occupied by Trans-Himalayan tectogen with late to post tectonic granitoid batholiths. This packet towards north is followed by ophiolite and accretionary complex of the Tsangpo Suture Zone towards the west and development of an incipient ophiolite observed towards east. Further south, the Himalayan belt starts with poorly metamorphosed cover sequence of Tethyan belt, which is tectonically underlain by high- and low-grade assemblages. The rocks exposed in the Tethys part belong to Lum La Formation in western part and Takshing Formation in central part in Subansiri basin. These belong to Super sequence IV according to Ravi Shanker at al (1989) and comprise schistose quartzite, staurolite- garnet-biotite schist and gneiss. The rocks belonging to Pidi, Monigong and Singing formations and exposed on the western margin of Eastern Syntaxial Bend (ESB) have been correlated with Lum La and Taksing formations by Kumar (1997). However, according to GSI (2010) these along with Subansiri Group of Singh et al (1985-86) have been included within Sela Group of Higher Himalaya.

The most prominent geological feature in Arunachal Himalayas towards east is the Eastern Syntaxial Bend (ESB), across which the tectonic belts take a sharp bend and swerve from NE – SW in the west to NW – SE in the east across the Siang gorge. Wadia (1931) attributed this bend to bending of the Himalayan orogen against the NE projecting foreland of Shillong Plateau. According to another school of thought, it is a case of meeting of two different trending tectonic domains – one ENE-WSW trending in the west and the other NE-SW trending in the east. This syntaxial bend is built up of Proterozoic to Cenozoic rocks characterized by distinct lithotectonic belts.

However, in the west of Eastern Syntaxial Belt (ESB) in Subansiri and Kameng basins, the Tethyan belt towards south is followed by rocks belonging to Se La group of Paleoproterozoic age in Higher or Central Himalayan belt, the rocks belonging to Bomdila Group of Paleo-Proterozoic and Dirang Formation of Meso-Proterozoic age in Lesser Himalaya. These are intruded by ultramafic dykes and sills, biotite granite episodically. The Proterozoic succession further south in Lesser Himalaya is followed by Paleozoic rocks belonging to Lower Gondwana Group which in turn are succeeded by Cenozoic rocks of Siwalik Group in Sub-Himalaya. According to Kumar (1997) the rocks belonging to Proterozoic age occupy the major part of Arunachal Himalaya and have been correlated with Super Sequences I (Sela Group), Super Sequence II (Bomdila Group) and Super Sequence III (Dirang Formation of Lesser Himalaya and Lum La Formation of

Tethyan Himalaya). The stratigraphic succession as established by Kumar (1997), geoscientists of GSI and those of other organisations in western and central parts of Arunachal Himalaya is presented in the **Table 5-1** below.

Table 5-1 Stratigraphic Succession in Arunachal Himalaya

Enothem	Erathem	System	Series	Group	Formation	Lithology
			Holocene		Newer Alluvium	Channel Alluvium Terrace Alluvium Alluvial Fans
			Pleistocene		Older Alluvium	High Level Terraces
-- **Himalayan Foothill Thrust (HFT)** -----------------------						
			Pliocene	Siwalik	Kimin	Alternate bands of conglomerate, soft sandstone and clays.
					Subansiri	Salt and pepper textured coarse to medium grained sandstone.
					Dafla	Alternate bands of sandstone shale and clay.
			Miocene		Kimi	Hard, grayish white to greenish sand stone, calcareous sand stone and red shale.
--- **Main Boundary Thrust (MBT)** --------------------------						
Phanerozoic		Paleogene	Oligocene			Tourmaline Granite
			Eocene			
			Paleocene			
			Miocene	**Yinkiong**	Dalbuing	Hard, grayish white to greenish sandstone, calc. sandstone and red shale.
					Geku	Mafic Volcanics
		Cretaceous				
		Jurassic				
		Triassic				

Enothem	Erathem	System	Series	Group	Formation	Lithology
					Yamne	Dark grey Dimictite with minor quartzite
					Abor Volcanics	Mafic Volcanics
	Paleozoic	Permian			Bhareli	Grey to dark Grey felspathic sandstone and grey to black carbonaceous shales with lenticular coal beds.
				Lower Gondwana	Bichom	A sequence of conglomerate, sandstone/ quartzite, purple shale and dimictite
					Miri	Basal garnetiferous schist with quartzite, phyllite, ochre schist, calc schist, and marble
-- Thrust (Bomdila) --------------------------------						
		Carboniferous				
		Devonian				
		Silurian				Biotite Granite
		Ordovician				
		Cambrian				
		Terminal				
	Neo Proterozoic	Cryogenian				Biotite Granite
		Tonian				
Proterozoic	Meso Proterozoic				Dirang (and equivalent Lum La and Takshing formations of Tethys Himalaya)	Granite Gneiss Basal garnetiferous schist with quartzite, phyllite, ochre schist, calc schist, and marble
	Paleo-proterozoic				Chilliepam	Bomdila Gneiss Ultramafic Dykes and sills. Alternate sequence of grayish white dolomite/ limestone and grey and purple carbonaceous phyllite.

Enothem	Erathem	System	Series	Group	Formation	Lithology
					Tenga	White to grayish white quartzite with intercalation of phyllite; inter bedded sequence of quartzite and pene-contemporaneous mafic volcanics and occasionally thin bands of marble/ dolomite
					Khetabari	Quartzite, garnet-mica schist, para-ampholite, acidic tuff, carbonaceous and graphitic phyllite, marble and calc silicate.
	---------------------------------------Main Central Thrust (MCT)--------------------------------					
				Sela	Galensiniak	Kyanite-sillimanite ± staurolite gneisses and schists and quartzite; migmatite.
					Taliha	Calc silicate, marble, graphitic schist, amphibolite, sillimanite and bands of hard quartzite

Area around the proposed projects exposes rocks belonging to Galensiniak Formation of Se La Group of Paleo- Proterozoic age. It is the oldest sequence of rock exposed in Arunachal Himalaya and includes ployphase deformed metasediments of green schist to amphibolite facies. This sequence is well exposed around Se La pass in the Higher Himalaya in western Arunachal Pradesh (Anon, 1974; Das et al., 1975). The southern limit is defined by a major tectonic plane, Main Central Thrust (MCT) separating it from the Dirang Formation of the Super Sequence III. In the north this sequence is overlain by the Lum La Formation, of Tethys Himalaya that has been considered equivalent to the Dirang Formation of the Lesser Himalaya (Tripathi et al., 1979). In the northeast, it has been mapped in higher reaches of Kamla River, upstream of Taliha in Subansiri River, and after taking a northerly swing, it outcrops in the Siyom River upstream of Yapuik and abuts against Tiding Suture further east. The Sela Group has been divided in to Taliha and Galensiniak formations. Taliha formation is represented by Calc silicate, marble, graphitic schist, amphibolite, sillimanite and bands of hard quartzite and Galensiniak Formation represented by biotite gneiss, Kyanite-sillimanite± staurolite gneisses and schists, quartzite and; migmatite.

The rock units of Subansiri/ basin are aligned as NE-SW trending zones with folded and thrusted structures. In the Subansiri basin the following major tectonic boundaries have been identified from south to north

- Himalayan Foothill Thrust (HFT)
- Main Boundary Thrust (MBT)
- Bomdila Thrust
- Sippi Thrust
- Main Central Thrust (MCT)

5.2.2.1. HIMALAYAN FOOT HILL THRUST

Himalayan Foot hill thrust marks the tectonic boundary between Holocene Brahmaputra Plains and Siwalik Group of rocks. The tectonic boundary has been identified as a high angle thrust and is not continuously exposed along its ENE-WSW strike continuity.

5.2.2.2. MAIN BOUNDARY FAULT/THRUST

It demarcates the tectonic boundary between the Lesser Himalayas and Outer Himalayas. It is also a northerly dipping steep thrust which trends in ENE-WSW direction. In Subansiri basin, Lower Gondwana Group of Permian age is juxtaposed with Siwalik Group of rocks of Miocene/Pliocene age along this thrust. Subsidiary to MBT are Dafla thrust, Dikrang fault and Tipi fault.

5.2.2.3. BOMDILA THRUST

Studies conducted by Department of Earth Sciences, IIT Roorkee indicate that in Subansiri basin, high grade metamorphic (Daparizo/Ziro gneiss) over rides the Lesser Himalayan sedimentary zone (Phyllites and Quartzite along a well-demarcated folded thrust. The southern most exposure of the thrust surface is called as Tamen Thrust, after the locality Tamen. Bomdila Group is thrusted, and the thrust separating them has been named as Tamen Thrust. This is due to the assumption that Ziro/ Dapirizo gneisses belong to Sela Group and not to Bomdila Group where these have been grouped by other workers like Kumar (1997), Kumar and Singh (1980) etc. The traverses carried out in the area also could not confirm the presence of so called Tamen thrust in the area just downstream of project site neat Tamen.

The Gondwana sediments and the metasediments of Bomdila group are separated from each other by a thrust that runs parallel to MBT Kumar and Singh (1980).

5.2.2.4. SIPPI THRUST

This thrust is well exposed along Sippi River, a tributary of Subansiri River where the Sipi quartzite of Menga Formation is juxtaposed with high grade Daparijo gneiss. This contact further extends along Kamla and Kurung river. In Kamla valley thick sequence of dolomite, phyllite, and quartzite constituting the basal part of Niumi Group is in contact with Ziro gneiss. This contact is well exposed in Gopu-Suko Nallah near Luba village. In Kurung area the slate phyllite sequence of Pungrung Formation lies beneath the overthrust Palin Gneiss along this thrust.

5.2.2.5. MAIN CENTRAL THRUST (MCT)

It marks the tectonic boundary between high-grade metamorphites of the Se La Group and low to medium grade metasediments of Dirang and Bomdila Group. It is a steep, north dipping thrust, which runs all along the Himalayas separating the Higher Himalayas from Lesser Himalayas. In the upper reaches of Kamla River, the rocks of Chilliepam Formation comprising dolomite, phyllite and quartzite are further succeeded by high grade metamorphic rocks of Taliha Formation of Se La Group with MCT as tectonic contact. In Subansiri basin, the main exposure of MCT is observed near Taliha where low grade metamorphosed quartzite-phyllite alteration of Sippi Quartzite is overridden by kyanite sillimanite schist/gneiss. According to Jain and Singh, the thrust is folded into a synform between Taliha and Baching and is again exposed around Nacho into an antiform. The erosion of this structure has exposed the Lesser Himalayan Sedimentary Zone (Menga and Nacho) into a window. Similarly, Jain and Singh have mentioned that the contact between Ziro/ Daporizo Gneisses and Schists of Bomdila Group represents MCT but that does not appear to be so according to Kumar (1997).

5.2.2.6. OTHER IMPORTANT THRUSTS

Tethys Himalaya located further north, is separated from Higher Himalaya by Trans Himalayan Thrust. This zone exposes rocks belonging to Super sequences III and XV of Ravi Shanker et al. (1989) and is bound by Indus - Tsang Po / Tidding Suture in the north.

Indus-Tsang Po Belt is located further north and consists of Cretaceous to Tertiary sediments and associated ultramafic, mafic, intermediate and acid magmatic rocks. It is separated from Tethyan or Trans Himalayan belt by Shyok Suture Zone.

The NW- SE trending Tiding Suture that defines the boundary between Indian Plate and Central Burmese Plates is located in the east of the project area on the eastern limb of ESB. Other important thrusts located in the area include Lohit Thrust east of Tiding Suture. Mishmi Thrust and Roing Fault located on the eastern margin of the Indian Plate in Mishmi Hills are other significant tectonic elements in the area surrounding the project.

5.2.3. Geology of Project Area

Proposed Oju Hydroelectric Project on the river Subansiri is located in Higher Himalaya in Upper Subansiri district of Arunachal Pradesh. The project area located in Higher Himalaya is characterized by highly rugged topography with precipitous hill slopes and deeply incised narrow valleys with steep abutment slopes. In general, altitude in the area varies between 800m near Taliha in the south and 2550m at Maja in the north. However, topography around Taksing is relatively less rugged. The river Subansiri, trunk river in the area flows through a narrow V-shaped valley in general. However, same is comparatively wider near Taksing and Redi where it is characterized by unpaired aggradational fluvial terraces.

Subansiri River after entering the Indian Territory at Asapbila initially flows towards east along a slightly sinuous course up to Baching and thereafter it follows a southeastern course in general. On its way the river is joined by many tributaries like Tsari Chu, Sitar, Kado Nadi, Sikyo, Mini Nadi, Ghagu Nadi etc. from northern bank and by Tadek Gio, Kojin Nadi, Ledi Ishi, etc from south bank. Drainage pattern in upper reaches in general is sub-dendertic and same is sub-parallel in lower reaches.

According to Singh et al (1985-86) rocks belonging Taksing Formation intruded by Maja Granite are exposed in the upstream reaches around the site proposed for the diversion structure whereas those belonging to Subansiri Group are extensively exposed in Subansiri valley between Taliha in southeast and Taksing in northwest. Subansiri Group comprises Taksing Formation and Galesiniak Formation. Taksing Formation comprises mainly schistose quartzite with interbedded staurolite-garnet schist, garnet biotite schist/calc-silicates and amphibolite. It is well exposed around Taksing. It is intruded by tourmaline leucogranite which is exposed extensively exposed around Maja.

Galesiniak Formation is most extensively developed in the Subansiri valley. It included Biotite gneiss, Garnetiferous Biotite Gneiss and Kyanite-Silliminita-Garnet Gneiss. GSI (2010)1, however, have these as similar to Sela Group that is considered to represent Central Crystallines of Western Himalaya and included these into same.

The river Subansiri upstream of the proposed site flows in southeasterly direction and turns towards NE through an acute bend near Redi. It again turns towards south east further downstream. The river in the area flows through a narrow and asymmetric V-shaped valley with left bank steeper as compared to left bank. The abutment slopes rise steeply above the riverbed and are covered by dense vegetation including trees and bushes.

The area around the proposed Oju Hydroelectric Project area exposes the meta-sedimantaries belonging to Gelensiniak Formation of Subansiri or Sela Group. These are intruded by Maja Granite which is light grey in colour, fine grained and profusely jointed. It is characterized by roundish concentrations of tourmaline and associated biotite gneiss into which it has intruded. It is exposed on the left bank of the river near Redi. Rocks predominantly exposed in the area include biotite gneiss, garnetiferous biotite gneiss and silimanite - kyanite- garnet gneiss belonging to Galensiniak Formation of Subansiri or Sela Group of Higher Himalaya. Biotite gneiss exposed in the area is light grey in colour, medium to fine grained and well foliated. Biotite gneiss imperceptibly grades into garnetiferous biotite gneiss, garnets measure up to a few milimetres and are randomly distributed in the gneiss. These are wrapped by foliation planes which in turn are defined by preferred orientation of biotite and felsic minerals.

Various litho-units exposed in the area exhibit polyphase deformation and structural elements produced due to several phases of deformation are folds, lineations and puckers and joints etc..

Bedrock exposed in the area is foliated jointed. Intensity of jointing is more on the upstream side around the area proposed for diversion dam as compared to that in the downstream reaches around. the site proposed for powerhouse. Bedrock in downstream reaches in the area around the site proposed for powerhouse is traversed by three prominent sets of joints including those oriented along the foliation.

It is also observed that the bedrock exposed in the upstream reaches around the site for diversion dam is more intensely jointed particularly on the left bank where Maja granite is exposed at higher elevations.;

5.3. Preliminary Geological Appraisal of Project Appurtenants

5.3.1. Diversion Site

The site proposed for about 95m high diversion dam is located downstream of the village Redi where the river Subansiri flows towards NE for a length of about 2500m through a fairly wide and slightly asymmetric shaped valley with left abutment relatively steeply disposed as compared to the right abutment. The river Subansiri turns towards SE downstream of that through a right angled bend and follows this alignment for a long distance. Riverbed at the site is about 100m wide at around El 1860m and is covered by fluvial deposits comprising boulders, cobbles and pebbles along with sandy matrix. The site proposed for about 95m high concrete gravity diversion dam exposes the rocks belonging to Taksing Formation comprising staurolite, garnetiferous schist, quartzite, calc-silicates and meta-amphibolite.

According to Singh et al (1985-86), the Taksing Formation at the site is intruded by Maja Granite, tourmaline bearing biotite granite that is exposed on the left abutment. The contact between the two is aligned along the river at the site. Bedrock exposed at the site is slightly weathered to fresh, foliated and jointed biotite gneiss is extensively exposed on both the abutments. Maja Granite is comparatively more intensely weathered. Bedrock exposed in the area is traversed by four prominent sets of joints including those oriented along the foliation. These are summarized in **Table 5-2** below:

Table 5-2 Joint Data of Diversion Dam Area

S.No.	Strike	Dip	
		Amount	Direction
1	N000º-N180º	20º	N270º
2	N095º- N275º	60º	N005º
3	N75º- N255º		N 165º
4	N75º- N255º	65º	N075º

Prima-facie the site appears to be suitable for about 95m high concrete gravity dam. However, surface, and subsurface explorations comprising detailed surface geological mapping, exploratory drilling and exploratory drifting would be required to be conducted at the site to determine the size and type of structure at the site. The intake can be properly located on the right abutment upstream of dam axis where bedrock comprising staurolite bearing biotite gneiss is either exposed or covered by thin veneer of slope wash deposits.

5.3.2. Headrace Tunnel

About 333.39 cumecs of design discharge from diversion site to 1850MW installed capacity underground powerhouse located on the right bank of Subansiri just upstream of confluence of Kuo Siko with Subansiri through a 10.6m diameter and 14820m long horseshoe shaped headrace tunnel aligned on the right bank of the river Subansiri.

The hill slopes on the right bank of the river in the area around the proposed HRT alignment are steep and covered by moderate dense vegetation. Bed rock is extensively exposed in the area. The proposed HRT, along its alignment is likely to encounter foliated and jointed staurolite and garnetiferous schist with quartzite, calc-silicate and meta-amphibolite belonging to Taksing Formation in the initial reaches. This will be followed by biotite gneiss, garnetiferous gneiss and sillimanite - kyanite - garnet gneiss belonging to Gelensiniak Formation of Subansiri or Sela Group of Higher Himalaya. Rocks likely to be encountered along the proposed headrace tunnel are expected to be of good to fair quality in general except for reaches where fracture/ shear zone are encountered where poor to very poor-quality rocks may be encountered in short reaches.

5.3.3. Powerhouse Complex

The powerhouse complex proposed for the project is located on the right bank of the river Subansiri just upstream of confluence of Keru/Kuo Siko with Subansiri includes a 20m diameter and 98.5m diameter open to sky surge shaft, four 4.0m diameter surface penstocks that bifurcate into eight 2.85 diameter pressure shafts, a 23m x 43.90m x 251.5m size and 1850 MW installed capacity powerhouse and two 8.5m x 7.25m size modified D-shaped tailrace tunnels with lengths varying between 193m and 171m.

The river at the site proposed for the powerhouse flows towards southeast through a narrow valley with steep abutment slopes. Due to rugged topography with steep slopes and narrow width of the valley, no suitable site for locating the powerhouse on the surface could be identified and same has been proposed to be located underground within the right abutment. The steep right bank slopes at the site proposed for the powerhouse complex expose garnetiferous biotite gneiss belonging to Gelesiniak Formation of Subansiri or Sela group of Higher Himalaya. The rocks exposed in the area are foliated and jointed. These are traversed by three prominent sets of joints including those oriented along the foliation. Therefore, the appurtenants of the project proposed in the powerhouse complex are likely to encounter jointed garnetiferous biotite granite which is expected to be good to fair quality. It is proposed to carryout detailed geological investigations including detailed geological mapping, exploratory drilling and drifting and in-situ rock mechanics testing in order to optimize the layout and obtain design parameters.

5.3.4. Seismicity

The area around the proposed projects is located in Higher Himalayan part of Main Himalayan Seismic Belt in Arunachal Himalaya. It is delimited by Indus Suture Zone (ISZ) in the north and Main central Thrust (MCT) in the south. Other thrusts / faults existing in the region include Main Boundary Thrust (MBT) and Himalayan Frontal thrust (HFT). This region is considered one of the most active seismic regions and has experienced two great earthquakes (Shillong Earthquake of 1897, M-8 and Assam Earthquake of 1950, M-8.7) in addition to numerous earthquakes that occur in the region. Seismically, the area falls in the Seismic Zone–V as per Map of India Showing Seismic Zones (IS-1893: Part-I: 2002). Accordingly, high rate of seismicity is to be taken into consideration and suitable seismic coefficient has to be incorporated in design of various project components after site specific studies during Feasibility stage/ DPR stage investigations of the project

5.4. References

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6. POWER POTENTIAL AND INSTALLED CAPACITY

6.1. Introduction

Oju hydroelectric project is proposed for development on Subansiri river in Upper Subansiri district of Arunachal Pradesh. The project scheme entails a run-of-the-river development with peaking power capability. Project components involve a concrete gravity dam and an underground powerhouse complex connected through a 14.78km long headrace tunnel. Project's hydrological assessment has been completed and the water availability series at the intake site has been approved by CEA/CWC vide their letter no 2/ARP/55/CEA/2012-PAC/4982-84 dated 9th Aug 2012. The present study provides assessment of the power potential of the project through detailed calculation of energy for various possible installed capacities. Optimization of the installed capacity is done considering various parameters such as analysis of incremental energy with increase in unit installed capacity, percentage utilization of runoff, peaking capabilities, and power systems requirements. The energy calculations and optimization studies are carried out to determine the most suitable installed capacity. General layout of the project arrived at after studying various alternatives is presented in **Plate 6-1**.

The diversion structure proposed to be used at the project would be a 95m high (above riverbed level) concrete gravity dam. As discussed in the report, significant riparian discharges would be released from the dam to comply with MoEF directives. It is proposed that these discharges be utilized to generate additional power at the toe of the dam before they are released in the river. A small dam-toe powerhouse is thus planned in addition to the main underground powerhouse. Power potential of the dam toe powerhouse is also covered in this report.

6.2. Water Availability

Long term flow series (10-daily discharges) are available for a period of 34 hydrologic years from 1973-74 to 1989-90, 1991-92 to 2002-02 and 2003-04 to 2008-09 at the Oju diversion site. The available series as approved by CEA/CWC are reproduced in **Annexure 6-1**. It is evident that inflows in the river exhibit temporal variations similar to other Himalayan rivers with high inflows during monsoon months of June to September and low flows during winter months of November to February. As is common for Arunachal rivers, higher inflows start in April itself and continue up to October.

6.3. Determination of 90% and 50% Dependable Years

As a first step in energy calculations and optimization studies, the 90% and 50% dependable years are determined from the derived flow series. Method recommended by CEA in their Manual on Best Practices in Hydro Power Engineering, has been used to this effect. As per this manual, the 90%

dependable year is defined as the year in which the annual generation has the probability of being equal to or higher than 90% during the expected period of operation of the scheme.

Thus, for determining 90% and 50% dependable years in the present case, unrestricted power potential and corresponding annual energy generation for all the 34 hydrological years has been computed with unlimited installed capacity. The results are shown in **Annexure 6-2**.

6.3.1. Basic Data and Assumptions for Calculation

The following data and assumptions are used in the calculations:

i. **Full Reservoir Level (FRL):** Full reservoir level for the project has been fixed at 1950m.

ii. **Minimum Drawdown Level (MDDL):** Minimum Drawdown level for the dam has been fixed at 1945.0m to provide storage capacity in the reservoir for convenience of operation/regulation of high flows during monsoon period and to meet the peaking storage requirements during low flow period

iii. **Average Reservoir Level (ARL):**

$$MDDL + \frac{2}{3}(FRL - MDDL) \quad 1945.0 + \frac{2}{3}(1950.0 - 1945.0)$$

= 1948.33m

iv. **Elevation of Centre Line of Distributors (CLD):** Water level below centre line of distributor has been calculated as El. 1303.5m (considering that the HFL at tailrace outfall is El. 1303m). Keeping a setting of 4.0m above this level, centre line elevation of distributors has been kept at 1307.50m.

v. **Head Losses:** Head losses in the water conductor system (all machine running at full capacity) have been calculated to be about 20m. Detailed calculations are attached as **Annexure 6-3.**

vi. **Design Head:** Calculation of design head for power potential study is based on the following levels:

Gross Head	=	ARL – CLD
	=	(1948.33 - 1307.5) = 640.83m
Net Head	=	Gross Head – Head Losses
	=	640.83 – 20 = 620.83m

vii. **Overall plant efficiency:** Considering the head available for power generation, Pelton turbines appear to be the suitable choice at the project. The following efficiencies applicable for Pelton turbine driven generating units have been considered:

Efficiency of turbine	:	92.5%
Efficiency of generator	:	98.5%
Overall plant efficiency	:	91.11%

viii. **Riparian Flow:** Current norms of MoEF state that a site-specific study need to be carried out for establishing the proper environmental flow during monsoon, non-monsoon and lean months. Environmental flow must mimic the pre-dam flow pattern of the river for sustaining the aquatic bio-diversity together with downstream user need and accordingly, water withdrawal for power generation is to be regulated. Minimum environmental flow release would be 20% of average of four months of lean period and 25% of flow during non-lean non-monsoon period corresponding to 90% dependable year. The cumulative flow releases including spillage during monsoon period should be 30% of the cumulative inflows during the monsoon period corresponding to 90% dependable year.

Keeping in view the above norms, following environmental releases have been considered in power potential studies:

- **Lean Period:** 20% of average of four months of lean period (11th Nov to 10th March) corresponding to 90% Dependable year works out to 9.74 cumec and the same has been considered as environmental release during this period.
- **Non Lean Non Monsoon Period:** 25% of average flow corresponding to 90% dependable year which works out to 49.43 cumec from 1st October 10th November (4 ten dailies) and 46.83 cumec from 11th March to 31st May and the same have been considered as environmental releases during these period.
- **Monsoon Period:** Minimum riparian flow as required during lean period are released during monsoon period ensuring at the same time that the cumulative releases including spillage are 30% of the cumulative inflows during the monsoon period corresponding to 90% dependable year. It is seen that in the instant case the cumulative releases (Riparian + Spillage) downstream of dam work out to 31.25% (refer **Table 6-1**) of the cumulative monsoon period inflows in 90% dependable year against minimum 30% required. Relevant computations are given as below**:**

Table 6-1: Percentage of Spills in Monsoon in 90% Dependable Year

Ten Daily Period		Flow in 90% Dependable year		Diversion for Power Generation		Spills + Environ. Releases
		Cumec	MCM	Cumec	MCM	MCM
Jun	I	290.13	250.67	280.39	242.26	8.42
	II	291.94	252.24	282.20	243.82	8.42
	III	487.09	420.85	333.39	288.05	132.80
Jul	I	725.67	626.98	333.39	288.05	338.93
	II	863.46	746.03	333.39	288.05	457.98
	III	606.68	576.59	333.39	316.85	259.74
Aug	I	412.89	356.74	333.39	288.05	68.69

Ten Daily Period		Flow in 90% Dependable year Cumec	Flow in 90% Dependable year MCM	Diversion for Power Generation Cumec	Diversion for Power Generation MCM	Spills + Environ. Releases MCM
	II	359.71	310.79	333.39	288.05	22.74
	III	474.82	451.27	333.39	316.85	134.42
Sep	I	423.55	365.95	333.39	288.05	77.90
	II	359.71	310.79	333.39	288.05	22.74
	III	304.48	263.07	294.74	254.65	8.42
Total		**4931.95**		**3390.76**	**1541.19**	**Total**
% Spill in Monsoon						**31.25**

ix. **Reservoir Capacity:** As mentioned above, Minimum Drawdown Level for the dam has been fixed at 1945.0m. Reservoir volume between FRL and MDDL provided for a live storage capacity of 2.065 MCM which is confirmed to be sufficient for minimum three hours peaking generation in a 24-hour period (1½ hour in every 12 hours period) for the proposed full installed capacity in a 90% dependable year. The calculation for storage requirement has been given in **Annexure 6-4.**

6.3.2. Results

Results from the computation of unrestricted annual energy generation for all the 34 years of the hydrologic series are presented in **Annexure 6-2**; the corresponding energy figures in descending order are given in **Table 6-2**

Using the method recommended by CEA, the 90% and 50% dependable years have been determined on the following basis:

- 90% Dependable Year: = (N+1) x0.9
- 50% Dependable Year: = (N+1) x0.5

where, N is the number of years for which the flow series is considered.

In the present case, N=34. Thus,

- 90% Dependable Year: = (34+1) x 0.9 = 32nd year.
- 50% Dependable Year: = (34+1) x 0.5 = 18th year.

Based on the above, year 1981-82 and year 2001-02 have been respectively determined as the 90% and 50% dependable years.

Table 6-2: Derivation of 90% and 50% Dependable

S.No	Year	Un Restricted Energy Generation in descending order (MU)	Rank	Remarks
1	2004-05	27324	1	
2	2008-09	23367	2	
3	2005-06	23163	3	
4	2003-04	21400	4	
5	1999-00	20902	5	
6	1991-92	20223	6	
7	2000-01	20157	7	
8	1998-99	20152	8	
9	1987-88	19682	9	
10	2006-07	19174	10	
11	1995-96	19028	11	
12	1985-86	18612	12	
13	1989-90	18598	13	
14	1975-76	18320	14	
15	2007-08	18059	15	
16	1974-75	18038	16	
17	1977-78	18036	17	
18	**2001-02**	**17971**	**18**	**50% Dependable Year**
19	1976-77	17396	19	
20	1979-80	16335	20	
21	1996-97	16111	21	
22	1984-85	16015	22	
23	1973-74	15935	23	
24	1986-87	15916	24	
25	1988-89	15826	25	
26	1983-84	15719	26	
27	1993-94	14822	27	
28	1982-83	14536	28	
29	1997-98	14455	29	
30	1978-79	13773	30	
31	1980-81	12460	31	
32	**1981-82**	**11506**	**32**	**90% Dependable Year**
33	1994-95	10251	33	
34	1992-93	9707	34	

6.4. Determination of the Installed Capacity

The following criteria have been used for optimization of the installed capacity:

i. Determination of installed capacity based on optimization of energy: Ratio of incremental energy to incremental installed capacity should be such that optimal energy is obtained per unit increase of installed capacity.
ii. Determination of installed capacity based on peaking power: In this case the installed capacity is determined keeping in view the operation of the plant as peaking station.

6.4.1. Determination of Installed Capacity on the Basis of Ratio of Incremental Energy to Incremental Installed Capacity (δkWh/δkW)

One of the most commonly used criterion for optimization of the installed capacity is based on the analysis of incremental energy that is generated with a unit increase in the installed capacity. This criterion gives a good idea about the "beneficial" installed capacity above which the incremental energy benefits cease to be attractive. A wide range of installed capacities is studied using this criterion and finally installed capacity beyond which incremental energy benefits cease to be attractive is selected.

In this optimization study, energy generation with different installed capacities is analysed. The energy computations are done for the 90% dependable year and the installed capacities are increased in steps of 50 MW. In each case, the gross energy which could be generated in the 90% dependable year with full installed capacity of the generating station is computed. The results are presented in **Annexure 6-5**.

The following parameters are derived from these results and are tabulated in **Table 6-3**.

- The annual gross energy generation (kWh) for each installed capacity considered.
- The incremental energy generation (δkWh) as the installed capacity is changed.
- The ratio of incremental energy to incremental installed capacity (δkWh/δkW).

The ratio of incremental energy to incremental installed capacity (δkWh/δkW) is plotted against the installed capacities in **Figure 6-1**and the incremental energy for each 50 MW change in the installed capacity is plotted in **Figure 6-2**.

Table 6-3: Incremental Energy Benefits in a 90% Dependable Year

Installed Capacity, MW	Annual Energy, MU	Annual Load Factor (%)	Lean Flow Load Factor (%)	kWh/ kW	δ kWh/ δ kW	Incremental Energy, MU
1500	7124.1	54.22%	14.41%	4749.4	-	-
1550	7294.5	53.72%	13.95%	4706.1	3408.0	170.4

Installed Capacity, MW	Annual Energy, MU	Annual Load Factor (%)	Lean Flow Load Factor (%)	kWh/ kW	δ kWh/ δ kW	Incremental Energy, MU
1600	7446.1	53.13%	13.51%	4653.8	3032.9	151.6
1650	7589.1	52.50%	13.10%	4599.4	2858.6	142.9
1700	7714.8	51.80%	12.72%	4538.1	2513.7	125.7
1750	7837.2	51.12%	12.36%	4478.4	2448.0	122.4
1800	7959.6	50.5%	12.01%	4422.0	2448.0	122.4
1850	8082.0	49.87%	11.69%	4368.6	2448.0	122.4
1900	8204.4	49.29%	11.38%	4318.1	2448.0	122.4
1950	8322.9	48.72%	11.09%	4268.2	2371.3	118.6
2000	8421.3	48.07%	10.81%	4210.7	1968.0	98.4
2050	8519.7	47.44%	10.55%	4156.0	1968.0	98.4
2100	8618.1	46.85%	10.30%	4103.9	1968.0	98.4

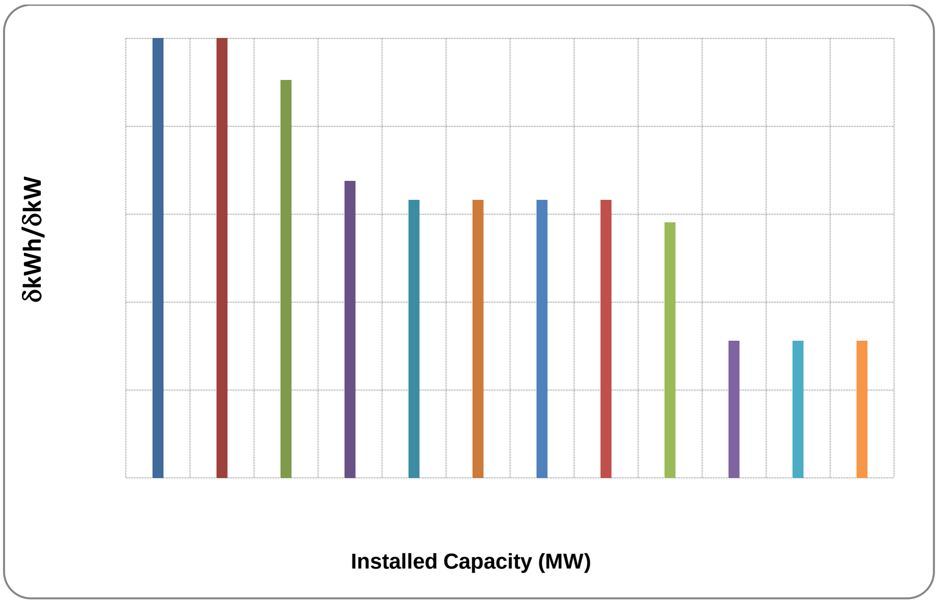


Figure 6-1: Installed Capacity Vs δ kWh/ δ kW

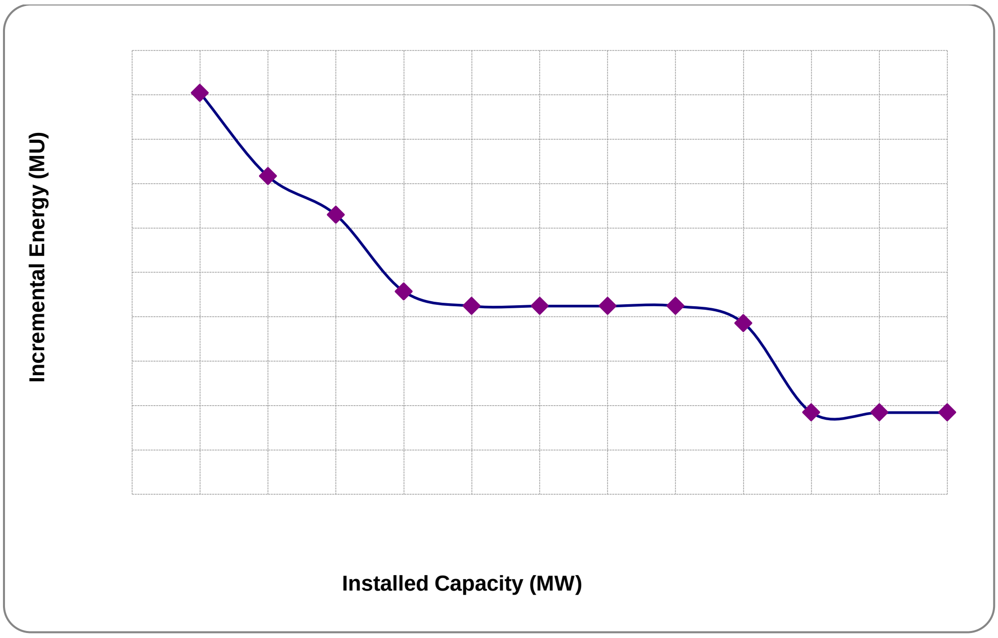


Figure 6-2: Incremental Energy Vs Installed Capacity

It is seen from **Table 6-3** and **Figure 6-1** that there is a sharp drop in incremental energy per kW when the installed capacity is increased from 1550MW to 1600MW. Further, the incremental energy per kW is constant for all values of installed capacity greater than 1850MW. The incremental energy per kW when the installed capacity is increased from 1550MW to 1600MW is about 3032.9 kWh and drops to 2448.0 kWh when the installed capacity is increased from 1800MW to 1850 MW.

Another important observation pertains to annual and lean period load factors. It can be seen that for installed capacity in the range from 1550MW to 1700MW the annual and lean period load factors vary from 53.72% to 51.8% and from 13.95% to 12.72%, respectively. These values are clearly higher than what is normally targeted in a run-of the-river hydro project with peaking capability. In comparison, the annual load factors for 1800MW and 1850MW are 50.5% and 49.87%, respectively, with the corresponding lean period load factors are 12.01% and 11.69%.

Thus, from incremental energy consideration as well as considering the load factors, 1850 MW appears to be beneficial threshold value of the installed capacity for Oju HEP.

6.4.2. Determination of Installed Capacity from the consideration of operating the Power Plant as a Peaking Station

As per CERC, a run-off-the-river generating station provided with pondage for peaking generation should be capable of providing minimum 3 hours peaking in 24 hours period for full installed capacity. From **Table 6-5**, it is seen that the average peaking hours is about 3.0hrs Thus, the available discharge will be able to provide average 3 hours peaking daily during the 4 months of lean period (Nov-Feb) provided adequate ponding is available.

Therefore, an installed capacity of 1850 MW will meet the peaking requirement for Oju Hydroelectric Project.

6.4.3. Ratio of Incremental Energy to Incremental Installed Capacity with Average Flow

As a further study, energy generation has been computed and analyzed for the average flow. Installed capacities as considered for working out incremental energy for 90% dependable year have been considered. In each case, energy which could be generated with average flow for the entire hydrologic series is computed and the incremental energy benefits with incremental installed capacity are worked out in a manner similar to that done for 90% dependable year flows. The results of energy generation are summarized in **Table 6-4**.

Table 6-4: Incremental Energy Benefits with Average Flows

Installed Capacity, MW	Annual Energy, MU	Annual Load Factor (%)	kWh/kW	δ kWh/ δ Kw	Incremental Energy, MU
1500 MW	8781.6	66.8%	5854.4	-	-
1550 MW	8973.6	66.1%	5789.4	3838.9	191.9
1600 MW	9157.2	65.3%	5723.2	3672.0	183.6
1650 MW	9340.8	64.6%	5661.1	3672.0	183.6
1700 MW	9524.4	64.0%	5602.6	3672.0	183.6
1750 MW	9708.0	63.3%	5547.4	3672.0	183.6
1800 MW	9891.6	62.7%	5495.3	3672.0	183.6
1850 MW	10071.6	62.1%	5444.1	3601.5	180.1
1900 MW	10243.2	61.5%	5391.2	3432.0	171.6
1950 MW	10414.8	61.0%	5340.9	3432.0	171.6
2000 MW	10586.4	60.4%	5293.2	3432.0	171.6
2050 MW	10758.0	59.9%	5247.8	3432.0	171.6

6.4.4. Incremental Energy Benefits with Average Energy for all Hydrological Years of the Series

The above incremental energy calculations are further repeated for all hydrological years of the series. In each case, average energy which could be generated for the entire hydrologic series with installed capacity of the generating station varying from 1500 MW to 2050 MW in steps of 50 MW is computed and incremental energy benefits with incremental installed capacity are worked out in a manner similar to that done for 90% dependable year flows. The results of energy generation are summarized in **Table 6-5**.

Table 6-5: Incremental Energy Benefits with Average Energy

Installed Capacity, MW	Annual Energy, MU	Annual Load Factor (%)	kWh/kW	δ kWh/ δ Kw	Incremental Energy, MU
1500 MW	8496.4	64.7%	5664.3	-	-
1550 MW	8678.9	63.9%	5599.3	3649.3	182.5
1600 MW	8857.4	63.2%	5535.8	3569.3	178.5
1650 MW	9033.5	62.5%	5474.9	3523.7	176.2
1700 MW	9207.5	61.8%	5416.2	3478.7	173.9
1750 MW	9378.8	61.2%	5359.3	3425.6	171.3
1800 MW	9545.9	60.5%	5303.3	3343.7	167.2
1850 MW	9709.6	59.9%	5248.4	3272.5	163.6
1900 MW	9870.5	59.3%	5195.0	3219.5	161.0
1950 MW	10028.9	58.7%	5143.0	3167.8	158.4
2000 MW	10184.6	58.1%	5092.3	3112.4	155.6
2050 MW	10339.1	57.6%	5043.5	3091.0	154.6

It can be seen from **Table 6-4** and **Table 6-5** that for an installed capacity of 1850 MW, the incremental energy δkWh/δkW indeed exceeds the normally desired value of 2000 when average flows are considered as well as when average energy for all hydrologic years of the series is considered.

6.4.5. Final Choice of Installed Capacity

On the basis of the studies presented above, the installed capacity of Oju HEP is, therefore, proposed to be 1850 MW. The corresponding design discharge would be 333.39 cumec.

Selection of Type of Turbine and Number of Generating Units

Type of turbine to be selected for a hydroelectric power project depends upon maximum net-head acting on the turbine, capacity of generating unit, operating head variation and part load operation requirements. Maximum net head is one of the most important criteria dictating type of turbine to be used. As per IS:12837, normal range of maximum net head for each type of turbine is given below:

- Pelton Turbine Above 300m
- Francis Turbine 30 to 400m (sometimes even up to 500 to 600m)

- Kaplan Turbine 10 to 60m
- Bulb Turbine 3 to 20m

The following factors have been taken into consideration for arriving at the unit sizes.

i. Units of same size should be provided to minimize costs through multiplicity of units, reduce inventory of spare parts & special tools required for operation and maintenance and ease of interchangeability.
ii. The units should be as large as possible to obtain the benefits of scales but on the other hand the penstocks, turbines and generators should not be so large that their components cannot be transported and assembled at site.

Keeping in view the above factors and for flexibility in operation and maintenance as well as limitations on transportation of equipment in hilly terrain, eight vertical axis Pelton turbines, each of 231.25 MW, are proposed for installation at Oju hydroelectric project.

6.4.6. Power Potential Exploited during Monsoon and Lean Periods for Full Hydrological Series

Assessment of power generation during monsoon season (June-September) for the 34 hydrological years is presented in **Figure 6-3**. It is evident that for about 89.50% of the period, installed capacity of 1850 MW can easily be achieved during monsoon season. It is also observed that installed capacity of more than 1850 MW is available for 366 10-daily periods out of total 408 10-daily periods of monsoon season for the entire flow series of 34 years.

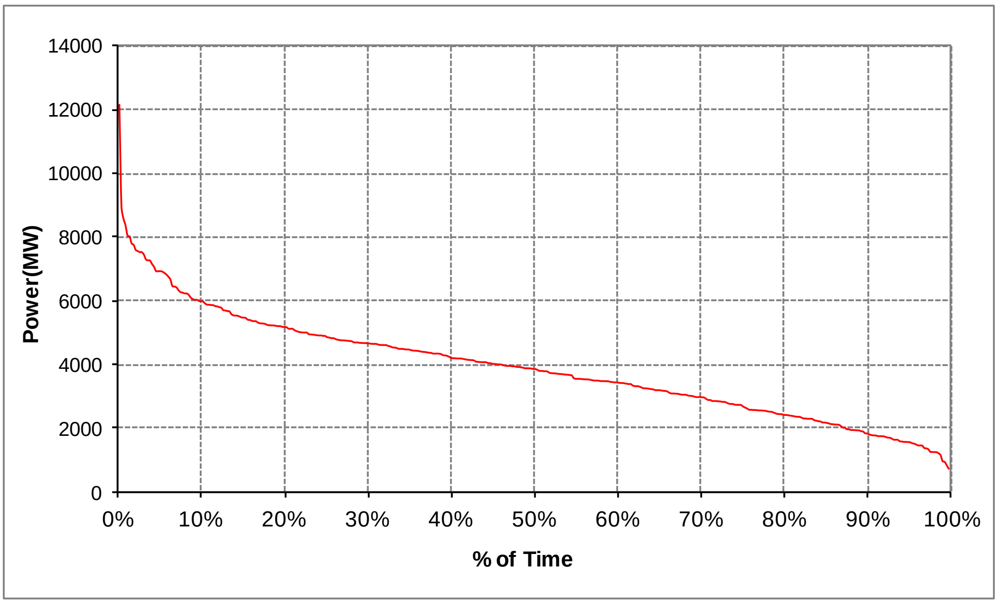


Figure 6-3: Power Generation (MW) in monsoon Season (June-Sep)

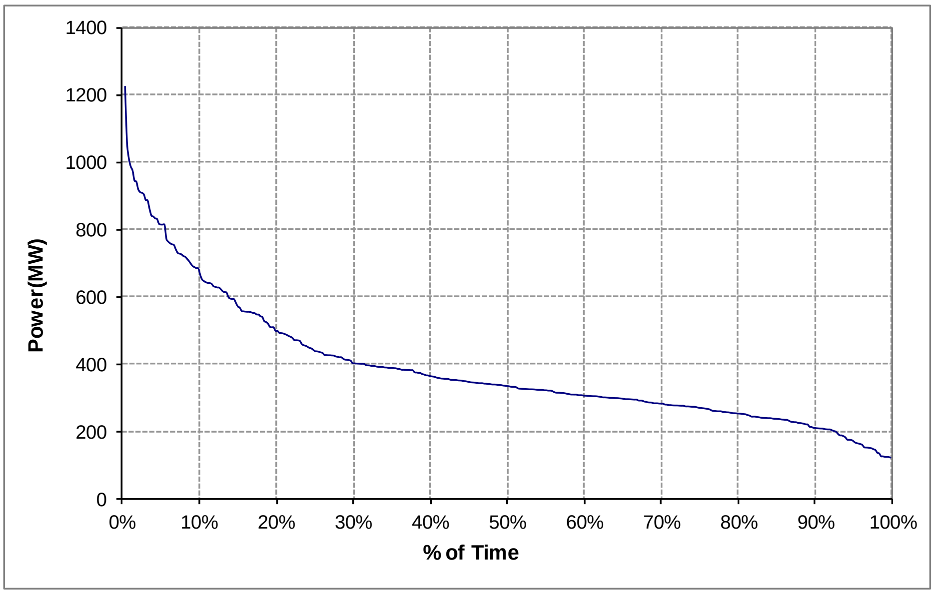


Figure 6-4: Power Generation (MW) in Non monsoon Season (Dec-Mar)

Assessment of power generation during non-monsoon season (Nov-Feb) for 34 hydrological years is presented in **Figure 6-4**. It is seen that for about 86.50% of the period, 231.25 MW (= 1850 MW/8) capacity is available during the lean season which means that the full installed capacity of 1850 MW will be available for 3 hours peaking. It is observed that installed capacity of 231.25 MW is available for 354 numbers of 10-daily periods out of total 408 ten-dailies of lean season for entire flow series.

6.4.7. Power and Energy Generation in 90% and 50% Dependable Years

Power and energy generation studies in 90% and 50% dependable year corresponding to installed capacity of 1850 MW are given in **Table 6-6** and **Table 6-7**. Power and energy generation restricted to 1850 MW for all 34 years of the hydrological series are given in **Annexure 6-6** (Sheet-1 and 2). The hours for which the Oju power plant will be able to provide daily peaking in various 10-daily periods of 90% and 50% dependable year, with the total peaking energy generated limited to maximum 4 hours, is also presented in **Table 6-6**.

6.5. Design Energy

As per CERC, design energy is the energy generated in a 90% dependable year at 95% plant availability. The energy generated in the 90% and 50% dependable years with an installed capacity of 1850MW.

Particulars	Design Energy (MU) From Underground Powerhouse
90% Dependable Year	7856
50% dependable year	9694

Table 6-6: Energy Generated in 90% Dependable Year (1981-82)

Table 6-5: Energy Generated in 90% Dependable Year (1981-82)

FRL(m) =	1950.00	Head Losses=	20.00 m
MDDL(m) =	1945.00	Net Head =	620.83 m
Normal TWL=	1307.50	Installed Capacity (IC)=	1850 MW
Efficiency =	91.11%	Riparian Flow (cumecs)=	As provided
		Design Discharge =	333.39 (m^3/sec)

Month		No. of Days	River Inflow (cumecs)	Riparian Flow (cumecs)	Flow for Power Generation (cumecs)	Design Head (m)	Unrestricted Power (MW)	Unrestricted Energy (MU)	Restricted to IC Power (MW)	Restricted to IC Energy (MU)	95 % Availability Power (MW)	95 % Availability Energy (MU)	Full capacity generation time/day (hrs)	Peaking time in 24hr period	Peaking Energy Generation (MU)
Jun	I	10	290.13	9.74	280.39	620.83	1556	373.42	1556	373.42	1556	373.42	21.25	6.00	105.45
	II	10	291.94	9.74	282.20	620.83	1566	375.83	1566	375.83	1566	375.83	21.38	6.00	105.45
	III	10	487.09	9.74	477.35	620.83	2649	635.72	1850	444.00	1758	421.80	24.00	6.00	105.45
Jul	I	10	725.67	9.74	715.93	620.83	3973	953.46	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	863.46	9.74	853.72	620.83	4737	1136.97	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	11	606.68	9.74	596.94	620.83	3312	874.49	1850	488.40	1758	463.98	24.00	6.00	116.00
Aug	I	10	412.89	9.74	403.15	620.83	2237	536.91	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	359.71	9.74	349.97	620.83	1942	466.08	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	11	474.82	9.74	465.08	620.83	2581	681.32	1850	488.40	1758	463.98	24.00	6.00	116.00
Sep	I	10	423.55	9.74	413.81	620.83	2296	551.10	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	359.71	9.74	349.97	620.83	1942	466.08	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	10	304.48	9.74	294.74	620.83	1636	392.53	1636	392.53	1636	392.53	22.33	6.00	105.45
Oct	I	10	349.24	49.43	299.81	620.83	1664	399.29	1664	399.29	1664	399.29	22.72	6.00	105.45
	II	10	205.79	49.43	156.36	620.83	868	208.24	868	208.24	868	208.24	11.85	6.00	105.45
	III	11	141.18	49.43	91.75	620.83	509	134.41	509	134.41	509	134.41	6.95	6.00	116.00
Nov	I	10	100.27	49.43	50.84	620.83	282	67.71	282	67.71	282	67.71	3.85	3.85	67.71
	II	10	78.90	9.74	69.16	620.83	384	92.10	384	92.10	384	92.10	5.24	5.24	92.10
	III	10	65.38	9.74	55.64	620.83	309	74.10	309	74.10	309	74.10	4.22	4.22	74.10
Dec	I	10	51.61	9.74	41.87	620.83	232	55.76	232	55.76	232	55.76	3.17	3.17	55.76
	II	10	44.34	9.74	34.60	620.83	192	46.08	192	46.08	192	46.08	2.62	2.62	46.08
	III	11	47.36	9.74	37.62	620.83	209	55.11	209	55.11	209	55.11	2.85	2.85	55.11
Jan	I	10	38.85	9.74	29.11	620.83	162	38.77	162	38.77	162	38.77	2.21	2.21	38.77
	II	10	38.42	9.74	28.68	620.83	159	38.19	159	38.19	159	38.19	2.17	2.17	38.19
	III	11	40.99	9.74	31.25	620.83	173	45.78	173	45.78	173	45.78	2.37	2.37	45.78
Feb	I	10	38.78	9.74	29.04	620.83	161	38.67	161	38.67	161	38.67	2.20	2.20	38.67
	II	10	46.26	9.74	36.52	620.83	203	48.63	203	48.63	203	48.63	2.77	2.77	48.63
	III	8	43.09	9.74	33.35	620.83	185	35.53	185	35.53	185.1	35.53	2.53	2.53	35.53
Mar	I	10	50.28	9.74	40.54	620.83	225	53.99	225	53.99	225	53.99	3.07	3.07	53.99
	II	10	92.24	46.83	45.41	620.83	252	60.47	252	60.47	252	60.47	3.44	3.44	60.47
	III	11	147.86	46.83	101.03	620.83	561	148.00	561	148.00	561	148.00	7.66	6.00	116.00
Apr	I	10	110.20	46.83	63.37	620.83	352	84.39	352	84.39	352	84.39	4.80	4.80	84.39
	II	10	128.63	46.83	81.80	620.83	454	108.94	454	108.94	454	108.94	6.20	6.00	105.45
	III	10	159.72	46.83	112.89	620.83	626	150.34	626	150.34	626	150.34	8.55	6.00	105.45
May	I	10	192.85	46.83	146.02	620.83	810	194.46	810	194.46	810	194.46	11.06	6.00	105.45
	II	10	463.77	46.83	416.94	620.83	2314	555.27	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	11	205.47	46.83	158.64	620.83	880	232.40	880	232.40	880	232.40	12.02	6.00	116.00
	Gross Energy, MU							**10411**		**8082**		**7856**			**3102**
													Design Energy (Sum of peaking and non peaking Energy), MU		**7856**

Summary for 90% dependable year

Un restricted Energy	10411 MU	
Restricted Energy	8082 MU	
Design Energy	7856 MU	
Firm Power	216 MW	Average in 4 consecutive lean months period
Firm Energy	623 MU	
Peaking Time	2.95 Hrs	Average in 4 consecutive lean months period

Table 6-7: Energy Generated in 50% Dependable Year (2001-02)

Table 6-6: Energy Generated in 50% Dendable Year (2001-02)

FRL(m) =	1950.00	Head Losses=	20.00 m
MDDL(m) =	1945.00	Net Head =	620.83 m
Normal TWL=	1307.50	Installed Capacity (IC)=	1850 MW
Efficiency =	91.11%	Riparian Flow (cumecs)=	As provided
		Design Discharge =	333.4 (m^3/sec)

Month		No. of Days	River Inflow (cumecs)	Riparian Flow (cumecs)	Flow for Power Generation (cumecs)	Design Head (m)	Unrestricted Power (MW)	Unrestricted Energy (MU)	Restricted to IC Power (MW)	Restricted to IC Energy (MU)	95 % Availability Power (MW)	95 % Availability Energy (MU)	Full capacity generation time/day (hrs)	Peaking time in 24hr period	Peaking Energy Generation (MU)
Jun	I	10	644.84	9.74	635.10	620.83	3524	845.81	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	454.59	9.74	444.85	620.83	2469	592.44	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	10	760.08	9.74	750.34	620.83	4164	999.29	1850	444.00	1758	421.80	24.00	6.00	105.45
Jul	I	10	444.35	9.74	434.61	620.83	2412	578.80	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	783.11	9.74	773.37	620.83	4291	1029.96	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	11	870.21	9.74	860.47	620.83	4775	1260.55	1850	488.40	1758	463.98	24.00	6.00	116.00
Aug	I	10	1251.63	9.74	1241.89	620.83	6891	1653.93	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	585.73	9.74	575.99	620.83	3196	767.09	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	11	827.86	9.74	818.12	620.83	4540	1198.51	1850	488.40	1758	463.98	24.00	6.00	116.00
Sep	I	10	1381.60	9.74	1371.86	620.83	7613	1827.02	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	585.73	9.74	575.99	620.83	3196	767.09	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	10	400.18	9.74	390.44	620.83	2167	519.98	1850	444.00	1758	421.80	24.00	6.00	105.45
Oct	I	10	490.37	49.43	440.94	620.83	2447	587.24	1850	444.00	1758	421.80	24.00	6.00	105.45
	II	10	389.46	49.43	340.03	620.83	1887	452.85	1850	444.00	1758	421.80	24.00	6.00	105.45
	III	11	226.14	49.43	176.71	620.83	981	258.88	981	258.88	981	258.88	13.39	6.00	116.00
Nov	I	10	159.00	49.43	109.57	620.83	608	145.93	608	145.93	608	145.93	8.30	6.00	105.45
	II	10	125.11	9.74	115.37	620.83	640	153.65	640	153.65	640	153.65	8.74	6.00	105.45
	III	10	103.68	9.74	93.94	620.83	521	125.11	521	125.11	521	125.11	7.12	6.00	105.45
Dec	I	10	81.84	9.74	72.10	620.83	400	96.02	400	96.02	400	96.02	5.46	5.46	96.02
	II	10	70.31	9.74	60.57	620.83	336	80.66	336	80.66	336	80.66	4.59	4.59	80.66
	III	11	75.09	9.74	65.35	620.83	363	95.73	363	95.73	363	95.73	4.95	4.95	95.73
Jan	I	10	61.61	9.74	51.87	620.83	288	69.08	288	69.08	288	69.08	3.93	3.93	69.08
	II	10	60.92	9.74	51.18	620.83	284	68.16	284	68.16	284	68.16	3.88	3.88	68.16
	III	11	64.99	9.74	55.25	620.83	307	80.94	307	80.94	307	80.94	4.19	4.19	80.94
Feb	I	10	61.49	9.74	51.75	620.83	287	68.92	287	68.92	287	68.92	3.92	3.92	68.92
	II	10	73.36	9.74	63.62	620.83	353	84.73	353	84.73	353	84.73	4.82	4.82	84.73
	III	8	68.33	9.74	58.59	620.83	325	62.42	325	62.42	325	62.42	4.44	4.44	62.42
Mar	I	10	79.72	9.74	69.98	620.83	388	93.20	388	93.20	388	93.20	5.30	5.30	93.20
	II	10	146.27	46.83	99.44	620.83	552	132.43	552	132.43	552	132.43	7.54	6.00	105.45
	III	11	234.46	46.83	187.63	620.83	1041	274.87	1041	274.87	1041	274.87	14.22	6.00	116.00
Apr	I	10	174.75	46.83	127.92	620.83	710	170.36	710	170.36	710	170.36	9.69	6.00	105.45
	II	10	203.97	46.83	157.14	620.83	872	209.27	872	209.27	872	209.27	11.91	6.00	105.45
	III	10	253.27	46.83	206.44	620.83	1146	274.93	1146	274.93	1146	274.93	15.64	6.00	105.45
May	I	10	296.55	46.83	249.72	620.83	1386	332.57	1386	332.57	1386	332.57	18.92	6.00	105.45
	II	10	319.03	46.83	272.20	620.83	1510	362.51	1510	362.51	1510	362.51	20.63	6.00	105.45
	III	11	425.30	46.83	378.47	620.83	2100	554.44	1850	488.40	1758	463.98	24.00	6.00	116.00
		Gross Energy, MU						**16875**		**10034**		**9694**			**3594**
Design Energy (Sum of peaking and non peaking Energy), MU															**9694**

Summary for 90% dependable year

Gross Energy	16875 MU	
Restricted Energy	10034 MU	
Design Energy	9694 MU	
Firm Power	393 MW	Average in 4 consecutive lean months period
Firm Energy	1131 MU	
Peaking Time	4.85 Hrs	Average in 4 consecutive lean months period

6.6. Dam-Toe Powerhouse

The releases downstream of the dam (riparian and spillage during monsoons) as detailed in **Table 6-8**are proposed to be utilized for power generation by constructing a mini powerhouse just downstream of the dam with a bye pass arrangement to ensure uninterrupted release of riparian discharge in case of any shutdown of generating unit(s).

Table 6-8: Flow for Dam-toe Powerhouse

Months		days	90% DY-1980-81 (Cumecs)	Riparian Flow (Cumecs)	Design Discharge for the proposed IC	Spillage (Cumec)	Flow for Dam Toe PH (Cumecs)	Remarks
Jun	I	10	290.13	9.74	333.39	0.00	9.74	31.25% of cummulative monsoon flows
	II	10	291.94	9.74	333.39	0.00	9.74	
	III	10	487.09	9.74	333.39	143.96	153.70	
Jul	I	10	725.67	9.74	333.39	382.54	392.28	
	II	10	863.46	9.74	333.39	520.33	530.07	
	III	11	606.68	9.74	333.39	263.55	273.29	
Aug	I	10	412.89	9.74	333.39	69.76	79.50	
	II	10	359.71	9.74	333.39	16.58	26.32	
	III	11	474.82	9.74	333.39	131.69	141.43	
Sep	I	10	423.55	9.74	333.39	80.42	90.16	
	II	10	359.71	9.74	333.39	16.58	26.32	
	III	10	304.48	9.74	333.39	0.00	9.74	
Oct	I	10	349.24	49.43	333.39	0.00	49.43	25% Non-monsoon non-lean period flows
	II	10	205.79	49.43	333.39	0.00	49.43	
	III	11	141.18	49.43	333.39	0.00	49.43	
Nov	I	10	100.27	49.43	333.39	0.00	49.43	
	II	10	78.90	9.74	333.39	0.00	9.74	20% of average lean period (Nov-Feb) flows
	III	10	65.38	9.74	333.39	0.00	9.74	
Dec	I	10	51.61	9.74	333.39	0.00	9.74	
	II	10	44.34	9.74	333.39	0.00	9.74	
	III	11	47.36	9.74	333.39	0.00	9.74	
Jan	I	10	38.85	9.74	333.39	0.00	9.74	
	II	10	38.42	9.74	333.39	0.00	9.74	
	III	11	40.99	9.74	333.39	0.00	9.74	
Feb	I	10	38.78	9.74	333.39	0.00	9.74	
	II	10	46.26	9.74	333.39	0.00	9.74	
	III	8	43.09	9.74	333.39	0.00	9.74	
Mar	I	10	50.28	9.74	333.39	0.00	9.74	
	II	10	92.24	46.83	333.39	0.00	46.83	25% Non-monsoon non-lean period flows
	III	11	147.86	46.83	333.39	0.00	46.83	
Apr	I	10	110.20	46.83	333.39	0.00	46.83	
	II	10	128.63	46.83	333.39	0.00	46.83	
	III	10	159.72	46.83	333.39	0.00	46.83	
May	I	10	192.85	46.83	333.39	0.00	46.83	
	II	10	463.77	46.83	333.39	416.94	463.77	
	III	11	205.47	46.83	333.39	0.00	46.83	

6.6.1. Basic Data and Assumptions for Determining Installed Capacity and Energy generation at Dam Toe Powerhouse

i. **Average Reservoir Level (ARL)**: 1948.33m (Same as for the main powerhouse).

ii. **Head Losses**: Head loss in the water conductor system is considered to be 3m. Detailed calculations are attached as **Annexure 6-7.**

iii. **Tail Water Level:** Normal tail water level with all the machines running is taken as El.1865.0m.

iv. **Design Head:** Calculation of design head for power potential study is based on the following levels:

Gross Head	=	ARL – TWL
	=	(1948.33 - 1865) = 83.33 m
Net Head	=	Gross Head – Head Losses
	=	83.33 - 3.0 = 80.33 m

v. Overall plant efficiency: Considering the head available for power generation a Francis turbine is the suitable choice for this dam toe power plant. The following efficiencies applicable for Francis turbine driven generating units have been considered:

Efficiency of turbine	:	94.0%
Efficiency of generator	:	98.5%
Overall plant efficiency	:	92.59%

6.6.2. Determination of Installed Capacity

The dam toe powerhouse is being provided to utilize riparian flow that is required to be let downstream of the dam continuously from environmental considerations. It is observed from **Table 6-8** that the minimum riparian flow during the entire lean period is about 9.74 cumec. Francis machines are not able to run at less than half load. Keeping this fact in view, unit size for dam toe powerhouse machines is fixed so as to have maximum design discharge of about 2*9.74=19.48 cumec. Further in view of the limited space consideration, it may not be economically viable to provide more than 2 units in the dam toe powerhouse. Accordingly, the installed capacity of the powerhouse works out to =9.81*0.9259*19.48*2*80.33/1000 ≅ 28 MW. The dam toe powerhouse is, therefore, proposed to be provided with 2 units of 14 MW each.

6.6.3. Energy Generation in 90% Dependable Year at Dam Toe Powerhouse

The dam toe powerhouse will be operating as a run of the river generating station. Energy generation at this powerhouse in the 90% dependable year with 95% machine availability would be 179 MU. Details are presented in **Table 6-9**.

Table 6-9: Energy Generated in 90% Dependable Year (1981-82) (Dam-toe Powerhouse)

FRL(m) =	1950.00	Head Losses=	3.00 m
MDDL(m) =	1945.00	Net Head =	80.33 m
Normal TWL=	1865.00	Installed Capacity (IC)=	28 MW
Efficiency =	92.59%	Riparian Flow (cumecs)=	As provided
		Design Discharge =	38.37 (m^3/sec)

Month		No. of Days	Riparian Flow (cumecs)	Spillage (cumecs)	Flow for Power Generation (cumecs)	Design Head (m)	Energy Restricted to IC		Energy with 95 % Availability	
							Power (MW)	Energy (MU)	Power (MW)	Energy (MU)
Jun	I	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	II	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	III	10	9.74	143.96	153.70	80.33	28.0	6.72	27	6.38
Jul	I	10	9.74	382.54	392.28	80.33	28.0	6.72	27	6.38
	II	10	9.74	520.33	530.07	80.33	28.0	6.72	27	6.38
	III	11	9.74	263.55	273.29	80.33	28.0	7.39	27	7.02
Aug	I	10	9.74	69.76	79.50	80.33	28.0	6.72	27	6.38
	II	10	9.74	16.58	26.32	80.33	19.2	4.61	19	4.61
	III	11	9.74	131.69	141.43	80.33	28.0	7.39	27	7.02
Sep	I	10	9.74	80.42	90.16	80.33	28.0	6.72	27	6.38
	II	10	9.74	16.58	26.32	80.33	19.2	4.61	19	4.61
	III	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
Oct	I	10	49.43	0.00	49.43	80.33	28.0	6.72	27	6.38
	II	10	49.43	0.00	49.43	80.33	28.0	6.72	27	6.38
	III	11	49.43	0.00	49.43	80.33	28.0	7.39	27	7.02
Nov	I	10	49.43	0.00	49.43	80.33	28.0	6.72	27	6.38
	II	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	III	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
Dec	I	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	II	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	III	11	9.74	0.00	9.74	80.33	7.1	1.88	7	1.88
Jan	I	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	II	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	III	11	9.74	0.00	9.74	80.33	7.1	1.88	7	1.88
Feb	I	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	II	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	III	8	9.74	0.00	9.74	80.33	7.1	1.36	7	1.36
Mar	I	10	9.74	0.00	9.74	80.33	7.1	1.71	7	1.71
	II	10	46.83	0.00	46.83	80.33	28.0	6.72	27	6.38
	III	11	46.83	0.00	46.83	80.33	28.0	7.39	27	7.02
Apr	I	10	46.83	0.00	46.83	80.33	28.0	6.72	27	6.38
	II	10	46.83	0.00	46.83	80.33	28.0	6.72	27	6.38
	III	10	46.83	0.00	46.83	80.33	28.0	6.72	27	6.38
May	I	10	46.83	0.00	46.83	80.33	28.0	6.72	27	6.38
	II	10	46.83	416.94	463.77	80.33	28.0	6.72	27	6.38
	III	11	46.83	0.00	46.83	80.33	28.0	7.39	27	7.02
Gross Energy, MU								**166**		**159**

7. CIVIL ENGINEERING STRUCTURES

7.1. Introduction

Oju Hydroelectric Project is proposed on Subansiri River in Arunachal Pradesh. The project is planned as a run-of-the-river scheme to generate 1878 MW (1850 MW + 28MW) with sufficient storage for meeting daily peak hour energy generation requirements. The project envisages construction of a concrete gravity dam. The maximum height of the dam is about 123m above the deepest foundation level. The diverted water shall be carried through a water conductor system planned on the right bank of Subansiri River to an underground powerhouse. The water conductor system comprises a power intake, a 14171m long headrace tunnel, an open to sky surge shaft, four pressure shafts which further bifurcated into two branches each, and a tailrace system to bring the water back into the Subansiri River. The underground powerhouse, housing eight units of 231.25 MW each, is proposed on the right bank of the river Subansiri. A dam toe powerhouse with 2 units of 14MW is also proposed on the right bank.

7.2. Project Components

Civil Engineering structures for the project comprise the following components:

i. Diversion Tunnels
ii. Cofferdams
iii. Dam
iv. Dam toe powerhouse for utilizing e-flows
v. Intake Structure
vi. Headrace Tunnel
vii. Surge Shaft
viii. Valve House
ix. Pressure Shafts/Penstocks
x. Underground Powerhouse and Transformer Cavern
xi. Tail-water Conductor System Tail Race tunnel

This chapter briefly describes the layout and design features of the civil engineering components.

7.3. Project Design Data

The following data is pertinent for layout and design of project components:

Full Reservoir Level	EL 1950m	Allotted Level
Maximum Tail-water Level	EL 1300m	Allotted Level
Design Flood (PMF)	6031 cumec	
GLOF	2512 cumec	
Design flood for river diversion	3603 cumec	1 in 25 year flood for monsoon period

7.4. River Diversion

7.4.1. General

Given the topography of the head works area and river's hydrological conditions, temporary diversion works would comprise of diversion tunnel(s) and cofferdams on both upstream and downstream sides.

7.4.2. Criteria for Selection of Diversion Flood

IS-14815:2000 recommends a flood frequency of 1 in 25 for non-monsoon yearly peaks. As per the Hydrological assessment of the project, peak value of 1 in 25-year flood for non-monsoon period is 1603 cumec.

Clause 4.1.1 of IS: 10084 (Part I) – 1982 gives a bit more flexibility to the designer and states that "the choice of a particular frequency shall be made on practical judgment, keeping in view the construction period and the stage of construction of the main structure and its importance".

However, considering the construction schedule of the main dam, the excavation of the dam foundation, consolidation grouting and concreting up to riverbed level would be difficult to be completed in one lean season. The construction activities are likely to be extended to the next monsoon season, thereby exposing the construction site to monsoon flood, which shall lead to overtopping of the cofferdam and filling up of the foundation pit with silt and riverbed materials. Thus, it would be prudent to consider 1 in 25 years monsoon flood as diversion flood for the project. As per the Hydrological assessment of the project, peak value of 1 in 25-year flood for monsoon period is 3603 cumec.

Noting that the valley upstream of the dam is quite steep and narrow, it will not provide much storage to attenuate the flood peaks; the diversion tunnel(s) should therefore be designed to have a peak outflow capacity of 3603 cumec.

7.4.3. Diversion Tunnel

Given the relatively large diversion discharge, two 12.7m diameter cicular shaped tunnels are proposed for Oju project on the right bank. The riverbed level near the entrance of the diversion tunnels is about 1868m; the upstream invert is therefore proposed at El. 1870.0m. The lowest riverbed near the tunnel exit is around

El. 1850m. Consequently, the downstream invert level of the tunnels is proposed at El. 1851m.

7.4.4. Inlet Structure

Inlet structure is provided to enable smooth entry of river water into the diversion tunnels. For the provision of a gate at inlet, the diversion tunnels inlet has been kept rectangular. Each tunnel consists of an RCC box section having two openings of 5.1m (W) x 12.7m (H) with 2.5m thick intermediate pier. Each opening is provided with fixed wheel vertical lift type gates.

The tunnel entrance is bell-mouthed with two-way transitions (top and side) for the smooth entry of water in the tunnel. For the top profile an ellipse with semi-major and semi-minor axes equal to 8m and 4m respectively has been proposed. While for the side profile, an ellipse with semi-major and semi-minor axes equal to 8m and 3m respectively has been proposed.

7.4.5. Outlet Structure

Outlet structure is provided to enable smooth exit of water from the diversion tunnels to the river. At the exit, each tunnel has a smooth transition from cicular to rectangular over a length of 17m. At the end of the outlet structure, cement concrete floor and a toe wall has been provided to prevent erosion beneath the outlet structure.

7.4.6. Upstream Cofferdam

The riverbed level where the cofferdam is placed is at El. 1866m. The bottom of the dam is proposed at El. 1864m. The water level attained for the design flood of 3603 cumec is about El. 1892m. Therefore, top of the upstream cofferdam is at El. 1893.50m. The height of cofferdam comes to about 27m above RCC raft level. As the cofferdam is designed for a 1 in 25 flood of the monsoon period, there is less probability that it gets overtopped during the monsoon period, as the construction period for the dam is about four years. Any failure of the cofferdam will result in loss of construction period, entailing great consequential damages. It is proposed to construct colcrete cofferdam with M20 concrete facings.

7.4.7. Downstream Cofferdam

The depth of water in the river for Q = 3603 cumec is about 8.85m. Taking into account any local constriction due to construction activities, downstream cofferdam can be made 11m above the riverbed level, i.e. the top of downstream cofferdam can be placed at about El. 1861m. Since the cofferdam is of a very small height, it is proposed to be a rock fill dam with central compacted random fill.

7.4.8. Final Closure of the Tunnels

Once the construction of the dam is over, diversion tunnels would be closed permanently by lowering the gates with the help of hydraulic hoists operated from the top of the inlet structure and plugged around the point of intersection of the extension of the dam axis and the centreline of the tunnels.

7.5. Dam and Spillway

7.5.1. General

In the project area, the valley is narrow and bedrock is exposed at several places. Based on site reconnaissance and preliminary studies, the dam site is proposed to be located 3.5km downstream of village Redi. A maximum gross head of about 642.5m is proposed to be utilized for power generation.

7.5.2. Principal Considerations

In addition to topographical and geological considerations, the following general principles are used while deciding the layout of the dam, spillway and the power intake

i. Given that a big concrete dam is envisaged, one of the main requirements is that sound bedrock should be available at a reasonable depth in the riverbed as well as in the abutments.
ii. Since Subansiri River is expected to carry some amount of sediment during monsoons, effective management of sediment removal from the reservoir should be ensured.
iii. The spillway should be placed centrally to the dam body so that there is no damage to the side rock on the downstream by the water jet coming out of the spillway.
iv. The intake should be so located that significant sediment deposit does not remain in front of the intake. In other words, position of the intake vis-à-vis the spillway should be such that sediment deposited in front of the intake is adequately removed during reservoir flushing.
v. The number and size of spillway gates and elevation of spillway crest should be such that the PMF and GLOF can be passed safely.
vi. The intake sill should be kept sufficiently high so that only the top, relatively sediment free layer of water is drawn into the water conductor system. In this regard, it may be noted that no de-sanding chambers are proposed in the project in view of a relatively high dam with reservoir extending to almost 3.13km. Position of the intake sill vis-à-vis the MDDL and the spillway crest is thus to be carefully decided.

7.5.3. General Layout of the Dam

General layout of the dam is shown in the relevant drawings. The dam comprises a spillway block which is flanked by non-overflow sections on both banks. As discussed below, the spillway is so designed that the water way is largely confined to the natural river width. Top of the dam is proposed at El. 1953 m, 3 m above the allotted FRL of 1950 m. The free board would adequately accommodate waves generated in reservoir by the wind action.

The deepest foundation level is assumed to be at El. 1830 m. This level corresponds to the level where good quality bedrock is expected to be available below the riverbed. The maximum height of the dam above the deepest foundation level would therefore be 123 m.

The dam comprises of 23 blocks, out of which 4 are overflow blocks, one auxiliary spillway block and 18 are non-overflow blocks. The length of the dam is about 355 m at the top

Numbering and width of the different dam blocks is given in the following table. The tentative arrangement is shown in drawings contained in Drawings volume.

Table 7-1: Arrangement of Dam Blocks

Block Numbers	Width of block at dam axis	Remarks
1 to 10	15.0m	Non-over flow blocks
11	18.5m	Intake Block for dam toe powerhouse
12	10m	Auxiliary spillway block
13 to 16	17.0m	Overflow blocks
17 to 22	15.0m	Non-over flow blocks
23	18.50 m	Non-over flow block

The width of overflow blocks is 17m. Sluice spillway of 8.0m width & 10.8m height is proposed in each spillway block to pass the flood safely. The crest of the spillway is proposed at El. 1900m. Each spillway block accommodates the twin piers of 4.5m width. Trajectory type energy dissipater is provided to dissipate the energy of flood discharge. Total length of the spillway block is 68m at the dam axis.

Out of 17 non overflow blocks, the width of each block in 16 non overflow blocks is 5m. The width of one non overflow extreme right end block is 18m.

One auxiliary spillway block of 10m width is provided to facilitate the passing of floating logs/debris.

7.5.4. Reservoir Operating Levels

The Full Reservoir Level (FRL) at the project has been fixed at El. 1950m. Reservoir area-capacity curve has been developed for the proposed dam axis. The gross storage capacity of the reservoir is about 15.588 MCM at FRL. As per the hydrological assessment for the project; the total annual inflow in the river in the 90% dependable year is 7464 MCM. The gross storage capacity is thus a small fraction of the total inflow even in a 90% dependable year, indicating that the reservoir is quite small. The reservoir will be used only for diurnal storage and its operation will be more like that of a reservoir behind a dam. Keeping this in mind, the MDDL of the reservoir is proposed at El. 1945m which provides sufficient live storage (2.065 MCM) corresponding to the three hours peaking in 24 hours period at full installed capacity.

7.5.5. Type of Dam

A concrete dam is ideally suited for adoption at the project site and a gravity type conventional dam is proposed therefore.

7.5.6. Freeboard

Freeboard for the dam has been calculated using the method given in IS-6512-1984. Maximum and effective fetch lengths have been calculated as 1559m and 524.77m, respectively, at the Full Reservoir Level. Wind velocity over land for Normal freeboard has been considered as 180km/hr (50m/sec) [IS: 875 (Part-III)]. Normal freeboard calculated is 1.76m. But, in case of high dam, dynamic effect of the velocity of approach may be significant and will deserve consideration. Therefore, free board proposed to be about 3m. Thus, the top of dam is proposed therefore at El. 1953.0m.

7.5.7. Non-overflow (NOF) Section of the Dam

Based on the stability analysis as discussed in this chapter, the upstream and downstream slope of the dam sections has been fixed as given below.

Top Level	=	El. 1953.00m
Deepest foundation level	=	El. ± 1830.00m
Top width of the dam	=	10m
Upstream slope	=	0.38(H):1(V) below El 1890.50m
Downstream slope	=	0.85(H):1(V) below El 1941.00m

Given the height of the dam section, requisite numbers of drainage and inspection galleries have been provided. Elevator shaft is provided in right side non-overflow section to access the galleries and stair shaft is provided in left side non-overflow section. In addition, as discussed in a subsequent section, grooves for storage of stop logs have also been provided in the right side non-overflow section.

7.5.8. Overflow Section

<u>Proposed Arrangement for Spillway</u>

The project design flood is a combination of PMF and GLOF, which are 6031 cumec and 2512 cumec, respectively. River Subansiri, like other Himalayan rivers, carries sediment load during the monsoon season. At this stage of project planning, determining reservoir operating levels and spillway and intake sill levels becomes important as they have a direct bearing on the sediment management in the reservoir as well as on the possible encroachment of live storage. Moreover, design of spillway itself has to be such that both flood control and sediment control are effectively ensured.

It is desirable that the spillway is accommodated within the valley so that excavation on both the banks is minimized.

In recent years, two approaches have been used for flood and sediment control in projects with large dams

i. Use of a crest spillway with bottom outlets for under-sluicing of floods and flushing of sediments.

ii. Provision of a low-level sluice spillway

Out of the two approaches, sluice type spillway is more commonly adopted in recent projects, such as Tala and Lower Subansiri. While Tala has been commissioned, Lower Subansiri is under construction. In both cases, extensive model studies have demonstrated that low level sluice spillways are adequately effective for flood and sediment management. At Tala, the low-level sluice spillway was in fact selected after a detailed study of various alternatives including provision of a two tier spillway.

A low-level sluice spillway with crest located significantly below the intake sill is therefore proposed here. It is worth noting that such an arrangement also simplifies the construction, as only one set of openings is to be constructed.

Hydraulic Design of Spillway

To optimize the spillway crest level, several studies were conducted to pass the PMF and GLOF with varying crest levels. The alternative with crest level of 1900m and 4 spillway bays has been finalized as it suitably fits in the valley width. Each bay is 8.0m (W) X 10.8m (H) and adjacent bays are separated by 9m wide twin piers. A 52.8m high solid breast wall is provided from the top of the bay to the top of the gate.

Discharging capacity of the spillway has been verified using the criterion given in IS: 11223-1984, which stipulates that 10% of the number of gates or at least one gate should be considered in-operational while deciding the dimensions of spillway waterway. It is confirmed that the proposed spillway has a discharging capacity to pass PMF of 6031 cumec and a GLOF value of 2512 cumec through four gates.

The top profile of the spillway bell mouth quadrant is $(X^2/256) + (Y^2/10.89) = 1$ and the bottom is flat. Downstream of the sluice crest, the water jet will follow a trajectory type profile. As such, ogee type profile cannot be given to the downstream spillway surface. The ogee surface is rather too steep for trajectory type flow. If provided, there will be negative pressure on the surface, resulting in cavitation. Moreover, even from a dam stability consideration, ogee profile is unsuitable. As such, hydraulically suitable trajectory type profile has been proposed. The basic equation of trajectory profile for the sluice is $X^2 = 4HY$, where 'H' is the head at the centreline of sluice (H=1950-1900-10.8/2=44.6m) and X Y are the coordinates. The profile for the spillway is adopted by the equation $X^2 = 195\ Y$ to give slightly flatter slope to avoid cavitation. (However, the trajectory profile will be confirmed by hydraulic model studies). The trajectory profile continues till it meets the tangent point of the flip bucket. The maximum width of the overflow block at foundation level is about 140.012m.

To protect the spillway crest from abrasive damage of boulders/sediment, the top 1.0m thickness of concrete in glacis and flip bucket portion is lined with silica fume concrete.

In summary, the proposed spillway has the following dimensions:

Crest Level	=	El. 1900m
Foundation Level	=	El. ± 1830m
Upstream slope	=	vertical and 0.35 (H):1(V) below El 1877.92m
Downstream Profile	=	$X^2 = 195Y$ up to tangent point of flip bucket

Energy Dissipation Arrangement

Various alternatives for energy dissipation were considered. Considering the relatively high energy to be dissipated and also transport of bed loads during the reservoir drawdown flushing, only a flip (or trajectory) bucket type with a pre-formed plunge pool is the most appropriate type of energy dissipator under the circumstances. Hence, a flip bucket has been proposed as energy dissipator. Hydraulic design of the flip bucket follows the procedure given in IS 7365:1985.

Salient features are as under:

Bucket invert level	=	El 1883.00m
Bucket radius	=	49m
Lip Angle	=	30°
Tangent point	=	El 1886.50m
Sill level of Bucket	=	El 1883.00m

It has been determined that the water trajectory will hit the riverbed at a horizontal distance of about 129.12m.

Aerator

Since high velocity of flow downstream of the spillway surface up to the flip bucket may cause cavitation of the surface of the spillway, aerator may be required. The need of aerator and its type will be decided at the time of hydraulic model study.

Gates

To control the outflow from the spillway, four nos. radial gates of size 8.0m (W) x 10.8m (H) have been provided. The centre line of the trunnion has been fixed at about El. 1914.20m, which is well above the water profile.

The choice of the radial gates is based on the following

i. Radial gates do not require slots in the piers and thus preclude trapping or deposition of floating debris during the passage of flood. Such debris trapping could otherwise pose several problems.
ii. Radial gates do not require a high overhead structure which the vertical lift gates require to support the gate hoist above the fully raised position of the gate.
iii. At partial gate opening, the radial gates have better coefficients of discharge than vertical lift gate.
iv. There is no down-pull on radial gates.

v. At partial gate openings, there are not vibration related problems/issues with radial gates.

Design and other pertinent details of the gates are provided in relevant sections.

Spillway Glacis

The spillway glacis will be protected with 1000mm thick high-performance concrete.

Breast Wall

Breast wall will be constructed with M25 grade of concrete spanning between the piers. Bottom of breast wall will also be protected with 1000mm thick high-performance concrete

The spillway stop-log groove is accommodated within the breast wall. The gantry crane for operation of the stop-logs will move over the breast wall.

Training Walls

Training walls, which are 4m wide, rest on the spillway section. Walls start from the end of pier from El. 1875m.

Stop Logs

One set of stop logs is proposed for the purpose of maintenance and inspection of the gates. The set constitutes seven units, i.e. six identical and interchangeable bottom units and one top unit. As mentioned in a subsequent section, a gantry crane of 35t capacity, along with a lifting beam, has been provided to manoeuvre the stop logs. It is proposed that three stop logs are stored in the stop log grooves themselves (by dogging them near the crest); the lifting beam will be stored in the remaining stop log groove. The top and the bottom pieces are proposed to be stored in a special storage groove provided in the right non-overflow section.

7.5.9. Auxiliary Spillway Section

In addition to the low-level sluice spillway, a chute type overflow spillway (10m wide) has also been provided adjacent to the left edge of the sluice spillway. It is envisaged that the chute spillway will facilitate passing of floating logs/debris downstream of the dam and to minimize the flow of logs/debris towards the intake. Model studies carried out at another project have confirmed that the floating mass initially accumulates near the intake but gets attracted towards the chute spillway once the latter starts to operate.

Pertinent dimensions of the Auxiliary spillway section are as follows

Crest Level	El. 1945.00m
Foundation Level of the block	El. ±1830.00m
Upstream slope	vertical below crest; 0.35 (H):1 (V) below El 1890.5m

Down-stream Profile	The crest is horizontal for some distance beyond which it is rounded off at a radius of 10m up to the tangent point, beyond which the slope is 0.85(H):1 (V)

Gates

One fixed wheel vertical lift type service gate of 6000(W) x 6000(H) has been provided for the auxiliary spillway. Another fixed wheel vertical lift type bulkhead gate of the same size is proposed upstream for inspection and maintenance of the main gate. Service gate is expected to remain closed except during flood season when the auxiliary spillway will be used to pass floating debris downstream. Bulkhead gate is provided for the emergency maintenance for service gate. Otherwise at the time of maintenance of service gate, reservoir should be kept below the crest level of gate. By lowering of reservoir level, energy generation will be affected. With this consideration bulkhead gate is also provided. The gates will be operated by the same gantry crane which is used for the stop logs of the spillway. A lifting beam of adequate capacity shall be used for lifting the gates.

7.5.10. Stability Analysis of Dam Blocks

Preliminary stability analysis has been carried out for both maximum overflow and maximum non-overflow sections of the dam. Procedure and criteria given in IS 6512:1984 has been used and the stability is checked for all load combinations prescribed in this code. The following parameters have been assumed for the stability analysis.

Design Criteria

The purpose of the design criteria is to provide a technical basis and guidance to carry out Stability Analysis of Concrete Gravity Dam. This section includes design considerations, load conditions and stability requirements for Concrete Gravity Dam. Engineering judgment must be exercised when evaluating procedures or situations not specifically covered herein.

Codes, Standards and Technical Documents Used

A. Codes

IS 6512 : 1984	-	Criteria for Design of Solid Gravity Dam
IS 1893 : 1984	-	Criteria for Earthquake resistant Design of Structures
IS 1893 : 2002	-	Criteria for Earthquake resistant Design of Structures (Part 1 general provision and buildings)

B. Technical Documents

ICOLD Bulletin	-	Bulletin 52, Earthquake Analysis of Dams

USACE	-	(US Army Corps of Engineers, 1995) - Gravity Dam Design Report EM 1110-2-2200
USBR	-	Design of Gravity Dams

C. Design Data

(i) Dam Data

Top of dam	El. 1953m
Full Reservoir Level	El. 1950m
Maximum Tail-water Level	El. 1863.68m
Spillway Crest Level	El. 1900m
Slope of Downstream Face	0.85 H: 1 V
Upstream Face Slope	0.35 H: 1 V
Top Width of Dam	10.0m
Deepest Foundation Level	El. 1830m
MDDL	El. 1945m

(ii) Concrete Data

Unit weight of Concrete	2.4 T/m^3
Characteristic Strength of Concrete, fck	15 N/mm^2
Permissible Compressive Stress in Direct Compression	4 N/mm^2
Modulus of Elasticity of Dam Material	19365 N/mm^2

Modulus of Elasticity of Concrete has been assumed to be 5000 $\sqrt{(f_{ck})}$ N/mm^2 as per Page 16, Section 6.2.3.1, IS - 456:2000

(iii) Water Data

The unit weight of water is taken as 10 kN/m^3. Variation of the density of water with temperature is not taken into account. A linear distribution of static water is assumed for analysis purposes. It is assumed to be on the higher side as it is will be detrimental to the stability.

(iv) Nappe Force

At small discharges, Nappe forces may be neglected in Stability Analysis. However, when the discharge over the overflow spillway approaches design discharge, Nappe forces become significant and may be taken into analysis. As per IS Code, the mass of the water flowing over the top of the spillway is not considered in the analysis since the water usually approaches spouting velocity and exerts little pressure on the spillway crest.

(v) Silt Data

Saturated unit weight of Silt / Sediment	1.925 T/m^3
Equivalent Hydrostatic Weight of Saturated Silt for Horizontal Silt Pressure	1.36 T/m^3
Angle of internal friction for calculation of passive pressure	45º

The values have been adopted as given in IS Code 6512: 1984.

(vi) Foundation Data

The following values have been assumed

C = 0.30 MPa (30 t/m^2) and ϕ= 46º

(vii) Drainage Gallery Data

Spacing of Drainage holes	3m c/c
Location of the bottom most drainage gallery from foundation	5.0m
Height of Gallery	2.5m
Width of Gallery	2m

The height and width of the gallery has been adopted as per requirement for grouting and drilling machine. The drainage gallery is located at a distance of approximately 5% of dam height at that location or 3.0m whichever is more.

(viii) Earthquake Data

The earthquake has been considered both for MCE and DBE condition.

Maximum Considered Earthquake (MCE)

The most severe earthquake which can be associated with the seismo-tectonic setup of the project area is known as the Maximum Considered Earthquake.

Design Basis Earthquake (DBE)

The earthquake, usually smaller than the MCE, associated with a specific seismo-tectonic structure or source area within the region examined, which reflects the level of earthquake protection desired for operational or economic reasons. It is usually considered to be half of MCE.

Seismic Parameter

Oju dam is located in Zone V as per the Seismic Zoning Map of India incorporated in IS: 1893 (part 1) – 2002. The horizontal earthquake or the inertia forces has been determined by both seismic coefficient and response spectrum methods in accordance with IS: 1893 - 1984. In seismic coefficient method, variation of the seismic coefficient along the height of the dam is taken as a linear function varying from zero at the dam base to 1.5 times the design seismic coefficient at the dam top. The horizontal inertial force is calculated by multiplying the seismic coefficient with the weight of dam at the corresponding level While in response spectrum method, the base shear and base moment is calculated as $0.6W.\alpha_h$ and $0.9W.y.\alpha_h$ respectively, where W is the weight of the dam, α_h is the horizontal seismic coefficient and y is height of the C.G. of dam above base. Higher of the above inertial force has been used in the stability analysis.

The vertical earthquake force has been determined by seismic coefficient method only by considering a linear variation from zero at the dam base to 1.5 times the design seismic coefficient at the dam top as per IS1893 - 1984. The vertical inertial force will be calculated by multiplying the seismic coefficient with the weight of dam at the corresponding level.

The earthquake forces (both horizontal and vertical) are treated as simple static inertial force and are combined with water and gravity loads.

The hydrodynamic pressure acting on the structure due to earthquake would be calculated as per IS:1893 - 1984.

Site specific seismic study for Oju HEP has been carried out by Indian Institute of Technology, Roorkee (IITR), India. Key results/recommendations from the study are presented in below table.

Particulars	DBE	MCE
Horizontal Peak ground acceleration, PGA_H	0.27 g	0.47 g
Vertical Peak ground acceleration, PGA_V	0.18 g	0.31 g
Horizontal seismic coefficient, α_h	0.24	-
Vertical seismic coefficient, α_v	0.16	-

Uplift Forces

Uplift should be assumed to exist between the dam and its foundation, below the contact plane, and should also be applied within any cracks within the dam. The uplift pressure will be assumed to vary linearly from the appropriate reservoir water pressure at the upstream face to the appropriate tail-water pressure at the downstream face. The uplift is assumed to act over 100 percent of the area.

The drainage system is supposed to work efficiently, so that reduction of 2/3rd of the head difference between the reservoir water level and tail-water level can be considered.

The rock in the foundation is assumed to be un-fissured.

The uplift pressure diagram will be modified if preliminary analysis indicates crack in the dam-foundation interface.

It is assumed that uplift pressures are not affected by earthquakes.

2 D Stability Analysis Using Pseudo Static Method

i. The following forces have to be considered to carry out stability analysis as per IS Code 6512: 1984:

ii. Dead load,
iii. Reservoir and tail-water loads,
iv. Uplift pressure
v. Earthquake forces,
vi. Earth and silt pressures,
vii. Ice pressure, (Not considered, as the formation of ice in the area is ruled out)
viii. Wind pressure, (IS:6512, Clause No. 5.7, for massive dam where wind effected area upstream of dam is too small (in the present case only this is only 3.0m above FRL), wind pressure is not a significant factor for the design, hence not considered)
ix. Wave pressure, (IS:6512, Clause No. 5.8.1, for massive dam wave pressure has little consequence, hence not considered)
x. Thermal loads (temperature shall be controlled during construction while pouring concrete by mixing adequate quantity of ice with concrete).

Assumptions

For consideration of stability, the following assumptions are made:

i. The dam is composed of individual transverse vertical elements, each of which carries its load to the foundation, without transfer of load from or to adjacent elements
ii. The vertical stress varies linearly from upstream face to downstream face on any horizontal section,

The analysis determines the safety of structure against sliding and stresses for various loading conditions as mentioned earlier.

Load Combinations

The Stability Analysis for the Concrete Gravity Dam will be carried out using the following load combinations: A, B, C, D, E, F and G, as mentioned in the IS Code 6512: 1984. In addition to above load combinations, normal operating condition with MCE earthquake has also been checked as load combination H.

i. Load Combination A (Construction Condition) — Dam completed but no water in reservoir and no tail-water.

   a) Dam fully constructed
   b) Reservoir Empty
   c) No silt load
   d) No tail water
   e) No Uplift

ii. Load Combination B (Normal Operating Condition) — Full reservoir elevation normal dry weather tail-water, normal uplift; ice and silt (if applicable).

   a) Dam fully constructed
   b) Silt Load
   c) Gates closed

d) Water at FRL

e) Normal tail water level

f) Normal Uplift (2/3 pressure release at drainage holes)

iii. Load Combination C (Flood Discharge Condition) — Reservoir at maximum flood pool elevation, all gates open, tail-water at flood elevation, normal uplift, and silt (if applicable).

a) Dam fully constructed

b) Silt Load

c) Gates fully open

d) Design Discharge flowing through Spillway

e) Reservoir at MWL

f) Max TWL at downstream

g) No water load over Glacis

h) Normal Uplift (2/3 pressure release at drainage holes)

iv. Load Combination D — Combination A, with earthquake.

v. Load Combination E — Combination B, with earthquake (DBE).

vi. Load Combination F — Combination C, but with extreme uplift (drains inoperative).

vii. Load Combination G — Combination E, but with extreme uplift (drains inoperative).

viii. Load Combination H — Combination B, with earthquake (MCE).

It may be noted that at the project site, temperature normally remains above freezing point, and there is no possibility of formation of ice in the reservoir.

Partial factor of safety against sliding

The Partial Factor of Safety against sliding has been considered and this has been taken as under. Values adopted are as per **Table 7-2** below (Refer Page-14, Section 5.12.2 of IS:6512 – 1984).

Table 7-2: Partial Factor of Safety against Sliding

S.No.	Loading Condition	Partial Factor of Safety	
		For Cohesion (F_c)	For friction ($F\Phi$)
i)	A - Construction Condition	3.6	1.5
ii)	B - Normal Operating Condition	3.6	1.5

S.No.	Loading Condition	Partial Factor of Safety For Cohesion (F_c)	For friction ($F\Phi$)
iii)	C - High Flood Condition	3.6	1.5
iv)	D - Construction Condition with DBE	2.4	1.2
v)	E - Normal Operating Condition with DBE	2.4	1.2
vi)	F - High Flood Condition with drains inoperative	1.2	1.0
vii)	G - Normal Operating Condition with DBE loads and drains inoperative	1.2	1.0
vii)	H - Normal Operating Condition with MCE *	1.2	1.0

<u>Non-Overflow Block</u>

The Stability Analysis of Non-Overflow block has been checked for section with maximum height. A one-meter-wide section will be analysed. The effect of openings and shafts has not been considered in the preliminary analysis, and they will be taken into account once data is available, and a refined analysis is done at a later stage. Gravity Method assumes that the dam is a 2D rigid block, and the foundation pressure distribution is assumed to be linear.

<u>Factor of Safety</u>

The factor of Safety is calculated as per IS Code 6512:1984, refer Page 15, Section 5.12.2.1.

$$F = \frac{w' \times \tan\phi + C' \times A}{P}$$

where $w' = \frac{(w - u)}{F_\phi}$, $C' = \frac{C}{F_C}$

F_ϕ and F_C as per Table given on previous page.

The proposed dam sections meet all the stability criteria with adequate factor of safety as shown in **Table 7-3** for overflow section and

Load Case	Description	FOS against sliding	Stress on heel (t/m^2)	Stress on toe (t/m^2)	All. Tensile stress in conc. (t/m^2)	All. Comp. stress in conc. (t/m^2)	All. Comp. stress in rock (t/m^2)
CASE A	CONSTRUCTION	INFINITY	194	111	20	500	852
CASE B	NORMAL OPERATING	1.64	93	150	0	500	575
CASE C	FLOOD DISCHARGE	1.68	97	140	20	500	852
CASE D1	CASE A + EQ (U/S & UP)	5.45	218	38	40	660	1769

Load Case	Description	FOS against sliding	Stress on heel (t/m^2)	Stress on toe (t/m^2)	All. Tensile stress in conc. (t/m^2)	All. Comp. stress in conc. (t/m^2)	All. Comp. stress in rock (t/m^2)
CASE D2	CASE A + EQ (U/S & DN)	7.24	280	74	40	660	1769
CASE E1	CASE B + EQ (D/S & UP)	1.08	-18	212	40	660	852
CASE E2	CASE B + EQ (D/S & DN)	1.56	56	243	40	660	852
CASE F	CASE C + FULL UPLIFT	2.37	51	136	40	660	1769
CASE G1	CASE E1 + FULL UP LIFT	1.16	-66	208	80	660	1769
CASE G2	CASE E2 + FULL UPLIFT	1.73	8	239	80	660	1769

Note: Negative stress indicates tensile stress.

Table 7-4 for non-overflow section.

Table 7-3: Summary of Results for Overflow section

Load Case	Description	FOS against sliding	Stress on heel (t/m^2)	Stress on toe (t/m^2)	All. Tensile stress in conc. (t/m^2)	All. Comp. stress in conc. (t/m^2)	All. Comp. stress in rock (t/m^2)
CASE A	CONSTRUCTION	INFINITY	194	111	20	500	852
CASE B	NORMAL OPERATING	1.64	93	150	0	500	575
CASE C	FLOOD DISCHARGE	1.68	97	140	20	500	852
CASE D1	CASE A + EQ (U/S & UP)	5.45	218	38	40	660	1769
CASE D2	CASE A + EQ (U/S & DN)	7.24	280	74	40	660	1769
CASE E1	CASE B + EQ (D/S & UP)	1.08	-18	212	40	660	852
CASE E2	CASE B + EQ (D/S & DN)	1.56	56	243	40	660	852
CASE F	CASE C + FULL UPLIFT	2.37	51	136	40	660	1769
CASE G1	CASE E1 + FULL UP LIFT	1.16	-66	208	80	660	1769
CASE G2	CASE E2 + FULL UPLIFT	1.73	8	239	80	660	1769

Note: Negative stress indicates tensile stress.

Table 7-4: Summary of Results for maximum non-overflow section

Load Case	Description	FOS against sliding	Stress on heel (t/m^2)	Stress on toe (t/m^2)	All. Tensile stress in conc. (t/m^2)	All. Comp. stress in conc. (t/m^2)	All. Comp. stress in rock (t/m^2)
CASE A	CONSTRUCTION	INFINITY	179	47	20	500	852
CASE B	NORMAL OPERATING	1.48	67	124	0	500	575
CASE C	FLOOD DISCHARGE	1.46	65	121	20	500	852
CASE D1	CASE A + EQ (U/S & UP)	6.17	211	-2	40	660	1769
CASE D2	CASE A + EQ (U/S & DN)	7.05	246	-1	40	660	1769
CASE E1	CASE B + EQ (D/S & UP)	1.13	-27	199	40	660	852
CASE E2	CASE B + EQ (D/S & DN)	1.35	17	197	40	660	852
CASE F	CASE C + FULL UPLIFT	2.07	24	115	40	660	1769
CASE G1	CASE E1 + FULL UP LIFT	1.22	-69	193	80	660	1769
CASE G2	CASE E2 + FULL UPLIFT	1.48	-26	191	80	660	1769

7.5.11. Foundation Profile and Treatment

The sound rock in the river portion has been assumed to be available at a depth of 20m below the riverbed. Foundation of the spillway section is thus proposed 20m below the riverbed so that competent rock foundation is ensured. The abutments are proposed to be stripped for a maximum height of 15 to 20m with intermediate berms between two slopes depending on site conditions.

The following foundation treatment is proposed:

a. Consolidation grouting

Consolidation grouting of foundation rock shall be done to increase foundation stiffness and decrease the variability of deformation modulus, if any, along the dam axis. Consolidation grouting shall also increase foundation shearing strength, stability of abutments, and improve contact between foundations and dam.

Provisions in IS 6066: 1994 “Pressure grouting of rock foundation in river valley project- recommendations” and IS: 11293 (part-II) -1993- “Guidelines for pressure grouting of rock foundations in river valley projects” shall be adopted for grouting works.

A grid of primary holes 3.0m x 3.0m shall be provided in the entire dam foundation. The grid of secondary holes 3.0m x 3.0m shall also be provided. The diameter of the holes shall be kept as 38mm. Hole inclination shall be either vertical or inclined, depending upon geological conditions. Depth of holes shall be 10.0m. However, the actual depth of consolidation grouting shall be as recommended by the geologist according to the site conditions.

b. Curtain Grouting

The presence of a reservoir upstream of the dam shall have an influence on the flow of seepage water through the dam foundation. This may result in an increase in uplift pressure under the structure, erosion of joints in-fills and excessive water loss. A grout curtain is therefore proposed in the dam foundation.

The depth of grout curtain depends upon the extent of fracturing of the foundation and water head in the reservoir. In general, the depth of grout curtain holes shall vary from 1/2 to 2/3 of the reservoir head at that point. According to the provision of section 3.5 of IS: 11293 (Part 2) -1993, the depth of grout curtain is given by:

$$D = 2\left(\frac{H}{3}\right) + 8$$

where D is the depth, in meters, of grout curtain at any point on the foundation rock and H is the height, in meters, of reservoir water at the point under consideration. The minimum depth of grout curtain shall be 10.0m.

Grout curtain is presently proposed in a single row with holes of 38mm diameter. Additional row(s) may be provided as required. Grout curtain shall be constructed in three phases. The primary holes at a wider and constant spacing shall be completed first. The secondary holes, located halfway between the primary holes, shall then be undertaken. Finally, the tertiary holes shall be completed between adjacent primary and secondary holes. The final spacing of holes shall be kept at 1.5 to 3.0m, according to rock fracturing. However, if the water tightness criteria to achieve permeability of foundation rock not less than one lugeon are not met, additional (quaternary) holes shall be added in critical areas.

Grout holes shall be aligned in lines parallel to the dam axis. In the valley floor, inclination of holes shall be kept vertical or ±10º from vertical towards upstream. The inclination shall be kept perpendicular to the slope on the abutments. In cases like vertical fractures, the inclination shall be modified so as to intercept the maximum number of fractures.

7.5.12. Joints

Transverse contraction joints are provided to divide the dam into convenient size monoliths to permit convenient and systematic construction and to prevent formation of undesirable cracks. IS 6512:1984 recommends a joint spacing of 15m to 25m. In case of the proposed dam, an average spacing of 17m has been provided for the overflow section. In non-overflow section, the joints have been provided at a spacing of 15m in the straight portions, except in the last block on the right side, which is 18m wide.

Each joint extends through the entire width of the dam. As such, the total length of the dam has been divided into 21 blocks.

In spillway the contraction joints have been provided between the twin piers.

No longitudinal joints have been provided. Contraction joints are proposed to be without shear keys and un-grouted.

7.5.13. Water Stops at Transverse Contraction Joints

Following the recommendations of IS 12200: 1987, each joint is provided with three PVC water stops near the upstream face. The water stops comprise two 300mm wide PVC water stops followed by a 200mm diameter formed drain to trap any water which has leaked past the two water stops. After the formed drain, another PVC water stop is provided to stop the water in the drain moving further downstream. The formed drain empties into the main drain of the drainage gallery.

7.5.14. Internal Drainage

Given the size of the dam, elaborate arrangement of drainage and inspection galleries has been provided. A foundation and drainage gallery is provided near the upstream face of dam and just above the foundation, closely following the foundation profile [IS:12966 (Part 1) -1992]. The proposed gallery is 2.0m wide and 2.5m high and accommodates a drain of 0.3m x 0.25m on the upstream side. The proposed size of gallery will considerably facilitate drilling of grout curtain and drainage holes.

Foundation drainage holes shall be provided to a depth equal to 75% of curtain grout depth. Drainage holes of 75mm diameter have been proposed at a spacing of 3m c/c, staggered with curtain grout holes. The drainage holes shall be slightly inclined towards downstream. Actual spacing shall be determined on the basis of geological conditions encountered at the dam site.

In addition, 200mm Ø vertical porous drains have been provided in the body of dam at a spacing of 3 meter to intercept seepage from the body of the dam, which shall be discharged into the gallery drain. The seepage water from the foundation and body of dam shall be collected in the sump from where it shall be pumped out to the d/s side above the max TWL.

7.5.15. Riparian Flow

Current norms of MoEF state that a site specific study need to be carried out for establishing the proper environmental flow during monsoon, non-monsoon and lean months. Environmental flow must mimic the pre-dam flow pattern of the river for sustaining the aquatic bio-diversity together with downstream user need and accordingly, water withdrawal for power generation is to be regulated. Minimum environmental flow release would be 20% of average of four months of lean period and 25% of flow during non-lean non-monsoon period corresponding to 90% dependable year. The cumulative flow releases including spillage during monsoon period should be 30% of the cumulative inflows during the monsoon period corresponding to 90% dependable year.

Keeping in view the above norms, following environmental releases have been considered in power potential studies

- *Lean Period*: 20% of average of four months of lean period (11th Nov to 10th March) corresponding to 90% Dependable year works out to 9.74 cumec and the same has been considered as environmental release during this period.

- *Non Lean Non Monsoon Period*: 25% of average flow corresponding to 90% dependable year which works out to 49.43 cumec from 1st October 10th November (4 ten dailies) and 46.83 cumec from 11th March to 31st May and the same have been considered as environmental releases during these period.

- *Monsoon Period*: Minimum riparian flow as required during lean period are released during monsoon period ensuring at the same time that the cumulative releases including spillage are 30% of the cumulative inflows during the monsoon period corresponding to 90% dependable year. It is seen that in the instant case the cumulative releases (Riparian + Spillage) downstream of dam work out to 31.25% (refer Table 7-5) of the cumulative monsoon period inflows in 90% dependable year against minimum 30% required. Relevant computations are given as below:

Table 7-5: Percentage of Spills in Monsoon in 90% Dependable Year

Ten Daily Period		Flow in 90% Dependable year		Diversion for Power Generation		Spills+Environmental Releases
		Cumec	MCM	Cumec	MCM	MCM
Jun	I	290.13	250.67	280.39	242.26	8.42
	II	291.94	252.24	282.20	243.82	8.42
	III	487.09	420.85	333.39	288.05	132.80
Jul	I	725.67	626.98	333.39	288.05	338.93
	II	863.46	746.03	333.39	288.05	457.98
	III	606.68	576.59	333.39	316.85	259.74
Aug	I	412.89	356.74	333.39	288.05	68.69
	II	359.71	310.79	333.39	288.05	22.74
	III	474.82	451.27	333.39	316.85	134.42
Sep	I	423.55	365.95	333.39	288.05	77.90
	II	359.71	310.79	333.39	288.05	22.74
	III	304.48	263.07	294.74	254.65	8.42
Total			**4931.95**		**3390.76**	**1541.19**
% Spill in Monsoon						**31.25**

The riparian releases may also be utilized for power generation by constructing a mini powerhouse just downstream of the dam with a bye pass arrangement to ensure uninterrupted release of riparian discharge in case of shutdown/tripping of generating unit (s).

7.6. Power Intake

7.6.1. General

The intake is placed just upstream of the dam on the right bank. The right abutment at the site rises above the riverbed at steep angle upto El 1915m and then at moderate angle beyond that. Bedrock comprising moderately foliated, moderately strong to strong and slightly weathered to fresh quartzite, schistose quartzite with occasional thin bands of schists are exposed upto an elevation of about El 1905m and above this the abutment is covered by slightly to moderately thick slope-wash deposits comprising rock blocks upto 3m size with silty matrix is observed. The overburden supports moderately thick vegetation.

The following codes and standards have been referred.

- IS 9761:1995 , Hydropower Intakes – Criteria for Hydraulic Design
- IS 11388:1995, Recommendations for design of trash rack for intakes
- Davis' Handbook of applied hydraulics, Fourth edition
- W.H. Hager; D.L. Visher, Dam Hydraulics

7.6.2. Layout of Power Intake

The intake structure is provided on right bank and is located as close to the dam as possible (nearest edge of intake is about 20m upstream of Dam axis). The orientation of intake is at 100° to the dam axis. As the intake is very near to the dam, the surface excavation for both the structures will be common. All the berms provided for dam excavation shall be extended upto the intake area with slight re-alignment of the berms in order to optimize the excavation.

The Intake is proposed to be raised from approximately El 1915.0m by filling concrete. The intake structure has its crest at El 1929.00m i.e. 29m above the main spillway crest. In plan, the upstream edge of the intake is 50.5m away from the nearest edge of the spillway bay. Upstream view of the spillway vis-à-vis the intake profile is shown in **Error! Reference source not found.**. This configuration will ensure a relatively silt free regime in the near area of intake. It is a very essential feature as no separate desilting arrangement is proposed for the removal of suspended silt from the water entering the HRT. A bell mouth type opening is provided with adequate water cushion to prevent formation of vortices. The proposed location is considered most suitable as per requirement of hydraulics and sediment management. However, the location of intake will be reconfirmed with the help of hydraulic model studies.

HRT of 10.4m diameter offtakes from the intake, which is 40m (L) x 27m (H). An operating platform at El.1953m houses the operating system for the intake gates. The size of the gate opening is 6.8m (W) x 6.9m (H) of two numbers.

The floor in front of intake sill is at El.1929.00m, 35.0m width of the intake transitions to 18.2m through S-curves made of circular, straight and elliptical profiles.

The trash racks are inclined at an angle of 12° to the vertical to facilitate mechanical cleaning by trash rack cleaning machine. For continuity, the piers are also inclined at the same angle. Trash racks have a clear span of 3.5m. The 24m high piers have beams in between to give them lateral stiffness.

Gates

Two gates have been provided for power intake in each opening. One vertical lift fixed wheel type service gate of 6.8m (W) x6.9m (H) has been provided for the power intake. Another vertical lift slide type bulkhead gate of the same size is proposed upstream for inspection and maintenance of the main gate. The gates will be operated by individual rope drum hoist of adequate capacity.

Trash Racks

The trash racks are inclined at an angle of 12º to the vertical, to facilitate mechanical cleaning by the trash rack cleaning machine. For continuity, the piers are also inclined at 78º and extend to top of platform at El. 1953m. Trash racks are eight in numbers, and each have a 3.5m of span in between piers. The 24m high piers have four beams in between to provide lateral stability.

7.7. Headrace Tunnel

7.7.1. Layout of HRT

The Headrace Tunnel is located on the right bank of river Subansiri. Two intake conduits are merged to form a single Head Race Tunnel (HRT) with the objective of conveying 334 cumec of design discharge from diversion site to powerhouse. The alignment of the HRT has been finalized as per guidelines specified in IS-4880 (Part-IV):

(a) Vertical cover is nowhere less than the internal water pressure head (H) over the crown of the tunnel.

(b) Horizontal/ lateral cover near nallah locations or near steep mountain slopes is nowhere less than two times the internal water pressure (2H).

(c) Maximum vertical cover above crown of the tunnel is in the order of 625m. Excessive in-situ vertical stresses and consequently any squeezing conditions cannot be avoided under high rock cover conditions (above 500-600m).

The minimum radius of curve in the tunnel alignment has been kept as 75m in order to provide ease in construction and minimize the bend losses in the HRT. Minimum numbers of bends have been kept in order to fulfil the criteria specified above.

It has been ensured that the hydraulic gradient line along the length of water conductor system is above the crown of the tunnel in order to avoid creation of vacuum conditions in HRT, and even during hydraulic transients.

Before finalizing the HRT alignments for Oju HEP, two alternative alignments were studied. Comparisons of both the alternatives are given in the below table.

Descriptions	Alternative-1	Alternative-2
Length of tunnels from intake to centre of surge shaft	14278m	14171m
Diameter of tunnel	10.4m	10.4m
Number of Construction Adits	7 (seven)	5 (five)
Number of bends	7	5
Minimum vertical cover above crown of HRT	88m below Setu Nalla	123m

Note: *HRT Alternative-1 alignment was presented in the first consultation meeting held in CEA on in April 2015.*

From the above table it is seen that length tunnel in Alternative-2 layout is shorter than Alternative-1 layout by about 107m. Moreover number of bends and construction Adits are less in Alternative-2 layouts. In view of these, Alternative-2 HRT alignment has been proposed for next level of design and engineering.

<u>Construction Adits to HRT</u>

Keeping in view the construction schedule of the project, five modified D-shaped construction adits of size 6.0m (W) x 7.0m (H) have been proposed along the length of the tunnel (Alternaive-2 HRT alignment).

7.7.2. Optimization Studies

The HRT is required to pass the design discharge of 334 cumec to generate 1850 MW of power. Optimization study to obtain the economical diameter of HRT has been carried out by considering a range of diameters from 9.6m to 11.6m.

It is evident from this study that the summation of construction cost and cost of energy loss due to friction is a minimum for 10.4m internal diameter.

Further, the flow velocity in the headrace tunnel with diameter of 10.4m and a circular shaped profile is about 3.93m/s for designed discharge of 334 cumec and is within the permissible limits.

Hence, as per economic considerations, a tunnel of finished diameter 10.4m and a horseshoe shape is recommended.

Considering a lining thickness of 600mm, the nominal excavated size would be 11.6m.

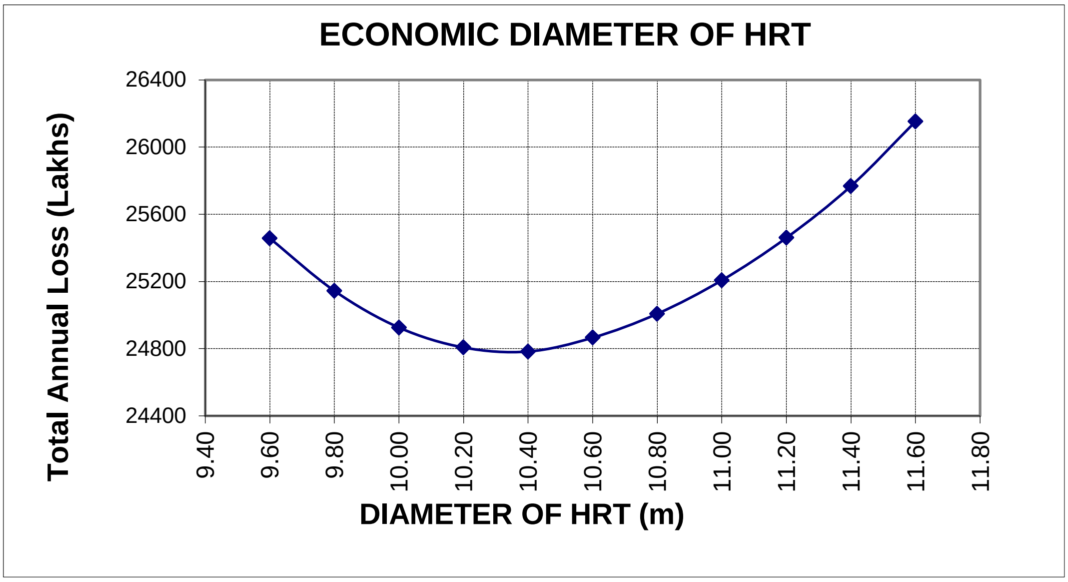


Figure 7-1: Optimization Study for Economical Diameter of HRT

7.7.3. Shape and Slope of HRT

The circular section has been adopted because of its structural stability as compared to other shape like modified horseshoe, horseshoe or D-shape. However, the excavated section would be modified at bottom with a horizontal base width of about 7.5m to facilitate construction. A slope of 1:291.6 has been provided in HRT till surge shaft so that the hydraulic gradient line is always above the overt of tunnel and vacuum situations are avoided.

7.7.4. Tunnel Support System

The general design approach (design of rock bolt, design of steel rib) shall be based on the recommendation given by the Indian Standard for different rock conditions .The design will also be checked by the empirical method given by the Rock Mass Rating (Bieniawaski) and Q system (Barton).

The following standard five classes requiring different support systems as discussed below:

a) Rock Class I (Very Good rock) - Rock under Class –I is not expected.

b) Rock Class II (Good rock) - The excavated section will be supported by shotcrete (un-reinforced) in the crown followed by systematic use of rock bolts.

c) Rock Class III (Fair rock) - The excavated section will be supported by shotcrete (reinforced with welded wire mesh or fibers) followed by systematic use of rock bolts.

d) Rock Class IV (Poor Rock) - The excavated section will be supported by shotcrete (reinforced with welded wire mesh or fiber) followed by systematic use of rock bolts.

e) Rock Class V (Very Poor rock) - The excavated section will be supported by steel ribs and RCC lagging

7.7.5. Drainage Holes

Drainage holes shall be provided in Class-IV and V rock during excavation of head race tunnel to relieve pore water. Minimum two holes, 76mm dia and about 0.75D long (D=finished dia), shall be provided in crown portion. Horizontal spacing of these holes shall be 6.0m c/c and shall be placed in staggered manner in alternate section. These holes shall be plugged during concrete lining. No reduction of external pressure shall be considered during lining design due to these drainage holes, as it may get chocked in long run. Provision of NRV (Non return valve) is also not envisaged due to ineffectiveness in long run.

7.7.6. Grouting

7.7.6.1. CONTACT GROUTING

In order to achieve proper contact between lining and rock, contact grouting is proposed to be done in top arch portion for entire length of tunnel; the holes for grouting shall be drilled at 3m c/c along the length in a staggered manner. The maximum pressure for contact grouting shall be 5.0 kg/cm^2. The holes for grouting shall extend 300 mm inside the rock mass.

7.7.6.2. CONSOLIDATION GROUTING

Consolidation grouting shall be done after contact grouting. The holes used for contact grouting shall be used for consolidation grouting also, but shall be re-drilled to extend up to 8m (about 0.75D, D = finished diameter) into the rock. The consolidation grouting shall be done in rock class-IV and V only. Number of holes in a grout plane shall be six holes. The arrangement of holes shall be staggered in alternate grout planes. The spacing of grout plane shall be 3 to 5m as per site condition. The maximum pressure for consolidation grouting shall be 7.0 kg/cm^2.

7.7.7. Plugs

After completion of all works in the HRT, concrete plugs will be provided in various adits near their junctions with HRT with vehicle access door (2.2mx2.2m). Dewatering arrangements shall also be provided in the plugs by embedding two 200mm pipes. Contact and consolidation grouting shall be carried out in all the plugs after concreting. Necessary network of grout pipes and cooling water pipes, if required, will be embedded in the concrete for this purpose. Plug with vehicle access door shall be provided in Adit-1, Adit-3 and Adit-5.

7.8. Surge Shaft

A surge tank is provided at the downstream end of the HRT to reduce the pressure surges created due to water hammer and to limit their further transmission into the HRT. The surge tank will also assist in supplying water to turbines in case of sudden start-up of a machine.

The following criteria are usually adopted to determine whether a surge tank is required in a given hydraulic system

According to a rule of thumb, a surge tank is usually necessary if L/H is equal to or more than 5; 'L' being length of HRT and 'H' the net head.

In the case of Oju, L=14217.7m and H is 624.5m, giving L/H of 22.77

A surge tank is clearly required.

Another criterion pertains to the acceleration time of the hydraulic system. The acceleration time of a hydraulic system is given by the equation

$$T_a = \frac{LV}{gH}$$

where,

L = Length of water conductor

V = velocity of flow in water conductor

H = Net head

g = Acceleration due to gravity

If the acceleration time of a hydraulic system is less than 2 seconds, no surge tank is required in the hydraulic system. For acceleration time between 2 and 5 seconds, surge tank may be provided for a stable operation of the system. For acceleration time greater than 5 seconds, a surge tank is almost always required.

In the present case, L = 14217.7m, H = 624.5m and V = 3.93m/sec which gives an acceleration time, Ta comes out to 9.12 seconds.

Hence a surge tank is clearly required.

7.8.1. Type of Surge Shaft

In order to satisfy the functional requirement, generally two types of Surge Shaft; either a Simple Surge Shaft or a Restricted Orifice Surge Shaft can be provided, which is largely governed by the topographic condition at the site location. For the present case a Restricted Orifice type Surge Shaft has been selected because of following advantages:

- In case of sudden load rejection, the water flows into Surge Shaft through the orifice creating an instant high pressure under the orifice slab. The rise in pressure helps in damping of the oscillations. The amplitude of oscillation in this case has shorter amplitude as compared to Simple Surge Shaft. Consequently, they die out very quickly and system becomes stable in shorter period of time.

For same design parameters, it generally results in lesser height of surge elevations, thereby making them cost effective and topographically suitable.

7.8.2. Sizing of the Surge Shaft

The following design criteria have been adopted for the sizing of surge shaft.

Minimum Surge shaft area (Restricted Orifice type)	The minimum net area must be larger than 1.6 times the Thoma area to ensure stability of the oscillations in case the power station is to be used in isolation.
Orifice area	Orifice area shall be selected such that it satisfies the criteria laid down by Calame and Gaden.
Top of surge shaft	There will be a minimum freeboard of 1.5m between top of surge shaft and maximum upsurge level.
Bottom of surge shaft / top of orifice slab	Bottom of surge shaft/ top of orifice slab shall be at least 2m below the minimum level due to down surge to avoid draining of the surge shaft.

Cross sectional area of Surge Shaft has been finalized based on criteria mentioned above.

(a) Size of Surge Shaft

Thoma concluded that for self-governed turbines, the Surge Shaft will only be hydraulically stable if the horizontal cross-sectional area of shaft exceeds a certain minimum value.

Thoma area of a Surge Shaft can be calculated from following formula:

$$A_{Th} = \frac{LA_t}{H_0 \Delta H} \frac{V^2}{2g}$$

Where,

A_{Th} = Thoma area required

L = Length of Headrace Tunnel

A_t = Cross sectional area of Headrace Tunnel

V = Velocity in the tunnel at design discharge

ΔH = Head loss in the Headrace Tunnel

H_0 = Net head for the project

g = Acceleration due to gravity

Over and above Thoma's area, a safety factor of 1.6 is to be considered to determine the required area of Surge Shaft.

$A \geq= A_{Th}$

Condition for hydraulic stability of Surge Shaft as per Thoma criteria is satisfied for 20m diameter circular section having area of 314.16m^2.

(b) Size of Orifice

As per Indian Standards IS: 7396 (Part 1), the area of the orifice must satisfy the condition given by Calame and Gaden for different flow conditions. Fulfilment of Calame and Gaden criteria ensures that for a given diameter of orifice, the pressure generated at the bottom of orifice due to water hammer caused by total load rejection becomes nearly equal to the pressure head due to maximum rise of water level in the Surge Shaft at the time of maximum upsurge. The condition is expressed as below:

$$\frac{Z^*}{\sqrt{2}} + \frac{1}{4}hf \leq h_{or} \leq \frac{Z^*}{\sqrt{2}} + \frac{3}{4}hf$$

Where,

h_f = Total head loss in the Headrace Tunnel

Z^* = Surge height corresponding to change in discharge neglecting friction and orifice losses.

h_{or} = Head loss in orifice, which is calculated by following formula:

$$h_{or} = \frac{Q_o^{\;2}}{C_d^{\;2} A_o^{\;2}\, 2g}$$

Z^* can be computed with the following equation:

$$Z^* = V_o \sqrt{\frac{L}{g}\frac{A_t}{A_s}}$$

Where,

A_t = Cross-sectional area of the Headrace Tunnel

A_s = Area of Surge Shaft

L = Length of Headrace Tunnel

V_o = Velocity in the Headrace Tunnel

Based on above, an orifice in the form of 4.2m diameter circular shape has been provided at the bottom of Surge Shaft.

7.8.3. Transient Analysis

Transient studies have been carried out both for maximum and minimum friction conditions separately. The basic data used in transient study are already mentioned in foregoing sections. During the transient state, the profile of water surface oscillations in the Surge Shaft is studied and the maximum and minimum water levels are recorded for different loading conditions.

Various methods have been developed to solve transient flow in pipes. These range from approximate equations to numerical solutions of non-linear Navier-Stokes equation. The hydraulic systems upstream of turbines are analyzed for transients using WHAMO software (**W**ater **H**ammer **A**nd **M**ass **O**scillation), developed by US army Corps of Engineers. WHAMO uses the finite difference technique to solve the partial differential equations of continuity and momentum.

Transients Conditions Analyzed

The surge tank has been designed to accommodate the maximum and minimum water levels anticipated under worst operating conditions of the units, as specified in IS -7396 (Part-1).

Up surge

The maximum upsurge level in the surge tank is computed for the following conditions explained below, and the higher value is adopted.

- Full load rejection, (100-0) at normal loading at full reservoir level,
- Specified load acceptance followed by full load rejection, (0-100-0) at normal loading at the instant of maximum velocity in the HRT at full reservoir level.

Note: Surge level with 10% overloading has been checked and it is within the permissible limit of free board, i.e., no overtopping of surge tank.

Down Surge

The minimum down surge level is computed for the following conditions explained below, and the lower value is adopted.

- Load rejection by all operative machines followed by load acceptance by all inoperative machines (100-0-100) at normal loading and (110-0-110) at 10% overloading at MDDL when the maximum negative velocity attained in HRT,
- Full load acceptance, (0-100) at normal loading and (0-110) at 10% overloading condition by all inoperative machines at minimum reservoir level.

Assumptions:

For the hydraulic analysis of surge tank, following assumptions have been made:

- Minimum estimated loss of head has been taken into account for determination of the amplitude of maximum upsurge, while maximum estimated head loss has been taken into account for evaluating the amplitude of the lowest down surge, as per recommendations in IS:7396 (Part-I) – 1985.

- The values of 'n' in the Manning's formula used for computing minimum and maximum friction losses in the conduit have been taken as 0.012 and 0.016, respectively for concrete lined reach of tunnel to compute maximum upsurge and minimum down surge. Whereas, for steel lined penstock, 'n' value has been taken as 0.011 for maximum upsurge and down surge.

- Ci, coefficient for inflow into surge tank = 0.7

- Co, coefficient for outflow from surge tank = 0.8

Result of Transient Analysis

As per the analysis, the maximum upsurge and minimum down surge levels are 2004.15m and 1891.71m, respectively

Based on criteria adopted and extreme surge elevations as arrived in Transient studies, top and bottom elevations of the Surge Shaft have been calculated as summarised below.

Fixing elevations of Surge Shaft

<table>
<tr><th rowspan="2">Parameters</th><th colspan="2">Surge Shaft</th></tr>
<tr><th>Maximum upsurge (masl)</th><th>Minimum Downsurge (masl)</th></tr>
<tr><td>Surge Level</td><td>2004.15</td><td>1891.71</td></tr>
<tr><td rowspan="2">Top of surge shaft</td><td colspan="2">Upsurge + 1.5m freeboard= 2005.65 masl</td></tr>
<tr><td colspan="2">2008 masl - Provided to minimise open excavation</td></tr>
<tr><td rowspan="2">Bottom of surge shaft (top of orifice Slab)</td><td colspan="2">Downsurge - 2.0m water cushion over orifice slab= 1889.71 masl</td></tr>
<tr><td colspan="2">1889.4 masl - Provided</td></tr>
</table>

Top of surge shaft is provided at El 2008 masl from topographical considerations to avoid excessive excavation at top. Surge shaft bottom (or top of orifice slab) is provided at El 1889.5 masl to have adequate water cushion to avoid draining of surge shaft during extreme downsurge.

Steel Liner around the Orifice

On sudden shut down of the power plant, all the flow going to the pressure shaft will be stopped all of a sudden, and water will rush at a very high velocity(of the order of 19-20m/s) into the surge shaft through the orifice. To protect the concrete of the orifice from damage, it is proposed to provide steel liner of 25mm thick in and around the orifice.

7.9. Valve House

Butterfly valves are proposed to isolate the pressure shaft from the water conductor system so as to facilitate its inspection and maintenance. The valves are housed in a cavern with invert at El 1877.0 m, which is 10m (W) x25m (H) x 64m (L). An EOT crane of 130/10 MT capacity is provided to handle the valves and their ancillary equipment.

7.10. Pressure Shafts

The two pressure shafts emanate from the circumference of the surge shaft with invert at El 1877.0m. Design discharge of 334 cumecs, carried by head race tunnel, is proposed to be conveyed to the machines by these two pressure shafts, 5.7m diameter, steel lined. Each pressure shaft is then bifurcated before start of unit penstocks. The diameter of the branch penstock shall be 4.0m. These branch penstocks shall again be bifurcated before entering into the powerhouse to feed eight generating units. The relatively high design discharge necessitates two individual shafts, so that the shaft diameter remains manageable.

Before finalizing the layout of pressure shafts, four alternative layouts have been studied with respect to different locations of powerhouse and type of pressure shafts. This has been discussed in Section 12 of this chapter. Alternative-4 layout has been selected for further design and engineering. The length of pressure shafts are as follows

- **Main Penstock (5.7mϕ)**

Main penstock, PS-1	=	497.223m
Main penstock, PS-2	=	497.862m
Total length main penstock	**=**	**995.0852m**

- **Intermediate Penstock (4.0mϕ)**

Intermediate penstock-1	=	466.434m
Intermediate penstock-2	=	432.172m
Intermediate penstock-3	=	397.990m
Intermediate penstock-4	=	372.965m
Total length of branch penstocks	**=**	**1669.551m**

- **Intermediate Penstock (2.85mϕ)**

Length of all unit penstock (1 to 8)	=	34.2m

- **Total length of unit penstocks** **=** **273.6m**

7.10.1. Economical Diameter

The methodology described in clause 6 of BIS code 11625:1986 has been adopted to determine the economic diameter main Pressure Shaft. As per the code, the most economic diameter of pressure shaft would be the one for which the annual cost, which includes the cost of power lost due to friction and charges for amortization of construction cost, maintenance, operation etc., is the minimum.

Following table shows steps and different parameters adopted for the calculation of economical diameter.

Number of main penstock		=	2	nos
Total design discharge		=	334	m^3/sec
Design discharge for one penstock	Q	=	167	m^3/sec
Increase in Head due to Water Hammer			13%	
Design Head		=	619.73	m
Design Head with water hammer	H	=	700.3	m
Rugosity coefficient	n	=	0.011	
Overall Efficiency	e	=	91.1%	
Allowable Stress in Steel	σ	=	265	Mpa
Cost of Energy	C_p	=	4	Rs/kWh
Cost of Steel	C_s	=	225	Rs/kg
Joints Efficiency of Penstock	e_j	=	95%	
Cost of Concrete Lining	C_c	=	6500	Rs/m^3
Cost of Excavation	C_e	=	4500	Rs/m^3
Annual load factor	p_f	=	52%	
Total Annual Charge	p	=	9.13%	of cost
Percentage by which steel is increased due to provision of stiffeners, backing strips etc.	i	=	5%	

Formula as per IS code

$$D^{22/3} = \frac{2.36 * 10^6 * Q^3 * n^2 * e * p_f * C_p}{\left[1.39 * C_e + 0.6 * C_c + \frac{121 * H * C_s * (1+i)}{\sigma * e_j}\right] * p}$$

By substituting the value of different parameters as given above: D =	5.605	m
Hence the diameter of main pressure shaft adopted	5.7	m
Diameter of branch penstock	4.0	m
Diameter of Unit Penstock	2.85	M

The economic diameter of the main pressure shafts is hence adopted as 5.7m and intermediate penstock as 4.0m. The diameter of unit penstocks is provided as 2.85m in order to have equal velocities as compared to main pressure shaft.

7.11. Access to Valve Chamber and Pressure Shafts

The following construction adits are provided for access to valve chamber and pressure shafts at different levels.

- One 7.0m (W) x 8.0m (H) modified D-shaped adits, 162m long has been provided to access the valve house bottom for installation top horizontal penstocks and valves.
- One 7.0m (W) x 8.0m (H) modified D-shaped adits, 87m long offtakes from the adit to bottom of valve chamber to access the PEC-1 for installation of vertical penstocks in upper reach.
- To facilitate excavation of top portion of the valve chamber, one independent modified D-shape adit of 5m (W) x 6m (H), 152m has been provided at the top of the valve chamber.
- One 7.0m (W) x 8.0m (H) modified D-shaped adit, 346.m long has been provided to access the penstock erection chamber (PEC-2) for excavation of intermediate horizontal pressure shafts and installation of intermediate horizontal penstocks and bifurcations (bifurcation type-1).
- One 6.0m (W) x 7.0m (H) modified D-shaped adit, 346 long has been provided to access the penstock erection chamber (PEC-3) at intermediate level for excavation of intermediate horizontal pressure shafts and installation of intermediate horizontal penstocks and vertical penstock in lower reach.
- One 6.0m (W) x 7.0m (H) modified D-shaped adit, 309m long has been provided to access the penstock erection chamber (PEC-4) at bottom for excavation and installation of bifurcations (bifurcation type-2) and unit penstocks.

7.12. Powerhouse Complex

General Arrangement

The underground powerhouse complex is proposed on the right bank of river Subansiri. The underground powerhouse complex mainly comprises of the following components:

- ➢ Powerhouse cavern
- ➢ Transformer cavern with GIS inside
- ➢ Open Pothead Yard

The approach to the main powerhouse cavern will be through a 706m long; 8m x 8m modified D-shaped Main Access Tunnel (MAT) which reaches to erection bay. The invert elevation of MAT portal is at about El. 1340m and it meets the erection bay at El. 1320m. The slope of the MAT is about 1 in 35.3.

The following access tunnels/construction adits have been provided in addition to MAT for approaching the powerhouse complex during construction or O&M stages,

- A branch adit (Adit A1), 6.0m (W) x 7.0m (H) in size and modified D-shaped off-takes from MAT and reaches the penstock erection chamber (PEC-4) (8.0m (W) x 8.0m (H) x 155m (L)) at the bottom of pressure shafts. The length of this adit is about 309m.
- A modified D-shaped construction adit (Adit A2) (6.0m (W) x 6.5m (H), 469m long has been provided for excavation of top portion of powerhouse cavern. This adit shall be used as ventilation tunnel (VT) in later stage.
- A modified D-shaped construction adit (Adit A3) (6.0m (W) x 6.5m (H), 109m long has been provided for excavation of top portion of transformer cavern offtakes from VT. This adit shall be a part of ventilation tunnel (VT) in later stage.
- A modified D-shaped construction adit (Adit A4) (6.0m (W) x 6.0m (H), 317m long has been provided to access the GIS floor. This adit shall be used as cable tunnel (CAT) in later stage.
- A 4m D-shaped tunnel connects the Control Block floor at El 1332.5m and the floor above the transformer hall at El 1332.8m, and will serve as a cable tunnel cum fire escape tunnel.
- For conducting in-situ tests for powerhouse, a 2.5m D-Shaped drift has been planned 30m above powerhouse crown. This drift shall be converted to drainage cum instrumentation gallery in later stage.

7.12.1. Powerhouse Cavern

The general arrangement of powerhouse has been developed for installation of eight vertical axis Pelton turbines, 231.25 MW each. The powerhouse cavern is 251.5m (L) x 22.0m (W) x 46.5m (H) in size. Units are spaced at 22.5m c/c. The 45m long erection bay is located at the right end, while the 25m long control block is located at the left end of the machine hall cavern. The centre line of machines is set at El 1307.5m. The main dimensions of the powerhouse components are as follows.

Machine Hall

Overall Dimensions:

Width	=	22m
Total Length	=	186.50m
Total Height	=	46.5m
Bottom El.	=	1296.5m
Crown El.	=	1343m

Sizing

For a vertical axis Pelton turbine, the overall width of the machine hall is governed by either the external diameter of the generator barrels plus clearances on the upstream and downstream sides or by the size of distributor and the spherical valve.

The overall length of the machine hall is set at 186.5 m, which includes space for housing eight generating units. The unit spacing and the other main dimensions of the powerhouse have been calculated as per standard procedures.

The machine hall will be provided with false ceiling through which ventilation and air ducts will pass. The arch roof and the walls of the powerhouse will be provided with drainage pipes, which will collect seepage water and drain into the drainage sump.

Control Block

The length of the control block is set at 25m. This provides 575 square meter of floor space on each of the six levels.

Erection Bay

In the general arrangement, the main access tunnel enters the erection bay. The length of erection bay is set at 40m (it is normally kept between 1.25 to 1.5 times the spacing between the units. But considering two units commissioning at a time, the length has been kept somewhat more) and provides for about 920 square meter for service area.

Machine Hall Floors

There are five main floors in the Machine Hall:

Floor at El. 1296.5m	Cooling Water Pumps Floor
Floor at El. 1304m	This is the MIV floor along the upstream wall of the machine hall. The runner removal door is provided on this floor towards the upstream side of turbine discharge pit
Floor at El. 1310m	This is the turbine floor along the upstream wall of the cavern. The access to the turbine pit is from this floor
Floor at El. 1314.5m	This is the generator floor; 5.3m x 2.5m runner removal hatches are provided on this floor.
Floor at El. 1320m	This is the main operating floor. It also has 5.3m x 2.5m hatches coinciding with hatches at floor El. 1314.5m

Control Block

Seven floors have been provided in the Control Block:

Floor at El. 1304m	This floor shall be used as Store
Floor at El. 1310m	This floor houses LP Compressor
Floor at El. 1314.5m	This floor houses Electrical workshop, battery bank.
Floor at El. 1320m	This floor houses Mechanical workshop, battery bank.

Floor at El. 1326m	This floor houses control room
Floor at El. 1332.5m	This floor has office and conference room.
Floor at El. 1336.5m	This is the topmost floor. It houses HVAC system and equipment for the elevator

EOT Cranes

Two gantry cranes of 250 t capacity with two auxiliary hooks capacity of 32t and 10t, each, are provided in the machine hall.

Structural Framework

The structural framework inside the machine hall and the Control block is proposed as reinforced concrete frame. Crane columns are of reinforced concrete, supported on the lowest rock support. The columns shall be anchored to the rock throughout their height, especially at different floor levels and at crane rail level, to reduce bending moments. The crane beam elevation is set at EL 1332.5m. The crane beam will also be fully anchored with rock all along its contact with the wall.

20mm expansion joints are provided between Erection Bay and Unit-1, between all units and Unit-8 and Control Block, by the provision of twin columns to avoid any lateral movement of the structural members in the powerhouse.

7.12.2. Transformer Hall Cavern

The transformer hall cavern is located 45m downstream of the machine hall. With reference to the width of rock pillar between the two underground cavities in rock, the following criterion proposed by Benson is used.

$$E_r = \frac{L_1 + L_2}{L_1 + L_2 + 2t}$$

where:

L1	=	width of the first excavation
L2	=	width of the second excavation
t	=	pillar thickness

The rock extraction ratio, Er, is an index representing the quantity of rock excavated. As can be seen from the above equation, an extraction ratio of 0.5 corresponds to a width of rock pillar equal to the average of the widths of adjacent excavations. Generally, it is advisable to minimize the extraction ratio of a rock pillar and value of around 0.5 or lower is sought.

For powerhouse complex, width of the powerhouse cavern in 23m and that of the transformer hall cavern is 16.5m. With a rock pillar of 45m, the extraction ratio comes out to be 0.31, which is acceptable.

In any case, this dimension would be reviewed and analysed during the detailed design through stress and deformation analysis using rock mechanics principles.

Overall Dimensions:

Width	=	16.5m
Total Length	=	269.85m
Total Height	=	25.5m
Invert El.	=	1320.8m
Crown El.	=	1346.3m
GIS El.	=	1332.8m

Sizing

The overall width of the transformer hall cavern is based on the assumption that the transformer cubicles would be of the order of 6.5m (L) x 6.5m (W) x 7.5(H). Additional space is required to transfer the transformers by rail to erection bay for installation/servicing and also to provide space for Unit TRT gates on downstream side. Transformer rails would be installed in the floor of transformer hall and the Main Access Tunnel joining the erection bay and the transformer hall.

The overall length of the transformer hall is set at 269.85m. It houses 26 transformer cubicles. Oil-water separator system is located at the left end. About 45.45m long space has been provided for housing of six Reactors. Space has also been provided to house two station service transformers (SST). Since it is a long transformer cavern, stairs are provided at both ends. One lift has also been provided to reach the GIS floor.

Gas Insulated Switchgear is also proposed to be installed in the transformer cavern itself. A concrete floor at which GIS will be located is proposed at El 1332.8m. An opening has been provided on this floor for loading and unloading GIS equipment.

A pit covered with grating is provided below all transformers to carry any oil spill towards the oil separator provided at the right end. The oil separator is 7.0m deep and 7.0m (L) x 4.3m (W) in size.

Grooves for eight unit TRT gates are also provided near downstream wall of transformer hall cavern.

Structural Framework

The structural framework inside the transformer hall is proposed as reinforced concrete frame. The columns are of reinforced concrete supported on the lowest rock support. The columns shall be anchored to the rock throughout their height, especially at different floor levels, to reduce bending moments. The crane beam elevation is set at El 1340.3m. The crane beam will also be fully anchored with rock all along its contact with the wall.

EOT Cranes

One gantry crane of 10T capacity is provided in the transformer hall.

Bus Duct Galleries

Eight bus duct galleries are provided between the machine hall cavern and the transformer hall cavern. The bus duct galleries connect the generator floor at El 1315.3m in machine hall to the main floor of the transformer hall cavern at El 1320.8m. All bus duct galleries emanate from the downstream wall at right angle to the machine hall. To accommodate some equipment, the galleries have 11.5m long level stretch in the beginning and 6.0m level stretch in the end. The bus duct galleries are 5.5m (W) and 5.5m (H), D-shaped.

Cable Tunnel

The construction Adit (Adit A-4) used for the excavation of the transformer cavern will be converted into cable tunnel to bring the cables to pothead yard located at El 1345.0m outside.

Cable Cum Fire Escape Duct

A smaller 4m D-shaped tunnel is provided between the control block of the powerhouse cavern and the transformer hall cavern. This tunnel will be used for cables coming from the control block of the powerhouse to be connected either to the equipment in the transformer hall cavern or to the pothead yard outside. This tunnel will also serve as emergency exit from the control block.

7.12.3. Pothead Yard Area

A 158x50m surface pothead yard area is proposed just near the portal face of the cable tunnel. The area accommodates a 400kV pothead yard, space for 132 kV/400 switchyard for pooling power from Dam Toe powerhouse, DG sets and control room.

The switchyard and its surrounding area will have their respective grounding system. The earthing grid will be designed and constructed for the operating voltages and short-circuit capacities corresponding to short-circuit and earth-fault current levels. For the evacuation of this power beyond the pothead yard, there will be four (4) outgoing overhead transmission lines.

The cables from the transformer cavern will come to pothead yard through a 6mx6m D-shaped cable tunnel.

7.13. Tail-water Conductor System

The tail-water conductor system of the project, emanating from the downstream wall of the powerhouse cavern, comprises of the following sub-components:

- Eight numbers unit TRT's of size 5.0m (W) x 7.25m (H) modified D-shaped.
- Two numbers intermediate TRT's of size 7.5m (W) x 7.25m (H) modified D-shaped.
- Two numbers main TRT's of size 9.5m (W) x 8.00m (H) modified D-shaped.

7.13.1. Unit Tailrace Tunnel

Eight-unit tailrace tunnels start from the downstream wall of the machine hall and run parallel with a flatbed slope till they meet intermediate tailrace tunnel. For inspection purpose in powerhouse, control gates have been provided just below the transformer cavern within the unit TRT's.

Intermediate Tailrace Tunnel

Two intermediate tailrace tunnels of length 56.5m each are provided to join unit TRT's and main TRT.

7.13.2. Main Tailrace Tunnel

Two main TRT's connected to intermediate TRT's to collect the water and finally send it back into the river. Main tailrace tunnels are 9.5m wide and length of about 1152.65m and 1148.80m respectively. Tailrace flows as an open channel and is designed to have critical flow at the outfall with water level at El. 1300m. At the outlet, a gate is provided to ensure the closure of the tunnel from downstream, in case of need. The gate control structure is outside in the open. To accommodate the gates, D-shaped structure has been transitioned to a rectangular shape.

7.14. Dam Toe Powerhouse

To utilize the riparian release, a mini surface powerhouse has been proposed at the toe of the dam. As per power potential study, the capacity of the power plant is 28MW having two units, each 14MW. The size of the powerhouse is 18m (W) x30m (H) x45m (L). To convey the design discharge of about 38.4 cumec to the power plant, two steel penstocks, each 2.0m in diameter, have been provided.

7.15. Instrumentation

Instrumentation technology helps in monitoring and evaluating the performance of structures. It helps in locating distress areas and providing remedial measures. Instrumentation monitoring combined with vigilant visual observations provides early warning of many conditions that could contribute to failures and incidents. It is to be planned and executed carefully to meet defined objectives. To meet these objectives, the instruments are to be carefully selected, located and plotted and to be judiciously evaluated in timely manner. Major considerations are reliability which includes simplicity, durability, longevity, precision accuracy and length of satisfactory performance history. The typical instrumentation proposed for Oju HEP is discussed in the following paras.

7.15.1. Dam Monitoring

It is important monitor the dam health during construction and operation through its life. Therefore, it is necessary to monitor effectively by the instrumentation system. The purpose is to maintain and improve dam safety by providing information to:

- Evaluate whether dam is performing as expected
- To give warning of any changes that could endanger safety of the dam

The instruments give quantitative information of the dam safety parameters and show its behaviour with variation in ambient conditions and water levels in the reservoir. They also indicate effect of ageing. Visual observations to detect offsets, misalignment, depression, seepage, leakage & cracking are also made.

The performance and safety of dam will be monitored during construction as well as during operation, by a number of safety instruments installed in the dam and foundation. The various parameters to be monitored and measured in the dam are Uplift, Stress/ Strain, Joint movement, horizontal and vertical displacement, seepage, temperature and seismicity. Typical instrumentation planned for the dam will include:

It is proposed that one overflow block and one non-over flow block be instrumented with standard set of instruments for monitoring the performance of the dam during construction and operation. The following instruments are proposed

i. Pore pressure cells

ii. Uplift measuring devices

iii. Stress meters

iv. Strain meters

v. No stress-strain meter

vi. Joint meters

vii. Temperature gauges

viii. Stand pipe piezometers

ix. Plumb lines (normal/inverted)

x. Bore hole extensometers

xi. Water level indicators

xii. Survey monuments

xiii. Discharge measuring weirs

xiv. Automatic weather station

xv. Strong motion recorder

xvi. Micro-seismic Instrument

7.15.2. Monitoring of Underground Works

Monitoring plays an important role during construction of the underground works in order to accurately evaluate the impact of geological conditions, effect of opening on nearby structures and construction methods to be used, determining the type of support structure. For diversion tunnel, headrace tunnel, surge shaft, pressure shafts and underground powerhouse complex, the parameter to be measured & monitored include convergence, crown displacement, upheaval, load on anchors/ rock bolts and steel supports etc.

Selection of instrumentation is based on reliability of the instruments, longevity of the instruments and efficient data collection & interpretation. The type of measurement and instrument location is adapted to the anticipated geological conditions as well as construction methods.

For diversion tunnel, headrace tunnel, surge shat, pressure shaft and underground powerhouse complex, the requirement for instrumentation is to ensure stability of excavation and measure parameters mainly addressed are convergence, deformation and load on support systems.

The instrument proposed for installation to measure convergence and deformation are convergence bolts (measurement with tap extensometers) and bore hole extensometer.

In the reaches where the geology warrants installation of steel supports, load cells will be provided to assess development of load in the section. Load cells shall also be provided on the anchors/rock bolts for measuring pressure on the bolts.

8. HYDROMECHANICAL EQUIPMENT

8.1. Introduction

For the purpose of isolating various components in the water conductor system, suitable hydro-mechanical equipments will be provided at the required locations. The features of these equipments are provided in subsequent sections.

8.2. Dam

8.2.1. Spillway Radial Gates

Four (4) nos. of spillway radial gates of opening size 8000mm wide x 10800mm high are provided to control the discharge through the spillway. Each gate will be operated by means of twin hydraulic hoist of adequate capacity (tentative capacity – 2 x 125MT) mounted on cardenic support. The sill of the gate is located at El. 1899.694m. The Radial gate shall be designed for the head corresponding to FRL of 1950.00m. The gates are designed to open/close against flowing water.

Main characteristics of the spillway radial gates:

i	Type of Gates	Radial
ii	Number of Gates	4
iii	Number of Openings	4
iv	Size of Opening	8.00m span x 10.8m high
v	Sill & Crest Level	1899.694m
vi	FRL	1950.00m
vii	Design Head (corresponding to FRL)	50.31m
viii	Operating conditions	Opening/Closing under unbalanced head conditions and flowing water.
ix	Type of Hoist	Twin Hydraulic cylinders (tentative capacity - 2 x 125 MT)
x	Governing Code	IS:4623

8.2.2. Stoplogs for Spillway gates

One set of sliding type stoplog is proposed to be provided to cater for the maintenance requirement of five spillway radial gates. The stop log set for opening size of 8000mm (W) x 13859mm (H) shall consist of six (6) identical and interchangeable bottom units and one (1) no. top unit each of almost equal height of 2310mm. The sill of the gate is located at El. 1900.00m. The stoplog units shall be designed for the head corresponding to FRL of 1950.00m. Stoplog units will have downstream skin plate and downstream sealing. The stoplogs will be required to be raised and lowered under balanced head condition. The balanced head condition will be achieved with the provision of bye-pass piping & manually operated valve arrangement provided in the civil structure. Stoplog will be operated with the help of a gantry crane of adequate capacity (tentative capacity 35 MT) through a lifting beam.

Main characteristics of the stoplog:

i	Type of gate	Vertical lift Slide type
ii	No. of Gates	1
iii	No. of opening	4
iv	Size of opening	8000mm x 13859mm
v	Size of stop log units	6 units of 8.00m span x 2.31m high
vi	FRL	1950.00m
vii	Sill Level	1900.00m
viii	Design Head (corresponding to FRL)	50.00m
ix	Operating conditions	Opening & Closing under Balanced head conditions.
x	Type of Hoist	Gantry Crane (tentative capacity– 35MT) using a lifting beam.
xi	Governing Code	IS:9349

8.2.3. Auxiliary Spillway Gates

One (1) no. vertical lift fixed wheel type Auxiliary Spillway gate and One (1) no. vertical lift fixed wheel type bulkhead gate are proposed to be provided in the auxiliary spillways.

Auxiliary Spillway gate shall be used to pass the trash and floating material from the reservoir and bulkhead gates shall be used to cater for maintenance requirement of auxiliary gates. Both bulkhead and auxiliary gates shall be designed as identical and interchangeable. The gates for opening size 6000mm wide x 4250mm high (including free board of 250mm) will have upstream skin plate and upstream sealing. The sill of the gates is located at El. 1946.00m. The gates will be designed for head corresponding to FRL, of El. 1950.00m. The gates will be required to be raised and lowered under unbalanced head condition.

The gates shall be operated with the help of common gantry crane operating spillway stoplog units.

Main Characteristics of the Auxiliary Spillway Gates:

i	Type of gate	Vertical lift fixed wheel type
ii	No. of gates	2
iii	No. of opening	1
iv	Size of opening	6000mm x 4250mm (including 250mm free board)
v	FRL	1950.00m
vi	Sill Elevation	1946.00m
vii	Operating conditions	Opening and closing under unbalanced head condition.
viii	Design Head	4.00m
ix	Type of Hoist	Common gantry crane (tentative capacity – 15MT) operating spillway stoplog units.
x	Governing Code	IS:4622

8.3. Diversion Tunnels Gate

For the purpose of plugging the diversion tunnels after the construction of the dam, four (4) nos. vertical lift, fixed wheel type gates are provided for opening size of 5100mm x 12700mm. The sill level of the gates is located at El. 1870.00m. The gates are to be designed for a head of 80.00m corresponding to FRL 1950.00m. The gates will have downstream skin plate and downstream sealing. The lowering of the gates shall be done in lean season. After lowering the gate, the water level in the river can rise to El. 1900.00m with all the spillway gates are kept opened. The gates shall be lowered by fixed rope drum hoist of adequate capacity (tentative capacity – 140MT) mounted on steel trestles located at deck floor at El.1893.50m.

Main characteristics of the Diversion tunnel:

i	Type of gate	Vertical lift wheel type
ii	No. of openings	4
iii	No. of gates	4
iv	Size of opening	5.10m span x 12.7m high
v	FRL	1950.00m
vi	Sill Elevation	1870.00m

vii	Design Head (corresponding to FRL)	80.00m
viii	Hoist	Rope drum hoist of adequate capacity. (tentative capacity – 140MT)
ix	Operation	Closing against flowing water and unbalanced head condition.
x	Governing Code	IS:4622

8.4. Power Intake

8.4.1. Trash Racks and Trash cleaning Machine

Eight (8) sets of trash racks each of size 3.50m x 24.00m (vertical height) shall be provided at the intake to prevent the entry of extraneous material into the HRT / Pressure Shaft / Powerhouse. The trash rack shall be provided in 12˚ inclined grooves and up to deck level El. 1953.00m. The trash racks shall be handled by the auxiliary hoist hook provided on trash rack cleaning machine.

A trash rack cleaning machine shall be provided for the cleaning the trashes.

Main characteristics of the trash racks:

i	Type	Fabricated Steel panels
ii	No. of Openings	8
iii	Size of opening	3.5m span x 24.00m high
iv	Sill Level	1929.00m
v	FRL	1950.00m
vi	Inclination of trash racks	12º
vii	Deck Level	1953.00m
viii	Design Head	6.00m Differential Pressure (As per IS:11388)
ix	Clear Opening between bars	60mm
x	Governing Code	IS:11388

8.4.2. Intake Bulkhead Gates

Two (2) nos. vertical lift slide type bulkhead gates for opening size of 6800mm wide x 6900mm high will be provided to cater for maintenance requirement of intake gates. The sill of the gates is located at El. 1929.00m. The gates will have upstream skin plate and upstream sealing. The bulkhead gates will be designed for water head corresponding to FRL El. 1950.00m. The gates shall be raised and lowered under balanced head condition achieved with the provision of fill-in valves provided in the upper portion of the gate. The gates will be operated by means of electrically operated rope drum hoists of adequate capacity (tentative capacity – 50MT) mounted on common steel trestle provided at El. 1953.00m.

Main characteristics of the Bulkhead gates:

i	Type of gate	Vertical lift slide type
ii	No. of openings	2
iii	No. of gates	2
iv	Size of opening	6.80m span x 6.90m high
v	FRL	1950.00m
	Sill Elevation	1929.00m
vii	Design Head	21.00m
viii	Operating conditions	Closing and opening under balanced head condition achieved by providing fill-in valves in the gates.
ix	Type of Hoist	Electrically operated rope drum hoist of adequate capacity (tentative capacity – 50MT)
x	Governing Code	IS:9349

8.4.3. Intake Gates

Two (2) nos. vertical lift fixed wheel type gates for opening size of 6800mm x 6900mm will be provided for intake. The sill of the gate is located at El. 1925.00m. The gate will have downstream skin plate and downstream sealing. The intake gate will be designed for water head corresponding to FRL El. 1950.00m. The gates shall be lowered against flowing water and unbalanced head condition and opened under balanced head condition created by a crack opening of 150mm. The gate will be operated by means of electrically operated rope drum hoist of adequate capacity (tentative capacity - 70MT) mounted on steel trestle provided at El. 1953.00m.

Main characteristics of the Intake gates:

i	Type of gate	Vertical lift wheel type
ii	No. of openings	2
iii	No. of gates	2
iv	Size of opening	6800mm x 6900mm
v	FRL	1950.00m
vi	Sill Elevation	1929.00m
vii	Design Head	21.00m
viii	Operating conditions	Closing against flowing water and under unbalanced head condition and opening under balanced head condition created by crack opening of 150mm.
ix	Type of Hoist	Electrically operated rope drum hoist of adequate capacity (tentative capacity – 70MT)
x	Governing Code	IS:4622

8.5. Unit Tailrace Tunnels

8.5.1. Stoplog Gate for Unit Tailrace Tunnels

One (1) set of vertical lift slide type stop logs are proposed to cater for maintenance requirement of eight (8) nos. of generating units. The stoplog sets for opening size of 5000mm wide x 4950mm high including free board of 500mm shall be fabricated in three (3) nos. identical and interchangeable units each of height 1650mm. The sill of the stoplog is located at EL 1299.05m.

Stoplog will have skin plate and sealing toward river side. The stoplog will be designed for maximum water level in tailrace i.e., 1303.50m. The stop logs will be required to be lowered under balanced head conditions. The lifting of stoplog units will be under balanced head condition, however the topmost unit of stoplog will be lifted under unbalanced water head condition. The gate will be operated by a monorail hoist of adequate capacity (Tentative capacity–5MT) through a lifting beam.

Main Characteristics of the Unit Tailrace Tunnel stoplog Gates:

i	Type of gates	Vertical lift Slide type
ii	No. of opening	8
iii	No. of Gates	1 Set

iv	Size of opening	5000mm x 4950mm (Including 500mm free board)
	Size of stop log units	3 units of 5.00m span x 1.65m high
v	Max. TWL	1303.50m
vi	Sill Elevation	1299.050m
vii	Design head	4.450m
viii	Operating conditions	Closing under balanced head condition. The stoplog units are lifted under balanced head condition; however, the topmost unit of stoplog is lifted under unbalanced head condition
ix	Type of Hoist	Monorail hoist of adequate capacity (Tentative capacity– 5MT) through lifting beam.
x	Governing Code	IS:5620

8.5.2. Tailrace Outfall Gates

Two (2) nos. fixed wheel type gate of size 8500mm wide x 4000mm high (including 600mm of free board) will be provided at the Tailrace Tunnel outfall structure to prevent the flow from the river side into the Tailrace Tunnel during high flood condition. The sill of the gate is located at El. 1296.60m. The gate will have skin plate and sealing toward river side. The gates will be designed for water head corresponding to maximum water level in the river i.e., El.1300.00m. The gates will be required to be lowered under unbalanced head conditions and raised under balanced water head condition created by crack opening of 150mm. The gates will be operated by a rope drum hoist of adequate capacity (Tentative capacity – 15MT) mounted on the steel trestle.

Main Characteristics of the Tailrace Outlet Gates:

i	Type of gates	Vertical lift Fixed Wheel type
ii	No. of opening	2
iii	No. of Gates	2
iv	Size of opening	8500mm x 4000mm (including freeboard of 600mm)
v	Max. Water Level in River	1300.00m
vi	Sill Elevation	1296.60m

vii	Design head	3.40m + silt load (silt up to 3.0m)
viii	Operating conditions	Closing under unbalanced head condition and opening under balanced head condition created by a crack opening of 150mm
ix	Type of Hoist	Rope drum hoist of adequate capac (Tentative capacity – 15MT)
x	Governing Code	IS:4622

8.6. Adit Gates

8.6.1. Adit Gates

Three (3) hinged type gates for opening size 2200mm wide x 2200mm high have been proposed to be provided in the concrete plug at construction Adit nos. 1, 3 & 5 to give access for vehicle to the headrace tunnel in the event of any inspection, repair, and maintenance in future. The gates will be operated manually under un-watered condition. The gates shall be provided with skin plate on the tunnel side and seals on the Adit side. The gates shall be hinged to the gate frames embedded in concrete.

Main Characteristics of the Adit Gates:

i	Type of gate	Hinged type
ii	No. of openings	3
iii	No of gates	2 (At Adit No – 3 & 5)
iv	Size of opening	2200mm x 2200mm
v	FRL	1950.00m
vii	Adit Invert level	1924.97m (At Adit No. – 1)
		1903.64m (At Adit No. – 3)
		1878.69m (At Adit No. – 5)
viii	Design head	25.03m (At Adit No. – 1)
		46.36m (At Adit No. – 3)
		71.31m (At Adit No. – 5)
ix	Operating conditions	Operated under un-watered condition

8.7. Dam Toe Powerhouse HM Works

Following HM works have been considered for Dam Toe Powerhouse

1. Intake Trash rack - 1 No. of 4.5m (W) x 17.5m (H)
2. Intake Gate - 1 No. Fixed wheel gate of Size 2.36m (W) x 3m (H) to be operated with Rope Drum Hoist
3. Draft Tube Gate – 2 Nos. of size 4.61m (W) x 2.38m (H) to be operated with Monorail crane.

9. POWER PLANT EQUIPMENT

9.1. Introduction

Oju Hydroelectric Project envisages an underground powerhouse having Eight (8) hydraulic turbine-driven generating units of 231.25 MW capacity each, with total installed capacity of 1850 MW. The project will utilize the discharge of 333.39m^3/sec under a maximum gross head of 642.50m.

Type of turbine will be vertical axis Pelton and directly coupled to the synchronous generators. Main inlet valves of spherical type shall be provided at the inlet of each turbine for isolation during shutdown and maintenance.

The generated voltage of 15.75kV shall be stepped up to 400kV through step-up transformers. These transformers shall be located in a separate transformer cavern adjacent to the main powerhouse cavity. Further evacuation of power shall be made through Gas Insulated Switchgear (GIS). GIS equipment will be located in GIS gallery on top of the transformer cavern. HV side of the transformers will be connected to the GIS through GIB (Gas Insulated Bus). Outgoing bays of GIS will be connected to outdoor pothead yard equipment through XLPE cables laid on racks mounted on the side wall of the cable tunnel.

The total power shall be evacuated through two 400kV double circuit line to the nearest pooling station.

The following equipment shall be covered under electromechanical package:

- Penstock Butterfly Valve and oil pressure system
- Main Inlet valve and oil pressure system
- Turbine
- Governor and oil pressure system
- Electric Overhead Traveling Crane for powerhouse, Penstock Valve House, and GIS
- Cooling water system
- Drainage and Dewatering system
- Heating, Ventilation and Air-conditioning system
- Compressed air system
- Fire Fighting system
- Mechanical workshop
- Oil handling system
- Generator
- Excitation system
- Isolated Phase Bus Duct System
- Generator Step up Transformer.
- Gas Insulated Switchgear

- High Voltage XLPE cable
- Outdoor Pot head yard equipment
- DC supply system
- Digital control system and SCADA
- Protection system
- Cabling system
- Auxiliary AC supply system
- DG Sets
- Communication system
- Illumination system
- Electrical workshop
- Grounding system

The description of major equipment is given under mechanical and electrical equipment sections.

9.2. Selection and Sizing of Generating Equipment

9.2.1. Turbine

9.2.1.1. MAIN TECHNICAL PARAMETERS

Type of Powerhouse	Under Ground
Installed capacity	8 x 231.25 MW
Type of Turbine	Pelton Turbine (6 Jet)
Axis orientation	Vertical
Direction of Rotation	Clockwise (when viewed from top)

Reservoir Levels

Full Reservoir Level	1950.00m
Minimum Draw Down Level	1945.00m
Normal Level	= MDDL + (2/3) x (FRL – MDDL) = 1945 + (2/3) x (1950 – 1945) = 1948.3m

Tail Water Levels

Maximum & Normal TWL	1303.50m

Elevation of Centre Line of Distributor	1307.50m

Discharge

Total Design discharge	333.39 m^3/ sec.
Unit discharge	41.67 m^3/ sec.

Head Losses

All units at rated load	20.00m
1 unit @ 10% load	0.1m
Rated Output of Turbine	234.78 MW (Assuming generator efficiency as 98.5 %)
Maximum Gross Head	= (FRL – Runner Center Line) = 1950.00 – 1307.50 = 642.50m

Operating Heads

Maximum net head	= (FRL – Runner Center Line – Head loss for one unit at 10% load) = 1950.00 – 1307.50 – 0.1 = 642.40m
Minimum net head	= (MDDL – Runner Center Line – Head loss for all units) = 1945.00 – 1307.50 – 20.00 = 617.50m
Rated net head (HR)	= (AVRL- Runner Center Line – Head loss for all units) = 1948.30-1307.50-20.00 = 620.80m

Turbine Speeds

Rated Synchronous Speed	300 rpm
Specific Speed	46.91 (kw-m units)
Specific Speed per jet	19.15 (kw-m units) for 6 jet machine

Selection of Type of Turbine

Type of turbine to be selected for a power project depends upon maximum net head acting on the turbine, capacity of generating unit, operation head variation and part load operation requirements. Maximum net head is one of the most important criteria dictating type of turbine to be used. As per IS:12837, normal range of maximum net head for each type of turbine is given below:

Type of turbine	Range of maximum net heads
Pelton Turbine	Above 300m
Francis Turbine	30 to 400m (sometimes even up to 500 to 600m)
Kaplan Turbine	10 to 60m
Bulb Turbine	3 to 20m

In Oju Project the maximum net head acting on turbine is 642.40m; hence the type of turbine for this project will be Pelton.

Calculation of Turbine parameters

The turbine speed, setting, other parameters and dimensions are calculated on the basis of theory given in the article "*Modern Trends in Selecting and Designing Pelton Turbines" by M/s F.de Siervo and A. Lugaresi, published in Waterpower and Dam Construction (WP&DC) in December 1978 issue.*

Specific speed and Synchronous Speed

Trial Specific speed per jet ($N_{sj}1$) and Trial Specific speed (N_{S1})

Trial Specific speed per jet ($N_{sj}1$) is calculated as per formula given in WP&DC article

Trial Specific Speed ($N_{sj}1$) = $85.49 \times H_R^{(-0.243)}$

= $85.49 \times 620.83^{(-0.243)}$

= 17.91

The trial specific speed (NS1) is determined for different number of jets and is given in the following table.

No. of jets	Nos.	4	5	6
Trial Specific Speed (NS1)	m-kW	35.35	40.44	44.14
Trial Rated Speed (n1) ($n = N_{S1} \times H_R^{1.25}/\sqrt{(MW \times 1000)}$)	rpm	226.10	258.62	282.32
Nearest Synchronous Speed (n)	rpm	230.77	250.00	300.00
Corresponding Design Sp. Speed (N_S)	m-kW	36.08	39.09	46.91
Corresponding Design Sp. Speed / Jet (N_{sj})	m-kW	18.04	17.48	19.15

The rated speed of 300 rpm with 6 jets is selected.

Design Specific Speed (Ns)

$= \quad n \times \sqrt{(1000 \times MW)} / H_R^{(1.25)}$

$= \quad 300 \times \sqrt{(1000 \times 234.78)}/620.83^{1.25}$

$= \quad 46.91$ (in kW-m units)

Design specific speed per jet

$= \quad N_s / \sqrt{(j)}$, where j is the no. of jets

$= \quad 46.91 / \sqrt{(6)}$

$= \quad 19.15$

Setting of Turbine (H_S)

In Pelton turbines, centre line of runner is kept above the maximum tailrace water level and its value is determined by the necessity to avoid interference between runner and water surface within the turbine casing.

The turbine setting with respect to maximum tail water level is calculated by the formula:

$$H_S = (1.87 + 2.24 \times Q / N_S)$$

where,

H_S = Turbine setting i.e., difference between Runner C.L. and max. TWL in Pit.

Q = Turbine Discharge = $41.67 m^3/ sec$

N_S = Specific speed = 46.91

H_S = (1.87 + 2.24 x 41.67 /46.91)

= 3.86m

To ensure sufficient clearance between runner and tailrace water surface and to provide proper ventilation in the pit some margin is kept in the setting, therefore the value of HS is kept 4.00m with a margin of 0.14m.

Therefore, Runner C.L. Elevation

= Maximum Tail Water Level + H_S

= 1303.50 + 4.00

= 1307.50m

Speed and Pressure Rise

As per IS:12837 speed rise and pressure rise shall be limited to 30% and 20% respectively. The Flywheel effect (GD^2) of the generating unit and closing time of deflectors and nozzles shall be designed to limit speed rise and pressure rise to above mentioned values.

Runner Pitch Circle Diameter (D_2)

The Runner Pitch circle diameter is determined by using a formula given in WP&DC article

$$D_2 = 84.5 \text{ X } ku \times (\sqrt{HR}) / n$$

where,

K_u = Runner Peripheral Velocity Coefficient

= 0.5445 - 0.0039 x N_{sj}, where N_{sj} is specific speed per jet

= 19.15

= 0.5445 - 0.0039 x 19.15

= 0.47

H_R = Rated net head = 620.83 m

n = Turbine Speed in rpm = 300

∴D2 = 84.5 x 0.47 x 620.830.5/300

= 3.30m

Other dimensions of turbine are calculated by using empirical relations mentioned in the article "*Modern trends in selecting & designing Pelton Turbines" by F. de Siervo and A. Lugaresi, published in Waterpower and Dam Construction, December 1978* and are given in the following table.

No.	Description	Formula	Value
i)	Jet Diameter (D_j)	$D_j = D_2 \times N_{Sj} / (250.74 – 1.796 \times N_{Sj})$	0.29m
Runner Dimensions (Refer **Figure 9-1**)			
i)	Runner Maximum diameter (D_3)	$D_3 = D_2 \times (1.028 + 0.0317 \times N_{sj})$	4.26m
ii)	Bucket Width (H_1)	$H_1 = 3.20 \times D_j^{0.96}$	0.98m
iii)	Bucket Length (H_2)	$H_1 = 3.23 \times D_j^{1.02}$	0.92m
Discharge Pit (Turbine Housing) Dimensions (Refer **Figure 9-2**)			
i)	Discharge Pit Diameter (L)	$L = 0.78 + 2.06 \times D_3$	9.60m
ii)	Runner Center line to turbine housing top (G)	$G = 0.196 + 0.376 \times D_3$	1.80m
iii)	Runner Center line to turbine housing bottom (F)	$F = 1.09 + 0.71 \times L$	9.55m
iv)	Tailrace Channel height (H)	$H = 0.62 + 0.513 \times L$	7.25m
v)	Tailrace Channel Width (I)	$I = 1.28 + 0.37 \times L$	5.00m
Distributor Dimensions (Refer **Figure 9-2**)			

i)	Inlet Velocity (V_i)	$V_i = (0.82 + 0.358 \times \sqrt{H_R})$	9.74m
ii)	Inlet diameter (A)	$A = \sqrt{((Q / V_i) \times (4 / \pi))}$	2.35m
ii)	Distributor Dimension (B)	$B = (0.595 + 0.694 \times L)$	7.23m
iii)	Distributor Dimension (C)	$C = (0.362 + 0.68 \times L)$	6.86m
iv)	Distributor Dimension (D)	$D = (-0.219 + 0.70 \times L)$	6.47m
v)	Distributor Dimension (E)	$E = (0.43 + 0.70 \times L)$	7.12m

9.2.2. Generator

The generators shall be vertical shaft suspended type. Generator Shaft and turbine shaft shall be coupled below the lower bracket. The main technical characteristics of the generators are as follows:

Generator Type	Suspended
Rated Power	256.95 MVA
Maximum continuous power	282.64 MVA (10% continuous overload)
Power Factor	0.9
Generator Voltage	15.75 ± 10%kV
Number of phases	3 phase
Frequency	50 ± 5% Hz
RPM	300 (Same as that of Turbine)
Grounding	Grounding through single-phase transformer
Insulation	Class F
Type of Cooling	Totally enclosed water and air cooled

The design of the generator will take into consideration the daily and seasonal cyclic loading and frequent starting of the units.

9.2.2.1. CALCULATION OF GENERATOR PARAMETERS

Generator parameters and dimensions are calculated as per IS: 12800 (Part – 1) and are given below:

Air Gap Diameter (D_g)

The maximum value of Air gap diameter Dg is also governed by the maximum permissible stresses in the rotor parts and rim, and these are directly linked with the peripheral velocity Vr at runaway speed.

The value of maximum peripheral rotor velocity V_r at rated speed can be calculated from fig - 15 (Graph of number of poles pair's v/s Peripheral Velocity in m/sec) of IS: 12800.

For 300 rpm machine, the number of pole pairs works out to be 10 and value of V_r = 80.62m/sec.

$D_g \quad = \quad (60/\pi) \times (V_r / n)$

Where, n is rpm of m/c = 300

$= \quad (60/\pi) \times 80.62/300$

$= \quad 5.13$ m

Outer Core Diameter (D_o)

Outer Core Diameter Do of the stator can be determined by the following formula given in IS: 12800

$D_o \quad = \quad D_g (1 + \pi/2p)$

Where, p = no. of pole pairs = 10

$= \quad 5.13 (1 + 3.14/2x10)$

$= \quad 5.94$

Stator Frame Diameter (D_f)

Stator Frame Diameter D_f can be determined by using following formula given in IS: 12800

$D_f \quad = \quad D_o + 1.2m$

$= \quad 5.94 + 1.2m$

$= \quad 7.14m$

Generator Barrel Diameter (D_b)

Generator Barrel Diameter (D_b) can be determined by the following formula given in IS: 12800.

$D_b \quad = \quad D_f + (2.3 \text{ to } 2.8)$ m

$= \quad 7.14 + 2.3m$

$= \quad 9.44m \approx 9.50m$

Outer Diameter of Generator Barrel (D_Φ)

Outer Diameter of Generator Barrel (D_Φ) can be determined by adding the thickness of wall of the barrel. For concrete barrel, the wall thickness varies from 600 to 750mm. Therefore, the outer diameter of barrel can be calculated by adding 1.2 to 1.5m to the inner diameter.

D_Φ = D_b + 1.2m

= 9.50 + 1.2m

= 10.70 m

Core Length of Stator (L_C)

Core Length of Stator (LC) can be determined by the following formula suggested in IS: 12800.

L_C = $W / (K_o \times D_g^2 \times n)$

where,

W = *rated kVA of the generator = 256950 kVA*

K_O = *output co-efficient = 6.32*

D_g = *air gap diameter = 5.13m*

n = *speed of machine = 300 rpm*

Output Co-efficient (K_o) is determined from "fig – 16" of IS: 12800, for 10 pole pairs.

Lc = 256950 / (6.32 x 5.132 x 300) m

= 5.15 m

Length of Stator Frame (L_f)

Length of Stator frame (L_f) can be determined by adding 1.5 to 1.6m to the length of stator core as suggested in IS: 12800.

L_f = L_C + (1.5 to 1.6) m

= 5.15 + 1.50m

= 6.65m

Weight of Turbine Runner

Estimated Weights of Pelton Runner and Turbine shaft are as follows.

Weight of Pelton Runner = 24.00 tonnes (for D_2 = 3.30m)

Weight of Turbine Shaft = 18.00 tonnes.

Load on thrust bearing due to Generator parts

Major Load on thrust bearing due to Generator parts is the weight of generator rotor and other rotating parts. The weight of generator rotor is a function of air gap diameter D_g and active core length L_C and can be determined from "fig. – 18" of IS: 12800. The Fig –18 gives Rotor weight / meter of core length vs Generator air gap diameter D_g.

∴ Load on generator bearing due to generator rotor = W_C x L_C tonnes

where,

WC	=	*Rotor weight / meter*
	=	*134 t/m for Generator air gap diameter Dg = 5.13m*
LC	=	*active core length of Rotor*
	=	*5.15m*

Load due to generator rotating parts = 134 x 5.15 tonnes

= 690.00 tonnes

Weight of Rotating Parts

Wt. of Rotating parts = Wt. of Gen. Rotating parts + Wt. of turbine Runner + Wt. of Turbine Shaft

= 690.00 + 24 + 18 tonnes

= 732 tonnes

Height of Bearing Bracket (h_j)

The height of load bearing bracket h_j for Suspended type Generator construction is given by following expression (Suggested in IS: 12800)

h_j = k √ D_f

where,

D_f	=	*Stator Frame Diameter = 7.14*
K	=	*0.65 for load of less than 50 tonnes per arm of bracket.*
	=	*0.75 for load of 50 to 100 tonnes per arm of bracket.*
	=	*0.85 for load of more than 100 tonnes per arm of bracket*.

Normally the number of arms of a bracket shall be decided on the basis of total load on the thrust bearing and the size of the bracket. Generally, bracket having 4 to 8 arms is taken.

Considering the total load on the bearing and the size of the bracket, a bracket having 6 arms will be taken.

Therefore, the load on each arm will be calculated as follows;

= Wt. of Rotor / No of arms

= 732 / 6 tonnes / Arm

= 122.00 tonnes / Arm

$\therefore$ k = 0.85 (since load per arm is more than 100 tonnes)

$\therefore$ hj = $0.85 \times \sqrt{7.14}$m

= 2.27m

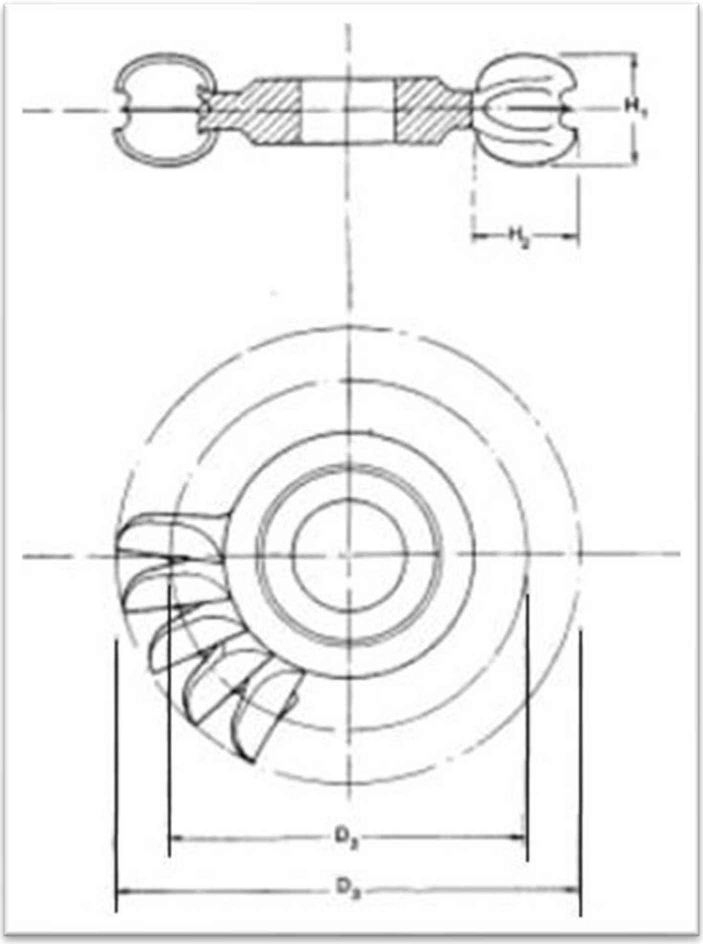
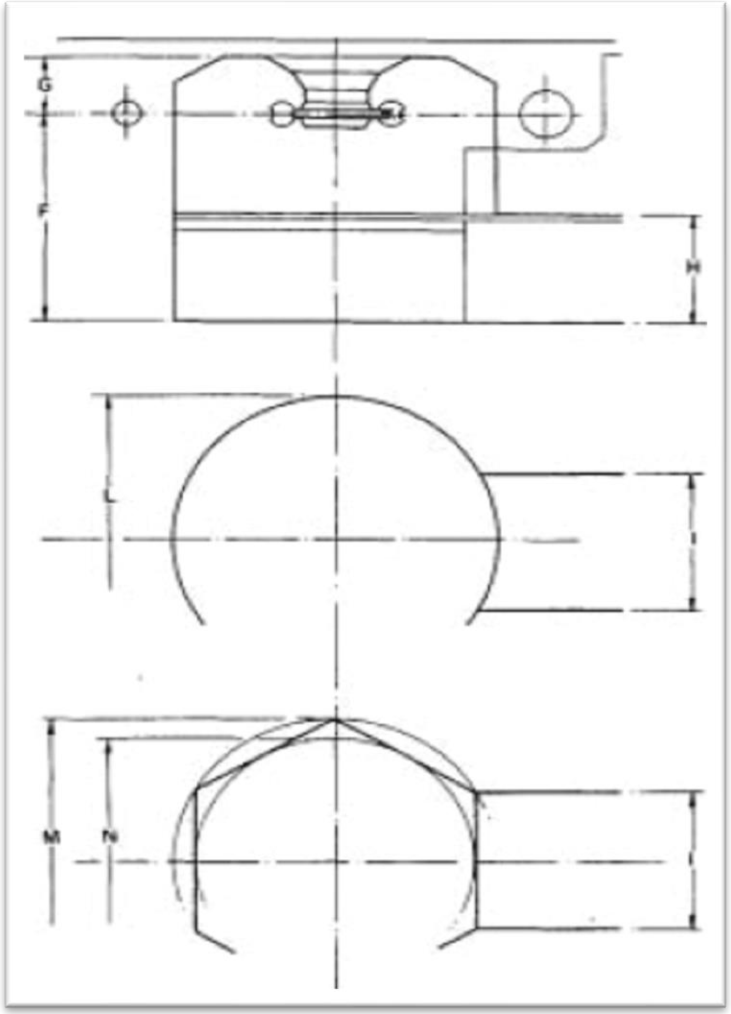


Figure 9-1 Dimensions of Runner



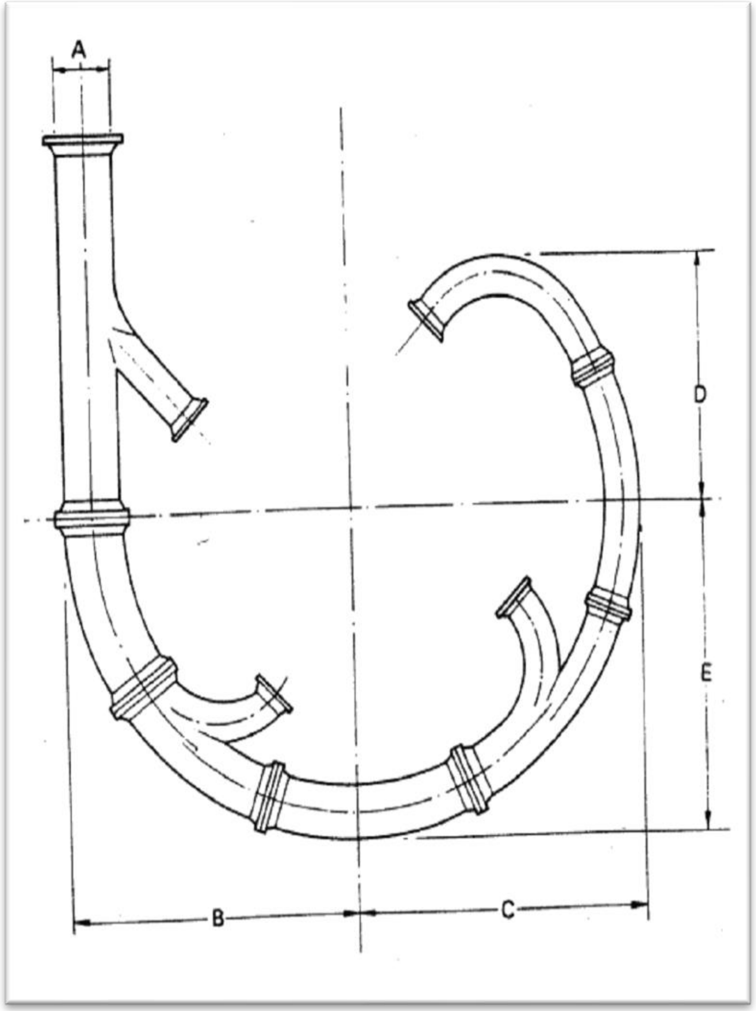


Figure 9-2 Dimensions of Discharge Pit and Distributor

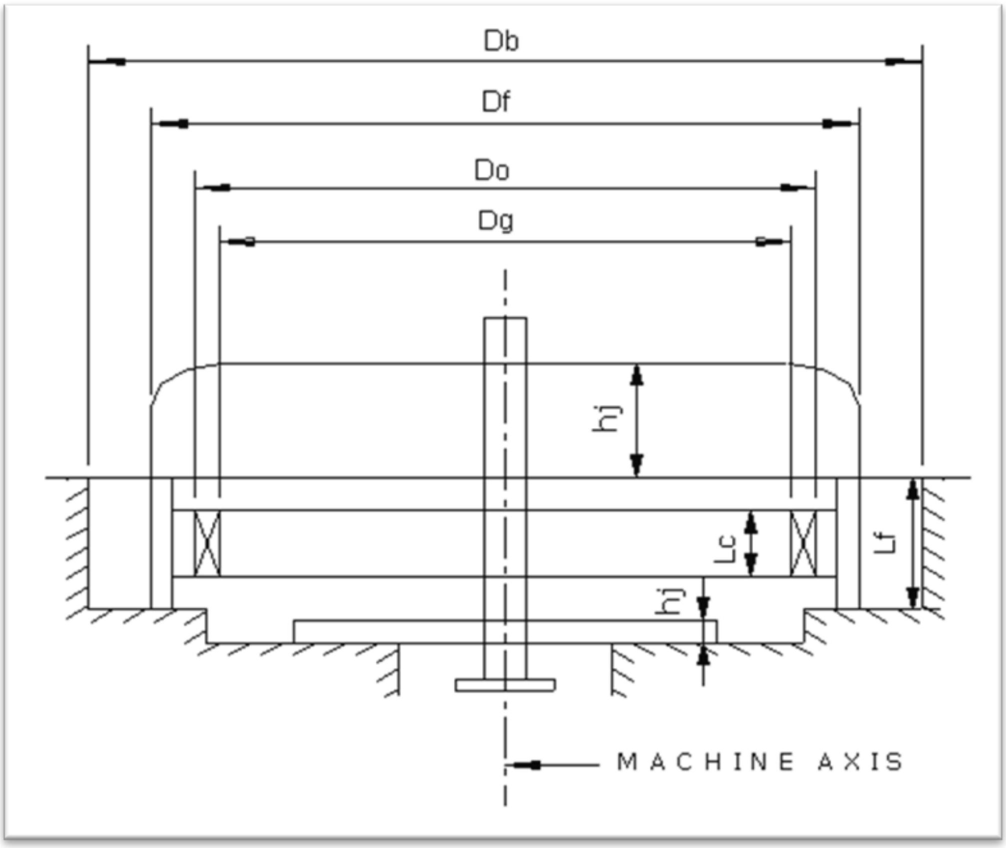


Figure 9-3 Dimensions of Generator

9.2.3. Dimensioning of Powerhouse

The dimensions of powerhouse depend upon turbine dimensions (i.e., Distributor and turbine Pit dimensions), generator barrel dimensions and electro-mechanical equipment layout at various floors. For Oju project with large unit rating and a greater number of units the powerhouse size optimization is important from civil and geological considerations as it is an underground powerhouse. The powerhouse dimensions and floor elevations are optimized on the basis of layout and tabulated below.

Powerhouse Dimensions

Unit spacing	22.50m
Upstream width	13.5m
Downstream width	9.50m
Total width	23.00m
Machine hall length (excluding erection bay)	186.50m
Length of Common Control Block	25.0m
Erection bay length	40.0m

Total length of powerhouse	251.50m
Floor Elevations	
Turbine Pit Floor Elevation	1299.10m
MIV Floor Elevation	1304.00m
Centreline Elevation of Distributor	1307.50m
Turbine Floor Elevation	1310.00m
Generator Floor Elevation	1314.50m
Operating Floor / Erection Bay Elevation	1320.00m
Crane Beam Elevation	1332.50m
EOT Crane	
EOT Crane No. x Capacity (Main / Aux. Hooks) (for each limb)	2 x 250 / 32 T
EOT Crane Lift (From service bay)	12.50m

9.3. Description of Equipment

9.3.1. Mechanical Equipment

Turbine

The turbine shall be of Vertical shaft Pelton type of rated capacity corresponding to match generator output of 231.25 MW at rated net head of 620.83m and rated speed of 300 rpm. Turbine shall comprise of runner, shaft, distributor, turbine housing, nozzle & deflector assemblies, nozzle servomotors, deflector servomotors, guide bearing etc.

Runner and Nozzles shall be of 13-4 Cr-Ni stainless steel. Turbine shaft shall be of forged carbon steel. Distributor, turbine housing, nozzle and deflector servomotors shall be fabricated from steel plate or shall be of cast fabricated construction. Turbine bearing shall be babbitt lined oil lubricated pivoted pad or shell type and shall be located above the turbine runner. A suitable arrangement shall be provided to prevent leakage from gap between stationary and rotating parts of the turbine.

To facilitate repair and maintenance of runner, a provision shall be made to remove the runner from the bottom without disturbing the generator components. A platform shall be provided in the turbine pit below the runner for the inspection of runner, nozzles, and deflectors.

Penstock Butterfly Valve

Four (4) penstock butterfly valves (one for each pressure shaft) of lattice disc type and nominal size 4000mm will be provided.

During normal operation, the valve will be opened and closed under balanced water pressure. Under emergency conditions the valve will be capable of closing against maximum flow.

The valve assembly shall consist of a valve body in two segments, a door with trunnions, service and maintenance seals, self lubricated bushes, lever etc. Service seal shall be provided on the downstream side whereas the maintenance seal shall be provided on the upstream sides of the valve. A dismantling joint and a manhole will be provided on the downstream side of the valve.

The valve shall be complete with inlet and outlet pipes, bypass arrangement, drain valve, air release valve, anti-vacuum valve and over velocity device. The valve will be opened by oil operated servomotor and closed by counter weights.

A hydraulic power pack of adequate capacity will be provided to open and close the valve.

<u>Main Inlet Valve</u>

Each turbine will be equipped with a main inlet valve (MIV) of spherical type. Nominal size of the valve shall be 2350mm.

During normal operation, the valve shall be opened and closed under balanced water pressure and operated by double acting oil operated servomotor connected to the valve door with lever. During emergency, the valve shall be capable to close against maximum flow by counter weight provided on the lever.

The valve assembly shall consist of a valve body in two segments, a door with trunnions, service and maintenance seals, self lubricated bushes, lever etc. Service seal shall be provided on the downstream side where as maintenance seal on the upstream side of the valve. Both service and maintenance seals shall be of stainless steel. A suitable base shall be provided to support the MIV on concrete foundation.

The valve shall be provided with a bypass arrangement to equalize pressure on both sides before opening the valve. A dismantling joint shall be provided on downstream of the valve to facilitate dismantling and removal of valve. A manually operated mechanical locking arrangement shall also be provided to lock the door in open and closed positions during its maintenance.

Independent high pressure oil system will be provided for the operation of MIV. The oil pressure system shall consist of sump tank, electric motor driven main and standby pumps mounted on the sump tank, oil pressure tank with associated accessories, bank of nitrogen bottles, oil piping & valves, instrumentation, protection, monitoring, and control equipments.

<u>Governor</u>

Each turbine will be equipped with electro hydraulic governor of digital type and compatible with station SCADA system. The governor shall be provided with necessary controls to enable accurate speed / power regulation. The governor shall be suitable for peaking as well as base load operation.

Governor shall be provided with an independent high pressure oil system. The oil pressure system shall consist of sump tank, electric motor driven main and standby pumps mounted on the sump tank, oil pressure tank with associated accessories, bank of nitrogen bottles, oil piping & valves, instrumentation, protection, monitoring, and control equipments.

Cooling Water System

Each unit will be provided with an independent cooling water system for supplying cooling water for the following purpose -

- Generator air coolers
- Generator thrust & upper guide bearings
- Generator lower guide bearing
- Turbine guide bearing
- Generators step up transformer
- HVAC System
- Firefighting system

Cooling water for each unit shall be taken from the respective tailrace. The C.W. System will consist of electric motor driven main & standby cooling water pumps, automatic back wash strainers, centrifugal separators, flow sensors, monitoring and control devices, piping and valves etc. The cooling water system of all the units shall be interconnected through isolating valves for redundancy. The return cooling water shall be discharged back into the tailrace of respective unit at a distance further downstream from the intake point.

The capacity of cooling water system shall be adequate to meet the cooling water requirements of generator air coolers, generator thrust and guide bearings, turbine guide bearing, oil pressure unit (if applicable), step-up transformers, HVAC system, firefighting system, and other station requirements.

Compressed Air System

A low pressure compressed air system consisting of one main & one standby compressor complete with electric motors, starters and base plates, two air accumulators, two air dryers, control, safety and isolating valves, pressure switches, air filters, moisture trap and piping will be provided.

The system shall provide air for generator brakes application, purging operation of centrifugal sand separators and other powerhouse utilities. The air required for generator brakes shall be stored in a dedicated accumulator and connected to the required point through independent piping. Another accumulator shall store the air for station service requirements and shall be connected to various service air outlets / connections located in the powerhouse and transformer cavern through separate piping.

Oil Handling System

The oil handling system shall consist of the following:

One mobile centrifuge type hydraulic and lubricating oil purifying unit of adequate capacity suitable for centrifuging largest single oil volume of equipment of one unit in 8 hours complete with all associated accessories, oil pump, oil heater, thermostatic control, discharge pump, control panel, instrumentation, piping and fittings.

One transformer oil purifying unit complete with feeding pump, oil heater, thermostatic control, filtering compartment, vacuum pump, dehydrating compartment, discharge pump, control panel, instrumentation, piping and fittings.

Heating, Ventilation and Air Conditioning (HVAC) System

The HVAC system shall be provided to maintain a healthy atmosphere and acceptable temperature levels in various areas of the powerhouse complex. The system shall consist of fresh air supply blowers, air handling units, air conditioning plant and exhaust fans located on various floors of the powerhouse & control block. The air circulation shall be through ducts routed in the powerhouse complex. In case of fire, the system shall also be used for smoke exhaust and pressurization of staircases and other escape passages to permit evacuation of the operating personnel.

Outside fresh air shall be supplied through the cable tunnel. Air circulation in powerhouse shall be automatically controlled and shall not be influenced by natural air movements.

Areas exposed to harmful gases or odours like battery room, toilets & kitchen / pantry etc. shall be maintained at a negative pressure by removing the air with exhaust fans discharging directly outside through dedicated ducts and no re-circulation of these airs shall be permitted.

The air from various other areas of the powerhouse and transformer cavern shall be re-circulated and partially removed by exhaust fans through ducts routed via cable tunnel / main access tunnel.

An air conditioning system shall be provided for control room, offices and conference room and shall be located in ventilation room located at the top floor of control block.

Water required for the air handling units and A. C. Plant / chiller units shall be tapped from common cooling water header and pumped by electric motor driven centrifugal pumps located in the control block. Cooling water system for HVAC shall be complete with all strainers, centrifugal separators, monitoring & control instruments, piping and valves etc.

Fire Fighting System

Water for firefighting shall be pumped from common cooling water header and stored in an overhead tank of sufficient capacity located in pothead yard area. Water level in the overhead tank will be maintained by electrically operated firefighting pumps. Automatic operation of these pumps shall be controlled by level switches / sensors mounted on the overhead tank.

The System will supply water to cater for the following requirements: -

- Water supply to all Deluges provided for governor & MIV oil pressure units, in service bay, at generator & turbine floors, control block area and mechanical & electrical workshop areas etc.

- Water supply to emulsifier system for transformers.
- Water supply to all sprinklers provided for generator protection.
- Water supply to all sprinklers provided for cable trays, mechanical utilities / facilities, and office area.
- Water supply to all hydrants provided in the entire complex.

Pothead yard area and Diesel Generator room.

The tank shall supply water for fire protection to entire areas of the powerhouse complex by gravity. The capacity of water tank will be adequate to supply water for two hours. The tank shall be filled using pumps in eight hours. The tank shall be partitioned to facilitate cleaning while ensuring availability of water during this period.

Hydrant System

A hydrant system shall be provided in the pothead yard, powerhouse, transformer hall and other areas of the complex. The piping network shall be mainly above ground and provided with isolating gate valves at strategic locations for isolation and directing water at desired locations.

Emulsifier System

An emulsifier system (or automatic High Velocity Water spray system) shall be provided for protection of the transformers. This system shall automatically detect, control and extinguish any outbreak of fire. Protection of transformers shall be achieved through a pipe ring around the equipment with nozzles at various selected points. The water supply to the ring shall be through deluge valve assemblies.

An emulsifier system of similar design is also envisaged for protection of the generators.

Medium Velocity Water Spray System (MVW)

An automatic Medium Velocity Water (MVW) spray system shall be provided for the cables protection. It shall comprise of a dry piping network along with deluge valve assembly, MVW spray nozzles and associated pipe fittings. The total cable tunnel and XLPE cable route will be divided into number of zones. Each zone will be controlled by an individual deluge valve. The deluge valves will be electrically inter-connected in such a way that whenever a deluge valve is operated the deluge valves of 2 adjacent zones will operate simultaneously.

Portable Fire Extinguishers

Portable fire extinguishers shall be provided in mechanical and electrical utility areas in control block.

EOT Cranes

The powerhouse will be equipped with two number 250 tons EOT cranes for handling Turbine, MIV, Generator components and transformers during erection and maintenance.

The two cranes shall be used in tandem with lifting beam for lifting generator rotor and stator.The Valve house will be equipped with one 63 MT EOT Crane for handling penstock valves and its components during erection and maintenance

One 10 tons pendant operated EOT crane shall be provided in the GIS cavern for handling GIS equipment.

EOT cranes shall consist of bridge, operator's cabin, trolley, main hoist, auxiliary hoist, electrical controls, safety devices, fittings and connections and all necessary accessories to handle equipment, including wire ropes for main hoist and auxiliary hoist. Main and auxiliary hoists will be mounted on the same trolley running on the bridge girders. The bridges will be of box girder structure.

Main runway rails and runway conductors along with required embedded parts for the cranes shall also be included.

Elevator

The powerhouse shall be equipped with one 8 passenger elevator, connecting all the floors of the powerhouse.

The construction of elevators shall be such that all motions shall take place smoothly and positively with no slippages, jerks and vibrations. The elevators shall be provided with all safety devices, alarms, fire service switch etc. There shall be provision in the elevator for auto landing to nearest floor in case of power failure.

DG Set

Two (2) 11kV diesel generator (DG) sets, having a nominal rating of 800kVA will provide an emergency source of power in the event of a power outage from SAT. The final rating of the DG set will be determined during detailed design stage.

The diesel generator set will be installed in housing located in the outdoor pothead yard area.

Mechanical Workshop

A mechanical workshop is proposed for the powerhouse to meet regular operational and maintenance (O&M) requirements. The mechanical workshop shall be equipped with general purpose machines like lathe, drilling machine, shaping and milling machines, hand grinders, power hacksaw, mobile welding sets, oxyacetylene cutting set and hand tools and measuring instruments. The mechanical workshop equipment shall be designed and constructed to suit the required needs of the powerhouse.

9.3.2. Electrical Equipments

Generator

Generator shall be vertical shaft, salient pole, and suspended type. The generator shall be directly coupled to the turbine shaft and rated for 256.95 MVA with 0.9 PF lag, 300 rpm, 50 Hz with an output voltage of 15.75kV. The generator will also be capable of operating at 10% continuous overload.

The generator shall have class F insulation and temperature rise restricted to class B insulation. Generator shall be complete with air cooled stator, rotor, shaft, thrust and guide bearings, upper bracket, lower bracket and other components etc.

The cooling of generator shall be closed circuit ventilation type where the air is cooled by stator air cooler and circulated inside generator by the movement of rotor.

Each generator shall be provided with high pressure lubrication system, brake dust collection system, pneumatic braking system, creep detectors and adequate monitoring devices which shall be integrated with station SCADA system. Generators shall be protected by two complementary main multifunctional relays providing both primary and back up protection.

Excitation System

The static excitation system shall match the field requirements of the 256.95 MVA hydro generator with 10% continuous overload capability. Excitation system shall be equipped with digital regulation panel, excitation transformer, field breaker, AC and DC field flashing equipment, Thyristor bridges, associated instrumentation, protection, and thyristor forced air cooling system.

The excitation system will interface with the unit control, powerhouse control and protection systems. The interface will be through modbus communication for controls and hard wired for protection system.

Isolated Phase Bus duct

The Connection between generator terminals and the generator step-up transformer will be achieved through Isolated Phase Bus duct (IPB) with taps for connecting excitation transformer, unit auxiliary transformer and LAVT. The LAVT shall house lightning arrester & voltage transformers. Generator Neutral shall be Grounded through a step-down transformer and housed in the neutral grounding cubicle. Current transformers for metering and protection on both neutral and phase side shall be provided

Generator Step up Transformer

26 (24 in service and two as spares) indoor type, single phase transformers with rated capacity of 94.22 MVA, 15.75 /400√3kV, 50 Hz shall be provided and placed in the transformer cavity adjacent to the powerhouse cavity on the downstream side. The transformers shall be ODWF type having off load tap changers, complete with HV terminations for connection to SF6 gas bus duct, bushing CT's, Neutral & LV bushings, all necessary fittings, auxiliary equipment, accessories etc. The transformers shall be isolated from one another by a fire brick wall.

Gas Insulated Switch Gear

The gas-insulated switchgear (GIS) will be installed on the GIS floor directly above the transformer hall. The GIS shall be double bus bar type consisting of eight generator / transformer incoming feeder circuit breaker bay modules, four outgoing overhead line feeder circuit breaker bay modules, one bus coupler circuit breaker bay module, Bus PT, XLPE cable terminal connection and control cabinets for each bay.

The interconnection between HV side of transformer and GIS GT bay shall be through gas insulated bus duct (GIB)

The outgoing overhead line feeder circuit breaker bay modules will be connected to the outdoor Pothead yard through single core 420kV XLPE insulated power cables. The cables will traverse the GIS floor and travel through the cable tunnel terminating at the cable sealing end located in the outdoor pothead yard.

Overhead crane, of approximate 10 Tons capacity, to lift the heaviest section of the GIS will be installed in the GIS hall.

Provision for two nos 80MVAR Bus reactors shall be made in the GIS. However the rating of bus reactors shall be as per the directive of PGCIL.

High Voltage XLPE cables

420kV, copper conductors, XLPE cables shall connect GIS with the outdoor pothead yard equipment. These cables will be laid on cable trays and supports and adequate fire protection shall be provided. Two nos single phase cable runs shall be provided as spare.

Cable terminations suitable for terminating cables at GIS end and with transmission line at the pothead end shall be provided along with necessary fittings and accessories. Over-voltage limiters shall be provided to adequately protect cable terminations, accessories, and outer polyethylene insulation of the cable against the induced over-voltages in the sheath due to lightning or switching surges.

Pothead Yard Equipments

The transmission and power evacuation system of OJU project will be designed to cater to the combined generation of all the eight machines for an installed capacity of 1850MW. For the evacuation of this power, there will be two (2) outgoing double circuit overhead transmission lines.

Each outgoing line will be equipped with lightning arrestors, high speed motorised earthing and disconnecting switches, PT, CT, CVT, wave trap etc.

The outdoor pothead yard and its surrounding area will have their respective grounding system. The earthing grid will be designed and constructed for the operating voltages and short-circuit capacities corresponding to short-circuit and earth-fault current levels.

Station Auxiliary AC Supply System

During normal running of the unit, each unit auxiliary board (UAB) will receive power from their respective unit auxiliary transformers (UAT). The UAB's will feed the unit auxiliaries of their respective units. However, in case of failure of the supply, the power requirements of a particular UAB will be met from the station service board (SSB). SSB's will be fed from 11kV switchgear and Station service transformers.

The power supply to station service board shall be made from two nos 50MVA, 400/11kV station auxiliary transformers (SAT). The station service boards, in addition to feeding the station auxiliary loads, can also back feed the UAB for black starting purposes and also feed the adjacent SSB in case of its supply failure. In case of failure of power from SAT, the supply of essential service loads will be assured from two emergency diesel generator set of adequate capacity.

An interlocking scheme controlled by a programmable logic controller (PLC) and interfacing with the general auxiliaries control unit will be provided to achieve the required automatic changeover logic from unit supply to station supply and vice-versa for the UAB and SSB.

Station DC Supply System

For utmost reliability, the Control, Protection, Alarm and Telemetering equipment will be fed from a DC supply. The DC supply is provided by main and redundant battery sets. Battery and charger sizes will be of sufficient capacity to fulfill the requirements. The batteries for the control, protection and emergency lighting will be 220V dc and those for the communication systems will be 48V dc.

There will be two 220V battery banks with separate chargers. One DC distribution board with suitable interlocking and switching arrangement shall feed the connected load. 48 V battery bank shall have a single charger unit and a dedicated distribution board.

An uninterruptible power supply (UPS) will also be provided to power equipments of the SCADA system.

Digital distributed control system and SCADA

The powerhouse will be equipped with one (1) modern distributed control system (DCS) complete with two (2) SCADA servers/operator workstations, two (2) (redundant) dispatch communication gateways, printers and a complete redundant communication network system (Local Area Network) including the following:

- Unit and Substation controllers,
- Pothead yard controller,
- General and station auxiliary controller,
- Intake gate controller,
- Automatic and manual synchronizing,
- Metering and monitoring,
- GPS clock system,
- Internal and external communication system,
- Uninterrupted power supply system.

The Distributed digital control system (DCS) shall provide data acquisition, monitoring, automatic control, and supervisory control of the complete hydroelectric equipment of the powerhouse. Hydroelectric equipment includes hydraulic turbine-generator sets, main transformer, circuit breakers, transmission line terminal equipment, intake gates, and ancillary equipment.

The DCS shall be designed for automatic and manual local/ remote control and indications.

Protection system

The protection system for the units, main step-up transformer and 400kV bus will be provided by modern multifunction relays and will include the trip and alarm interfaces for the generator and transformer protections.

There will be two independent protection schemes: the main and the back-up protections. The various protection relays will be grouped in these two categories, each of them connected to the separate cores of instrument transformers, to ensure duplication of fault initiation.

These functions are provided in multifunction numerical relays, which will interface with the DCS LAN for status, alarm, remote configuration, and event retrieval. These relays will allow faster operating time, be more reliable and require less maintenance. They also provide internal monitoring, so any internal failure can be quickly identified.

Cabling System

The types of cables which will be used at the powerhouse for medium voltage and low voltage systems, control and protection systems, instrumentation and communication equipment are classified as follows:

- 11kV, 3-core power cables;
- 415 V power cables rated for 1000 V;
- 300 V control and instrumentation cables;
- Fibre optic control / communication cables;
- Multi conductor and special cables.

Communication System

The communication system provided for the powerhouse will include:

- One (1) complete set of internal station communication system including a paging System, a Telephone System and a Public Address System;
- One (1) Point to Multipoint digital radio system including Central base station, antenna, transmitter / receiver, aand integrated multiplexer (MUX) for the powerhouse and one (1) Outstation radio cabinet with integrated MUX for the colony will be provided for communication between the powerhouse, the dam and the colony.
- Power line carrier communication system for communication with load dispatch centre.
- Radio system will also provide any data link required between the dam and the powerhouse.

Illumination System

A complete illumination system is proposed for the powerhouse. Lighting will be designed to provide different illumination levels in various facilities of the power stations. The illumination system will be comprised of the following:

- Indoor lighting system;
- Outdoor lighting system;
- Emergency lighting system.

Lighting will be designed to provide different illumination levels in various facilities of the power stations. The illumination system for powerhouse complex shall be supplied from the powerhouse illumination boards, which shall be connected to station service board (SSB).

The entire lighting network of the powerhouse shall be supplied from two different boards, each board supplying half of the powerhouse lighting load.

In case of station supply failure, an emergency lighting system will be provided. The emergency lighting will be monitored by a controller and operated by the 220 Vdc system. It will provide essential lighting in the Powerhouse, Transformer & GIS Hall, and access tunnels.

Grounding System

The underground earthing network shall consist of underground earth mat in powerhouse cavern, GIS-cum-transformer cavern, tailrace, pothead yard and other adjoining functional areas. It shall be composed of interconnected mesh of grounding conductors suitably spaced and buried in raft and grounding rods driven vertically in ground connected to mesh. The purpose of this underground earthing network is to lower the overall grid resistance to a value of 0.5 Ω.

The earthing system shall provide:

- Adequate protection of personnel against dangerous voltages, currents and arcs,
- Low earthing impedance for the transformer neutrals and the generator neutrals and sufficiently low neutral conductor impedance,
- The fault currents shall flow through the earthing system,
- Limiting the induced capacitively transformed voltages on electronic cables, circuits, panels and other equipment to low voltage, weak current.

Electrical workshop

An electrical workshop is proposed for the powerhouse to meet regular operational and maintenance (O&M) requirements. The electrical workshop will be equipped with measuring, testing and calibrating devices, as well as general tools and equipment. The electrical workshop equipment will be designed and constructed to suit the required needs of the powerhouse.

9.3.3. Power Evacuation System

The entire power (1850MW + 10% overload) of Oju Project is proposed to be evacuated through two double circuit lines to the nearest pooling station.

10. INFRASTRUCTURAL FACILITIES

10.1. General

Oju Hydroelectric Project is planned as a run-of-the-river scheme with sufficient storage for meeting daily peak hour energy generation requirements. The project envisages construction of tunnels and cofferdams, a concrete gravity dam & intake structure, headrace tunnel, surge shaft, butterfly valve house, pressure shaft/penstocks and underground powerhouse with an installed capacity of 1850MW, tailrace tunnel and switch yard. A dam toe powerhouse of 28MW capacity is also proposed.

The infrastructural works set up envisaged for the development of the project including the estimated requirement of land, both for infrastructure as well as permanent works are outlined in this chapter.

10.2. Project Location and Access

The dam site is located about 220km from Daporijo, district head quarter of Upper Subansiri district in Arunachal Pradesh. Dam site and Powerhouse area can be accessed by a newly constructed BRO road from Limeking. The dam site is located at about ~~70~~60.0km upstream of Limeking and powerhouse site is located at about ~~25~~40.0km upstream of Limeking on the right bank of Subansiri river (called Si Nigit river). Single lane metalled road connects Limeking with Daporijo which is about 150km. Daporijo can be accessed from North Lakhimpur using either Pahumara-Kimin-Ziro-Daporijo road (300km) or Silapathat-Likabali-Basar-Daporizo Road (275km). Silapathar is accessible from North Lakhimpur and also from Dibrugarh via Bogibeel bridge across river Bramhaputra.

10.3. Infrastructure Plan

The infrastructure works at Oju HEP would broadly comprise:

a. Job facilities

b. Route Survey

   i) Rail head facilities,

   ii) Road transport facilities,

c. Project Roads/Bridges to Work Sites

d. Owner's and Contractors Colonies,

e. Construction power set up,

f. Telecom system,

g. Disposal areas,

h. Borrow areas/quarries,

i. Explosive Magazines, and

j. Acquisition of Land.

The details of the above are discussed hereinafter:

10.4. Job facilities Areas

Various job facilities for construction of the project would set up in the project area to develop an optimal working environment suiting to the project component's locations.

10.4.1. Stores and Warehouses

The storage of materials and spares required for various activities of the project would be efficiently managed. Adequate material supply and its appropriate storage is the backbone of any job.

Two central warehouses have been planned; one would be established for the dam complex and the other for the powerhouse complex which would receive all incoming supplies. Cement, reinforcement steel and other job specific items of material could also be sent directly to the respective sites as per their demand. However, the explosive will be stored in Magazines proposed to be in an isolated area from where explosive materials will be supplied as per their demand. The warehouses would stock electrical items separately.

10.4.2. Source of Material for Aggregate Production

Aggregate for concreting shall predominantly be used from in-situ rock quarry and about 50% of the excavated muck from Dam and tunnels/caverns are proposed to be used for coarse and fine aggregate production.

10.4.3. Aggregate and Concrete Production Plants

Adequate capacity of aggregate production plants (AP plants), concrete production plants (BM plants) and ice plant for dam concreting shall be provided near the project components to cater overall demand of concrete and shotcrete. The various components where consumption of concrete is envisaged are as follows:

a) Dam Site Area

Concrete would be required for the following major works falling in this area:

- Main dam,
- Intake structure,

- Diversion tunnels and their portals, and

b) Headrace Tunnel and Construction Adits

c) Powerhouse Complex

In the powerhouse area, concrete would be required mainly for the following components of the powerhouse complex:

- Surge Shaft,
- Valve house,
- Pressure shafts/Penstocks,
- Main powerhouse cavern,
- Transformer Hall,
- Unit Tailrace Tunnels
- Main Tailrace Tunnels
- Cable Tunnel
- Pot head Yard
- All construction adits to powerhouse complex

The quantities involved in the construction of the civil works, both in the dam and powerhouse areas, are large. The concentration of construction activity would be confined to two main areas i.e., the dam area and the powerhouse area. These two working zones are about 20km apart. Due to this large distance, it would be more efficient and pragmatic to set up independent service, repair, and storage facilities near these areas.

Moreover, sufficient aggregate storage areas for at least two week's requirements shall be planned near each aggregate and BM plant location for any breakdown of aggregate production plant. For dam concreting following additional plants will be required.

10.4.4. Transportation of Aggregates and Concrete

Adequate provision of equipment shall be made for transportation of raw materials from quarry sites to aggregate processing & crushing plants, transportation, and placement of concrete from BM plants to work sites.

10.4.5. Construction Plant Areas

The construction of all the plants would be taken up after the land is acquired and the contract for construction of job facilities is awarded. Proper terraces would be developed for locating the foundations of the plants. The erection works would start after the foundations are ready.

The aggregate processing plant, batching and mixing plant, compressor house and field workshops are proposed to be provided at different sites. Suitable dumping areas for excavated material and quarry sites are also to be planned during the course of works.

10.4.6. Water Supply

The provision of adequate water supply for both construction purposes and for use of personnel will be required. A suitable water pumping scheme is envisaged for tapping the water from nallahs to fulfil the day-to-day requirement of the project. A water treatment plant is also envisaged at a suitable location to ensure availability of safe drinking water.

10.4.7. Electrical Equipment Storage Yard

The project involves installation of eight generating units each of 231.25 MW along with a dam toe powerhouse of 28MW. A storage yard having open space and covered sheds will be provided near the powerhouse for storing the electric and mechanical parts of the electromechanical equipment of the generating units on receipt from manufactures. The equipment will be shifted from this yard to powerhouse as the erection activity commences. Necessary heating arrangement for the delicate electrical equipment will be put in the place for safeguarding the parts.

10.5. Route Survey

The route to the project comprises of rail heads, roads/highways and water ways as outlined below.

10.5.1. Rail Head Facilities

Silapathar which is in Assam is considered the nearest railhead for the project. Bulk consignments would be received at this station and after unloading the rail wagons, they would be temporarily stocked in a warehouse/store shed which would be constructed near the station. From this warehouse, the consignments would be transported to the project site in trucks/trailers as required.

10.5.2. Inland Water Ways

The river Brahmaputra can be used from Bangladesh Border to Bogibeel for transportation of bulk consignment to project site after unloading at Bogibeel Ghat.

10.5.3. Road Facilities

The transportation of the material would be done in either of the following three manners:

a) Directly from the manufacturers' premises to the project site by road, or

b) By rail transport up to Silapathar Rail Head and thereafter by road transport to the project site, o

c) By inland water transport up to Bogibeel Ghat and thereafter by road transport to the project site

10.6. Project Roads/Bridges to Work Sites

10.6.1. Project Roads

To execute the various civil works, roads would be made for linking the work site to other sites and to job facility areas. They would essentially be unpaved and would be constructed at a workable gradient so that loaded construction equipment does not have to toil hard to go up slope. The general gradient proposed for the roads is 1 in 15. It would be attempted to keep the road surface at the curves horizontal. An open drain would be constructed along the hill side which would outfall into culverts at suitable locations. The hill side slope would be retained with breast walls at appropriate locations. The valley side of the road would be provided with parapets at suitable intervals for safety reasons and retaining walls wherever necessitated.

10.6.2. Bridges over Water Ways

Both permanent and temporary bridges would be constructed to cross the waterways falling in the alignments of the roads. The bridge shall be designed considering 70R loading.

10.6.3. Residential and Non-Residential Buildings

Residential buildings will be required to house staff working during the construction of the project and subsequently for the operational and maintenance staff at the barrage as well as at the powerhouse.

Temporary facilities at appropriate locations, including colonies for the contractors, will be required during the construction of the project. Some of these may be retained after the completion of the project for the benefit of both permanent project staff and the local population.

Non-residential facilities will include:

- Parking and general storage areas (covered and uncovered);
- Storage facilities for cement, steel and other materials including chemicals.

- Facilities for storage and delivery of fuel.
- Explosive magazines.
- Maintenance workshop for heavy earth moving equipment and transport vehicles.
- Workshop for fabrication of, for example, steel linings.
- Testing laboratory.
- Accommodation for support staff.
- School and primary health care centre.
- Bank and Post Office.
- Recreation centre including club and auditorium.
- Guest Houses and Conference Halls.

Provisions for market.

Additional amenities such as fire station, police station, bus stand and other public utilities may also be provided in consultation with the local administration.

10.7. Construction Power Set Up

Construction power would not be available for the project from any resources in the state. The requirement would have to be met only by installing diesel generating sets. The requirement of construction power would vary at each individual site depending upon the equipment deployed. The power requirement for construction activities is estimated to about 25.0 MVA taking into consideration the capacity of electric driven equipments which are to work during the construction period and lighting. The possibility of constructing small hydro power plants on streams in the vicinity of the project would also be explored at DPR stage.

10.8. Telecom Set Up

To ensure efficient coordination of works at various sites during construction, adequate and reliable telecommunication network is necessary. V-sat system and mobile towers shall be installed in the project area for communication purpose with other parts of the country/world. It is also proposed to provide an independent 100 line exchange (EPABX) for the project works. The lines from this exchange will be extended to all project camp and work sites.

One Multipoint digital radio system including central base station, antenna, transmitter/ receiver and integrated multiplexer (MUX) shall also be provided for the different work sites, colony, stores and offices.

10.9. Muck Disposal Areas

The spoil from various construction sites would be disposed off at designated areas in a controlled manner to protect the environment. About 50% of the muck generated is proposed to be carried to the aggregate processing plants for production of coarse and fine aggregates. The balance quantity and material found unsuitable for processing would be directed to the designated disposal sites.

10.10. Quarries/Borrow Areas

To meet the requirement of coarse and fine aggregates for all components of the project, several in situ rock quarries are to be identified in the vicinity of the project taking into techno-economic considerations involving suitability of material for use & minimum lead.

10.11. Explosive Magazines

Permanent explosive magazines of adequate capacity would be constructed to store the explosives and detonators required for the construction of the project components.

10.12. Construction Adits and Access Tunnels

To facilitate construction of main project components, a network of approach adits and access tunnels of appropriate sizes has been planned.

10.13. Acquisition of Land for the Project

Land would be required for locating the permanent works as well as for setting up the infrastructural facilities necessary for constructing the project in an expeditious and optimal manner.

Of the total extent of area of land required, some would be acquired permanently while the balance can be obtained on lease from the owners for a definite time period and returned to them after the project is completed. In the latter case, it would be restored to its original condition as far as possible. The tentative requirement of land to be acquired have been worked out and are given is given in **Table 10-1** below.

Table 10-1: Requirement of Land (Tentative)

S.No.	Description	Total Area (ha)
1	Submerged area excluding riverbed	34.3
	Submerged Area- Riverbed on upstream of Dam Axis	8.9
2	Upstream of Dam Axis above FRL	12.5
	Downstream of Dam Axis excluding riverbed	64.8
	Riverbed Downstream of Dam Axis	3.2
3	HRT up to surge shaft Including Adits	38.9
4	Powerhouse complex including Pothead yard	115.7
5	Store, workshop & Penstock fabrication yard	50.0
6	Permanent Colony, Transit Camp & Guest house	60.0
7	Temporary Colony/ Labour Colony	20.0
8	Quarry sites	100.0
9	Muck disposal Areas	105.0
10	Aggregate Processing and Batching & Mixing plant	20.0
11	Project Roads	122.5
12	Explosive Magazine	2.5
	Total Land Requirement	**758.3**
	Say,	**760**

11. CONSTRUCTUION PLANNING

Activities related to implementation of the project are divided into the following sub-activities:

- Preparation and approval of the DPR
- Obtaining approval of all statuary clearances
- Pre-construction activities
- Project construction and commissioning

A brief description of each of these sub-activities along with an estimate of their completion time and schedule is given in the sections to follow.

11.1. Preparation and Approval of the DPR

Currently, the project is in Feasibility Stage. The next stage of the project would be preparation of Detailed Project Report (DPR) which is likely to be completed by December 2022. Thereafter, clearance of the DPR by statutory authorities is estimated to take about 06 months.

11.2. Construction Schedule

It is proposed to complete the project and commission all the eight units in a period of 72 months from the date of start of the project. Construction of all the works shall be taken up simultaneously in such a manner so as to complete the works in a period of 65 months allowing a period of 1 month for initial filling and testing of the water conductor system and commissioning and testing of the units in the next 7 months. Refer tentative construction schedule in **Annexure 11-1**.

11.3. Preconstruction Activities

The execution of the project is planned to start with effect from the month of January of the year 2024 of start of execution (taken as zero month). All administrative, financial and legal formalities for execution of the project are required to be completed by this time. It is necessary that all infrastructural works as mentioned below are completed before zero month so that construction of main works is started on schedule:

a) Acquisition of land required for construction of structures, bridges and roads, project colonies, stores, workshops etc.

b) Up-gradation and construction of access roads:
- Road to Dam site, Diversion Tunnel inlet & Outlet, HRT Intake, top of Surge Shaft, to access pressure shaft/penstock at various level and powerhouse sites.
- Approach road to quarry site.

- Approach roads to muck disposal areas.
- Approach road to explosive magazine store.

c) Areas for Aggregate processing plants, Batching and Mixing plants, Workshop, and offices to be earmarked and made available,

d) Availability of construction power at Dam complex, Powerhouse complex, surge shaft & Pressure Shaft Site (i.e., downstream end of HRT), top of Surge Shaft and Colony and workshops sites.

e) Construction of residential and non-residential buildings, stores etc as per requirement.

The infrastructural works shall be started 12 months before zero month so as to ensure that all such works are completed before the scheduled date of start of construction of the main civil works of the project. Special attention would be paid to the early completion of main access roads and bridges.

11.4. Tender and Contracts

The contract for various packages shall be finalized in advance of the starting of the work at site. All contracts for infrastructural development works shall be finalized 12 months before starting month of execution (i.e., the Zero Month) to ensure the completion of all such works before the start of the main civil works. All contracts relating to the civil works shall be finalized at least 6 months before starting month of execution and order for manufacturing and supply relating to electro-mechanical equipment shall be finalized in all respects by the Zero Month.

Procurement of plant and machinery required for construction of the project and its availability at site will be done by the civil construction agency by the Zero Month.

11.5. Scheduled Working Hours

Equipment planning for calculating requirement of equipment is carried out based on the number of working days available, which depend upon climatic conditions in the project area. In the project area a working season of 8 months is considered possible after allowing for monsoon season of 4 months. The scheduled working hours (annual production hours), considering 25 working days per month, accordingly, work out as under:

Shift per day	Annual Production Hours	
Single shift work/day	= 8 x 25 x 6	= 1200 hours
Two shift work/day	= 8 x 25 x 11	= 2200 hours
Three shift work/day	= 8 x 25 x 15	= 3000 hours

For underground works execution will be carried out almost throughout the year round the clock though the progress may be less during rainy days due to constraints associated with the monsoon season.

Since the production capability would be affected during monsoon months especially for the supplies/services and muck disposal, etc., suitable reduction in the progress has been taken into account for the year as a whole.

Planning for all above-ground and underground works has been done considering three shifts-working.

11.6. Construction Methodology

Preliminary construction methodology for various works is given below.

11.6.1. River Diversion

The Subansiri River is diverted through two diversion tunnels by constructing two cofferdams capable of withstanding a 1 in 25 year frequency flood. River diversion arrangement so as to create dry working area for construction of concrete gravity dam comprises of:

i. Two diversion tunnels on the right bank, each of 12.7m dia circular shaped and concrete lined.

ii. Random filled pre-cofferdam- upstream and downstream.

iii. A Colcrete upstream and random filled downstream cofferdam.

The sequence of construction of diversion system shall be as below:

i. Construction of protective guide bunds by utilizing rock plug in front of DT inlet and outlet.

ii. Open excavation and construction of portals.

iii. Excavation of diversion tunnels by heading both from upstream and downstream side.

iv. Bench excavation both on upstream and downstream side once the heading operation is completed.

v. Overt and invert lining of DT followed by grouting wherever necessary.

vi. The structures at both the inlet and outlet portals of diversion tunnels to be established concurrently during excavation and lining.

vii. Erection of H. M. equipment.

viii. Removal of protective guide bund and diversion of river flow

ix. Construction of upstream and downstream pre-cofferdams

x. Construction of main upstream and downstream cofferdams.

xi. Plugging of diversion tunnels

11.6.1.1. PROTECTIVE GUIDE BUNDS

Adequate working area opposite the tunnels would be required for working, dewatering sump, etc. A ring bund opposite to the tunnel portal has been located by leaving a rock ledge in a manner which meets the construction requirements. The rock ledge if required shall be strengthened by dumping and compacting excavated materials.

An open dewatering sump of sufficient capacity would be constructed in the pit area and pumps of adequate capacity would be installed near/above it for dewatering seepage and surface run-off water.

11.6.1.2. OPEN EXCAVATION AND CONSTRUCTION OF PORTAL

Open cut excavation for exposing the inlet & outlet portals would be carried out for which access roads have been provided. On reaching the crown level of the tunnels, the excavation of the tunnel face would be done at a slope of 1 in 6 for stability. Any overhangs or reverse slopes would be avoided for safety reasons. Slope protection works in the form of shotcrete/rock bolts required thereof would be done concurrently.

11.6.1.3. DIVERSION TUNNELS

After construction of the portal, excavation of diversion tunnel shall be started from both the faces (inlet and outlet faces). The section being large, full-face excavation of the diversion tunnels would not be resorted to. Instead, the excavation would be done in stages by dividing the section into two parts viz. heading & benching. Bench excavation would be carried out after completion of heading.

Drilling of holes for blasting would be done by two boom drill jumbos with a man basket. Haulage of excavated material shall be done by a combination of loader/excavator and dumpers of adequate capacity. As the excavation proceeds, rock support system by way of rock bolts, shotcrete as required shall be provided. To support the face, sealing shotcrete shall also be provided if required. Drilling for rock bolts shall also be carried out with two-boom drill jumbo.

After bench excavation is completed, concrete lining of diversion tunnel will start. The concrete lining shall be done using a 12m long hydraulically operated collapsible Gantry Shutter moving on rails.

Transit mixer and concrete pumps of adequate capacity shall be deployed for transportation and placement of concrete. The concreting from the entry and exit ends of the diversion tunnels would be carried out concurrently.

11.6.1.4. INLET AND OUTLET STRUCTURE

During the time when all the above cited activities viz. excavation of diversion tunnel and concrete lining of diversion are going on, following activities will also be carried out concurrently in the sequence given below:

- Concreting of the inlet & outlet structures

- Laying of CC Blocks in front and on sides of inlet & outlet structures
- Second stage concreting for gates in the groves etc,
- Installation of HM equipments and testing of the same
- Removal of rock ledge in front of portal.

11.6.1.5. CONSTRUCTION OF PRE-COFFERDAMS

For construction of the concrete faced rock fill cofferdams, earthen dykes would need to be constructed as soon as the construction of diversion tunnel is over. Excavated material from diversion tunnel and dam abutment stripping shall be used for building up the pre cofferdams.

11.6.1.6. CONSTRUCTION OF MAIN COFFERDAMS

In order to create a dry working area for construction of main dam, the diversion scheme envisaging one upstream cofferdam and another downstream cofferdam along with two diversion tunnels to have an alternative path of water, has been planned.

The work of construction of cofferdams shall be taken up after the diversion tunnels have been completed and construction of pre cofferdams is over. The upstream cofferdam is about 27m high and about 186.0m long. The downstream cofferdam is about 11m high and about 105.0m long.

Upstream cofferdam shall be constructed of colcrete and downstream cofferdam shall be random fill type. Excavated material from diversion tunnel and dam abutment stripping shall be used for rock fill.

11.6.1.7. PLUGGING OF DIVERSION TUNNELS

Plugging of diversion tunnel will be taken up at any time during lean period after completion of all activities in the dam complex and HRT is ready for conveying water for power generation. By this time diversion tunnel gates at inlet would be lowered. Plugging activities will be carried out from downstream side of diversion tunnel i.e., from outlet portal

11.6.1.8. CONSTRUCTION PROGRAM

The construction program as scheduled for river diversion is shown in the following table:

Activity	**Duration**	**Starting month**	**Ending month**
Construction of Ring Bunds near Upstream & downstream portals and Development of upstream and downstream portals of all two diversion tunnels	1 months	Month 1	Month 1
Diversion Tunnel-I			

Activity	Duration	Starting month	Ending month
Excavation - Heading and Benching (Both from upstream and downstream side)	9 months	Month 2	Month10
Concreting & Inlet and outlet structure	8 months	Month 6	Month 13
Diversion Tunnel-II			
Excavation - Heading and Benching (Both from upstream and downstream side)	12 months	Month 2	Month 13
Concreting & Inlet and outlet structure	10 months	Month 8	Month 17
Installation of diversion tunnel gates	10 months	Month 9	Month 18
Upstream pre coffer and main Cofferdam	6 months	Month 14	Month 19
Downstream pre coffer and main Cofferdam	5 months	Month 15	Month 19

11.6.2. Dam and Intake

The working period on the dam site is limited to 8 months in a year as no work is possible during monsoon from the month of June to Sept due to heavy rain falls. The civil works of the Dam are proposed to be completed in 3.5 years after diversion of the river. Another one year will be taken for erection of hydro-mechanical works. Excavation of the abutments shall be undertaken while the diversion works are in progress.

The construction methodology for the main dam mainly consists of the following activities.

i. Abutment stripping
ii. Dewatering of whole dam area,
iii. Excavation of bed up to sound rock profile,
iv. Dental excavation and treatment of shear zones, if any,
v. Laying of concrete,
vi. Consolidation grouting,
vii. Curtain grouting,
viii. Drainage holes,
ix. Laying of Spillway Bridge,
x. Erection of hydro mechanical equipment's

Before construction of the main works is taken up, it is essential to develop the basic infrastructure facilities such as construction of temporary/permanent roads. Aggregate Processing Plant (APP), Concrete Batching and Mixing plant (BM), Ice plants, concrete placement arrangement and other miscellaneous facilities pertaining to supply of water, supply of compressed air, setting up of telecommunications & wireless facility, setting up of diesel generators and distribution arrangements to meet the power requirements of work.

11.6.2.1. EXCAVATION

The excavation for blocks located on right and left abutment above river water level shall be taken up along with the works of diversion arrangement. For approach to these dam blocks for excavation, suitable haul roads from the project construction roads shall be established. The excavation of dam pit below river water level shall be taken up after diversion works are completed and river is diverted through the diversion tunnel. The area between the cofferdams shall be dewatered and excavation shall be taken up by establishing suitable haul roads. For excavation in overburden material, combination of hydraulic excavator and dumpers shall be used. For rock excavation, drilling and blasting shall be done with crawler drill. In addition, rock drills with or without pusher legs will also be used.

Shotcrete of required thickness shall be provided on all cut slope surface to prevent the rock from weathering. Shotcreting of those rock surfaces which shall remain permanently exposed i.e., which shall not be covered by dam concreting shall be reinforced with wire mesh. In addition to shotcreting, rock bolts, as required for stability of rock slopes shall also be provided.

11.6.2.2. CONCRETING

Concreting in a particular dam block shall be started after excavation and proper geological mapping and foundation treatment of that particular block. The concerting of dam blocks essentially consists of three main activities viz. manufacture of concrete which includes Aggregate Processing Plant for production of Aggregate, Batch and Mixing Plant for production of concrete and Ice Plant for production of ice.

Transportation of concrete from Batching & Mixing Plant shall be done with the help of conveyor belt or transit mixer or diesel locos. The placement of concrete shall be done with the help of tower crane/ cable carne.

Compaction of concrete shall be done with the help of hydraulic vibrators with ϕ150 mm needles mounted on crawlers. Vibration of concrete close to shuttering and conduits shall be done by use of ϕ65 mm needle vibrators. Curing of concrete will be done by use of water spray nozzles. PVC water stops across transverse contraction joints shall be provided as per provisions of IS: 12200-2001.

11.6.2.3. CONSOLIDATION GROUTING

To improve the foundation rock surface, consolidation grouting shall be taken up after placement of minimum one layer of concrete over the foundation rock surface. The depth of holes for consolidation grouting, the spacing of holes and grout pressures shall depend on geological conditions actually encountered at site after completion of excavation upto designated foundation level. The holes shall be vertical or inclined depending upon dip direction of bedding planes.

For grouting, grout pumps of adequate capacity will be used. Full depth grouting/stage grouting method shall be adopted depending upon the geological conditions of the rock. In full depth method, each hole shall be drilled to the full desired depth, washed, pressure tested and grouted in one operation. This method shall be adopted only in areas where the foundation rock has only small cracks and joints with no risk of surface leakage. For heterogeneous strata, where the return of rock discontinuities is subject to large variations in relation to the depth of the holes, full depth grouting shall not be adopted and descending order or ascending order stage grouting shall be done.

11.6.2.4. CURTAIN GROUTING

The purpose of curtain grouting is to decrease the uplift pressure under the structure to check the erosion of in-fills of joints and to decrease the water losses through foundation rock. The depth of grout curtain depends on the water head in reservoir and the extent of fracturing of the rock foundation so as to achieve an imperviousness of 1 lugeon. The spacing of holes for grouting shall depend on permeability values of foundation strata at various depths. Rotary/percussion drills shall be used to drill curtain grout holes to the required depth. Where joint orientations permit, the grout holes shall be along the dam axis and their inclination shall be vertical in the valley floor and perpendicular to the slope of abutments. If vertical fractures are present, this arrangement does not allow for the maximum number of fractures to be intercepted and the inclination of the grout holes will be modified. As per common practice, the drill holes shall be inclined towards upstream at 5º to 10º from the vertical. A single row of holes shall generally be provided. However, if required, double or triple row of holes shall be provided for grout curtain. The grouting holes and the grouting through holes shall be done in three phases. Primary holes shall be drilled from 6 to8m and grouted first. The secondary holes are then located midway between primary holes and shall be grouted. Finally, the tertiary holes are drilled and grouted midway between primary and secondary holes.

The stage grouting procedure shall be used to permit treatment of various zones individually. Depending upon the geological conditions, descending order or ascending order stage grouting shall be used.

11.6.2.5. DRAINAGE HOLES

After curtain grouting is completed and desired impermeability is attained, drainage holes of ϕ76 mm shall be drilled by percussion/rotary drills from the drainage and grouting gallery and on downstream side of grout curtain. The depth of drainage holes shall be approximately 75% of the depth of holes for curtain grouting and the spacing of these drainage holes shall be 3m c/c. The drainage holes shall not be drilled in the foundation gallery till curtain grouting is completed within 30m from the location of drainage holes. Within the body of the dam, ϕ200 mm formed drains shall be provided @ 3m c/c to relieve the water pressure developed, if any. The water from galleries shall be collected in the sump and shall be pumped out of the dam body.

11.6.2.6. FOUNDATION DRAINAGE/GROUTING GALLERY

The Drainage/grouting gallery in the dam body shall be provided for drilling of holes for curtain grouting and pressure grouting of drill holes and also to provide drainage holes to collect seepage water from the foundation and the body of the dam.

11.6.2.7. INSPECTION/ INSTRUMENTATION/ APPROACH GALLERIES

Drainage/grouting gallery serves the purpose of inspection of dam body near the foundation of blocks. However, additional galleries both longitudinal and transverse direction shall be provided for inspection of dam body at different levels, to collect seepage water and to install the instruments essential for measurement of various parameters such as stresses, strains, temperature, deformation etc and to provide the approaches to these instruments.

11.6.2.8. VENTILATION OF GALLERIES IN DAM BLOCKS

Drainage/grouting galleries as well as inspection galleries shall be provided for proper ventilation through ϕ300 MS pipes in connecting galleries with downstream face of the dam at appropriate level above the maximum Tailwater Level. At least one such pipe shall be provided in each block. Though the main purpose of these approach galleries is to provide approach to drainage galleries to start the work of curtain grouting, these will serve the purpose for ventilation of galleries also

11.6.2.9. CONSTRUCTION PROGRAM

The tentative construction program as schedule for construction of dam & intake is shown in the following table.

Activity	Duration	Starting month	Ending month
Dam			
Excavation on left & right abutment and in intake above El. 1870 m including slope protection	11 months	Month 4	Month 14
Excavation of Dam below El. 1870 to foundation Level & Plunge Pool	4 months	Month 15	Month 18
Foundation Mapping & Treatment, Mud Matting, Concreting in Dam & Plunge Pool including 1st & 2nd stage gate embedment consolidation grouting	46 months	Month 17	Month 62
Installation of radial, spillway stop logs, auxiliary spillway gates	24 months	Month 41	Month 64
Curtain grouting and drilling of drainage holes	20 months	Month 45	Month 64
Miscellaneous and finishing works	6 months	Month 61	Month 66
Intake			

Activity	Duration	Starting month	Ending month
Concreting of Pedestal for intake and power conduit including 1st stage gate embedment and installation of intake & trash rack gates	29 months	Month 25	Month 53

11.6.3. Headrace Tunnel

The total length of HRT is 14.17km with a finished dia of 10.4 m. The total tunnel is proposed to be excavated by conventional drill and blast method of excavation from twelve faces followed by concreting using six construction adits. All adits will be D-shaped with size 6.0m (W) x 7.0m (H).

Excavation in heading would be taken up by drilling and blasting method. Drilling of holes for blasting would be done by two boom drill jumbos. The excavation shall be taken up from all headings concurrently. The maximum length of tunnel to be excavated from one face is 1500.0m. It is planned to achieve an average progress of 90m per month by (heading) and 100m by benching. Haulage of excavated material shall be done by a combination of loader and dumpers of adequate capacity. As the excavation proceeds, rock support system by way of rock bolts, shotcrete as required shall be provided. Thus, excavation of the HRT is planned to be completed by the 39th month.

Collapsible shutters with traveller and concrete pump with concrete distribution system for continuous lining of the tunnel is proposed to be used at each face. The invert concreting shall follow as an overlapping activity. The concreting of HRT will therefore get completed by 54th month. A period of 13 months will be required for grouting and another 10 months for plugging the adits and installation of adit gates. Thus, this work is proposed to be completed by 65th month.

Activity	Duration	Starting month	Ending month
Open excavation, slope protection, development of portal and excavation of all Adits	6 months	Month 1	Month 6
Heading and Benching of all HRT faces from Adits	34 months	Month 6	Month 39
Concreting of HRT	20 months	Month 35	Month 54
Grouting, Cleaning, and finishing works	13 months	Month 43	Month 55
Plugging of Adits Grouting, Cleaning, and finishing works & Installation of adit plugging gates	10 months	Month 56	Month 65

11.6.4. Surge Shaft

The semi underground (open to sky type) surge shaft consists of a shaft of 20m diameter and 118.25m height above HRT.

The excavation of the surge shaft will be done first by making a pilot shaft from bottom using a raise climber. Mucking shall be done from bottom of surge shaft with adequate capacity and number of dumpers in combination with loader or hydraulic excavator.

After completion of the pilot shaft, the widening will be done from top to bottom. The widening will be done from the top by drilling, blasting and scaling. A platform lowered from top shall be used for the purpose. The muck generated will be thrown through the pilot shaft in the HRT and will be taken out through top horizontal pressure shafts from valve house side.

Concreting of the surge shaft will be undertaken at the end. It will be carried out from bottom to top. The concreting of surge shaft is proposed to be carried out by deploying a slip form shutter.

The shutter would be lowered by winch erected at top of shaft which is to be concreted after steel reinforcement has been erected. Transportation of concrete from BM plant shall be done by adequate capacity of Transit Mixer. Concrete pump of adequate capacity will be used for concrete placement and needle vibrators for vibration of concrete

11.6.4.1. CONSTRUCTION PROGRAM

The tentative construction program as schedule for construction of surge shaft is shown in the following table.

Activity	Duration	Starting month	Ending month
Open Excavation of Surge Shaft with slope Protection & Excavation of Pilot Shaft	12 months	Month 1	Month 12
Widening of Shaft from top	11 months	Month 31	Month 41
Concreting, Grouting and finishing works	22 months	Month 43	Month 64

11.6.5. Butterfly Valve House

Butterfly valve house [10m (W) x 25m (H) x 64m (L)] has been planned as a underground structure. Excavation for valve house shall be carried out by drilling and blasting method same as HRT. Open excavation shall be carried out to develop the valve house.

11.6.5.1. CONSTRUCTION PROGRAM

The tentative construction program as schedule for construction of Butterfly Valve House is shown in the following table.

Activity	Duration	Starting month	Ending month
Excavation of Valve House & Construction of Valve House Building	8 months	Month 37	Month 44

Concreting of Valve House + embedment of HM works+ Finishing Works	16 months	Month 45	Month 60

11.6.6. Pressure Shafts/Penstock

The excavation of the 2 nos. top horizontal underground pressure shafts, 5.7m dia shall be carried out from valve house side by using conventional drilling and blasting method.

After valve chamber, about 277m deep 2 nos. of pressure shafts will be done from top or bottom using raise climber/borer equipment. Each pressure shaft will then bifurcate in two intermediate pressure shaft of 4.0m diameter. The excavation of vertical portion of 4 nos. intermediate pressure shaft shall be carried out using raise climber/borer equipment. Each intermediate pressure shaft shall be bifurcated into 2.85m diameter unit penstock. Three construction adits will be provided excavation and steel lining of pressure shaft and penstocks.

The erection of penstock liners in top horizontal portion, inclined portion and vertical will be carried out separately. The erection of penstocks bottom horizontal portion will be done through the Penstock erection chamber at the bottom of penstocks. Adequate capacity of transit mixer and concrete pump will be provided for concreting in Pressure shaft/ penstocks.

11.6.6.1. CONSTRUCTION PROGRAM

The tentative construction program as schedule for construction of pressure shaft/penstock is shown in the following table.

Activity	Duration	Starting month	Ending month
Pressure Shaft / Penstock			
Pressure Shaft upstream of Valve House			
Development of Portal of U/G pressure shaft headers P-1 & P-2	4 months	Month 1	Month 4
Pressure Shaft D/s of Valve House P-1 & P-2 (Excavation, Construction of rail tracks and pedestals & Erection)	32 months	Month 5	Month 36
Intermediate Pressure Shafts			
IPS -1 to IPS-4			
Excavation, Construction of rail tracks and pedestals & Erection	46 months	Month 5	Month 50
Unit Penstock UP-1 to UP-8			
Excavation, Construction of rail tracks and pedestals & Erection	46 months	Month 17	Month 62

11.6.7. Powerhouse Complex

The excavation of arch roof of powerhouse [22.0m (W) x 46.5m (H) x 251.5m (L)] and transformer hall (16.5m (W) x 25.5m (H) x 269.85m (L)) cavities shall be done by excavating central drift and widening the drift followed by the benching to various levels. Excavation will be done by two boom drill jumbo and wagon drills. The mucking of the cavities will be done from access tunnel and adit to unit penstocks. The Powerhouse (PH) and the Transformer Hall (TH) caverns are connected by eight nos. of Bus Duct Galleries.

Eight nos. of unit TRT and two main TRT [9.5m (W) x 8.0m (H)] will be provided. Excavation will be done by heading and benching method by two boom drill jumbo. Mucking shall be done from adequate capacity and number of dumpers in combination with loader or hydraulic excavator.

Open excavation shall be carried out to develop the pothead yard (50.0m x 185.0m). The open excavation consists of common excavation and rock excavation. For common excavation, combination of hydraulic excavator and dumpers shall be used. For rock excavation, drilling and blasting shall be done with rock drills with or without pusher legs. In addition, crawler drills shall also be used. The excavators shall be assisted by Dozers as needed. The cut slope shall be protected with shotcrete and rock bolts as per design and drawing.

Adequate capacity of transit mixer and concrete pump will be provided for concreting in Powerhouse complex area.

11.6.7.1. CONSTRUCTION PROGRAM

The tentative construction program as schedule for construction of powerhouse complex is shown in the following table.

Activity	Duration	Starting month	Ending month
Powerhouse Cavern			
Development of Portal and construction of Main Access Tunnel	8 months	Month 1	Month 8
Adit-A2 (Adit to Powerhouse Crown) & PH Cavity Excavation	40 months	Month 1	Month 40
Concreting of Powerhouse & Architectural and finishing works	31 months	Month 34	Month 64
Transformer Cavern, Bus Ducts & Cable Duct			
Excavation of Adit-A3 & Transformer Hall	24 months	Month 7	Month 30
Concreting of Transformer Hall	10 months	Month 31	Month 40
Tailrace Tunnels			
Excavation of Tailrace Tunnel - Heading and Benching	17 months	Month 13	Month 29

Concreting of Tailrace Tunnel, grouting and finishing works & Installation of TRT gates	27 months	Month 30	Month 56
Pothead Yard			
Switch Yard Excavation	8 months	Month 37	Month 44
Switch Yard Concreting and other Development works	12 months	Month 49	Month 60

11.7. Electro-Mechanical Equipment

Design, manufacturing of all electrical-mechanical equipments shall be undertaken immediately after award of the contract and its supply to the project site shall be completed in about two months prior to erection of the same at site.

Proposed schedule for design, manufacturing, supply, erection, testing, and commissioning of electro-mechanical equipments is as follows:

Items	Design, Manufacturing & Supply	Erection	Testing and Commissioning
EOT Crane	9 months	2 months	1 month
Turbine & Generator	60 months	40 months	6 months
Transformers/GIS	12 months	6 months	6 months
Switchyard	12 months	8 months	2 months

11.8. Commissioning of Units

Construction of all major activities mainly dam; water conductor system and powerhouse complex shall be completed by 65th month i.e., May 2029. Built-up of reservoir, filling and testing of the water conductor system shall be taken up in 66th month. Commissioning and testing of Unit-1 will be taken up first and is proposed to be completed in 67th month. Thereafter commissioning and testing of other units (two units at a time) will be taken up at an interval of 1.5 months as shown in the schedule below.

Activity	Duration	Starting month	Ending month
Filling and testing of water conductor system	1 month	Month 66	Month 66
Testing And Commissioning			
Unit-1 & 2	1 months	Month 67	Month 67
Unit-3 & 4	1 months	Month 68	Month 68

Activity	Duration	Starting month	Ending month
Unit-5 & 6	1 months	Month 69	Month 69
Unit-7 & 8	1 months	Month 70	Month 70
Unit-1 & 2 of Dam Toe Powerhouse	2 months	Month 71	Month 72

11.9. Project Organization

11.9.1. General

The project organization proposed for the execution of the project is to be headed by the Project Director or Project Manager. The Project Management will basically be divided into the following working groups.

i. Technical Management
ii. Mechanical operation and Maintenance
iii. Electrical Power supply and distribution
iv. Administration and Infrastructure
v. Stores and Procurement
vi. Finance

11.9.2. Working Areas of the Project

During construction of the project main working areas will be as under:

- Infra structure works
- Construction of Diversion Tunnels and Cofferdams
- Main Gravity Dam and Intake Area
- Headrace Tunnel and Adits
- Surge Shaft and Pressure Shaft
- Under Ground Powerhouse Complex
- TRT, TRT out fall structure and Pothead Yard
- All HM and E&M works

Other Working Areas

- Quality Control
- PMC & Contract
- Geotechnical
- Construction Power and Telecommunication
- Procurement
- Stores

- Mechanical
- Training and Human Resources
- Finance and Accounts
- Medical
- Public Relation
- Security and Vigilance

12. PRELIMINARY COST ESTIMATE

12.1. General

The preliminary cost estimate has been made on the basis of component sizes as per the preliminary layout and design computations.

12.2. Principles Adopted for Estimation of the Project Cost

The basis for working out the hard cost of the project is given below:

i. The unit rates for different items have been taken as per the present-day rates for these items of works for ongoing projects of almost of the same magnitude in the North-Eastern region. The unit rate includes all prevalent taxes.

ii. The quantities of various items have been worked out from the drawings prepared on the basis of preliminary planning and design of various components of works including HM works.

iii. Cost of E&M works has been taken @ ₹ 1.5 crore per MW of installed capacity.

iv. A provision of 3% of the cost has been made to cover contingencies in the estimate of different components of civil works.

v. A provision of 2% of cost for work charged establishment.

vi. A provision of 1 % for building construction workers welfare cess.

vii. A provision of 1.5 % for insurance during construction.

viii. A provision of 0.1 % for project monitoring.

ix. Contractor overhead and profit @20% has been considered.

12.3. Project Cost

The present-day cost consists of the following components:

12.3.1. C-Works

Works under this sub head are as under:

a) Diversion tunnels

b) Cofferdams

c) Dam

d) Hydro mechanical works

12.3.2. J-Power Plant Civil Works

Under this sub-head, provision has been made for the following works:

a) HRT Intake

b) Headrace Tunnel

c) Surge Shaft

d) Pressure Shaft / Penstock and Valve House

e) Powerhouse Complex

f) Tailrace Tunnel

g) Construction Adits and Access tunnels

h) Pothead yard

i) Hydro mechanical works

12.3.3. Subhead Expenditure

In addition to the component costs, provision for sub-head wise expenditure has also been made. The cost provision for these items (mentioned below) has been made on lump sum basis of C-works/J-Power Plant/I-Works, generally as per the latest guidelines for formulation of DPRs for hydroelectric projects issued by CEA.

Item	Provision as % of Civil Works
A-Preliminary	2% (I-Works)
B-Land	2% (I-Works)
K-Buildings	2.5% (I-Works)
O-Miscellaneous	4% (I-Works)
P- Maintenance	1% (C+J+K)
R- Communication	4% (I-Works)
X-Environment & Ecology	5% (I-Works)
Y-Losses on Stock	0.25% (C+J+K)
Establishment	As per CEA guideline norms
Q-Special T & P and T&P	1% (I-WORKS) Max. 200 lacs each
Receipts & Recoveries	(-) 15% (Q T&P +K-buildings)
Capitalized Value of abatement of Land Revenue	5% (B-Land)

Audit & Accounts Charges & H.O. Establishment	0.25% (I-Works) as per CEA guidelines

12.3.4. Hard Cost

The present-day tentative cost has been worked out and presented in **Annexure 12-1**. A summary of the estimated cost is given below.

Table 12-1: Summary of Tentative Cost Estimate

Particulars	Present day Estimated Cost (₹ in Crore)
Diversion Tunnels and Cofferdams	391.15
Dam including Spillway and associated works	1690.53
Intake, HRT, TRT and associated structures	1920.90
Powerhouse, Penstock, Pot Head Yard and associated structures	1062.55
Other Direct charges like Roads, land, buildings etc. and indirect charges	1586.85
Total Civil Works	6651.98
E&M works	2817.00
TOTAL	**9468.98**

The other indirect costs such as interest and escalation during construction have been worked out separately and discussed in Chapter-13.

13. ECONOMIC AND FINANCIAL EVALUATION

13.1. Policy Guidelines of the Government of India

Central Electricity Regulatory Commission (C.E.R.C.), hereafter referred to as "Commission" was constituted in July,1988 under the Electricity Regulatory Commissions Act,1988 with the omission of Section 43A (2) of the Electricity (Supply) Act 1948, which enabled the Central Government to determine the terms and conditions of tariff, the jurisdiction to regulate tariff came to be vested in the Commission. Consequently, the Commission initiated steps to determine the terms and conditions of tariff.

Under Section 61 of the Electricity Act 2003 (hereinafter referred to as "the Act") the Commission is to specify the terms and conditions for the determination of the tariff. Section 62 of the Act envisages that based on the terms and conditions specified by the Commission, the Commission shall determine the actual tariff.

The economic appraisal and the evaluation of the Oju Hydroelectric Project have been made in this Chapter, in accordance with the latest Commission regulations *(No. L-1/236/2018-CERC dated 19th February 2021)* and other subsequent notifications of the commission.

The details of working out the capital cost on completion and fixation of tariff for sale are discussed below.

13.2. Construction Period of the Project

Oju hydroelectric project is envisaged to be completed in 6 years, after 2 years of preconstruction activities and infrastructure works including land acquisition. Another period of about 2 years is likely to be taken for jobs connected with the preparation of DPR and its TEC from CEA/CWC. In other words, full project benefits are considered to be available 10 years from now.

13.3. Equity in the Project

In line with norms of the Financial Institutions, it is proposed to invest 30% of the Project cost as equity.

13.4. Loan Component

In view of the above, the loan component of the project is taken as 70%.

The loan component will include term loan from Indian/International Financial Institutions, Suppliers credit, ECB or such other instruments, which will be finalized at the time of financial closure of the project.

13.5. Interest on Loan Capital

An interest rate of 12.0% per annum has been adopted for working out the interest during construction. The interest rate on working capital has been adopted as 13.50%.

13.6. Repayment Period

As per CERC guidelines, the repayment of loan has been considered from the first year of commercial operation of the project equal to the annual depreciation allowed.

13.7. Annual Escalation

The rate of escalation has been taken as 6% for civil works (simple) and 5% for E&M works

13.8. Phasing of Expenditure

The phasing of expenditure has been worked out on the basis of anticipated construction schedule. The phasing of expenditure of the present estimated cost, for both civil and E&M, has been done as under:

Year		Civil Works	E&M Works
Pre-Construction Period		As %age of present day estimated cost	
1	1st Half Year	0.0%	0.0%
	2nd Half Year	1.23%	0.0%
2	1st Half Year	1.26%	0.0%
	2nd Half Year	2.47%	0.0%
Construction Period		As %age of (estimated present day cost - expenditure during pre-construction period)	
1	1st Half Year	9.14%	0%
	2nd Half Year	8.02%	0%
2	1st Half Year	12.36%	15%
	2nd Half Year	6.39%	0%
3	1st Half Year	7.63%	0%
	2nd Half Year	6.18%	0%
4	1st Half Year	9.26%	0%
	2nd Half Year	8.04%	10%
5	1st Half Year	12.90%	25%
	2nd Half Year	4.75%	25%

6	1st Half Year	9.72%	25%
	2nd Half Year	0.67%	0%

The detailed half yearly phasing of expenditure of the total hard cost including escalation during construction is given in Error! Reference source not found. for civil works and in Error! Reference source not found. for E&M works.

13.9. Financial Charges

All Financial Institutions (both Indian and Foreign) charge what are known as Front-end or Management fees on loan capital. These are made to cover the financial commitment/service charges. Since this is an established practice, the same has been considered in calculations of the capital cost. These charges have been taken as 1.0% of the loan capital.

13.10. Interest during Construction

The details of cash flow during construction period and the calculation of interest during construction including interest on IDC are shown in Error! Reference source not found..

13.11. Completion Cost of the Project

The total cost of the project including escalation, IDC and financing charge will be as below:

	Items	(₹ Crores)
A.	**Hard Cost of the Project**	
	Civil Works including HM works	6651.98
	E & M Works	2817.00
	Sub Total	**9468.98**
B.	**Escalation**	
	Civil Works including HM works	2775.78
	E & M Works	1214.83
	Sub Total	**3990.61**
	Total Project Cost (A+B)	**13459.59**
C.	**IDC and Financing Costs**	**3653.45**
	Total Project Completion Cost (A+B+C)	**17113.04**

The completion cost is based on the tentative financial assessment, and it may vary based on firm financial package.

13.12. Fixation of Tariff

The tariff has been worked out on the basis of the Central Electricity Regulatory Commission guidelines for the period 2019-24.

13.13. Units Available For Sale

As already brought out, total generation of units in 90% dependable year is 7926 million. Out of this, as per guidelines, 1.2% of the units generated are accounted for auxiliary consumption which includes loss in the transformation up to bus bars, which works out to 95.11 million units. Thus, the net energy available at bus bar will be 7830.89 MU.

13.14. Free Power to Home State

12% royalty and 1% for local area development in the shape of free power shall be provided to the home state. This is as per MOU between NECL and Government of Arunachal Pradesh. The energy available after accounting free power works out to 6812.87 MU

13.15. Rates of Depreciation

As per CERC Guidelines, the depreciation up to 90% of the capital cost is allowed during the operating period. Weighted average rate of depreciation (%) is calculated as per the rates specified in Appendix-III of the CERC Regulations for various components. Depreciation is then calculated as per straight line method using this weighted average rate of depreciation for the first 12 years from the date of commercial operation of the project and the remaining depreciation shall be spread over the balance useful life of the project. The weighted average rate of depreciation has been taken as 5.0%.

13.16. Operation and Maintenance Expenses

As per CERC Norms, the operation and maintenance expenses shall be fixed to 3.5% of the original cost of the project (excluding the cost of rehabilitation & resettlement works) and shall be subject to annual escalation of 5.72% per annum for the subsequent years.

13.17. Return on Equity

The return on equity has been computed in rupee terms on the equity base determined in accordance with Regulation 12. It shall be computed on pre-tax basis at the base rate of 16.5% to be grossed up as per clause (3) of the regulation. An additional return of 0.5% shall be allowed if the project is completed within the time specified in Appendix-II of the regulations.

The return on equity has been computed by grossing up the base rate with normal tax rate applicable to the company rounded of to three decimal points as per following formula:

Rate of pre-tax ROE = Base rate/(1-t) and equals to 20.876% for the company is paying Minimum Alternate Tax @ 20.96% during tax holiday and 24.996% for the period company is paying normal corporate tax @ 33.99% including surcharge and cess.

13.18. Discount Rate

The discount rate for financial analysis has been calculated as per CERC as shown below.

Calculation of Discount Rate as per CERC

Debt	=	70%
Equity	=	30%
Corporate Tax Rate (CTR)	=	30.0%
Risk Free Rate	=	8.15%
Beta (β)	=	0.96
Equity Market Risk Premium (RP)	=	5.60%
Market Rate of Interest (MR)	=	12.00%
Cost of Debt (0.7*MR*(1-CTR))	=	5.88% (A)
Cost of Equity (0.3*(RF+ β*RP))	=	4.06% (B)
Discounting Rate (A+B)	=	9.94%

13.19. Basic Parameters for Financial Analysis

The following basic parameters have been used to determine the capital cost of the project and the sale rate of energy per kWh (Unit)

1	Construction Period	=	6 years after 2 years pre-construction and another 2 years for TEC approval
2	Plant useful life	=	35 years
3	Debt-Equity Ratio	=	70:30
4	Interest Rate on Term Loan during construction	=	12.00%

5	Interest Rate on working capital	=	12.00%
6	Return on Equity	=	16.5%
7	O & M charges	=	2% of total cost
8	O & M escalation rate	=	5.72% p.a.
9	Escalation during construction for civil works	=	6% p.a.
10	Escalation during construction for E & M works	=	5% p.a.
11	Auxiliary consumption including Transformation losses	=	1.2% of total energy
12	Free Power to Home state	=	12%+1%
13	Financing Charges	=	1.0% of loan amount
14	Min. Alternate Tax (For 1st 10 Years)	=	20.96%
15	Rate of Income Tax (After 10 Years)	=	33.99%

13.20. Calculation of Tariff

Calculation of tariffs for primary energy during 35 years of plant useful life at powerhouse bus bar with or without free power to home state are presented in Error! Reference source not found. and Error! Reference source not found., respectively. The following table shows the levellized tariffs of the project.

Particulars	90% Dependable Year 35 Years Operation
Levellised Tariff / kWh (with free power to the State), ₹/kWh	5.65
1st Year Tariff (with free power to the State), ₹/kWh	5.79
Levellised Tariff / kWh (without free power to the State), ₹/kWh	4.92

14. ENVIRONMENTAL AND ECOLOGICAL ASPECTS

14.1. Introduction

The proposed hydroelectric project, while providing planned benefit i.e. hydropower generation could also lead to a variety of adverse environmental impacts as well. However, by proper planning at the inception and design stages and by adopting appropriate mitigating measures in the planning, design, construction and operation phases, the adverse impacts can be minimized to a large extent, whereas the beneficial impacts could be maximized.

The present Chapter outlines the information on baseline environmental setting and also attempts a preliminary assessment of impacts likely to accrue during project construction and operation phases of the proposed project. The Chapter also outlines the framework of Environmental Management Plan (EMP) for mitigation of adverse impacts. An Environmental Monitoring Program too been delineated in the present chapter for implementation during project construction and operation phases.

14.2. Policy, Legal and Administrative Framework

The principal Environmental Regulatory Agency in India is the Ministry of Environment and Forests (MoEF), Government of India. MoEF formulates environmental policies and accords environmental clearance for the projects. The State Pollution Control Board (SPCB) accords No Objection Certificate (NOC), Consent for Establishment and Consent for Operation for the projects.

As per the guidelines pertaining to Environmental clearance issued by Ministry of Environment and Forests (MoEF) dated September 14, 2006, the Terms of Reference (TOR) for the EIA study is to be approved by MoEF. In this connection, Form-I along with TOR in the prescribed format is submitted to MoEF. The same is reviewed by the Environmental Appraisal Committee of River Valley Projects of MoEF. The important Environmental legislations laid down for conservation of environment are presented in **Table 14-1**.

Table 14-1: Key Environmental Legislations in India

Name	Scope and Objective	Key Areas	Operational Agencies/Key Players
Water (prevention and Control of Pollution) Act, 1974, 1988	Prevention and control of water pollution and enhancing the quality of water	Controls sewage and industrial effluent discharges	Central and State Pollution Control Boards

Name	Scope and Objective	Key Areas	Operational Agencies/Key Players
Air (Prevention and Control of Pollution) Act 1981, 1987	Prevention and control of air pollution	Controls emissions of air pollutants	Central and State Pollution Control Boards
Forest (Conservation) Act, 1980, 1988	Acquisition of common property such as forests; halt India's rapid deforestation and resulting Environmental degradation	Regulates access to natural resources, state has a monopoly right over land; Restriction on de-reservation and using forest for non-forest purpose	State Government and Central Government
Wildlife (protection) Act, 1972,1993	Protection of wildlife due to adverse impacts on account of various project related activities	Creates protected areas (National parks/ sanctuaries) categories of wildlife which are protected	Wildlife Advisory Boards; Central Zoo Authorities
Environment (Protection) Act, 1986	Protection and improvement of environment	Umbrella legislation which supplements pollution laws	Central Government nodal agency MoEF, can delegate powers to state departments of Environments
National Rehabilitation and Resettlement Policy 2007	Resettlement and Rehabilitation of project affected population	Social issues	Central Government
EIA Notification 1994, 2006	Procedure and norms of Environmental Clearance for various categories of projects	Environmental Protection	Project Developer, Central and State governments

14.3. Study Area

The study area can be divided as below:

- Submergence area
- Area to be acquired for various project appurtenances
- Area within 10km radius of the main project components like dam, powerhouse, etc.
- Area within 10km upstream of reservoir tip
- Area within 10km distance from the reservoir rim along both the river banks.

- Catchment Area incorporated at the dam site within Indian portion.

14.4. Environmental Baseline Status

The description of environmental setting or baseline environmental status is an integral part of any EIA study. The objectives of the assessment of baseline environmental status of the study area are to:

- Assess the existing environmental quality, as well as the environmental impacts of the alternatives being studied.
- Identify environmentally significant factors or areas that could preclude the proposed development.
- Provide sufficient information so that decision-makers and reviewers can develop an understanding of the project needs as well as the environmental characteristics of the area.

The environmental baseline status has been described in the following sections.

14.4.1. Meteorology

The climate in the project area varies significantly with altitude. Climatologically, following four seasons are identified in the project area:

- Monsoon Season: June to September
- Lean Season: Mid-November to Mid-March
- Non-Monsoon/Non-Lean Season: October to Mid-November to Mid-March to May

Within the study area, significant temperature variations, vis-à-vis elevation and exposure to the sun are observed. As the insolation at high altitudes is intense, temperatures in the open are considerably higher than in shade in summer. The months of May and June are the warmest months of the year with mean maximum temperature at around 25ºC. With the withdrawal of monsoons, towards the end of September, day and night temperatures begin to fall up to January, which is the coolest month with mean minimum temperature of 7.5ºC.

Rainfall in the study area shows high spatial variation and varies significantly with elevation and aspect. Majority of rainfall occurs during monsoon season lasting from June to September. Rainfall decreases rapidly after September and October to December are the driest months of the year. Thunderstorms accompanied by rains occur in summer season and also in the month of October. The relative humidity is high during monsoon months. During rest of the year, the relative humidity is slightly lower.

14.4.2. Water Quality

The proposed project is located in an area with low population density with no major sources of pollution. There are no industries in the area. The area under agriculture is quite less, which coupled with negligible use of agro-chemicals, means that apart from domestic sources, pollution loading from other sources is virtually negligible. Thus, water quality is expected to be quite good in the area.

14.4.3. Terrestrial Flora

14.4.3.1. FOREST TYPES

Within the study area, forests belonging to sub-tropical and temperate categories can be observed. The forest types in the study area are briefly described in the following paragraphs.

14.4.3.2. SUB-TROPICAL VEGETATION

The subtropical forests occur at the elevation from 900-1800m and are basically of evergreen and dense in nature. These forests are also rich in species diversity and can broadly be divided into two subtypes.

14.4.3.3. SUB-TROPICAL BROAD LEAVED FORESTS

The dominant trees in these forests are *Castanopsis armata, Castanopsisindica, Ficus gaspurriniana, Kydiaglabrescence, Magnolia pterocarpa, Michelia oblonga, Quercus semicarpifolia, Ulmuslanceifolia,* etc. *Among the small trees and shrubs, Actinudia callosa, Berberis wallichiana, Camellia caudata, Lasianthus longicauda, Mahonia acanthifolia, Myrsine semiserrata, Photiniaintegrifolia, Rubus moluccanus, Sterculia hamiltonii, Viburnum foetidum,* and various species of *Clerodendrum, Symplocos,* etc. are common*. Argyreia wallichii, Clematis gauriana, Holboelia latifolia, Crawfordia speciosa, etc. are some of the commonly observed climbers. Epiphytic orchids e.g., Bulbophyllum, Coelogyne, Dendrobium, Octochilus,* etc. along with some terrestrial ones like *Goodyera, Habenaria, Malaxis,* etc. frequently occur in these forests*. Equisetum ramosissimum, Lycopodium clavatum* flourish along the roadside slopes.

14.4.3.4. SUB-TROPICAL PINE FORESTS

These forests occur at elevations between 1200-1800m. The dominant species are represented by Pinus merkusii, Pinus roxburghii, and Pinus wallichiana found in association with other tree species like Alnus nepalensis, Betula alnoides, etc. The herbaceous species of Ajuga, Elsholtzia, Pogostemon, and Potentilla are of common occurrence whereas ferns like Pteridium aquilinum, Gleichenia glaucaform thickets along forest margins. Epiphytes are not commonly observed in this forest type.

14.4.3.5. TEMPERATE VEGETATION

These forests occur in the form of a continuous belt between 1800-3500m altitudes. These forests can be divided into two sub-types:

14.4.3.6. TEMPERATE BROAD-LEAVED FOREST

These forests occur in between 1800-2800 m. Trees like Acer pectinatum, A. oblongum, alnusnepalensis, Exbucklandiapopulnea, Rhododendron spp., Castanopsis indica, Populus gamblei, P. ciliata etc. form the top storey where as the middle storey is represented by species of Prunus, Rubus, Spiraea, Symplocos, Rhododendron etc. Thelower storey is composed of small trees e.g Caryopteris odorata, Debregesia longifolia, Illicium griffithii, Lyonia ovalifolia, and shrubs like Mahonia acanthiifolia, Myrsinese miserrata, Vaccinium sprengelii, etc. Climbers are rare whereas various epiphytic species of Agapetes, Rhododendron, Vaccinium are common along with several orchids, ferns and lichens. Plagiogyriascandens, a dimorphic fern, is very common in these forests.

14.4.4. Fauna

The list of faunal species observed in the study area is outlined in Table 14-2. The entire project area has fairly good forest coverage. It serves as a habitat for manyfaunal species. But, with progress of time, due to increase in human interference, shifting cultivation and other activities, wildlife in the study area has been affected.

The mammalian species recorded from the area are Felis bengalensis (Leopard Cat), Felis mormorata (Marbled Cat), Vulpes bengalensis (Indian fox), Canis aureus (Jackal), Petaurista candidulus (Giant Flying Squirrels), Muntiacus muntjac (Barking Deer), Apodemus sylvaticus (common Field mouse).

Amphibian fauna recorded from the area includes Euphlyctes cyanophlyctes, Linnonectus limnocharis, Rana tigrina, Racophorus maximus, Polypedates leucomystax, Bufo melanostictus, etc..

The commonly observed avi-fauna includes White Breasted Kingfisher (Halcyon smyrnesis), Red Vented Bulbul (Pycnonotus jocosus), Mountain imperial pigeon (Ducula badia), Mountain imperial pigeon (Ducula badia), Indian roller (Coracias benghalensis), Mountain bulbul (Hypsipetes meclellandii), etc. are reported in the area.There are no national parks or wildlife sanctuaries within the study area.

14.4.5. Fisheries

The fish fauna found in the Subansiri River, and its tributaries are *Garra gotyla gotyla, Naemachellus botiabotia, Channa punctatus, Schizothorax richardsonii, Barilius bendelisis, Labeo dero, Mastacem belusarmatus,* etc.

Fish migration is generally related to the breeding behaviour of the species. Most of the species of fish are periodic in breeding and require specific ground throughout their life. *Schizothorax richardsonii* is the only migratory fish found in the project area. It moves downstream during the summer and monsoon months. The exotic trout *Salmo trutta fario is* restricted to high altitude water and therefore, will not be affected by the project.

14.5. Prediction of Impacts

Prediction is essentially a process to forecast the future environmental conditions of the project area that might be expected to occur because of the implementation of the project. Based on the project details and the baseline environmental status, potential impacts as a result of the construction and operation of the proposed project have been identified.

14.5.1. Impacts on Land Environment

The major impacts anticipated on land environment during construction are as follows:

1. Quarrying operations
2. Operation of construction equipment
3. Muck disposal
4. Acquisition of land

1. <u>Quarrying Operations</u>

A project of this magnitude would require significant amount of construction material. Quarries with a total area of 100 ha have been identified for extrication of construction material. The quarrying operations are semi-mechanized in nature. Normally, in a hilly terrain, quarrying is normally done by cutting a face of the hill. A permanent scar is likely to be left, once quarrying activities are over. With the passage of time, rock from the exposed face of the quarry under the action of wind and other erosion forces, get slowly weathered and after some time, they become a potential source of landslide. Thus it is necessary to implement appropriate slope stabilization measures to prevent the possibility of soil erosion and landslides in the quarry sites.

2. <u>Operation of Construction Equipment</u>

During construction phase, various types of equipment will be brought to the site. These include crushers, batching plant, drillers, earthmovers, rock bolters, etc. The siting of various construction equipment would require significant amount of space.

Similarly, space will be required for storing of various other construction equipment. In addition, land will also be temporarily acquired, i.e. for the duration of project construction for storage of quarried material before crushing, crushed material, cement, rubble, etc. Efforts must be made for proper siting of these facilities.

Various criteria for selection of these sites would be:

- Proximity to the site of use
- Sensitivity of forests in the nearby areas
- Proximity from habitations
- Proximity to drinking water source

Efforts must be made to site the contractor's working space in such a way that the adverse impacts on environment are minimal, i.e. to locate the construction equipment, so that impacts on human and faunal population are minimal.

3. Muck Disposal

Muck generation and disposal could lead to various adverse impacts. The muck needs to be disposed at designated sites. As a part of the project investigations, various sites have been identified for muck disposal. A total area of 105 ha has been earmarked for muck disposal. This could lead to following impacts:

- loss of land
- problems regarding stability of spoil dumps
- access to spoil dump areas

A part of the muck can be used for the following purposes:

- use of suitable rock from the excavation as aggregate in the mixing of concrete.
- use of muck for maintenance of roads.
- use of muck in coffer dam.
- use as backfill material in quarry and borrow pits.

The balance muck shall be disposed at designated sites Muck, if not securely transported and dumped at pre-designated sites, can have serious environmental impacts, such as:

- Muck, if not disposed properly, can be washed away into the main river which can cause negative impacts on the aquatic ecosystem of the river.
- Muck disposal can lead to impacts on various aspects of environment. Normally, the land is cleared before muck disposal. During clearing operations, trees are cut, and undergrowth perishes as a result of muck disposal.
- In many of the sites, muck is stacked without adequate stabilisation measures. In such a scenario, the muck moves along with runoff and creates landslide like situations. Many a times, boulders/large stone pieces enter the river/water body, affecting the benthic fauna, fisheries, and other components of aquatic biota.
- Normally muck disposal is done at low lying areas, which get filled up due to stacking of muck. This can sometimes affect the natural drainage pattern of the area leading to accumulation of water or partial flooding of some area which can provide ideal breeding habitat for mosquitoes.

4. Acquisition of Land

The total land to be acquired for the project is 760 ha. of the land to be acquired for the project the submergence area of the dam is only 34.3 ha. As per ownership, land could be government, forest or private land. Based on the ownership status of land to be acquired for the project, appropriate compensatory measures shall be implemented. The land requirement for various project appurtenances is given in **Table 14-2**.

Table 14-2: Land requirement for various project appurtenances

S.No.	Description	Area (ha)
1	Submerged Area excluding riverbed	34.3
2	Riverbed on upstream of Dam Axis	8.9
3	Dam complex & utilities facility Area	77.3
4	Riverbed on downstream of Dam Axis	3.2
5	HRT up to surge shaft Including Adits	38.9
6	Powerhouse complex including Pothead yard	115.7
7	Store, workshop & Penstock fabrication yard	50.0
8	Permanent Colony, Transit Camp & Guest house	60.0
9	Labour Colony	20.0
10	Quarry sites	100.0
11	Muck disposal Areas	105.0
12	Aggregate Processing and Batching & Mixing plant	20.0
13	Project Roads	122.5
14	Explosive Magazine	2.5
	Total Land Requirement	758.3
	Say,	**760**

14.5.2. Impacts on Water Environment

A. Construction Phase

i. Sewage from Labour Camps

The peak labour strength likely to be employed during project construction phase is about 1500 workers and 500 technical staff. The employment opportunities in the area are limited. Thus, during the project construction phase, some of the locals may get employment. It has been observed during construction phase of many of the projects; the major works are contracted out, who bring their own skilled labour. However, it is only in the unskilled category, that locals get employment. The construction phase, also leads to mushrooming of various allied activities to meet the demands of the immigrant labour population in the project area. Based on experience of similar projects and above referred assumptions, the increase in the population as a result of migration of labour population during construction phase is expected to be of the order of 4,000.

The domestic water requirement has been estimated as 135 lpcd. Thus, total water requirements work out to 0.54 mld. It is assumed that about 80% of the water supplied will be generated as sewage. Thus, total quantum of sewage generated is expected to be of the order of 0.43 mld. The BOD load contributed by domestic sources will be about 180 kg/day. It is assumed that the sewage is discharged without any treatment for which, the minimum flow required for dilution of sewage is about 1.5 cumec. Detailed DO modelling was done using Streeter Phelp's model. The D.O. level was estimated using the following equation:

$$D_t = \frac{K_1 L_A \left[10^{-K1t} - 10^{-K2t}\right]}{K_2 - K_1} + D_A 10^{-K2t}$$

Dt = D.O. deficit downstream at time t.

K1 = Deoxygenation rate

K2 = Reaeration rate

LA = Ultimate upstream BOD

DA = D.O. deficit upstream

t = Time of stream flow upstream to point at which D.O. level is to be estimated

The results of D.O. model are summarized in **Table 14-3**.

Table 14-3: Results of D.O. Modelling due to disposal of sewage from labour camps in river Subansiri

Distance from outfall (km)	D.O. (mg/l)
0.1	8.0
0.2	8.0
0.3	8.0
0.4	8.1
0.5	8.1
1.0	8.2

It can be observed from Table 14-3, that no impact is anticipated on river water quality, as a result of disposal of sewage from labour camps. Even though no impact is envisaged on water quality of river Subansiri, as a result of disposal of untreated sewage, it is recommended to commission units for treatment of sewage generated from labour camps. In the proposed project, sewage is proposed to be treated, prior to disposal.

ii. Effluent from Crushers

During construction phase, at least one crusher will be commissioned at the quarry site by the contractor involved in construction activities. It is proposed only crushed material would be brought at construction site. Water is required to wash the boulders and to lower the temperature of the crushing edge. About 0.1m3 of water is required per ton of material crushed. The effluent from the crusher would contain high-suspended solids. The effluent, if disposed without treatment can lead to marginal increase in the turbidity levels in the receiving water bodies. It is proposed to treat the effluent from crushers in settling tank prior to disposal.

B. Operation Phase

The major sources of water pollution during project operation phase include:

- Effluent from project colony.
- Impacts on reservoir water quality.

i. Effluent from Project Colony

During project operation phase, due to absence of any large-scale construction activity, the cause and source of water pollution will be much different. Since, only a small number of O&M staff will reside in the area in a well-designed colony with sewage treatment plant and other infrastructure facilities, the problems of water pollution due to disposal of sewage are not anticipated.

In the operation phase, about 100 families (total population of 500) will be residing in the project colony. About 0.07 ld of sewage will be generated. The total BOD loading will be order of 22.5kg/day. It is proposed to provide biological treatment facilities including secondary treatment units for sewage so generated from the BOD load after treatment will reduce to about 2-2.5 kg/day. It shall be ensured that sewage from the project colony be treated in a sewage treatment plant so as to meet the disposal standards for effluent. Thus, with commissioning of facilities for sewage treatment, no impact on receiving water body is anticipated. Thus, no impacts are anticipated as a result of disposal of effluents from the project colony.

ii. Impacts on Reservoir Water Quality

The flooding of previously forest and agricultural land in the submergence area will increase the availability of nutrients resulting from decomposition of vegetative matter. Phytoplankton productivity can supersaturate the euphotic zone with oxygen before contributing to the accommodation of organic matter in the sediments. Enrichment of impounded water with organic and inorganic nutrients will be the main water quality problem immediately on commencement of the operation. However, this phenomenon is likely to last for a short duration of few years from the filling up of the reservoir. In the proposed project, most of the land coming under reservoir submergence is barren, with few patches of trees. These trees too are likely to be cleared before filling up of the reservoir. The proposed project is envisaged as a runoff the river scheme, with significant diurnal variations in reservoir water level. In such a scenario, significant re-aeration from natural atmosphere takes place, which maintains Dissolved Oxygen in the water body. Thus, in the proposed project, no significant reduction in D.O. level in reservoir water is anticipated.

14.5.3. Impacts on Air Environment

14.5.3.1. CONSTRUCTION PHASE:

In a water resources project, air pollution occurs mainly during project construction phase. The major sources of air pollution during construction phase are:

- Pollution due to fuel combustion in various equipment
- Emission from various crushers
- Dust emission from muck disposal

i. Pollution due to fuel combustion in various equipment

The operation of various construction equipment requires combustion of fuel. Normally, diesel is used in such equipment. The major pollutant which gets emitted as a result of combustion of diesel is SO2. The SPM emissions are minimal due to low ash content in diesel. The short-term increase in SO2, even assuming that all the equipment are operating at a common point, is quite low, i.e. of the order of less than 1µg/m3. Hence, no major impact is anticipated on this account on ambient air quality.

ii. Emissions from crushers

The operation of the crusher during the construction phase is likely to generate fugitive emissions, which can move even up to 1km in predominant wind direction. During construction phase, one crusher each is likely to be commissioned near proposed dam and proposed powerhouse sites. During crushing operations, fugitive emissions comprising mainly the suspended particulate will be generated. Since, there are no major settlements close to the dam and powerhouse, hence, no major adverse impacts on this account are anticipated. However, during the layout design, care should be taken to ensure that the labour camps, colonies, etc. are located outside the impact zone of the crushers.

iii. Dust emission from muck disposal

The loading and unloading of muck is one of the source of dust generation. Since, muck will be mainly in form of small rock pieces, stone, etc., with very little dust particles. Significant amount of dust is not expected to be generated on this account. Thus, adverse impacts due to dust generation during muck disposal are not expected.

14.5.4. Impacts on Noise Environment

14.5.4.1. CONSTRUCTION PHASE

The impacts on ambient noise levels in a hydro-electric project are expected only during the project construction phase, due to operation of construction equipment. Likewise, noise due to quarrying, blasting, vehicular movement will have some adverse impacts on the ambient noise levels in the area.

i. Impacts due to operation of construction equipment

The noise level due to operation of various construction equipment is given in **Table 14-4**.

Table 14-4: Noise level due to operation of various construction equipment

Equipment	Noise level dB(A)
Earth moving	
Compactors	70-72
Loaders and Excavator	72-82
Dumper	72-92
Tractors	76-92
Scrappers, graders	82-92
Pavers	86-88
Truck	84-94
Material handling	
Concrete mixers	75-85
Movable cranes	82-84
Stationary	
Pumps	68-70
Generators	72-82
Compressors	75-85

Under the worst-case scenario, considered for prediction of noise levels during construction phase, it has been assumed that all these equipment generate noise from a common point. The increase in noise levels due to operation of various construction equipment is given in **Table 14-5**.

Table 14-5: Increase in noise levels due to operation of various construction equipment

Distance (m)	Ambient noise levels dB(A)	Increase in noise level due to construction activities dB(A)	Increase in ambient noise level due to construction activities dB(A)
100	36	45	34
200	36	39	29
500	36	31	25
1000	36	25	25
1500	36	21	24

Distance (m)	Ambient noise levels dB(A)	Increase in noise level due to construction activities dB(A)	Increase in ambient noise level due to construction activities dB(A)
2000	36	19	24
2500	36	17	24
3000	36	15	24

It would be worthwhile to mention here that in absence of the data on actual location of various construction equipment, all the equipment have been assumed to operate at a common point. This assumption leads to over-estimation of the increase in noise levels. Also, it is a known fact that there is a reduction in noise level as the sound wave passes through a barrier. The transmission loss values for common construction materials are given in **Table 14-6**.

Table 14-6: Transmission loss for common construction materials

Material	Thickness of construction material (inches)	Decrease in noise level dB(A)
Light concrete	4	38
	6	39
Dense concrete	4	40
Concrete block	4	32
	6	36
Brick	4	33
Granite	4	40

In addition there are attenuation due to the following factors.

- Air absorption
- Rain
- Atmospheric inhomogeneities.
- Vegetal cover

Thus, no increase in noise levels is anticipated as a result of various activities, during the project construction phase. The noise generated due to blasting is not likely to have any effect on habitations. However, blasting can have adverse impact on wildlife, especially along the alignment of the tunnel portion. It would be worthwhile to mention that no major wildlife is observed in and around the project site. Hence, no significant impact is expected on this account.

ii. Impacts on Labour

The effect of high noise levels on the operating personnel, has to be considered as this may be particularly harmful. It is known that continuous exposures to high noise levels above 90 dB(A) affects the hearing acuity of the workers/operators and hence, should be avoided. To prevent these effects, it has been recommended by Occupational Safety and Health Administration (OSHA) that the exposure period of affected persons be limited as per the maximum exposure period specified in Table 14-7.

Table 14-7: Maximum Exposure Periods specified by OSHA

Maximum equivalent continuous Noise level dB(A)	Unprotected exposure period per day for 8 hrs/day and 5 days/week
90	8
95	4
100	2
105	1
110	½
115	¼
120	No exposure permitted at or above this level

14.5.5. Impacts on Biological Environment

14.5.5.1. IMPACTS ON TERRESTRIAL FLORA

Construction Phase

i. Increased Human Interferences

The direct impact of construction activity of any water resource project in a Himalayan terrain is generally limited in the vicinity of the construction sites only. As mentioned earlier, a large population (4,000) including technical staff, workers and other group of people are likely to congregate in the area during the project construction phase. It can be assumed that the technical staff will be of higher economic status and will live in a more urbanized habitat, and will not use wood as fuel, if adequate alternate sources of fuel are provided. However, workers and other population groups residing in the area may use fuel wood, if no alternate fuel is provided for whom alternate fuel could be provided. There will be an increase in population by about 4,000 of which about 3,2000 are likely to use fuel wood. On an average, the fuel wood requirements will be of the order of 1,200m3. The wood generated by cutting tree is about 2 to 3m3. Thus every year fuel wood equivalent to about 500-600 trees will be cut, for meeting fuel wood requirements, if no alternate sources of fuel are provided. Hence to minimize impacts, community kitchens have been recommended. These community kitchens shall use LPG or diesel as fuel.

ii. Impacts due to Vehicular movement and blasting

Dust is expected to be generated during blasting, vehicle movement for transportation of construction material or construction waste. The dust particles shall settle on the foliage of trees and plants, thereby reduction in amount of sunlight falling on tree foliage. This will reduce the photosynthetic activity. Based on experience in similar settings, the impact is expected to be localized upto a maximum of 50 to 100m from the source. In addition, the area experiences rainfall for almost 8 to 9 months in a year. Thus, minimal deposition of dust is expected on flora. Thus, no significant impact is expected on this account.

iii. Acquisition of forest land

During project construction phase, land will be required for location of construction equipment, storage of construction material, muck disposal, widening of existing roads and construction of new project roads. The total land requirement for the project is 760 ha, a part of which could be forest land. No rare and endangered species are observed in the forest to be acquired for the project.

Operation Phase

i. Increased accessibility

During the project operation phase, the accessibility to the area will improve due to construction of roads, which in turn may increase human interferences leading to marginal adverse impacts on the terrestrial ecosystem. The increased accessibility to the area can lead to increased human interferences in the form of illegal logging, lopping of trees, collection of non-timber forest produce, etc. Based on the experience in similar projects, no major adverse impacts during operation phase on this account are anticipated.

14.5.5.2. IMPACTS ON TERRESTRIAL FAUNA

Construction Phase

i. Disturbance to Wildlife

Based on the field studies and interaction with locals, it was confirmed that no major wildlife is reported in the proposed submergence area. It would be worthwhile to mention here that most of the total submergence of 34.3 ha lies within the gorge portion. Thus, creation of a reservoir due to the proposed project is not expected to cause any significant adverse impact on wildlife movement. The project area and its surroundings are not reported to serve as habitat for wildlife nor do they lie on any known migratory route. Thus, no impacts are anticipated on this account.

During the construction period, large number of machinery and construction workers shall be mobilized, which may create disturbance to wildlife population in the vicinity of project area. The operation of various equipment will generate significant noise, especially during blasting which will have adverse impact on fauna of the area. The noise may scare the fauna and force them to migrate to other areas. Likewise siting of construction plants, workshops, stores, labour camps etc. could also lead to adverse impact on fauna of the area.

ii. Impacts due to Increased Human Interferences

During the construction phase, accessibility to area will lead to influx of workers and the people associated with the allied activities from outside will also increase. Increase in human interference could have an impact on terrestrial ecosystem. Thus, it is necessary to implement strict surveillance system in the project area during construction phase.

iii. Impacts due to Siting of Construction Equipment

Siting of construction equipment, godowns, stores, labour camps, etc. may generally disturb the fauna in the area. However, as per the present level of investigations, no large-scale fauna is observed in the area. Thus, impacts on this account are not expected to be significant. However, few stray animals sometimes venture in and around the project site. Thus, to minimize any harm due to poaching activities from immigrant labour population, strict anti-poaching surveillance measures shall be implemented, during project construction phase. The same have been suggested as a part of the Environmental Management Plan (EMP).

Operation Phase

i. Increased accessibility

During the project operation phase, the accessibility to the area will improve due to construction of roads, which in turn may increase human interferences leading to marginal adverse impacts on the terrestrial ecosystem. The increased accessibility can adversely affect the wildlife in the area. Since significant wildlife population is not found in the region, adverse impacts of such interferences are likely to be marginal.

14.5.5.3. IMPACT ON AQUATIC FLORA

Construction Phase

During construction phase wastewater mostly from domestic source will be discharged mostly from various camps of workers actively engaged in the project area. Sufficient water for dilution will be available in river Subansiri to keep the DO of the river to significantly high levels.

Operation Phase

The completion of the proposed hydroelectric project would bring about significant changes in the riverine ecology, as the river transforms from a fast-flowing water system to a quiescent lacustrine environment. Such an alteration of the habitat would bring changes in physical, chemical and biotic life. Among the biotic communities, certain species can survive the transitional phase and can adapt to the changed riverine habitat. There are other species amongst the biotic communities, which, however, for varied reasons related to feeding and reproductive characteristics cannot acclimatize to the changed environment, and may disappear in the early years of impoundment of water. The micro-biotic organisms especially diatoms, blue-green and green algae before the operation of project, have their habitats beneath boulders, stones, fallen logs along the river, where depth is such that light penetration can take place. But with the damming of river, these organisms may perish as a result of increase in depth.

14.5.5.4. IMPACTS DUE TO DAMMING OF RIVER

The damming of river Subansiri due to the proposed hydroelectric project in creation of 34.3 ha of submergence area. The dam will change the fast flowing river to a quiescent lacustrine environment. The creation of a pond will bring about a number of alterations in physical, abiotic and biotic parameters both in upstream and downstream directions of the proposed barrage site. The micro and macro benthic biota is likely to be most severely affected as a result of the proposed project.

The reduction in flow rate of river Subansiri, especially during lean period is likely to increase turbidity levels downstream of the dam. Further reduction in rate of flow would result in adverse impacts on riverine ecology. Environmental Flows will be released to sustain riverine ecology. In addition, the Environmental Flow will be supplemented by contributions from perennial streams joins the intermediate catchment between dam and powerhouse

14.5.5.5. IMPACTS ON MIGRATORY FISH SPECIES

The obstruction created by the dam would hinder migration of species Schizothorax sp. (from upper reaches to the lower reaches). These fishes undertake annual migration for feeding and breeding. Therefore, fish migration path will be obstructed due to high dam and fishes are expected to congregate below the dam wall. It is also proposed that the artificial seed production in hatchery may be adopted which can be stocked in the river stretches downstream and upstream of the proposed barrage.

14.5.6. Impacts on Socio-Economic Environment

A project of this magnitude is likely to entail both positive as well as negative impacts on the socio-cultural fabric of the area. During construction and operation phases, a lot of allied activities will mushroom in the project area.

14.5.6.1. IMPACTS DUE TO INFLUX OF LABOUR FORCE

During the construction phase a large labour force, including skilled, semi-skilled and un-skilled labour force of the order of about 4000 persons (including family members, is expected to immigrate into the project area. It is felt that most of the labour force would come from other parts of the country. However, some of the locals would also be employed to work in the project. The labour force would stay near to the project construction sites.

The project will also lead to certain negative impacts. The most important negative impact would be during the construction phase. The labour force that would work in the construction site would settle around the site. They would temporarily reside there. This may lead to filth, in terms of domestic wastewater, human waste, etc. Besides, other deleterious impacts are likely to emerge due to inter-mixing of the local communities with the labour force. Differences in social, cultural and economic conditions among the locals and labour force could also lead to friction between the migrant labour population and the local population.

14.5.6.2. ECONOMIC IMPACTS OF THE PROJECT

Apart from direct employment, the opportunities for indirect employment will also be generated which would provide great impetus to the economy of the local area. Various types of business like shops, food-stall, tea stalls, etc. besides a variety of suppliers, traders, transporters will concentrate here and benefit immensely as demand will increase significantly for almost all types of goods and services. The business community as a whole will be benefited. The locals will avail these opportunities arising from the project and increase their income levels. With the increase in the income levels, there will be an improvement in the infrastructure facilities in the area.

14.5.6.3. IMPACTS DUE TO LAND ACQUISITION

Another most important deleterious impact during construction phase will be that, pertaining to land acquisition. About 760 ha of land proposed to be acquired for the proposed Oju Hydroelectric Project. As a part of which could be private land. Based on the present level of investigations, the ownership status of land to be acquired for the project is not known.

As a part of CEIA study, the quantum of private land to be acquired shall be identified. Subsequently, the number of families likely to lose land or homestead or both shall also be identified. It is worthwhile to mention, that population density is very low in the project area. Hence, number of PAFs would be quite less.

A socio-economic survey for the Project Affected Families (PAFs) shall be conducted. Based on the findings of the survey an appropriate Resettlement and Rehabilitation Plan will be formulated.

14.6. Environmental Management Plan

Based on the environmental baseline conditions and project inputs, the adverse impacts will be identified and a set of measures will be suggested as a part of Environmental Management Plan (EMP) for their amelioration. An outline of various measures suggested as a part of Environmental Management Plan is briefly described in the following sections.

14.6.1. Environmental Measures during Construction Phase

14.6.1.1. FACILITIES IN LABOUR CAMPS

It is recommended that project authorities can compulsorily ask the contractor to make semi-permanent structures for their workers. These structures could be tin sheds. These sheds can have internal compartments allotted to each worker family. The sheds will have electricity and ventilation system, water supply and community latrines.

The water for meeting domestic requirements may be collected from the rivers or streams flowing upstream of the labour camps.

14.6.1.2. SANITATION FACILITIES

One community toilet can be provided per 20 persons. The sewage from the community latrines can be treated in a sewage treatment plant before disposal.

14.6.1.3. SOLID WASTE MANAGEMENT FROM LABOUR CAMPS

For solid waste collection, suitable number of masonry storage vats, each of 2m3 capacity should be constructed at appropriate locations in various labour camps. These vats should be emptied at regular intervals and should be disposed at identified landfill sites. Suitable solid waste collection and disposal arrangement shall be provided. A suitable landfill site should be identified and designed to contain municipal waste from various project township, labour colonies, etc.

14.6.1.4. PROVISION OF FREE FUEL

During the construction period of the project, there would be around 2000 labour and technical staff would be involved in the project construction work. Many families may prefer cooking on their own instead of using community kitchen. In the absence of fuel for cooking, they would resort to tree cutting and using wood as fuel. To avoid such a situation, the project authority should make LPG and/ or kerosene available to these migrant workers.

The supply of LPG and kerosene can be ensured on regular basis. A local depot can be established through LPG/ kerosene suppliers for supply of the same.

14.6.2. Muck Disposal

A part of the muck generated, is proposed to be utilised for construction works after crushing it into the coarse and fine aggregates. The balance quantum of muck would have to be disposed. The muck shall be disposed at designated muck disposal sites, i.e. with an area of 105 ha. As suggested by MoEF, muck disposal sites shall be located at a minimum distance of 30m from HFL. The sites shall then be stabilized by implementing bioengineering treatment measures.

In the hilly area, dumping is done after creating terraces thus usable terraces are developed. The overall idea is to enhance/maintain aesthetic view in the surrounding area of the project in post-construction period and avoid contamination of any land or water resource due to muck disposal.

Suitable retaining walls shall be constructed to develop terraces so as to support the muck on vertical slope and for optimum space utilization. Loose muck would be compacted layer wise. The muck disposal area will be developed in a series of terraces of boulder crate wall and masonry wall to protect the area/muck from flood water during monsoons. In-between the terraces, catch water drain will be provided.

The terraces of the muck disposal area will be ultimately covered with fertile soil and suitable plants will be planted adopting suitable bio-technological measures. Various activities proposed as a part of the management plan are given as below:

- Land acquisition for muck dumping sites.
- Civil works (construction of retaining walls, boulder crate walls etc.)
- Dumping of muck.
- Levelling of the area, terracing, and implementation of various engineering control measures e.g., boulder, crate wall, masonry wall, catch water drain.
- Spreading of soil
- Application of fertilizers to facilitate vegetation growth over disposal sites.

For stabilization of muck dumping areas following measures of engineering and biological measures have been proposed

Engineering Measures

- Wire crate wall
- Boulder crate wall
- Retaining wall
- Catch water Drain

Biological Measures

- Plantation of suitable tree species and soil binding species
- Plantation of ornamental plants
- Barbed wire fencing

14.6.3. Restoration Plan for Quarry Sites

Based on the present level of investigations, three quarry sites with total area of 100 ha have been identified. The following biological and engineering measures are suggested for the restoration of quarry site:

- Garland drains around quarry site to capture the runoff and divert the same to the nearest natural drain.
- Construction of concrete guards check the soil erosion of the area.
- The pit formed after excavation be filled with small rocks, sand, and farmyard manure.
- Grass slabs will be placed to stabilized and to check the surface runoff of water and loose soil.

- Bench terracing of quarry sites once extraction of construction material is completed.

14.6.4. Restoration and Landscaping of Project Sites

The working area of dam site, powerhouse complex colony area have been selected for beautification of the project area after construction is over. The reservoir created due to the construction of barrage may be a local point of tourist attraction. This could be used for sport fishing, so there is a need to construction of benches for sitting, development of resting sheds and footpath. The beautification would be carried out by developing flowering beds for plantation ornamental plant and flower garden.

There would be sufficient open space in powerhouse complex and colony area. Forested area in the powerhouse complex would provide aesthetic view and add to natural seismic beauty. The beautification in the colony area would be carried out by development of flowering beds for plantation of ornamental plant, creepers, flower garden and a small park, construction of benches for sitting, resting sheds, walk way and fountain.

14.6.5. Compensation for Acquisition of Forest Land

Based on the ownership status of land to be acquired, it is proposed to afforest twice the forest area being acquired for the project. The species for afforestation shall be selected in consultation with local forest department. In addition, the project proponents will also provide additional compensation on account of cost of trees and NPV of forests, as decided by the Forest Department.

14.6.6. Wildlife Conservation

It is recommended to commission check posts along few sites, i.e. barrage site, powerhouse site, labour camps, construction material storage site etc. during project construction phase. Each check post will have 4 guards. One Range Officer would be employed to supervise the operation of these check-posts and ensure that poaching does not become a common phenomenon in the area. These check posts also will also be provided with appropriate communication facilities and other infrastructure as well.

14.6.7. Greenbelt Development

Although the forest loss due to reservoir submergence and other project appurtenances have been compensated as a part of compensatory afforestation, it is proposed to develop greenbelt around the periphery of various project appurtenances, selected stretches along reservoir periphery.

The green belt on either side of the reservoir will reduce the sedimentation and ensure protection of the reservoir area from any other human activity that could result in the reservoir catchment damage. On moderately steep slopes tree species will be planted for creation of green belt which are indigenous, economically important, soil binding in nature and an thrive well under high humidity and flood conditions. In addition greenbelt is recommend around permanent colony for the project.

14.6.8. Sustenance of Riverine Fisheries

i. Release of Minimum Flow

It is recommended to maintain a minimum flow to ensure survival and propagation of invertebrates and fish. Based on the current norms of MoEF, at this stage, minimum environmental flow releases have been proposed as 20% of average of four months of lean period and 25% of flow during non-lean non-monsoon period corresponding to 90% Dependable year. The cumulative flow releases including spillage during monsoon period has been proposed as 30% of the cumulative inflows during the monsoon period corresponding to 90% dependable year. However, The exact quantum of environmental flow during monsoon, non-lean non-monsoon and lean months would be arrived at based on the site specific study to be carried out as a part of EIA and as per recommendations of Basin Study For Subansiri being got carried out by the CWC/MoEF.

In addition, there are numerous perennial streams joining the main river between the dam and powerhouse at regular intervals. These streams will significantly augment the environmental flows in the intermediate river stretch.

Table 14-8: Streams Joining Subansiri River between Oju Dam & Powerhouse

Location	Notation	Name of the stream nallah	Catchment area (sq km)	Max elevation (m)
Streams joining **Left Side** to Main Stream Of Subansiri	**L 1**	Dio Siko - Oyi Siko	73.00	5063
	L 2	Rijugna Siko	10.14	4365
	L 3	Niyonthi Siko	7.40	4264
	L 4		5.86	3802
	L 5		3.87	3509
	L 6		3.41	3527
Streams joining **Right Side** to Main Stream Of Subansiri	**R 1**	Chetu Suko	17.51	4391
	R 2	Doju Bung Nalla	16.98	4389
	R 3	Oju Siko	41.77	4870
	R 4	Yang Siko	3.52	3486
Subansiri Catchment Area Between Dam and Powerhouse			**222.79**	

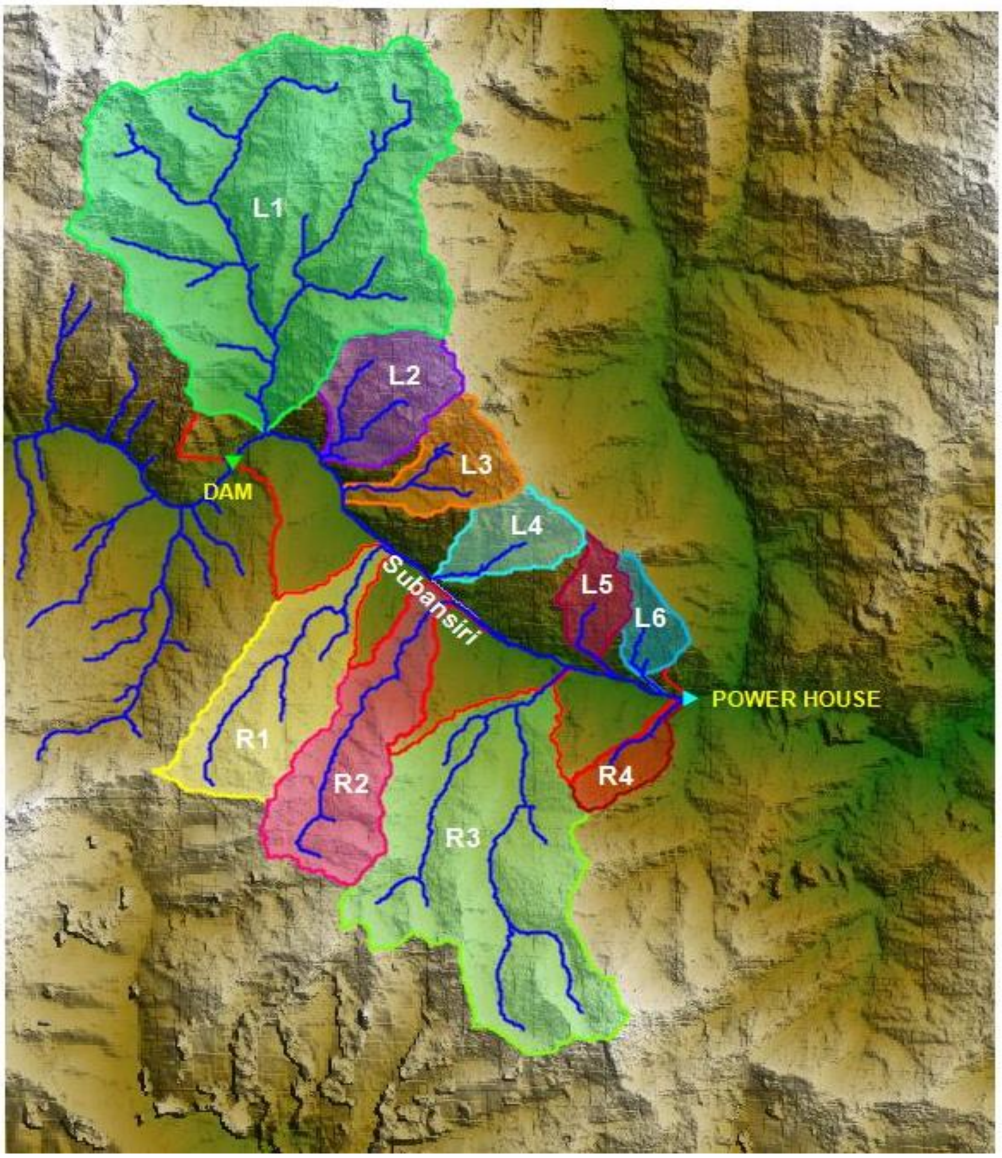


Figure 14-1: Streams Joining Subansiri River between Oju Dam & Powerhouse

However, the exact amount of riparian flows would be worked out during EIA studies on approval of power potential studies.

ii. Sustenance of Endemic Fisheries

It is proposed to implement supplementary stocking programmes for the project area. It is proposed to stock reservoir, river Subansiri upstream and the downstream sides. The stocking will be done for a stretch of 10km on the upstream and downstream sides of dam site. The stocking can be done annually by the Fisheries Department, Arunachal Pradesh. To achieve this objective, facilities to produce seed of trout need to be developed at suitable sites.

14.6.9. Public Health Delivery System

The suggested measures are given in following paragraphs:

- The site selected for habitation of workers shall not be in the path of natural drainage.
- Adequate drainage system to dispose storm water drainage from the labour colonies shall be provided.
- Adequate vaccination and immunization facilities shall be provided for workers at the construction site.
- The labour camps and resettlement sites shall be away from a main water body or quarry areas.

As a part of Health Delivery System, following measures shall be implemented:

Clearing of river basins, shoreline, mats and floating debris, etc. to reduce the proliferation of mosquitoes.

Development of medical facilities in the project area and near labour camps

14.6.9.1. INFRASTRUCTURE

Dispensary: Considering the number of rooms, staff quarters and open space etc., it is estimated that 10,000 sq. feet of plot will be required for dispensary

First Aid Posts: Temporary first aid posts shall be provided at major construction sites. These will be constructed with asbestos sheets, bamboo, etc.

14.6.10. Maintenance of Water Quality

The sewage generated from the labour camps, as mentioned earlier, is proposed to be treated in sewage treatment plant prior to disposal. In the project operation phase, a plant colony with about 50 quarters is likely to be set up. The sewage so generated would be treated through a sewage treatment plant, equipped with secondary treatment units.

14.6.11. Control of Noise

The suggested measures are given in following paragraphs:

- contractors will be required to maintain properly functioning equipment and comply with occupational safety and health standards.
- construction equipment will be required to use available noise suppression devices and properly maintained mufflers vehicles to be equipped with mufflers recommended by the vehicle manufacturer.
- staging of construction equipment and unnecessary idling of equipment within noise sensitive areas to be avoided whenever possible.

- use of temporary sound fences or barriers to be evaluated.
- monitoring of noise levels will be conducted during the construction phase of the project. In case of exceeding of pre-determined acceptable noise levels by the machinery will require the contractor(s) to stop work and remedy the situation prior to continuing construction.

14.6.12. Control of Air Pollution

Minor air quality impacts will be caused by emissions from construction vehicles, equipment and DG sets, and emissions from transportation traffic. Frequent truck trips will be required during the construction period for removal of excavated material and delivery of select concrete and other equipment and materials. The following measures are recommended to control air pollution:

- Contractor will be responsible for maintaining properly functioning construction equipment to minimize exhaust.
- Construction equipment and vehicles will be turned off when not used for extended periods of time.
- Unnecessary idling of construction vehicles to be prohibited.
- Effective traffic management to be undertaken to avoid significant delays in and around the project area.
- Road damage caused by sub-project activities will be promptly attended to with proper road repair and maintenance work. An amount of Rs. 2.0 million has been earmarked for this purpose.

14.6.12.1. DUST CONTROL

To minimize issues related to the generation of dust during the construction phase of the project, the following measures have been identified:

- Identification of construction limits (minimal area required for construction activities).
- When practical, excavated spoils will be removed as the contractor proceeds along the length of the activity.
- When necessary, stockpiling of excavated material will be covered or staged offsite location with muck being delivered as needed during the course of construction.
- Excessive soil on paved areas will be sprayed (wet) and/or swept and unpaved areas will be sprayed and/or mulched. The use of petroleum products or similar products for such activities will be strictly prohibited.
- Contractors will be required to cover stockpiled soils and trucks hauling soil, sand, and other loose materials (or require trucks to maintain at least two feet of freeboard).

- Contractor shall ensure that there is effective traffic management at site. The number of trucks/vehicles to move at various construction sites to be fixed.

- Dust sweeping - The construction area and vicinity (access roads and working areas) shall be swept with water sweepers on a daily basis or as necessary to ensure there is no visible dust.

14.7. Resettlement and Rehabilitation Plan

About 760 ha of land is to be acquired for various project appurtenances. Based on the present level of investigations, quantum of private land to be acquire, the number of project affected families is not available. The number of families likely to lose land will be finalized as a part of the CEIA study. In addition, information of any family losing homestead or other private properties shall also be ascertained. Socio-economic survey for the Project Affected Families (PAFs) will be conducted. Based on the findings of the survey an appropriate Resettlement and Rehabilitation Plan will be formulated as per the norms and guidelines of as per the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013,

14.8. Catchment Area Treatment

The following aspects are proposed as a part of the Catchment Area Treatment Plan shall be prepared as a part of the EIA study:

- Delineation of micro-watersheds in the river catchment and mapping of critically degraded areas requiring various biological and engineering treatment measures.

- Identification of area for treatment based upon Remote Sensing & GIS methodology and Silt Yield Index (SYI) method of AISLUS coupled with ground survey.

- Prioritization of watershed for treatment based upon SYI.

- Spatial Information in each micro watershed to be earmarked on maps.

- CAT plan would be prepared with year-wise Physical and financial details.

14.9. Infrastructure Development under Local Area Development Committee (LADC)

A lump-sum budget @0.5% of the Project Cost has been proposed for construction of Infrastructure and Local Area Development Committee works. The activities envisaged are given as below:

- Education Facilities

- Strengthening of existing PHSCs/ Health Care Facilities
- Bus Stops
- Approach Roads and Widening of Existing Road
- Infrastructure and Community Development
- Drinking Water Supply and Restoration of Dried Up Sources
- Miscellaneous activities

14.10. Environmental Monitoring Programme

The Environmental Impact Assessment is basically an evaluation of future events. It is necessary to continue monitoring certain parameters identified as critical by relevant authorities under an Environmental Monitoring Programme. This would anticipate any environmental problem so as to take effective mitigation measures. An Environmental Monitoring Programme will be formulated for implementation during project construction and operation phases. The cost estimates and equipment necessary for the implementation of this programme shall also be covered as a part of the Comprehensive EIA study.

The Environmental monitoring programme for implementation during construction and operation phases is given in **Table 14-9** and **Table 14-10** respectively.

Table 14-9: Summary of Environmental Monitoring Programme during Project Construction Phase

S.no	Item	Parameters	Frequency	Location
1	Effluent from septic tanks	pH, BOD, COD, TSS, TDS	Once every month	Before and after treatment from Sewage Treatment plant
2	Water-related diseases	Identification of water related diseases, adequacy of local vector control and curative measure, etc.	Three times a year	Labour camps and colonies
3	Noise	Equivalent noise level (L_{eq})	Once in three months	At major construction sites.
4	Air quality	PM_{10} SO_2 and NO_2	Once every season	At major construction sites

Table 14-10: Summary of Environmental Monitoring Programme during Project Operation Phase

S.no	Items	Parameters	Frequency	Location
1	Water	pH, Temperature, EC, Turbidity, Total Dissolved Solids, Calcium, Magnesium, Total Hardness, Chlorides, Sulphates, Nitrates, DO. COD, BOD, Iron, Zinc, Manganese	Thrice a year	• 1km upstream of dam site • Reservoir area • 1, 5 and 10km downstream of Tailrace discharge
2	Effluent from Sewage Treatment Plant (STP)	pH, BOD, COD, TSS, TDS	Once every week	Before and after treatment from Sewage Treatment Plant (STP)
3	Erosion & Siltation	Soil erosion rates, stability of bank embankment, etc.	Twice a year	-
4	Ecology	Status of afforestation programmes of green belt development	Once in 2 years	-
5	Water-related diseases	Identification of water-related diseases, sites, adequacy of local vector control measures, etc.	Three times a year	Villages adjacent to project sites
6	Aquatic ecology	Phytoplanktons, zooplanktons, benthic life, fish composition	Once a year	• 1km upstream of dam site • Reservoir area • 1, 5 and 10km downstream of Tailrace discharge
7	Land use	Land use pattern using satellite data	Once in a year	Catchment area
8.	Soil	pH, EC, texture, organic matter	Once in a year	Catchment area

14.11. Conclusions

Based on the preliminary assessment of environmental issues considered in the present Chapter, it can be concluded that the project is likely to entail certain adverse environmental impacts. However, these can be ameliorated to a large extent by implementing appropriate mitigative measures. Presently, a detailed EIA study is being conducted with an objective to assess various impacts likely to accrue as a result of construction and operation of the proposed project. Appropriate management measures too shall be delineated as a part of Environmental Management Plan (EMP), which will be covered as a part of the CEIA study.

ANNEXURES

10-DAILY FLOW SERIES AT OJU DIVERSION INTAKE

										90% DY																				50% DY						
Months		No. of days	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Jun	I	10	424.59	583.81	440.10	546.56	995.48	364.71	139.84	272.06	290.13	358.87	585.82	398.01	934.00	357.74	295.80	271.08	458.88	570.32	179.12	446.26	681.42	522.70	624.28	524.16	545.26	646.98	529.97	644.84	543.82	820.62	591.67	925.73	884.43	640.62
	II	10	828.27	816.58	408.18	872.17	834.07	523.81	372.36	292.30	291.94	631.67	674.06	802.32	848.60	590.43	559.61	389.73	723.84	842.19	160.29	282.10	437.89	766.34	441.59	864.92	620.18	677.22	715.73	454.59	953.06	1039.60	682.18	1089.11	934.14	1038.32
	III	10	856.40	350.73	899.41	746.38	709.14	912.79	747.80	294.30	487.09	803.23	943.21	529.93	894.03	1063.05	648.65	390.29	636.38	797.05	277.61	340.07	502.34	983.98	779.41	577.77	1169.26	1302.18	867.43	760.08	1418.90	1355.47	842.17	886.32	1098.67	800.11
Jul	I	10	428.39	850.36	985.49	949.16	713.51	701.88	868.74	255.32	725.67	959.41	903.20	793.36	1102.48	671.40	1016.43	916.64	857.59	1458.05	271.88	524.26	653.55	1261.36	1057.12	868.04	1174.15	1090.62	851.27	444.35	1631.46	1410.37	680.65	844.84	692.10	848.63
	II	10	325.92	976.89	1034.02	964.69	677.48	560.19	695.67	473.33	863.46	764.74	562.58	809.14	1285.70	757.05	866.03	494.00	848.30	1061.02	434.66	521.66	320.75	1008.93	1321.64	756.14	1032.92	953.07	1375.58	783.11	1463.02	1559.73	1098.47	900.92	914.15	1003.36
	III	11	853.11	793.41	1134.76	472.09	754.59	637.40	809.99	331.46	606.68	1259.13	762.49	963.05	1010.40	673.57	1111.30	774.51	734.62	597.23	291.43	852.87	363.59	695.06	854.29	340.93	913.08	853.80	675.23	870.21	948.66	1008.22	818.02	767.20	2205.50	1214.79
Aug	I	10	1176.67	789.74	679.24	555.74	628.17	783.67	717.81	813.26	412.89	383.07	285.02	393.67	444.78	549.90	977.15	507.58	565.22	1139.60	465.57	965.02	227.78	482.27	650.37	391.06	998.15	468.71	893.22	1251.63	825.42	954.84	1141.87	357.43	804.82	582.05
	II	10	469.67	450.68	425.05	720.77	649.97	744.49	731.90	629.84	359.71	546.74	710.26	739.21	519.28	896.17	880.97	637.25	820.06	723.22	324.58	566.88	233.98	626.52	402.56	765.65	470.71	841.43	945.04	585.73	1368.98	423.11	328.98	640.01	1260.96	1328.42
	III	11	303.66	876.55	501.81	836.69	979.49	257.72	767.83	792.75	474.82	463.63	503.78	323.83	636.50	733.47	692.84	1242.66	581.22	632.63	535.84	816.76	235.62	622.45	608.37	315.85	1134.58	1071.18	920.68	827.86	1092.23	758.29	1521.45	705.96	608.59	1053.28
Sep	I	10	316.57	717.66	1127.46	620.33	647.88	235.25	912.49	721.13	423.55	304.79	463.23	474.49	997.63	502.24	1230.09	950.13	810.76	798.28	448.91	705.81	217.77	553.66	514.87	450.23	1078.28	1068.76	934.80	1381.60	1322.41	969.43	709.51	373.66	1153.18	1068.24
	II	10	693.86	856.46	729.30	646.94	649.97	744.49	731.90	629.84	359.71	546.74	710.26	739.21	519.28	896.17	880.97	637.25	820.06	723.22	324.58	566.88	233.98	626.52	402.56	765.65	470.71	841.43	945.04	585.73	1368.98	423.11	328.98	640.01	1260.96	434.08
	III	10	415.44	745.32	552.80	602.45	793.28	593.71	509.46	735.30	304.48	409.53	669.86	565.85	684.63	435.69	897.41	507.24	807.69	1070.72	250.47	595.55	182.68	902.03	392.46	611.78	596.18	473.07	744.06	400.18	954.24	642.22	560.19	311.59	334.42	353.15
Oct	I	10	374.51	607.86	637.92	502.16	571.51	436.48	454.21	347.83	349.24	250.50	236.66	437.52	460.31	431.91	600.07	505.47	706.80	600.55	280.45	417.87	214.80	587.71	382.08	387.69	295.11	581.44	415.03	490.37	1032.61	812.84	491.05	468.46	511.22	364.69
	II	10	456.76	404.69	542.68	400.49	434.06	337.51	520.66	192.07	205.79	182.13	330.15	422.99	279.57	395.35	347.22	323.64	564.33	593.34	298.60	229.21	234.05	389.85	244.80	271.47	330.27	620.29	351.17	389.46	522.57	591.17	296.49	324.91	584.05	313.93
	III	11	1088.01	487.42	366.03	269.33	244.08	158.47	370.24	198.62	141.18	176.01	238.72	328.92	239.12	196.60	284.59	267.49	290.84	365.34	542.48	163.04	234.72	308.37	195.14	179.53	456.56	440.56	260.90	226.14	439.70	313.26	382.90	258.50	298.74	423.09
Nov	I	10	142.54	158.46	161.53	150.77	162.87	125.46	141.21	110.95	100.27	127.22	135.65	141.64	171.67	138.92	171.49	140.10	158.56	189.77	87.30	126.74	88.21	167.00	147.92	129.00	174.70	187.51	181.62	159.00	232.59	177.47	202.94	175.96	194.11	182.13
	II	10	112.16	124.69	127.11	118.64	128.16	98.72	111.12	87.30	78.90	100.11	106.74	111.46	135.09	109.31	134.94	110.24	124.77	149.33	68.69	99.73	69.41	131.41	116.40	101.51	137.47	147.55	142.92	125.11	175.57	145.18	161.88	127.57	163.37	143.32
	III	10	92.95	103.33	105.33	98.31	106.21	81.81	92.08	72.35	65.38	82.96	88.46	92.36	111.95	90.59	111.82	91.36	103.39	123.75	56.92	82.64	57.52	108.90	96.46	84.12	113.92	122.28	118.43	103.68	148.47	111.72	136.21	122.65	122.00	118.77
Dec	I	10	73.37	81.57	83.15	77.61	83.84	64.58	72.69	57.11	51.61	65.49	69.83	72.91	88.37	71.51	88.27	72.12	81.62	97.69	44.94	65.24	45.41	85.96	76.14	66.40	89.93	96.52	93.49	81.84	114.53	90.28	100.43	99.31	101.49	93.75
	II	10	63.03	70.07	71.43	66.67	72.02	55.47	62.44	49.06	44.34	56.26	59.98	62.63	75.91	61.43	75.83	61.95	70.11	83.91	38.60	56.04	39.01	73.84	65.41	57.04	77.25	82.92	80.31	70.31	96.04	82.10	83.94	90.48	82.15	80.54
	III	11	67.32	74.84	76.29	71.21	76.92	59.25	66.69	52.40	47.36	60.09	64.07	66.90	81.08	65.61	80.99	66.17	74.89	89.63	41.23	59.86	41.66	78.87	69.86	60.93	82.51	88.56	85.78	75.09	83.78	94.38	80.45	82.09	81.39	86.02
Jan	I	10	55.23	61.41	62.59	58.42	63.11	48.61	54.72	42.99	38.85	49.30	52.57	54.89	66.52	53.83	66.45	54.29	61.44	73.54	33.83	49.11	34.18	64.71	57.32	49.99	67.70	72.66	70.38	61.61	69.76	80.44	72.39	75.71	82.66	70.58
	II	10	54.61	60.72	61.89	57.77	62.41	48.07	54.11	42.51	38.42	48.75	51.98	54.27	65.78	53.23	65.71	53.68	60.75	72.71	33.45	48.56	33.80	63.99	56.68	49.43	66.94	71.85	69.59	60.92	67.27	81.46	67.25	72.94	87.75	69.79
	III	11	58.27	64.78	66.03	61.63	66.58	51.28	57.72	45.35	40.99	52.00	55.45	57.90	70.18	56.79	70.10	57.27	64.82	77.57	35.68	51.81	36.06	68.26	60.47	52.73	71.41	76.65	74.24	64.99	69.23	74.76	65.48	66.96	88.39	74.45
Feb	I	10	55.12	61.28	62.47	58.31	62.98	48.52	54.61	42.91	38.78	49.20	52.46	54.78	66.39	53.72	66.32	54.18	61.32	73.39	33.76	49.01	34.11	64.58	57.20	49.89	67.56	72.51	70.24	61.49	75.73	75.23	63.39	85.44	80.37	70.43
	II	10	65.77	73.12	74.53	69.57	75.15	57.89	65.16	51.19	46.26	58.70	62.59	65.36	79.21	64.10	79.13	64.64	73.16	87.56	40.28	58.48	40.70	77.05	68.25	59.52	80.61	86.52	83.80	73.36	67.30	111.72	67.95	110.27	96.36	84.04
	III	8	61.26	68.10	69.42	64.80	70.00	53.92	60.69	47.68	43.09	54.68	58.30	60.88	73.78	59.70	73.70	60.21	68.15	81.56	37.52	54.47	37.91	71.77	63.57	55.44	75.08	80.59	78.06	68.33	74.02	119.55	158.55	82.24	75.60	78.28
Mar	I	10	71.47	79.45	80.99	75.60	81.66	62.90	70.80	55.63	50.28	63.79	68.02	71.02	86.08	69.65	85.99	70.25	79.50	95.15	43.77	63.55	44.23	83.73	74.17	64.68	87.60	94.02	91.07	79.72	105.25	137.49	105.43	102.57	75.51	91.32
	II	10	131.13	145.78	148.60	138.70	149.84	115.42	129.91	102.07	92.24	117.04	124.80	130.31	157.94	127.80	157.76	128.89	145.87	174.59	80.31	116.59	81.15	153.63	136.09	118.68	160.72	172.51	167.09	146.27	371.36	184.02	158.69	95.22	95.12	167.56
	III	11	210.19	233.67	238.19	222.32	240.17	185.00	208.23	163.60	147.86	187.60	200.04	208.87	253.15	204.85	252.88	206.59	233.81	279.84	128.73	186.89	130.08	246.25	218.13	190.22	257.61	276.51	267.82	234.46	607.71	255.37	105.47	124.54	224.75	268.57
Apr	I	10	156.66	174.16	177.53	165.70	179.00	137.88	155.20	121.94	110.20	139.82	149.09	155.67	188.68	152.68	188.47	153.98	174.27	208.57	95.94	139.29	96.95	183.54	162.58	141.78	192.00	206.09	199.61	174.75	150.71	279.00	141.21	366.67	142.86	200.17
	II	10	182.85	203.28	207.22	193.41	208.94	160.94	181.15	142.33	128.63	163.20	174.02	181.71	220.23	178.21	219.99	179.72	203.40	243.44	111.99	162.58	113.16	214.23	189.76	165.49	224.11	240.55	232.99	203.97	209.71	317.88	313.07	228.74	191.71	233.64
	III	10	227.05	252.42	257.31	240.17	259.44	199.84	224.94	176.73	159.72	202.65	216.09	225.63	273.47	221.29	273.17	223.17	252.58	302.30	139.06	201.88	140.51	266.02	235.63	205.49	278.28	298.70	289.31	253.27	250.93	357.11	171.35	418.15	368.44	290.13
May	I	10	257.84	236.96	352.06	444.62	165.19	188.54	292.51	170.06	192.85	203.13	243.38	506.78	273.92	224.41	166.05	232.87	495.23	218.68	280.31	374.22	390.86	284.34	262.23	275.21	302.69	381.80	291.50	296.55	311.72	349.11	325.17	205.04	367.58	270.89
	II	10	293.01	275.27	249.26	379.56	250.73	204.70	256.38	268.38	463.77	241.88	355.01	311.76	202.82	214.30	242.45	194.38	505.80	335.66	292.79	296.12	488.74	520.51	330.68	287.98	306.25	283.63	244.88	319.03	371.36	449.24	516.44	469.48	322.77	250.93
	III	11	250.85	357.82	304.10	328.83	429.50	159.96	260.50	295.58	205.47	492.77	604.04	394.04	147.94	315.36	530.34	493.69	418.15	431.98	297.70	536.24	529.04	685.09	448.09	376.88	595.75	666.54	512.90	425.30	607.71	463.75	508.59	617.23	563.47	451.33
Avg. Monsoon flow (June -Sept)			590.84	735.67	744.37	710.23	754.63	586.03	669.15	520.76	467.89	623.26	647.57	627.93	823.11	677.67	839.15	649.19	721.00	863.65	331.78	602.55	356.66	752.75	671.79	598.19	853.13	859.09	865.38	750.80	1155.35	946.04	781.81	704.11	1019.13	868.19
Avg. Non-Monsoon flow (Oct-May)			195.77	188.04	192.38	180.95	178.44	131.35	168.81	123.57	120.62	136.26	160.60	179.62	161.87	151.57	186.87	163.10	212.68	212.26	133.39	155.48	137.69	210.04	160.56	146.34	194.38	229.94	188.38	178.35	264.26	240.77	199.97	204.51	210.39	189.01
Yearly Average			327.82	371.08	376.88	357.86	371.03	283.33	336.05	256.33	236.70	299.04	323.37	329.46	382.89	327.42	404.89	325.58	382.59	429.99	199.70	304.91	210.88	391.44	331.43	297.37	414.57	440.23	414.67	369.69	562.11	476.51	394.45	371.50	480.71	416.02
Average of Lean Flow (Nov-Feb)			75.16	83.56	85.18	79.50	85.88	66.15	74.46	58.50	52.87	67.09	71.53	74.69	90.53	73.25	90.43	73.88	83.61	100.07	46.03	66.83	46.51	88.06	78.00	68.02	92.12	98.88	95.77	83.84	106.23	103.11	103.65	99.17	104.79	96.04
Annual Inflow Vol.(MCM)			10338	11703	11885	11285	11701	8935	10598	8084	7464	9431	10198	10390	12075	10325	12769	10267	12065	13560	6298	9616	6650	12344	10452	9378	13074	13883	13077	11659	17727	15027	12439	11716	15160	13120

Unrestricted Energy Potential (MU)

Riparian Flow(m^3/sec)= 0.00 : FRL = 1950.00 m : Head Losses= 20.00 m

: MDDL = 1945.00 m : Net Head = 620.83 m

Plant Efficiency = 91.11% : Normal TWL= 1307.50 m

Month		No. of Days	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Page &[P	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2003-04	2004-05	2005-06	2006-07
Jun	I	10	565.46	777.51	586.12	727.90	1325.76	485.71	186.24	362.32	386.39	477.94	780.18	530.06	1243.88	476.43	393.94	361.02	611.13	759.54	238.55	594.32	907.50	696.12	831.41	698.07	726.17	861.64	705.80	858.79	724.25	1092.89	787.98	1232.87
	II	10	1103.08	1087.51	543.61	1161.54	1110.80	697.60	495.90	389.28	388.80	841.25	897.70	1068.52	1130.15	786.32	745.28	519.04	964.00	1121.61	213.47	375.70	583.17	1020.60	588.10	1151.89	825.94	901.91	953.20	605.41	1269.27	1384.52	908.52	1450.46
	III	10	1140.54	467.10	1197.82	994.02	944.42	1215.64	995.91	391.94	648.70	1069.73	1256.15	705.75	1190.65	1415.75	863.86	519.78	847.52	1061.50	369.72	452.90	669.01	1310.45	1038.00	769.46	1557.20	1734.22	1155.23	1012.26	1889.67	1805.19	1121.59	1180.39
Jul	I	10	570.52	1132.49	1312.46	1264.07	950.24	934.75	1156.97	340.03	966.43	1277.73	1202.87	1056.58	1468.26	894.16	1353.66	1220.76	1142.12	1941.81	362.08	698.20	870.39	1679.86	1407.85	1156.04	1563.71	1452.47	1133.71	591.78	2172.75	1878.31	906.48	1125.14
	II	10	434.05	1301.00	1377.09	1284.76	902.26	746.05	926.48	630.37	1149.94	1018.47	749.23	1077.60	1712.27	1008.23	1153.36	657.90	1129.75	1413.05	578.87	694.74	427.17	1343.68	1760.14	1007.01	1375.62	1269.28	1831.97	1042.93	1948.42	2077.22	1462.92	1199.83
	III	11	1249.77	1162.31	1662.38	691.59	1105.44	933.77	1186.60	485.58	888.76	1844.58	1117.02	1410.83	1480.20	986.75	1628.01	1134.63	1076.19	874.92	426.93	1249.42	532.64	1018.24	1251.50	499.45	1337.63	1250.78	989.19	1274.82	1389.75	1477.00	1198.37	1123.92
Aug	I	10	1567.07	1051.76	904.60	740.12	836.59	1043.68	955.97	1083.09	549.88	510.17	379.58	524.28	592.35	732.35	1301.35	675.99	752.75	1517.70	620.04	1285.20	303.35	642.28	866.15	520.81	1329.32	624.22	1189.57	1666.90	1099.28	1271.64	1520.72	476.02
	II	10	625.50	600.21	566.07	959.91	865.62	991.50	974.73	838.81	479.06	728.14	945.91	984.47	691.57	1193.50	1173.26	848.68	1092.14	963.17	432.27	754.96	311.61	834.39	536.12	1019.68	626.88	1120.60	1258.59	780.06	1823.18	563.49	438.13	852.35
	III	11	444.85	1284.11	735.13	1225.72	1434.91	377.55	1124.84	1161.35	695.59	679.20	738.02	474.40	932.45	1074.50	1014.98	1820.45	851.46	926.78	784.98	1196.52	345.17	911.86	891.24	462.71	1662.11	1569.24	1348.76	1212.78	1600.07	1110.86	2228.86	1034.20
Sep	I	10	421.60	955.77	1501.53	826.14	862.84	313.30	1215.24	960.39	564.08	405.91	616.92	631.92	1328.63	668.87	1638.21	1265.37	1079.76	1063.14	597.85	939.99	290.02	737.35	685.69	599.61	1436.03	1423.36	1244.95	1839.99	1761.16	1291.07	944.91	497.63
	II	10	924.07	1140.62	971.27	861.58	865.62	991.50	974.73	838.81	479.06	728.14	945.91	984.47	691.57	1193.50	1173.26	848.68	1092.14	963.17	432.27	754.96	311.61	834.39	536.12	1019.68	626.88	1120.60	1258.59	780.06	1823.18	563.49	438.13	852.35
	III	10	553.28	992.60	736.21	802.33	1056.48	790.69	678.49	979.26	405.50	545.40	892.11	753.59	911.78	580.24	1195.15	675.53	1075.67	1425.97	333.57	793.14	243.29	1201.31	522.67	814.76	793.98	630.03	990.93	532.95	1270.84	855.30	746.05	414.97
Oct	I	10	498.77	809.54	849.57	668.77	761.13	581.30	604.91	463.23	465.11	333.61	315.18	582.68	613.03	575.21	799.16	673.18	941.30	799.80	373.50	556.51	286.07	782.70	508.85	516.32	393.02	774.35	552.73	653.07	1375.21	1082.53	653.97	623.89
	II	10	608.30	538.96	722.73	533.37	578.07	449.49	693.41	255.80	274.07	242.56	439.69	563.33	372.33	526.52	462.42	431.02	751.56	790.20	397.67	305.26	311.70	519.20	326.02	361.54	439.85	826.09	467.68	518.68	695.95	787.31	394.86	432.71
	III	11	1593.89	714.05	536.22	394.56	357.57	232.15	542.39	290.97	206.82	257.85	349.72	481.85	350.30	288.01	416.91	391.86	426.07	535.21	794.71	238.85	343.86	451.75	285.87	263.00	668.84	645.40	382.21	331.29	644.14	458.91	560.93	378.69
Nov	I	10	189.83	211.03	215.12	200.79	216.91	167.09	188.06	147.76	133.54	169.43	180.66	188.63	228.63	185.01	228.39	186.58	211.17	252.73	116.26	168.79	117.48	222.41	197.00	171.80	232.66	249.72	241.88	211.75	309.76	236.35	270.27	234.34
	II	10	149.37	166.06	169.28	158.00	170.68	131.47	147.99	116.26	105.08	133.32	142.15	148.44	179.91	145.58	179.71	146.82	166.17	198.88	91.48	132.82	92.44	175.01	155.02	135.19	183.08	196.50	190.34	166.62	233.82	193.35	215.59	169.90
	III	10	123.79	137.61	140.28	130.93	141.45	108.95	122.63	96.35	87.07	110.48	117.81	123.00	149.09	120.65	148.92	121.67	137.69	164.81	75.81	110.06	76.60	145.03	128.46	112.03	151.72	162.85	157.72	138.08	197.73	148.79	181.40	163.34
Dec	I	10	97.71	108.63	110.74	103.36	111.66	86.01	96.81	76.06	68.73	87.22	93.00	97.10	117.69	95.24	117.56	96.05	108.70	130.10	59.85	86.89	60.48	114.48	101.40	88.43	119.77	128.54	124.51	108.99	152.53	120.23	133.75	132.26
	II	10	83.94	93.32	95.13	88.79	95.91	73.87	83.16	65.34	59.05	74.93	79.88	83.41	101.10	81.81	100.99	82.50	93.37	111.75	51.41	74.63	51.95	98.34	87.11	75.96	102.88	110.43	106.96	93.64	127.90	109.34	111.79	120.50
	III	11	98.62	109.64	111.76	104.32	112.68	86.80	97.70	76.76	69.38	88.03	93.86	98.01	118.78	96.12	118.65	96.94	109.71	131.30	60.40	87.69	61.03	115.54	102.34	89.26	120.87	129.74	125.66	110.00	122.73	138.26	117.86	120.26
Jan	I	10	73.55	81.78	83.36	77.80	84.05	64.74	72.88	57.25	51.74	65.66	70.01	73.10	88.59	71.69	88.50	72.30	81.82	97.94	45.05	65.40	45.52	86.18	76.34	66.58	90.16	96.77	93.73	82.05	92.91	107.13	96.41	100.83
	II	10	72.73	80.87	82.42	76.94	83.12	64.02	72.06	56.61	51.17	64.92	69.23	72.28	87.60	70.89	87.51	71.49	80.91	96.83	44.55	64.67	45.01	85.22	75.49	65.83	89.15	95.69	92.68	81.13	89.59	108.49	89.56	97.14
	III	11	85.36	94.90	96.73	90.29	97.54	75.12	84.56	66.44	60.05	76.18	81.23	84.82	102.81	83.20	102.69	83.90	94.96	113.64	52.27	75.90	52.83	100.00	88.59	77.25	104.61	112.29	108.76	95.21	101.42	109.52	95.93	98.09
Feb	I	10	73.41	81.61	83.20	77.66	83.88	64.62	72.73	57.15	51.65	65.52	69.87	72.96	88.42	71.54	88.32	72.16	81.66	97.74	44.96	65.27	45.43	86.01	76.18	66.44	89.98	96.57	93.54	81.89	100.86	100.19	84.42	113.79
	II	10	87.59	97.38	99.26	92.65	100.08	77.10	86.78	68.17	61.61	78.18	83.36	87.05	105.49	85.37	105.38	86.09	97.43	116.61	53.64	77.88	54.20	102.61	90.89	79.27	107.35	115.23	111.60	97.70	89.63	148.79	90.49	146.86
	III	8	65.27	72.56	73.96	69.04	74.58	57.45	64.66	50.80	45.91	58.26	62.11	64.86	78.61	63.61	78.52	64.15	72.61	86.90	39.97	58.03	40.39	76.47	67.73	59.07	79.99	85.86	83.17	72.80	78.86	127.37	168.92	87.62
Mar	I	10	95.18	105.81	107.86	100.68	108.75	83.77	94.29	74.09	66.96	84.95	90.59	94.58	114.64	92.76	114.52	93.56	105.88	126.72	58.29	84.63	58.90	111.51	98.78	86.14	116.66	125.21	121.29	106.17	140.17	183.11	140.41	136.60
	II	10	174.64	194.15	197.90	184.72	199.55	153.71	173.01	135.94	122.84	155.87	166.21	173.54	210.34	170.20	210.10	171.65	194.27	232.52	106.96	155.27	108.07	204.60	181.24	158.06	214.04	229.75	222.53	194.80	494.57	245.07	211.34	126.81
	III	11	307.92	342.32	348.94	325.69	351.84	271.02	305.05	239.67	216.61	274.83	293.05	305.99	370.85	300.10	370.46	302.65	342.52	409.95	188.58	273.79	190.56	360.75	319.55	278.66	377.39	405.08	392.35	343.47	890.27	374.11	154.51	182.45
Apr	I	10	208.64	231.94	236.43	220.68	238.39	183.63	206.69	162.40	146.76	186.21	198.56	207.32	251.28	203.34	251.00	205.07	232.09	277.77	127.77	185.50	129.12	244.44	216.52	188.82	255.70	274.47	265.84	232.73	200.71	371.57	188.06	488.32
	II	10	243.52	270.72	275.97	257.58	278.26	214.34	241.25	189.55	171.31	217.35	231.76	242.00	293.30	237.34	292.98	239.35	270.88	324.21	149.15	216.52	150.70	285.31	252.72	220.40	298.47	320.36	310.29	271.64	279.29	423.35	416.94	304.63
	III	10	302.38	336.17	342.68	319.85	345.52	266.14	299.57	235.37	212.71	269.89	287.78	300.49	364.20	294.71	363.80	297.21	336.38	402.60	185.20	268.86	187.13	354.28	313.81	273.67	370.61	397.80	385.30	337.30	334.18	475.59	228.20	556.88
May	I	10	343.39	315.58	468.87	592.14	220.00	251.09	389.56	226.48	256.83	270.52	324.13	674.92	364.80	298.87	221.14	310.13	659.54	291.23	373.31	498.38	520.54	378.68	349.23	366.52	403.12	508.47	388.21	394.94	415.14	464.94	433.06	273.07
	II	10	390.23	366.60	331.96	505.49	333.92	272.62	341.44	357.42	617.64	322.13	472.80	415.20	270.11	285.40	322.89	258.87	673.62	447.03	389.93	394.37	650.90	693.21	440.39	383.53	407.86	377.73	326.13	424.88	494.57	598.29	687.79	625.25
	III	11	367.49	524.19	445.49	481.72	629.20	234.34	381.62	433.01	301.01	721.89	884.89	577.25	216.73	461.99	776.93	723.24	612.57	632.83	436.12	785.57	775.02	1003.63	656.43	552.11	872.75	976.45	751.38	623.05	890.27	679.38	745.06	904.22
Total, MU			**15935.31**	**18038.42**	**18320.15**	**17395.50**	**18035.71**	**13772.57**	**16335.30**	**12460.12**	**11505.84**	**14536.43**	**15719.12**	**16015.27**	**18612.39**	**15915.75**	**19681.80**	**15826.24**	**18597.52**	**20901.64**	**9707.46**	**14821.60**	**10250.88**	**19027.85**	**16110.97**	**14455.03**	**20152.03**	**21399.71**	**20156.96**	**17970.63**	**27324.05**	**23162.93**	**19174.18**	**18058.58**

Rip

Month		No. of Days	2007-08	2008-09
Jun	I	10	1177.87	853.17
	II	10	1244.07	1382.82
	III	10	1463.19	1065.57
Jul	I	10	921.73	1130.19
	II	10	1217.45	1336.26
	III	11	3230.97	1779.62
Aug	I	10	1071.85	775.16
	II	10	1679.32	1769.17
	III	11	891.56	1543.01
Sep	I	10	1535.78	1422.66
	II	10	1679.32	578.10
	III	10	445.37	470.32
Oct	I	10	680.83	485.69
	II	10	777.83	418.09
	III	11	437.64	619.81
Nov	I	10	258.51	242.56
	II	10	217.57	190.87
	III	10	162.48	158.18
Dec	I	10	135.16	124.85
	II	10	109.41	107.26
	III	11	119.23	126.02
Jan	I	10	110.09	94.00
	II	10	116.86	92.95
	III	11	129.49	109.07
Feb	I	10	107.04	93.80
	II	10	128.33	111.92
	III	8	80.55	83.40
Mar	I	10	100.56	121.62
	II	10	126.68	223.15
	III	11	329.25	393.44
Apr	I	10	190.26	266.58
	II	10	255.32	311.16
	III	10	490.68	386.39
May	I	10	489.54	360.77
	II	10	429.86	334.18
	III	11	825.46	661.18
Total, MU			**23367.11**	**20222.98**

AVERAGE HEAD LOSS CALCULATIONS

				All Machine Running at Full Load	
		Design Discharge For HRT	Q	333.4	m^3/sec
		Full Reservoir Level	FRL	1950	m
		Minimum Drawdown Level	MDDL	1945	m
		Sill Level of Trash Rack		1919	m
		Center level of turbine		1305	m
1	**Losses in Trash Rack**				
		Clear Width of Trash Rack Opening		18	m
		Height of Trash Rack For MDDL Condition		26	m
		Ratio of Clear Opening to Total Area	R	0.65	
		Flow Area Without Clogging		303.79	m^2
		Gross Area of Trash Rack		468.00	m^2
		Flow Velocity Without Clogging		1.097	m/sec
	(i)	**First Method**			
		(IS:11388-1995)			
		Ratio of net area to gross Area	R	0.65	
		Trash rack loss coefficient ($K = 1.45-0.45 \times R-R^2$)	K	0.74	
		Flow velocity on net area	v_1	1.097	m/sec
		Head loss ($ht = KxV_1^2/2g$)	h_t	**0.045**	m
	(ii)	**Second Method**			
		(IS:11388-1995)			
		Inclination of rack bar with horizontal	α	90	Deg
		Factor for the bar shape (Rounded Assumed)	k	1.83	
		Velocity through trash rack on gross area	v_2	0.712	m^2
		Multiplication factor for bracing & frame (m = 1.75 to 2.0)		2.00	
		Head loss $\{hr = k \times (t/b)^2 \times (v_2^2/2g) \times \sin(\alpha)\}$	h_t	**0.028**	m
		Head loss through trash rack	hr	**0.045**	m
2	**Losses in Head Race Tunnel**				
	i)	**Bell mouth Entrance Loss**			
		(IS:4880 Part-III -1995 & Design of Small Dams))			
		Design discharge	Q	333.39	m^3/sec
		Bell mouth opening height	h_e	12.50	m
		Bell mouth opening width	b_e	15.00	m
		Total area of opening	A	187.5	m^2
		Entrance loss coefficient for square bell mouth (Avg. Value)	K_e	0.16	
		Flow velocity through entrance	v_3	1.778	m/sec
		Head loss through entrance ($h_e = k_e \times v_3^2/2g$)	h_e	**0.026**	m
	ii)	**Transition Loss (Bell mouth to Gate Location, Contraction)**			
		(IS:4880 Part-III -1995 & Design of Small Dams)		333.39	
		Length of transition	L	15	m
		Flow velocity trough bell mouth opening	v_1	1.778	m/sec
		Width of gate	B	12.2	m
		Height of gate	H	8	m
		Gate opening area	A_2	97.6	
		Flow velocity	v_4	3.42	m/sec
		For smooth transition, loss coefficient	k_t	0.1	m
		Head loss in transition $\{ k_t \times (v_4^2 - v_3^2)/2g \}$	h_t	**0.043**	m

iii)	**Frictional loss in transition**			
	Average velocity	V	2.597	m/sec
	Average perimeter	P	43.7	m
	Average area	A	142.55	m^2
	Average hydraulic radius	R	3.26	m
	Manning's roughness coefficient	n	0.014	
	Head loss in transition due to friction { V^2 x n^2 } x L / { $R^{4/3}$ }	h_{ft}	**0.004**	m
iv)	**Gate slot loss**			
	(IS:4880 Part-III -1995)			
	Gate loss coefficient	k_g	0.19	
	No. of Gates	n	2	
	Flow velocity trough gate	v_4	3.416	m/sec
	Head loss due to gate slot { $h_q = k_q \times v_4^2/2g$ }	hg	**0.226**	m
v)	**Transition loss from intake gate to circular head race tunnel (Gradual Contraction)**			
	(IS:2951 Part-II -1965)			
	Length of transition	L	15	
	Dia. Of head race tunnel	D	10.60	m
	Area of head race tunnel	A	93.18	m^2
	Wetted perimeter	P	34.63	m
	Hydraulic radius	R	2.69	m
	Flow velocity through head race tunnel	v_5	3.58	m/sec
	Loss coefficient	k	0.100	
	Head loss in transition { $k_t \times (v_5^2 - v_4^2)/2g$ }	h_t	**0.006**	m
vi)	**Frictional loss in transition**			
	Average velocity	V	3.50	m/sec
	Average perimeter	P	36.85	m
	Average area	A	95.39	m^2
	Average hydraulic radius	R	2.59	m
	Manning's roughness coefficient	n	0.014	
	Head loss in transition due to friction { V^2 x n^2 } x L / { $R^{4/3}$ }	h_{ft}	**0.010**	m
vii)	**Frictional head loss in HRT**			
	Length of head race tunnel	L	14800	m
	Manning's roughness coefficient	n	0.014	
	Head loss due to friction { V_5^2 x n^2 } x L / { $R^{4/3}$ }	h_f	**9.92**	m
viii)	**Bend Loss**			
	(IS:2951 Part-II -1965)			
1	Bend radius	R	400	m
	Bend angle	α	56.8	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	37.74	
	Bend loss coefficient	K_b	0.07	
2	Bend radius	R	400	m
	Bend angle	α	35.32	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	37.74	
	Bend loss coefficient	K_b	0.06	
3	Bend radius	R	150	m
	Bend angle	α	62.58	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	14.15	
	Bend loss coefficient	K_b	0.07	
4	Bend radius	R	150	m
	Bend angle	α	72.38	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	14.15	
	Bend loss coefficient	K_b	0.075	

5	Bend radius	R	250	m
	Bend angle	α	23.16	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	23.58	
	Bend loss coefficient	K_b	0.045	
6	Bend radius	R	100	m
	Bend angle	α	54.28	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	9.43	
	Bend loss coefficient	K_b	0.065	
7	Bend radius	R	250	m
	Bend angle	α	37.23	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	23.58	
	Bend loss coefficient	K_b	0.06	
8	Bend radius	R	400	m
	Bend angle	α	61.57	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	37.74	
	Bend loss coefficient	K_b	0.07	
	Total Bend Loss Coefficient	KB	0.515	
	Bend loss ($h_B = k_B \times v_5^2/2g$)	h_B	**0.34**	m
ix)	**Transition at Surge Shaft Junction (Circular to rectangular)**			
	(IS:4880 Part-III -1995 & Design of Small Dams)			
	Width of HRT	B	8.80	m
	Height of HRT	H	10.60	m
	Length of transition	L	10	m
	Cross sectional area of HRT	A	93.3	m^2
	Wetted perimeter	P	38.8	m
	Hydraulic radius	R	2.40	m
	Flow velocity	v_6	3.57	m/sec
	Head loss coefficient for smooth transition	k_T	0.1	
	Head loss in transition { $h_t = k_T \times (v_6^2 - v_5^2)/2g$ }	ht	**0.000**	m
x)	**Head Loss due to friction in transition**			
	Length of transition	L	10.00	m
	Average area	A	93.23	m^2
	Average perimeter	P	36.72	m
	Average hydraulic radius	R	2.54	m
	Average velocity	V	3.58	m/sec
	Manning's roughness coefficient	n	0.014	
	Head loss due to friction { $V^2 \times n^2$ } x L / { $R^{4/3}$ }	hf	**0.007**	m
xi)	**Transition in surge shaft area (HRT to Pressure Shaft)**			
	(IS:4880 Part-III -1995 & Design of Small Dams)			
	Discharge after transition in Pressure shaft		83.347	m^3/sec
	Width of section after transition	B	3.19	m
	Height of section after transition	H	4.00	m
	Length of transition	L	20	m
	Angle of Side walls	α		
	Cross sectional area of HRT after transition	A	12.76	m^2
	Wetted perimeter	P	14.38	m
	Hydraulic radius	R	0.89	m
	Flow velocity after transition	v_7	6.53	m/sec
	Loss coefficient for smooth transition	K_T	0.1	
	Head loss in transition { $h_t = k_T \times (v_7^2 - v_6^2)/2g$ }	ht	**0.152**	m

3	**Losses in Pressure Shaft(Dia. 4.1m)**			
	Discharge through Pressure Shaft	Q	83.35	m^3/sec
	Length of transition	L	5	m
	Dia. of penstock	D	4.00	m
	Cross sectional area of penstock	A	12.57	m^2
	Wetted perimeter for penstock	P	12.57	m
	Hydraulic radius	R	1	m
	Flow velocity through penstock	v_8	6.633	m/sec

	i)	**Loss due to transition from from rectangular to circular (IS:2951 Part-II -1965)**			
		Loss coefficient	K	0.10	
		Head loss { h = k x $(v_8^2-v_7^2)/2g$ }	h_{ex}	**0.007**	m
	ii)	**Loss due to butterfly valve (Design of SmallDams)**			
		Dia. of valve	D	4.00	m
		Area of valve	A	12.57	m^2
		Velocity through valve	v_9	6.63	m/sec
		Valve loss coefficient	k_v	0.4	
		Head loss due to valve fitting { $h_v = k_v \times v_9^2/2g$ }	h_v	**0.90**	m
	iii)	**Frictional loss in pressure shaft**			
		Dia. Of PS		4	m
		Length of pressure shaft	L	434	m
		Manning's roughness coefficient for steel	n	0.011	
		Head loss due to friction { $V_8^2 \times n^2$ } x L / { $R^{4/3}$ }	h_f	**2.310**	
	iv)	**Bend Losses (IS:2951 Part-II -1965)**			
	1	Bend radius	R	15	m
		Bend angle	α	67.5	Deg.
		Ratio of bend radius to dia. Of tunnel	R/D	3.75	
		Bend loss coefficient (Assumed smooth surface)	K_b	0.1	
	2	Bend radius	R	20	m
		Bend angle	α	90	Deg.
		Ratio of bend radius to dia. Of tunnel	R/D	5.00	
		Bend loss coefficient (Assumed smooth surface)	K_b	0.095	
	3	Bend radius	R	12	m
		Bend angle	α	90	Deg.
		Ratio of bend radius to dia. Of tunnel	R/D	3.00	
		Bend loss coefficient (Assumed smooth surface)	K_b	0.12	
		Total bend loss coefficient	k_B	0.315	
		Head loss due to bends { $h_b = k_B \times v_8^2/2g$ }	h_b	**0.706**	m
4	**Losses in Pressure Shaft(Dia. 2.9m)**				
		Discharge through Pressure Shaft	Q	41.67	m^3/sec
		Length of transition	L	4	m
		Dia. of penstock	D	2.85	m
		Cross sectional area of penstock	A	6.38	m^2
		Wetted perimeter for penstock	P	8.95	m
		Hydraulic radius	R	0.7125	m
		Flow velocity through penstock	v_{10}	6.53	m/sec
	i)	**Loss due to bifurcation (IS:2951 Part-II -1965)**			
		Diameter of main	D_{main}	4.00	m
		Diameter of Branch	D_{br}	2.9	m
		Qb/Q		0.5	
		Angle of divergence		60	Deg.
		Head Loss Coefficient		0.54	
		Discharge		41.67	m^3/sec
		Velocity		6.533	m/sec
		Head Loss		**1.175**	m
	iii)	**Frictional loss in pressure shaft**			
		Dia. of PS		2.85	m
		Length of pressure shaft	L	381	m
		Manning's roughness coefficient for steel	n	0.011	
		Head loss due to friction { $V_8^2 \times n^2$ } x L / { $R^{4/3}$ }	h_f	**3.091**	

iv)	**Bend Losses**			
	(IS:2951 Part-II -1965)			
1	Bend radius	R	12	m
	Bend angle	α	90	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	4.21	
	Nos. of bend		2	
	Bend loss coefficient (Assumed smooth surface)	K_b	0.2	
2	Bend radius	R	12	m
	Bend angle	α	46.03	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	4.21	
	Bend loss coefficient (Assumed smooth surface)	K_b	0.07	
3	Bend radius	R	12	m
	Bend angle	α	30	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	4.21	
	Bend loss coefficient (Assumed smooth surface)	K_b	0.06	
	Total bend loss coefficient	k_B	0.33	
	Head loss due to bends { $h_b = k_B \times v_{10}^2/2g$ }	h_b	**0.718**	m
v)	**Head Loss in Reducer**			
	Dia. of reducer	d	2.30	m
	Length of reducer	L	2.53	m
	Cross sectional area of reducer	A	4.15	m^2
	Flow velocity in reducer	v_{11}	10.03	m/sec
	Loss coefficient due to reducer (Smooth transition)	k	0.1	
	Head loss in transition { $k_t \times (v_{11}^2 - v_8^2)/2g$ }	h_{rd}	**0.289**	m
vi)	**Head Loss in Spherical valve (MIV)**			
	Dia. of Spherical valve		2.80	m
	Flow Velocity Through Valve		10.03	m/sec
	Head Loss Coefficient Through Valve		0.00	
	Head Loss Through Spherical Valve ($hv = kv \times v_{11}^2$)/2g		**0.00**	m
	Head Loss From Intake to SS		**10.78**	**m**
	Head Loss SS to MIV		**9.19**	**m**
	Total Head Loss		***19.97***	**m**
		Say	**20.00**	**m**

CALCULATION OF PONDAGE REQUIREMENT

Required Reservoir Capacity =	1889451 m^3	Available Reservoir Capacity =	2065000 m^3
	1.889 MCM	Block Hours	12 Hrs
Riparian flow =	As provided cumec	Number of Peakings in 24 Hours	2.0
Installed Capacity=	1850 MW	Peaking Time	2.0 Hrs
		Non Peaking Time	10 Hrs

Month		No. of Days	River Inflow	Riparian flow	Net inflow available for diversion	Design Discharge	Total volume of water in one block due to inflow	Machine Availability	Minimum Peaking Duration with water stored in reservoir due to inflow	Duration with available Res. capacity	Required Reservoir Capacity For Obtaing Max. Peaking upto Max. 2 Hrs
			m^3/sec	m^3/sec	m^3/sec	m^3/sec	m^3	%	(Hr)	(Hr)	m^3
Jun	I	10	290.13	9.74	280.39	333.39	12112848	95%	2.00	2.00	261565
	II	10	291.94	9.74	282.20	333.39	12191040	95%	2.00	2.00	248533
	III	10	487.09	9.74	477.35	333.39	20621520	95%	2.00	2.00	0
Jul	I	10	725.67	9.74	715.93	333.39	30928176	95%	2.00	2.00	0
	II	10	863.46	9.74	853.72	333.39	36880704	95%	2.00	2.00	0
	III	11	606.68	9.74	596.94	333.39	25787808	95%	2.00	2.00	0
Aug	I	10	412.89	9.74	403.15	333.39	17416080	95%	2.00	2.00	0
	II	10	359.71	9.74	349.97	333.39	15118704	95%	2.00	2.00	0
	III	11	474.82	9.74	465.08	333.39	20091456	95%	2.00	2.00	0
Sep	I	10	423.55	9.74	413.81	333.39	17876592	95%	2.00	2.00	0
	II	10	359.71	9.74	349.97	333.39	15118704	95%	2.00	2.00	0
	III	10	304.48	9.74	294.74	333.39	12732768	95%	2.00	2.00	158245
Oct	I	10	349.24	47.86	301.38	333.39	13019616	95%	2.00	2.00	110437
	II	10	205.79	47.86	157.93	333.39	6822576	95%	2.00	2.00	1143277
	III	11	141.18	47.86	93.32	333.39	4031424	95%	2.00	2.00	1608469
Nov	I	10	100.27	47.86	52.41	333.39	2264112	95%	1.99	2.00	1889451
	II	10	78.90	9.74	69.16	333.39	2987712	95%	2.00	2.00	1782421
	III	10	65.38	9.74	55.64	333.39	2403648	95%	2.00	2.00	1879765
Dec	I	10	51.61	9.74	41.87	333.39	1808784	95%	1.59	2.00	1569664
	II	10	44.34	9.74	34.60	333.39	1494720	95%	1.31	2.00	1331429
	III	11	47.36	9.74	37.62	333.39	1625184	95%	1.43	2.00	1432144
Jan	I	10	38.85	9.74	29.11	333.39	1257552	95%	1.10	1.99	1141969
	II	10	38.42	9.74	28.68	333.39	1238976	95%	1.09	1.99	1126782
	III	11	40.99	9.74	31.25	333.39	1350000	95%	1.18	2.00	1216798
Feb	I	10	38.78	9.74	29.04	333.39	1254528	95%	1.10	1.99	1139500
	II	10	46.26	9.74	36.52	333.39	1577664	95%	1.38	2.00	1395748
	III	8	43.09	9.74	33.35	333.39	1440720	95%	1.26	2.00	1289014
Mar	I	10	50.28	9.74	40.54	333.39	1751328	95%	1.54	2.00	1527158
	II	10	92.24	47.86	44.38	333.39	1917216	95%	1.68	2.00	1648567
	III	11	147.86	47.86	100.00	333.39	4320000	95%	2.00	2.00	1560373
Apr	I	10	110.20	47.86	62.34	333.39	2693088	95%	2.00	2.00	1831525
	II	10	128.63	47.86	80.77	333.39	3489264	95%	2.00	2.00	1698829
	III	10	159.72	47.86	111.86	333.39	4832352	95%	2.00	2.00	1474981
May	I	10	192.85	47.86	144.99	333.39	6263568	95%	2.00	2.00	1236445
	II	10	463.77	47.86	415.91	333.39	17967312	95%	2.00	2.00	0
	III	11	205.47	47.86	157.61	333.39	6808752	95%	2.00	2.00	1145581
									Max Capacity		**1889451**

Annual Energy (MU) Calculation for Different Installed Capacities in 90% Dependable Year

Riparian Flow (cumec) = As provided FRL = 1950.00 m Head Losses= 20.00 m
Plant Efficiency = 91.11% MDDL = 1945.00 m Net Head = 620.83 m
Centre Line of Distributors = 1307.50 m

Month		No. of Days	River Inflow	Riparian Flow	Net inflow	Unrestricted		Annual Energy Energy (MU)			Annual Energy Energy (MU)													
						Power (MW)	Energy (MU)	1500 MW	1550 MW	1600 MW	1650 MW	1700 MW	1750 MW	1800 MW	1850 MW	1900 MW	1950 MW	2000 MW	2050 MW	2100 MW	2150 MW	2200 MW	2250 MW	2300 MW
			Discharge (cumecs)					270.31	279.32	288.34	297.35	306.36	315.37	324.38	333.39	342.40	351.41	360.42	369.43	378.44	387.45	396.46	405.47	414.48
Jun	I	10	290.13	9.74	280.39	1555.90	373.42	360.00	372.00	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42	373.42
	II	10	291.94	9.74	282.20	1565.95	375.83	360.00	372.00	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83	375.83
	III	10	487.09	9.74	477.35	2648.85	635.72	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	468.00	480.00	492.00	504.00	516.00	528.00	540.00	552.00
Jul	I	10	725.67	9.74	715.93	3972.75	953.46	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	468.00	480.00	492.00	504.00	516.00	528.00	540.00	552.00
	II	10	863.46	9.74	853.72	4737.36	1136.97	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	468.00	480.00	492.00	504.00	516.00	528.00	540.00	552.00
	III	11	606.68	9.74	596.94	3312.47	874.49	396.00	409.20	422.40	435.60	448.80	462.00	475.20	488.40	501.60	514.80	528.00	541.20	554.40	567.60	580.80	594.00	607.20
Aug	I	10	412.89	9.74	403.15	2237.11	536.91	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	468.00	480.00	492.00	504.00	516.00	528.00	536.91	536.91
	II	10	359.71	9.74	349.97	1942.01	466.08	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	466.08	466.08	466.08	466.08	466.08	466.08	466.08	466.08
	III	11	474.82	9.74	465.08	2580.77	681.32	396.00	409.20	422.40	435.60	448.80	462.00	475.20	488.40	501.60	514.80	528.00	541.20	554.40	567.60	580.80	594.00	607.20
Sep	I	10	423.55	9.74	413.81	2296.26	551.10	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	468.00	480.00	492.00	504.00	516.00	528.00	540.00	551.10
	II	10	359.71	9.74	349.97	1942.01	466.08	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	466.08	466.08	466.08	466.08	466.08	466.08	466.08	466.08
	III	10	304.48	9.74	294.74	1635.53	392.53	360.00	372.00	384.00	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53	392.53
Oct	I	10	349.24	47.86	301.38	1672.39	401.37	360.00	372.00	384.00	396.00	401.37	401.37	401.37	401.37	401.37	401.37	401.37	401.37	401.37	401.37	401.37	401.37	401.37
	II	10	205.79	47.86	157.93	876.38	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33	210.33
	III	11	141.18	47.86	93.32	517.85	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71	136.71
Nov	I	10	100.27	47.86	52.41	290.83	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80	69.80
	II	10	78.90	9.74	69.16	383.77	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10	92.10
	III	10	65.38	9.74	55.64	308.74	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10
Dec	I	10	51.61	9.74	41.87	232.33	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76	55.76
	II	10	44.34	9.74	34.60	191.99	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08	46.08
	III	11	47.36	9.74	37.62	208.75	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11	55.11
Jan	I	10	38.85	9.74	29.11	161.53	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77	38.77
	II	10	38.42	9.74	28.68	159.14	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19	38.19
	III	11	40.99	9.74	31.25	173.40	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78	45.78
Feb	I	10	38.78	9.74	29.04	161.14	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67	38.67
	II	10	46.26	9.74	36.52	202.65	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63	48.63
	III	8	43.09	9.74	33.35	185.06	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53
Mar	I	10	50.28	9.74	40.54	224.95	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99	53.99
	II	10	92.24	47.86	44.38	246.28	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11	59.11
	III	11	147.86	47.86	100.00	554.92	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50	146.50
Apr	I	10	110.20	47.86	62.34	345.94	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02	83.02
	II	10	128.63	47.86	80.77	448.21	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57	107.57
	III	10	159.72	47.86	111.86	620.73	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97	148.97
May	I	10	192.85	47.86	144.99	804.57	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10	193.10
	II	10	463.77	47.86	415.91	2307.93	553.90	360.00	372.00	384.00	396.00	408.00	420.00	432.00	444.00	456.00	468.00	480.00	492.00	504.00	516.00	528.00	540.00	552.00
	III	11	205.47	47.86	157.61	874.60	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89	230.89
Annual Gross Energy (MU)							**10407.91**	**7120.72**	**7291.12**	**7442.77**	**7585.70**	**7713.47**	**7835.87**	**7958.27**	**8080.67**	**8203.07**	**8321.63**	**8420.03**	**8518.43**	**8616.83**	**8715.23**	**8813.63**	**8908.94**	**8994.44**
Potential Exploited (%)								68.42%	70.05%	71.51%	72.88%	74.11%	75.29%	76.46%	77.64%	78.82%	79.95%	80.90%	81.85%	82.79%	83.74%	84.68%	85.60%	86.42%
Incremental Energy (kWh/kW)								-----	3408.00	3032.88	2858.56	2555.48	2448.00	2448.00	2448.00	2448.00	2371.29	1968.00	1968.00	1968.00	1968.00	1968.00	1906.13	1710.06
Load factor (Annual)								54.19%	53.70%	53.10%	52.48%	51.80%	51.11%	50.47%	49.86%	49.29%	48.72%	48.06%	47.44%	46.84%	46.27%	45.73%	45.20%	44.64%
Load factor (Lean Period)			(in 4 consecutive lean months period)					14.41%	13.95%	13.51%	13.10%	12.72%	12.36%	12.01%	11.69%	11.38%	11.09%	10.81%	10.55%	10.30%	10.06%	9.83%	9.61%	9.40%
Firm Energy								622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72	622.72

AVERAGE HEAD LOSS CALCULATIONS - Dam Toe Powerhouse

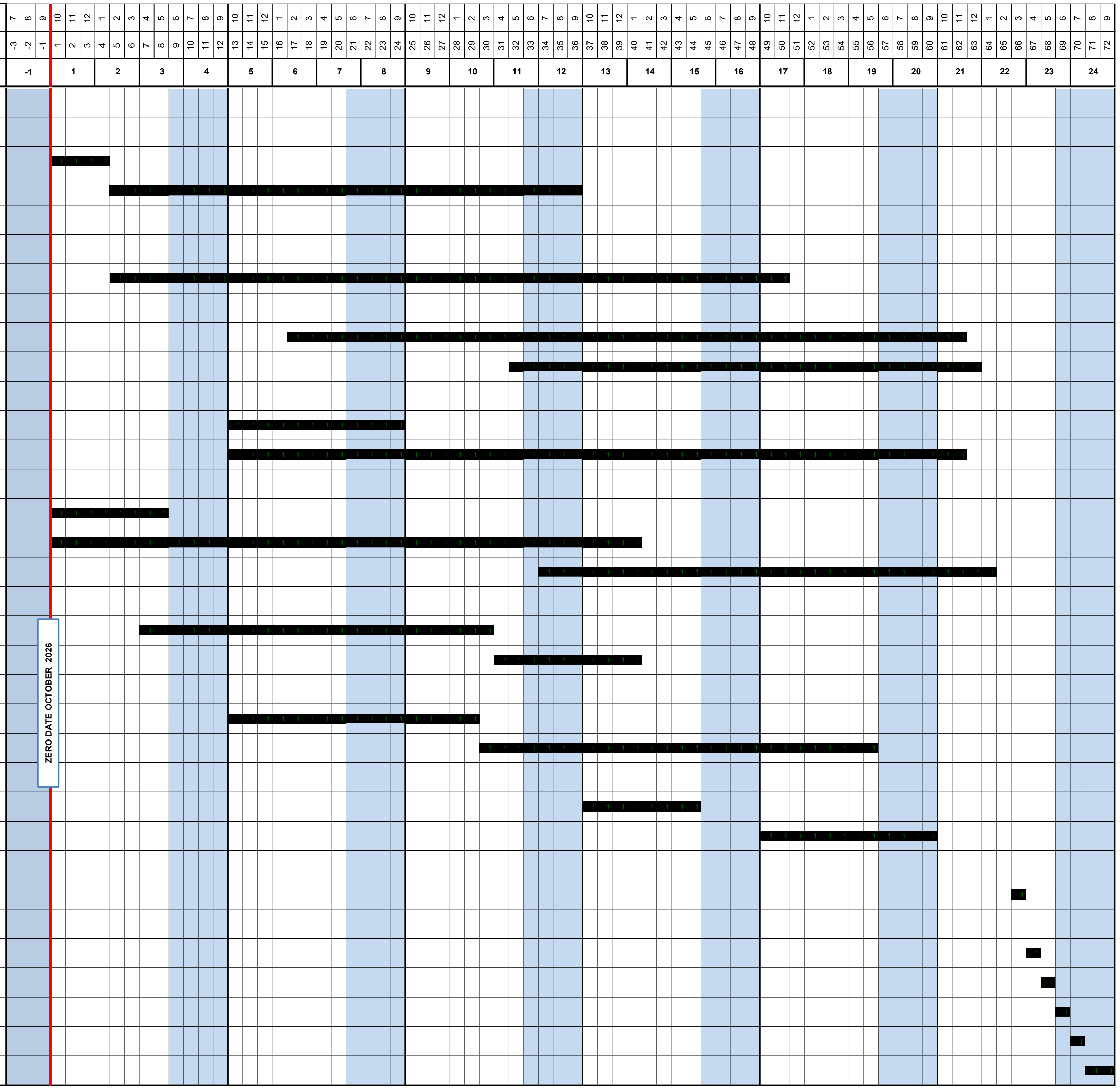
			All Machine Running at Full Load	
	Design Discharge For HRT	Q	45.23	m^3/sec
	Full Reservoir Level	FRL	1950	m
	Minimum Drawdown Level	MDDL	1945	m
	Sill Level of Trash Rack		1935	m
	Center level of turbine		1860	m
1	**Losses in Trash Rack**			
	Clear Width of Trash Rack Opening		5.5	m
	Height of Trash Rack For MDDL Condition		10	m
	Flow Area Without Clogging		35.75	m^2
	Gross Area of Trash Rack		55.00	m^2
	IS:11388-1995			
	Ratio of net area to gross Area	R	0.65	
	Trash rack loss coefficient ($K = 1.45-0.45 \times R-R^2$)	K	0.74	
	Flow velocity on net area	v_1	1.265	m/sec
	Head loss ($ht = KxV_1^2/2g$)	h_t	**0.060**	m
i)	**Gate slot loss**			
	(IS:4880 Part-III -1995)			
	Gate loss coefficient	k_g	0.19	
	No. of Gates	n	1	
	Flow velocity trough gate	v_4	5.688	m/sec
	Head loss due to gate slot { $h_q = k_q \times v_4^2/2g$ }	hg	**0.313**	m
ii)	**Frictional loss in pressure shaft**			
	Dia. Of PS		3.25	m
	Length of pressure shaft	L	170	m
	Manning's roughness coefficient for steel	n	0.011	
	Head loss due to friction { $V_8^2 \times n^2$ } x L / { $R^{4/3}$ }	h_f	**0.908**	
iii)	**Bend Losses**			
	(IS:2951 Part-II -1965)			
1	Bend radius	R	15	m
	Bend angle	α	90	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	8.57	
	Bend loss coefficient (Assumed smooth surface)	K_b	0.095	
2	Bend radius	R	15	m
	Bend angle	α	90	Deg.
	Ratio of bend radius to dia. Of tunnel	R/D	8.57	
	Bend loss coefficient (Assumed smooth surface)	K_b	0.095	
	Head loss due to bends { $h_b = k_B \times v_8^2/2g$ }	h_b	**0.000**	m

4	**Losses in Branch Penstocks (Dia. 2.25m)**			
	Discharge through Pressure Shaft	Q	22.615	m^3/sec
	Length of transition	L	5	m
	Dia. of penstock	D	2.25	m
	Cross sectional area of penstock	A	3.98	m^2
	Wetted perimeter for penstock	P	7.07	m
	Hydraulic radius	R	0.5625	m
	Flow velocity through penstock	v_{10}	5.69	m/sec
i)	**Loss due to bifurcation (IS:2951 Part-II -1965)**			
	Diameter of main	D_{main}	3.25	m
	Diameter of Branch	D_{br}	2.25	m
	Qb/Q		0.5	
	Angle of divergence		60	Deg.
	Head Loss Coefficient		0.54	
	Discharge		22.615	m^3/sec
	Velocity		5.688	m/sec
	Head Loss		**0.890**	m
iii)	**Frictional loss inBranch Penstocks**			
	Dia. of PS		2.25	m
	Length of pressure shaft	L	30	m
	Manning's roughness coefficient for steel	n	0.011	
	Head loss due to friction { V_8^2 x n^2 } x L / { $R^{4/3}$ }	h_f	**0.253**	
	Total Head Loss		***2.42***	**m**
			Say 3.0 m	

ZERO DATE OCTOBER 2026

S.No.		ACTIVITY NAME	Duration Provided	Starting Month	-	Ending Month
1		**CONSTRUCTION OF DIVERSION TUNNEL**				
	-	Construction of Ring Bunds near Upstream & downstream portals and Development of upstream and downstream portals of all two diversion tunnels	**1 months**	Month 1	-	Month 1
	-	**Diversion Tunnel-I**				
	-	Excavation - Heading and Benching (Both from upstream and downstream side)	**9 months**	Month 2	-	Month 10
	-	Concreting & Inlet and outlet structure	**8 months**	Month 6	-	Month 13
	-	**Diversion Tunnel-II**				
	-	Excavation - Heading and Benching (Both from upstream and downstream side)	**12 months**	Month 2	-	Month 13
	-	Concreting & Inlet and outlet structure	**10 months**	Month 8	-	Month 17
	-	Installation of diversion tunnel gates	**10 months**	Month 9	-	Month 18
		Upstream pre coffer and main Cofferdam	**6 months**	Month 14	-	Month 19
		Downstream pre coffer and main Cofferdam	**5 months**	Month 15	-	Month 19
2	-	**Dam**				
	-	Excavation on left & right abutment and in intake above El. 1870 m including slope protection	**11 months**	Month 4	-	Month 14
	-	Excavation of Dam below El. 1870 to foundation Level & Plunge Pool	**4 months**	Month 15	-	Month 18
		Foundation Mapping & Treatment, Mud Matting, Concreting in Dam & Plunge Pool including 1st & 2nd stage gate embedment consolidation grouting	**46 months**	Month 17	-	Month 62
	-	Installation of radial, spillway stop logs, auxiliary spillway gates	**24 months**	Month 41	-	Month 64
	-	Curtain grouting and drilling of drainage holes	**20 months**	Month 45	-	Month 64
	-	Miscellaneous and finishing works	**6 months**	Month 61	-	Month 66
3	-	**Intake**				
	-	Concreting of Pedestal for intake and power conduit including 1st stage gate embedment and installation of intake & trash rack gates	**29 months**	Month 25	-	Month 53
4	-	**HRT**				
	-	Open excavation, slope protection, development of portal and excavation of all Adits	**6 months**	Month 1	-	Month 6
	-	Heading and Benching of all HRT faces from Adits	**34 months**	Month 6	-	Month 39
		Concreting of HRT	**20 months**	Month 35	-	Month 54
		Grouting, Cleaning, and finishing works	**13 months**	Month 43	-	Month 55
	-	Plugging of Adits Grouting, Cleaning, and finishing works & Installation of adit plugging gates	**10 months**	Month 56	-	Month 65
5	-	**SURGE SHAFT**				
	-	Open Excavation of Surge Shaft with slope Protection & Excavation of Pilot Shaft	**12 months**	Month 1	-	Month 12
	-	Widening of Shaft from top	**11 months**	Month 31	-	Month 41
	-	Concreting, Grouting and finishing works	**22 months**	Month 43	-	Month 64
6	-	**VALVE HOUSE**				
	-	Excavation of Valve House & Construction of Valve House Building	**8 months**	Month 37	-	Month 44
	-	Concreting of Valve House + embedment of HM works+ Finishing Works	**16 months**	Month 45	-	Month 60

S.No.		ACTIVITY NAME	Duration Provided	Starting Month	-	Ending Month
7		**Pressure Shaft / Penstock**				
	-	Pressure Shaft upstream of Valve House				
	-	Development of Portal of U/G pressure shaft headers P-1 ando P-2	4 months	Month 1	-	Month 4
	-	Penstock Header P-1 & P-2 (Excavation, Construction of rail tracks and pedestals & Erection)	32 months	Month 5	-	Month 36
	-					
		Intermedaite Pressure Shafts IPS-1 to IPS-4				
	-	Excavation, Construction of rail tracks and pedestals & Erection	46 months	Month 5	-	Month 50
	-	Horizontal Intermediate Pressure Shafts- IPS-1 to IPS-4				
	-	Excavation, Construction of rail tracks and pedestals & Erection	46 months	Month 17	-	Month 62
	-	Penstock Wyes	32 months	Month 32	-	Month 63
		Unit Penstocks- (8 Nos)				
	-	Excavation of Adits for Pressure Shafts & Penstocks	12 months	Month 13	-	Month 24
	-	PB-1 to 8 (Excavation, Erection, Grouting and Finishing)	50 months	Month 13	-	Month 62
8	-	**Powerhouse Cavern**				
	-	Development of Portal and construction of Main Access Tunnel	8 months	Month 1	-	Month 8
	-	Adit-A2 (Adit to Powerhouse Crown) & PH Cavity Excavation	40 months	Month 1	-	Month 40
	-	Concreting of Powerhouse & Architectural and finishing works	31 months	Month 34	-	Month 64
9	-	**Transformer Cavern, Bus Ducts & Cable Duct**				
		Excavation of Adit-A3 & Transformer Hall	24 months	Month 7	-	Month 30
	-	Concreting of Transformer Hall	10 months	Month 31	-	Month 40
10	-	**Tailrace Tunnels**				
	-	Excavation of Tailrace Tunnel - Heading and Benching	17 months	Month 13	-	Month 29
	-	Concreting of Tailrace Tunnel, grouting and finishing works & Installation of TRT gates	27 months	Month 30	-	Month 56
11		**Pothead Yard**				
	-	Switch Yard Excavation	8 months	Month 37	-	Month 44
	-	Switch Yard Concreting and other Development works	12 months	Month 49	-	Month 60
12	-	**Electro-Mechanical Equipment**				
	-	Filling and testing of water conductor system	1 months	Month 66	-	Month 66
		Testing And Commissioning				
	-	Unit-1 & 2	1 months	Month 67	-	Month 67
	-	Unit-3 & 4	1 months	Month 68	-	Month 68
	-	Unit-5 & 6	1 months	Month 69	-	Month 69
	-	Unit-7 & 8	1 months	Month 70	-	Month 70
		Unit-1 & 2 of Dam Toe Powerhouse	2 months	Month 71	-	Month 72



OJU HYDROELECTRIC PROJECT

ABSTRACT OF COST ESTIMATES FOR CIVIL AND HYDRO MECHANICAL WORKS

(Price Level May 2022)

DIRECT CHARGES

S.No	Description		Amount(Rs.in Lacs)
I	**WORKS**		
1	A-Preliminary		12758.9
2	B-Land		**12758.9**
3	C-Works		
	C-1 Diversion Tunnel		33350.0
	C-2 Coffer Dams		5765.0
	C-3 Dam		153376.0
	C-4 Hydro Mechanical for C-Works		15677.0
	Sub-total C-Works		**208168.0**
4	J-WORKS		
	J-1 Intake		18565.0
	J-2 Construction Adits and Accessess Tunnels for J-works		17980.0
	J-3 Head Race Tunnel		122360.0
	J-4 Surge Shaft		8190.0
	J-5 Pressure Shaft, Valve Chamber & PEC		71530.0
	J-6 Power House Complex		27210.0
	J-7 Tail Race Tunnel		23910.0
	J-8 Pothead Yard		7515.0
	J-9 Hydro Mechanical for J-Works		1085.0
	Sub-total J-Works		**298345.0**
5	K-Buildings		15948.6
6	M-Plantation		235.0
7	O-Miscellaneous		25517.7
8	P-Maintenance		5290.0
9	Q-Special T & P		200.0
10	R-Communication		25517.7
11	X-Environment, Ecology & Afforestaton		31897.2
12	Y-Losses on Stock		1306.2
	TOTAL I-WORKS		**637943.0**
II	Establishment		26410.0
	(According to CEA Guidelines, April 2012, Revision 3.0)		
III	T &P (1.0% of I-works limited to 200 Lacs)	LS	200.0
IV	Receipts and Recoveries (-)	(-)	1270.0
	TOTAL DIRECT CHARGES		**663283.0**

INDIRECT CHARGES

V	Audit & Accounts @ 0.25% of I-Works		1594.9
VI	Capitalization of abatement of land revenue @ 5% of cost of Culturable land.		320.0
	TOTAL INDIRECT CHARGES		**1914.9**
	TOTAL OF DIRECT & INDIRECT CHARGES		**665197.9**
	TOTAL CIVIL WORKS COST	**Say**	**6,651.98 Crores**

A-PRELIMINARY

S.No.		Description	Unit	Qty.	Rate (Rs)	Amount (Rs. Lacs)
1		Cost of investigations done for PFR preparation				15.00
2		Cost of EIA/EMP Studies				50.00
3		Topographical Surveys				400.00
4		**Geological Investigations**				
	a)	Sub-surface drilling				1500.00
	b)	Drifting				500.00
	c)	Seismic Refraction				25.00
	d)	Labortary Testing				25.00
	e)	In-situ Tesing				75.00
	f)	3-D Logging and geo-mapping				30.00
5		Site specific design earthquake parameter study				6.00
6		Hydrological and silt data collection	(Detail as per Annexure-A-1)			52.75
7		Meteorological data collection	(Detail as per Annexure-A-2)			155.20
8		**Construction material survey**				
	a)	Collection and transportation of samples				8.00
	b)	Laboratory testing of samples				15.00
9		**Seismological Stations (5 Nos)**				
	a)	Setting up	Nos	5	1500000	75.00
	b)	R&M of stations (5 Nos)(@4.0 lac/per year/station)	Sth Year	25	1000000	250.00
10		Hydrulic Model Testing for Power Intake, Dam and Spillway and Tail Race System	Nos	4	250	1000.00
11		**Equipment**				
	a)	Survey and Mathematical Instruments				100.00
	b)	Cost of Communication including V-SAT, Wire less network, Fax, Couriers				200.00
12		Establishment of office and transit camp at site				
	a)	Rent for one no transit camp at Along from 2008 for 10 Years @50000/pm				60.00
	b)	Rent for one no transit camp at Itanagar from 2008 for 10 years @40000/pm				48.00
	c)	Office, furniture, equipment etc.			L.S.	50.00
13		Approach roads for pre-construction investigation for Dam complex, Power House Complex, HRT etc.	m	5000	1500	75.00
14		Vehicles for site inspections including running and maintnance during pre-costruction investigation	(Detail as per Annexure-A-3)			51.05
15		**Design and Engineering**				
		Engineering consultancy and prepartion of DPR and Tender Level Design				2500.00
					TOTAL	**7266.0**
A		Add @ 1 % for building construction workers welfare cess				72.7
B		Add @ 0.1 % for Project Monitoring				7.3
					TOTAL	**7345.9**
					Say	**7350.00**

CARRYING OUT HYDRO METEOROLOGICAL OBSERVATIONS PER YEAR

1		**Discharge measurement /Relative humidity/Temperature**			
a)	i)	1 No gauge reader @Rs. 18000/- PM for twelve months	=	2,16,000	Rs.
	ii)	1 No beldar @ Rs. 12000/- PM for twelve months	=	1,44,000	Rs.
	iii)	T A for above staff	=	25,000	Rs.
	iv)	Bonus for above staff	=	40,000	Rs.
b)		Additional labour for flood seasons i.e. for hourly gauge and for hourly discharge observation for three months			
	i)	2 no gauge reader @ Rs 18000 per month for 3 months	=	1,08,000	Rs.
	ii)	2 no beldar @ Rs 12000 per month for 3 months	=	72,000	Rs.
c)		Labour for gauge site after rainy season			
	i)	1 no Mason @ Rs 18000 per month for 1 month	=	18,000	Rs.
	ii)	2 no beldar @ Rs 12000 per month for 1 month	=	24,000	Rs.
d)		Material and equipments			
	i)	Paint for gauge	=	2,000	Rs.
	ii)	Wooden floats 1000 nos @ Rs. 5 each	=	5,000	Rs.
	iii)	Other misc item i.e stationary, ink, Carbon, papers, stop watch, torches etc.	=	5,000	Rs.
		Sub - total	**=**	**6,59,000**	Rs.
		GRAND TOTAL	**=**	**6.59**	**lakhs**
		CHARGES FOR 8 YEARS		**52.75**	**lakhs**

RAIN GAUGE AND SNOW GAUGE SITES

Sr. No.	Description		Amount in (Rs.)	
a)	Establishment one observer and one helper			
	- One observer @ 18000 /- per month for one year	=	216000	
	- One helper @ Rs 12000 /- month for one year	=	144000	
b)	Material and equipment LS		25000	
	Establishment of laboratory for silt analysis etc. (L.S.)	=	10.00	lakhs
	Sub - total	**=**	**13.85**	**lakhs**
	Add 3% for contingencies	=	0.42	lakhs
c)	Supply of Design storm value from IMD		1.25	lakhs
	Grand Total	**=**	**15.52**	**lakhs**
	CHARGES FOR 10.0 YEARS		**155.20**	**lakhs**

SPECIAL TOOLS AND PLANTS REQUIRED FOR INVESTIGATIONS

Annexure A-3(1)

R/M CHARGES OF 4 NOS INSPECTION VEHICLES (Jeeps)

Sr.No.	Description			Amount Rs. Lakh	
i)	It is proposed that the Inspection Vehicles will cover about 45 Kms distance per day.				
ii)	Total distance covered in a year taking 25 days in a month = 45*12*25	13500 km/year			
iii)	Out turn rate of vehicles @ Rs. 31 per km (Refer Item E-6, Annexure 16-2,Volume-VI)				
iv)	R/M charges per vehicle per Year		=	4.19	lakhs
	R/M charges for 4 vehicles for 1.5 years	4 No. Vehicles	=	25.11	lakhs
		Total	**=**	25.11	**lakhs**

Annexure A-3(2)

R/M CHARGES FOR CARS (2 No)

Sr.No.	Description			Amount Rs. Lakh	
	Establishment				
	It is proposed that the vehicle will cover about 65 kms distance per day.				
	Total distance covered in a year taking 25 days in a month =25*12*65	19500 kms			
	Out turn rate of vehicles @ Rs. 29 per km (Refer Item E-4, Annexure 16-2,Volume-VI)				
	R/M charges per vehicle per Year		=	5.66	lakhs
	R/M charges per vehicle per Year		=	**5.66**	**lakhs**
	R/M charges for two vehicle for 1.5 years		=	16.97	**lakhs**

Annexure A-3(3)

R/M CHARGES FOR TRUCKS (1 No)

Sr.No.	Description			Amount Rs. Lakh	
	Establishment				
	It is proposed that the vehicle will cover about 35 kms				
	distance per day.				
	Total distance covered in a year taking 25 days				
	in a month =25*12*35	10500 kms			
	Out turn rate of vehicles @ Rs.57 per km (Refer Item E-2, Annexure 16-2,Volume-VI)				
	R/M charges per vehicle per Year		=	5.99	lakhs
	R/M charges per vehicle per Year		=	**5.99**	**lakhs**
	R/M charges for one vehicle for 1.5 years		=	8.98	**lakhs**

B - LAND

S.No.		Description	Unit	Govt./ Forest Land		Private Land		Total amount (Rs. Lakhs)
				Area	Amount (Rs. Lakhs)	Area	Amount (Rs. Lakhs)	
1	i)	Land cost asper Annexure B-1	Ha	87.5	104.0	556.5	6323.0	
		TOTAL			**104.00**		**6323.00**	**6427.00**
2	i)	Compensation to forest department for cutting of trees (Approximate 5000 trees @Rs. 1000 per tree)						50.00
	ii)	Compensation for crops and fruit trees @35% cost of private land	35%					2213.05
3		Resettlement & Rehabilitation plan (R & R Plan	As per EIA/EMP					1433.24
4		Solatium charges for compulsory acquisition @ 30% of cost of private land	30%					1896.90
5		Legal charges @ 1% of total cost of land (1% of A)	1%					64.27
6		Interest on 25% amount of total compensation for 2 years of the cost of private land @	12%					189.69
7		Establishment Charges for land acquisition and Rehabilitation (6.25% of A)	6.25%					401.69
8		Cost for demarcation and measurement @ 1% of cost of land (1% of A)	1%					64.27
		TOTAL COST OF LAND						12740.11
A		Add @ 1 % for building construction workers welfare cess						127.4
B		Add @ 0.1 % for Project Monitoring						12.7
							TOTAL	12880.2
							Say	**12885.00**

Note: Detals of land as per Annexure B-1 and details given in drawing for Infrastructure Works/ Job Facilities

Tentative:Land requirement for Oju H.E.P

Sl. No	Zone	Area (Ha)	Facility Areas	Classification of Land (Ha)			Govt. Land/ Forest Land			Private Land		
							Area	Land cost (Rs. In Lakh/Ha)	Land cost (Rs. In lakhs)	Area	Land cost inc. Traditional right (Rs. In Lakh/Ha)	Land cost (Rs. In lakhs)
1	A	175	Reservoir Area	Cultivable land under Horticulture, Agri/Forest	10.125					10.125	15.00	151.88
			Stack Piling, SP-2	Undeveloped cultivable land with gentle slope and flat area with motorable road.	6.750					6.750	12.50	84.38
			Part of Stack Piling, SP-1	Undeveloped cultivable land with gentle slope and flat area without motorable road.	104.625					104.625	11.50	1203.19
			Working Area, A3	Undeveloped /Uncultivable slope land	13.500					13.500	10.00	135
			Part of working area, A2	River Bed	40.000		40.0	1.19	47.51			
					Total	175.0						
2	B	43	Dumping Area D1	Cultivable land under Horticulture, Agri/Forest	2.150					2.150	15.00	32.25
			APP Plant-1	Undeveloped cultivable land with gentle slope and flat area with motorable road.	2.150					2.150	12.50	26.88
			Part of Stack Piling, SP-1	Undeveloped cultivable land with gentle slope and flat area without motorable road.	34.400					34.400	11.50	395.6
			Road R5, R11, R12 and R13	Undeveloped /Uncultivable slope land	4.300					4.300	10.00	43
			Area for Misc. work facility									
					Total	43.0						
3	C	28	Part of working Area, A2	Cultivable land under Horticulture, Agri/Forest	1.400					1.400	15.00	21
			AggregateStorage Bins for BM-1	Undeveloped cultivable land with gentle slope and flat area with motorable road.	1.400					1.400	12.50	17.5
			Store Area, A4	Undeveloped cultivable land with gentle slope and flat area without motorable road.	22.400					22.400	11.50	257.6
			Store Area, A5	Undeveloped /Uncultivable slope land	2.800					2.800	10.00	28
			Track for Diesel Loco									
			Track for Conveyor Belt									
			Road R5, R6 and R11									
			Area for Misc. work facility									
					Total	28.0						
4	D	32	Dam Area	Cultivable land under Horticulture, Agri/Forest	1.350					1.350	15.00	20.25
			DT outlet 1&2	Undeveloped cultivable land with gentle slope and flat area with motorable road.	1.350					1.350	12.50	16.88
			DT outlet 3&4	Undeveloped cultivable land with gentle slope and flat area without motorable road.	21.600					21.600	11.50	248.4
			Adit-1 Portal Area	Undeveloped /Uncultivable slope land	2.700					2.700	10.00	27
			Dumping Area D3	River Bed	5.000		5.0	1.19	5.94			
			Foundation for Cable Cranes									
			Road R5, R6, R7, R8 and R9									
			Area for Misc. work facility									
					Total	32.0						

5	E	38	Adit-2 Portal Area	Cultivable land under Horticulture, Agri/Forest	1.900					1.900	15.00	28.5
			Dumping Area D4	Undeveloped cultivable land with gentle slope and flat area with motorable road.	1.900					1.900	12.50	23.75
			BM-2 Plant Area	Undeveloped cultivable land with gentle slope and flat area without motorable road.	30.400					30.400	11.50	349.6
			APP Plant-2	Undeveloped /Uncultivable slope land	3.800					3.800	10.00	38
			Dumping Area D2									
			Part of Road R6, R6(A) & R6(B)									
			Area for Misc. work facility									
					Total	**38.0**						
6	F	13	Adminstrative Block, A6	Cultivable land under Horticulture, Agri/Forest	0.650					0.650	15.00	9.75
				Undeveloped cultivable land with gentle slope and flat area with motorable road.	0.650					0.650	12.50	8.13
				Undeveloped cultivable land with gentle slope and flat area without motorable road.	10.400					10.400	11.50	119.6
				Undeveloped /Uncultivable slope land	1.300					1.300	10.00	13
					Total	**13.0**						
7	G	96	Explosive Magazine	Cultivable land under Horticulture, Agri/Forest	4.800					4.800	15.00	72
			Security Camp	Undeveloped cultivable land with gentle slope and flat area with motorable road.	4.800					4.800	12.50	60
			Adit-3 Portal	Undeveloped cultivable land with gentle slope and flat area without motorable road.	76.800					76.800	11.50	883.2
			BM-3 and APP-3 Plant	Undeveloped /Uncultivable slope land	9.600					9.600	10.00	96
			Dumping Area D5									
			Dumping Area D6									
			Working Area, A7									
			Colony Area A8									
			Working Area, A9									
			Road R1, R2, R3 and R10									
			Area for Misc. work facility									
					Total	**96.0**						
7	H	54	Adit-4 Portal Area	Cultivable land under Horticulture, Agri/Forest	4.050					4.050	15.00	60.75
			Pothead Yard	Undeveloped cultivable land with gentle slope and flat area with motorable road.	2.700					2.700	12.50	33.75
			Power Complex	Undeveloped cultivable land with gentle slope and flat area without motorable road.	41.850					41.850	11.50	481.28
			All Adits in PH Complex, MAT	Undeveloped /Uncultivable slope land	5.400					5.400	10.00	54
			Surge Shaft									
			Valve Chamber and Pressure Shaft									
			BM-4 Plant Area and working area A11									
			Working Area A10									
			Road R1, R2, R4 and R17									
			Area for Misc. work facility									
					Total	**54.0**						

8	I	37	APP Plant-4	Cultivable land under Horticulture, Agri/Forest	1.850					1.850	15.00	27.75
			TRT outlet	Undeveloped cultivable land with gentle slope and flat area with motorable road.	1.850					1.850	12.50	23.13
			Working Area A12	Undeveloped cultivable land with gentle slope and flat area without motorable road.	29.600					29.600	11.50	340.4
			Dumping Area D7	Undeveloped /Uncultivable slope land	3.700					3.700	10.00	37
			Road R4									
			Area for Misc. work facility									
					Total	37.0						
9		11	Under Ground Structure									
			DT	Undeveloped /Uncultivable slope land	2.000					2.000	10.00	20
			HRT	Undeveloped /Uncultivable slope land	8.000					8.000	10.00	80
			TRT	Undeveloped /Uncultivable slope land	1.000					1.000	10.00	10
			Other under ground structures included in the Zones		Total	11.0						
10		87	Quarry Area									
			RQ-1	Undeveloped /Uncultivable slope land	23.00					23.000	10.00	230
			RQ-2	Undeveloped /Uncultivable slope land	9.00					9.000	10.00	90
			RQ-3	Undeveloped /Uncultivable slope land	12.50					12.500	10.00	125
			RQ-4 (Already included in Zone-F)									
			RQRBM-5 (Already included in Zone-A)									
			RQRBM-6	River Bed	6.50		6.5	1.19	7.72			
			RQRBM-7	River Bed	27.00		27.0	1.19	32.07			
			NRSQ-1	River Bed	9.00		9.0	1.19	10.69			
					Total	87.0						
11		30	Approach Roads									
			R1	Undeveloped /Uncultivable slope land	20.00					20.000	10.00	200
			R2	Undeveloped /Uncultivable slope land	10.00					10.000	10.00	100
			Other Roads and Bridges included in the Zones									
					Total	30.00						
					Total	644.0	87.5		104.0	556.5		6323

C-WORKS

ABSTRACT OF COST

Sl. No.	DESCRIPTION	AMOUNT (Rs. in Lakhs)
C-1	Diversion Tunnel	33350.0
C-2	Coffer Dams	5765.0
C-3	Dam	153376.0
C-4	Hydro Mechanical for C-Works	15677.0
	TOTAL	**208168.0**

C-1 Diversion Tunnels

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
A	**SURFACE WORKS**				
1	Site Clearance (@10 lakhs for 2 sites)		LS		20.0
2	Open Excavation				
	(a) In Soil	54613	m^3	625	341.3
	(b) In Rock	127431	m^3	1110	1414.5
3	Slope Protection				
	(a) Rock Bolt (25mm dia)	9000	Rm	1145	103.1
	(b) Shotcrete M35	900	m^3	14885	134.0
	(c) Welded Wire Mesh	9000	m^2	996	89.6
	(d) Drainage Holes (76mm Dia)	2300	Rm	280	6.4
4	Portal, Inlet & Outlet				
	(a) Concrete (M30A20)	280	m^3	9705	27.2
	(b) Concrete (M25A20)	10655	m^3	8980	956.8
	(c) Concrete (M15A20)	1750	m^3	7300	127.8
	(d) Concrete (M10A20)	1950	m^3	6895	134.5
	(e) Reinforcement Steel - Fe500	742	MT	155750	1155.7
	(f) Compacted Backfill	13344	m^3	380	50.7
5	RCC slab (M20A20)	2308	m^3	8500	196.2
6	Stone craters in wire nets	1730	m^3	4630	80.1
B	**UNDERGROUND WORKS**				
7	(a) Underground Excavation	348945	m^3	2312	8067.6
	(b) Over break	20647	m^3	1541	318.2
8	Tunnel Rock Support				
	(a) Rock bolt (25mm dia)	52066	Rm	1145	596.2
	(b) Rock Anchors (25mm dia)	0	Rm	1145	0.0
	(c) Shotcrete M35	5081	m^3	14885	756.3
	(d) Welded Wire Mesh	31664	m^2	996	315.4
	(e) Forepoleing (32mm Dia)	5790	Rm	1590	92.1
	(f) Steel Ribs - ISHB250	850	MT	206105	1751.9
	(g) Steel Plates	90	MT	202485	182.2
	(h) Tie Rods	15	MT	155750	23.4
	(i) Precast Lagging -75mm thick (M20A20)	879	m^3	19210	168.9
	(j) Backfill Concrete (M15A20)	5500	m^3	7300	401.5
	(k) PVC Water stops	172	Rm	810	1.4
	(l) Drainage Holes (76mm Dia)	3709	Rm	280	10.4
	(m) Drilling for Pregrouting	5000	Rm	1145	57.3
	(n) Cement Pregrouting	500	MT	18340	91.7
	(o) Admixture for pregrouting	20	MT	140	0.0
	(p) Placing Grout Material- Pre Grouting	10000	Bags	743	74.3
9	Tunnel Lining				
	(a) Concrete (M25A20)	106650	m^3	9250	9865.1

	(b) Reinforcement Steel - Fe500	876	MT	155750	1364.4
10	Grouting				
	(I) <u>Drilling</u>				
	(a) Drilling for consolidation grouting	7488	Rm	525	39.3
	(b) Drilling for contact grouting	4680	Rm	430	20.1
	(II) <u>Material</u>				
	(a) Cement (consolidation grouting)	749	MT	18340	137.3
	(b) Admixture (consolidation grouting)	30	MT	140000	41.9
	(c) Cement (Contact Grouting)	140	MT	18340	25.7
	(d) Admixture(Contact Grouting)	6	MT	140000	7.9
	(III) <u>Placing Grout Material</u>				
	(a) Cosolidation Grouting	14976	Bags	2000	299.5
	(b) Contact Grouting	2808	Bags	743	20.9
11	Tunnel Plugging				
	(a) Concrete (M25A20)	2600	m^3	9250	240.5
	(b) Concrete (M20A20)	6700	m^3	8500	569.5
12	Instrumentation @ 1% of cost of works except L.S. Items				303.6
13	Dewatering @ 1% of cost of works except L.S. Items				303.6
14	Contingencies @3% of cost of works except L.S. Items				910.8
15	Work Charged Establishment @ 2% of cost of works except L.S. Items				607.2
				Total	**32503.7**
A	Add @ 1 % for building construction workers welfare cess				325.0
B	Add @ 1.5 % for Insurance of Project Components during Construction				487.6
C	Add @ 0.1 % for Project Monitoring				32.5
				TOTAL	33348.8
				Say	**33350.0**

C-2 Coffer Dams

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. in Lakhs)
1	Site Clearance including boulders and bushes			L.S.	20.0
2	Excavation in Mixed Soil / River Bed Materials				
	(a) Excavation in Common Soil	18437	m^3	625	115.2
	(b) Excavation in Hard Rock	7901	m^3	1110	87.7
3	Dumped Rock fill in Coffer Dam	152441	m^3	1565	2385.7
4	Concrete Cutoff Wall & Membrane (M20A20)	3846	m^3	8500	326.9
5	Reinforcement Steel - Fe500	192	MT	155750	299.0
6	Grouting				
	(a) Drilling	13387	Rm	1400	187.4
	(a) Cement grout	2008	MT	18340	368.3
	(b) Admixture	80	MT	140	0.1
	(a) Placing Grouting material	40161	Bags	2000	803.2
7	PVC Water Stops	886	Rm	810	7.2
8	Maintenance of Coffer Dams @10% of items (1 to 7)				460.1
9	Dismantling and Removal of Coffer Dam (15% of total coffer dam volume)	22866	m^3	625	142.9
10	Dewatering @ 3% of cost of works except L.S. Items				155.5
11	Contingencies @3% of cost of works except L.S. Items				155.5
12	Work Charged Establishment @ 2% of cost of works except L.S. Items				103.7
				Total	**5618.5**
A	Add @ 1 % for building construction workers welfare cess				56.2
B	Add @ 1.5 % for Insurance of Project Components during Construction				84.3
C	Add @ 0.1 % for Project Monitoring				5.6
				TOTAL	5764.6
				Say	**5765.0**

C-3 Dam

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. in Lakhs)
1	Site Clearance		LS		25.0
2	Surface Excavation				
	(a) Common Excavation	701891	m^3	625	4386.8
	(b) Rock Excavation	539226	m^3	1110	5985.4
3	Slope protection works & Rock Support				
	(a) Rock Bolt 25mm dia	17991	Rm	1145	206.0
	(b) Shotcrete M35	1403	m^3	14885	208.9
	(c) Welded Wiremesh	14034	m^2	996	139.8
	(d) Rock Anchor 32mm dia -Plunge Pool	30320	Rm	1515	459.3
4	Foundation Treatment				
A	Drainage Holes (76mm Dia)	27203	Rm	280	76.2
B	Grouting				
	(I) Drilling				
	(a) Drilling for consolidation grouting	31916	Rm	1735	553.7
	(b) Drilling for curtain grouting	5600	Rm	2245	125.7
	(II) Material				
	(a) Cement (Consolidation Grouting)	4787	MT	18340	878.0
	(b) Admixture (Consolidation Grouting)	191	MT	140000	268.1
	(c) Cement curtain grouting	840	MT	18340	154.1
	(d) Admixture curtain grouting	34	MT	140000	47.0
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	95748	Bags	2000	1915.0
	(b) Curtain grouting	16800	Bags	3981	668.8
5	Cement Concrete Works :				
	i) M15A150	429489	m^3	7495	32190.2
	ii) M20A40	11388	m^3	9135	1040.3
	iii) M20A40	152425	m^3	9135	13924.0
	iv) M25A40	445434	m^3	9430	42004.4
	v) M30A20	867	m^3	10540	91.4
	vi) M60A20(HPC) (4 kg microsilica per bag of cement)	12328	m^3	16065	1980.5
	vii) CC Blocks	5589	m^3	17100	955.7
	viii) M20A20-Concrete in Cladding in Plunge Pool	6896	m^3	8500	586.2
	Total Cement Concrete in Dam				**92772.7**
6	Reinforcement Steel - Fe500	15671	MT	155750	24407.6
7	Providing and fixing PVC Water Seal	6325	Rm	810	51.2
8	Providing Lift		LS		80.0
9	Misc. Ancillary Works such as Stair case, Architectural treatment, illumination of Dam etc		LS		80.0
	Sub Total				**133489.4**
10	Instrumentation @ 3.0% of cost of works except L.S. Items				3999.9
11	Dewatering @ 4% of cost of works except L.S. Items				5333.2
12	Contingencies @3% of cost of works except L.S. Items				3999.9

13	Work Charged Establishment @ 2% of cost of works except L.S. Items	2666.6
		149488.9
A	Add @ 1 % for building construction workers welfare cess	1494.9
B	Add @ 1.5 % for Insurance of Project Components during Construction	2242.3
C	Add @ 0.1 % for Project Monitoring	149.5
	Total of Concrete Dam & Spillway	**153376.0**

C-4 COST OF HYDRO MECHANICAL EQUIPMENT (C-WORKS)

Sl. No	Details of Items	Size Capacity	No/Set	Unit	Material +Fabrication Cost	Transportation Insurance and site storage (Rs.) @2%	VAT @4%	Transportation within the site	Erection and Commissioning(E&C) (Rs./MT)	Contractor Profits @20%	Total cost per MT	Unit weight (MT)	Total weight (MT)	Total cost (Rs. Lacs)
1	2	3	4	5	6	7			8		9	10	11	16
1	**Diversion Tunnel Gate**													
a)	Fixed Wheel Gate	4.2m x 10.6m	4 Nos.	MT	264351	5287	10786	11249	22498	59620	373790	106.00	424	1584.9
b)	Embedment Parts (1st & 2nd Stage)		4 Sets.	MT	209203	4184	8535	11249	28122	49715	311009	43.60	174.4	542.4
c)	Rope drum hoist complete with control equipment	(Capacity 160 MT)	4 Sets.	LS										800.0
d)	Hoist supporting structure including housing, foundation anchors etc.		4 Sets.	MT	209203	4184	8535	11249	28122	49715	311009	50.00	200	622.0
	Total													**3549.3**
2	**Spillway Radial Gates & Hoist**	8.0m x 12.18m												
a)	Radial gates		5 Nos.	MT	308222	6164	12575	11249	28122	69519	435851	190.00	950	4140.6
b)	Embedment Parts (1st & 2nd Stage)		5 Sets.	MT	209203	4184	8535	11249	28122	49715	311009	35.10	175.5	545.8
c)	Hydraulic Hoist including power packs and control	(Capacity 2x270 MT)	5 Sets.	LS										2250.0
d)	Support for hoist, approach ladder, walkway etc.		5 Sets.	MT	209203	4184	8535	11249	28122	49715	311009	15.00	75	233.3
	Total													**7169.7**
3	**Spillway Stoplog & Gantry Crane**	8.0m x 20.0m												
a)	Stoplog units		1 Set	MT	212530	4251	8671	11249	16873	48131	301705	210.00	210	633.6
b)	Embedment Parts (1st & 2nd Stage)		5 Sets	MT	209203	4184	8535	11249	28122	49715	311009	60.71	303.55	944.1
c)	Lifting Beam		1 No.	MT	209203	4184	8535	11249	28122	49715	311009	6.50	6.5	20.2
d)	Gantry Crane including reeling drum	(Capacity 50 MT)	1 No.	MT										75.0
e)	Gantry rails and fixtures		1 Set	MT	209203	4184	8535	11249	28122	49715	311009	23.50	23.5	73.1
f)	1st & 2nd stage Embedded parts for storage grooves		1 Set	MT	209203	4184	8535	11249	28122	49715	311009	2.50	2.5	7.8
	Total													**1753.7**
4	**Auxiliary Spillway Gate**	6.0m x 3.2m												
a)	Fixed Wheel Gate		1 No.	MT	264351	5287	10786	11249	22498	59620	373790	7.00	7	26.2
b)	Embedment Parts (1st & 2nd Stage)		1 Set	MT	209203	4184	8535	11249	28122	49715	311009	2.93	2.93	9.1
c)	Lifting Beam		1 No.	MT	209203	4184	8535	11249	28122	49715	311009	2.50	2.5	7.8
	Total													**43.1**
5	**Auxiliary Spillway Bulkhead Gate**	6.0m x 3.2m												
a)	Fixed Wheel Bulkhead Gate		1 No.	MT	264351	5287	10786	11249	22498	59620	373790	7.00	7	26.2
b)	Embedment Parts (1st & 2nd Stage)		1 Set	MT	209203	4184	8535	11249	28122	49715	311009	2.93	2.93	9.1
	Total													**35.3**
6	**Intake Trashracks**	4.4m x 30.0m												
a)	Intake trashracks		5 Sets.	T	181443	3629	7403	11249	22498	43038	269260	45.00	225	605.8
b)	Embedment Parts for complete opening (1st & 2nd Stage)		5 Sets.	T	209203	4184	8535	11249	28122	49715	311009	8.22	41.1	127.8
c)	Lifting Beam		1 No.	T	209203	4184	8535	11249	28122	49715	311009	1.50	1.5	4.7
d)	Trashrack Cleaning Machine complete with rails		1 Set	T										200.0
	Total													**938.3**
7	**Bulk head Gate for Intake with hoists**	6.5m x 7.5m												
a)	Slide Type bulk head gate		2 Nos.	MT	285548	5711	11650	11249	22498	63859	400515	32.00	64	256.3
b)	Embedment Parts (1st & 2nd Stage)		2 Sets.	MT	209203	4184	8368	11249	28122	49715	310842	11.42	22.84	71.0
c)	Rope drum hoist complete with control equipment	(Capacity 45 MT)	2 Sets.	MT								45.00		80.0
	Total													**407.3**
8	**Intake Gates & Hoists**	6.5m x 7.5m												
a)	Intake Gates (FW)		2 Nos.	MT	264351	5287	10786	11249	22498	59620	373790	40.00	80	299.0
b)	Embedment Parts (1st & 2nd Stage)		2 Sets.	MT	209203	4184	8535	11249	28122	49715	311009	14.11	28.22	87.8
c)	Rope drum hoist complete with control equipment	(Capacity 75 MT)	2 Sets.	MT								75.00		100.0
d)	Hoist supporting structure including housing, foundation anchors etc.		2 Sets.	MT	209203	4184	8535	11249	28122	49715	311009	27.00	54	167.9
	Total													**654.7**

	Total	**14551.4**
	Work Charge Establishment and Contingency @5%	727.6
	Total of Hydromechanical Works (C4) (Rs. In Lakhs)	**15279.0**
A	Add @ 1 % for building construction workers welfare cess	152.8
B	Add @ 1.5 % for Insurance of Project Components during Construction	229.2
C	Add @ 0.1 % for Project Monitoring	15.3
	TOTAL	**15676.2**
		15677.0

J-POWER PLANT CIVIL WORKS

ABSTRACT OF COST

Sl. No.	DESCRIPTION	AMOUNT (Rs. in Lakhs)
J-1	Intake	18565.0
J-2	Construction Adits and Accessess Tunnels for J-works	17980.0
J-3	Head Race Tunnel	122360.0
J-4	Surge Shaft	8190.0
J-5	Pressure Shaft and Valve Chamber	71530.0
J-6	Power House Complex	27210.0
J-7	Tail Race Tunnel	23910.0
J-8	Pothead Yard	7515.0
J-9	Hydro Mechanical for J-Works	1085.0
	TOTAL	**298345.0**

INTAKE STRUCTURE

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. in Lakhs)
1	Site Clearance		LS		10.0
2	Excavation				
	(a) Excavation in Common Soil	27000	m^3	625	168.8
	(b) Excavation in Hard Rock	63000	m^3	1110	699.3
3	Slope Protection				
	(a) Rock Bolt 25mm dia	5751	Rm	1145	65.8
	(b) Shotcrete M35	575	m^3	14885	85.6
	(c) Welded Wiremesh	5751	m^2	996	57.3
	(d) Drainage Hole (76dia)	1438	Rm	280	4.0
4	Portal				
	(a) Concrete (M25A20)	19027	m^3	8980	1708.6
	(b) Reinforcement Steel -Fe500	1522	MT	155750	2370.5
5	Intake Foundation				
	(a) Concrete (M15A20)	165000	m^3	7300	12045.0
	(b) Concrete (M30A20)	189	m^3	9705	18.3
	Sub - Total				**17233.3**
6	Contingencies @3% of cost of works except L.S. Items				516.7
7	Work Charged Establishment @ 2% of cost of works except L.S. Items				344.5
	TOTAL OF INTAKE STRUCTURE				**18094.5**
A	Add @ 1 % for building construction workers welfare cess				180.9
B	Add @ 1.5 % for Insurance of Project Components during Construction				271.4
C	Add @ 0.1 % for Project Monitoring				18.1
				TOTAL	**18564.9**
	TOTAL OF DAM & INTAKE STRUCTURE				**18565.0**

J-2 Construction Adits and Accessess Tunnels for J-works

ABSTRACT OF COST

Sl. No.	DESCRIPTION	AMOUNT (Rs. in Lakhs)
J-2a	Construction Adits and Accessess Tunnels for J-works	15940.0
J-2b	Main Access Tunnel Tunnel	2040.0
	TOTAL	**17980.0**

J-2a Construction Adits and Accessess Tunnels for J-works

Adit-1 , L=200.50m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-2 , L=325.50m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-3 , L=480.96m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-4 , L=251.94m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-5 , L=480.96m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-6 , L=251.94m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A1 , L=108.15m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A2 , L= 76.32m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A3 , L=428.80m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A4 , L=356.34m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A5 , L=202.93m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A6 , L=157.94m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A7 , L=268.13m ,6m(W) X 7m(H) , Modified D-Shaped
Adit-A8 , L=[illegible] ,6m(W) X 7m(H) , Modified D-Shaped

Total length = 3564 m

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
A	**SURFACE WORKS**				
1	Site Clearance(@4.0lakhs for 10 sites)				40.0
2	Open Excavation				
	(a) Open Excavation	47508	m^3	625	296.9
	(b) In Rock	20360	m^3	1110	226.0
3	Slope Protection				
	(a) Rock bolt (25mm dia)	11580	Rm	1145	132.6
	(b) Shotcrete M35	852	m^3	14885	126.8
	(c) Welded Wire Mesh	8522	m^2	996	84.9
	(d) Concrete (M20A20)	644	m^3	8500	54.7
	(e) Backfill Concrete (M15A20)	127	m^3	7300	9.3
	(f) Reinforcement Steel - Fe500	52	MT	155750	81.0
	(g) Drainage Holes (76mm Dia)	1242	Rm	280	3.5
B	**UNDERGROUND WORKS**				
4	Underground Excavation				
	(a) Underground Excavation	215354	m^3	2632	5668.1
	(b) Over break	15035	m^3	1755	263.8
5	Tunnel Rock Support				
	(a) Rock Bolt (25mm dia)	33475	Rm	1145	383.3
	(b) Rock Anchors (25mm dia)	46800	Rm	1235	578.0
	(c) Shotcrete M35	5605	m^3	14885	834.3
	(d) Welded Wire Mesh	44000	m^3	996	438.2
	(e) Forepoleing (32mm Dia)	18281	Rm	1590	290.7
	(f) Steel Ribs - ISHB200	1000	MT	206105	2061.1
	(g) Steel Plates	42	MT	202485	85.0
	(h) Tie Rods	9	MT	155750	14.0
	(i) Precast Lagging -75mm thick (M20A20)	713	m^3	19210	137.0
	(j) Backfill Concrete (M15A20)	4188	m^3	7300	305.7
6	Concrete Works				
	(a) Concrete (M30A20)	10	m^3	9705	1.0
	(b) Concrete (M20A20)	9214	m^3	8500	783.2
7	Drainage Holes (76mm Dia)	16250	Rm	280	45.5
8	Grouting in Plugging Zone				
	(I) Drilling				

	(a) Drilling for consolidation grouting	3664	Rm	525	19.2
	(b) Drilling for contact grouting	255	Rm	430	1.1
	(II) Material				
	(a) Cement (Consolidation Grouting)	366	MT	18340	67.2
	(b) Admixture (Consolidation Grouting)	15	MT	140000	20.5
	(c) Cement (Contact Grouting)	8	MT	18340	1.4
	(d) Admixture(Contact Grouting)	0.3	MT	140000	0.4
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	7328	Bags	2000	146.6
	(b) Contact Grouting	153	Bags	743	1.1
9	Tunnel Plugging				
	(a) Concrete (M25A20)	13587	m^3	8980	1220.1
	(b) Boulder Filling	116	m^3	1175	1.4
	(c) Reinforcement Steel - Fe500	107	MT	155750	166.7
10	Instrumentation @ 0.5% of cost of works except L.S. Items				72.8
11	Dewatering @ 1% of cost of works except L.S. Items				145.5
12	Contingencies @3% of cost of works except L.S. Items				436.5
13	Work Charged Establishment @ 2% of cost of works except L.S. Items				291.0
				Total	**15536.0**
A	Add @ 1 % for building construction workers welfare cess				155.4
B	Add @ 1.5 % for Insurance of Project Components during Construction				233.0
C	Add @ 0.1 % for Project Monitoring				15.5
				TOTAL	15940.0
				Say	**15940.0**

J-2b Main Access Tunnel (8m(W) X 8m(H) , Modified D-Shaped)

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	Site Clearance		LS		5.0
2	(a) Underground Excavation	37670	m^3	2632	991.5
	(b) Over break	1884	m^3	1755	33.1
3	Tunnel Rock Support				
	(a) Rock Bolt (25mm dia)	7087	Rm	1145	81.1
	(b) Rock Anchors (25mm dia)	1893	Rm	1235	23.4
	(c) Shotcrete M35	1025	m^3	14885	152.6
	(d) Welded Wire Mesh	8000	m^3	996	79.7
	(e) Forepoleing (32mm Dia)	2282	Rm	1590	36.3
	(f) Steel Ribs - ISHB200	114	MT	206105	235.0
	(g) Steel Plates	7	MT	202485	14.2
	(h) Tie Rods	2	MT	155750	2.5
	(i) Precast Lagging -75mm thick (M20A20)	81	m^3	19210	15.6
	(j) Backfill Concrete (M15A20)	562	m^3	7300	41.0
4	Drainage Holes (76mm Dia)	2253	Rm	280	6.3
5	Concrete Works				
	(a) Concrete (M20A20)	1663	m^3	8500	141.4
6	Instrumentation @ 1% of cost of works except L.S. Items				18.5
7	Dewatering @ 1% of cost of works except L.S. Items				18.5
8	Contingencies @3% of cost of works except L.S. Items				55.6
9	Work Charged Establishment @ 2% of cost of works except L.S. Items				37.1
				Total	**1988**
A	Add @ 1 % for building construction workers welfare cess				19.9
B	Add @ 1.5 % for Insurance of Project Components during Construction				29.8
C	Add @ 0.1 % for Project Monitoring				2.0
				TOTAL	2039.9
				Say	**2040.0**

J-3 Head Race Tunnel

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	(a) Underground Excavation	1686380	m^3	2499	42142.6
	(b) Over break	94682	m^3	1666	1577.4
2	Tunnel Rock Support				
	(a) Rock Bolt (25mm dia)	277849	Rm	1145	3181.4
	(b) Rock Anchors (25mm dia)	99890	Rm	1145	1143.7
	(c) Shotcrete M35	19211	m^3	14885	2859.6
	(d) Welded Wire Mesh	55000	m^2	996	547.8
	(e) Forepoleing (32mm Dia)	79199	Rm	1590	1259.3
	(f) Steel Ribs - ISHB250	4550	MT	206105	9377.8
	(g) Steel Plates	437	MT	202485	884.9
	(h) Tie Rods	51	MT	155750	79.4
	(i) Precast Lagging -75mm thick (M20A20)	3572	m^3	19210	686.2
	(j) Backfill Concrete (M15A20)	25500	m^3	7300	1861.5
	(k) Drilling for Pregrouting	57953	Rm	1145	663.6
	(l) Cement Pregrouting	5795	MT	18340	1062.9
	(m) Admixture for pregrouting	232	MT	140000	324.5
	(n) Placing Grout Material- Pre Grouting	115906	Bags	743	861.2
3	Drainage Holes (76mm Dia)	13701	Rm	280	38.4
4	Tunnel Lining				
	(a) Concrete (M25A20)	410480	m^3	9250	37969.4
	(b) Reinforcement Steel - Fe500	1488	MT	155750	2317.6
5	Grouting				
	(I) Drilling				
	(a) Drilling for Consolidation grouting	23555	Rm	525	123.7
	(b) Drilling for contact grouting	29444	Rm	430	126.6
	(II) Material				
	(a) Cement (Consolidation grouting)	2356	MT	18340	432.0
	(b) Admixture (Consolidation Grouting)	94	MT	140000	131.9
	(c) Cement (Contact Grouting)	883	MT	18340	162.0
	(d) Admixture(Contact Grouting)	35	MT	140000	49.5
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	47110	Bags	2000	942.2
	(b) Contact Grouting	17666	Bags	743	131.3
6	Instrumentation @ 1% of cost of works except L.S. Items				1109.4
7	Dewatering @ 1.5% of cost of works except L.S. Items				1664.1
8	Contingencies @3% of cost of works except L.S. Items				3328.1
9	Work Charged Establishment @ 2% of cost of works except L.S. Items				2218.8
				Total	**119258.4**
A	Add @ 1 % for building construction workers welfare cess				1192.6
B	Add @ 1.5 % for Insurance of Project Components during Construction				1788.9
C	Add @ 0.1 % for Project Monitoring				119.3
				TOTAL	122359.2
				Say	**122360.0**

J-4 Surge Shaft

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
A	**SURFACE WORKS**				
1	Site Clearance				10.0
2	Open Excavation				
	(a) Excavation on Common Soil	64135	m^3	625	400.8
	(b) Excavation in Hard Rock	27487	m^3	1110	305.1
3	Slope Protecton				
	(a) Rock Bolt 25mm Dia	3713	Rm	1145	42.5
	(b) Shotcrete M35	297	m^3	14885	44.2
	(c) Welded Wire Mesh	2970	m^2	996	29.6
	(d) Drainage Holes (76mm Dia)	3062	Rm	280	8.6
B	**UNDERGROUND WORKS**				
4	(a) Underground Excavation	72660	m^3	2740	1990.9
	(b) Over break (5% of total excavation)	3633	m^3	1827	66.4
5	Rock Support				
	(a) Rock Bolt 25mm Dia	26259	Rm	1220	320.4
	(b) Rock Anchors (25mm dia)	8640	Rm	1220	105.4
	(c) Shotcrete M35	937	m^3	14885	139.5
	(d) Welded Wire Mesh	9369	m^2	996	93.3
	(e) Steel Ribs - ISHB250	283	MT	206105	583.5
	(f) Precast Lagging -75mm thick (M20A20)	198	m^3	19210	38.0
6	Concrete Work				
	(a) Concrete (M25A20)	13044	m^3	8980	1171.3
	(b) Concrete (M15A20)	920	m^3	7300	67.2
	(c) Reinforcement Steel - Fe500	1044	MT	155750	1626.0
7	Grouting				
	(I) Drilling				
	(a) Drilling for consolidation grouting	5205	Rm	525	27.3
	(b) Drilling for contact grouting	1377	Rm	430	5.9
	(II) Material				
	(a) Cement (Consolidation Grouting)	521	MT	18340	95.5
	(b) Admixture (Consolidation Grouting)	21	MT	140000	29.1
	(c) Cement (Contact Grouting)	41	MT	18340	7.6
	(d) Admixture(Contact Grouting)	2	MT	140000	2.3
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	10410	Bags	2000	208.2
	(b) Contact Grouting	626	Bags	743	4.7
8	Instrumentation @ 1% of cost of works except L.S. Items				74.1
9	Dewatering @ 1.5% of cost of works except L.S. Items				111.2
10	Contingencies @3% of cost of works except L.S. Items				222.4
11	Work Charged Establishment @ 2% of cost of works except L.S. Items				148.3
					7980.0

A	Add @ 1 % for building construction workers welfare cess	79.8
B	Add @ 1.5 % for Insurance of Project Components during Construction	119.7
C	Add @ 0.1 % for Project Monitoring	8.0
	TOTAL	8187.5
	TOTAL OF SURGE SHAFT	**8190.0**

J-5 Pressure Shaft, Valve Chamber & Penstock Erection Chambers

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	Underground Excavation				
i)	(a) Valve Chamber & Penstock Erection Chamber	60142	m^3	2110	1269.0
	(b) Over break (5% of total excavation)	3007	m^3	1407	42.3
ii)	(a) Pressure Shaft in Horizontal reach	55000	m^3	3087	1697.7
	(b) Over break (5% of total excavation)	2750	m^3	2058	56.6
iii)	(a) Pressure Shaft in Vertical reach	75000	m^3	22184	16638.2
	(b) Over break (5% of total excavation)	3750	m^3	2058	77.2
2	Rock Support				
	(a) Rock Bolt 25mm Dia	42586	Rm	1145	487.6
	(b) Rock Bolt 25mm Dia (Pressure Shaft)	54000	Rm	2470	1333.8
	(c) Shotcrete M35	2739	m^3	14885	407.7
	(d) Welded Wire Mesh	5215	m^2	996	51.9
	(e) Steel liner - ASTM537 Cl. II	15000	MT	220300	33045.0
3	Pressure Shaft & Valve Chamber Concrete Work				
	(a) Backfill Concrete (Horizontal PS - M15A20)	38000	m^3	8680	3298.4
	(b) Backfill Concrete (Vertical PS - M15A20)	45000	m^3	9550	4297.5
	(c) Concrete (M20A20)	1220	m^3	8500	103.7
	(d) Reinforcement Steel - Fe500	85	MT	155750	132.4
4	Grouting				
	(I) Drilling				
	(a) Drilling for consolidation grouting	45000	Rm	525	236.3
	(b) Drilling for contact grouting	7000	Rm	430	30.1
	(II) Material				
	(a) Cement (Consolidation Grouting)	4500	MT	18340	825.3
	(b) Admixture (Consolidation Grouting)	180	MT	140000	252.0
	(c) Cement (Contact Grouting)	210	MT	18340	38.5
	(d) Admixture(Contact Grouting)	8	MT	140000	11.8
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	90000	Bags	2000	1800.0
	(b) Contact Grouting	-50924	Bags	743	-378.4
5	Drainage Holes (76mm Dia)	5563	Rm	280	15.6
6	Instrumentation @ 0.5% of cost of works except L.S. Items				328.9
7	Dewatering @ 0.5% of cost of works except L.S. Items				328.9
8	Contingencies @3% of cost of works except L.S. Items				1973.1
9	Work Charged Establishment @ 2% of cost of works except L.S. Items				1315.4
				TOTAL	**69717.0**
A	Add @ 1 % for building construction workers welfare cess				697.2
B	Add @ 1.5 % for Insurance of Project Components during Construction				1045.8
C	Add @ 0.1 % for Project Monitoring				69.7
				TOTAL	71529.6
	TOTAL OF PRESSURE SHAFT				**71530.0**

J-6 POWER HOUSE COMPLEX

ABSTRACT OF COST

Sl. No.	DESCRIPTION	AMOUNT (Rs. in Lakhs)
J-6a	Power House Cavern	18095.0
J-6b	Transformer Hall Cavern	5955.0
J-6c	Bus Duct & Cable Tunnel	340.0
J-6d	Draft Tube Tunnels	2820.0
	TOTAL	**27210.0**

J-6a Power House Cavern

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	(a) Underground Excavation	224811	m^3	2110	4743.5
	(b) Over break (5% of total excavation)	11241	m^3	1407	158.1
2	Rock Support				
	(a) Rock bolt (32mm dia)	103218	Rm	1515	1563.8
	(b) Shotcrete M35	3750	m^3	14885	558.2
	(c) Welded Wiremesh	25000	m^2	996	249.0
3	Power House Foundation				
	(a) Concrete (M20A20)	20792	m^3	8715	1812.0
	(b) Reinforcement Steel - Fe500	2079	MT	155750	3238.0
4	Power House Super Structure				
	(a) Concrete (M25A20)	11649	m^3	9675	1127.0
	(b) Reinforcement Steel - Fe500	1281	MT	155750	1995.2
5	Drainage Holes (76mm Dia)	7136	Rm	280	20.0
6	**Miscellaneous & Ancillary Works**				
	(a) Providing and fixing PVC seal		LS		10.0
	(b) Elevators		LS		150.0
	(c) Water Supply & Sewage		LS		25.0
	(d) Architectural Work/ Finish				
	- Floor	12259	m^2	2000	245.2
	- Wall	15385	m^2	1500	230.8
	- Acid proof floor	500	m^2	2500	12.5
	(e) Sanitary and Sewage treatment		LS		20.0
	(f) False Ceiling including Frame work	6335	m^2	2500	158.4
	(g) Plumbing and Drainage		LS		20.0
	(h) Mic. Metal Works		LS		20.0
	(i) Collapsible Shutters		LS		15.0
	(j) Doors & Window		LS		15.0
	(k) Damp proof		LS		25.0
	(l) Railing for stairs		LS		10.0
	(m) Architecture fee		LS		15.0
7	Instrumentation @ 1% of cost of works except L.S. Items				154.6
8	Dewatering @ 1.5% of cost of works except L.S. Items				232.0
9	Grouting @ 0.25% of cost of works except L.S. Items				38.7
10	Contingencies @3% of cost of works except L.S. Items				463.9
11	Work Charged Establishment @ 2% of cost of works except L.S. Items				309.3
				TOTAL	**17636.0**
A	Add @ 1 % for building construction workers welfare cess				176.4
B	Add @ 1.5 % for Insurance of Project Components during Construction				264.5
C	Add @ 0.1 % for Project Monitoring				17.6
				TOTAL	**18094.5**
				Say	**18095.0**

J-6b Transformer Hall Cavern

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	(a) Underground Excavation	112950	m^3	2110	2383.2
	(b) Over break (5% of total excavation)	5648	m^3	1407	79.4
2	Rock Support				
	(a) Rock bolt (32mm dia)	56905	Rm	1515	862.1
	(b) Shotcrete M35	2625	m^3	14885	390.7
	(c) Welded Wiremesh	17500	m^2	996	174.3
3	Transformer Hall Concrete Work				
	(a) Concrete (M25A20)	5722	m^3	9675	553.6
	(b) Reinforcement Steel - Fe500	458	MT	155750	713.3
	(c) Rail Track for Transformer	90	MT	202485	182.2
4	Drainage Holes (76mm Dia)	4943	Rm	280	13.8
5	Brick Masonry (1 : 4)	572	m^3	8425	48.2
6	Architectural Work/ Finish		LS		50.0
7	Instrumentation @ 0.5% of cost of works except L.S. Items				27.0
8	Dewatering @ 1% of cost of works except L.S. Items				54.0
9	Contingencies @3% of cost of works except L.S. Items				162.0
10	Work Charged Establishment @ 2% of cost of works except L.S. Items				108.0
				TOTAL	**5802.1**
A	Add @ 1 % for building construction workers welfare cess				58.0
B	Add @ 1.5 % for Insurance of Project Components during Construction				87.0
C	Add @ 0.1 % for Project Monitoring				5.8
				TOTAL	**5953.0**
				Say	**5955.0**

J-6c Bus Duct & Cable Tunnel

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	(a) Underground Excavation	6715	m^3	2632	176.7
	(b) Over break	369	m^3	1755	6.5
2	Tunnel Rock Support				
	(a) Rock bolt (25mm dia)	2951	Rm	1145	33.8
	(b) Shotcrete M35	369	m^3	14885	54.9
	(c) Welded Wiremesh	3690	m^2	996	36.8
3	Drainage Holes (76mm Dia)	641	Rm	280	1.8
4	Instrumentation @ 0.5% of cost of works except L.S. Items				1.6
5	Dewatering @ 1.0% of cost of works except L.S. Items				3.1
6	Contingencies @3% of cost of works except L.S. Items				9.3
7	Work Charged Establishment @ 2% of cost of works except L.S. Items				6.2
				TOTAL	**330.7**
A	Add @ 1 % for building construction workers welfare cess				3.3
B	Add @ 1.5 % for Insurance of Project Components during Construction				5.0
C	Add @ 0.1 % for Project Monitoring				0.3
				TOTAL	**339.3**
				Say	**340.0**

J-6e Draft Tube Tunnels

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	(a) Underground Excavation	24275	m^3	2632	638.9
	(b) Over break (5% of total excavation)	1214	m^3	1755	21.3
2	Tunnel Rock Support				
	(a) Rock Bolt (25mm dia)	4051	Rm	1145	46.4
	(b) Shotcrete M35	393	m^3	14885	58.4
	(c) Welded Wiremesh	3600	m^2	996	35.9
3	Tunnel Lining				
	(a) Concrete (M20A20)	7800	m^3	8500	663.0
	(b) Concrete (M30A20)	160	m^3	9705	15.5
	(c) Reinforcement Steel - Fe500	624	MT	155750	971.9
	(d) Drainage Holes (76mm Dia)	405	Rm	280	1.1
4	Grouting				
	(I) Drilling				
	(a) Drilling for consolidation grouting	1620	Rm	525	8.5
	(b) Drilling for contact grouting	405	Rm	430	1.7
	(II) Material				
	(a) Cement (Consolidation Grouting)	162	MT	18340	29.7
	(b) Admixture (Consolidation Grouting)	6	MT	140000	9.1
	(c) Cement (Contact Grouting)	6	MT	18340	1.1
	(d) Admixture(Contact Grouting)	0	MT	140000	0.3
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	3240	Bags	2000	64.8
	(b) Contact Grouting	122	Bags	743	0.9
5	Instrumentation @ 0.5% of cost of works except L.S. Items				12.8
6	Dewatering @ 1.5% of cost of works except L.S. Items				38.5
7	Contingencies @3% of cost of works except L.S. Items				77.1
8	Work Charged Establishment @ 2% of cost of works except L.S. Items				51.4
				Total	**2748.4**
A	Add @ 1 % for building construction workers welfare cess				27.5
B	Add @ 1.5 % for Insurance of Project Components during Construction				41.2
C	Add @ 0.1 % for Project Monitoring				2.7
				TOTAL	**2819.9**
				Say	**2820.0**

J-7 Tail Race Tunnel

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
A	**SURFACE WORKS**				
1	Site Clearance		LS		10.0
2	Open Excavation				
	(a) In Soil	9061	m^3	625	56.6
	(b) In Rock	3883	m^3	1110	43.1
3	Slope Protection				
	(a) Rock Bolt (25mm dia)	334	Rm	1145	3.8
	(b) Shotcrete M35	38	m^3	14885	5.7
	(c) Welded Wiremesh	380	m^2	996	3.8
	(d) Drainage Holes (76mm Dia)	95	Rm	280	0.3
4	Portal, Inlet & Outlet				
	(a) Concrete (M25A20)	1661	m^3	9250	153.6
	(b) Reinforcement Steel - Fe500	118	MT	155750	183.8
	(c) Stone Masonry (1:6)	57	m^3	4360	2.5
B	**UNDERGROUND WORKS**				
5	(a) Underground Excavation	206371	m^3	2499	5157.2
	(b) Over break	11900	m^3	1666	198.3
6	Tunnel Rock Support				
	(a) Rock Bolt (25mm dia)	70424	Rm	1145	806.4
	(b) Shotcrete M35	5773	m^3	14885	859.3
	(c) Welded Wiremesh	26000	m^2	996	259.0
	(d) Forepoleing (32mm Dia)	23820	Rm	1590	378.7
	(e) Steel Ribs - ISHB250	978	MT	206105	2015.7
	(f) Steel Plates	65	MT	202485	131.6
	(g) Tie Rods	8	MT	155750	12.5
	(h) Precast Lagging -75mm thick (M20A20)	647	m^3	19210	124.3
	(i) Drilling for Pregrouting	1681	Rm	1145	19.2

	(j) Cement Pregrouting	168	MT	18340	30.8
	(k) Admixture for pregrouting	7	Rm	140000	9.4
	(l) Placing Grout Material- Pre Grouting	3362	Bags	743	25.0
	(m) Backfill Concrete (M15A20)	12763	m^3	7300	931.7
7	Drainage Holes (76mm Dia)	3531	Rm	280	9.9
8	Tunnel Lining				
	(a) Concrete (M20A20)	48947	m^3	8500	4160.5
	(b) Reinforcement Steel - Fe500	2447	MT	155750	3811.2
9	Grouting				
	(I) Drilling				
	(a) Drilling for Consolidation grouting	32781	Rm	525	172.1
	(b) Drilling for contact grouting	6185	Rm	430	26.6
	(II) Material				
	(a) Cement (Consolidation Grouting)	3278	MT	18340	601.2
	(b) Admixture (Consolidation Grouting)	131	MT	140000	183.6
	(c) Cement (Contact Grouting)	206	MT	18340	37.8
	(d) Admixture(Contact Grouting)	8	MT	140000	11.5
	(III) Placing Grout Material				
	(a) Cosolidation Grouting	65562	Bags	2000	1311.2
	(b) Contact Grouting	4123	Bags	743	30.6
10	Instrumentation @ 0.5% of cost of works except L.S. Items				108.8
11	Dewatering @ 1.5% of cost of works except L.S. Items				326.5
12	Contingencies @3% of cost of works except L.S. Items				653.1
13	Work Charged Establishment @ 2% of cost of works except L.S. Items				435.4
				Total	**23302.3**
A	Add @ 1 % for building construction workers welfare cess				233.0
B	Add @ 1.5 % for Insurance of Project Components during Construction				349.5
C	Add @ 0.1 % for Project Monitoring				23.3
				TOTAL	**23908.2**
				Say	**23910.0**

J-8 Pothead Yard

Sl. No.	DESCRIPTION	Qty	Unit	Rate (Rs.)	AMOUNT (Rs. Lakhs)
1	Site Clearance		LS		10.0
2	Open Excavation				
	(a) In Soil	177444	m^3	625	1109.0
	(b) In Rock	411081	m^3	1110	4563.0
3	Slope Protection				
	(a) Rock Bolt (25mm dia)	40040	Rm	1145	458.5
	(b) Shotcrete M35	2002	m^3	14885	298.0
	(c) Welded Wiremesh	20020	m^2	996	199.4
	(d) Drainage Holes (76mm Dia)	6256	Rm	280	17.5
4	Concrete Work				
	(a) M25A20	385	m^3	8980	34.6
	(b) Reinforcement Steel - Fe500	39	MT	155750	60.7
5	Brick Masonry (1 : 4)	166	m^3	8425	14.0
6	Roof Russ				
	a) Truss	12	MT	202485	24.3
	b) Roofing	398	Sqm	1000	4.0
7	Fencing		LS		25.0
8	Fire Fighting		LS		25.0
9	Security Gate		LS		20.0
10	Switchyard foundation		LS		50.0
	Sub Total				**6913.0**
11	Dewatering @ 1% of cost of works except L.S. Items				67.8
12	Contingencies @3% of cost of works except L.S. Items				203.4
13	Work Charged Establishment @ 2% of cost of works except L.S. Items				135.6
				TOTAL	**7319.7**
A	Add @ 1 % for building construction workers welfare cess				73.2
B	Add @ 1.5 % for Insurance of Project Components during Construction				109.8
C	Add @ 0.1 % for Project Monitoring				7.3
				TOTAL	**7510.0**
				Say	**7515.0**

J-9 COST OF HYDRO MECHANICAL EQUIPMENT (J-WORKS)

Sl. No	Details of Items	Size Capacity	No/Set	Unit	Material +Fabrication Cost	Transportation Insurance and site storage (Rs.) @2%	VAT @4%	Transportation within the site	Erection and Commissioning(E&C) (Rs./MT)	Contractor Profits @20%	Total cost per MT	Unit weight (MT)	Total weight (MT)	Total cost without Taxes and duties (Rs. Lacs) (without MPP)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*12*	*13*	*10*	*11*	*16*
1	**Draft tube gate & gantry crane**	6.0m x 5.76m												
a)	Slide gate		8 Nos.	T	285548	5711	11650	11249	22498	63859	400515	19.00	152	608.8
b)	Embedment Parts (1st & 2nd Stage)		8 Sets.	T	209203	4184	8535	11249	28122	49715	311009	8.17	65.36	203.3
c)	Lifting beam		1 No.	T	209203	4184	8535	11249	28122	49715	311009	5.00	5	15.6
d)	Gantry crane including cable reeling drum	(Capacity 25 MT)	1 Set	LS										20.0
e)	Gantry rail and fixtures		1 Set	T	209203	4184	8535	11249	28122	49715	311009	23.50	23.5	73.1
	Total													**920.7**
2	**Adit Gates**	2.2m x 2.2m												
a)	**Gate-1**													
i)	Gate weight		1 No.	T	209203	4184	8535	11249	28122	49715	311009	6.70	6.7	20.8
ii)	Embedment Parts (1st & 2nd Stage)		1 Set	T	209203	4184	8535	11249	28122	49715	311009	2.27	2.27	7.1
	Total													**27.9**
a)	**Gate-Adit-2**													
i)	Gate weight		1 No.	T	209203	4184	8535	11249	28122	49715	311009	6.70	6.7	20.8
ii)	Embedment Parts (1st & 2nd Stage)		1 Set	T	209203	4184	8535	11249	28122	49715	311009	2.27	2.27	7.1
	Total													**27.9**
b)	**Gate-Adit-3**													
i)	Gate weight		1 No.	T	209203	4184	8535	11249	28122	49715	311009	6.70	6.7	20.8
ii)	Embedment Parts (1st & 2nd Stage)		1 Set	T	209203	4184	8535	11249	28122	49715	311009	2.27	2.27	7.1
	Total													**27.9**

	Total	**1004.4**
	Work Charge Establishment and Contingency @5%	50.2
	TOTAL	**1054.6**
A	Add @ 1 % for building construction workers welfare cess	10.5
B	Add @ 1.5 % for Insurance of Project Components during Construction	15.8
C	Add @ 0.1 % for Project Monitoring	1.1
	TOTAL	**1082.0**
	Total of Hydromechanical Works (J8) (Rs. In Lakhs)	**1085.0**

K- BUILDINGS
COST OF BUILDINGS
ABSTRACT OF COST

S.No.		Description	Amount (Rs. Lacs)
1		**Residential Buildings**	
	a)	Permanent (Item : K-1)	2611.00
	b)	Temporary (Item : K-1)	3630.00
2		**Non-residential Buildings**	
	a)	Permanent (Item : K-2)	3100.00
	b)	Temporary (Item : K-2)	3711.00
3		**Yards**	
		Permanent (Item : K-2)	55.00
		Temporary (Item : K-2)	550.00
		TOTAL	**13657.00**
A		Add @ 1 % for building construction workers welfare cess	136.6
B		Add @ 0.1 % for Project Monitoring	13.7
		TOTAL	13807.2
		Say	**13810.00**

COST ESTIMATE OF RESIDENTIAL BUILDINGS

S.No.	Description		Plinth Area (Sq. m)	Rate (Rs./Sq m)	Amount (Rs. Lacs)
A.	**Residential Buildings- Permanent**				
	Building Cost (Item : K-3)		12575	13,850	1741.64
	Allowing escalation	19.4%		2684	337.53
	Land development	1.5%			26.12
	Colony roads	2.0%			34.83
	Fencing, boundary walls, security/ observation booths	1.0%			17.42
	Lawns, Gardens and plantation	1.0%			17.42
	Internal water supply	5.0%			87.08
	Internal sanitation	5.0%			87.08
	Electrical Installations	7.0%			121.91
	Retaining wall & terracing	8.0%			139.33
				Total	2610.37
				Say	**2611.00**
B.	**Residential Buildings- Temporary**				
	Building Cost (Item : K-3) Rate (3/4 of Rs. 13850)		25545	10388	2653.49
	Allowing escalation	19.4%		2013	514.25
	Land development	1.5%			26.12
	Colony roads	2.0%			34.83
	Fencing, boundary walls, security/ observation booths	1.0%			17.42
	Lawns, Gardens and plantation	1.0%			17.42
	Internal water supply	4.0%			69.67
	Internal sanitation	4.0%			69.67
	Electrical Installations @ 7%	5.0%			87.08
	Retaining wall & terracing	8.0%			139.33
				Total	3629.27
				Say	**3630.00**

COST ESTIMATE OF NON-RESIDENTIAL BUILDINGS

S.No.	Description		Plinth Area (Sq. m)	Rate (Rs./Sq m)	Amount (Rs. Lacs)
A.	**Non-Residential Buildings- Permanent**				
	Building Cost (Item : K-3)		16925	12,000	2031.00
	Allowing escalation	19.4%		2326	393.61
	Building Cost at Gurgaon for office		600	38000	228.00
	Land development	1.5%			30.47
	Colony roads	2.0%			40.62
	Fencing, boundary walls, security/ observation booths	1.0%			20.31
	Lawns, Gardens and plantation	1.0%			20.31
	Internal water supply	2.5%			50.78
	Internal sanitation	2.5%			50.78
	Electrical Installations	3.5%			71.09
	Retaining wall & terracing	8.0%			162.48
				Total	3099.43
				Say	**3100.00**
B.	**Non-Residential Buildings- Temporary**				
	Building Cost (Item : K-3) Rate (3/4 of Rs. 12000)		30750	9000	2767.50
	Allowing escalation	19.4%		1744	536.34
	Land development	1.5%			30.47
	Colony roads	2.0%			40.62
	Fencing, boundary walls, security/ observation booths	1.0%			20.31
	Lawns, Gardens and plantation	1.0%			20.31
	Internal water supply	2.0%			40.62
	Internal sanitation	2.0%			40.62
	Electrical Installations @ 7%	2.5%			50.78
	Retaining wall & terracing	8.0%			162.48
				Total	3710.04
				Say	**3711.00**
C.	**YARD**				
	Permanent buildings		2200	2500	55.00
	Temporary buildings		22000	2500	550.00

DETAILS OF RESIDENTIAL BUILDINGS (PERMANENT & TEMPORARY)

I) Residential Buildings Near Dam Site

S. No	Description	Permanent Building					Temporary Building				
		No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)	No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)
1	Type - VI(S)	0	0	0	0	0	0	0	0	0	0
2	Type-VI	0	0	0	0	0	0	0	0	0	0
3	Type-V	0	0	0	0	0	21	140	2940	1	2940
4	Type-IV	0	0	0	0	0	15	100	1500	1	1500
5	Type-III	2	80	160	1	160	5	80	400	1	400
6	Type-II	9	70	630	1	630	17	70	1190	1	1190
7	Type-I(A)	1	60	60	1	60	1	60	60	1	60
8	Type-I(B)	0	50	0	1	0	1	50	50	1	50
9	Field hostel for Sr. Executives (FH-1)	0	0	0	0	0	0	40	0	0	0
10	Field hostel for other Executives (FH-2)	0	0	0	0	0	137	35	4795	1	4795
11	Field hostel for supervisor (FH-3)	0	0	0	0	0	17	30	510	1	510
12	Field hostel for workman (FH-4)	0	0	0	0	0	73	25	1825	1	1825
13	Barracks for security staff	5	25	125	1	125	3	25	75	1	75
	TOTAL					975					13345

II) Residential Buildings Near Power House Site

S. No	Description	Permanent Building					Temporary Building				
		No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)	No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)
1	Type - VI(S)	6	225	1350	1	1350	0	0	0	0	0
2	Type-VI	12	190	2280	1	2280	0	0	0	0	0
3	Type-V	14	140	1960	1	1960	14	140	1960	1	1960
4	Type-IV	10	100	1000	1	1000	10	100	1000	1	1000
5	Type-III	5	80	400	1	400	5	80	400	1	400
6	Type-II	14	70	980	1	980	20	70	1400	1	1400
7	Type-I(A)	1	60	60	1	60	1	60	60	1	60
8	Type-I(B)	1	50	50	1	50	0	50	0	1	0
9	Field hostel for Sr. Executives (FH-1)	15	40	600	1	600	15	40	600	1	600
10	Field hostel for other Executives (FH-2)	72	35	2520	1	2520	109	35	3815	1	3815
11	Field hostel for supervisor (FH-3)	10	30	300	1	300	13	30	390	1	390
12	Field hostel for workman (FH-4)	0	25	0	0	0	96	25	2400	1	2400
13	Barracks for security staff	4	25	100	1	100	7	25	175	1	175
	TOTAL					11600					12200

DETAILS OF NON-RESIDENTIAL BUILDINGS (PERMANENT & TEMPORARY)

I) Non- Residential Buildings Near Dam and Power house site

S. No	Description	Permanent Building					Temporary Building				
		No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)	No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)
1	Office	1	3000	3000	1	3000	2	775	1550	1	1550

2	Dispensary	1	350	350	1	350	1	250	250	1	250
3	Child Welfare centre	1	500	500	1	500	2	150	300	1	300
4	Office Club and Auditorium	1	500	500	1	500	1	200	200	1	200
5	Staff club	1	400	400	1	400	1	200	200	1	200
6	Indoor Game Hall	1	400	400	1	400	0	0	0	0	0
7	School	1	1000	1000	1	1000	0	0	0	0	0
8	Shopping Centre	1	750	750	1	750	0	0	0	0	0
9	LPG Godwon	1	100	100	1	100	2	100	200	1	200
10	Bank	1	350	350	1	350	0	0	0	0	0
11	Post Office	1	100	100	1	100	0	0	0	0	0
12	Telephone exchange	1	100	100	1	100	0	0	0	0	0
13	Fire station	1	100	100	1	100	2	200	400	1	400
14	Sub station	1	100	100	1	100	4	100	400	1	400
15	DG Building	2	100	200	1	200	2	400	800	1	800
16	Water supply, filter plant and pump houses	1	200	200	1	200	2	75	150	1	150
17	Quality control lab	1	200	200	1	200	2	250	500	1	500
18	Model room	1	100	100	1	100	1	200	200	1	200
19	Explosive Megazine	0	0	0	0	0	3	300	900	1	900
20	Cement stores	1	1000	1000	1	1000	14	1000	14000	1	14000
21	EM and HM stores/ fabrication	0	0	0	0	0	2	2750	5500	1	5500
22	General stores	2	200	400	1	400	2	300	600	1	600
23	Workshop	2	200	400	1	400	2	400	800	1	800
24	Weigh Bridge/ POL station	1	150	150	1	150	1	150	150	1	150
25	Miscellaneous buildings	0	0	0	0	0	2	100	200	1	200
26	Police Post	1	50	50	1	50	1	50	50	1	50
27	Check Post	5	25	125	1	125	0	0	0	0	0
28	Canteen	1	100	100	1	100	1	100	100	1	100
29	Hospitals	2	2000	4000	1	4000	1	500	500	1	500
30	Sewage disposal Plant/area	1	300	300	1	300	2	300	600	1	600
31	Petrol/ Diesel Pumps	1	200	200	1	200	2	50	100	1	100
32	Community Hall	1	500	500	1	500	2	100	200	1	200
33	Library	1	100	100	1	100	2	50	100	1	100
34	Bus stop	1	50	50	1	50	2	50	100	1	100
	TOTAL					15825					29050

II) Stores at Nagaon and Gogamukh

S. No	Description	**Permanent Building**					**Temporary Building**				
		No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)	No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)
1	Office	0	0	0	0	0	2	200	400	1	400
2	General store	0	0	0	0	0	2	500	1000	1	1000
3	Weigh Bridge/ POL station	0	0	0	0	0	2	125	250	1	250
4	Check post	0	0	0	0	0	2	25	50	1	50
	TOTAL					0					1700

III) Liasion Office at Guwahati, Along, Dibrugarh, Itanagar

S. No	Description	Permanent Building					Temporary Building				
		No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)	No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)
1	Office	4	150	600	1	600	0	0	0	0	0
2	General store	2	225	450	1	450	0	0	0	0	0
3	Check post	2	25	50	1	50	0	0	0	0	0
	TOTAL					1100					0

YARDS FOR EM & HM EQUIPMENT, WORKSHOPS AND PARKING ETC. (PERMANENT AND TEMPORARY)

S. No	Description	Permanent Building					Temporary Building				
		No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)	No	Plinth area required for one set (sqm)	Plinth area required (Sqm)	No of storey	Floor area (Sqm)
1	Yard for EM and HM equipment at Dam site	0	0	0	1	0	1	3500	3500	1	3500
2	Yard for workshop, parking etc. at Dam site	0	0	0	1	0	1	4500	4500	1	4500
3	Yard for EM and HM equipment at Power House Area	1	750	750	1	750	1	3000	3000	1	3000
4	Yard for workshop, parking etc. at Power House Area	1	750	750	1	750	1	3750	3750	1	3750
5	Yards at Nagaon and Gogamukh	0	0	0	1	0	2	2000	4000	1	4000
6	Yards at Guwahati and Along	0	0	0	1	0	2	1250	2500	1	2500
7	Parks	1	700	700	1	700	1	750	750	1	750
	TOTAL					2200					22000

DETAILS OF PERMANENT / TEMPORARY RESIDENTIAL BUILDINGS

S.No.	Particulars	Type of Quarter													
		VI(S)	VI	V	IV	III	II	I(A)	I(B)	FH-1	FH-2	FH-3	FH-4	Barrak	Total
	AREA	225	190	140	100	80	70	60	50	40	35	30	25	25	
1	PROJECT DIRECTOR	1													1
2	VICE PRESIDENT	5													5
3	PROJECT MANAGER		1												1
4	GENERAL MANAGER		11												11
5	ASSISTANT GENERAL MANAGER			48											48
6	RESIDENT MANAGER				27										27
7	ASSISTANT MANAGER									30					30
8	PROJECT ENGINEER						44								44
9	FIELD ENGINEER										98				98
10	JUNIOR ENGINEER										63				63
11	ASSISTANT										157				157
12	SENIOR GEOLOGIST				2										2
13	GEOLOGIST							4							4
14	JUNIOR GEOLOGIST								2						2
15	COOK												20		20
16	DOCTORS				5										5
17	NURSE/COMPOUNDER						16								16
18	OFFICE BOY												109		109
19	SECURITY/ CHOWKIDAR											40	40	20	100
20	FOREMAN					11									11
21	MECHANIC					6									6
	TOTAL	**6**	**12**	**48**	**34**	**17**	**60**	**4**	**2**	**30**	**318**	**40**	**169**	**20**	**760**

M-PLANTATION

S.No.	Description	Qty	Unit	Rate (Rs.)	Amount (Rs. Lacs)
1	Cost of planting trees along project roads, Dam Complex area, residential colonies and office area	25000	Nos	150	37.50
2	Cost of digging pits	25000	Nos	100	25.00
3	Cost of protection by barbed wire	25000	Nos	350	87.50
4	Maintenance of road side plantation for 6.5 years	25000	Nos	50	81.25
				TOTAL	**231.25**
A	Add @ 1 % for building construction workers welfare cess				2.3
B	Add @ 0.1 % for Project Monitoring				0.2
				TOTAL	**233.8**
	TOTAL			**Say**	**235.00**

O-MISCELLANEOUS

S.No.	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
A	**Capital cost**				
1	Construction Power	(Details as per Annex. O-I)			4133.00
2	Providing and fixing fire fighting	L.S.			100.00
3	Purchase of equipment for quality control/field laboratories				50.00
4	Providing telecommunication system, faxes and wireless equipment and satellite, communication	(Details as per Annex. O-II)			345.00
5	Providing Hospital equipment	L.S.			200.00
6	Children park and welfare centre for official and labour	L.S.			25.00
7	Water supply, purification and distribution arrangements including purchase of water tankers, cost of tanks and chlorination	L.S.			150.00
8	Providing sewage disposal and storm water drains at various colonies sites	L.S.			150.00
9	Furnishing and equiping of rest houses and field hostels of officers and staff				150.00
10	Purchase of furniture and other articles for labour welfare senters and clubs and schoo				50.00
B	**Running & Maintenance of Service**				
1	Maintenance of power arrangements for Colony, office and other non-works structures		(Details as per Annex. O-III)		22865.00
2	Running of Medical centre		(Details as per Annex. O-1)		481.00
3	Electrification including street lighting		(Details as per Annex. O-2)		82.00
4	Water supply including purification & distribution works		(Details as per Annex. O-3)		53.00
5	Sewage disposal and storm water drainage works		(Details as per Annex. O-4)		53.00
6	Maintenance of parks & welfare centres, clubs and school	6	Years	10.00	60.00
7	R&M of telecommunication system and post office				
	Initially 1 year for Infrastructure	1	Year	5	5.00
	Remaining 6.5 years for Construction	6	Years	25	150.00
8	Security Arrangements		(Details as per Annex. O-5)		1182.00
9	Fire fighting equipments	6	Years	10.00	60.00
10	R&M of rest house and field hostel for 6 years				
	Initially 1 year for Infrastructure	1	Year	5	5.00
	Remaining 6.5 years for Construction		Years	10	0.00
11	Running & maintenance of inspection vehicles		(Details as per Annex. O-6)		942.00
12	Running & maintenance of Cars		(Details as per Annex. O-7)		408.00
13	Running & maintenance of Bus		(Details as per Annex. O-8)		1215.00
14	Running and maintenance of ambulance vans		(Details as per Annex. O-9)		55.00
15	Running and maintenance of Pay vans, Station wagons and Explosive vans		(Details as per Annex. O-10)		216.00

16	Sweeping, Cleaning & horticulture and floriculture in colony				
	Initially 1 year for Infrastructure	1	Year	3	3.00
	Remaining 6.5 years for Construction	6	Years	10	60.00
17	R&M of research and quality control laboritries for 6.5 years				
	Initially 1 year for Infrastructure	1	Year	5	5.00
	Remaining 6.5 years for Construction	6	Years	10	60.00
18	Labour welfare compensation and retrenchment benefits			LS	150.00
19	R&M of lightening fixtures for offices, residential complexes and road, street lightening				
	Initially 1 year for Infrastructure	1	Year	3	3.00
	Remaining 5 years for Construction	6	Years	15	90.00
20	R&M of field workshop				
	Initially 1 year for Infrastructure	1	Year	5	5.00
	Remaining 6.5 years for Construction	6	Years	20	120.00
C	**Miscellaneous**				
1	Foundation stone laying	L.S			25.00
2	Inaugration Ceremony and visit of Dignatories	L.S			50.00
3	Maintenace of petrol/diesel pumps	L.S			15.00
4	Procurement of technical literatures	L.S			25.00
5	Models exhibition	L.S			25.00
6	Canteen Facilities and cooperative stores	L.S			20.00
7	Running of School				
	Initially 1 year for Infrastructure	1	Year	5	5.00
	Remaining 6.5 years for Construction	6	Years	10	60.00
8	Photographic & cinematographic equipments and their maintenance	L.S			50.00
9	Group Insurance	L.S			50.00
10	Publication Pamphlets	L.S			10.00
11	Time keeping cabin	L.S			10.00
12	Flood alarming system	L.S			30.00
13	Publicity and information center	L.S			20.00
14	Training personnel abroad including study courses and visits	L.S			50.00
15	Award to workers	L.S			50.00
				Say	34176.00
As per CEA guidelines, provision under this sub-head should be 1.5% of cost of I-works subject to maximum of Rs. 40 Crore. As cost of construction power arrangement and R&M of construction power amounts to Rs.269.98 crore, the cost of other items will be nil as per CEA guidelines considering ceiling of Rs 40 Crore. Therefore, ceiling of Rs. 40 Crores has been employed for O-Miscellaneous exclusive of provisions made for Construction Power i.e Rs.269.98Crs.				**Total**	**30,998.00**
A	Add @ 1 % for building construction workers welfare cess				310.0
B	Add @ 0.1 % for Project Monitoring				31.0
				TOTAL	**31339.0**
				Say	**31340.0**

The Cost Estimate for the Construction Power is given below;

Annexure O-I

S No.	Description	QTY	Unit Rate (Rs in lakhs)	Total (Rs in Lakhs)
1	500kVA ,DG Sets	10	58.7	586.5
2	1000kVA, DG Sets	23	116.6	2682.5
3	630KVA, 11/415V Distribution Transformers including cables and accessories	2	0.008/KVA	10.1
4	250KVA, 11/415V Distribution Transformers including cables and accessories	2	0.008/KVA	4.0
5	11kV Subtransmission System at Hilly Terrain	4	6	24.0
6	Switchgears, cables and other accessories for item no 1, 2	LS		65.0
7	Spares	@ 5%		165.4
8	Erection cost	@ 8%		264.6
9	Transpotation cost	@ 10%		330.7
	TOTAL			**4133**

Annexure O-II

S No.	Description		QTY	Amount (Rs in lakhs)
1	EPABX		1 No	25
2	Laying of OFC for BSNL telephone connections between Along and Oju Project (100 Km)			
	@2.0 lakh/km			200
3	Local area networking		LS	35
4	Multi Channel VSAT system		LS	25
5	LDST connections		LS	45
6	Misc equipment		LS	15
	TOTAL			**345**

Annexure O-III

ESTIMATE OF CONSTRUCTION POWER

It is estimted to have the load centres with load demands as detailed below

S No.	Area	Maximum Load Demand (MVA)
1	Batching Plants	0.97
2	Refrigeration System (Ice Plant)	0.50
3	Aggregate Process plants	3.90
4	Cableway for Concreting at Damsite	3.60
5	Belt Conveyor at Damsite for carriage of aggregates	1.00
6	Dam & Intake	1.45
7	Tunnels	5.21
8	Power House Complex	6.29
9	Total (MVA)	22.92
10	20% of Total (MVA) for Colony, offices and other non works structures	4.58
11	TOTAL CONSTRUCTION POWER FOR THE PROJECT	27.50
	Say	**27.00**

It is proposed to install Diesel Genrating Sets for reliable power supply for Construction power as no grid power will be available.

Annexure O-IV

MAINTENANCE OF POWER ARRANGEMENT

For Colony, offices and other non works structures

1 Electrical Power Consumption

20% of Total (MVA) output from O-III **4.58** MVA

Period	% of Load	MVA	MU at 50% Load Factor
1st year	10%	0.46	2.0
2nd year	30%	1.37	6.0
3rd year	75%	3.44	15.1
4th year	75%	3.44	15.1
5th year	50%	2.29	10.0
6th year	25%	1.15	5.0
		Total	53.2

2 Electrical Energy Charges

a	Total Units Reqd (for 50% Load Factor)	53.2	MU
b	Losses in System @ 2.5%	1.3	MU
	Total Requirement (a + b)	54.5	MU

3 Cost of energy for colony, offices and other non work structures @41.93 Rs./unit **22865** lakhs

Annexure O-1

R/M OF DISPENSARY PER YEAR

Sr.No.	Description		Amount Rs. Lakh	
	Establishment			
i)	5 Doctor @60000/- per month on Temporary basis		36.00	
ii)	8 Compounder @ 20000/- per month for one year	=	19.20	
	2 Technician @ 18000/- per month for one year	=	4.32	
	8 Nurses @ 10000/- per month for one year	=	9.60	
iii)	1 Chowkidar @ 4000/- per month for one year	=	0.48	
iv)	Bonus for above staff	=	5.00	
v)	TA for above staff	=	2.50	
vi)	Medicine etc. L.S. per year	=	3.00	
	Total	**=**	**80.10**	**lakhs**
	Total for 6.0 years	**=**	**481.00**	**lakhs**

Annexure O-2

R/M CHARGES FOR ELECTRIFICATION

Sr.No.	Description		Amount Rs. Lakh
	Establishment		
i)	3 Lineman @ Rs.15000/- per month for one year	=	5.40
ii)	3 Nos beldar @ 6000/- per month for one year	=	2.12
iii)	Miscellaneous material LS/year	=	2.00
iv)	Bonus for above staff	=	2.50
v)	TA for above staff	=	1.50
	Total / year	**=**	**13.52 lakhs**
	Total for 6.0 years	**=**	**82.00 lakhs**

Annexure O-3

R/M OF CHARGES FOR WATER SUPPLY PER YEAR

Sr.No.	Description		Amount Rs. Lakh	
	Establishment			
i)	1 Mason @ 15000/- per month for one year	=	1.80	
ii)	1 Fitter @ 15000/- per month for one year	=	1.80	
iii)	3 Nos beldar @ 6000/- per month for one year	=	2.16	
iv)	Miscellaneous material LS/year	=	1.50	
v)	Bonus for above staff	=	1.00	
vi)	TA for above staff	=	0.50	
	Total / year	**=**	**8.76**	**lakhs**
	Total for 6.0 years	**=**	**53.00**	**lakhs**

Annexure O-4

R/M CHARGES FOR SEWERAGE DISPOSAL

Sr.No.	Description		Amount Rs. Lakh
	Establishment		
i)	1 Mason @ 15000/- per month for one year	=	1.80
ii)	1 Fitter @ 15000/- per month for one year	=	1.80
iii)	3 Nos beldar @ 6000/- per month for one year	=	2.16
iv)	Miscellaneous material LS/year	=	1.50
v)	Bonus for above staff	=	1.00
vi)	TA for above staff		0.50
	Total / year	**=**	**8.76 lakhs**
	Total for 6.0 years	**=**	**53.00 lakhs**

Annexure O - 5

R/M OF TWO NUMBER SECURITY CHECK POST

Sr.No.	Description		Amount Rs. Lakh	
	Establishment			
i)	100 Security Guards @ 15000/- per month for one year	=	180.00	
ii)	Bonus for above staff	=	12.00	
iii)	TA for above staff	=	5.00	
	Total / year	**=**	**197.00**	**lakhs**
	Total for 6.0 years	**=**	**1,182.00**	**lakhs**

Annexure O-6

R/M CHARGES OF 50 NOS INSPECTION VEHICLES (Jeeps)

Sr.No.	Description			Amount Rs. Lakh	
i)	It is proposed that the Inspection Vehicles will cover about 45 Kms distance per day.				
ii)	Total distance covered in a year taking 25 days in a month = 45*12*25	13500			
iii)	Out turn rate of vehicles @ Rs. 31 per km (Refer Item E-6, Annexure 16-2,Volume-VI)				
iv)	R/M charges per vehicle per Year		=	4.19	lakhs
	1st Year	10 Nos vehicles	=	41.85	lakhs
	2nd Year	20 Nos vehicles	=	83.70	lakhs
	3rd Year	30 Nos vehicles	=	125.55	lakhs
	4th Year	40 Nos Vehicles	=	167.40	lakhs
	5th - 6th year	50 Nos Vehicles	=	523.13	lakhs
		Total	**=**	**942.00**	**lakhs**

Annexure O-7

R/M CHARGES FOR CARS (12 NOS)

Sr.No.	Description		Amount Rs. Lakh
	Establishment		
	It is proposed that the vehicle will cover about 65 kms distance per day.		
	Total distance covered in a year taking 25 days in a month =25*12*65		19500.00 kms
	Out turn rate of vehicles @ Rs. 29 per km (Refer Item E-4, Annexure 16-2,Volume-VI)		
	R/M charges per vehicle per Year	=	5.66 lakhs
	R/M charges per vehicle per Year	=	**5.66 lakhs**
	R/M charges for twelve vehicle for 6.0 years	=	**408.00 lakhs**

Annexure O-8

R/M CHARGES FOR BUSES (5 NOS)

Sr.No.	Description			Amount Rs. Lakh
	Establishment			
	Average distance covered/day in Shift by five buses			
i)	Colony to Dam site	=	15 Kms/shift	
ii)	Colony to Power house site	=	15 Kms/shift	
iv)	In three Shifts = 15*3*5	=	225.00 Kms / day	
v)	Total distance covered in one year	=	67500 Km	
vi)	Out turn rate of vehicles @ Rs.60 per km (Refer Item E-3, Annexure 16-2,Volume-VI)			
	Charges per Year		=	**40.50**
		Total charges for 6.0 years	=	**1215.0**

Annexure O-9

R/M CHARGES FOR AMBULANCE VAN (2 NOS)

Sr.No.	Description	Amount Rs. Lakh
	Establishment	
	It is proposed that the vehicle will cover about 35 kms distance per day.	
	Total distance covered in a year taking 25 days in a month =25*12*35 10500.00 kms	
	Out turn rate of vehicles @ Rs.43 per km (Refer Item E-5, Annexure 16-2,Volume-VI)	
	R/M charges per vehicle per Year =	**4.52 lakhs**
	R/M charges for two vehicle for 6.0 years =	**55.00 lakhs**

Annexure O-10

R/M CHARGES FOR Pay Vans, Station Wagons, Explosive vans (6 NOS)

Sr.No.	Description		Amount Rs. Lakh
	Establishment		
	It is proposed that the vehicle will cover about 35 kms		
	distance per day.		
	Total distance covered in a year taking 25 days		
	in a month =25*12*35 10500.00 kms		
	Out turn rate of vehicles @ Rs.57 per km (Refer Item E-2, Annexure 16-2,Volume-VI)		
	R/M charges per vehicle per Year	=	**5.99 lakhs**
	R/M charges for six vehicle for 6.0 years	=	**216.00 lakhs**

Sl. No	EQUIPMENT	Capacity of Machine	Units consumption/hr	Numbers																		Consumption (kWh)																	
				Dam & Intake	Diversion Tunnel	HRT Adit-1	HRT Adit-2	HRT Adit-3	HRT Adit-4	Adit- A1	Adit- A4	MAT	Valve Chamber	Surge Shaft	Pressure Shaft	Power House	Transformer Hall	Collection Gallery	Draft Tube Tunnels	Tail Race Tunnel	Quarry Site	Dam & Intake	Diversion Tunnel	HRT Adit-1	HRT Adit-2	HRT Adit-3	HRT Adit-4	Adit- A1	Adit- A4	MAT	Valve Chamber	Surge Shaft	Pressure Shaft	Power House	Transformer Hall	Collection Gallery	Draft Tube Tunnels	Tail Race Tunnel	Quarry Site
1	**Air Compressor (Electric)**	1000cfm	160		4	1	1	1	1			1										-	640	160	160	160	160	-	-	160	-	-	-	-	-	-	-	-	-
2	**Air Compressor (Electric)**	500cfm	75	4	4	2	2	2	2			2									11	300	300	150	150	150	150	-	-	150	-	-	-	-	-	-	-	-	825
3	**2 Boom Drill Jumbo**	2Boom	72		4	1	1	1	1			2										-	288	72	72	72	72	-	-	144	-	-	-	-	-	-	-	-	-
4	**Aggregate Processing Plant**:APP-1	750TPH	1,500	1																		1,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	**Aggregate Processing Plant**:APP-2 to 4	200TPH	800			1		1				1										-	-	800	-	800	-	-	-	800	-	-	-	-	-	-	-	-	-
6	**Batching and Mixing Plant**:BM-1	300cum/hr	440	1																		440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	**Batching and Mixing Plant**:BM-2 to 4	100cum/hr	175		1			1				1										-	175	-	-	175	-	-	-	175	-	-	-	-	-	-	-	-	-
8	**Belt Conveyor**	750TPH	1,000	1																		1,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	**Cable Crane (4 Nos.)**	30T	900	4																		3,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	**Ice Plant**	350TPD	500	1																		500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	**Concrete Pump**	40cum/hr	50	2	8	1	1	1	1				1	1	2	1	1	1	1	1		100	400	50	50	50	50	-	-	-	50	50	100	50	50	50	50	50	-
13	**Grout Pump**	30kW	15	2	4	1	1	1	1					1	2				2	1		30	60	15	15	15	15	-	-	-	-	15	30	-	-	-	30	15	-
14	**Alimak Raise Climber**		30												2							-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-
15	**Winch**	10T	6											1		1						-	-	-	-	-	-	-	-	-	-	6	-	6	-	-	-	-	-
16	**Winch**	30T	19	1										1	2	1						19	-	-	-	-	-	-	-	-	-	19	37	19	-	-	-	-	-
17	**Ventilation Blower**	110kW	83		8	3	4	4	2	1	1	2										-	660	248	330	330	165	83	83	165	-	-	-	-	-	-	-	-	-
18	**Workshop**		1,000	1												1						1,000	-	-	-	-	-	-	-	-	-	-	-	1,000	-	-	-	-	-
19	**Miscellneous Works**		1,500													1						-	-	-	-	-	-	-	-	-	-	-	-	1,500	-	-	-	-	-
20	**Penstock fabrication yard**		1,500												1							-	-	-	-	-	-	-	-	-	-	-	1,500	-	-	-	-	-	-
																					Sub Total	8,489	2,523	1,495	777	1,752	612	83	83	1,594	50	89	1,727	2,574	50	50	80	65	825
																					Total (I)	22917 KVA																	
				BUILDINGS, OFFICES AND COLONYS ETC.																		4583 KVA																	
				TOTAL CONSTRUCTION POWER REQUIREMENT FOR NAYING HEP (MVA) MVA																		27.0 MVA																	

Numbers

Sl. No	EQUIPMENT	Capacity of Machine	Units consumption/hr	Dam	Diversion Tunnel	HRT Adit-1	HRT Adit-2	HRT Adit-3	HRT Adit-4	HRT Adit-5	HRT Adit-6	Adit- A1	Adit- A2	Intake & Desilting chamber	MAT	Valve Chamber	Surge Shaft	Pressure Shaft	Power House	Transformer Hall	Collection Gallery	Draft Tube Tunnels	Tail Race Tunnel	Quarry Site
1	Air Compressor (Electric)	1000cfm	160		2	1	1	1	1	1	1			1	1									
2	Air Compressor (Electric)	500cfm	75	4	2	2	2	2	2	2	2			2	2									11
3	2 Boom Drill Jumbo	2Boom	72		2	1	1	1	1	1	1			1	2									
4	Aggregate Processing Plant:APP-1	600TPH	1,300	1																				
5	Aggregate Processing Plant:APP-2 to 4	200TPH	800			1		1							1									
6	Batching and Mixing Plant:BM-1	########	360	1																				
7	Batching and Mixing Plant:BM-2 to3	########	200		1			1																
8	Batching and Mixing Plant:BM-4 to 5	90cum/hr	160								1				1									
9	Tower Crane (3 Nos.)		200	3																				
10	Ice Plant	350TPD	500	1																				
11	Concrete Pump	40cum/hr	50	2	4	1	1	1	1	1	1			1		1	1	4	1	1	1	1	1	
12	Grout Pump	30kW	15	2	2	1	1	1	1	1	1			1			1	4				2	1	
13	Alimak Raise Climber		30															4						
14	Winch	10T	6														1		1					
15	Winch	30T	19	1													1	4	1					
16	Ventilation Blower	110kW	83		4	3	4	4	2	1	1	1	1		2									
17	Workshop		1,000	1															1					
18	Miscellneous Works		1,500																1					
19	Penstock fabrication yard		2,500															1						

Consumption (kWh)

Sl. No	EQUIPMENT	Dam	Diversion Tunnel	HRT Adit-1	HRT Adit-2	HRT Adit-3	HRT Adit-4	HRT Adit-5	HRT Adit-6	Adit- A1	Adit- A2	Intake & Desilting chamber	MAT	Valve Chamber	Surge Shaft	Pressure Shaft	Power House	Transformer Hall	Collection Gallery	Draft Tube Tunnels	Tail Race Tunnel	Quarry Site
1	Air Compressor (Electric)	-	320	160	160	160	160	160	160	-	-	160	160	-	-	-	-	-	-	-	-	-
2	Air Compressor (Electric)	300	150	150	150	150	150	150	150	-	-	150	150	-	-	-	-	-	-	-	-	825
3	2 Boom Drill Jumbo	-	144	72	72	72	72	72	72	-	-	72	144	-	-	-	-	-	-	-	-	-
4	Aggregate Processing Plant:APP-1	1,300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Aggregate Processing Plant:APP-2 to 4	-	-	800	-	800	-	-	-	-	-	-	800	-	-	-	-	-	-	-	-	-
6	Batching and Mixing Plant:BM-1	360	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Batching and Mixing Plant:BM-2 to3	-	200	-	-	200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Batching and Mixing Plant:BM-4 to 5	-	-	-	-	-	-	-	160	-	-	-	160	-	-	-	-	-	-	-	-	-
9	Tower Crane (3 Nos.)	600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Ice Plant	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Concrete Pump	100	200	50	50	50	50	50	50	-	-	50	-	50	50	200	50	50	50	50	50	-
12	Grout Pump	30	30	15	15	15	15	15	15	-	-	15	-	-	15	60	-	-	-	30	15	-
13	Alimak Raise Climber	-	-	-	-	-	-	-	-	-	-	-	-	-	-	119	-	-	-	-	-	-
14	Winch	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	6	-	-	-	-	-
15	Winch	19	-	-	-	-	-	-	-	-	-	-	-	-	19	75	19	-	-	-	-	-
16	Ventilation Blower	-	330	248	330	330	165	83	83	83	83	-	165	-	-	-	-	-	-	-	-	-
17	Workshop	1,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,000	-	-	-	-	-
18	Miscellneous Works	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,500	-	-	-	-	-
19	Penstock fabrication yard	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,500	-	-	-	-	-	-
	Sub Total	4,209	1,374	1,495	777	1,777	612	530	690	83	83	447	1,579	50	89	2,954	2,574	50	50	80	65	825

Total (I)	20391 KVA
BUILDINGS, OFFICES AND COLONYS ETC.	4078 KVA
TOTAL CONSTRUCTION POWER REQUIREMENT FOR OJU HEP (MVA) — MVA	25.0 MVA

P-MAINTENANCE

S.No.	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
	1% of following works:				
1	C-Works				2081.68
2	J-Power Plant-Civil Works				2983.45
3	K-Buildings				159.49
	TOTAL				**5224.62**
A	Add @ 1 % for building construction workers welfare cess				52.2
B	Add @ 0.1 % for Project Monitoring				5.2
				TOTAL	**5282.1**
				Say	**5290.00**

Q-SPECIAL TOOLS AND PLANTS

As the construction of civil works will be carried out by a separate construction agency, machinery required for infrastructure works, their subsequent repair/maintenance and supervision of works such as jeeps, buses, cars, ambulances etc. has mainly been made under this sub-head.

Construction time of the project = 6.5 Years

S.No.	Description	Qty.	Unit	Rate (Rs. Lacs)	Life in Years	% Utilization	Amount (Rs. Lacs)
1	Ambulance	2	Nos.	7	10	65%	9.10
2	Shift Buses	3	Nos.	10	10	65%	19.50
3	School Buses	2	Nos.	10	10	65%	13.00
4	Jeeps	48	Nos.	4.5	8	81%	175.50
5	Cars	18	Nos.	5	8	81%	73.13
6	Pay vans	2	Nos.	8	10	65%	10.40
7	Station wagons	2	Nos.	8	8	81%	13.00
8	Explosive van, 10T	2	Nos.	8	10	65%	10.40
9	Truck, 10T	2	Nos.	8	10	65%	10.40
10	Water Sprinkler	5	Nos.	8	10	65%	26.00
11	Diesel Tanker	2	Nos.	10	10	65%	13.00
	Provision to be made under sub-head Q-Special T & P=						**373.43**
A	Add @ 1 % for building construction workers welfare cess						3.7
B	Add @ 0.1 % for Project Monitoring						0.4
				TOTAL			**377.5**
							380.00

R-COMMUNICATION

S.No.	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	Average width of project roads is kept as 7.5m except the power house road which is 10.0m. Formation cutting, soling and metaling, provision of retaining walls, guard rail wherever necessary including dewatering complete in all respects.				
a)	Total length of mettaled road (Formation width 10m)	7.50	Km	350.0	2625.0
b)	Total length of mettaled road (Formation width 7.5m)	13.98	Km	300.0	4192.5
c)	Total length of gravel road (formation width 7.5m)	13.98	Km	250.0	3493.8
2	Main Bridge to Cross Siyom River	88.0	m	7.5	660.0
3	Small Bridge (Total 9 Bridge over Nalla)	190.5	m	3.5	666.8
4	Local widening at curves, filling deeps and strengthening of bridges/ culverts on Along - Yapik road near project site (Along to Yapik 100 km)	100.0	km	150.0	15000.0
				TOTAL	**26638.0**
A	Add @ 1 % for building construction workers welfare cess				266.4
B	Add @ 0.1 % for Project Monitoring				26.6
				TOTAL	**26931.0**
				Say	**26935.0**

X-ENVIRONMENT, ECOLOGY AND AFFORESTATION

S.No.	Description	Qty	Unit	Rate (Rs. Lacs)	Amount (Rs. Lacs)
1	Biodiversity Conservation & Management Plan	Job			386.80
2	Action Plan for Catchment Area Treatment (including Mitigation measures for Shifting Cultivation)	Job			304.84
3	Fishery Conservation & Management Plan	Job			291.44
4	Waste Management Plan	Job			148.00
5	Public Health Delivery Plan	Job			104.00
6	Energy Conservation Measures	Job			40.00
7	Muck Disposal Plan	Job			1977.50
8	Landscaping and Restoration Plan	Job			347.00
9	Disaster Management Plan	Job			115.55
10	Reservoir Rim Treatment	Job			217.50
11	Resettlement & Rehabilitation plan (R&R Plan) *	Job			1433.24
12	Compensatory Afforestation	Job			1042.58
13	NPV	Job			6047.16
14	Environment Monitoring Programme	Job			208.40
				Sub Total	**12664.01**
	Total cost without R&R plan (Provision for R&R Plan has been kept under B-Land)			**TOTAL**	**11230.77**
A	Add @ 1 % for building construction workers welfare cess				126.6
B	Add @ 0.1 % for Project Monitoring				12.7
				TOTAL	**12803.3**
	Note: The cost has been taken from EIA/EMP report			**Say**	**12805.00**

* Cost of local area development has been taken as 1% free power in axcess of the free power to the home state

Y-LOSSES ON STOCK

S.No.	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	Provision made @ 0.25% on the cost of C-Works, J-Power Plant civil works, K-Buildings				1306.15
				TOTAL	**1306.15**

II ESTABLISHMENT

S.No	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	Establishment (> Rs. 3000 Crores Up to Rs. 6000 Crores) Rs. 135.00 Crores plus 2.00% of cost exceeding Rs. 3000 Crores				20004
2	Scattered works				400
3	Gestation Period more than 6 Years				1000
4	Design & Engineering (25% of BEC-C)				5001
				Total	**26410**

III T&P

S.No	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	1.0% of I-works limited to 200 Lacs				200
				TOTAL	**200**

IV RECEIPT AND RECOVERIES

S.No	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	Q-Special T & P Credit on account of resale value of Special T & P			(-)	0.00
2	Buildings				
	Cost recoverable on account of resale value of temp. buildings @ 15% of cost buildings			(-)	1183.65
3	Credit on account of resale value of telephone equipment @ 25%			(-)	86.25
	TOTAL credit for Receipt and Recoveries			(-)	**1269.90**
				say	**1270.00**

V AUDITS & ACCOUNTS

S.No	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	Audit & Accounts & Pro-rata of H.O. Establishment (0.25% of I-Works) *(Provision of 0.25% of I-Works for more than 2000crore and 0.5% of I-Works for cost upto 1000crore)*				1594.86
				Total	**1594.86**
				Say	

VI Capitalization of abatement of Land revenue

S.No	Description	Qty	Unit	Rate (Rs. Lac)	Amount (Rs. Lacs)
1	Capitalization of abatement of land revenue @ 5% of cost of private land.			LS	316.15
				Total	**320.00**

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
C-1 Diversion Tunnels																		
1- Open Excavation																		
a. In Soil	m^3	54,613	54,613															
b. In Rock	m^3	1,27,431		1,27,431												73910	31858	31858
2- Underground Excavation																		
a. Rock	m^3	3,48,945		3,48,945												202389	87237	87237
b. Over Break	m^3	20,647		20,647														
3- Rock Bolt - 25mm Dia	m	61,066												61,066				
		-												-				
4- Rock Anchors - 25mm Dia	m	-													-			
		-													-			
5- Reinforcement Steel -Fe500	MT	1,618									1,618							
6- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	850										850						
Steel Ribs - ISHB-200	MT	-										-						
Stiffner ASTM 537 class II steel	MT	-										-						
b. Steel Plates	MT	90										90						
c. Tie Rod	MT	15									15							
Steel liner ASTM 537 class II steel	MT	-											-					
7- Plane Shotcrete (M35)	m^3	6,253				52,523		2,126	6378									
8- Welded Wiremesh	m^2	40,664																
9- Forepoles (32mm Dia)	m	5,790																
10- R.C.C Lagging (M20A20)	m^3	879				#REF!		791	396		53							
11- Concrete Blocks	m^3					#REF!		-	-		-							
11- Grouting																		
a. Drilling for Consolidation Grouting	m	12,488																
b. Drilling for Contact Grouting	m	4,680																
c. Cement for Grouting	Bags	27,784				27,784			1945									
12- Concreting (DAM)		-																
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
12- Concreting other than Dam Area																		
a. M10A40	m^3	1,950				#REF!		#REF!	#REF!									
b. M15A20	m^3	7,250				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
c. M20A20	m^3	2,308				#REF!		#REF!	#REF!									
d. M20A20 -HRT	m^3	6,700				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
e. M25A20 -DT	m^3	1,19,905				#REF!		#REF!	#REF!									
f. M30A20	m^3	280				#REF!		#REF!	#REF!									
13- Boulder Pitching (Compacted)	m^3	20					24											
14- Stone Pitching (HAND PACKED) 200mm thick	m^3	1,730					2,093											
15- Stone Masonry Works	m^3	-					-											
16- Brick Works	m^3	-				-			-	-								
15- Drainage Holes (76mm Dia)	m	6,009																
16- PVC Water Seal	m	172																

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
C-2 Upstream and Downstream Coffer Dams																		
1- Open Excavation																		
a. In Soil	m^3	18,437	18,437															
b. In Rock	m^3	7,901		7,901												4583	1976	1976
2- Underground Excavation																		
a. Rock	m^3	-		-												0	0	0
b. Over Break	m^3	-		-														
3- Rock Bolt - 25mm Dia	m	-												-				
		-												-				
4- Rock Anchors - 25mm Dia	m	-													-			
		-													-			
2- Reinforcement Steel -Fe500	MT	192									192							
3- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	-										-						
b. Steel Ribs - ISHB-200	MT	-										-						
c. Stiffner ASTM 537 class II steel	MT	-										-						
d. Steel Plates	MT	-										-						
e. Tie Rod	MT	-									-							
f Steel liner ASTM 537 class II steel	MT	-											-					
4- Plane Shotcrete (M35)		-				-		-	0									
a. Plane Shotcrete (M35) 50mm	m^2	-				-		-	-									
b. Plain Shotcrete with wiremesh 100mm	m^2	-				-		-	-									
c. Plain Shotcrete with wiremesh 150mm	m^2	-				-		-	-									
d. SFRS (M35) 50mm	m^2	-				-		-	-									
e. SFRS (M35) 100mm	m^2	-				-		-	-									
f. SFRS (M35) 150mm	m^2	-				-		-	-									
g. SFRS (M35) 200mm	m^2	-				-		-	-									
5- Welded Wiremesh	m^2	-																
6- Forepoles (32mm Dia)	m	-																
7- R.C.C Lagging (M20A20)	m^3	-				#REF!		-	-		-							
8- Concrete Blocks	m^3	-				#REF!		-	-		-							
3- Grouting																		
Drilling for Consolidation Grouting	m	-																
a. Drilling for Grouting	m	#REF!																
b. Cement for Grouting	Bags	#REF!				#REF!			#REF!									
4- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
4- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
b. M15A20	m^3	-				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
a. M20A20	m^3	3,846				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
5- Boulder Pitching (Compacted)	m^3	-					-											
5- Stone Pitching (HAND PACKED) 200mm thick	m^3	1,52,441					1,84,454											
6- Stone Masonry Works	m^3	-					-											
7- Brick Works	m^3	-				-			-	-								
8- Drainage Holes (76mm Dia)	m	-																
6- PVC Water Seal	m	886																

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
C-3 Dam & Intake																		
1- Open Excavation																		
a. In Soil	m^3	#REF!	#REF!															
b. In Rock	m^3	#REF!		#REF!												#REF!	#REF!	#REF!
2- Underground Excavation																		
a. Rock	m^3	-		-												0	0	0
b. Over Break	m^3	-		-														
2- Rock Bolt - 25mm Dia	m	#REF!												#REF!				
														-				
3- Rock Anchors - 25mm Dia	m	-													-			
3- Rock Anchors - 32mm Dia		30,320													30,320			
4- Reinforcement Steel -Fe500	MT	#REF!									#REF!							
5- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	-										-						
b. Steel Ribs - ISHB-200	MT	-										-						
c. Stiffner ASTM 537 class II steel	MT	-										-						
d. Steel Plates	MT	-										-						
e. Tie Rod	MT	-									-							
f Steel liner ASTM 537 class II steel	MT	-											-					
5- Plane Shotcrete (M35)	m^3	#REF!				#REF!		#REF!	#REF!									
6- Welded Wiremesh	m^2	#REF!																
7- Forepoles (32mm Dia)	m	-																
8- R.C.C Lagging (M20A20)	m^3	-				#REF!		-	-		-							
6- Concrete Blocks	m^3	5,589				#REF!		4,807	2,403		475							
7- Grouting																		
a. Drilling for Consolidation Grouting	m	31,916																
b. Drilling for Contact Grouting	m	5,600																
c. Cement for Grouting	Bags	1,12,548				1,12,548			7878									
8- Concreting (DAM)																		
a. M15A150	m^3	4,29,489				#REF!		#REF!	#REF!									
b. M20A40	m^3	11,388				#REF!		#REF!	#REF!									
c. M20A75	m^3	1,52,425				#REF!		#REF!	#REF!									
d. M25A40	m^3	4,45,434				#REF!		#REF!	#REF!									
e. M30A20	m^3	867				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	12,328			#REF!	#REF!		#REF!	#REF!									
9- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20	m^3	#REF!				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
b. M20A20	m^3	6,896				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
c. M25A20	m^3	#REF!				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
d. M30A20	m^3	#REF!				#REF!		#REF!	#REF!									
10- Boulder Pitching (Compacted)	m^3	-					-											
11- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
12- Stone Masonry Works	m^3	-					-											
13- Brick Works	m^3	-				-			-	-								
10- Drainage Holes (76mm Dia)	m	#REF!																
11- PVC Water Seal	m	6,325																

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
C-4 Development of Muck Disposal Area for C-works																		
1- Open Excavation																		
a. In Soil	m^3	-	-															
b. In Rock	m^3	-		-												0	0	0
2- Underground Excavation																		
a. Rock	m^3	-		-												0	0	0
b. Over Break	m^3	-		-														
3- Rock Bolt - 25mm Dia	m	-												-				
														-				
4- Rock Anchors - 25mm Dia	m	-													-			
															-			
5- Reinforcement Steel -Fe500	MT	-									-							
6- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	-										-						
b. Steel Ribs - ISHB-200	MT	-										-						
c. Stiffner ASTM 537 class II steel	MT	-										-						
d. Steel Plates	MT	-										-						
e. Tie Rod	MT	-									-							
f Steel liner ASTM 537 class II steel	MT	-											-					
7- Plane Shotcrete (M35)		-				-		-	0									
a. Plane Shotcrete (M35) 50mm	m^2					-		-	-									
b. Plain Shotcrete with wiremesh 100mm	m^2					-		-	-									
c. Plain Shotcrete with wiremesh 150mm	m^2					-		-	-									
d. SFRS (M35) 50mm	m^2					-		-	-									
e. SFRS (M35) 100mm	m^2					-		-	-									
f. SFRS (M35) 150mm	m^2					-		-	-									
g. SFRS (M35) 200mm	m^2					-		-	-									
8- Welded Wiremesh	m^2	-																
9- Forepoles (32mm Dia)	m	-																
10- R.C.C Lagging (M20A20)	m^3	-				#REF!		-	-		-							
11- Concrete Blocks	m^3	-				#REF!		-	-		-							
12- Grouting						-												
a. Drilling for Consolidation Grouting	m	-																
b. Drilling for Contact Grouting	m	-																
c. Cement for Grouting	Bags	-				-			0									
13- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
14- Concreting other than Dam Area		-																
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
b. M15A20	m^3	-				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
e. M20A20	m^3	-				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
15- Boulder Pitching (Compacted)	m^3	-					-											
16- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
17- Stone Masonry Works	m^3	-					-											
18- Brick Works	m^3	-				-			-	-								
19- Drainage Holes (76mm Dia)	m	-																

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
J-1 Construction Adits and Accesses tunnels for J-works																		
1- Open Excavation																		
a. In Soil	m^3	47,508	47,508															
b. In Rock	m^3	20,360		20,360												11809	5090	5090
2- Underground Excavation																		
a. Rock	m^3	2,53,024		2,53,024												146754	63256	63256
b. Over Break	m^3	16,919		16,919														
3- Rock Bolt - 25mm Dia	m	52,142												52,142				
														-				
4- Rock Anchors - 25mm Dia	m	48,693													48,693			
															-			
5- Reinforcement Steel -Fe500	MT	159									159							
6- Structural Steel																		
Steel Ribs - ISHB-250	MT	-										-						
a. Steel Ribs - ISHB-200	MT	1,114										1,114						
Stiffner ASTM 537 class II steel	MT	-										-						
b. Steel Plates	MT	49										49						
c. Tie Rod	MT	11									11							
Steel liner ASTM 537 class II steel	MT	-											-					
7- Plane Shotcrete (M35)	m^3	7,482				62,849		2,544	7632									
8- Welded Wiremesh	m^2	60,522																
9- Forepoles (32mm Dia)	m	20,563																
10- R.C.C Lagging (M20A20)	m^3	794				#REF!		715	357		48							
11- Concrete Blocks	m^3	-				#REF!		-	-		-							
11- Grouting																		
a. Drilling for Consolidation Grouting	m	3,664																
b. Drilling for Contact Grouting	m	255																
c. Cement for Grouting	Bags	7,481				7,481			524									
12- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
12- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20	m^3	4,877				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
b. M20A20	m^3	11,521				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
c. M25A20	m^3	13,587				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
d. M30A20	m^3	10				#REF!		#REF!	#REF!									
13- Boulder Pitching (Compacted)	m^3	116					140											
14- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
15- Stone Masonry Works	m^3	-					-											
16- Brick Works	m^3	-				-			-	-								
14- Drainage Holes (76mm Dia)	m	19,745																
15- PVC Water Seal																		

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
J-2 Headrace Tunnel																		
1- Open Excavation																		
a. In Soil	m^3	-	-															
b. In Rock	m^3	-		-												0	0	0
1- Underground Excavation																		
a. Rock	m^3	16,86,380		16,86,380												978101	421595	421595
b. Over Break	m^3	94,682		94,682														
2- Rock Bolt - 25mm Dia	m	2,77,849												2,77,849				
														-				
3- Rock Anchors - 25mm Dia	m	99,890													99,890			
															-			
4- Reinforcement Steel -Fe500	MT	1,488									1,488							
5- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	4,550										4,550						
Steel Ribs - ISHB-200	MT	-										-						
Stiffner ASTM 537 class II steel	MT	-										-						
b. Steel Plates	MT	437										437						
c. Tie Rod	MT	51									51							
f Steel liner ASTM 537 class II steel	MT	-											-					
6- Plane Shotcrete (M35)	m^3	19,250				1,61,700		6,545	19635									
7- Welded Wiremesh	m^2	55,000																
8- Forepoles (32mm Dia)	m	79,199																
9- R.C.C Lagging (M20A20)	m^3	3,572				#REF!		3,215	1,607		214							
10- Concrete Blocks	m^3	-				#REF!		-	-		-							
10- Grouting																		
a. Drilling for Consolidation Grouting	m	81,508																
b. Drilling for Contact Grouting	m	29,444																
c. Cement for Grouting	Bags	1,80,682				1,80,682			12648									
11- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
11- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20	m^3	25,500				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
e. M20A20	m^3	-				#REF!		#REF!	#REF!									
b. M20A20 -HRT	m^3	4,10,480				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
12- Boulder Pitching (Compacted)	m^3						-											
13- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
14- Stone Masonry Works	m^3	-					-											
15- Brick Works	m^3	-				-			-	-								
12- Drainage Holes (76mm Dia)	m	13,701																
13- PVC Water Seal																		

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
J-3 Surge Shaft																		
1- Open Excavation																		
a. In Soil	m^3	64,135	64,135															
b. In Rock	m^3	27,487		27,487												15943	6872	6872
2- Underground Excavation																		
a. Rock	m^3	72,660		72,660												42143	18165	18165
b. Over Break	m^3	3,633		3,633														
3- Rock Bolt - 25mm Dia	m	29,972												29,972				
														-				
4- Rock Anchors - 25mm Dia	m	8,640													8,640			
															-			
5- Reinforcement Steel -Fe500	MT	1,044									1,044							
6- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	283										283						
b. Steel Ribs - ISHB-200	MT	-										-						
c. Stiffner ASTM 537 class II steel	MT	-										-						
d. Steel Plates	MT	-										-						
e. Tie Rod	MT	-									-							
f Steel liner ASTM 537 class II steel	MT	-											-					
7- Plane Shotcrete (M35)	m^3	1,234				10,365		420	1259									
8- Welded Wiremesh	m^2	12,339																
9- Forepoles (32mm Dia)	m	-																
9- R.C.C Lagging (M20A20)	m^3	198				#REF!		178	89		12							
10- Concrete Blocks	m^3	-				#REF!		-	-		-							
10- Grouting																		
a. Drilling for Consolidation Grouting	m	5,205																
b. Drilling for Contact Grouting	m	1,377																
c. Cement for Grouting	Bags	11,036				11,036			773									
11- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
11- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20	m^3	920				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
b. M20A20	m^3	13,044				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
12- Boulder Pitching (Compacted)	m^3	-					-											
13- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
14- Stone Masonry Works	m^3	-					-											
15- Brick Works	m^3	-				-			-	-								
12- Drainage Holes (76mm Dia)	m	3,062																
13- PVC Water Seal																		
J-4 Pressure shaft and Valve Chamber																		
1- Open Excavation																		
a. In Soil	m^3	-	-															
b. In Rock	m^3	-		-												0	0	0
1- Underground Excavation																		
a. Rock	m^3	1,73,214		1,73,214												100465	43304	43304
b. Over Break	m^3	8,661		8,661														
2- Rock Bolt - 25mm Dia	m	85,182												85,182				
		-												-				
3- Rock Anchors - 25mm Dia	m	-													-			
															-			

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
3- Reinforcement Steel -Fe500	MT	85									85							
4- Structural Steel																		
Steel Ribs - ISHB-250	MT	-										-						
Steel Ribs - ISHB-200	MT	-										-						
a. Steel liner SAILMA 600HI steel	MT	15,000											15,000					
Steel Plates	MT	-										-						
Tie Rod	MT	-									-							
b. Steel liner ASTM 537 class II steel	MT	-											-					
5- Plane Shotcrete (M35)	m^3	2,267				19,041		771	2312									
6- Welded Wiremesh	m^2	5,215																
7- Forepoles (32mm Dia)	m	-																
8- R.C.C Lagging (M20A20)	m^3	-				#REF!		-	-		-							
9- Concrete Blocks	m^3	-				#REF!		-	-		-							
7- Grouting																		
a. Drilling for Consolidation Grouting	m	45,000																
b. Drilling for Contact Grouting	m	7,000																
c. Cement for Grouting	Bags	39,076				39,076			2735									
8- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
8- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
b. M15A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20 - PS Horizontal	m^3	38,000				#REF!		#REF!	#REF!									
b. M15A20 - PS vertical	m^3	45,000				#REF!		#REF!	#REF!									
c. M20A20	m^3	1,220				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
9- Boulder Pitching (Compacted)	m^3	-					-											
10- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
11- Stone Masonry Works	m^3	-					-											
12- Brick Works	m^3	-				-			-	-								
9- Drainage Holes (76mm Dia)	m	4,851																
10- PVC Water Seal																		
J-5 Power House Complex																		
1- Open Excavation																		
a. In Soil	m^3	-	-															
b. In Rock	m^3	-		-												0	0	0
1- Underground Excavation																		
a. Rock	m^3	4,33,470		4,33,470												251413	108368	108368
b. Over Break	m^3	21,707		21,707														
2- Rock Bolt - 25mm Dia	m	39,306												39,306				
3- Rock Bolt - 32mm Dia		1,60,123												1,60,123				
3- Rock Anchors - 25mm Dia	m	-													-			
		-																
4- Reinforcement Steel -Fe500	MT	4,749									4,749				4749			
5- Structural Steel																		
Steel Ribs - ISHB-250	MT	-										-						
a. Steel Ribs - ISHB-200	MT	-										-						
Stiffner ASTM 537 class II steel	MT	-										-						
b. Steel Plates	MT	-										-						
Tie Rod	MT	-									-							
Steel liner ASTM 537 class II steel	MT	-											-					
5- Plane Shotcrete (M35)	m^3	8,137				68,351		2,767	8300									

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Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
6- Welded Wiremesh	m^2	52,145																
7- Forepoles (32mm Dia)	m	-																
8- R.C.C Lagging (M20A20)	m^3					#REF!		-	-		-							
7- Concrete Blocks	m^3	1,808				#REF!		1,555	777		154							
8- Grouting																		
a. Drilling for Consolidation Grouting	m	5,277																
b. Drilling for Contact Grouting	m	771																
c. Cement for Grouting	Bags	11,042				11,042			773									
9- Concreting (DAM)						#REF!		#REF!	#REF!									
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
9- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20	m^3	-				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
a. M20A20	m^3	20,792				#REF!		#REF!	#REF!									
b. M20A20 -HRT	m^3	7,800				#REF!		#REF!	#REF!									
c. M25A20	m^3	21,206				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
d. M30A20	m^3	160				#REF!		#REF!	#REF!									
10- Boulder Pitching (Compacted)	m^3	-					-											
11- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
12- Stone Masonry Works	m^3	-					-											
10- Brick Works	m^3	572				292			154	2,86,000								
11- Drainage Holes (76mm Dia)	m	15,904																
12- PVC Water Seal																		
J-6 Tail Race Tunnel																		
1- Open Excavation																		
a. In Soil	m^3	9,061	9,061															
b. In Rock	m^3	3,883		3,883												2253	971	971
2- Underground Excavation																		
a. Rock	m^3	2,06,371		2,06,371												119696	51593	51593
b. Over Break	m^3	11,900		11,900														
3- Rock Bolt - 25mm Dia	m	70,758												70,758				
		-												-				
4- Rock Anchors - 25mm Dia	m	-													-			
		-													-			
4- Reinforcement Steel -Fe500	MT	2,565									2,565							
5- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	978										978						
Steel Ribs - ISHB-200	MT	-										-						
Stiffner ASTM 537 class II steel	MT	-										-						
b. Steel Plates	MT	65										65						
c. Tie Rod	MT	8									8							
Steel liner ASTM 537 class II steel	MT	-											-					
6- Plane Shotcrete (M35)	m^3	2,788				23,419		948	2844									
7- Welded Wiremesh	m^2	26,380																
8- Forepoles (32mm Dia)	m	23,820																
9- R.C.C Lagging (M20A20)	m^3	647				#REF!		582	291		39							
10- Concrete Blocks	m^3	-				#REF!		-	-		-							
10- Grouting																		
a. Drilling for Consolidation Grouting	m	34,462																
b. Drilling for Contact Grouting	m	6,185																
c. Cement for Grouting	Bags	73,047				73,047			5113									
11- Concreting (DAM)		-																
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
11- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
a. M15A20	m^3	12,763				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
e. M20A20	m^3	-				#REF!		#REF!	#REF!									
b. M20A20 -HRT	m^3	48,947				#REF!		#REF!	#REF!									
c. M25A20	m^3	1,661				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
12- Boulder Pitching (Compacted)	m^3	-					-											
13- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
12- Stone Masonry Works	m^3	57					69											
13- Brick Works	m^3	-				-			-	-								
13- Drainage Holes (76mm Dia)	m	3,626																
14- PVC Water Seal																		

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
J-7 Pothead Yard																		
1- Open Excavation																		
a. In Soil	m^3	1,77,444	1,77,444															
b. In Rock	m^3	4,11,081		4,11,081												238428	102771	102771
2- Underground Excavation																		
a. Rock	m^3	-		-												0	0	0
b. Over Break	m^3	-		-														
2- Rock Bolt - 25mm Dia	m	40,040												40,040				
		-												-				
3- Rock Anchors - 25mm Dia	m	-													-			
		-													-			
3- Reinforcement Steel -Fe500	MT	39									39							
4- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	-										-						
b. Steel Ribs - ISHB-200	MT	-										-						
c. Stiffner ASTM 537 class II steel	MT	-										-						
a. Structural Steel in Roof Truss	MT	12										12						
e. Tie Rod	MT	-									-							
f Steel liner ASTM 537 class II steel	MT	-											-					
5- Plane Shotcrete (M35)	m^3	2,002				16,817		681	2042									
6- Welded Wiremesh	m^2	20,020																
7- Forepoles (32mm Dia)	m	-																
8- R.C.C Lagging (M20A20)	m^3	-				#REF!		-	-		-							
9- Concrete Blocks	m^3	-				#REF!		-	-		-							
10- Grouting						-												
a. Drilling for Consolidation Grouting	m	-																
b. Drilling for Contact Grouting	m	-																
c. Cement for Grouting	Bags	-				-			0									
11- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
7- Concreting other than Dam Area																		
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
b. M15A20	m^3	-				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
e. M20A20	m^3	-				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
a. M25A20	m^3	385				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
8- Boulder Pitching (Compacted)	m^3	-					-											
8- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
9- Stone Masonry Works	m^3	-					-											
8- Brick Works	m^3	166				85			44.82	83,000								
9- Drainage Holes (76mm Dia)	m	6,256																
10- PVC Water Seal																		
J-8 Development of Muck Disposal Area for J-works																		
1- Open Excavation																		
a. In Soil	m^3	-	-															
b. In Rock	m^3	-		-												0	0	0
2- Underground Excavation																		
a. Rock	m^3	-		-												0	0	0
b. Over Break	m^3	-		-														
3- Rock Bolt - 25mm Dia	m	-												-				
4- Rock Anchors - 25mm Dia	m	-													-			
5- Reinforcement Steel -Fe500	MT	-									-							
6- Structural Steel																		
a. Steel Ribs - ISHB-250	MT	-										-						
b. Steel Ribs - ISHB-200	MT	-										-						
c. Stiffner ASTM 537 class II steel	MT	-										-						
d. Steel Plates	MT	-										-						
e. Tie Rod	MT	-									-							
f Steel liner ASTM 537 class II steel	MT	-											-					
7- Plane Shotcrete (M35)		-				-		-	0									

Oju HYDROELECTRIC PROJECT (1800 MW)

CONSTRUCTION MATERIAL REQUIREMENT

Particulars	Units	Quantity	Open Excavation (Cum)	Rock excavation(Cum)	Silica (MT)	Cement (Bag)	Boulders (Cum)	Coarse Aggregate (Cum)	Fine Aggregate (Cum)	Bricks (No.)	Rein. Steel (MT)	Struct. Steel (MT)	Penstock Steel (MT)	Rock Bolts (25/32mm)	Rock Anchors (25/32mm)	Gelatin (Kg)	Detonator (Nos)	Fuse Coil (Nos)
8- Welded Wiremesh	m^2	-																
9- Forepoles (32mm Dia)	m	-																
10- R.C.C Lagging (M20A20)	m^3	-				-		-	-		-							
11- Concrete Blocks	m^3	-				-		-	-		-							
12- Grouting						-												
a. Drilling for Consolidation Grouting	m	-																
b. Drilling for Contact Grouting	m	-																
c. Cement for Grouting	Bags	-																
13- Concreting (DAM)																		
a. M15A150	m^3	-				#REF!		#REF!	#REF!									
b. M20A40	m^3	-				#REF!		#REF!	#REF!									
c. M20A75	m^3	-				#REF!		#REF!	#REF!									
d. M25A40	m^3	-				#REF!		#REF!	#REF!									
e. M30A20	m^3	-				#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3	-			#REF!	#REF!		#REF!	#REF!									
14- Concreting other than Dam Area		-																
a. M10A20	m^3	-				#REF!		#REF!	#REF!									
b. M15A20	m^3	-				#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3	-				#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3	-				#REF!		#REF!	#REF!									
e. M20A20	m^3	-				#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3	-				#REF!		#REF!	#REF!									
g. M25A20	m^3	-				#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3	-				#REF!		#REF!	#REF!									
i. M30A20	m^3	-				#REF!		#REF!	#REF!									
15- Boulder Pitching (Compacted)	m^3	-					-											
16- Stone Pitching (HAND PACKED) 200mm thick	m^3	-					-											
17- Stone Masonry Works	m^3	-					-											
18- Brick Works	m^3	-				-			-	-								
19- Drainage Holes (76mm Dia)	m	-																
J Gate Chambers																		
1- Open Excavation																		
a. In Soil	m^3		-															
b. In Rock	m^3			-												0	0	0
2- Underground Excavation																		
a. Rock	m^3			-												0	0	0
b. Over Break	m^3			-														
3- Rock Bolt - 25mm Dia	m													-				
4- Rock Anchors - 25mm Dia	m														-			
5- Reinforcement Steel -Fe500	MT										-							
6- Structural Steel																		
a. Steel Ribs - ISHB-250	MT											-						
b. Steel Ribs - ISHB-200	MT											-						
c. Stiffner ASTM 537 class II steel	MT											-						
d. Steel Plates	MT											-						
e. Tie Rod	MT										-							
f. Steel liner ASTM 537 class II steel	MT												-					
7- Plane Shotcrete (M35)																		
8- Welded Wiremesh	m^2																	
9- Forepoles (32mm Dia)	m																	
10- R.C.C Lagging (M20A20)	m^3					-		-	-		-							
11- Concrete Blocks	m^3					-		-	-		-							
12- Grouting						-												
a. Drilling for Consolidation Grouting	m																	
b. Drilling for Contact Grouting	m																	
c. Cement for Grouting	Bags																	
13- Concreting (DAM)																		
a. M15A150	m^3					#REF!		#REF!	#REF!									
b. M20A40	m^3					#REF!		#REF!	#REF!									
c. M20A75	m^3					#REF!		#REF!	#REF!									
d. M25A40	m^3					#REF!		#REF!	#REF!									
e. M30A20	m^3					#REF!		#REF!	#REF!									
f. M60A20(HPC) (4 kg microsilica per bag of cement)	m^3				#REF!	#REF!		#REF!	#REF!									
14- Concreting other than Dam Area																		
a. M10A20	m^3					#REF!		#REF!	#REF!									
b. M15A20	m^3					#REF!		#REF!	#REF!									
c. M15A20 - PS Horizontal	m^3					#REF!		#REF!	#REF!									
d. M15A20 - PS vertical	m^3					#REF!		#REF!	#REF!									
e. M20A20	m^3					#REF!		#REF!	#REF!									
f. M20A20 -HRT	m^3					#REF!		#REF!	#REF!									
g. M25A20	m^3					#REF!		#REF!	#REF!									
h. M25A20 -DT	m^3					#REF!		#REF!	#REF!									
i. M30A20	m^3					#REF!		#REF!	#REF!									
15- Boulder Pitching (Compacted)	m^3						-											
16- Stone Pitching (HAND PACKED) 200mm thick	m^3						-											
17- Stone Masonry Works	m^3						-											
18- Brick Works	m^3					-			-	-								
19- Drainage Holes (76mm Dia)	m																	
		Total	#REF!	#REF!	#REF!	#REF!	1,86,780	#REF!	#REF!	3,69,000	#REF!	8,428	15,000	#REF!	1,92,292	#REF!	#REF!	#REF!

OJU HYDROELECTRIC PROJECT (1800 MW)
Construction Material Requirement

Particulars	Units	Diversion Tunnels	U/S & D/S Pre Coffer Dam	U/S Coffer Dam	D/S Coffer Dam	Dam	Intake	Muck Disposal Area (C-work)	Head Race Tunnel	Surge Shaft	Pressure Shaft	Valve Chamber	Penstock erection chamber-1	Penstock erection chamber-2	Power House Cavern	Transformer Hall Cavern	Collection Gallery	Bus Duct & Cable Duct	Draft Tube Tunnels	Pot Head Yard	Adits/ Accesses Tunnels	Main Access Tunnel	Tail Race Tunnel	Muck Disposal Area (J-work)	TOTAL
1- Open Excavation																									
a. In Soil	m^3	54,613	4,872	11,051	2,514	7,01,891	#REF!			64135										177444	47508		9061		**#REF!**
b. In Rock	m^3	1,27,431	2,088	4,736	1,077	5,39,226	#REF!			27487										411081	20360		3883		**#REF!**
2- Underground Excavation																									
a. Rock	m^3	3,48,945							16,86,380	72659.7	130000	26929	7821	8464	224811	112950	64719	6715	24275		215354	37670	206371		**3174064**
b. Over Break	m^3	20,647							94,682	3633	6500	1346	391	423	11241	5648	3236	369	1214		15035	1884	11900		**178148**
3- Rock Bolt - 25mm Dia	m	61,066				17,991	#REF!		2,77,849	29972	54000	20232	5248	5702			32304	2951	4051	40040	45055	7087	70758		**#REF!**
4- Rock Bolt - 32mm Dia															103218	56905									
5- Rock Anchors - 25mm Dia	m	-							99,890	8640											46800	1893			**157223**
6- Rock Anchors - 32mm Dia						30,320																			
7- Reinforcement Steel -Fe500	MT	1,618	-	163	29	15,671	#REF!		1,488	1044		85			3360	458	307		624	39	159	0	2565		**#REF!**
8- Structural Steel																									
a. Steel Ribs - ISHB-250	MT	850							4,550	283.11													978		**6661**
b. Steel Ribs - ISHB-200	MT																		0		1000	114			**1114**
c. Steel liner SAILMA 600HI steel	MT										15000														**15000**
d. Steel Plates	MT	90							437										0	12	42	7	65		**653**
e. Tie Rod	MT	15							51												9	2	8		**85**
f. Steel liner ASTM 537 class II steel	MT										0														**0**
9- Shotcrete		6,253	-	-	-	1,403	#REF!	-	19,250	1,234	1,150	624	236	257	3,750	2,625	1,001	369	393	2,002	6,457	1,025	2,788	-	**#REF!**
a. Plain Shotcrete (M35)																									
b. Plain Shotcrete with wire mesh 50mm	m^2	43,727							2,75,000		23000								650		24097	4500	3000		
c. Plain Shotcrete with wire mesh 100	m^2	40,664				14,034	#REF!		55,000	12339		6240	2362	2566			10005	3690	3600	20020	52522	8000	26380		
d. SFRS (M35) 150mm	m^2														25000	17500									
e. SFRS (M35) 200	m^2																								
f. SFRS (M35)	m^2																								
g. SFRS (M35)	m^2																								
10- Welded Wire mesh	m^2	40,664				14,034	#REF!		55,000	12,339		5,215			25,000	17,500	2,355	3,690	3,600	20020	52,522	8,000	26,380		**#REF!**
11- Forepoles (32mm Dia)	m	5,790							79,199										0		18281	2282	23820		**129372**
12- R.C.C Lagging (M20A20)	m^3	879							3,572	198									0		713	81	647		**6090**
13- Concrete Blocks	m^3					5,589											1808								**7397**
14- Grouting																									
a. Drilling for Consolidation Grouting	m	12,488				31,916			81,508	5205	45000						3657		1620		3664		34462		**219520**
b. Drilling for Contact Grouting	m	4,680	#REF!	12,761	626	5,600			29,444	1377	7000						366		405		255		6185		**#REF!**
c. Cement for Grouting	Bags	27,784	#REF!	38,283	1,878	1,12,548			1,80,682	11,036	39,076						7,680		3,362		7,481		73,047		**#REF!**
15- Concreting (DAM)																									
a. M15A150	m^3					4,29,489																			**429489**
b. M20A40	m^3					11,388																			**11388**
c. M20A75	m^3					1,52,425																			**152425**
d. M25A40	m^3					4,45,434																			**445434**
e. M30A20	m^3					867																			**867**
f. M60A20(HPC) (4 kg micro silica per bag of cement	m^3					12,328																			**12328**
16- Concreting																									
a. M10A20	m^3	1,950																							**1950**
b. M15A20	m^3	7,250					#REF!		25,500	920									0		4315	562	12763		**#REF!**
c. M15A20 - PS Horizontal	m^3										38000	0													**38000**
d. M15A20 - PS vertical	m^3										45000														**45000**
e. M20A20	m^3	2,308	-	3,268	578	6,896				13043.8		1220			20792						9858	1663			**59627**
f. M20A20 -HRT	m^3	6,700							4,10,480										7800				48947		**473927**
g. M25A20	m^3						#REF!								11649	5722	3835			385	13587		1661		**#REF!**
h. M25A20 -DT	m^3	1,19,905																							**119905**
i. M30A20	m^3	280					#REF!												160		10				**#REF!**
17- Boulder Pitching (Compacted)	m^3	20																			116				**136**
18- Stone Pitching (HAND PACKED) 200mm thick	m^3	1,730	16,390	1,28,988	7,063																				**154171**
19- Stone Masonry Works	m^3																						57		**57**
20- Brick Works	m^3															572				166					**738**
21- Drainage Holes (76mm Dia)	m	6,009				27,203	#REF!		13,701	3062	3300	867	328	356	7136	4943	2779	641	405	6256	17492	2253	3626		**#REF!**
22- PVC Water Seal	Rm	172	-	742	144	6,325																			**7383**

TRACTEBEL engie

	Particulars	C-1	C-2	C-3	C-4	C-5	J-1	J-2	J-3	J-4	J-5	J-6	J-7	J-8	J-9	
	1- Open Excavation															
	a. In Soil	54613	18437	#REF!	0		0	64135	0	0	177444	47508	9061	0		
	b. In Rock	127431	7901	#REF!	0		0	27487	0	0	411081	20360	3883	0		
	2- Underground Excavation	0	0	0	0		0	0	0	0	0	0	0	0		
	a. Rock	348945	0	0	0		1686380	72660	173214	433470	0	253024	206371	0		
	b. Over Break	20647	0	0	0		94682	3633	8661	21707	0	16919	11900	0		
	3- Rock Bolt - 25mm Dia	61066	0	#REF!	0		277849	29972	85182	39306	40040	52142	70758	0		
		0	0	0	0		0	0	0	160123	0	0	0	0		
	4- Rock Anchors - 25mm Dia	0	0	0	0		99890	8640	0	0	0	48693	0	0		
		0	0	30320	0		0	0	0	0	0	0	0	0		
	5- Reinforcement Steel	1618	192	#REF!	0		1488	1044	85	4749	39	159	2565	0		
	6- Structural Steel	0	0	0	0		0	0	0	0	0	0	0	0		
	b. Steel Ribs - ISHB-200	850	0	0	0		4550	283	0	0	0	0	978	0		
	c. Steel Ribs - ISMB-200	0	0	0	0		0	0	0	0	0	1114	0	0		
	f. Stiffener ASTM 537 class II steel	0	0	0	0		0	0	15000	0	0	0	0	0		
	g. Steel Plates	90	0	0	0		437	0	0	0	12	49	65	0		
	h. Tie Rod	15	0	0	0		51	0	0	0	0	11	8	0		
	i. Steel liner ASTM 537 class II steel	0	0	0	0		0	0	0	0	0	0	0	0		
	7- Shotcrete	6253	0	#REF!	0		19250	1234	2267	8137	2002	7482	2788	0		
	Plane Shotcrete (M35)	6253	0	#REF!	0		19250	1234	2267	8137	2002	7482	2788	0		
	Plain Shotcrete with wire mesh	43727	0	0	0		275000	0	23000	650	0	28597	3000	0		
	Plain Shotcrete with wire mesh	40664	0	#REF!	0		55000	12339	11168	17295	20020	60522	26380	0		
	SFRS with wire mesh (M35)	0	0	0	0		0	0	0	42500	0	0	0	0		
	SFRS with wire mesh (M35)	0	0	0	0		0	0	0	0	0	0	0	0		
	SFRS with wire mesh (M35)	0	0	0	0		0	0	0	0	0	0	0	0		
	SFRS with wire mesh (M35)	0	0	0	0		0	0	0	0	0	0	0	0		
	8- Welded Wire mesh	40664	0	#REF!	0		55000	12339	5215	52145	20020	60522	26380	0		
	9- Forepoles	5790	0	0	0		79199	0	0	0	0	20563	23820	0		
365.4	10- R.C.C Lagging (M20A20)	879	0	0	0		3572	198	0	0	0	794	647	0		6,090
628.75	11- Concrete Blocks	0	0	5589	0		0	0	0	1808	0	0	0	0		7,397
	12- Grouting	0	0	0	0		0	0	0	0	0	0	0	0		
	a. Drilling for Consolidation Grouting	12488	0	31916	0		81508	5205	45000	5277	0	3664	34462	0		
	b. Drilling for Contact Grouting	4680	#REF!	5600	0		29444	1377	7000	771	0	255	6185	0		
	c. Cement for Grouting	27784	#REF!	112548	0		180682	11036	39076	11042	0	7481	73047	0		
	13- Concreting (DAM)	0	0	0	0		0	0	0	0	0	0	0	0		
	a. M15A150	0	0	429489	0		0	0	0	0	0	0	0	0		4,29,489
	b. M20A40	0	0	11388	0		0	0	0	0	0	0	0	0		11,388
	c. M20A75	0	0	152425	0		0	0	0	0	0	0	0	0		1,52,425
	d. M25A40	0	0	445434	0		0	0	0	0	0	0	0	0		4,45,434
	e. M30A20	0	0	867	0		0	0	0	0	0	0	0	0		867
	f. M60A20(HPC) (4 kg micro silica per bag of cer	0	0	12328	0		0	0	0	0	0	0	0	0		12,328
	14- Concreting	0	0	0	0		0	0	0	0	0	0	0	0		
	a. M10A20	1950	0	0	0		0	0	0	0	0	0	0	0		1,950
	b. M15A20	7250	0	#REF!	0		25500	920	0	0	0	4877	12763	0		#REF!
	c. M15A20 - PS Horizontal	0	0	0	0		0	0	38000	0	0	0	0	0		38,000
	d. M15A20 - PS vertical	0	0	0	0		0	0	45000	0	0	0	0	0		45,000
	e. M20A20	2308	3846	6896	0		0	13044	1220	20792	0	11521	0	0		59,627
	f. M20A20 -HRT	6700	0	0	0		410480	0	0	7800	0	0	48947	0		4,73,927
	g. M25A20	0	0	#REF!	0		0	0	0	21206	385	13587	1661	0		#REF!
	h. M25A20 -DT	119905	0	0	0		0	0	0	0	0	0	0	0		1,19,905
	i. M30A20	280	0	#REF!	0		0	0	0	160	0	10	0	0		#REF!
	15- Boulder Pitching (Compacted)	20	0	0	0		0	0	0	0	0	116	0	0		
	16- Stone Pitching (HAND PACKED) 200mm thick	1730	152441	0	0		0	0	0	0	0	0	0	0		
	17- Stone Masonry Works	0	0	0	0		0	0	0	0	0	0	57	0		
	18- Brick Works	0	0	0	0		0	0	0	572	166	0	0	0		
	19- Drainage Holes (76mm Dia)	6009	0	#REF!	0		13701	3062	4851	15904	6256	19745	3626	0		
	20- PVC Water Seal	172	886	6325	0		0	0	0	0	0	0	0	0		

PHASING OF COST OF CIVIL WORKS

(Rs. Lacs)

S.No.	ACTIVITY/ITEM	Basic Cost as on May 2022 Price Level	Pre Construction Stage			Zero Date October 2026	Construction Stage												Basic Cost as on May 2022 Price Level	Total Escalation	Completed Cost
			YEAR - 3	YEAR - 4			YEAR - 1		YEAR -2		YEAR -3		YEAR -4		YEAR -5		YEAR -6				
			H-II	H-I	H-II		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	56-60	61-66	67-72			
	DIRECT CHARGES																				
	I - Works																				
1	A - PRELIMINARY																				
	Phasing of expenditure in %age		*5.0%*	*5%*	*4.0%*		*15%*	*15%*	*20%*	*20%*	*5%*	*5%*	*5%*	*1%*	*0%*	*0%*	*0%*	*0%*			
	Basic Cost at Oct 2010 Price Level	12758.86	637.9	637.9	510.4		1913.8	1913.8	2551.8	2551.8	637.9	637.9	637.9	127.6	0.0	0.0	0.0	0.0	12758.86		
	Escalation		124.40	143.54	130.14		545.44	602.86	880.36	956.91	258.37	277.51	296.64	63.16	0.00	0.00	0.00	0.00		4279.3	
	Completion Cost		762.3	781.5	640.5		2459.3	2516.7	3432.1	3508.7	896.3	915.4	934.6	190.7	0.0	0.0	0.0	0.0			17038.18
2	B - LAND																				
	Phasing of expenditure in %age		*7.5%*	*8%*	*15.0%*		*30%*	*15%*	*15%*	*10%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*			
	Basic Cost at Oct 2010 Price Level	12758.86	956.9	956.9	1913.8		3827.7	1913.8	1913.8	1275.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12758.86		
	Escalation		186.60	215.31	488.03		1090.88	602.86	660.27	478.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		3722.4	
	Completion Cost		1143.5	1172.2	2401.9		4918.5	2516.7	2574.1	1754.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			16481.26
3	**C - Works**																				
	C-1 Diversion Tunnels																				
	Phasing of expenditure in %age						40.50%	25.25%	24.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.00%			
	Basic Cost as on May 2022 Price Level	33350.00					13506.8	8420.9	8087.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3335.0	33350.00		
	Escalation						3849.42	2652.58	2790.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2051.03		11343.2	
	Completion Cost						17356.2	11073.5	10877.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5386.0			44693.17
	C-2 Coffer Dams																				
	Phasing of expenditure in %age						0.00%	0.00%	91.25%	8.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%			
	Basic Cost as on May 2022 Price Level	5765.00					0.0	0.0	5260.6	504.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5765.00		
	Escalation						0.00	0.00	1814.89	189.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		2004.1	
	Completion Cost						0.0	0.0	7075.5	693.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			7769.06
	C-3 Dam																				
	Phasing of expenditure in %age						0.00%	0.00%	5.90%	5.50%	7.00%	7.00%	10.00%	15.60%	21.03%	3.38%	24.60%	0.00%			
	Basic Cost as on May 2022 Price Level	153376.00					0.0	0.0	9049.2	8435.7	10736.3	10736.3	15337.6	23926.7	32247.3	5176.4	37730.5	0.0	153376.00		
	Escalation						0.00	0.00	3121.97	3163.38	4348.21	4670.30	7131.98	11843.69	16929.83	2872.92	22072.34	0.00		76154.6	
	Completion Cost						0.0	0.0	12171.2	11599.1	15084.5	15406.6	22469.6	35770.4	49177.1	8049.4	59802.8	0.0			229530.63
	C-4 Hydromechanical for C-works																				
	Phasing of expenditure in %age						*0.00%*	*7.00%*	*18.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*8.61%*	*23.35%*	*43.04%*	*0.00%*			
	Basic Cost as on May 2022 Price Level	15677.00					0.0	1097.4	2821.9	0.0	0.0	0.0	0.0	0.0	1349.8	3660.6	6747.4	0.0	15677.00		
	Escalation						0.00	345.68	973.54	0.00	0.00	0.00	0.00	0.00	708.64	2031.62	3947.22	0.00		8006.7	
	Completion Cost						0.0	1443.1	3795.4	0.0	0.0	0.0	0.0	0.0	2058.4	5692.2	10694.6	0.0			23683.70
	Total C-Works																				
	Basic Cost at Oct 2010 Price Level	**208168.00**					**13506.75**	**9518.27**	**25218.98**	**8940.12**	**10736.32**	**10736.32**	**15337.60**	**23926.66**	**33597.09**	**8837.02**	**44477.88**	**3335.00**	208168.00		
	Escalation						**3849.42**	**2998.25**	**8700.55**	**3352.54**	**4348.21**	**4670.30**	**7131.98**	**11843.69**	**17638.47**	**4904.55**	**26019.56**	**2051.03**		97508.6	
	Completion Cost						**17356.17**	**12516.52**	**33919.53**	**12292.66**	**15084.53**	**15406.62**	**22469.58**	**35770.35**	**51235.57**	**13741.57**	**70497.43**	**5386.03**			305676.56

4	**J - Works**																
	J-1 Intake																
	Phasing of expenditure in %age			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	26.00%	24.00%	0.00%		
	Basic Cost as on May 2022 Price Level	18565.00		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9282.5	4826.9	4455.6	0.0	18565.00		
	Escalation			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4873.3	2678.9	2606.5	0.0		10158.8	
	Completion Cost			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14155.8	7505.8	7062.1	0.0			28723.77
	J-2 Construction Adits and Accessess Tunnels																	
	Phasing of expenditure in %age			100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%			
	Basic Cost as on May 2022 Price Level	17980.00		17980.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17980.00		
	Escalation			5124.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		5124.3	
	Completion Cost			23104.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			23104.30
	J-3 Head Race Tunnel																	
	Phasing of expenditure in %age			0.00%	16.60%	17.20%	6.55%	17.54%	9.60%	10.92%	5.17%	10.27%	4.17%	1.99%	0.00%			
	Basic Cost as on May 2022 Price Level	122360.00		0.0	20311.7	21046.1	8008.5	21460.2	11752.2	13355.8	6326.9	12563.8	5105.8	2429.2	0.0	122360.00		
	Escalation			0.0	6398.2	7260.9	3003.2	8691.4	5112.2	6210.4	3131.8	6596.0	2833.7	1421.1	0.0		50658.8	
	Completion Cost			0.0	26709.8	28306.9	11011.7	30151.6	16864.3	19566.3	9458.7	19159.7	7939.6	3850.3	0.0			173018.84
	J-4 Surge Shaft																	
	Phasing of expenditure in %age			20.00%	0.00%	20.00%	3.64%	6.31%	3.74%	6.31%	11.48%	12.62%	7.48%	8.42%	0.00%			
	Basic Cost as on May 2022 Price Level	8190.00		1638.0	0.0	1638.0	297.8	516.9	306.3	516.9	940.3	1033.9	612.7	689.2	0.0	8190.00		
	Escalation			466.8	0.0	565.1	111.7	209.4	133.3	240.4	465.4	542.8	340.0	403.2	0.0		3478.0	
	Completion Cost			2104.8	0.0	2203.1	409.5	726.3	439.6	757.3	1405.7	1576.6	952.7	1092.4	0.0			11668.03
	J-5 Pressure Shaft and Valve Chamber		Zero Date October 2026															
	Phasing of expenditure in %age			23.60%	15.42%	17.10%	7.50%	0.00%	0.00%	10.00%	10.00%	12.90%	3.48%	0.00%	0.00%			
	Basic Cost as on May 2022 Price Level	71530.00		16881.1	11029.9	12231.6	5364.8	0.0	0.0	7153.0	7153.0	9227.4	2489.2	0.0	0.0	71530.00		
	Escalation			4811.1	3474.4	4219.9	2011.8	0.0	0.0	3326.1	3540.7	4844.4	1381.5	0.0	0.0		27610.0	
	Completion Cost			21692.2	14504.4	16451.5	7376.5	0.0	0.0	10479.1	10693.7	14071.7	3870.8	0.0	0.0			99140.01
	J-6 Power House Complex																	
	Phasing of expenditure in %age			11.04%	18.13%	8.74%	4.18%	6.65%	10.60%	15.36%	7.16%	7.31%	4.27%	6.56%	0.00%			
	Basic Cost as on May 2022 Price Level	27210.00		3004.4	4931.8	2377.4	1136.4	1810.6	2884.8	4178.7	1948.4	1989.7	1162.1	1785.7	0.0	27210.00		
	Escalation			856.3	1553.5	820.2	426.1	733.3	1254.9	1943.1	964.5	1044.6	645.0	1044.6	0.0		11286.0	
	Completion Cost			3860.7	6485.3	3197.6	1562.5	2543.8	4139.7	6121.8	2912.9	3034.3	1807.1	2830.3	0.0			38496.04
	J-7 Tail Race Tunnel																	
	Phasing of expenditure in %age			0.00%	0.00%	23.33%	11.40%	15.27%	14.35%	15.78%	9.35%	10.52%	0.00%	0.00%	0.00%			
	Basic Cost as on May 2022 Price Level	23910.00		0.0	0.0	5577.2	2726.4	3651.4	3431.2	3772.8	2235.7	2515.2	0.0	0.0	0.0	23910.00		
	Escalation			0.0	0.0	1924.1	1022.4	1478.8	1492.6	1754.4	1106.7	1320.5	0.0	0.0	0.0		10099.5	
	Completion Cost			0.0	0.0	7501.3	3748.8	5130.2	4923.8	5527.2	3342.4	3835.7	0.0	0.0	0.0			34009.47
	J-8 Pothead Yard																	
	Phasing of expenditure in %age			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	38.75%	11.25%	33.13%	16.88%	0.00%	0.00%			
	Basic Cost as on May 2022 Price Level	7515.00		0.0	0.0	0.0	0.0	0.0	0.0	2912.1	845.4	2489.3	1268.2	0.0	0.0	7515.00		
	Escalation			0.0	0.0	0.0	0.0	0.0	0.0	1354.1	418.5	1306.9	703.8	0.0	0.0		3783.3	
	Completion Cost			0.0	0.0	0.0	0.0	0.0	0.0	4266.2	1263.9	3796.2	1972.0	0.0	0.0			11298.33
	J-9 Hydro Mechanical for J-Works																	
	Phasing of expenditure in %age			0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.36%	27.64%	59.00%	0.00%			
	Basic Cost as on May 2022 Price Level	1085.00		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.9	299.9	640.2	0.0	1085.00		
	Escalation			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.1	166.5	374.5	0.0		617.0	
	Completion Cost			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	221.0	466.4	1014.6	0.0			1702.03
	Total J-Works																	
	Basic Cost at Oct 2010 Price Level	**298345.00**		**39503.52**	**36273.40**	**42870.32**	**17533.84**	**27439.08**	**18374.51**	**31889.29**	**19449.72**	**39246.68**	**15764.80**	**9999.85**	**0.00**	298345.00		

	Escalation					11258.50	11426.12	14790.26	6575.19	11112.83	7992.91	14828.52	9627.61	20604.51	8749.47	5849.91	0.00		122815.83	
	Completion Cost					50762.02	47699.51	57660.58	24109.03	38551.90	26367.42	46717.80	29077.34	59851.19	24514.27	15849.76	0.00			421160.83

						Zero Date October 2026															
5	K-Buildings																				
	Phasing of expenditure in %age		*4%*	*4%*	*8%*		*5.00%*	*5.00%*	*10.00%*	*15.00%*	*14.00%*	*7.50%*	*7.50%*	*7.50%*	*5.00%*	*2.50%*	*2.50%*	*2.50%*			
	Basic Cost as on May 2022 Price Level	15948.58	637.9	637.9	1275.9		797.4	797.4	1594.9	2392.3	2232.8	1196.1	1196.1	1196.1	797.4	398.7	398.7	398.7	15948.58		
	Escalation		124.40	143.54	325.35		227.27	251.19	550.23	897.11	904.28	520.32	556.21	592.09	418.65	221.29	233.25	245.21		6210.4	
	Completion Cost		762.3	781.5	1601.2		1024.7	1048.6	2145.1	3289.4	3137.1	1716.5	1752.3	1788.2	1216.1	620.0	632.0	643.9			22158.95
6	M-Plantation																				
	Phasing of expenditure in %age						*2.50%*	*2.50%*	*2.50%*	*15.00%*	*15.00%*	*15.00%*	*15.00%*	*15.00%*	*7.50%*	*5.00%*	*2.50%*	*2.50%*			
	Basic Cost as on May 2022 Price Level	235.00					5.9	5.9	5.9	35.3	35.3	35.3	35.3	35.3	17.6	11.8	5.9	5.9	235.00		
	Escalation						1.67	1.85	2.03	13.22	14.28	15.33	16.39	17.45	9.25	6.52	3.44	3.61		105.0	
	Completion Cost						7.5	7.7	7.9	48.5	49.5	50.6	51.6	52.7	26.9	18.3	9.3	9.5			340.05
7	O-Miscellaneous																				
	Phasing of expenditure in %age		*3%*	*3%*	*5%*		*2.50%*	*2.50%*	*15.00%*	*15.00%*	*15.00%*	*15.00%*	*15.00%*	*5.00%*	*2.50%*	*2.50%*	*0.00%*	*0.00%*			
	Basic Cost as on May 2022 Price Level	25517.72	637.9	637.9	1275.9		637.9	637.9	3827.7	3827.7	3827.7	3827.7	3827.7	1275.9	637.9	637.9	0.0	0.0	25517.72		
	Escalation		124.40	143.54	325.35		181.81	200.95	1320.54	1435.37	1550.20	1665.03	1779.86	631.56	334.92	354.06	0.00	0.00		10047.6	
	Completion Cost		762.3	781.5	1601.2		819.8	838.9	5148.2	5263.0	5377.9	5492.7	5607.5	1907.4	972.9	992.0	0.0	0.0			35565.32
8	P-Maintenance																				
	Phasing of expenditure in %age						*2.50%*	*2.50%*	*5.00%*	*15.00%*	*15.00%*	*15.00%*	*15.00%*	*15.00%*	*5.00%*	*5.00%*	*2.50%*	*2.50%*			
	Basic Cost as on May 2022 Price Level	5290.00					132.3	132.3	264.5	793.5	793.5	793.5	793.5	793.5	264.5	264.5	132.3	132.3	5290.00		
	Escalation						37.69	41.66	91.25	297.56	321.37	345.17	368.98	392.78	138.86	146.80	77.37	81.33		2340.8	
	Completion Cost						169.9	173.9	355.8	1091.1	1114.9	1138.7	1162.5	1186.3	403.4	411.3	209.6	213.6			7630.83
9	Q-Special T & P																				
	Phasing of expenditure in %age		*4%*	*4%*	*8%*		*2.50%*	*5.00%*	*7.50%*	*15.00%*	*15.00%*	*10.00%*	*8.00%*	*8.00%*	*8.00%*	*5.00%*	*0.00%*	*0.00%*			
	Basic Cost as on May 2022 Price Level	200.00	8.0	8.0	16.0		5.0	10.0	15.0	30.0	30.0	20.0	16.0	16.0	16.0	10.0	0.0	0.0	200.00		
	Escalation		1.56	1.80	4.08		1.43	3.15	5.18	11.25	12.15	8.70	7.44	7.92	8.40	5.55	0.00	0.00		78.6	
	Completion Cost		9.6	9.8	20.1		6.4	13.2	20.2	41.3	42.2	28.7	23.4	23.9	24.4	15.6	0.0	0.0			278.60
10	R-Communication																				
	Phasing of expenditure in %age		*20%*	*20%*	*40%*		*5.00%*	*5.00%*	*5.00%*	*5.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*			
	Basic Cost as on May 2022 Price Level	25517.72	5103.5	5103.5	10207.1		1275.9	1275.9	1275.9	1275.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25517.72		
	Escalation		995.19	1148.30	2602.81		363.63	401.90	440.18	478.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		6430.5	
	Completion Cost		6098.7	6251.8	12809.9		1639.5	1677.8	1716.1	1754.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			31948.19
11	X-Environment, Ecology & Afforestation																				
	Phasing of expenditure in %age		*4%*	*4%*	*8%*		*7.50%*	*7.50%*	*10.00%*	*10.00%*	*10.00%*	*10.00%*	*10.00%*	*5.00%*	*5.00%*	*5.00%*	*2.50%*	*1.50%*			
	Basic Cost as on May 2022 Price Level	31897.15	1275.9	1275.9	2551.8		2392.3	2392.3	3189.7	3189.7	3189.7	3189.7	3189.7	1594.9	1594.9	1594.9	797.4	478.5	31897.15		
	Escalation		248.80	287.07	650.70		681.80	753.57	1100.45	1196.14	1291.83	1387.53	1483.22	789.45	837.30	885.15	466.50	294.25		12353.8	
	Completion Cost		1524.7	1563.0	3202.5		3074.1	3145.9	4290.2	4385.9	4481.5	4577.2	4672.9	2384.3	2432.2	2480.0	1263.9	772.7			44250.92
12	Y loses -Provision made @ 0.25% ofC+J+K																				
	Basic Cost as on May 2022 Price Level	1306.15	1.6	1.6	3.2		134.5	116.5	174.2	72.2	101.0	75.8	121.1	111.4	184.1	62.5	137.2	9.3	1306.15		
	Escalation		0.31	0.36	0.81		38.34	36.69	60.10	27.06	40.91	32.96	56.29	55.16	96.65	34.69	80.26	5.7		566.3	
	Completion Cost		1.9	2.0	4.0		172.9	153.2	234.3	99.2	141.9	108.7	177.3	166.6	280.8	97.2	217.4	15.1			1872.49
	Total of I-Works																				
	Basic Cost as on May 2022 Price Level	**637943.05**	**9259.77**	**9259.77**	**17754.01**		**64132.94**	**54987.46**	**82902.60**	**41918.08**	**49023.29**	**38886.80**	**57044.15**	**48527.04**	**76356.23**	**27582.09**	**55949.18**	**4359.63**	637943.05		
	Escalation		**1805.65**	**2083.45**	**4527.27**		**18277.89**	**17321.05**	**28601.40**	**15719.28**	**19854.43**	**16915.76**	**26525.53**	**24020.88**	**40087.02**	**15308.06**	**32730.27**	**2681.17**		266459.1	
	Completion Cost		**11065.42**	**11343.22**	**22281.28**		**82410.83**	**72308.51**	**111504.00**	**57637.36**	**68877.72**	**55802.56**	**83569.68**	**72547.92**	**116443.26**	**42890.15**	**88679.46**	**7040.80**			904402.17

II	Establishment																				
	Basic Cost as on May 2022 Price Level	26410.00	383.34	383.34	734.99		2655.02	2276.41	3432.06	1735.35	2029.50	1609.86	2361.55	2008.96	3161.05	1141.86	2316.22	180.48	26410.00		
	Escalation		74.75	86.25	187.42		756.68	717.07	1184.06	650.76	821.95	700.29	1098.12	994.43	1659.55	633.73	1354.99	111.00		11031.06	
	Completion Cost		458.1	469.6	922.4		3411.7	2993.5	4616.1	2386.1	2851.4	2310.2	3459.7	3003.4	4820.6	1775.6	3671.2	291.5			37441.06
III	T & P																				
	Phasing of expenditure in %age						8.00%	8.00%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.50%	8.00%	8.00%			
	Basic Cost as on May 2022 Price Level	200.00					16.00	16.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	16.00	16.00	200.00		
	Escalation						4.56	5.04	5.87	6.38	6.89	7.40	7.91	8.42	8.93	9.44	9.36	9.84		90.0	
	Completion Cost						20.6	21.0	22.9	23.4	23.9	24.4	24.9	25.4	25.9	26.4	25.4	25.8			290.00
IV	Receipts & Recoveries (-)																				
	Phasing of expenditure in %age						0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	50.00%			
	Basic Cost as on May 2022 Price Level	1270.00					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	635.00	635.00	1270.00		
	Escalation						0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	371.48	390.53		762.0	
	Completion Cost						0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1006.5	1025.5			2032.00
	TOTAL OF DIRECT CHARGES																				
	Basic Cost as on May 2022 Price Level	**663283.05**	**9643.11**	**9643.11**	**18489.00**		**66803.96**	**57279.87**	**86351.66**	**43670.43**	**51069.78**	**40513.67**	**59422.71**	**50552.99**	**79534.28**	**28740.95**	**57646.41**	**3921.11**	663283.05		
	Escalation		**1880.41**	**2169.70**	**4714.69**		**19039.13**	**18043.16**	**29791.32**	**16376.41**	**20683.26**	**17623.45**	**27631.56**	**25023.73**	**41755.50**	**15951.23**	**33723.15**	**2411.49**		276818.18	
	Completion Cost		**11523.52**	**11812.81**	**23203.69**		**85843.09**	**75323.03**	**116142.98**	**60046.84**	**71753.05**	**58137.11**	**87054.26**	**75576.72**	**121289.78**	**44692.18**	**91369.56**	**6332.60**			940101.23
	INDIRECT CHARGES																				
(a)	Audit & Accounts @ 0.25% of I - Works					**Zero Date October 2026**															
	Basic Cost as on May 2022 Price Level	1594.86	23.15	23.15	44.39		160.33	137.47	207.26	104.80	122.56	97.22	142.61	121.32	190.89	68.96	139.87	10.90	1594.86		
	Escalation		4.51	5.21	11.32		45.69	43.30	71.50	39.30	49.64	42.29	66.31	60.05	100.22	38.27	81.83	6.70		666.1	
	Completion Cost		27.7	28.4	55.7		206.0	180.8	278.8	144.1	172.2	139.5	208.9	181.4	291.1	107.2	221.7	17.6			2261.01
(b)	Capitalization of abatement of land revenue																				
	Basic Cost as on May 2022 Price Level	320.00	24.00	24.00	48.00		96.00	48.00	48.00	32.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	320.00		
	Escalation		4.68	5.40	12.24		27.36	15.12	16.56	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		93.4	
	Completion Cost		28.7	29.4	60.2		123.4	63.1	64.6	44.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			413.36
	Total of Indirect Charges																				
	Basic Cost as on May 2022 Price Level	1914.86	47.15	47.15	92.39		256.33	185.47	255.26	136.80	122.56	97.22	142.61	121.32	190.89	68.96	139.87	10.90	1914.86		
	Escalation		9.19	10.61	23.56		73.05	58.42	88.06	51.30	49.64	42.29	66.31	60.05	100.22	38.27	81.83	6.70		759.51	
	Completion Cost		56.34	57.76	115.94		329.39	243.89	343.32	188.09	172.19	139.51	208.92	181.37	291.11	107.23	221.70	17.60			2674.37
	TOTAL DIRECT & INDIRECT CHARGES																				
	Basic Cost as on May 2022 Price Level	**665197.91**	**9690.26**	**9690.26**	**18581.38**		**67060.30**	**57465.34**	**86606.92**	**43807.23**	**51192.34**	**40610.88**	**59565.32**	**50674.31**	**79725.17**	**28809.91**	**57786.28**	**3932.01**	**665197.91**		
	Escalation		**1889.60**	**2180.31**	**4738.25**		**19112.18**	**18101.58**	**29879.39**	**16427.71**	**20732.90**	**17665.73**	**27697.87**	**25083.78**	**41855.71**	**15989.50**	**33804.97**	**2418.19**		**277577.69**	
	Completion Cost		**11579.86**	**11870.57**	**23319.64**		**86172.48**	**75566.92**	**116486.30**	**60234.94**	**71925.24**	**58276.62**	**87263.19**	**75758.09**	**121580.89**	**44799.41**	**91591.25**	**6350.20**			**942775.59**
	AMOUNT IN CRORES																				
	Basic Cost as on May 2022 Price Level	**6651.98**	**96.90**	**96.90**	**185.81**		**670.60**	**574.65**	**866.07**	**438.07**	**511.92**	**406.11**	**595.65**	**506.74**	**797.25**	**288.10**	**577.86**	**39.32**	**6651.98**		
	Escalation		**18.90**	**21.80**	**47.38**		**191.12**	**181.02**	**298.79**	**164.28**	**207.33**	**176.66**	**276.98**	**250.84**	**418.56**	**159.89**	**338.05**	**24.18**		**2775.78**	
	Completion Cost		**115.80**	**118.71**	**233.20**		**861.72**	**755.67**	**1164.86**	**602.35**	**719.25**	**582.77**	**872.63**	**757.58**	**1215.81**	**447.99**	**915.91**	**63.50**			**9427.76**
	Escalation per year	**6.00%**																			
	Total months upto mid of half yearly distribution		**39**	**45**	**51**		**57**	**63**	**69**	**75**	**81**	**87**	**93**	**99**	**105**	**111**	**117**	**123**			
	Escalation in %age		19.50%	22.50%	25.50%		28.50%	31.50%	34.50%	37.50%	40.50%	43.50%	46.50%	49.50%	52.50%	55.50%	58.50%	61.50%			
	Escalation Factor		1.20	1.23	1.26		1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.50	1.53	1.56	1.59	1.62			

PHASING OF COST OF EM WORKS

ACTIVITY/ITEM	Basic Cost as on May 2022 Price Level	Pre Construction Stage			Zero Date October 2026	Construction Stage												Basic Cost as on May 2022 Price Level
		YEAR - 3	YEAR - 4			YEAR - 1		YEAR -2		YEAR -3		YEAR -4		YEAR -5		YEAR -6		
		H-II	H-I	H-II		0-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	56-60	61-66	67-72	
EM Escalation	5.00%					23.75%	26.25%	28.75%	31.25%	33.75%	36.25%	38.75%	41.25%	43.75%	46.25%	48.75%	51.25%	
						0.00%	0.00%	15.00%	0.00%	0.00%	0.00%	0.00%	10.00%	25.00%	25.00%	25.00%	0.00%	100.00%
EM Cost	2817		EM Cost			0	0	422.55	0	0	0	0	281.7	704.25	704.25	704.25	0	2817
Escalation			Escalation			0.00	0.00	121.48	0.00	0.00	0.00	0.00	116.20	308.11	325.72	343.32	0.00	1215
Escalated cost			**Escalated cost**			**0.0**	**0.0**	**544.0**	**0.0**	**0.0**	**0.0**	**0.0**	**397.9**	**1012.4**	**1030.0**	**1047.6**	**0.0**	**4032**

CALCULATION OF IDC AND FINANCING CHARGES (CIVIL WORKS AND E&M WORKS)

PRESENT DAY COST		
CIVIL	9427.76	Crores
E&M	4031.83	Crores
TOTAL	13459.59	Crores
INTEREST RATE (R%)	12.00%	
HALF YEARLY INTEREST RATE (R% /2)	6.00%	
MONTHLY INTEREST RATE (R% /12)	1.00%	
EQUITY	30%	
LOAN	70%	
FINANCING CHARGES	1.00%	

(Figure in Crores)

Sl.no.	Particulars	Expenditure to be made Till Sep 2026	Construction Period												Total
			YEAR - 1		YEAR -2		YEAR -3		YEAR -4		YEAR - 5		YEAR - 6		
1	**Period**		**0-6**	**7-12**	**13-18**	**19-24**	**25-30**	**31-36**	**37-42**	**43-48**	**49-54**	**56-60**	**61-66**	**67-72**	
2	**No. of Months**		6	6	6	6	6	6	6	6	6	6	6	3	
3	**Present Day Cost (Crores)**														
	Civil	467.70	861.72	755.67	1164.86	602.35	719.25	582.77	872.63	757.58	1215.81	447.99	915.91	63.50	**9427.76**
	E&M	0.00	0.00	0.00	544.03	0.00	0.00	0.00	0.00	397.90	1012.36	1029.97	1047.57	0.00	**4031.83**
	Total	**467.70**	**861.72**	**755.67**	**1708.90**	**602.35**	**719.25**	**582.77**	**872.63**	**1155.48**	**2228.17**	**1477.96**	**1963.48**	**63.50**	**13459.59**
4	**Financial Charges(Crores)**	119.79													**119.79**
5	**Equity Amount**		434.77	226.70	512.67	180.70	215.78	174.83	261.79	346.64	668.45	443.39	589.05	19.05	**4073.81**
6	**Debt(Loan) Amount**		1014.45	528.97	1196.23	421.64	503.48	407.94	610.84	808.84	1559.72	1034.57	1374.44	44.45	**9505.56**
7	**I.D.C.**		**30.43**	**78.01**	**133.05**	**187.17**	**222.79**	**259.49**	**300.95**	**356.18**	**442.19**	**538.59**	**633.49**	**351.33**	**3533.66**
8	**Debt component of IDC**		21.30	54.61	93.13	131.02	155.95	181.64	210.66	249.32	309.54	377.02	443.44	245.93	**2473.56**
9	**Equity component of IDC**		9.13	23.40	39.91	56.15	66.84	77.85	90.28	106.85	132.66	161.58	190.05	105.40	**1060.10**
10	**Total Equity Amout**		443.9	250.11	552.6	236.9	282.6	252.7	352.1	453.5	801.1	605.0	779.1	124.4	**5133.91**
11	**Total Debt Amount(Loan)**		1035.76	583.58	1289.36	552.66	659.43	589.58	821.51	1058.16	1869.25	1411.59	1817.88	290.38	**11979.13**
12	**Loan Outstanding at the end of the Period**		1035.76	1619.33	2908.69	3461.36	4120.78	4710.36	5531.87	6590.03	8459.28	9870.87	11688.75	11979.13	

(a)	**Total cost of Civil and E&M works with escaltion**	**13459.59**	**Crores**
(b)	**Total Financing Charges**	**119.79**	**Crores**
(c)	**Total Interest during Construction**	**3533.66**	**Crores**
(c)	**TOTAL COST INCLUDING IDC & FINANCING CHARGES**	**17113.04**	**Crores**

IDC & FC	**3653.45**	**Crores**

CALCULATION OF LEVELLIZED TARIFF (Without Free Power to Home State)

Annual Generation in 90% Dependable Year	7926.00 MU	Total Cost Including IDC		17113.04 Crs	O&M Charges (on total cost)	3.50 %	Interest Rate on Loan	12.00 %	
Auxiliary Consumption	1.20 %	Equity	30.00 %	5133.91 Crs	Rate of Increase of O&M Charges (Compounded)	6.64 %	Interest Rate on Working Capital	13.20 %	
Transformation Losses	0.00 %	Loan	70.00 %	11979.13 Crs	Maintenance Spares on O&M Charges	15.00 %	Return On Equity	16.50 %	
Free Power to Home State (1st -5th year)	0.00 %	Cost of Land (Excluding R & R)		64.27 Crs	Rate of Increase of Maintenance Spares (Compounded)	5.72 %	Discounting Rate for LT	9.94 %	
Free Power to Home State (6th -10th year)	0.00 %	Cost of R&R		14.332 Crs			Rate of return on equity (Pre-tax) (up to 10th year)		20.876%
Free Power to Home State (11th -15th year)	0.00 %				Period of higher rate of depreciation as per CERC	12 Yr	Rate of return on equity (from 11th year onwards)		24.996%
Free Power to Home State (From 16th year onward)	0.00 %				Period of applicability of MAT	10 Yr			
Additional Free Power	0.00 %								
Net Saleable Energy (1st -5th year)	7830.89 MU				Useful Life of the Project	35 Yr			
Net Saleable Energy (6th -10th year)	7830.89 MU				Operation Period of the Project	35 Yr			
Net Saleable Energy (11th -15th year)	7830.89 MU								
Net Saleable Energy (From 16th year onward)	7830.89 MU								

Year	Outstanding Loan (Rs. Crores)	Interest On Loan (Rs. Crores)	Depreciation (Rs. Crores)	Return on Equity (Rs. Crores)	O&M Charges (Rs. Crores)	O&M for One Month (Rs. Crores)	Maintenance Spares (Rs. Crores)	Two Months Average Billing (Rs. Crores)	Interest on Working Capital Cost (Rs. Crores)	Total Amount (Rs.Crores)	Charges/Unit (Rs./kWh)	Discounting Factor @9.94%	Discounted Tariff (Rs./kWh)
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
1	11979.1	1390.6	781.7	1071.7	598.5	49.9	89.8	658.0	105.3	3947.7	5.04	1.00	5.04
2	11197.5	1296.8	781.7	1071.7	638.2	53.2	95.7	649.0	105.3	3893.7	4.97	0.91	4.52
3	10415.8	1203.0	781.7	1071.7	680.6	56.7	102.1	640.4	105.5	3842.5	4.91	0.83	4.06
4	9634.1	1109.2	781.7	1071.7	725.8	60.5	108.9	632.4	105.8	3794.2	4.85	0.75	3.65
5	8852.5	1015.4	781.7	1071.7	773.9	64.5	116.1	624.8	106.3	3749.1	4.79	0.68	3.28
6	8070.8	921.6	781.7	1071.7	825.3	68.8	123.8	617.9	107.0	3707.3	4.73	0.62	2.95
7	7289.2	827.8	781.7	1071.7	880.1	73.3	132.0	611.5	107.8	3669.2	4.69	0.57	2.65
8	6507.5	734.0	781.7	1071.7	938.6	78.2	140.8	605.8	108.9	3634.9	4.64	0.52	2.39
9	5725.8	640.2	781.7	1071.7	1000.9	83.4	150.1	600.8	110.1	3604.6	4.60	0.47	2.16
10	4944.2	546.4	781.7	1071.7	1067.4	88.9	160.1	596.5	111.6	3578.8	4.57	0.43	1.95
11	4162.5	452.6	781.7	1283.3	1138.2	94.9	170.7	629.0	118.1	3773.9	4.82	0.39	1.87
12	3380.9	358.8	781.7	1283.3	1213.8	101.2	182.1	626.3	120.1	3757.6	4.80	0.35	1.69
13	2599.2	296.3	259.3	1283.3	1294.4	107.9	194.2	540.8	111.2	3244.6	4.14	0.32	1.33
14	2339.9	265.2	259.3	1283.3	1380.4	115.0	207.1	550.6	115.2	3303.4	4.22	0.29	1.23
15	2080.6	234.1	259.3	1283.3	1472.0	122.7	220.8	561.4	119.4	3368.2	4.30	0.27	1.14
16	1821.3	203.0	259.3	1283.3	1569.8	130.8	235.5	573.2	124.0	3439.4	4.39	0.24	1.06
17	1562.0	171.9	259.3	1283.3	1674.0	139.5	251.1	586.2	128.9	3517.4	4.49	0.22	0.99
18	1302.7	140.8	259.3	1283.3	1785.1	148.8	267.8	600.5	134.2	3602.7	4.60	0.20	0.92
19	1043.4	109.6	259.3	1283.3	1903.7	158.6	285.6	616.0	139.9	3695.9	4.72	0.18	0.86
20	784.1	78.5	259.3	1283.3	2030.1	169.2	304.5	632.9	146.1	3797.3	4.85	0.17	0.80
21	524.8	47.4	259.3	1283.3	2164.9	180.4	324.7	651.3	152.6	3907.5	4.99	0.15	0.75
22	265.5	16.3	259.3	1283.3	2308.6	192.4	346.3	671.2	159.7	4027.2	5.14	0.14	0.70
23	6.2	0.4	259.3	1283.3	2461.9	205.2	369.3	695.4	167.6	4172.5	5.33	0.12	0.66
24	0.0	0.0	259.3	1283.3	2625.4	218.8	393.8	724.1	176.4	4344.4	5.55	0.11	0.63
25	0.0	0.0	259.3	1283.3	2799.7	233.3	420.0	754.7	185.9	4528.2	5.78	0.10	0.59
26	0.0	0.0	259.3	1283.3	2985.6	248.8	447.8	787.3	195.9	4724.1	6.03	0.09	0.56
27	0.0	0.0	259.3	1283.3	3183.9	265.3	477.6	822.2	206.6	4933.0	6.30	0.09	0.54
28	0.0	0.0	259.3	1283.3	3395.3	282.9	509.3	859.3	218.0	5155.9	6.58	0.08	0.51
29	0.0	0.0	259.3	1283.3	3620.7	301.7	543.1	898.9	230.2	5393.5	6.89	0.07	0.48
30	0.0	0.0	259.3	1283.3	3861.1	321.8	579.2	941.1	243.2	5646.9	7.21	0.06	0.46
31	0.0	0.0	259.3	1283.3	4117.5	343.1	617.6	986.2	257.0	5917.1	7.56	0.06	0.44
32	0.0	0.0	259.3	1283.3	4390.9	365.9	658.6	1034.2	271.8	6205.3	7.92	0.05	0.42
33	0.0	0.0	259.3	1283.3	4682.5	390.2	702.4	1085.4	287.5	6512.6	8.32	0.05	0.40
34	0.0	0.0	259.3	1283.3	4993.4	416.1	749.0	1140.0	304.3	6840.3	8.73	0.04	0.38
35	0.0	0.0	259.3	1283.3	5325.0	443.7	798.7	1198.3	322.2	7189.7	9.18	0.04	0.37
												(A1)	(B1)
												10.66	52.43
								Levellized Tariff (LT) in Rs./kWh				**LT**	**4.92**

CALCULATION OF LEVELLIZED TARIFF (Without Free Power to Home State)

Annual Generation in 90% Dependable Year	7926.00 MU	Total Cost Including IDC		17113.04 Crs	O&M Charges (on total cost)	3.50 %	Interest Rate on Loan	12.00 %	
Auxiliary Consumption	1.20 %	Equity	30.00 %	5133.91 Crs	Rate of Increase of O&M Charges (Compounded)	6.64 %	Interest Rate on Working Capital	13.20 %	
Transformation Losses	0.00 %	Loan	70.00 %	11979.13 Crs	Maintenance Spares on O&M Charges	15.00 %	Return On Equity	16.50 %	
Free Power to Home State (1st -5th year)	0.00 %	Cost of Land (Excluding R & R)		64.27 Crs	Rate of Increase of Maintenance Spares (Compounded)	5.72 %	Discounting Rate for LT	9.94 %	
Free Power to Home State (6th -10th year)	0.00 %	Cost of R&R		14.332 Crs			Rate of return on equity (Pre-tax) (up to 10th year)		20.876%
Free Power to Home State (11th -15th year)	0.00 %				Period of higher rate of depreciation as per CERC	12 Yr	Rate of return on equity (from 11th year onwards)		24.996%
Free Power to Home State (From 16th year onward)	0.00 %				Period of applicability of MAT	10 Yr			
Additional Free Power	0.00 %								
Net Saleable Energy (1st -5th year)	7830.89 MU				Useful Life of the Project	35 Yr			
Net Saleable Energy (6th -10th year)	7830.89 MU				Operation Period of the Project	35 Yr			
Net Saleable Energy (11th -15th year)	7830.89 MU								
Net Saleable Energy (From 16th year onward)	7830.89 MU								

Year	Outstanding Loan (Rs. Crores)	Interest On Loan (Rs. Crores)	Depreciation (Rs. Crores)	Return on Equity (Rs. Crores)	O&M Charges (Rs. Crores)	O&M for One Month (Rs. Crores)	Maintenance Spares (Rs. Crores)	Two Months Average Billing (Rs. Crores)	Interest on Working Capital Cost (Rs. Crores)	Total Amount (Rs.Crores)	Charges/Unit (Rs./kWh)	Discounting Factor @9.94%	Discounted Tariff (Rs./kWh)
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
1	11979.1	1390.6	781.7	1071.7	598.5	49.9	89.8	658.0	105.3	3947.7	5.04	1.00	5.04
2	11197.5	1296.8	781.7	1071.7	638.2	53.2	95.7	649.0	105.3	3893.7	4.97	0.91	4.52
3	10415.8	1203.0	781.7	1071.7	680.6	56.7	102.1	640.4	105.5	3842.5	4.91	0.83	4.06
4	9634.1	1109.2	781.7	1071.7	725.8	60.5	108.9	632.4	105.8	3794.2	4.85	0.75	3.65
5	8852.5	1015.4	781.7	1071.7	773.9	64.5	116.1	624.8	106.3	3749.1	4.79	0.68	3.28
6	8070.8	921.6	781.7	1071.7	825.3	68.8	123.8	617.9	107.0	3707.3	4.73	0.62	2.95
7	7289.2	827.8	781.7	1071.7	880.1	73.3	132.0	611.5	107.8	3669.2	4.69	0.57	2.65
8	6507.5	734.0	781.7	1071.7	938.6	78.2	140.8	605.8	108.9	3634.9	4.64	0.52	2.39
9	5725.8	640.2	781.7	1071.7	1000.9	83.4	150.1	600.8	110.1	3604.6	4.60	0.47	2.16
10	4944.2	546.4	781.7	1071.7	1067.4	88.9	160.1	596.5	111.6	3578.8	4.57	0.43	1.95
11	4162.5	452.6	781.7	1283.3	1138.2	94.9	170.7	629.0	118.1	3773.9	4.82	0.39	1.87
12	3380.9	358.8	781.7	1283.3	1213.8	101.2	182.1	626.3	120.1	3757.6	4.80	0.35	1.69
13	2599.2	296.3	259.3	1283.3	1294.4	107.9	194.2	540.8	111.2	3244.6	4.14	0.32	1.33
14	2339.9	265.2	259.3	1283.3	1380.4	115.0	207.1	550.6	115.2	3303.4	4.22	0.29	1.23
15	2080.6	234.1	259.3	1283.3	1472.0	122.7	220.8	561.4	119.4	3368.2	4.30	0.27	1.14
16	1821.3	203.0	259.3	1283.3	1569.8	130.8	235.5	573.2	124.0	3439.4	4.39	0.24	1.06
17	1562.0	171.9	259.3	1283.3	1674.0	139.5	251.1	586.2	128.9	3517.4	4.49	0.22	0.99
18	1302.7	140.8	259.3	1283.3	1785.1	148.8	267.8	600.5	134.2	3602.7	4.60	0.20	0.92
19	1043.4	109.6	259.3	1283.3	1903.7	158.6	285.6	616.0	139.9	3695.9	4.72	0.18	0.86
20	784.1	78.5	259.3	1283.3	2030.1	169.2	304.5	632.9	146.1	3797.3	4.85	0.17	0.80
21	524.8	47.4	259.3	1283.3	2164.9	180.4	324.7	651.3	152.6	3907.5	4.99	0.15	0.75
22	265.5	16.3	259.3	1283.3	2308.6	192.4	346.3	671.2	159.7	4027.2	5.14	0.14	0.70
23	6.2	0.4	259.3	1283.3	2461.9	205.2	369.3	695.4	167.6	4172.5	5.33	0.12	0.66
24	0.0	0.0	259.3	1283.3	2625.4	218.8	393.8	724.1	176.4	4344.4	5.55	0.11	0.63
25	0.0	0.0	259.3	1283.3	2799.7	233.3	420.0	754.7	185.9	4528.2	5.78	0.10	0.59
26	0.0	0.0	259.3	1283.3	2985.6	248.8	447.8	787.3	195.9	4724.1	6.03	0.09	0.56
27	0.0	0.0	259.3	1283.3	3183.9	265.3	477.6	822.2	206.6	4933.0	6.30	0.09	0.54
28	0.0	0.0	259.3	1283.3	3395.3	282.9	509.3	859.3	218.0	5155.9	6.58	0.08	0.51
29	0.0	0.0	259.3	1283.3	3620.7	301.7	543.1	898.9	230.2	5393.5	6.89	0.07	0.48
30	0.0	0.0	259.3	1283.3	3861.1	321.8	579.2	941.1	243.2	5646.9	7.21	0.06	0.46
31	0.0	0.0	259.3	1283.3	4117.5	343.1	617.6	986.2	257.0	5917.1	7.56	0.06	0.44
32	0.0	0.0	259.3	1283.3	4390.9	365.9	658.6	1034.2	271.8	6205.3	7.92	0.05	0.42
33	0.0	0.0	259.3	1283.3	4682.5	390.2	702.4	1085.4	287.5	6512.6	8.32	0.05	0.40
34	0.0	0.0	259.3	1283.3	4993.4	416.1	749.0	1140.0	304.3	6840.3	8.73	0.04	0.38
35	0.0	0.0	259.3	1283.3	5325.0	443.7	798.7	1198.3	322.2	7189.7	9.18	0.04	0.37
												(A1)	(B1)
												10.66	52.43
								Levellized Tariff (LT) in Rs./kWh				**LT**	**4.92**

Tractebel is a global engineering company delivering game-changing solutions for a carbon-neutral future. Insights gathered during our more than 150 years of experience in energy, urban, nuclear and water projects combined with local expertise allow us to tackle complex future-oriented projects. By connecting strategy, design, engineering and project management, our community of 5,000 imaginative experts helps companies and public authorities create positive impact towards a sustainable world, where people, planet and profit collectively thrive. With offices in Europe, Africa, Asia, the Middle East and Latin America, the company registered a turnover of 581 million Euros in 2020. Tractebel is part of the ENGIE Group, a global reference in low-carbon energy and services.

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