NEW & RENEWABLE ENERGY DEVELOPMENT CORPORATION OF ANDHRA PRADESH LTD.

FINAL REPORT

CHITRAVATHI PUMPED STORAGE HYDRO ELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME - I
REPORT

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July 2021

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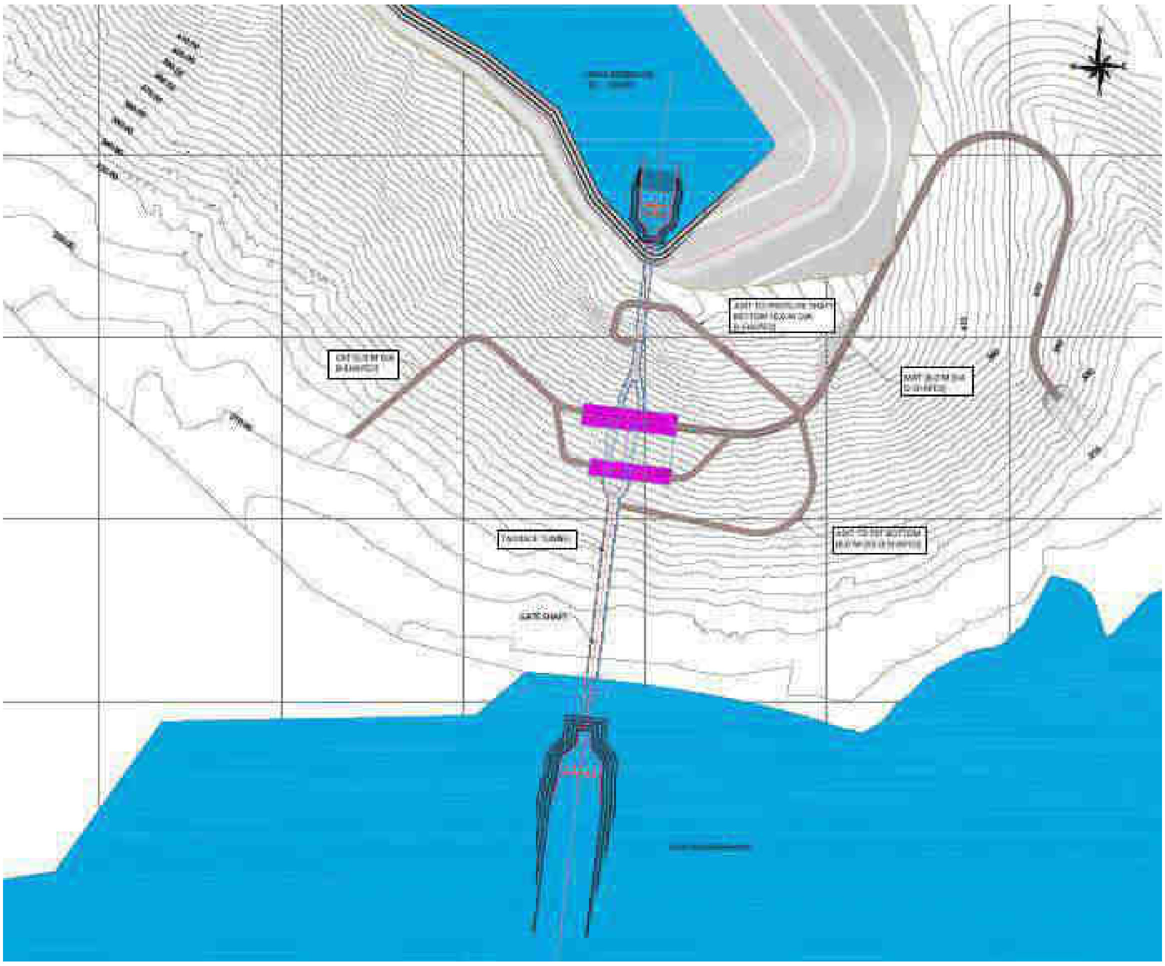

DOCUMENT RECORD

Project Name	Chitravathi Pumped Storage Project
Name of Client	New & Renewable Energy Development Corporation of Andhra Pradesh Ltd.
Doc No	AAEI/POWER/2376/FSR/01
Doc Title	Feasibility Study Report

Rev No	Date of Issue	Description
R0	11-03-2021	Feasibility Study Report
R1	10-07-2021	Feasibility Study Report

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FEASIBILITY REPORT

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Introduction

1 INTRODUCTION

1.1 GENERAL

M/s New & Renewable Energy Development Corporation of Andhra Pradesh Ltd., (NREDCAP) formerly Non-conventional Energy Development Corporation of Andhra Pradesh Limited (NEDCAP) is the nodal agency for development of renewable power in the state of Andhra Pradesh. The genesis of Non-conventional Energy Development Corporation of Andhra Pradesh Limited (NREDCAP) took place in the year 1986 with the help of Government of Andhra Pradesh. The sole objectives of NREDCAP are to:

- Generate electricity through renewable sources like wind and solar on decentralized manner
- Conserve energy in rural areas
- Import & adopt viable technology & machinery in the areas of Non-conventional energy sources & ensures post installation service
- Impart training and to promote research and development in the field of Non-conventional energy sources

India is leading the world's renewable energy revolution and is on track to achieve 175 GW of RE capacities by 2022. Solar capacity increased in the last 5.5 years from around 2.6 GW to more than 34 GW. India's renewable energy (RE) capacity is expected to cross 100 GW (1GW = 1,000 MW) this year and the country looks on course to meeting its target of achieving 175 GW generation capacity from RE by 2022.

Under the Paris Agreement, GOI has committed to a target of generating 40 per cent electricity from non-fossil fuel sources by 2030. At the United Nations Climate Action Summit in September last year, GOI said India was setting an RE generation capacity target of 450 GW by 2030.

Today, Wind & Solar are the lowest cost source of new energy, however their inherent infirm nature & non-schedulability presents a huge challenge for integrating large RE capacities, while maintaining grid stability. Increasing RE capacities coupled with ever changing dynamic demand curves of the States/DISCOMs/STUs are leading to sub-optimal utilization of the existing base-load assets resulting in high fixed cost pass through per kWh and additional burden to the consumers.

The installed capacity of Renewables in the state of Andhra Pradesh is about 8,534.218MW by the end of, January 2021. The state is also contemplating development of about 10,000 MW under Green Energy Corporation Limited and 17,800 MW under export policy. Thus, because of the state's thrust and importance on development of renewable energy, the state may experience higher capacity additions in the next few years.

Flexible Energy Generation Assets that have a capability to supply both Base Load & Peaking Power efficiently and economically are the need of the future and the necessary solution to address the dynamic evolving energy needs of India. The increasing energy demand of the country can only be met sustainably by developing the much required Flexible Energy Generation Assets immediately.

In order to utilize the surplus solar energy during day time effectively for meeting the energy requirement during peak hours and also to utilize these schemes for grid balancing, NREDCAP has identified some of the potential areas for development of pumped storage hydroelectric plants.

While battery storage solutions are still evolving, integrating Wind & Solar with time tested and proven Pumped Storage solutions presents an optimal, economically viable & scalable solution to supply Schedulable Power On-Demand (SPOD) with both base load and peak load capabilities to the Nation. Pumped Storage solutions provide the necessary scale (large volume of energy storage) and have a long life cycle resulting in lowest cost of delivered SPOD energy over the life of the projects.

Developing pumped storage projects independently, integrating with Wind-Solar resources, without impacting the existing natural water systems / irrigation systems is necessary to sustainably power the future needs of our country while maintaining grid stability.

Accordingly, NREDCAP had taken up the detailed studies and preparation of project reports in respect of seven locations so as to take up schemes for construction. The present report describes the feasibility of establishing pumped storage scheme at Chitravathi Balancing Reservoir, Ananthapuramu District of Andhra Pradesh.

1.2 TYPE OF THE PROJECT

Pumped storage hydropower project is typically a configuration of two water reservoirs at different elevations that can generate power (discharge) as water moves down through a turbine; this draws power as it pumps water (recharge) to the upper reservoir. Pumped storage hydropower capabilities can be characterized as open loop-where there is an on-going hydrologic connection to a natural body of water-or closed loop, where the reservoirs are not connected to an outside body of water.

Low-cost surplus off-peak electric power is typically used to run the pumps. This project is operated when inexpensive electricity is available either from intermittent sources (such as solar, wind) and other renewable's, or excess electricity from continuous base-load sources (such as coal or nuclear) to be saved for periods of higher demand. Although the losses of the pumping process make the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest and also helps in stabilising and for grid balancing.

This Feasibility report is for establishing pumped storage scheme at Chitravathi Balancing Reservoir comprising of 500 MW / 2805 MWH storage capacity, located at Ananthapuramu District, Andhra Pradesh. The Chitravathi Pumped Storage Project will comprise of two reservoirs. The existing Chitravathi balancing reservoir will be the lower reservoir and a new reservoir is to be constructed on the hill top with low height embankments of maximum height 53.0m to create the desired storage capacity and used cyclically for energy storage and discharge. Evaporation losses, if any will be recouped periodically. This Project envisages non-consumptive re-utilization of 0.22 TMC of water for recirculation among these two reservoirs.

1.3 LOCATION OF THE PROJECT AREA

The geographical coordinates of the proposed upper reservoir are at longitude 77°56'2.6"E & latitude is 14°34'26.93"N and that of existing lower reservoir are at 77°56'51"E and 14°33' 31"N. Sri Penchikala Basi Reddy Chitravathi Balancing Reservoir is constructed across Chitravathi River near Parnapalli village of Lingala Mandal of YSR Kadapa District with a storage capacity of 10.00TMC. The project lies in border of YSR Kadapa and Ananthapuramu districts. The Chitravathi dam is in YSR Kadapa District and the reservoir is in Ananthapuramu District. The new upper reservoir is proposed on the left bank of Chitravathi Dam, near Peddakotla village.

Figure 1-1: Project Location Map

1.4 COMMUNICATION FACILITIES

The Chitravathi PSP is proposed on the left bank of Chitravathi Dam, near Peddakotla village. Village is located in Tadimarri Mandal of Ananthapuramu district in Andhra Pradesh, India. It is situated 2 kms away from sub-district headquarter Tadimarri and 10.4 kms away from district headquarter Ananthapuramu. The site is easily approachable by NH-205 from Ananthapuramu. Nearest railway head is Ananthapuramu from where project site is located at around 50 kms away. The nearest international airport is at Tirupati which is about 260 km from the project site and sea port is at Krishnapatnam which is about 295 km from the project site.

1.5 GENERAL CLIMATIC CONDITIONS IN THE PROJECT AREA

The climate of Andhra Pradesh varies considerably, depending on the geographical region. Monsoons play a major role in determining the climate of the state. Summers last from March to June. July to September is the season for tropical rains in Andhra Pradesh. The state receives heavy rainfall from the Southwest Monsoon during these months. About one third of the total rainfall in Andhra Pradesh is brought by the Northeast Monsoon. October and November see low-pressure systems and tropical cyclones form in the Bay of Bengal which, along with the Northeast Monsoon, bring rains to the southern and coastal regions of the state. November, December, January, and February are the winter months in Andhra Pradesh. Since the state has a long coastal belt the winters are not very cold.

Ananthapuramu has a semi-arid climate, with hot and dry conditions for most of the year. Summer start in late February and peak in May with average high temperatures around the 37 °C (99 °F) range. Ananthapuramu gets pre-monsoon showers starting as early as March, mainly through north-easterly winds blowing in from Kerala. Monsoon arrives in September and lasts until early November with about 250 mm (9.8 in) of precipitation. A dry and mild winter starts in late November and lasts until early February; with little humidity and average temperatures in the 22–23 °C (72–73 °F) range. Total annual rainfall is about 22 in (560 mm).

1.6 GENERAL DESCRIPTION OF TOPOGRAPHY, PHYSIOGRAPHY AND GEOLOGY OF THE PROJECT AREA

The Project area is an undulatory terrain dotted by detached linear, rounded, conical denudational hills, residual hillocks or mounds, inselbergs, all made up of igneous rocks with strike ridges formed of sedimentary rocks forming eastern boundary. These strike ridges are called as Mutchkonda hill ranges. The project area falls in Chitravathi river basin, which is a tributary of the Penneru river. Parallel drainage system on the linear and strike ridges, parallel drainage system on rounded or domal hills and dendritic drainage pattern on the undulaory terrain has developed.

Geological setup of the Project area is unique in terms of Indian Stratigraphy as the site is located in the vast Dharwar Craton which is occupied by igneous and a suite of metavolcanic -metasedimentary rocks (Archaean to PaleoProterozoic Eras) and which are juxtaposed on the eastern side by a spectacular crescent shaped YSR Kadapaa Basin in which thick pile of sediments were deposited (Meso to Neo Proterozoic Eras).In the project area, Eparachaean unconformity has developed impersistently between granite and thin quartzite horizon. Foliation of Granite gneisses and bedding of quartzite are aligned along N 30-45 W- S30-45 E direction. but foliation dips vary 45 to 70 due S60 - 45 W, but quartzite shows 10 -15 due N60-45E. Granite gneisses are represented by hornblende-biotite gneiss, hornblende gneiss, biotite gneiss and older granites and these are classified as Peninsular Gneisses Complex I and ii. These, at places, shows migmatitic structures. Younger granites, equivalent to close pet Granites, are represented by pink or grey granites. These are intruded by three sets of dykes, quartz reefs, aplite, sepidote and quartzofelspathic veins

1.7 HISTORICAL BACKGROUND OF THE PROJECT:

1.7.1 Earlier proposal

Techno-Commercial Feasibility Study Report of the project was prepared by the WAPCOS Limited in May 2020. The study of WAPCOS covers the two alternative locations for the upper reservoir; one is on left bank (named as Option-1) and second is on right bank (named Option-2).

In Option-1, the upper reservoir is proposed on left bank at geographical co-ordinate N- 14° 34' 26.93" E- 77° 56'2.60" in NW direction of existing lower Reservoir. The highest possible elevation is at EL-500m on the hilltop. At this location the flat surface area is inadequate to create required capacity in reservoir. Therefore, it is proposed to create Pondage through excavating a pit upto desired depth for optimum live storage.

In other option named as Option-2, the upper reservoir is proposed on Right bank at geographical co-ordinate N- 14° 31' 38.46" E- 77° 57' 31.09". The highest possible elevation is at EL-500m on the hilltop. At this location the flat surface area is inadequate to create required capacity in reservoir. Therefore, it is proposed to create Pondage through excavating a pit upto desired depth for optimum live storage.

Further, Option-1 worked out to be more economical and was the preferred option for further study.

1.7.2 Present proposal

The existing Chitravathi Balancing Reservoir has been proposed as lower reservoir for the Pumped storage scheme with Full Reservoir Level of 298 m and Minimum draw down level of 282.55m. An artificial reservoir is proposed as upper reservoir which is constructed by excavating a pit and forming partial embankment/bund at elevation-495.0m. The live storage capacity for pumped storage scheme required is 6.26 MCM (0.22 TMC). The proposed project will generate 500 MW of power by utilizing net rated head of 189.40 m. The water from the upper reservoir will be diverted through Power House and TRT to the existing lower reservoir. The water will be pumped back to the upper reservoir through TRT-Reversible Turbines-pressure shaft-HRT to upper reservoir.

The project also comprises of a lower intake adjacent to existing Chitravathi reservoir to pump the water to upper reservoir.

The present proposal consist the following components:

- ❖ Upper Reservoir and Embankment/Bund
- ❖ Upper Intake
- ❖ Penstock
- ❖ Powerhouse and Transformer Cavern
- ❖ Tailrace Tunnel
- ❖ TRT outlet Coffer Dam
- ❖ TRT Intake/Lower Intake

1.8 NEED FOR THE PROJECT, POSSIBLE OPTIONS AND JUSTIFICATION FOR SELECTED OPTION

The state of Andhra Pradesh had an installed capacity of 25,508.94 MW as on June 2021. Currently the state government has commissioned 8791.98MW of renewable energy as of June 2021 comprising of 4083.57 MW of wind power, 4116.01MW of solar power, 102.6MW of small hydro, 171.25MW from Biomass, 65.45MW from Biomass Energy, 206.95MW with co-generation with Bagasse, 6.15MW from municipal solid waste, 40.01MW with industrial waste.

Government of Andhra Pradesh is also developing solar capacity of 10,000 MW through Andhra Pradesh Green Energy Corporation Ltd. and identified sites to the tune of 17,800 MW under the Renewable Energy Export Policy. This large scale injection of solar power into the grid necessitates the proposals for storage of energy systems for the following aspects:

- ❖ The total energy generation from the renewables of about 36,592MW contributes about 68% of total installed capacity in the state of Andhra Pradesh.
- ❖ Energy reliability on the Solar & wind power over the entire year may create the demand to supply issues as well as grid instability issues.
- ❖ Large scale energy storage systems are not available in Andhra Pradesh.

- Ultra mega solar projects connected to the grid may have variations in the grid frequency due to sudden changes in the generation by way of cloud cover, rains etc., hence a quick response system like PSP is required for grid balancing

1.9 ALTERNATIVE STUDIES CARRIED OUT FOR VARIOUS MAJOR COMPONENTS OF THE PROJECT AND FINAL CHOICE OF THE PROJECT PARAMETERS.

A detailed alternative study has been carried out to find out the best location of upper reservoir on left bank and Right bank of the existing reservoir. Various alternatives were studied considering construction of reservoir with entire excavation portion and combination of excavation and construction of embankment dam. The selection criteria were to utilise the maximum possible excavated material in filling and storage cost per MCM. Based on selection criteria upper reservoir at Left bank (LC-3) has been considered for the further study.

Based on the alternative study for upper reservoir, the left bank is found more suitable for the development of the Chitravathi PSP.

For left bank upper reservoir, following alternative of power houses were studied:

- Surface power house in the open pit
- Underground power house- Alternative-1
- Underground power house Alternative-2

Feasibility of surface power house is studied, but found not suitable mainly due to following reasons:

- Excavation of more than 60 m deep power house pit adjacent to the operational reservoir.
- Possibility of very high seepage through the reservoir charged rock mass.
- Constructability and operation issue related to dewatering of seepage flow.
- Larger quantities of excavation muck and slope stabilisation measures.
- Limited space available between reservoir boundary and the toe of the hill and therefore possibility of destabilisation of hill slope for deep excavations.

However, further exploration for Surface Powerhouse will be done at DPR Stage.

For underground powerhouse, both the alternative has similar arrangement except minor changes in the length of pressure shaft and TRT. The Alternative-2 provides larger working area and flatter uphill slope. Further, the length of pressure shaft in the Alternative-2 is comparatively 30% less. Therefore underground power house alternative-2 is chosen for the development of the proposed PSP.

1.10 NATURAL RESOURCES OF THE STATE/REGION

The state of Andhra Pradesh is highly blessed with land, water, forests and mineral resources. With a coast-line of 974 kilometres, the state stands as the 2nd longest coast line in the country. It has about 17 small and big rivers flowing through different parts of the state. Out of these, the major two rivers are Krishna and Godavari stretching thousands of square kilometres of land and creating largest perennial cultivated area in the country.

1.11 SOCIO-ECONOMIC ASPECTS

The proposed area consists of 5 Tehsils of which four are in Annathapur district namely Putlur, Mudigubba, Tadimarri, Yellnur & other in kadapa district namely Lingala tenhsil. Parnapalli & Peddhakotlapalli villages are directly affected by the project activities.

Total households in study area tehsil are 1493. The total population of study area is 5738, of which 2873 are male and 2865 are female. Sex ratio in study area is 997 female per 1000 males. Nearly 14.3% of the population of the Ananthapuramu district area belongs to Scheduled Castes, while the population of Scheduled Tribes is only 3.8%. In study area, 21.7% and 0.9% of the total population belongs to Scheduled Castes and Scheduled Tribes, respectively.

Average literacy rate in in Ananthapuramu district is 63.57% of which 73.62% are males and 53.97% are females. The total literacy rate in the tehsils falling under study area is 61.33%, with 73.64% males and 48.97% females. 52.66_% of the total population of study area is working population. Of this working population 33.63% are main workers and 19.03% are marginal workers. 47.33% of the total population of the study area population is considered as non-workers.

1.12 LAND REQUIRED FOR THE PROJECT CONSTRUCTION

For the development of Chitravathi PSP, land would be required for construction of project components, reservoir area, muck dumping, construction camps and colony, etc. Total land required for the construction of proposed activities is approximately 136 ha. break up of land required for different components is given below.

Land required for Upper Reservoir and Embankment	:	51 Ha
Land required for Underground Structure	:	10 Ha
Land required for Project Facilities	:	65 Ha
Land required for New Road	:	10 Ha

1.13 POPULATION AFFECTED BY THE PROJECT AND OCCUPATION OF THE PEOPLE AFFECTED

There is no settlement in the entire project area. As such no population is affected by the project. As per information available till date, all the land in the project area is identified as Unacessed waste land

1.14 ENVIRONMENTAL ASPECTS.

Lower reservoir for Chitravathi PSP is existing and the Upper reservoir will be constructed newly. There will be land required for formation of upper reservoir. Also, the land required are for the construction of power house complex and its appurtenant works viz., Intake structure, penstocks, powerhouse, Tail Race Channel etc. The land required for the construction of various components is about 136 Ha including storage by formation of Chitravathi PSP Upper reservoirs. Based on assessment of environmental impacts, management plan has to be formulated for slope Treatment, and other environmental issues. Detailed EIA studies will be carried out at DPR stage.

1.15 INTER STATE / INTER-NATIONAL ASPECTS

The Chitravathi is an inter-state river in southern India that is a tributary of the Pennar River. Rising in Karnataka, it flows into Andhra Pradesh and its basin covers an area of over 5,900 km^2.

Chitravathi river originates at Chikkaballapur and flows through the Chikkaballapur district of Karnataka before entering Andhra Pradesh where it drains the districts of Anantapur and YSR Kadapa before joining the Pennar. Among the mandals that it drains in the two states are Bagepalli, Gorantla, Hindupur, Bukkapatnam, Dharmavaram, Tadipatri and Kadiri. The Chitravathi river joins the Pennar at Gandikota in Kadapa district.

Water resources development should be as per the agreement Mysore-Madras agreement in 1982 and 1933, which states that no state can't take up any new irrigation works on 15 inter-state rivers unilaterally. Further, there are import of waters from Krishna rivers to Pennar, so the allocations made by KWDT-1 in its report and decisions of Krishna basin should be adhered.

However, as the proposed project is a pumped storage project, no consumptive utilisation of water is envisaged, except for recouping the evaporation losses of 0.15 MCUM in the upper reservoir. All the project components of the proposed PSP are within the state of Andhra Pradesh and the submergence due to construction of upper reservoir also lies within the state of Andhra Pradesh.

As the Consumptive use of the project is only 0.15 MCUM, which is less than 10 MCUM, therefore no interstate issue on sharing of water, construction of new project, benefits and cost is involved.

1.16 DEFENCE ANGLE, IF ANY.

The project area doesn't have any coastal belt, international borders or any defence activity in the vicinity.

1.17 HYDROLOGY

The proposed storage project is being planned by creating a new upper reservoirs. The upper reservoir do not have any natural streams draining into the reservoir. The upper reservoir does not have any catchment draining into the reservoir, whereas the existing lower reservoir has a catchment of 5431 Sq.km. that drains the runoff into the reservoir.

The Chitravathi PSP upper reservoir has a gross storage capacity of 6.40MCM (0.226 TMC). The live storage of Chitravathi PSP Upper reservoir is 6.26MCM (0.22TMC). Operational pattern of Chitravathi PSP has been kept in such a way that 0.22TMC of water will be utilized for the proposed Chitravathi PSP. The project is a pumped storage scheme and hence, no consumptive utilization of water is required for its operation. The annual loss in the volume of the upper reservoir due to evaporation works out to 0.21MCM and the annual yield in to the reservoir through precipitation is 0.07 MCM. The net annual loss in the storage thus works out to 0.15 MCM which will be taken from the existing Chitravathi Balancing Reservoir. The total catchment area of the existing Chitravathi Balancing Reservoir is 5431 Sq. Km and the design flood discharge is 4080 Cumec. The gross storage capacity of the Chitravathi Balancing reservoir is 283.1 MCM (10 TMC) and the live storage is 281.85 MCM (9.956 TMC).

1.18 INSTALLED CAPACITY

The Chitravathi PSP is proposed with a Storage Capacity of 2805 MWH with Rating of 500 MW. This Project comprises of 2 units of 250 MW each. The installed capacity of a pumped storage scheme is influenced by the requirements of daily peaking power requirements, flexibility in efficient operation of units, storage available in the reservoirs and the area capacity characteristics. The Project will generate 500 MW by utilizing a design discharge of 297.26Cumec with rated head of 189.4 m. The Chitravathi PSP will utilize 556 MW to pump 0.22 TMC of water to the upper reservoir in 6.49 hours.

The volume of water required for turbine mode of operation is equated to the pumped mode. Annual energy generation by Chitravathi PSP in Turbine mode is 963.19 MU, Annual energy consumption by Chitravathi PSP in Pump mode is 1251.01 MU.

1.19 POWER EVACUATION

1 no. 400 KV moose double circuit transmission line to connect at Chitravathi PSP Central Pooling Substation. This double circuit transmission line will be used for both evacuation of generated power and input of power during pumping mode.

1.20 CONSTRUCTION PLANNING & SCHEDULE

It is proposed to construct the project within a period of 48 months including 9 months for pre-construction works. Detailed description of equipment planning & construction schedule is provided in the chapter Construction Programming & Plant Equipment's.

1.21 COST AND BENEFITS OF THE SCHEME

The total estimated cost of the project including direct and indirect charges excluding Interest during construction is Rs. 179759.40 Lakhs (1797.59 Cr). For the installed capacity of 500MW, the cost per MW of installed capacity works out to be Rs. 3.59 Cr. The project would generate designed energy of 963.19 MU. Other benefit of this storage project can be in the form of spinning reserve with almost instantaneous start-up from zero to full power supply, supply of reactive energy, primary frequency regulation, voltage regulation etc.

1.22 SALIENT FEATURES OF THE SCHEME

1. LOCATION	
Country State District	India Andhra Pradesh Anantapur/ Kadapa
River	Chitravathi river a tributary of Pennar River
Upper Reservoir	N- 14° 34' 26.93" E- 77° 56'2.60"
Chitravathi Reservoir (Lower Reservoir)	N14° 34' and Long. E77° 57' 31.09"
Access to the Project	
Road	Accessible from State Highway SH 121
Airport	Tirupati: 260 km
Railhead (with unloading facilities)	Chinnekunta Palli : 30 km
Port	Krishnapatnam : 280 km
2. PROJECT	
Type	Pumped Storage Project

Installed Capacity	500 MW
Peak Operating duration	5.61 Hr.
3.0 CIVIL STRUCTURE	
3.1 UPPER RESERVOIR (New) (Excavated Pit)	
FRL	EL. 495 m
MDDL	EL. 460 m
Bed Level of Reservoir	EL. 459 m
Available Live storage	0.22 TMC (6.26 MCM)
3.2 LOWER RESERVOIR (Existing)	
FRL	EL. 298 m
MDDL	EL. 282.55 m
Live storage	9.956 TMC (281.85 MCM)
Dead Storage	0.044 TMC (1.25 MCM)
3.3 Upper Intake Structure	
Type	Bank Tower Type Intake
Size of Intake	5 bays of 4.5 width each
Sill Level of Intake	EL. 437 m
3.4.1 Main Pressure Shaft Tunnel (Steel Lined)	
Diameter	7.7 m
Length	312 m.
No. of Tunnel	1
3.4.2 Branch Pressure Shaft Tunnel (Steel Lined)	
Diameter	7.5 m
Length	62 m each.
No. of Tunnel	2
3.4 Tailrace Tunnel (Concrete Lined)	
Shape	Circular
Length	300.6 m
Diameter	10.7 m
3.5 Outlet Structural Lower Intake/Pump Intake	
Type	Trapezoidal type with anti-vortex louver
Size of Intake	6 bays of 5.7 width each

Sill Level of Intake	EL. 263 m
3.6 Powerhouse	
Type	Underground,
Size	105mx23.5mx51.5m
3.7 Transformer Room including Secondary GIS	
Type	Underground
LxWx H	90 mX18.5 mX30.0 m
3.8 Main Access Tunnel (MAT)	
Type	D-shape
Size	8 m dia.
3.8Cable Access Tunnel (CAT)	
Type	D-shape
Size	6 m dia.
4.0 Electromechanical Equipment	
4.1 Pump Turbine	
Type	Vertical axis reversible Francis Turbine
Number of unit	2 (Two)
Max. Head as Turbine	206.22 m
Rated Turbine Head	189.40 m
Min. Head as Turbine	155.77 m
Turbine Output at Rated Head	250 MW
Max. Head as Pump	218.68 m
Rated Pump Head	200.54 m
Min. Head as Pump	168.23 m
Max. discharge of Turbine at rated Turbine head	148.63 Cumec
Turbine Centre Line	EL 245.45 m
Rated Speed	214.30 rpm
4.2 Generator-Motor	
Type	3 phase AC Synchronous Generator - Motor, Semi Umbrella Type
Number of unit	2
Motor Generator Capacity	327 MWVA

Rated Voltage	15 kV
Rated Frequency	50 cycles per second
Synchronous Speed	214.30 rpm
4.3 Transmission Line	
Type	Double Circuit moose Conductor
Capacity Voltage Level	400 kV
Length	Talaricheruvu - 45 KM (Approx.)
4.4 Project Cost	
Item	Estimated Cost (INR-Cr)
Civil and HM Works	989.49
Electro-mechanical Works	808.10
IDC	230.13
Total	2027.72

4.5 Project Benefit's

Off Peak Energy Rate (INR/kWh)	First Year Tariff (INR/kWh)	Levellised Tariff(INR/kWh)
3	8.37	7.82
2.5	7.70	7.15
2.0	7.03	6.48
0.0	4.36	3.81

Chapter-2

Justification of the Project from Power Supply Angle

2 JUSTIFICATION OF THE PROJECT FROM POWER SUPPLY ANGLE

2.1 GENERAL

The state of Andhra Pradesh is the South Eastern Region in India bordered by Chhattisgarh on the north, Telangana in the north west, Orissa in the north east, Tamil Nadu in the south, Karnataka in the west & Bay of Bengal to the East. The state covers an area of 1, 62,975 km^2 and is the seventh largest Indian state. It is the tenth most populous state with 5 Cr. populations. It has the second longest costal line of 974km. It is also known as the Rice Bowl of India for being major producer of rice in the country. It has wide variety of minerals with treasure for 48 minerals & is very rich in Bauxite, Barytes, limestone & Mica compared to other states. The main river systems of the state are Krishna and its tributaries, Thungabhadra, Penna, Godavari and its tributaries.

Andhra Pradesh has currently 25,251.17 MW of installed capacity as against 1, 13,690.61MW in southern region & 3, 77,260.67 MW in the country as of 31st January 2021.

2.2 JUSTIFICATION OF PROJECT FROM POWER SUPPLY-DEMAND CONSIDERATIONS

As the world witnessing the climatic changes largely caused due to the energy generation from the carbon emissions, the role of the renewables has gathered more importance & hope to preserve the environment for the future generations. Most of the developed & developing nations recognised the importance of the renewables & prioritised to rapidly increase the percentage of the renewables over the conventional energy. India with its huge population & high demand for the power consumption leading from the front is on track to achieve 175 GW of RE capacity by 2022 and had set an ambitious target of 450GW clean energy from the renewables by the year 2030.

Demand for the utilization of power has been on study rise with average annual rate of about 8-9% in the country. The total installed capacity at the end of January 2021 stood at 3,77,260.67 MW with thermal power accounting for 61.46% (231870.72 MW), hydro power for 12.20% (46059.22MW) & Renewables including nuclear power accounting for 26.32% (99330.74MW). The energy generation is divided into six regions as shown in the Table 2-1 below:

Table 2-1: Total Amount of installed capacity in the country

Sl. No	Region	Thermal (MW)	Hydro (MW)	Renewables* (MW)	Nuclear (MW)	Total (MW)
1.	Northern Region	61,459.05	20,271.87	18,142.62	1,620.00	1,01,493.54
2.	**Southern Region**	**54,699.99**	**11,774.83**	**43,895.79**	**3,320.00**	**1,13,690.61**
3.	Eastern Region	27,387.05	4,639.12	1,579.80	0.00	33,605.97

4.	Western Region	85,701.61	7,558.80	28,528.14	1,840.00	1,23,628.55
5.	North Eastern Region	2,582.98	1,814.00	369.17	0.00	4,766.74
6.	Islands	40.05	0.00	35.22	0.00	75.27
	Total	2,31,870.72	46,059.22	92,550.74	6,780.00	**3,77,260.67**

* includes renewables from solar, wind & small hydro (Source - CEA)

India with its limited coal resources desires to reduce the carbon emissions & oil dependency by utilizing the clean energy resources such as wind, solar & hydro. The current generation of power from the renewables stand at 38.52% (145.39 GW) including nuclear & hydropower more than 25MW. To achieve the ambitious target of 450GW clean energy by 2030 with quantum jump in the generation, nuclear & hydro are the major sources with more viability while nuclear power has its own disadvantages while the hydro power majorly depends on the water as major source which is abundantly available in the country.

As per the Table 2-1, the southern region has been maintaining 48: 52 ratio of thermal generation to renewable energy generation compared to other regions. However the contribution of the hydro power stands at 20%, solar & wind power around 75% of the total renewables combined together. 75% energy reliability on the Solar & wind power over the entire year may create the demand to supply issues as well as grid instability issues. Suitable infrastructure is required to store or utilize the surplus energy generated during the peak generation & less demand. To avoid such circumstances a balancing source has to be developed along with the renewables in a large scale, which can be acheived with development of pumped storage hydro power generation projects.

Central Electricity Authority(CEA) in its annual load generation & balancing report has estimated the country demand & anticipated power supply for the year 2020-21 as shown in the Table 2-2. The Gross Energy in the country has been assessed as 1408 Billion Units (BU) for the current year.

Table 2-2: Peak & Energy demand in various regions of the country

Sl.No	Region	Peak				Energy			
		Demand	Availability	Surplus(+) / Deficit (-)		Requirement	Availability	Surplus(+) / Deficit (-)	
		(MW)	(MW)	(MW)	(%)	(MU)	(MU)	(MU)	(%)
1.	Northern	70,200	74,543	4,343	6.2	4,21,300	4,41,030	19,730	4.7
2.	Western	61,310	64,888	3,578	5.8	4,02,799	4,16,164	13,364	3.3
3.	**Southern**	**57,276**	**54,289**	**-2,987**	**-5.2**	**3,89,962**	**3,98,373**	**8,412**	**2.2**

4.	Eastern	26,404	28,501	2,098	7.9	1,74,925	1,70,464	-4,461	-2.6
5.	North-Eastern	3,094	3,242	148	4.8	18,542	19,054	513	2.8
	Total	1,99,348	2,17,507	18,160	9.1	14,07,527	14,45,085	37,558	2.7

Source CEA - Load Generation Balance Report 2020-21

As per the Table 2-2 surplus energy is anticipated in all the regions except the eastern region. In the southern region it was estimated a peak deficit of 5.2% for the current year 2020-21. This may further widen due to the increase in the energy demands with the rapid growth & industrialization in the southern region. Thus an alternate balancing source of energy generation is required to meet the peak demand in the southern region in the years ahead.

Southern region comprises states of Andhra Pradesh, Telangana, Karnataka, Kerala, Tamil Nadu & Pondicherry. Out of 113.69GW installed in the southern region, the state of Andhra Pradesh with a total installed capacity of 25.25GW and anticipated surplus power for the year 2021 is about 7%. However due to the rapid industrialization & developmental activities, Government of India target to achieve 450GW of energy by more reliable & balancing source is to be developed in the state.

Table 2-3: Installed capacity, peak & Energy demand of Southern region

Sl. No	State	Thermal (MW)	Hydro (MW)	Renew-ables* (MW)	Nuclear (MW)	Total (MW)	Peak		Energy	
							Demand (MW)	Availability (MW)	Require-ment (MU)	Availability (MW)
1.	**Andhra Pradesh**	**14,688.20**	**1,673.60**	**8,762.09**	**127.27**	**25,251.17**	**10,900**	**12,074**	**71841**	**76865**
2.	Telangana	9,910.54	2,497.93	4,361.23	148.73	16,900.43	14,088	12,218	88,410	80,577
3.	Karnataka	10,308.10	3,586.60	15,387.98	696.00	29,980.73	14,040	14,125	80,628	86,677
4.	Kerala	3,050.46	1,856.50	484.54	362.00	5,753.50	4,594	4,229	27,549	24,401
5.	Tamil Nadu	14,512.60	2,178.20	14,890.62	1,448.00	33,029.44	16,800	17,448	11,7111	12,5117
6.	Pondicherry	283.00	0.00	9.33	86.00	378.33	502	485	3,250	3,564
7.	Central-unallocated	1,814.00			450.00	2,264.00	-	-	-	-

	Total	54,699.90	11,774.80	43,895.80	3,320.00	1,13,690.60	57,576	54,289	3,89,962	3,98,373

Though the state of Andhra Pradesh has surplus power as on June 2021 as shown in Table 2-3, but the growth of state & the targets set by the state to achieve a net exporter of power by producing clean energy in the next five years.

Andhra Pradesh has an installed capacity of renewable projects aggregating to 8791.98MW as on 31.01.2021. Government of Andhra Pradesh (GoAP) vide G.O.Ms.No.20 Dated: 17-07-2020 has issued Renewable Energy Export Policy, 2020 applicable for a period of 5 years to facilitate 120 GW renewable energy projects. The following projects are already identified for development under the RE export policy

Table 2-4: List of sites identified for development of ultra-mega solar parks

Sl.No	Location/Site	District	Capacity
1	Kadiri	Ananthapuramu & YSR Kadapa	4000 MW
2	Obuladevucheruvu(ODC)	Ananthapuramu	2400 MW
3	Ralla Anantapur	Ananthapuramu	2400 MW
4	Badvel	YSR Kadapa	1400 MW
5	Kalasapadu	YSR Kadapa	2000 MW
6	Owk	Kurnool & Ananthapuramu	2400 MW
7	Kolimigundla	Kurnool & YSR Kadapa	3200 MW
		TOTAL	17800 MW

Generation from renewable sources (like solar, wind and NCE's) will be available partially (i.e, seasonal or intermittently in a day). To manage large swings in net power demand during the day, optimal solution would be flattening the RE generation instead of backing down and ramping up thermal generation. Flexible Energy Generation Assets that have a capability to supply both Base Load & Peaking Power efficiently and economically are the need of the future and the necessary solution to address the dynamic evolving energy needs of India.

Pumped Storage hydro-electric projects are the most reliable option available in the current scenario for large-scale energy/power storage systems required for maintaining grid stability.

2.3 DETAILS OF SCHEME FOR EVACUATING POWER

Generated Power from the proposed Chitravathi Pumped Storage Project to be connected through 400kV double circuit line on 400kV towers. The power requirement for the pumping mode will be drawn through the same 400kV switchyard and the 400kV transmission lines by back-feeding the generator transformers. 400/220kV substation at Talaricheruvu, which is about 50 kms is considered as grid substation. However, the selection of substation, transmission line networks, voltage and adequacy check shall be studied in consultation with APTRANSCO during the DPR Stage.

2.4 RESOURCES FOR POWER DEVELOPMENT IN THE STATE

The state of Andhra Pradesh is covered by three basins namely Godavari river basin, Krishna River basin & Pennar basin. The state is resource rich with abundant water resources. Coal is the main source of energy for the state. Due to the geographic location Andhra Pradesh is identified as rich in solar resources.

2.4.1 Coal Resources

Coal is the main source of energy for the thermal power generation in the state of Andhra Pradesh. Currently as of 31st January 2021 out of 14,688.20 MW installed thermal power a total of 10430.71 MW of Energy is generated from the available coal resources in the state through private partners, state owned & central owned firms. According to the GOI, the state of Andhra Pradesh has very limited coal resources of 1581 Million tonnes of coal. It stands in eighth position in the country. Presently two coal block mines has been allocated by the GOI to the state through Andhra Pradesh Mineral Development Corporation Ltd. (APMDC) namely Madanpur south coal mine with 183.38 million tonnes of coal in kobra district, Chhattisgarh & suliyari coal mine with 145 million tonnes of coal in singrauli district, Madhya Pradesh.

2.4.1 Hydro Resources

The main source of the hydro power for the state are from the Krishna & Godavari river basins. The major rivers in the state are Godavari, Krishna, Tungabhadra, Pennar, Vamsadhara, Nagavalli & Sileru. Most of the rivers are rain fed catchments with abundant rainfall in the rainy seasons & dry during the summers. South west monsoons are the life line for these rivers. Krishna & Godavari are the two perennial rivers that flow from the west to east into Bay of Bengal. A total of 1798 MW of hydro power generating dams have been built across the Krishna, Godavari, sileru & its tributaries.

2.4.2 Renewable Resources

The state of Andhra Pradesh lies in the South Eastern Region with hot & humid climate. Summers extend from March to June with temperature ranges from 20°C to 45°C. Monsoon season starts in the month of June till September. About of one-third of total rain fall in the state depends on the North East monsoons. Majority of the rainfall depends on the south west monsoons. Winters in Andhra Pradesh are cooler with average temperature ranges from 13°C to 30°C. There is abundant solar energy resources for the clean energy development for almost 300 days in a year. The state of Andhra Pradesh has second longest coast line next to Gujarat with 974kms. Hence there is abundant scope of wind power generation in the state. Due to the large coastline there is a possibility of development of nuclear power in the state. Andhra Pradesh has a potential of 54,916MW of renewable power in India. Currently the state government has commissioned 8791.98MW of renewable energy as of June 2021 comprising of 4083.57 MW of wind power, 4116.01MW of solar power, 102.6MW of small hydro, 171.25MW from Biomass, 65.45MW from Biomass Energy, 206.95MW with co-generation with Bagasse, 6.15MW from municipal solid waste, 40.01MW with industrial waste.

2.5 AVAILABLE GENERATING CAPACITY IN THE STATE/REGION FROM DIFFERENT SOURCES

The available generating capacity in India from various modes of power generation is given in Table 2-1. The available generating capacity in the state/region from various modes of power generation is given in table below.

Table 2-5: Available generating capacity in the state/region from different sources as on 30.12.2021

Sl.No	Location	Thermal	Nuclear	Hydro	RES (MNRE)	Grand Total
1	Andhra Pradesh	14,688.21	127.27	1,673.6	8,605.56	25,094.64
2	Southern Region	54,699.99	3,320	11,774.83	43,665.36	1,13,460.18

Source: Installed Capacity Monthly Reports – Dec 2020

2.5.1 Peak load and energy requirement in future in all India/region/state up to the likely date of project completion

Power Supply Position in the country

The power supply position in the country shows that there is a deficiency of 0.6% in meeting peak power and 0.3% deficiency in meeting the energy requirement.

Year	Energy				Peak			
	Requirement	Availability	Surplus(+)/Deficts(-)	Peak	Demand	Peak	Met	Surplus(+)/Defcts(-)
(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)	(%)
2009-10	8,30,594	7,46,644	-83950	-10.1	1,19,166	1,04,009	-15157	-12.7
2010-11	8,61,591	7,88,355	-73236	-8.5	1,22,287	1,10,256	-12031	-9.8
2011-12	9,37,199	8,57,886	-79313	-8.5	1,30,006	1,16,191	-13815	-10.6
2012-13	9,95,557	9,08,652	-86905	-8.7	1,35,453	1,23,294	-12159	-9
2013-14	10,02,257	9,59,829	-42428	-4.2	1,35,918	1,29,815	-6103	-4.5
2014-15	10,68,923	10,30,785	-38138	-3.6	1,48,166	1,41,160	-7006	-4.7
2015-16	11,14,408	10,90,850	-23558	-2.1	1,53,366	1,48,463	-4903	-3.2

2016-17	11,42,929	11,35,334	-7595	-0.7	1,59,542	1,56,934	-2608	-1.6
2017-18	12,13,326	12,04,697	-8629	-0.7	1,64,066	1,60,752	-3314	-2
2018-19	12,74,595	12,67,526	-7070	-0.6	1,77,022	1,75,528	-1494	-0.8
2019-20	12,91,010	12,84,444	-6566	-0.5	1,83,804	1,82,533	-1271	-0.7
2020-21*	9,40,694	9,37,518	-3176	-0.3	1,84,033	1,82,888	-1145	-0.6

* Upto January 2021 (Provisional), Source : CEA

The 19th Electric power survey committee (EPSC) has projected on all India basis during the year 2021-22 & 2026-27 as 1566BU & 2047 BU. The peak demand has been estimated as 226GW & 299GW for the period 2021-22 & 2026-27 respectively. The peak load and energy demand for the various regions are estimated as below shown in the Table 2-6.

Table 2-6: Peak load & Energy demand projections

Sl.No	Region	Energy Demand (MU)		Peak Demand (MW)	
		2021-22	2026-27	2021-22	2026-27
1	Northern	4,68,196	6,16,345	73,770	97,182
2	Western	4,81,501	6,27,624	71,020	94,825
3	**Southern**	**4,20,753**	**5,50,992**	**62,975**	**83,652**
4	Eastern	1,71,228	2,17,468	28,046	35,674
5	North-Eastern	23,809	34,305	4,499	6,710
6	A & N Islands	475	632	97	129
7	Lakshadweep	62	73	11	13
	All India	15,66,023	20,47,434	2,25,751	2,98,774

The projected energy & peak demand for the southern states are as shown below Table 2-7:

Table 2-7: Projected energy & peak demand for the southern states

Sl.No	Region	Energy Demand (MU)		Peak Demand (MW)	
		2021-22	2026-27	2021-22	2026-27
1	**Andhra Pradesh**	**78,540**	**1,11,485**	**11,843**	**16,820**
2	Telangana	84,603	1,04,345	14,499	18,653
3	Karnataka	85,932	1,10,368	14,271	18,481
4	Kerala	31,371	39,357	5,263	6,603
5	Tamil Nadu	1,36,643	1,80,989	20,273	27,392
6	Puducherry	3,664	4,448	583	708
	Southern Region	**4,20,753**	**5,50,992**	**62,975**	**83,652**

The availability of peak demand & energy for the year 2020-21 in the state of Andhra Pradesh is 12,074 MW & 76,865 MU as shown in Table 2-3. There is a gap of 4,746MW of peak demand & 34,620MU of Energy with in next five years.

Peak load and energy requirement in the state

The state level forecasts was carried out by the Discoms towards the requirement of peak power for 4th Control Period (FY2019-20 to FY2023-24) and for the 5th Control Period (FY2024-25 to FY2028-29)

Table 2-8: State peak demand for 4th Control Period

Sl.No	Description	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24
1	Energy Requirement at State level (MUs)	64,030	68,606	73,212	79,146	85,776	93,106
2	State Peak Demand (MW)	10,532	11,450	12,219	13,209	14,315	15,539

Table 2-9: State peak demand for 5th Control Period

Sl.No	Description	FY 25	FY 26	FY 27	FY 28	FY 29	CAGR
1	Energy Requirement at State level (MUs)	1,01,306	1,10,561	1,21,302	1,33,594	1,47,599	9.2%
2	State Peak Demand (MW)	16,907	18,452	20,245	22,286	24,633	9.6%

Source: APERC: Load Forecasts and Resource Plans

Based on the energy generation and energy input for power procurement the table below summarises Energy (MU) balance at State level for 4th Control Period (FY2019-20 to FY2023-24) and Indicative Forecasts & Plans for the 5th Control Period (FY2024-25 to FY2028-29)

Table 2-10: Energy Surplus/Deficit Summary for 4th Control Period

Sl.No	Location/Site	FY 19	FY 20	FY 21	FY 22	FY 23	FY 24
1	State Energy Availability (MU)	73,865	77,998	85,203	82,200	80,204	80,658
2	State Energy input (MU)	60,971	66,313	71,355	76,951	83,152	90,033
3	State Energy Surplus/ (Deficit) (MU)	12,894	11,685	13,847	5,248	-2,949	-9,375

Table 2-11: Energy Surplus/Deficit Summary for 5th Control Period

Sl.No	Location/Site	FY 25	FY 26	FY 27	FY 28	FY 29	CAGR
1	State Energy Availability (MU)	80,570	80,521	80,446	80,439	80,436	0.9%
2	State Energy input (MU)	97,707	1,06,247	1,16,046	1,27,141	1,39,665	8.6%

3	State Energy Surplus/ (Deficit) (MU)	-17,138	-25,726	-35,600	-46,702	-59,229	

Source: APERC: Load Forecasts and Resource Plans

As can be seen from the table, there is a deficit of energy from FY 2023

2.5.2 Likely addition to generating capacity in future in the all India/region/state indicating power supply position with & without the project under consideration and improvement in the hydro-thermal mix.

As per the 19th EPS report it is projected that India will have an installed capacity of 479.418GW & 619.066GW by the end of 2021-22 & 2026-27 respectively from various sources of energy as shown in Table 2-12.

Table 2-12: Projection of Installed Energy in the India

Sl.No	Type	2021-22		2026-27	
		(MW)	%	(MW)	%
1.	Coal + Lignite	2,17,302	45.3	2,38,150	38.5
2.	Hydro	51,301	10.7	63,301	10.2
3.	Gas	25,735	5.4	25,735	4.2
4.	Nuclear	10,080	2.1	16,880	2.7
5.	Renewables	1,75,000	36.5	2,75,000	44.4
	Total capacity	4,79,418	100.0	6,19,066	100.0

Upcoming major power projects to be installed in next five years by the state & central governments are as below in Table 2-13.

Table 2-13: List of major power projects to be installed in next five years by the state & central governments

Sl.No	Name	Units (MW)	Capacity (MW)
1.	Dr. Narla Tata Rao TPS st -V (unit -8)	1X 800	800
2.	Sri Damodaran Sanjeevaiah TPP st-II (unit-1)	1 X 800	800
3.	Bhavanapadu TPP phase-I (units-1 & 2)	2 X 660	1320
4.	Thamminapatnam TPP Stage -II unit 3 & 4	2 X 350	700
5.	Rayalaseema TPP stage-IV (unit no:06)	1 X 600	600
6.	Polavaram Hydro electric project	12 X 80	960
7.	Upper Sileru pumped storage scheme	9 X 150	1350
8.	Lower Sileru power house	2 X 115	230
		Total	6760

2.6 NECESSITY OF THE PROPOSED CHITRAVATHI PUMPED STORAGE PROJECT

The state of Andhra Pradesh had an installed capacity of 25,508.94 MW as on June 2021. Currently the state government has commissioned 8791.98MW of renewable energy as of June 2021 comprising of 4083.57 MW of wind power, 4116.01MW of solar power, 102.6MW of small hydro, 171.25MW from Biomass, 65.45MW from Biomass Energy, 206.95MW with co-generation with Bagasse, 6.15MW from municipal solid waste, 40.01MW with industrial waste.

Government of Andhra Pradesh is also developing solar capacity of 10,000 MW through Andhra Pradesh Green Energy Corporation Ltd. and identified sites to the tune of 17,800 MW under the Renewable Energy Export Policy. This large scale injection of solar power into the grid necessitates the proposals for storage of energy systems for the following aspects:

- ❖ The total energy generation from the renewables of about 36,592 MW contributes about 68% of total installed capacity in the state of Andhra Pradesh.
- ❖ Energy reliability on the Solar & wind power over the entire year may create the demand to supply issues as well as grid instability issues.
- ❖ Large scale energy storage systems are not available in Andhra Pradesh.
- ❖ Ultra mega solar projects connected to the grid may have variations in the grid frequency due to sudden changes in the generation by way of cloud cover, rains etc., Hence a quick response system like PSP is required for grid balancing

2.7 PUMPED STORAGE BENEFITS AND ANCILLARY SERVICES

Pumped storage offers multiple benefits to a power system. In addition to providing energy storage, pumped storage can provide power immediately and can be rapidly adjusted to respond to changes in energy demands. These benefits are part of a large group of benefits, known as ancillary services which include the following.

Spinning Reserves – on-line reserve capacity that is synchronized to the grid and ready to meet electric demand within 10 minutes of a request. Spinning Reserve is needed to maintain system frequency stability during emergency operating conditions and unforeseen load swings.

Non-Spinning Reserves – off-line generation capacity that can be ramped to capacity and synchronized to the grid within 10 minutes of a request, and that is capable of maintaining that output for at least two hours. Non-Spinning Reserve is needed to maintain system frequency stability during emergency conditions.

Frequency Regulation – on-line generation equipped with automated generation control that can respond rapidly, on a seconds to minute basis, to fluctuations in load. Regulation up is an increase in output and regulation down is a decrease in energy output in response to an automated signal.

Chapter-3

Basin Development

3 BASIN DEVELOPMENT

3.1 THE COURSE OF THE RIVER

The Chitravathi is an inter-state river in southern India that is a tributary of the Pennar River. Rising in Karnataka, it flows into Andhra Pradesh and its basin covers an area of over 5,900 km^2.

Chitravathi River originates at Chikkaballapur and flows through the Chikkaballapur district of Karnataka before entering Andhra Pradesh where it drains the districts of Anantapur and YSR Kadapa before joining the Pennar. The Chitravathi river basin covers an area of 5,908 km2. Among the mandals that it drains in the two states are Bagepalli, Gorantla, Hindupur, Bukkapatnam, Dharmavaram, Tadipatri and Kadiri. The river joins the Pennar at Gandikota in Kadapa district where the Gandikota irrigation project is being undertaken by the Government of Andhra Pradesh. Chitravathi is a seasonal river that comes alive after the monsoons. Along with the Papagni, it forms a part of the middle Pennar sub-basin and is a right bank tributary of the Pennar.

The Chitravathi Pumped Storage Project is proposed over Chitravathi Balancing Reservoir (CBR). Chitravathi Balancing Reservoir (CBR) was constructed on river Chitravathi, a tributary of Pennar of Pennar basin, to augment irrigation to an ayacut of 60,000 acres already existing under the Pulivendula Branch Canal (PBC).

Pulivendula Branch Canal receives water from South Canal of Mid Pennar Dam through Thumpera deep cut. The canal takes off from pickup anicut constructed across Chitravathi River downstream of Chitravathi dam near Goddumarri Village with carrying capacity of 580 Cusecs. 4.40 TMC of water is allocated to PBC on prorate basis from TBP HLC System and receives 2.00TMC from self catchment. The PBC system receives water from Km 72.00 of Mid Pennar south Canal and runs 10.0 Km from Tumpera Deep Cut, then after it runs 10.00 Km length in Hosuramma Vanka to reach Chitravathi River and then 11.00Km in Chitravathi River to reach Anicut near Goddumarri Village of Yellanur Mandal of Ananthapur District. Due to scarcity rain fall and depending up of release of water from TBP HLC system is not fully satisfactory. Hence the Chitravathi Balancing Reservoir is constructed across Chitravathi River near Parnapalli village of Lingala Mandal of YSR Kadapa District with a storage capacity of 10.00TMC and completed the Reservoir during the 2009.

3.1.1 Power potential of the river basin and stages of development

The Pennar basin extends over states of Andhra Pradesh and Karnataka having an area of 55,213 Sq.km with maximum length and width of 433 km and 266 km. The basin lies between 77°1' to 80°10' east longitudes and 13°18' to 15°49' north latitudes. The fan shaped basin is bounded by the Erramala range on the north, by the Nallamala and Velikonda ranges of the Eastern Ghats on the east, by the

Nandidurg hills on the south and by the narrow ridge separating it from the Vedavati valley of the Krishna Basin on the west. The other hill ranges in the basin to the south of the river are the Seshachalam and Paliconda ranges. The Pennar (also known as Uttara Pinakini) is one of the major rivers of the peninsula.

The Pennar rises in the Chenna Kasava hill of the Nandidurg range, in Chikkaballapura district of Karnataka and flows towards east eventually draining into the Bay of Bengal. The total length of the river from origin to its outfall in the Bay of Bengal is 597 km. The principal tributaries of the river joining from left are the Jayamangali, the Kunderu and the Sagileru whereas the Chiravati, the Papagni and the Cheyyeru joins it from right. The major part of basin is covered with agriculture accounting to 58.64% of the total area and only 4.97% of the basin is covered by water bodies.

Pennar basin extends over an area of 55,213 sq. Km in the states of Andhra Pradesh and Karnataka. The State-wise distribution of drainage area covers 48,276 Sq. Km in Andhra Pradesh and 6,937 sq. Km in Karnataka.

Most of the projects constructed in the basin were medium and minor schemes. Tungabhadra high level canal in Krishna basin irrigated areas in Pennar basin also. The only major project in the basin is the Somasila project. M/s Balaji Energy Pvt Ltd operates about 20 MW capacity MHS on left flank of Somasila Reservoir, Nellore District.

Dr. K. Sriramakrishnaiah Penna Ahobilam balancing reservoir (PABR) is an irrigation project located across Penna River in Anantapur district of Andhra Pradesh state. Anantapuramu city gets its drinking water from the PABR. A 20MW small hydro power project is operational at PABR.

3.1.2 Whether trans-basin diversion of waters involved

The K.C.Canal was constructed between 1863 and 1870 as an irrigation and navigation canal. This canal interconnects the rivers Penner and Tungabhadra. It starts from the Sunkesula barrage located on the Tungabhadra River near Kurnool. The navigation system was abandoned during 1933 and the canal continued to be a major irrigation source.

Alternate water supply from Srisailam reservoir is provided via Srisailam right main canal constructed under Telugu Ganga project. Also water can be pumped and fed to K.C. Canal from the recently commissioned Muchumarri lift or Handri-Neeva lift canal pump house from the Srisailam reservoir when its water level (up to 798 ft msl) is below the minimum drawdown level of Pothireddypadu head regulator which also feeds Telugu Ganga, Srisailam right bank canal and Galeru Nagari projects. Although there is assured water allocation of 10 tmcft for this project, most of the water meant for KC canal is drawn though the escape channel at banacherla cross regulator and taken to Somasila project for use by Nellore district depriving Rayalaseema of its allocated water.

Almatti- Pennar link:

The link envisages diversion of 1980 Mm3 (69.923 TMC) of waters from Krishna for enroute utilisation in Krishna and Pennar basins. A 587.175 km long link canal off takes from the right bank of Almatti dam and outfalls into Maddileru river, a tributary of Pennar river. The annual irrigation proposed through the link is 258334 ha Domestic and industrial requirements 22 Mm3 (0.777 TMC) and 34 Mm3 (1.200 TMC) respectively. Transmission loss in the link canal is estimated to be 210 Mm3 (7.416 TMC). A power house is proposed at the canal off take with an installed capacity of 13.5 MW and annual power generation of about 42.5 MU.

Krishna (Srisailam) -Pennar link:

Link canal off takes from the foreshore of the existing Srisailam Reservoir and envisaged through the Srisailam Right Main Canal upto Banakacherla cross regulator then from the water will be let out into Nippulavagu stream through an existing escape channel. The water will reach the Pennar river through natural stream Nippulavagu, Galeru and Kunderu. The total length of the link is 204 km. The proposed diversion through the link is 82 TMC, out of which 74 TMC will be discharged in to the Pennar river and 8 TMC being transmission losses.

The link canal envisages diversion of 2310 Mm3 (81.577 TMC) of water from Srisailam reservoir on Krishna to Pennar river through natural streams in partial exchange to the surplus water of Mahanadi and Godavari rivers proposed to be brought to the Krishna river. This link canal, however, serves no irrigation or power purposes.

Nagarjunasagar-Somasila link:

The link project envisages diversion of 12146 Mm3 (428.932 TMC) of water from Nagarjunasagar, part of it (8167 Mm3(288.415 TMC)) through the link canal and the balance through the existing Nagarjunasagar Right Bank Canal (NSRBC). Out of the 3979 Mm3 (140.517 TMC) diverted through NSRBC, 2356 Mm3 (83.201 TMC) would be to meet part demand of the existing command area of NSRBC. The remaining part of the demand (1623 Mm3 (57.315 TMC)) is proposed to be met from the Godavari (Inchampalli) - Krishna (Pulichintala) link canal. The total length of Krishna (Nagarjunasagar) - Pennar (Somasila) link canal is 393.02 km. The canal will run parallel and adjacent to the existing NSRBC upto the tail end of NSRBC at 202.75 km and then traverse a distance of 190.27 km before joining Somasila reservoir on Pennar. The balance quantity of 1623 Mm3 (57.315 TMC) available in NSRBC after meeting the demands of NSRBC is proposed to be transferred from NSRBC to the link canal at the tail end of NSRBC. Thus a total quantity of 9790 Mm3 would flow through the link canal after the tail end of NSRBC.

The proposed project is a pumped storage project, and the allocated water will be recycled between the upper and lower reservoirs on a daily cycle basis. Only, water lost due to evaporation in upper reservoirs which is negligible can be replenished from the yield in to the upper reservoir. As such, inter linking proposals of the rivers do not affect the proposed Pumped storage project.

3.1.3 Fitment of the scheme in the overall basin development

The Chitravathi pumped storage project proposed at Chitravathi balancing reservoir is contemplated only to produce peak electricity and will not impact the existing commitments and operations of Chitravathi balancing reservoir. The project envisages non consumptive utilisation of water and the PSP is operational by recirculation of water. The water will be pumped and stored in the upper reservoir during the availability of surplus power in the grid and the same water will be utilised for generation of power during peaking hours. The pumped storage project is proposed to be operated on a daily cycle basis. Hence, there is no need to alter the operational levels and the strategy of the existing Chitravathi Balancing Reservoir.

Also, there is very less hydro power potential available in the basin and the proposed PSP will serve as a storage scheme to generate peaking power to the tune of 500MW to the state.

3.1.4 Fitment of the scheme in the power potential assessment studies carried out by CEA

The proposed Chitravathi Pumped Storage Project is not part of the assessment studies carried out by CEA.

3.1.5 Effect of future upstream/downstream developments on the potential of proposed scheme

The proposed Chitravathi Pumped Storage Project is not a run-off-river project and is envisaged as a storage power for generating peaking power by recirculation of water. Hence, the proposed PSP project will not have any effect of future upstream or downstream developments.

3.1.6 Conversion of Storage Scheme to ROR, if any

The proposed Chitravathi pumped storage project is not a case of conversion of storage scheme to ROR.

Chapter-4

Interstate/International Aspects

4 INTERSTATE/INTERNATIONAL ASPECTS

4.1 THE COURSE OF THE RIVER

The Chitravathi is an inter-state river in southern India that is a tributary of the Pennar River. Rising in Karnataka, it flows into Andhra Pradesh and its basin covers an area of over 5,900 km^2.

Chitravathi River originates at Chikkaballapur and flows through the Chikkaballapur district of Karnataka before entering Andhra Pradesh where it drains the districts of Anantapur and Cuddapah before joining the Pennar. Among the mandals that it drains in the two states are Bagepalli, Gorantla, Hindupur, Bukkapatnam, Dharmavaram, Tadipatri and Kadiri. The Chitravathi river joins the Pennar at Gandikota in Kadapa district.

4.1.1 Distribution of catchment in states/countries and yields from the catchment of state/ countries concerned

Pennar basin extends over an area of 55213 sq. km. which is nearly 1.7% of the total geographical area of the country. The basin lies in the States of Andhra Pradesh and Karnataka. The State-wise distribution of drainage area is given below:

State	:	Drainage area (sq. km.)
Andhra Pradesh	:	48276
Karnataka	:	6937
Total	:	55213

The catchment area of the project upto Chitravathi balancing reservoir is 5341 Sq. km, of which 4557 sq.km in Andhra Pradesh and the rest 874 sq. km is in Karnataka. The catchment contribution for Chitravathi balancing reservoir works out to 16 % from Karnataka and 84% from Andhra Pradesh.

4.2 EFFECT OF THE FOLLOWING ON THE PROJECT

4.2.1 Inter-state agreement on sharing of waters, sharing of benefits and costs, acceptance of submergence in the upstream state(s)

Water resources development should be as per the agreement Mysore-Madras agreement in 1982 and 1933, which states that no state can't take up any new irrigation works on 15 inter-state rivers unilaterally.

Further, there are import of waters from Krishna rivers to Pennar, so the allocations made by KWDT-1 in its report and decisions of Krishna basin should be adhered.

However, as the proposed project is a pumped storage project, no consumptive utilisation of water is envisaged, except for recuping the evaporation losses of 0.15 MCum in the upper reservoir. All the project components of the proposed PSP are within the state of Andhra Pradesh and the submergence due to construction of upper reservoir also lies within the state of Andhra Pradesh.

As the Consumptive use of the project is only 0.15 MCum, which is less than 10 MCUM, therefore no interstate issue on sharing of water, construction of new project, benefits and cost is involved.

4.2.2 Inter-state adjudication

The proposed project is within the state. Hence, forth no interstate aspects are involved.

4.2.3 Inter-State aspects of territory, property etc. coming under submergence, oustees rehabilitation, compensation etc.

All the project components and the submergence due to upper reservoir are completely in the state of Andhra Pradesh. Hence, no Inter-State aspects of territory, property etc. coming under submergence, oustees rehabilitation, compensation etc.

4.2.4 Any other aspect of the project involving inter-state problems

Not Applicable.

4.2.5 International aspects

The project is confined to southern peninsular region of India with no International boundaries. As such, no International aspects are not involved in the proposed Chitravathi Pumped Storage Project.

4.2.6 International Agreement

Not Applicable.

4.3 EXISTING RIPARIAN USE, QUANTUM OF WATER PRESENTLY UTILIZED, COMMITMENTS FOR ON-GOING PROJECTS, PLANS FOR FUTURE DEVELOPMENT, BALANCE SHARE OF THE STATE/COUNTRY AND PROPOSED UTILIZATION BY THIS PROJECT.

The proposed pumped storage does not involve consumption use of water except for recouping of evaporation losses. The storage contemplated for the Upper Reservoir is about 6.40 MCM is very negligible as compared to the 90% dependable yield of about 950MCM in to the lower reservoir.

As such, there will be no change or alterations in the operation levels or operational patterns of the existing Chitravathi balancing reservoir, existing riparian use, quantum of water presently utilized, commitments for on-going projects, plans for future development, balance share of the state/country and proposed utilization by this project.

Chapter-5

Survey and Investigations

5 SURVEY AND INVESTIGATIONS

5.1 GENERAL

Chitravathi Pumped Storage Project (PSP) is located in Anantapuramuamu Dist of Andhra Pradesh in India. Chitravathi PSP will comprise of two reservoirs i.e. Chitravathi Balancing Reservoir (already existing) as a lower reservoir and Chitravathi PSP Upper Reservoir (to be constructed newly). This project is a one of its kind because the proposed upper reservoir is not located on any river course and the existing Chitravathi Balancing reservoir is located across river Chitravathi.

5.2 PROJECT LOCATION

The present proposal envisages a Pump Storage project between the proposed upper reservoir & the existing Chitravathi Balancing reservoir, by installing reversible Francis turbines (total installed capacity 500 MW) near Lingala Village in Tadimarri Taluk of YSR Kadapa district.

The preliminary study contemplates the existing Chitravathi balancing reservoir as a lower reservoir and two possible options were identified for the upper reservoir at the nearby hilltop. The Topography of the project area suggests that, highest contour available in the vicinity of the project is of the order of 500m. Accordingly two possible locations of the Upper Reservoirs namely Option-1 (Left bank) and Option-2 (Right bank) have been considered for optimizing the project layout.

In the option – I (Left bank), the upper reservoir is proposed on left bank at geographical co-ordinate N -14° 34' 26.93" E - 77° 56'2.60" in NW direction of existing lower Reservoir.

In the option – 2 (Right bank), the upper reservoir is proposed on Right bank at geographical co-ordinate N - 14° 31' 38.46" E - 77° 57' 31.09".

To firm up the techno-economic viability of both the options, topographical survey was carried out on the left bank and right bank during the period 24.11.2020 to 31.12.2020. The locations of option-I and option – 2 are shown the figure below:

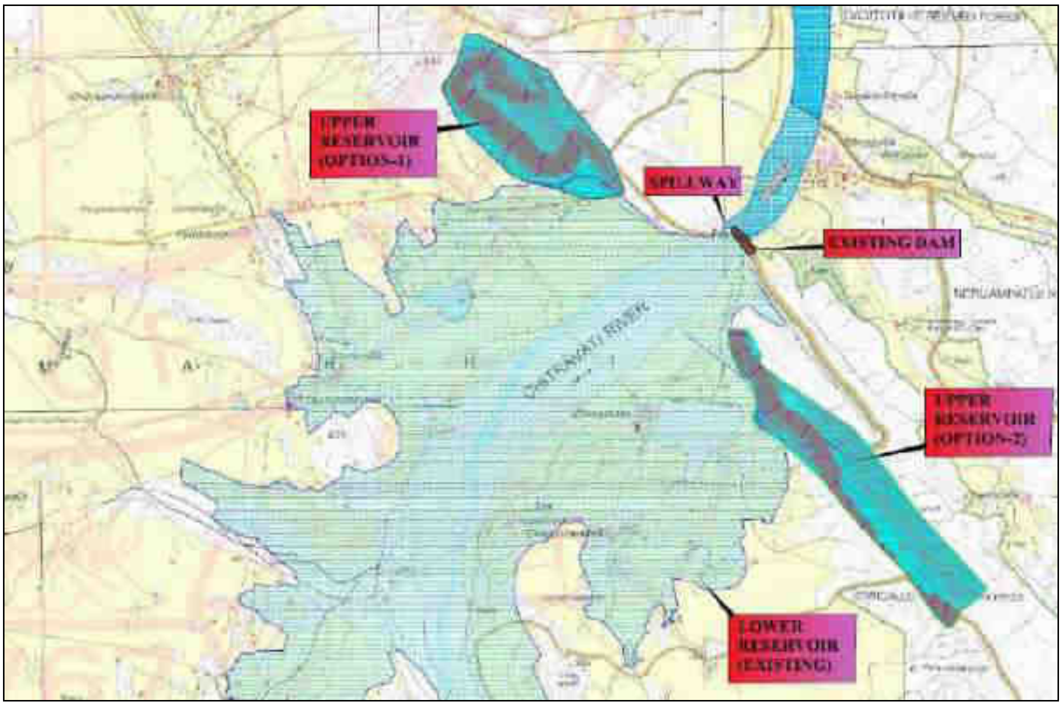


Figure 5-1: Project Location Map

5.3 SALIENT FEATURES OF THE PROJECT

The salient features of the project as envisaged during the TCFR are given in Table 5-1.

Table 5-1: Salient Features of the Project Location

S.No.	Item	Description
1	**Location**	
	Country	India
	District	Ananthapuramu / Kadapa
	State	Andhra Pradesh
2	**Access**	
	Nearest Airport	Kadapa : 121 km Kurnool : 230 km
	Road	Accessible from State Highway SH121
	Railhead (with unloading facilities)	Chinnekunta Palli : 30 km
	Port	Krishnapatnam : 280 km
3	**Geographical co-ordinates of Dam Site**	
	Upper Reservoir	N- 14° 34' 26.93" E- 77° 56'2.60" (Option – 1) N- 14° 31' 38.46" E- 77° 57' 31.09" (Option-2)
	Chitravathi Reservoir (Lower Reservoir)	N 14° 34' and Long. E 77° 57' 31.09"
4	**Project**	

	Type	Pumped Storage Project
5	**Reservoir**	
5.1	Upper Reservoir (New)	
	Full Reservoir Level (FRL)	El. 475.00 m
	Minimum Drawdown Level	El. 455.00 m
	Live Storage Envisaged	6.01 MCM (0.21 TMC)
5.2	Lower Reservoir (Existing Chitravathi Balancing Reservoir)	
	Full Reservoir Level (FRL)	El. 298.00 m
	Minimum Drawdown Level	El. 283.00 m
	Gross Storage	283.1 MCM (10.00 TMC)
	Live Storage	281.85 MCM (9.956 TMC)

5.4 TOPOGRAPHICAL SURVEY

5.4.1 General

The proposed Chitravathi Pumped Storage Project is in the border of the Kadapa District and Ananthapuramu District. The Upper reservoir at present is inaccessible in both the options and the Lower is accessible from nearest road network which is at about 4 km to 5 km from State Highway SH-121.

5.4.2 Survey & Planned Activities

The TCFR were made in May 2020 by 'WAPCOS Limited' on topographical map developed from satellite imageries. To firm up the project parameters detailed topographical survey is carried out in for the area.

5.4.3 Reconnaissance Survey

Reconnaissance survey is basically a preliminary walk through survey conducted by team of surveyors headed by survey in charge (Project Manager) to collect the first hand information along the project corridor, which will become basis for conducting subsequent detailed surveys. The Reconnaissance survey was carried out on 17.11.2020 & 24.11.2020 which involved collection of general topography of the alignment; habitations/forest area/hilly area, existing roads, stream crossings. Reconnaissance survey was conducted using hand held GPS and cameras to collect general coordinates of all important locations along with their photographs.

Figure 5-2: Reconnaissance Survey

5.4.4 Bench Marks /Control Points

The main aim of conducting topographical surveys is to represent all the ground features in the drawing to a certain scale. In order to achieve this, a network of reference structures called control points/Bench Marks are established in the project area and all the survey activity is carried out with reference to these control points. The bench mark is transferred from existing Chitravati dam. Following the basic principle of surveying i.e., “to work from whole to part” the network of control points are established along the project. Depending on the importance of these points and their subsequent usage, these control points are classified as Primary and Secondary Control Points.

Primary Control Points

These are the main reference points established with DGPS duly following minimum observation time of 2hrs or more. These are established on existing structures in the project area or in the neighbourhood so that they are not disturbed and are used for all subsequent surveys as reference. The horizontal coordinates ('X' and 'Y') are taken from the DGPS observation from the GTS benchmarks.

Secondary Control Points

Secondary Control Points or GCPs (Ground Control Points) are markings on ground at clear sky view locations. These are established with reference to the primary control network. These Ground control points are set down at an interval of 250m within view of planned coverage area and are collected with RTK DGPS.

Figure 5-3: Establishment of Control Point

5.4.5 Drone Survey

A UAV (Unmanned Aerial Vehicle) is any aircraft that can navigate without a human pilot on board. UAV is also referred to as a drone which contains Camera, IMU and GPS. These are light weight, can fly at low levels, less costly compared to the manned aircraft. Raster data are collected in the form of geo referenced digital images with GSD below 2cm per pixel.

Figure 5-4: UAV (Unmanned Aerial Vehicle) - Drone

Flight Planning & Drone Imageries

UAV/Drone will be controlled by remote controller through wireless network. Drone will be operated by using GCS (Ground Control Station). With their in-built GPS and highly responsive flight control systems, drone will be able to fly and maintain very specific, accurate zig-zag flight patterns, flying backwards and forwards across a site until the entire area gets photographed. Flight plan will be prepared in GCS by maintaining sufficient overlap (60% End Overlap & 30% Side overlap), flying at low altitude, nadir camera view and drawing waypoints. This flight plan will be pre-programmed, saved and uploaded to the drone before commencement of flying. Drone will be taken off, executes the flight plan and will capture the study area as per flight plan. The photographs will be captured in ideal weather conditions. If a problem/hazard is encountered drone operator / pilot will manually control and land the drone safely. Proper safety precautions will be maintained during the mission.

The consultant shall ensure to collect the data ensuring the following ideal conditions:

- Sun angle not less than 30^0 to minimise the shadows
- Cloud free durations with minimal smoke, smog, fog and dust
- Minimum moisture conditions
- No break between the flight lines
- Horizontal accuracy of 10cm GSD
- World geodetic datum 84 (WGS-84)
- Deliverables confirming to Universal Transverse Mercator (UTM) coordinate system

Figure 5-5: Capturing the aerial images with UAV

Generation of Orthomosaic and Point Cloud

Once the UAV completes capturing the site, the photographs and Geodata is copied and processed together into a usable orthomosaics. This is done with Desktop software solution like pix4D, Photoscan, etc. These Geotagged photos is loaded into software and divided into a set of pixels. The software then determines pixels from each photograph that match each other and will create automatic tie points, generates orthomosaic and point cloud. GCPs coordinates will be assigned manually to the corresponding pixels of GCP Markings in the photograph.

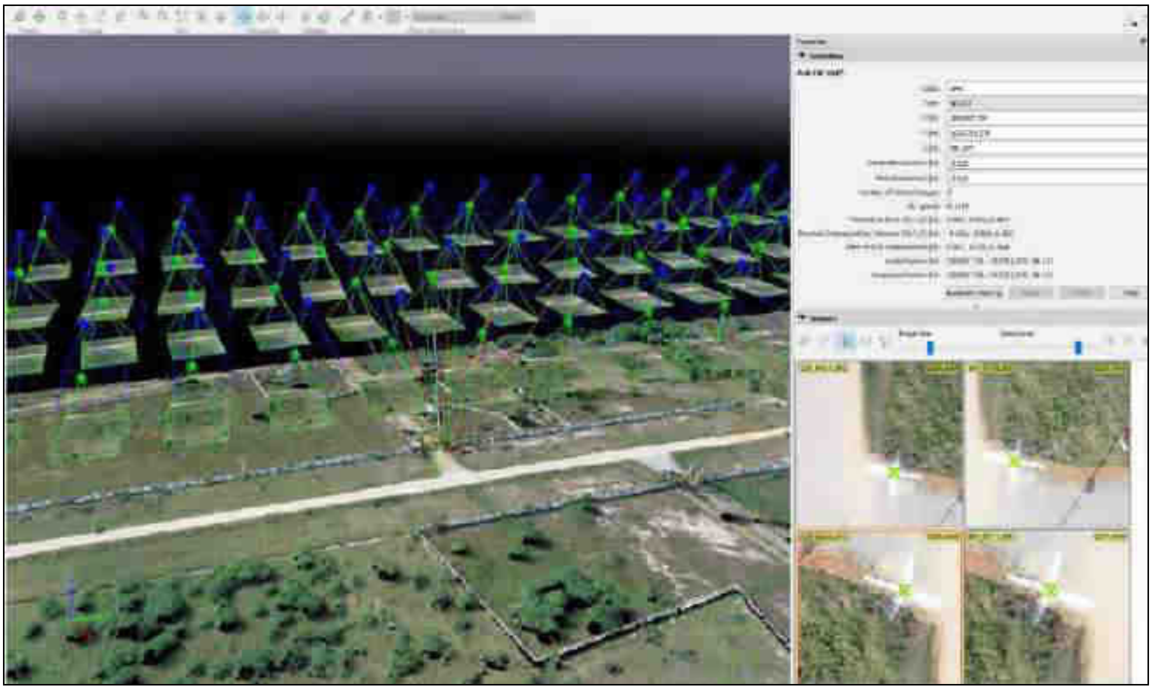


Figure 5-6: Post processing of Images into Orthomosaics

5.4.6 Preparation of Topographical Map

All the existing features like Roads, bridges, culverts, buildings, trees, waterways, pylons, poles and all man made features above the ground will be vectorized on the Orthomosaic in CAD platform and the drawings generated.

5.5 ARCHAEOLOGICAL SURVEYS IN THE RESERVOIR AREA

The upper reservoir is proposed on the hill top of the existing Chitravathi balancing reservoir. No archaeological structures exist in the proposed upper reservoir area. Hence, no archaeological surveys are carried out for the proposed project.

5.6 MINERAL SURVEYS IN THE CATCHMENT AREAS

No significant minerals are found in the proposed upper reservoir area and the project components. Mineral survey is not required for the project.

5.7 RIGHT OF WAY SURVEYS FOR THE RESERVOIRS-THESE SHALL COVER SURVEY FOR RIGHT OF APPROACH ROADS, WHICH MAY BE CLAIMED BY OWNERS TO VARIOUS STRUCTURES ABOVE FRL

There exists a cart track from which lead to the project components. The same road shall be further developed for reaching all the project components. Right of way for using these roads shall be taken by the project developers.

5.8 COMMUNICATION SURVEYS

Temporary and permanent buildings for the use of project officers are proposed near the project site.

The proposed Chitravathi Pumped Storage Project is in the border of the Kadapa District and Ananthapuramu District.

The Upper reservoir at present is inaccessible in both the options. The Chitravathi PSP is proposed on the left bank of Chitravathi Dam, near Peddakotla village, located in Tadimarri Mandal of Ananthapuramu district in Andhra Pradesh, India. It is situated 2 kms away from sub-district headquarter Tadimarri and 10.4 kms away from district headquarter Ananthapuramu. The site is easily approachable by NH-205 from Ananthapuramu. Nearest railway head is Ananthapuramu from where project site is located at around 50 kms away. The nearest international airport is at Tirupati which is about 260 km from the project site and sea port is at Krishnapatnam which is about 295 km from the project site.

5.9 GEOLOGY & GEO-TECHNICAL FEATURES

5.9.1 Introduction:

In order to assess the geological feasibility of the proposed Chitravathi PSP on the left bank of Chitravathi reservoir in Anantapur district, AP, the following Geological studies have been carried out.

5.9.2 Desk Studies:

- Collection and study of published Regional Geological maps and geological literature covering the project site.
- Study of Geological data of Chitravathi dam foundations.
- Study of satellite imagery data of the area to know geomorphological set up, presence of any buried channels of Chitravathi river, lineaments, faults and folds.

- Study of Seismo-tectonic set up of the area.

5.9.3 Field Studies:

Carried out field traverses on scale 1:50,000, in and around project site, in order to map different lithological units exposed, in order to collect structural data and to delineate any geological adverse features within or in the vicinity of the project site.

The geological data so collected is synthesized, analysed and presented below:

Geomorphology

Geomorphology has got genetic relation to geology and plays an important role in modelling the land use, land cover regime of the area. Weathering (chemical and mechanical), fluvial processes and man act as agents in modifying the land forms.

Study of its role is very important in the present human environment and Knowledge of Land use and Land cover pattern is useful in the planning lay out of any major Project.

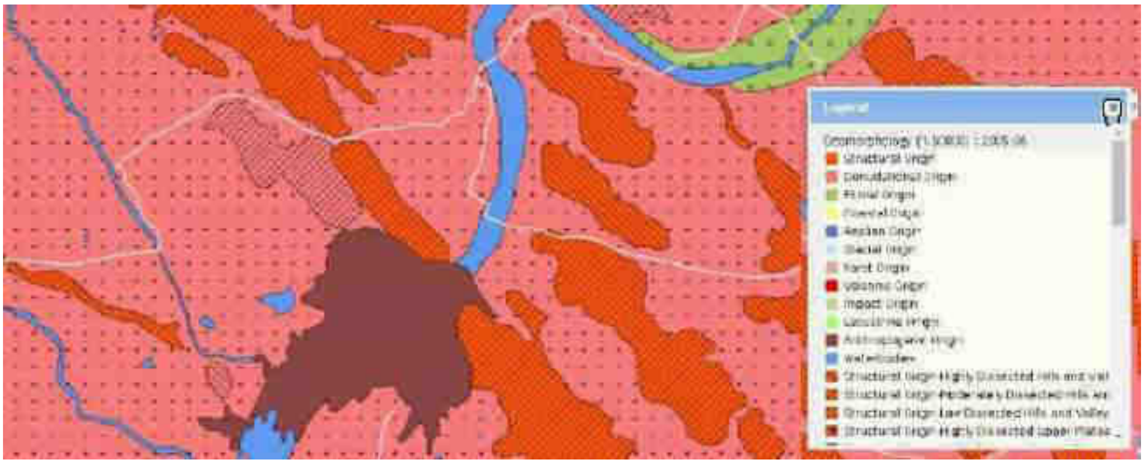


Figure 5-7: Geomorphology

Major land forms identified in the area are:

Structural Hills

These are linear to arcuate hills of quartzites with narrow valleys showing definite trend lines. Locally they are named as Mutchukonda hill ranges which forms part of western boundary of Cuddapa Basin They extend upto Pulasalanutala and Doricallu reserved forest towards southeast. They are extension of Palakondas in Kadapaha district and Erramalaies in the Anantapur and Kurnool districts. They are located in parts of Simhadripuram, Vellanur, Putlur, Kondapuram and Tadimarri mandals. The maximum width of these hills is about 12 km with intervening valleys. They attain maximum height of 490m above masl. The Chitravathi River cuts its way into Kadapaha district through interstices in these strike ridges. They show reddish tone and rough texture on the satellite image. The structural hills are made up of quartzites and cherty dolomites in the present study area extending in NW and SE directions.

Denudational hills are a group of massive erosion resistant hills formed due to differential erosion and weathering. All the denudational hills occur as detached, scattered hills within the Peninsular Gneissic Complex terrain outside the Cuddapah Basin, within the study area. They formed basement to Cuddapah Group of rocks (Nagaraja Rao et al. 1987). These are occupied by forests in the study area and are identified by light or dark brownish with mix green colour due to thick forest cover. The proposed project site is located on one of the denudational hillocks and occupied by quartzites underlain by Granite/Granite gneisses. Bed rock occurs as detached jointed outcrops or in situ weathered bouldery form.

Prominent denudational hill ranges of the area are:

- ❖ Nagasamudram hills- These are linear low lying broken hills passing through the sub basins of Chitravathi River and drained by Nagasamudram vanka and Paleteru. They run through the mandals of Ramagiri, Chennakothapalli, Konganpalli and Dharmavaram. The maximum width of these hill ranges is 5 km and raise to a maximum elevation of 820m and average elevation being 550m above msl.
- ❖ Mallappakonda Hills- These are discontinuous hill ranges extending from Dharmavaram town into Karnataka in the south and Kadapaha district in the east covering parts of Maddileru and Jilledubanderu subbasins. They raise to a maximum height of 900 m above masl.

Hill slopes of any hill are denudational in origin and controlled by dips of bedding, joints or fault zones within bed rock. Control of bedding on slope angle is well manifested in structural ridges formed of sedimentary rocks in the immediate vicinity of proposed project site. In case of denudational hills formed of granitic rocks they are controlled by joints. Slope may expose hard resistant bed rock, boulders, angular blocks of rock dislodged from higher elevations or covered by granular soils mixed with rock fragments.

Slope failures in deep weathered soils may result in convex slopes. In hard rock slope failures such as planar or wedge failures or toppling may occur depending on geometry of discontinuities and nature of secondary filled in material.

Residual hills

These are erosional end features in the process of formation of pediplains. They are a series of scattered hillocks formed by differential erosion. In the satellite image these features occur as small dark greenish brown patches. However, these features are not useful for urbanization, agriculture, only forest growth is observed in the study area. Parts of Penukonda hill ranges extending between Dharmavaram and Karnataka represent residue hill ranges.These residuals are seen near Bandlapally, Nallipareddy, Ramapuram

Inselbergs

Inselbergs are isolated remnants of residual hillocks. They are mostly seen in granitic terrain in the western part of the project site. They are three types of inselbergs.

- Domed,
- Bornhards
- Tors

These are seen north of Bonadaledu, near Dugumari,SW of Narsapuram and around Gollapalli.

Dyke Ridge

It is a narrow linear ridge with heap of boulders of dolerite composition or steep massive ridge standing above the ground level or sometimes highly jointed. At places these intrusives get exposed on the top of granite hills.

Pediment

It is a gently sloping smooth surface of erosional bedrock of granite gneiss between hill and plain with thin veneer of detritus. A pediment is a gently inclined erosional surface carved in bedrock. These are formed with moderate slopes of 50˚ to 70˚. They are adjacent to the structural hills in the study area. It is devoid of any kind of land use land cover features. These feature show greenish colour and fine texture in the satellite image.

Pediplain

Pediplains is a broad, relatively flat surface formed by the joining of several pediments. The vast area towards west of the proposed structure forms the pediplain terrain. It is dotted with inselbergs, N-S trending hill ranges. It is usually formed in arid or semi-arid climates and may have a thin veneer of sediments. The pediplains represent the last stage of landform evolution i.e. the final result of the processes of erosion. On the basis of weathering it is further classified as moderately weathered and shallow weathered.

Pediplain (moderately weathered)

This unit is mostly observed along the channel fills with a little lateral spread. It is also seen in the ayacut areas of tanks.

Pediplain (Shallow Weathered)

The Pediplain shallow weathered, develops partly by erosional and partly by deposition. This will have a thin deposition of weathered material, i.e., up to 10mts.

Structural Valleys

These linear valleys occur between structural hills and are occupied by dolomites and shales.

VFS (Valley Fill Shallow)

It constitutes unconsolidated sediments such as boulders, cobbles, pebbles, gravel, sand and silt deposited by streams/rivers normally in a narrow fluvial valley. Such features are exposed in the narrow valleys.

The area falls in Chitravathi river sub basin of Penneru basin.

Chitravathi river originates near Gollahalli in Karnataka and enters AP kodikonda, in Anantapur district. It travels for 45 km in Karnataka and 160 km in Anantapur and YSR districts and joins Penneru river at about 5 km NE of Kondapuram Village. It crosses narrow Mutchukonda hills near Parnapalli village, where Chitravathi Dam was built.

Major tributaries are Jilledubanderu, Maddileru, Vangaperu, Nagasamudram vanka, Paleteru and Samavathi.

Lower order streams in granitic terrain have developed dendritic drainage pattern, whereas on the strike ridges parallel pattern has developed. On the round shaped hills radial drainage has developed. In the vempally area disappearance of streams and springs are also noticed.

5.9.4 Regional Geology

Regional Geology gives a broad spectrum of geological set up in and around the project site, which includes lithological assemblages/variations, stratigraphy and structural features.

Knowledge of Regional geological set up is necessary in order to correlate and establish proper stratigraphic sequence, interprete subsurface exploratory and geophysical data, if any, and assess suitability of the proposed structures in the given geological frame work, select suitable alignment and provide accurate geological basic data helpful to the designer to come out with judicious, innovative geological friendly and most economic designs.

In case of aseismic design of dams it is necessary to study the tectonic frame work of land mass within 360 km radius of the proposed major super structures, such as gravity dams, apart from history of seismic events that have occurred in the past.

This site is unique in terms of Indian Stratigraphy as the site is located in the vast Dharwar Craton which is occupied by igneous and metavolcanic and metasedimentary rocks juxtaposed by spectacular crescent shaped Cuddapaha Basin in which thick pile of sediments were deposited. Extensive geological studies have been carried out by several workers on these two contrast geological terrains.

The age of rock types in Dharwar Craton range from 3.6 -2.6 Ga, and belong to Archaean Era. Where as sedimentary rocks in Cuddapaha Basin belong to Meso to Neo Proterozoic Eras. (**Volume-II -Drawings-A "Plate").**

Table 5-2: Litho Stratigrapghy

ERAS	Group	Formation	Lithology	Thickness
Meso to Neo Proterozoic	Chitravathi	Gandikota Quartzite	Quartzite, Shale sills of Olivine Dolerite	3300 m
do		Tadipatri Shale	Shale, ash-fall tuffs, quartzite, dolomites with intrusives (flows, sills, ignimbrites, tuffs)	4600 m
do		Pulivndula Quartzite	Conglomerates an quartzites	
do	Papagni	Vempalli Dolomite	Stromatolitic dolomite, dolomite, shale, mudstone, Chert breccia, quartzites and intrusives (Tholeitite, spilite,	1900 m

			dolerite)	
do		Gulcheru Quartzite	Conglomerate ,arkose, quartzite and shale	28- 210 m
Paleoproterozoic	YOUNGER INTRUSIVES	CLOSEPET GRANITE	Anorthosite, Syenite, Granophyre Dolerite/gabbro, lamprophyre Grey and Pink Granites Pink and Grey Granites	
Archaean			Quartzite, BI/BMQ/Ferruginous Quartzite Quartzite-chlorite-sericite-schist Metabasalt/hornblende schist, amphibolite Metaultramafite/metapyroxenite /talc-tremolite schist, metagabbro	
do	PGC		Horneblende-biotite-gneiss/horneblende gneiss/biotite gneiss, migmatite gneissss, Granitoids	

Dharwar Craton

It is one of the stable shield in the Indian Sub-Continent. Other cratons being Bastar,Singhbhum and Aravalli-Bundelkhand.

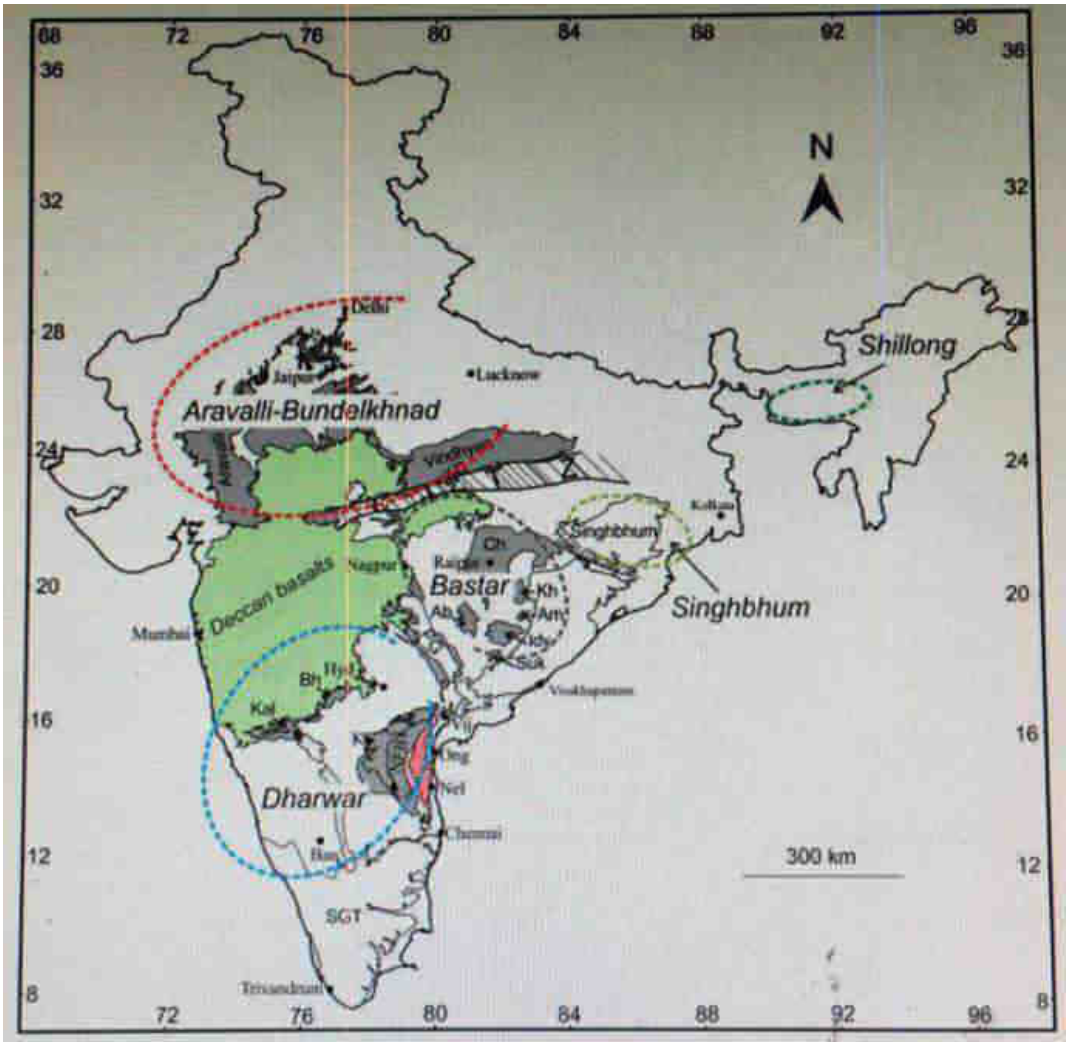


Figure 5-8: Cratons of India

The word Craton was first proposed by German Geologist L.Kober in 1921 as ' Kratogen' referring to stable continental platforms. This Dharwar Craton, covers a total area of 2, 70,000 km^2.

It is bounded in the south by Pan-African Pandyan mobile belt or Southern Granulite Terrain (SGT), Neo Proterozoic Eastern Ghats Mobile Belt (EGMB) in the east, Arabian Sea to the west, northwest-southeast-trending Godavari Graben in the northeast and the Cretaceous Deccan Trap cover towards north.

It is a typical Archaean granite-greenstone terrine with a Peninsular gneissic basement which is represented by Tonalite-Trondhjemite-Granodiorite (TTG) lithological assemblages.

This cratonic block has been divided into two parts 1) Eastern Dharwar Block, and 2) western Dharwar Block. Both are separated by Closepet Granite.

Both blocks are characterized presence of several low to high grade metamorphosed schist belts.

1) Babudan 2) Shimoga 3) Gadag 4) Chitradurga 5) Javanhalli 6) Sondur (all in western block)

7) Ramgiri-Penkacherla 8) Srigire 9) Hongurd 10)Kolar 11) Kadiri 12) Jonnagiri 13) Hutti

14) Veligallu 15) Raichur 16) Gadwal 17) Nellore and 18) Khammam schist belts.

These schist belts have formed host to several valuable minerals, like Gold, Iron ore, manganese, mica etc. Kolar mines are the biggest Gold mines in India.

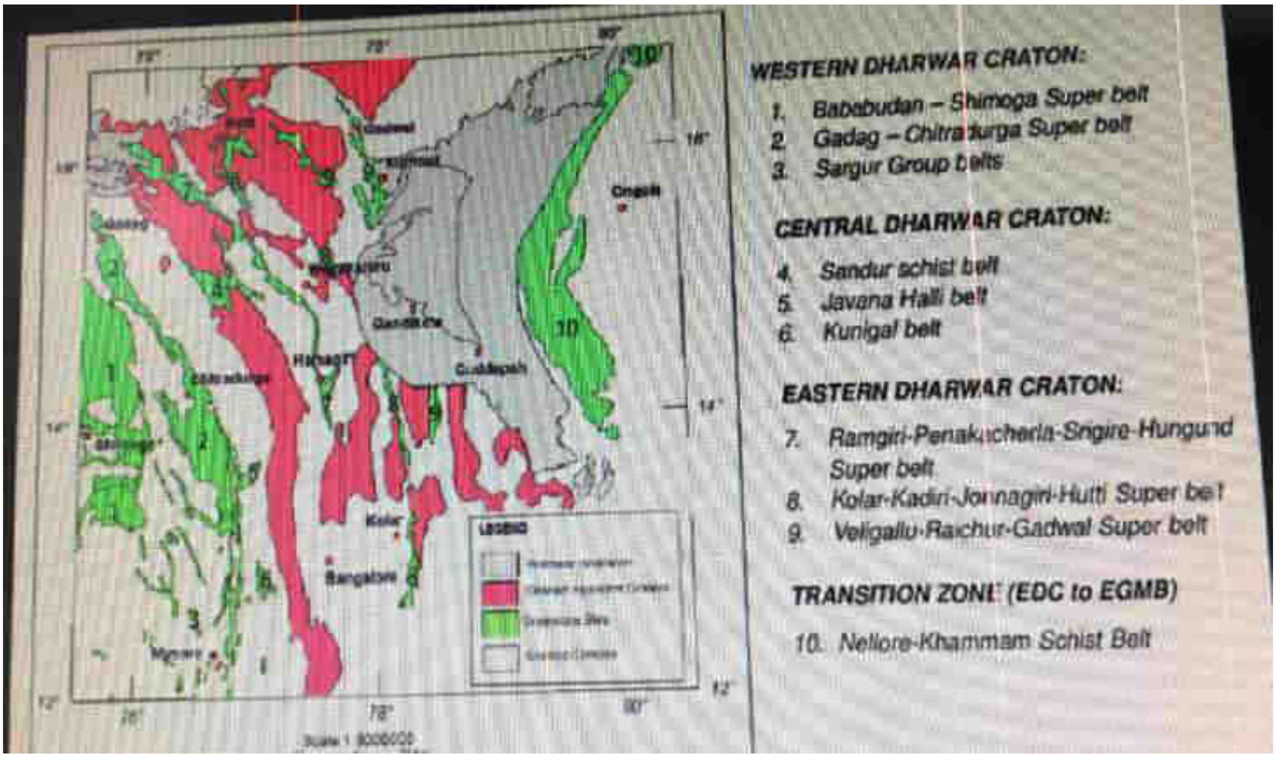


Figure 5-9: Schist Belts of Dharwar Craton

The Western Block of the craton comprises large schist belts (Dharwar type) accumulated in distinct sedimentary basins. Schist belts 1 to 6 are located in this Block.

Eatern Dharwar Craton Block is dominantly occupied by Tonalite-Tromamite-Granodiorite (TTG) gneisses (age 3.0 – 3.4 Ga) with minor schist belts of Sargur age (3.0 – 3.3 Ga), major schist belts (7 to 15) of Dharwar age (2.9 – 2.6 Ga) containing predominant platformal sediments and a few late Archaean granitoid plutons dated in the age range of 2.60 to 2.65 Ga.

A Brief stratigraphic sequence of both the Blocks is given in the Table 5-3.

Table 5-3: Stratigraphy of Dharwar Craton Blocks

WDC	EDC	Age (Ma)
Younger granite	Younger granite	2500-2600
(chitradurga,arsikere)	(closepet and equivalents)	
	Kolar group)	Dharwar supergroup
Chitrdurga group)	Yaswanthnagar formation)	2600-2800
Babudan group)	Unconformity	
	enclaves of older gneiss	3000
Peninsular gneiss	Warangle group	
Sargur group	Salem group	3100-3300
Gorur gneiss	Putative basement	
		3300-3400

Eastern Dharwar Craton Block

The present project is located in the Eastern Dharwar Craton. It is characterised by extensive young granites and remobilised older basement gneisses with remnants schist belts of Dharwar Group. These schist belts are narrow, linear with trend varying from N-S to NW-SE. These belts in the close vicinity of Project site, in the Anantapur District, are:

1) Ramgiri - Penkacherla and 2) Kadiri schist belts

With reference to the Project site Ramagiri - Penkacherla Schist Belt is located about 50 km, west and Kadiri schist belt is located southeast of PSP Project.

These belts dominantly consists of mafic metavolcanics rocks predominantly tholeiitic composition and include subordinate amounts of felsic metavolcanic rocks and banded iron formations (BIF).

Ramagiri-Penakacherla Schist Belt:

The NNW-SSE trending linear Ramagiri-Penakacherla schist belt (Plate) occurs in the south central part of EDC extending over a length of about 120 km with width ranging from 0.25 m up to 2.7 km. The schist belt comprises of volcano clastic meta-sedimentary rocks of amphibolite-chlorite sericite schists, turbiditic meta greywackes/argillites, phyllites, siliceous shale, serpentine, auriferous quartz veins, minor gabbroic intrusions and surrounding with banded ferruginous quartzites (BFQ).

The vast country surrounding these belts and project site occupied by granites, granite gneisses belonging to PGC and younger pink and grey granite intusives equivalent to Closepet Granite clan.

At the contact with the granites these schistose rocks show mylonatized zones trending along NE-SW to NW-SE.

Dark grey coloured coarse grained hornblende-biotite granite with feeble gneissosity at places, occupies relatively flat pediplains. Medium to coarse grained granodiorite plutons of pink to grey colour occur in the hillocks standing over the pediplains. The mafic component of these rocks is found to increase gradually near the contact areas with basic intrusives and the schist belts. Several fracture trends are marked along E-W, NE-SW and NW-SE and N-S directions. However, NE-SW,NW-SE and E-W trending fractures are more dominant. Regional schistosity and gneissosity shows a N-S trend in the schist belt and gneisses. Younger granitic intrusions are also found to occur along N-S

Peninsular Gneissic Complex (PGC):

Peninsular gneissic basement is represented by Tonalite-Trondhjemite-Granodiorite (TTG) lithological assemblages. It is subdivided into PGC-I and PGC-II.

Peninsular Gneiss-I consists mainly of amphibolite-facies gneisses of TTG composition with four major components, namely, (i) a layered and banded complex consisting of quartzo - feldspathic biotite gneiss alternating with amphibolites and ultramafic material, (ii) banded hornblende-biotite migmatitic gneiss, (iii) banded migmatitic garnet-bearing paragneiss and (iv) homogeneous trondhjemitic-granitic plutons. These gneisses acted as the basement for a widespread belt of schists.

Peninsular Gneiss-II mainly comprises gneissic rocks with granodioritic and granitic composition, representing remobilised parts of the older crust.

Closepet Granite:

The closepet granite is unique linear body, consisting diverse granitic rocks. It is named after the town Closepet, which was named for Major Close, a British Army officer, but now the town is known as Ramanagaram. This intrusive pluton body is 200 km long and 20-30 km wide bounded by shear zones. It displays easterly convexity that mirrors the configuration of Dharwar schist belts of the area. It occurs in two parts with a gap area near Kalyandurg. Depth wise it is divided into 3 depth zones:

1. Rootzone 2.Transfer zone 3. Intrusion zone with a gap zone. It's established age is 2510-2530ma.y.

PGC and closepet granites are being used as dimensional stones, Within Anantapur district several such mines are located.

Dykes:

Mafic dyke swarms of different generations in different geological intervals all over the world are well known in Precambrian terrains. The Dharwar craton has been well studied for its crustal evolution and regional distribution of mafic dykes by many workers. Mafic Dyke swarms in the EDC are widespread and have intruded various lithologies such as gneisses, greenstone belts and granitoids. Major dyke trends are along NW-SE and NE-SW.E-W, WNW-ESE and ENE-WSW directions.

E-W trending dykes are steeply dipping or nearly vertical. They are very long, segmented and discontinuous and show more than 3 kms spatial separation. These dykes often show gently sinuous shape for the whole intrusion. NW-SE to N-S trending dykes are relatively shorter and are mostly deformed and deflected parallel to the shear zones. Some of the E-W dykes are abruptly terminated or displaced by NW-SE trending dykes or shear/fault zones. Near Modukulakunta, a N70°W –S70°E trending dyke abruptly ends at N30°W-S30°E trending shear zone. Another set of dykes trending NE-SW are thin and are closely spaced and their intensity of occurrence is more in the eastern part. These are distinctly discontinuous. Closely spaced fractures are also observed adjacent to the NE-SW dyke swarms and spacing of fracture sets also varies. The intensity of NE-SW dykes varies from place to place. There are several other small scale dykes trending in different directions.

In general, some of these dykes are quartz tholeiites that are common in E-W, NE-SW trending dykes, while more alkaline often with olivine are significantly seen in NW-SE trending dykes. Mafic dykes of this Region are predominantly doleritic to tholeiitic in nature followed by older amphibolite dykes. These dykes are melanocratic in colour, aphanites to sub-phaneritic in texture, with grain sizes ranging from 0.2 to 1.55 mm. Magnetite, plagioclase feldspar and pyroxenes are common minerals and are easily recognisable.

The contact zones with host rock are sharp or mylonitization of basic rocks with mylonitic foliation and very fine grain size reduction along with smooth soapy surface development is common.

These dykes are used as building stones and some of them of good quality and size are mined as black granites. At places these dykes form the ground water barrier arresting down dip flow of ground water.

<u>Cuddapaha Supergroup Of Rocks:</u>

The project site is bordered on the eastern side by Cuddapaha Basin.

This Basin is polyhistoric, intracratonic and comprises of the Cuddapah Supergroup and the Kurnool Group of sedimentary rocks belonging to Meso to Neo Proterozoic Eras. A major unconformity separates the Cuddapah Supergroup from the overlying Kurnool Group.

This Basin having a length of 450 km and average width of 150, occupies a total area of 44000 sq.km covering YSR (Kadapa)district, parts of Anantapur, Kurnool, Chittore, Prakasham, Nellore and Guntur Districts of AP and Mahabubnagar and Nalgonda districts of TS.

Million years back this Cuddapaha Basin was land locked sea into which a rhythmic and cyclic deposits were deposited which were lithified and subsequently undergone tectonic deformations and uplifted.

The Basin is characterized by quartzite, shale, and carbonate cycles and at places they were intruded by volcanic flows and sills.

The detailed stratigraphy, structures/tectonics, and evolution of the Cuddapah Basin are given by Nagaraja Rao et al. (1987); also Ramakrishnan and Vaidyanadhan (2008); King (1872).

The basin is subdivided into 5 sub- Basins based on lithological variations and depositional history.

This Basin is:

1) Papagni 2) Srisailam 3) Nallamalai 4) Kurnool and 5) Palnadu

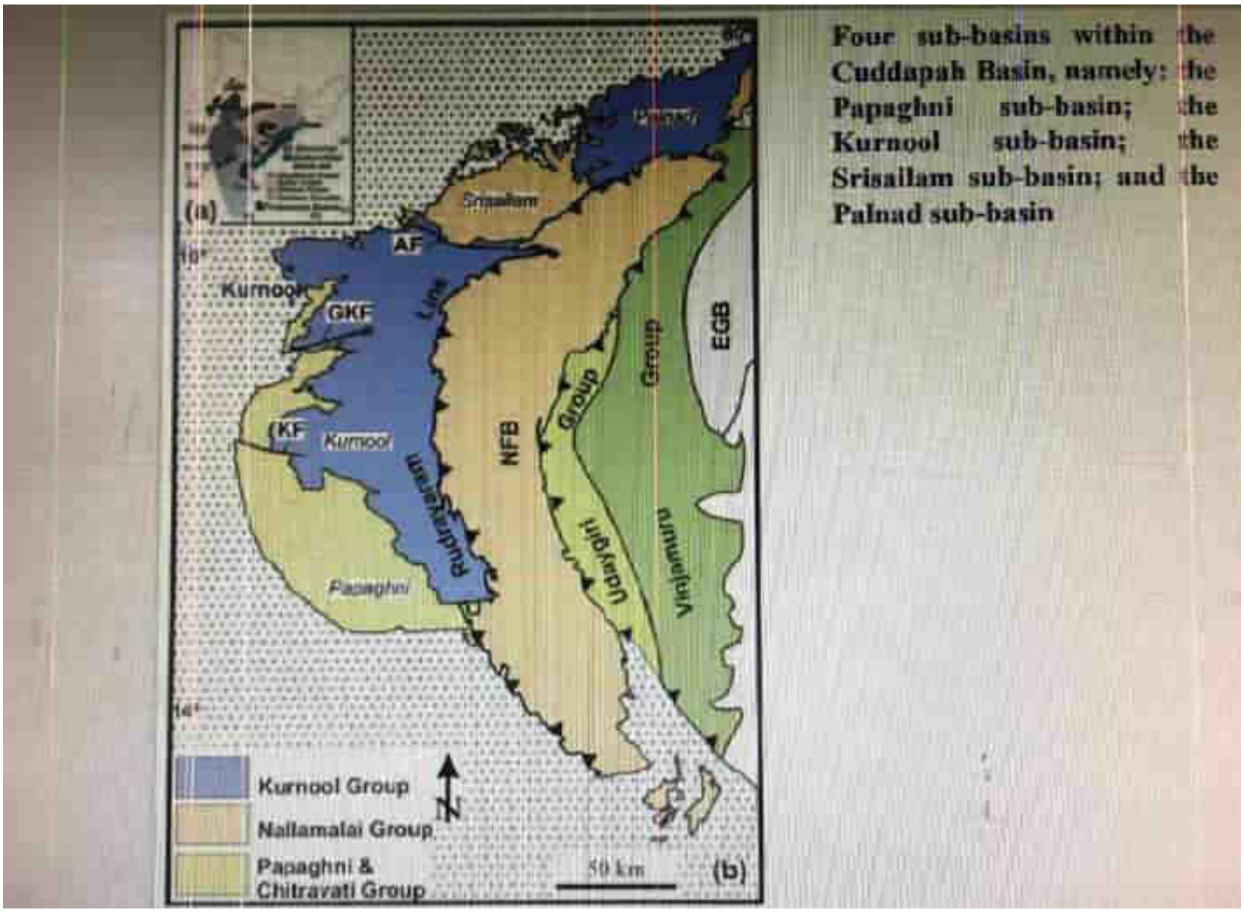


Figure 5-10: Cuddapaha Basin and sub basins

Basins 1, 2, 3 are occupied Cuddapaha Super Group of rocks and basins 4 and 5 are occupied by Kurnool Group of rocks, all represented by a repetitive cycle of quartzite-shale-limestone lithological units.

Papagni Sub Basin:

The Crescent shaped Papagni sub Basin is occupied by the oldest formations belonging to Cuddapaha Super Group and occupies southwestern part of main Basin. The Chitravathi PSP project site is located close to this Papagni sub basin on the western side.

It is characterised by massive to planar bedding, tabular cross bedding, trough cross bedding, intraformational breccia and pebble-clast conglomerate.

The planar beds are made up of well-sorted and well-rounded medium grained sands.

Cross beds are tabular and individual sets are 30-70cm thick.

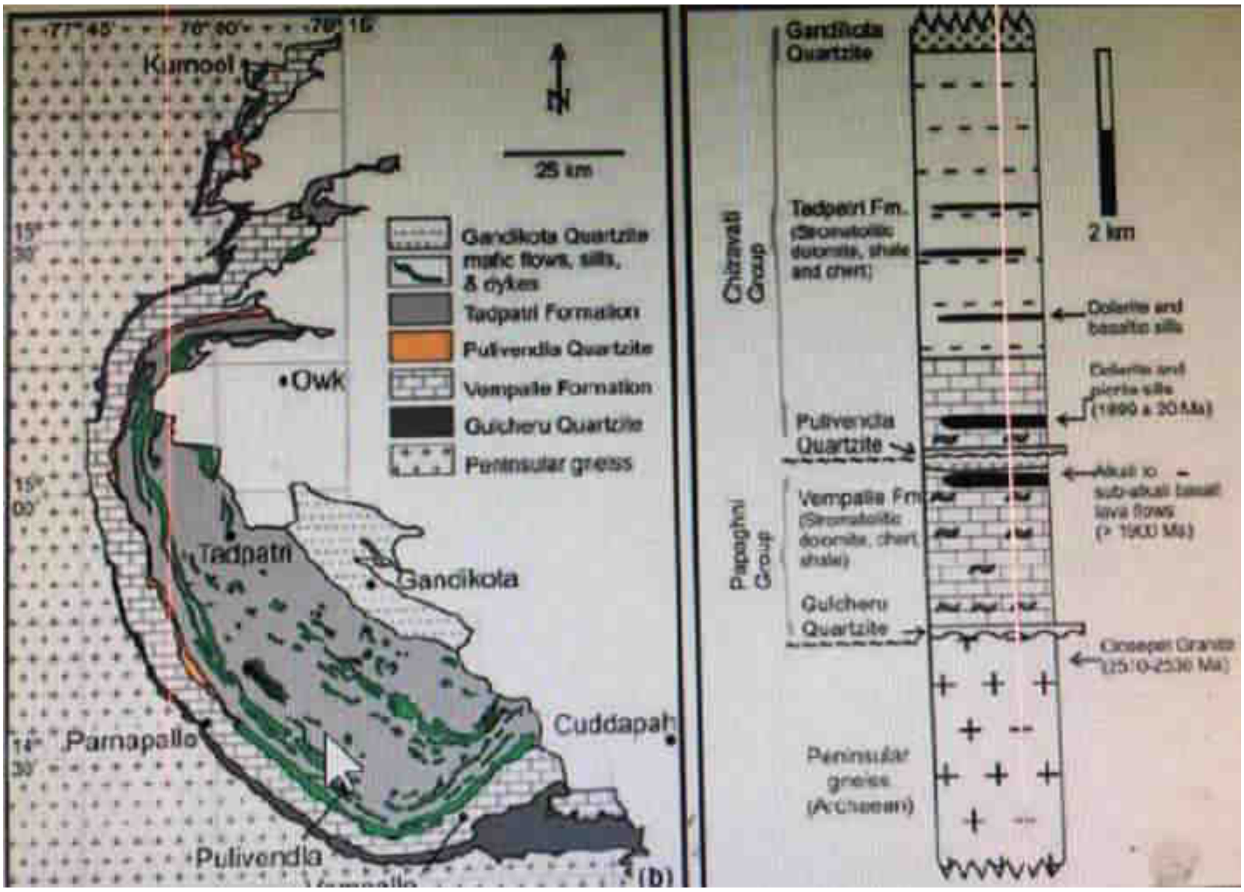


Figure 5-11: Papagni Sub Basin

The general stratigraphic Sequence of this Sub – Basin which is in the immediate vicinity of PSP project site, is given below.

Table 5-4: Lithostratigrapghy

Group	Formation	Lithology	Thickness
Chitravathi	Gandikota Quartzite	Quartzite, Shale sills of Olivine Dolerite	3300 m
	Tadipatri Shale	Shale, ash-fall tuffs, quartzite, dolomites with intrusives (flows, sills, ignimbrites, tuffs)	4600 m
	Pulivndula Quartzite	Conglomerates and quartzites	
Papagni	Vempalli Dolomite	Stromatolitic dolomite, dolomite, shale, mudstone, Chert breccia, quartzites and intrusives (Tholeitite, spilite, dolerite)	1900 m
	Gulcheru Quartzite	Conglomerate, arkose, quartzite and shale	28- 210 m
	E p a r c h a e a n un	C o n f o r m i t y	
	Archaean Gnisses,Granites &	Greenstones	

<u>Papagni Group:</u>

The sub-elliptical Papagni sub basin consists of sedimentary rocks belonging to the Papagni Group. They are represented by Gulcheru Formation (conglomerate, quartzite, arkose and shale), Vempalli Formation by dolomite, shale and subordinate quartzites. They are overlain by Pulivendula quartzites and Tadapatri shales of Chitravathi Group,

They are emplaced by basaltic and picrate sills and dolerite dykes.

<u>Gulcheruvu Quartzite:</u>

The Gulcheruvu Quartzites forms strike ridges running along the southwestern Basin margin up to Papagni River, where they change the direction because of folding. The width of these ridges varies from 1 to12 km and depth 28-210 m. They un-conformably overlie on the Gneisses and Granites of

Archaean Era. In the up dip direction they show steep dips/scarp faces and gentle slopes down dip direction.

Gulcheruvu Quartzites are basically siliclastic sediments. On the basis of lithological variations, sedimentary structures, bedding characteristics and texture they are divided into 5 different units

Facies no	Litho type	Thickness
5	Pitted quartzite	60m
4	Purple shale and siltstone	80m
3	Grey cross bedded quartzite	50m
2	Dark brown ferruginous quartzite	5m
1	Pink massive Quartzite	45-115m

Pink massive Quartzite:

Pink massive Quartzites normally crops out as steep cliffs. It is lower most unit of the Gulcheruvu Quartzite formation. Its thickness ranges from 45 to 115 m increasing from west to east. An impersistent epiclastic basal conglomerate varying in thickness from 1.0 to 3.0 m occurs within this unit. This basal conglomerate is lensoidal in shape. It is oligomicritic to polymicritic and comprises of sub angular to rounded clasts of quartz, chert and jasper. It grades into gritty quartzite that comprises of well-rounded granules of quartz, chert and jasper.

Petrographically, it is dominantly quartz-arenite. At places it grades into quartz-wacke.

Dark brown ferruginous quartzites occur below rubble cover.

Grey cross bedded quartzite is exposed along steep cliff faces as well as along gentle slopes.

Purple shale and siltstone gets exposed wherever pitted quartzites are eroded.

Pitted quartzite forms the down dip rock cover of Gulcheruvu Quartzites.

These Gulcheruvu Quartzites at places formed host for uranium mneralization at greater depths as established at Tummallapalli, north east of project site,

The nonconformity contact between basement and Gulcheru quartzite runs along a NNW-SSE trend (Vempalli Dolomites Formation).

Vempalli Dolomite formation comprises of massive dolostone, conglomerate, grey shale, impure dolostones, purple shale/mudstone and cherty dolostone. Maximum thickness of these lithological variants as established is 1900 m.

Massive dolostone is dull white coloured. Impure Dolomite shows alternate grey to dark grey, bluish grey coloured layers of carbonate and siliceous sediments with disseminated sulphides. At places, it is micritic in nature with abundant phosphatic rich layers.

Both dolostones are hard and massive and shows primary sedimentary structures like ripple marks, mud cracks. Stromatolites are also common in dolostones. Diagenitic features like stylolites are also observed at places. They are overlain by purple/brown shales with gradational contacts. The shale mostly appears like mudstone. It is overlain by Cherty dolostone with intercalated shale. Chert also occurs as lenses, stringers and nodules. Chert beds are thin and rarely exceed 15 cms. The thickness of the interlayered shale bands vary from 1 mm to 30 cm. Caving and solution leaching zones are reported in the cherty dolostones at places. This unit is most wide spread in the area. Intra formational conglomerates are also reported in this horizon at places.

These rock types exhibit facies variation along strike direction and thickness of individual formations is not uniform. Shales and dolomites show gradational contact, with quartzites they show sharp contact.

The younger basic sills and dykes trending N80°W-S80°E are exposed north of the project site between vemula and Vempalli.

Vempalli formations occupy the broad valley between Gulcheruvu strike ridges and these linear basic intrusives. Within the valley, the dolostones form rounded or conical hills at places. These bedded dolostones give stepped appearance of hill slopes and they exhibit elephant skin weathering.

The upper part of the Vempalle Formation is marked by the presence of sills and basic flows (Nagaraja Rao et al. 1987).

Vempalli dolomites formed host to asbestos, steatite, barites due to intrusives of basic sills and dykes. Uranium mineralization was also reported from these formations and dolostone is also used as building material

Chitravathi Group:

The overlying Chitravathi Group is separated dis conformably from the underlying Papaghni Group. The Chitravathi Group consists of the:

- Pulivendula Formation (quartzite),
- Tadpatri Formation (shale and dolomite). and
- Gandikota Formation (quartzite).

Conglomerates containing quartz, chert, jasper and volcanic clasts, grits and quartzitic sandstones of Pulivendula Formation overlie the Vempalle Formation in para conformable contact. The Tadpatri Formation contains many basaltic and picritic sills and lava flows and acid volcanics.

The Nallamalai Group, in the eastern part of the Cuddapah basin, rests over the Papaghni Group with an angular unconformity. Further east, it rests directly on the granitic basement. NNE-SSW trending Nallamalai Formations consists of the arenaceous dominated Bairenkonda and argillaceous Cumbum Formations (GSI 1981).These have undergone several phases of tectonic deformations resulting in folding, refolding and faulting.

The Kurnool Basin lying between Papagni and Nallamalai Basin are occupied by a repetitive sequence of quartzite, shale and limestone. These Kurnool Group of rocks are sub divided into the following formations:

- Nandyala Shale
- Koilkuntla Limestone
- Paniam Quartzite
- Owk Shale
- Narji Limestone
- Banganpalli Quartzites:

These are non-metamorphosed and not undergone any tectonic deformations. They are either horizontal are show sub horizontal dips. They show at places minor warpings. Cement grade limestone occurs within Narji Limestones and also locally it shows karstification. 2 km long Belum caves with multi passages, are located in these formations. Diamonds were mines at places within the Banganpalli Quartzites

Tectonics:

The earth's crust has undergone several Orogenic movements in the past geological history. These movements have left several imprints on the rock formations and land mass. The imprints of these tectonic deformations are manifested by schistocity, gneissocity, foliation shearing, faults, folds, emplacement of dykes, quartz reefs.

Satellite interpretations and field studies help in delineating these features. Dharwar Craton and Cuddapaha Basin attracted several well reputed Organisations like GSI, NGRI, Geology wings of Universities and individual earth Scientists to study the Geological Treasure.

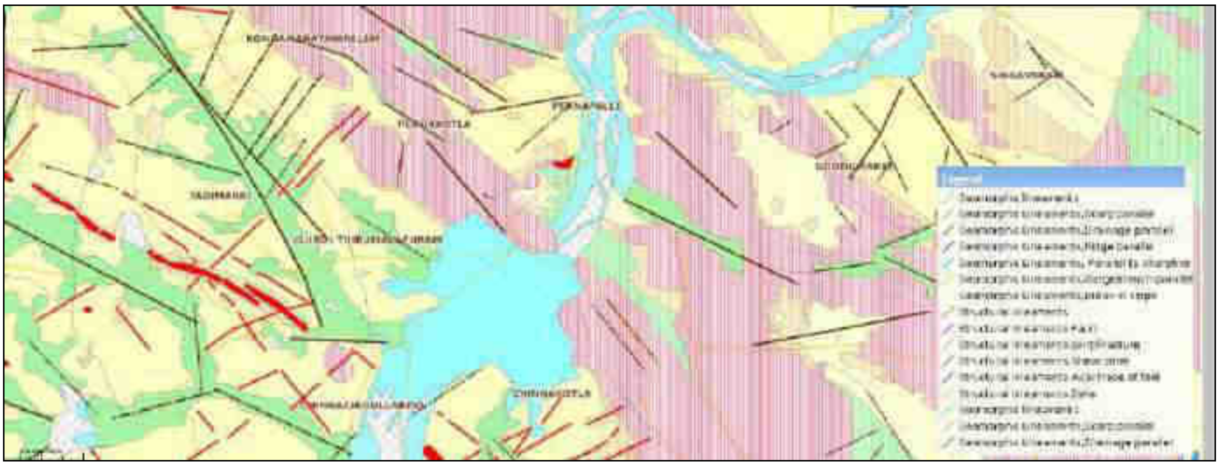


Figure 5-12: Lineament Map

The Dharwar granite-greenstone terrine shows effects of three phases of deformations, which are equated to Kenoran Orogeny and Hudsonian Orogeny.

First two deformations gave rise to the NNW-SSE to NWSE-trending penetrative fabric marked by the general schistosity, and transcrustal major faults and shears parallel to it, the third episode produced broad warps along E-W- to ENE-WSW-trending axes. On regional-scale E–W shearing and associated compression has also gave rise megascopic structures such as schistosity, gneissosity,foliation conjugate joints and younger dyke emplacement.

According to a structural model of the Dharwar craton, the WDC represents a major synclinorium, while the EDC represents a major anticlinorium, the limb portion of which is occupied by the Closepet Granite.

After granite emplacement the craton attained rigidity. Later magmatic events like mafic dyke activity and kimberlite activity took place along the deep crustal faults/fractures (as per deep seismic sounding (DSS) profile-GSI 1981),These Kimberlites form host rock for Dimonds, which were mined near wajrakarur, Anatapur district.

In case of Cuddapaha Super Group of rocks, lower members have not witnessed any major tectonic deformations.

The contact between the basement granitoids and the Gulcheru quartzite is marked by unconformity ,well known as Eparchaean Unconformity, characterized by conglomerate bed along the contact. This contact is relatively at higher elevation than the Cuddapah basin margin.

The Greenville or Eastern Ghats Orogeny is most intensively imprinted in the Cuddapah basin sedimentary rocks, but it shows increased impact towards east. The crescent shape of the Nallamalai fold belt in the east is due to the E–W compression related to thrusting followed by NNE–SSW compression. The E–W maximum compression is related to the Eastern Ghats Orogeny, which is responsible for the development of several sympathetic E–W faults due to N–S pull. The Nllamala formations show predominantly plunging and cross folds.

Faults are differentiated on the basis of their location, and classified as:

- Basement faults
- Supracrustal faults.

First category faults occur in the basement terrain, ie., Dharwar Craton area and 2 nd category are manifested in overlying Cuddapaha Basin rocks. The location of well-known faults and their distance from the PSP project site are tabulated below:

Table 5-5: Faults on the Regional scale

Base Line Faults:

Sl.no	Name of the fault	Strike of the fault	Distance from the project site with direction	Rock types involved
1	Bukkapatnam fault	E-W	45 km -south	PGC
2	Mazor Shearzone	NW-SE	45 km N40W	DO
3	Guntakallu fault	N70˚E-S70˚W	95 km-north	DO
4	Wazrakarur fault	N70˚E-S70˚W	95 km northwest	DO
5	Krishna river fault	N60˚E-S60˚W	245 km – do-	Dharwar schists-PGC
6	Raichur-Nagarkurnool fault	E-W	185 km -north	PGC
7	Dharma-Thungabhadra fault	N70˚E-S70˚W	200 km N 70˚ W	Dharwaar schists-PGC

8	Kumadavathi-Narikallu fault	N60°E-S60°W	180 km –N80°W	-DO-
9	Gundekola –Rapura fault	N70°E-S70°W	135 km-N70°W	DO

Table 5-6: Supracrustal Faults

Sl.no	Name of the fault	Strike of the fault	Distance from the project site with direction	Rock types involved
1	Pyapalli fault	N60°W-S60°E	65 km -north	Cuddapahas
2	Gani-Kalva fault	N70°E-S70°W	95 km-north	Kurnools
3	Rampura fault	NS	55 km-southwest	cuddapahas
4	Atmakur fault	N70°W-S70°E	140 km-northeast	-do-
5	Bhavanasi river fault	N80°W-S80°E	100 km- do-	-do
6	Rudravagu fault	EW	185 km –do-	-do-
7	Nallamai Shearzone	NS-NE-SW	90 km east	-do-
8	Papagni fault	NE-SW	75 km southeast	-do-
9	Gundlakamma fault	N30°W-S30°E	240 km southeast	-do- PGC
10	Vempalli fault	EW	southeast	Cuddapahs
11	Idupayala Fault	E-W	do	-do-

Idupulapaya fault and northerly dipping Vempalle fault are located in Vempalli terrain,towards south east of PSP project site. The Geological Survey of India's overall map of the Cuddapah basin was used as a reference. The Vempalle fault, north to the Idupulapaya fault, runs 40 km from Vempalle village in the west to Kadapa town in the east. It cuts all the three sub-basins of Cuddapah, viz., Papaghni, Nallamalai and Kurnool, and also the Rudravaram line. The western tip of the E–W Idupulapaya fault is compensated against parallel strike slip faults at high angle.

Deep seismic studies by Kaila et al. (1979) revealed NNW–SSE to N–S lineaments extending up to the Moho, and that the basin first developed in the western part by down-faulting.

E–W and N–S extension joints are reported from Pulivendula, Vempalle, Madyalabodu and the Poltala temple areas. The older E-W joints are formed by maximum compression along E-W and minimum principal stress along N-S direction

5.9.5 Seismicity:

The seismicity in the region is only sporadic, both in space and time. Local network data has indicated two major clusters-west of Bellary, between Dhrma-Tungabhadra and Kumudavati-Narahalli Fault and west of Bhadra Lineament.

Most significant earthquake event of the area is the Bellary earthquake of 1st April 1843.This event occurred in a ENE-WSW linear belt bound on either side by Dharma-Thungabhadra and Kumudavati – Narahalla faults. This earthquake with Imax=VII was widely felt in the Deccan Plateu. The radius of perceptibility was above 300km. Damage to civil structures were reported from epicentral region.

Shimoga earthquake occurred on May 12,1975. The shock had a magnitude 4.7 and maximum intensity V. The focal depth and felt radius were 35 km and 140 km, respectively.

The strongest earthquake with magnitude 5.2 occurred close to Ongole town on 27 th march 1967, which was felt at vizayawada also. The epicentre was close to Ongole town. One of the nodal planes strkes parallel to the north SSSwesterly trending Gundlakamma fault.

Bhadrachalam earthquake in April 1969 with magnitude of 5.3 on the richer scale. It was felt at far off places like Hyderabad.

Several hot/thermal springs are located in the area, closest is located near Kalwa –Gani area.

The project area is located in the border districts of Ananthapur & cuddapah in the Rayalseema region of Andhra Pradesh. As per the seismic zonation map of India, the Project area lies in the seismic zone-II.

5.9.6 Geological Assessment of Project Site

Quadrangle maps (1:250000) published by Geological Survey of India have been studied to understand the geological and tectonic setup of the project site. Traverse geological mapping (1:50000 scale) of the project area was carried out to delineate the geological setup along both the alignments and to select geologically most feasible alignment of the two alternative alignments 1 and 2.

The proposed project site is located in the Dharwar Craton area and close to the western margin of the Cuddapaha Basin. The hillock over which upper reservoir is proposed is a 'Cuesta' with apex aligned along N45°W-S45°E direction. This is located on the left bank of the Chitravathi river and is about 1.50 km from the original course of the Chitravathi river, before formation of reservoir. Width of the original river course was 750m (toposheet no 57 F/14). Now the nearest distance between the toe of the hillock and FRL of the Chitravathi reservoir is about 50m.

Description of alternatives:

Alternative-1 is aligned along N45°W-S45°E direction and is along the strike direction of the hillock. Lower Intake will be located in the foreshore area of reservoir and upper intake on the nosal portion of the hillock

Alternative-2 is aligned along N30°E-S30°E direction and near perpendicular to the strike direction of the hillock. Lower intake will be about 50m from the foreshore of the reservoir.

The major geomorphological land forms of the area are denudational hills of granites and granite gneisses and strike ridges formed of quartzites, pediment zones surrounding these hills, which merge into pediplaine, narrow valley fill between strike ridges and flood deposits.

Upper reservoir for the alternative proposals is common and will be located on the denudational hillock. The shape of the hillock indicates that it is a cuesta, in geological terms, which shows subhorizontal dip slopes and steep slope dipping in opposite direction. Ground levels on the hill top varies from 480m to 500m.The hillock is formed of granite gneiss and granite belonging to Peninsular granite gneiss, but on the hill top 3-6 m thick Gulcheruvu quartzite is exposed. Both are separated by Eparchaean unconformity, marked by a conglomerate bed. It shows pebbles of quartz, jasper, and chalcedony. Gulcheruvu quartzite is fine grained, hard and compact. Areal expression of this quartzite horizon is irregular. The bedding strikes along N 35°W-S35°E with 15° dip towards N55° E, ie., towards Cuddapaha Basin.

Western slopes of this hillock exposes fine to medium grained, grey to pinkish grey granite is the predominant rock type of the area with subordinate hornblende-biotite gneiss, migmatite granite/gneiss falling under tonalit-trondjomite-granodiorite clan and belongs to Peninsular Gneissic Complex of Archaean Era. (Formed about 3000m.years back). These have formed basement to Dharwar Green Schistose rocks as well as Cuddapaha Super Group of rocks. On the hill top, where upper reservoir is proposed, these rocks are overlain by 3 – 6m thick Gulcheruvu quartzites of Cuddapaha Super Group.

These granitic rocks in the area mainly consists of quartz, feldspar, hornblende and biotite as major minerals and they show euhedral crystallanity & phaneric equigranular texture. At places, they show porphyritic texture depending on development of larger feldspar crystals. Interlocking type of growth between individual crystals imparts high strength to these types of granites. At places, outcrops of hornblende biotite granite gneiss are also seen. These show gneissic texture with alternating repetition of leucocratic and melanocratic bands. Leucocratic bands are quartzo-feldspathic layers and melanocratic layers are mainly consists hornblende and mica minerals. Some granite gneissic members show parallel arrangement of platy minerals like micas. Migmatites belonging to Granite clan are formed due to granitization of older metamorphic (Sargurus). Depending on the stage of this process, they may exhibit some of the migmatitic structures like schilerns, nebulitic and at places, unassimilated enclaves of older basic metamorphics. These metamorphic enclaves exhibit lensoidal or rectangular shapes of different sizes. Normally in PGC country all varieties of granitoids showing different areal and depth extensions, may be met with,

These rock types are, at places, intruded by younger pink granites equivalent to Closepet granite formation, and shows intrusive relationship in the form of tongues and apophyses with PGC granitoids. These rock types are again emplaced by thin quarto-feldspathic veins, pegmatite, aplite and epidote veins. At other places, these granitic rocks are intruded by dolerite and gabbro dykes. There are no exposed dykes in the project area. If such intrusive dykes are there, they may show sharp or sheared contact with host rock.

These exposed granitic is traversed by predominantly three sets of discontinuities. Discontinuities met with in some of the outcrops are tabulated below:

Table 5-7: Joint Set of Project Site

Joint set no	Strike of joint	Dip and dip direction	Persistence And spacing	Orientation with relation to longer axis of water conductor system	Special observations
1	N20°-40°W-S20°-40°E	10°-15° due N70°-50°E; 45° -75° due S45°-15°E	>2.0 m; 0.20- 2.0 m	Transverse	These are strike joints
2	N 20°-40° E S20°-40°W	40° -70° due N 70°-50°W	random	Skew	
3	N60°-70°W	Vertical or steepely dipping on either side	random	transverse	
4	N70°-80°E-S70°-80°W	Vertical	random	Transverse	

Of above joint sets, set 1 is most predominant. Strike of foliation of metamorphics and granite gneisses and bedding of sedimentary rocks of Cuddapaha Basin, all are along this direction. The long axis of hillock, over which upper reservoir is proposed, is also aligned along this direction.

Geometry of joints, their configuration, spacing dictates hill slope morphometry, stability of natural slopes and excavated slopes and rock mass quality. In granites, some of the joints become imperistant depth wise and also tight. If joints extend into nearby reservoir they may form seepage path depending on its aperture opening and nature of filled in material, if any. At places, they rendered the bed rock blocky in nature, as observed along the slopes of the hillock. Actually, joints configuration, spacing and persistence dictates the shape and angle of hill slopes. Both limbs of this cuesta, dip slope and steep slopes, are stable and any landslides, rock mass movement are not observed.

5.9.7 Rock quality Characterization

Exposed bed rock on the hills or hill slopes shows effects of weathering in the form surface staining, opening of joints, loosening of rock blocks, dislodging them from parent rock. Naturally at depth, where bed rock do not undergo any weathering it will be compact and stable and they will show better rock mechanical properties when compared to exposed rock.

When calculating rock mass Quality, RQD values are most important in RMR as well as Q system. In the absence of subsurface exploratory data RQD will be worked out from the joints exposed on rock outcrops and using the following formula.

RQD = 110.4-3.68 Jn (Jn=joint frequency=no of joints per meter depth).

On exposed rock outcrops of granites, RQD values may vary from 50-70%. As such, it is inferred that Good to excellent RQD values can be expected in the rock media of the underground structures.

5.9.8 Rocmechanical properties

Close to the project site rock mechanical properties were determined on the similar granite rock.

The values available are given below

Sp.gr -2.76 g/cm2, water absorption-0.12%, porosity 0.36

UCS 1866 Kg/Cm2 (Dry), Tensile strength 98 kg/cm2, Abrasion 6-7 and RQD 80-90%

The values indicate that the granite is compact in nature with high strength as per Deere and Millers's classification of intact rock. The data suggest the bed rock with such values will form good rock media for underground structures, tunnels as well as foundations of super structures,

5.9.9 Hydrogeology

The area falls in Chitravathi river basin with 1st, 2nd and 3rd order streams developing dendritic drainage pattern, indicating compactness of the media, whereas on the strike ridge parallel drainage pattern is observed suggesting that they are structural controlled.

Ground water in the area occurs in phreatic conditions in the weathered zones and under semi confine condition in fractured and jointed rock. In the surrounding areas ground water was intercepted 25->40 m bgl. The general ground water flow gradient is towards Chitravathi river. In hard rock the ground water is confined to fracture zones, which trend along NNW-SSE and NE-SW. The deepest hole drilled in the area by CGWB for ground water is 305m.

From hydrogeological studies of open wells, tube wells, road cuts in and around the area, a generalised sub soil profile has been inferred.

On the pediplain terrain

- 0.0– 6.0 m Top soil +SDR
- 6.0- 10.0 HDR
- 10.0- 15.0 hard rock ,may be fractured or weathered/stained along joints, but hard
- Below fresh, compact and hard rock
- Near hill (in the structures sites)
- 0.0-2.00 m scree
- 2.00-4.00 m loosened or rolled rock
- 4.00-6.00m weathered hard rock
- Below- hard and compact rock.
- Thickness of individual strata varies from place to place. The above data shows maximum thicknesses.

On the hill top and dip slope quartzites are exposed sporadically. On the steep hill slopes which house the structures granites are exposed sporadically.

From the geological studies geological sections (Volume-II, Drawings "Plates") are prepared and also geological plan to assess geological feasibility of both the alignments.

Table 5-8: Salient features of the structures and rock cover

Sl.No	structure	Width/Dia-meter (m)	Minimum Rock Cover Required (m)	Rock cover Provided (m)
1	Upper Intake	-	-	-
2	HRT	7.7	(2.5 x D) =19.25	50m
3	Vertical Pressure shaft	7.7	(2.5 x D) =19.25	50m
4	Horizontal pressure shaft	7.7	(2.5 x D) =19.25	110 -140m
5	Powerhouse	23.5	(3 X Width)=70.5	106.26m
6	Transformer Cavern	18.5	(3 X Width)=55.5	75.54m
7	Draft tube	5.5	(2.5 x D) =13.75	60-80m
8	TRT	10.7	(2.5 x D) =26.75	26 -50

Rock cover

Ground levels along hill slopes vary from RL 300-495m.With this ground levels and tentative subsurface profile hard rock cover above the crowns of the underground structures is worked out and presented in the above table. From this data it is inferred that **m**ore than 2D hard rock cover will be available above crowns of the pressure shafts, power house and transformer caverns, and draft tube and tail race tunnels. In case of two underground caverns (Power house and Transformer caverns) the rock cover varies from106.26 to 60.86 m. In case of TRT rock cover varies from 15 to 50m.

Lateral cover

Since these two underground structures are located much deep inside, sufficient lateral cover is available.

Rock Ledge

The rock ledge between Power house and Transformer cavern

Sufficient rock ledge of 41m is available between both the underground caverns. As per standards the width should be equivalent to total combined widths of both the caverns.

Nature of Rock mass

As discussed, granite and its variants will form the rock media. Available geological data suggests that hard and compact rock will house all the structures. Rock mass Quality of this media will fall in good

Category for 60%, fair category 20%, poor category 10% and very poor category 10% pf structures lengths. These surmises are made on the basis of excavation history of tunnels made in such granites in other places with similar geological setup. However, underground geological nature will be seldom uniform and unexpected geological adverse conditions may be met with. As the structures are located at greater depths better scenario can be expected. In case of TRT, located close to Chitravathi River and at shallow depth, it may show weathering along joints to deeper depths and weathered dipping gneissic bands. In TRT, excavations will be along feeble foliation direction, In such a case geological setup can be inferred in advance by 3 D Geological mapping of face during execution. In the end 25 m of TRT bed rock with deeply weathered joints mat be met with. As such steel supports needs to be provided. In hard rock at reasonably deeper depths air blasts may occur, especially in underground caverns, draft tubes and pressure shafts.

Depending on joints configuration, spacing of joints and joints nature planar failures and wedge failures may occurs along walls of PH, and as well as crown portions. In case migmatites with enclaves, there will be possibility of loosened enclaves falling from roof. Controlled blasting helps in minimising roof falls and to obtains smooth face which saves quantity of the concrete. Stage excavation of PH and TC has to be planned. Supports like SFRS, Rock bolts and steel ribs are to be provided as per rock class as well as size of structure. Steel supports are also required at junction locations. In case of upper intake structure, at the proposed foundation level hard rock is available. In case of Lower Intake structure also hard rock with weathering grade of W0 or W1 may be met with. Since the site is within reservoir area, water seepage is anticipated during execution. As such excavation and construction may be undertaken during peak summer. Alternatively, this location can be tackled from TRT. Since groundwater in the area is reported between depths 25-40 m, water seepage is anticipated during excavation of vertical Pressure shaft and TRT. Water seepage is also anticipated along the contact of pink granite with older granite or dyke contact with host rock, if they are present

In case of upper Reservoir, where rock fill dam is proposed, Granite will be met with towards western dam portion, whereas on the eastern side it will be Quartzite's, with slope angle varying from 10°-15°. This quartzite may be 3-6m thick, below which weathered granite may be met with. Stability against sliding of this rock fill dam under horizontal thrust needs to be assessed. In order to avoid any possible sliding the following suggestions may be considered.

1. Parallel key trenches 2) Trimming the slope against down dip 3) Provision of Thrust blocks 4) providing stepped foundations. In case of Western side dam, seepage from down dipping open

foliation joints, if present, may cause slope failures or destabilisation. Hence, grouting from bottom of the cut off trench may be necessary up to depths equivalent to FRL.

Orientation of longer axis of power house has to be fixed by hydro fracture tests or analysis of joints data by stereo projections or DIPS. In order to prepare baseline geotechnical report as required by designer subsurface explorations are to be carried out as per IS standards. Instrumentation needs to be provided in PH, PSs and pore pressure meters in case of embankment dam.

Conclusions

On the basis of available geological data, configuration of the hillock, adverse discontinuities which forms seepage paths at alternative site -1, it is opined that alternative-2 is relatively more feasible and preferred.

Chapter-6

Hydrology

6 HYDROLOGY

6.1 GENERAL

Chitravathi Pumped Storage Project (PSP) is located in Anantapur Dist of Andhra Pradesh in India. Chitravathi PSP will comprise of two reservoirs i.e. Chitravathi Balancing Reservoir (already existing) as a lower reservoir and Chitravathi PSP Upper Reservoir (to be constructed newly). The proposed upper reservoir is not located on any river course and the existing Chitravathi Balancing reservoir is located across river Chitravathi. The Chitravathi Balancing Reservoir is constructed across Chitravathi River near Parnapalli village of Lingala Mandal of YSR Kadapa District with a storage capacity of 10.00TMC and was completed during the year 2009.

6.2 OBJECTIVES OF THE STUDY

The objective of the study is to assess the various parameters for project planning and design of proposed Chitravathi PSP scheme.

- To assess the water availability for running the proposed PSP scheme throughout the year
- Estimate the design flood for Chitravathi PSP Upper Reservoir
- To assess the demand of water for refilling the reservoir due to evaporation, pumping operation etc. No consumptive loss of water is envisaged.
- To estimate the sediment loads

6.3 RIVER SYSTEM

The Chitravathi is a tributary of the Pennar River. Starting in Karnataka, it flows into Andhra Pradesh and its basin covers an area of over 5,900 km2.

Chitravathi River originates at Chikkaballapur and flows through the Chikkaballapur district of Karnataka before entering Andhra Pradesh where it drains the districts of Anantapur and YSR Kadapa before joining the Pennar. The river joins the Pennar at Gandikota in Kadapa district where the Gandikota irrigation project is taken up by the Government of Andhra Pradesh. Chitravathi is a seasonal river that comes alive after the monsoons. Along with the Papagni, it forms a part of the middle Pennar sub-basin and is a right bank tributary of the Pennar.

Figure 6-1: Pennar Basin Map Showing Chitravati River

Figure 6-2: Pennar Basin Projects

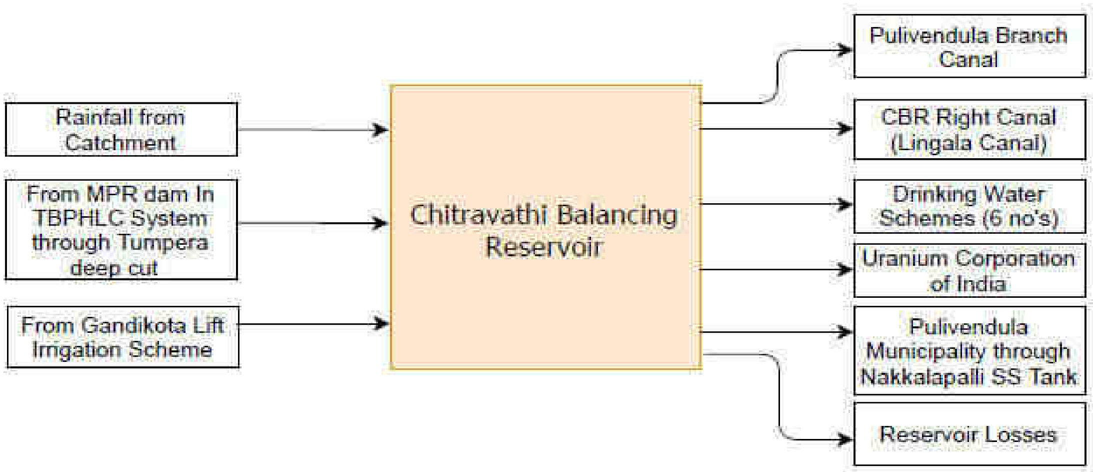


Figure 6-3: Chitravathi Balancing Reservoir Inflows & Outflows

6.4 THE PROJECT

The present proposal envisages a Pump Storage project between the Proposed upper reservoir & the existing Chitravathi Balancing reservoir, by installing reversible Francis turbines (total installed capacity 500 MW) near Parnapalli village of Lingala Mandal of YSR Kadapa district. Since the proposed scheme is a pumped storage scheme and envisages to utilize the water allocated from Chitravathi Balancing Reservoir, no modification in the operating levels of existing Chitravathi Balancing Reservoir are needed. Moreover, only recycling of storage in the proposed upper reservoir is utilised for PSP operation. As such hydrological study is required to the extent to see the amount of water loss from the reservoirs and the quantity of water required for refilling the reservoir. Key parameters of Chitravathi balancing reservoir are given in Chapter 8 "Reservoir".

6.5 PROJECT COMPONENTS

The Chitravathi PSP envisages construction of Upper reservoir which is proposed to be located on the flat / gradually sloping land. The water from upper reservoir shall be utilized for peaking power generation. After generation, the water from Lower dam shall be pumped back to upper dam during off peak hours through reversible turbines.

The storage project is proposed with the following major components, however details parameters are given in Chapter 10 "Civil Design":

- Formation of Upper reservoir
- Upper Intake from Upper reservoir
- A steel lined penstock tunnel/pressure shaft to feed water to generating units

- ❖ Concrete Lined Tail Race Tunnel
- ❖ Power House, switch yard and other auxiliary units

The discharge from Power House would be collected in the Lower dam after power generation. The same shall be pumped back to upper reservoir by the reversible turbines.

6.6 CLIMATE

The catchment enjoys a monsoon climate with its characteristics rhythms. On the basis of the local rainfall conditions, four seasons including two monsoon regimes are recognized: South-West monsoon (June to September) North-East monsoon (October to December), winter period (January to February) and hot weather period (March to May).

On the Eastern slopes of the Eastern Ghats, heavy North-East monsoon showers occur. In the hot weather extending from the middle of February to the middle of June, the entire basin is practically dry and the interior of the basin, especially Kadapa district, experiences severe heat. The major part of the basin receives its rainfall from the South-West monsoon while areas adjacent to the seacoast receive some rainfall from the retreating monsoon.

The annual average maximum, minimum and mean temperature for the basin is found to be 32.71°C, 21.63°C and 27.17°C respectively. (Source: Reassessment of Water Resources Potential of India, CWC). In general, humidity is high during the monsoon period and moderate during non-monsoon period. The relative humidity in the catchment of Pennar ranges from 21% to 84%. Maximum relative humidity is observed during the month of October which is around 75% and maximum wind velocity of 18.9 km/hour has been reported in the month of July. Due to arid climate, evapotranspiration takes place at a high rate with a value nearly of 200 mm at Anantapur district during May.

6.7 HYDRO METEOROLOGICAL DATA

Annual and monthly precipitation data of 30 years (1991-2020), were collected from Chief planning officer, Ananthapuram, Andhra Pradesh. The monthly rainfall data is shown in the Table 6-1.

Table 6-1: Monthly Rainfall Data

ANANTHAPURAM*													
Year/Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
1991	0.9	1.8	6.6	17.9	45.2	107.7	28.5	31.3	76.9	125.5	54.3	0.7	497.3
1992	0.0	0.0	0.0	7.8	54.9	41.0	34.3	36.0	69.3	122.1	100.8	0.0	466.2
1993	0.0	0.0	17.0	1.6	18.4	76.9	75.9	108.7	102.5	69.0	31.7	33.9	535.6

1994	0.0	0.0	0.0	42.7	18.9	9.2	35.9	15.4	11.9	196.2	17.9	0.0	348.1
1995	1.9	0.0	0.0	0.0	43.0	33.7	195.9	158.9	141.7	72.1	0.0	0.0	647.2
1996	0.0	0.0	0.0	8.8	46.1	247.9	64.6	150.9	148.8	290.1	13.6	7.7	978.6
1997	2.1	0.0	41.7	5.0	10.0	35.1	7.2	82.8	196.9	23.9	16.4	11.5	432.4
1998	0.0	0.0	0.0	10.4	23.7	21.1	133.0	183.1	117.2	174.3	60.7	6.5	729.9
1999	0.0	7.6	6.7	0.0	51.3	40.5	35.3	106.4	158.9	54.1	16.1	0.0	476.9
2000	0.0	23.3	0.0	30.1	59.8	74.9	51.9	115.2	25.6	115.9	15.0	7.5	519.2
2001	0.0	0.0	0.0	65.4	0.5	15.8	18.1	60.4	159.2	213.5	24.0	0.0	556.9
2002	0.0	0.0	0.0	13.9	149.2	18.3	10.0	21.2	52.6	91.9	17.8	0.0	375.0
2003	0.0	2.5	3.6	12.7	0.0	19.4	43.9	39.2	17.1	150.6	0.0	0.0	289.1
2004	0.0	0.0	20.1	29.7	141.2	41.0	128.3	2.3	103.8	52.7	5.3	0.0	524.4
2005	0.0	0.8	0.0	19.3	43.8	60.1	178.0	77.7	161.5	171.5	38.5	20.1	771.3
2006	0.0	0.0	21.7	0.8	66.8	59.3	13.6	27.0	118.5	72.9	50.4	0.0	430.9
2007	0.0	0.0	0.0	20.6	55.9	173.0	63.5	141.3	175.0	86.0	14.4	14.8	744.5
2008	0.0	9.0	44.0	0.0	31.5	49.0	72.8	83.2	209.7	73.1	77.0	0.0	649.3
2009	0.0	0.0	5.6	4.8	33.3	57.7	9.7	134.7	140.0	21.5	63.9	6.1	477.3
2010	4.1	0.0	0.0	27.5	66.9	89.7	140.5	117.7	40.3	92.8	149.3	7.6	736.3
2011	0.0	0.0	0.0	16.1	59.3	68.1	75.5	125.0	35.1	101.7	25.4	3.1	509.3
2012	0.0	0.0	1.2	41.2	32.3	4.5	91.5	110.7	69.1	95.4	61.9	3.9	511.6
2013	0.0	8.3	0.0	10.7	15.5	27.0	52.0	25.3	222.3	100.1	0.8	0.0	462.0
2014	0.0	0.0	5.3	12.1	33.4	45.5	27.7	42.3	34.5	35.5	3.9	5.0	245.2
2015	0.0	0.2	13.0	53.1	31.4	54.7	20.3	120.6	140.5	107.7	115.6	2.5	659.7
2016	14.2	0.1	0.0	0.2	89.1	98.2	115.1	23.3	54.6	4.9	2.7	16.4	419.0
2017	0.9	0.0	3.9	6.8	39.6	96.9	39.6	80.1	193.6	271.2	8.0	0.0	740.5
2018	0.0	0.7	5.8	12.9	41.5	60.5	14.3	19.5	104.8	16.9	8.9	0.0	285.7
2019	3.6	0.0	0.0	8.1	40.5	25.1	13.5	63.5	239.5	101.0	12.9	14.2	521.9
2020	0.5	0.0	1.4	57.6	14.1	97.6	144.8	33.1	245.4	71.3	71.9	27.1	765.0

* Monthly average rainfall of Tadimarri, Bathalapalli and Mudigubba rainguage stations

6.8 ANNUAL RAINFALL ANALYSIS

Rainfall distribution of Ananthapuram district has been studied for 30 years (1991-2020) precipitation data. Figure 6.3 shows the annual rainfall variation and it is shown that the maximum rainfall of 978.6 mm occurred in 1996 followed by 2005 (771.30 mm) and minimum rainfall occurred in 2014 of 245.2 mm and that in 2018 (285.7 mm) being the second lowest. The year 1996 is referred as 'wet year' and 2014 as 'dry year' among the study period. It is also shown that the average rainfall for the selected study period of 30 years is 543.5 mm.

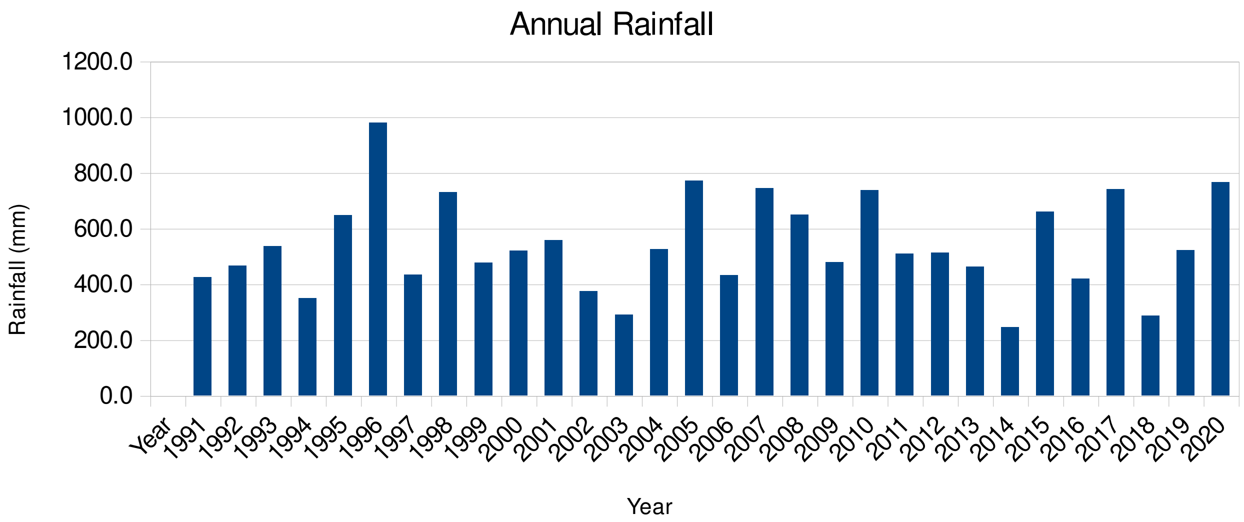


Figure 6-4: Annual rainfall distribution in the catchment area during 1991-2020

6.9 MONTHLY RAINFALL ANALYSIS

The mean monthly rainfall analysis of Ananthapuram district (Table 6-1) shows that the September month observed maximum average rainfall of 118.9 mm and October month shows the second highest of 105.9 mm for the study period of 30 years. While the lowest mean rainfall occurred in the month of January (0.9 mm), followed by February, (1.7 mm).

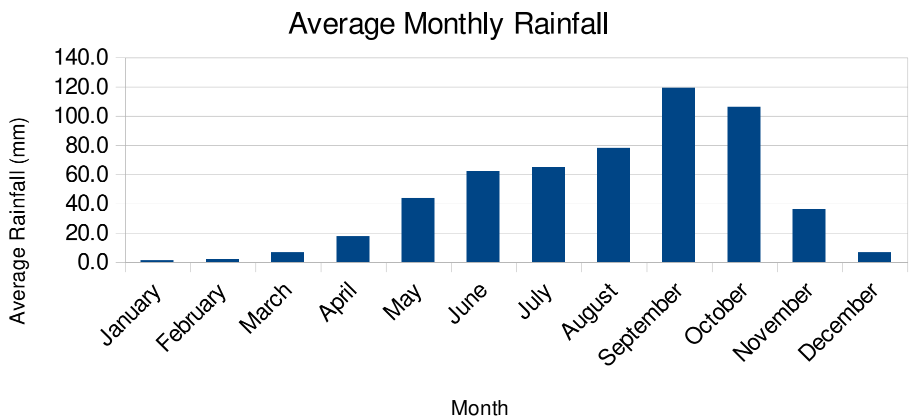


Figure 6-5: Annual monthly rainfall distribution in the catchment during 1991-2020

6.10 PROCESSING OF PRECIPITATION DATA

6.10.1 Quality of Data

The hydro meteorological data is collected from the rain gauge stations near the catchment area of Chitravathi Balancing reservoir and such data has been analysed in which the rainfall data has been checked for consistency & gaps using statistical procedures.

- Since there is no data available about sediment sampling both for bed load & suspended sediment load, estimation of sediment rate has been done using "CWC Compendium on silting of Reservoirs in India" based on geographic locations
- Similarly, for the flow observation, no Gauge & discharge stations are available at project site or anywhere on the U/S & D/S of the reservoir. However, as the lower reservoir is already existing and the upper reservoir do not have any stream/nala draining into the reservoir, no specific rainfall runoff analysis is required for the upper reservoirs. The yield into the reservoir has been arrived based on analysis of rainfall data and conversion to flows using Strange's table
- Data of evaporation, temperature, humidity, radiation, wind velocity has been collected from the nearest observation station near the project site

6.10.2 Consistency of Data

A time series is said to be consistent if all its values belong to the same statistical distribution. Inconsistent data should not be used to predict the design parameters, since such data may indicate change in regime of the concerned parameters, which needs to be accounted for while estimating them for design purposes. A dataset may not be consistent due to various reasons. Some of them are (i) changes in the underlying process or system, and (ii) changes in measuring the variables of the system, including defects in measuring equipment. In case of spatially variable measurements, such as rainfall, inconsistency resulting from the former reason will be reflected in measurements taken at different locations. In such a case, the dataset needs to be handled as it is, and no corrections need to be made to it. However, if it is the latter reason, then, the inconsistency will be seen only in those measurements taken from that specific equipment where changes have occurred.

a) External Consistency

Changes in working of rain-gauges can be checked and corrected, if necessary, through consistency checks on data collected from them. Checking for inconsistency of a given dataset, which is one among many such datasets collected, is done by double-mass curve technique (external consistency). For example, this method compares cumulative rainfall measurements at a given rain-gauge station to the cumulative mean rainfall measurements at all the other rain-gauge stations chosen to calculate the areal average rainfall over the catchment. It is important to note that the accumulation of values is started from the latest record, backwards. A sudden change in the slope of curve resulting from such comparison indicates a "changed" rain-gauge. This test is repeated on all the rain-gauges of concern. In the event of finding changed equipment, the precipitation values beyond the period of change of regime are corrected using the relation

$$P_{cx} = P_x \frac{M_c}{M_a}$$

where,

Pcx = corrected precipitation at any time period at station X

Px = original recorded precipitation at the same time period at station X

Mc = corrected slope of the double-mass curve

Ma = original slope of the double-mass curve

b) Internal

For datasets that are not prepared in conjunction with other datasets, consistency may be checked using Single-mass curve technique (internal consistency). For example, runoff of a river at a given point along its length may be checked for consistency using this method. The cumulative values of runoff time series are plotted with respect to time. Next, the plot is checked for changes in slope, which indicates a change in regime of the variable under concern, runoff in our case, and hence, its consistency.

Data from rain-gauge stations of YSR Kadapa district have been checked using single mass curve method, before being used in the rainfall-runoff analysis. It was observed that the data at all the stations is consistent which is presented below.

Figure 6-6: Rainfall Data Consistency

6.11 WATER AVAILABILITY AT PROJECT LOCATION

The proposed storage project is being planned on the allocated water for utilization by recirculation from Chitravathi Balancing Reservoir. The upper reservoir is far away from any river course and do not have any natural streams draining into the reservoirs. The yield into the reservoir is assumed to be exactly proportional to area, which of the reservoir is 0.25 Sq.km (0.25 Sq.km at FRL of catchment). The runoff coefficient is taken as 1.0 since, the storm will occur directly over the surface of the upper reservoir. The 90% dependable yield (arrived from 30 years of annual rainfall 1991 to 2020) into the reservoir through precipitation works out to 0.07227MCum (0.25 Sq.km X 289.07 mm).

Since the upper reservoir is not located across any stream, therefore, no specific hydrological studies are required to assess the specific yield in to the reservoir through rainfall-runoff correlations and the design flood. Hence, the hydrological studies are carried out to assess the water availability for running the proposed PSP scheme throughout the year and the demand of water for refilling the reservoir due to evaporation, pumping operation etc. No consumptive loss of water is envisaged.

The daily operation data of existing lower reservoir since its operation in 2009, for 10 years is collected from the dam authorities from 2010-11 to 2019-20. Using the daily reservoir water availability at Chitravathi Balancing Reservoir, the flow duration diagram is developed and shown below. Annual flows with dependability of 50%, 75% and 90% at Chitravathi Balancing and corresponding flows to be available are tabulated below.

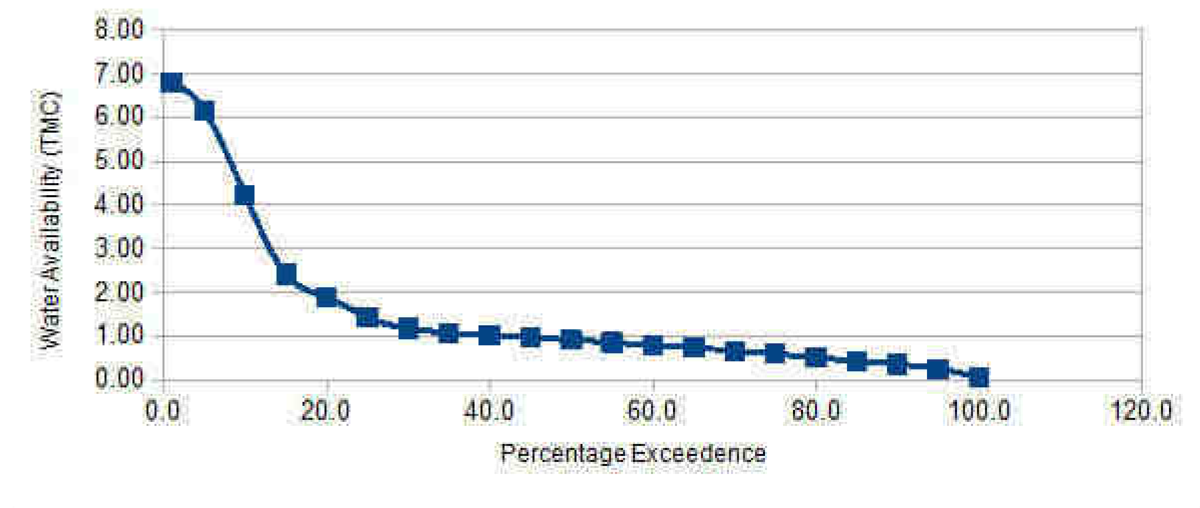


Figure 6-7: Flow Duration Curve (Chitravathi Reservoir)

Table 6-2: Total net flows at Chitravathi Balancing Reservoir

Sl. No	Dependability	TMC	MCM
1	50 %	0.91	25.76
2	75 %	0.59	16.70
3	90 %	0.35	9.905

The annual monthly evaporation loss from the reservoir is calculated based on the actual monthly evaporation data of Chitravathi Balancing Reservoir.

From Table 6-2 the 90% dependable net flows available in Chitravathi balancing reservoir is 9.905 MCM. The quantum of water required for operation of PSP, 6.61 MCM is available throughout the year.

6.12 EVAPORATION

The annual monthly evaporation loss from the reservoir is calculated based on the actual monthly evaporation data of Chitravathi Balancing Reservoir.

The evaporation volume from reservoir is assumed to be exactly proportional to submerged area, which of the upper reservoir varies is 0.25 Sq.km (at FRL) and 0.14 Sq.km (at MDDL). The submerged areas of the upper reservoir at each medium storage capacity between FRL and MDDL are used for estimating annual losses due to evaporation, since the relation between the water levels and the reservoir areas above MDDL of the upper reservoir are almost same. The annual losses due to the evaporation from the upper reservoir is 0.21 MCM. The annual yield in to the reservoir through precipitation is 0.07227MCum. The balance loss of 0.15 MCM (0.005 TMC) due to evaporation, which is negligible will be compensated by pumping from Chitravathi Balancing Reservoir.

Table 6-3: Total net flows at Chitravathi Balancing Reservoir

Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
3.457	3.095	2.383	2.162	2.581	2.680	2.756	2.288	3.248	4.326	4.542	3.941	37.460

6.13 SEDIMENTATION

6.13.1 Sedimentation Rate

The estimated silt load for the proposed reservoirs has been arrived based on "Compendium on Silting of Reservoirs in India (2015)" published by CWC.

As per the CWC publication, a sediment rate of 378 m3/sq.km/year is based on the average sediment rate in the region of Deccan Peninsular east flowing rivers including Godavari and south Indian rivers derived from the capacity survey carried out for reservoirs in this region.

6.13.2 Trap Efficiency

Trap Efficiency of the reservoir is determined on the basis of Brune's Curves (IS: 12182:1987). The capacity – inflow ratio of the reservoir is determined and the corresponding trap efficiency factor is read from the Brune's Curves shown in Figure 6-8.

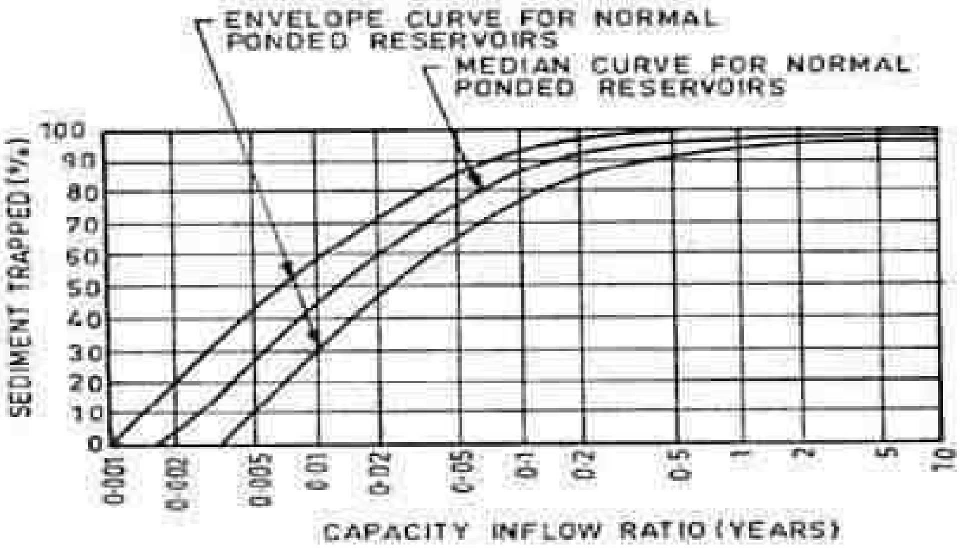


Figure 6-8: Brune's Curve

6.13.3 Sediment Volume

As per I.S. guidelines 12182-1987 "Determination of effects of sedimentation in planning and performance of reservoir", feasible service time of the reservoir for hydropower shall not less than 70 years.

The upper reservoir does not have any nala or catchment draining into the reservoir. The area (C.A.) of upper reservoir at FRL is 0.25 Sq.km. The total sediment volumes for 70 years at upper Reservoir is calculated as following (assuming the sediment from lower reservoir will be carried out into the upper reservoir during pumping as a worst case scenario)

Sediment volume of upper dam = 378 × 0.25 × 70 = 0.0066 MCM

The estimated annual sediment volumes for upper dam are 0.0066 MCM. The ratios of the annual sediment volumes to gross storage capacity of upper dam are negligible. Thus, the reservoir sediment problem is insignificant.

The Minimum Drawdown Level (MDDL) of the upper reservoir is kept at EL. 460 m with corresponding dead storage capacity of 0.140 MCM against the estimated sediment volumes of 0.0066 MCM. The estimated sediment volumes are contained well below the dead storage itself and have no effect of sediment in the reservoir.

6.13.4 Sediment Distribution

The sediment entering into the reservoir gets deposited in it with the passage of time, and thereby, reduces its dead storage as well as its live storage capacity. This causes the bed level near the dam to rise and the raised bed level is termed as new zero elevation (NZE). The revised storage-elevation relationships, based on sediment-loading of the reservoir, are worked out for fixing the live storage of the reservoir and in locating the outlets to withdraw water from it for downstream needs.

Empirical area reduction method or the area increment method is used for predicting sediment distribution in reservoirs. Empirical area reduction method is used for the proposed reservoir as per IS 5477 (Part 2):1994 (Reaffirmed 2004). The new zero elevation for the upper dam after feasible service time, i.e. 70 years, was computed as EL. 459.10 m which is below the Minimum draw down level of EL. 460.00 m.

6.14 DESIGN FLOOD

The design flood for a hydraulic structure is the maximum flood that can be safely discharged through the structure without causing any damage to it. As per the latest Indian Standards and guidelines of the Central Water Commission (CWC), the design flood for a hydraulic structure may be one the following:

- Probable Maximum Flood
- Standard Project Flood
- Flood of Specified Frequency (T-Year Flood)

The design flood may be the maximum probable flood or the standard project flood or a flood corresponding to some desired frequency of occurrence depending upon the standard of security that should be provided against possible failure of the structure.

As per IS 11223:1985, inflow design flood for the safety of a dam is the flood for which, when used with standard specifications of other factors as mentioned in subsequent clauses, the performance of the dam should be safe against overtopping and structural failure, and the spillway and its energy dissipation arrangements, if provided for a lower flood, should function reasonably well.

The selection criteria depend upon the functional importance, with judicious combination of safety and economy in the event of failure.

As per the Manual of Estimation of Design Flood (CWC) and IS 11223:1985, the criteria for adopting the design flood depends upon the classification of the dam, based on storage capacity and hydraulic head is furnished in Table 6-4.

Table 6-4: Design flood adoption criteria

S.No.	Classification	Gross storage (MCM)	Hydraulic head (m)	Design flood
1	Small	0.5 to 10	7.5 to 12	100 – year flood
2	Medium	10 to 60	12 to 30	SPF
3	Large	>60	>30	PMF

Floods of larger or smaller magnitude may be used if the hazard involved in the eventuality of a failure is particularly high or low. The relevant parameters to be considered in judging the hazard in addition to the size would be:

- ❖ Distance to and location of the human habitations on the downstream after considering the likely future developments.
- ❖ Maximum hydraulic capacity of the downstream channel at a level at which catastrophic damage is not expected.

The Chitravathi PSP upper reservoir can be classified as “Small” by storage criterion being less than 10 MCM. However, it is a large dam by hydraulic head consideration, as the head is more than 30 m. Therefore, the dam should be designed for the Probable Maximum Flood (PMF).

As the catchment area of the upper dam (0.25Sqkm) is small and the time of concentration is short, Rational Formula and one-day storm will be applicable for design flood study.

6.14.1 Probable Maximum Precipitation (PMP)

The 1 day PMP value has been assessed from PMP atlas for Cauvery and other East flowing River Basin (2015) and worked out in order of 64.4 cm for the catchment of Upper Dam and Lower Dam respectively. The same has been adopted as design storm for the Upper Dam.

6.14.2 Probable Maximum Flood (PMF)

The design flood has been estimated based on Rational Formula. 1-hour PMP was calculated as 299.42 mm/hr. The PMF of upper dam is calculated as following.

Q = 0.278CIA

Where,

C : runoff coefficient taken as 0.56 (Ref. from Table-15.1.1, Text Book of Applied Hydrology by Ven Te Chow)

I : rainfall intensity (mm/hour)

A : catchment area (km^2)

Design Flood Calculations for Upper Dam:

C : runoff coefficient = 0.56

1-day PMP value = 64.4 cm (worked out with Ref. from PMP atlas for Cauvery and other East flowing River Basin (2015))

tc = Time of Concentration = 1 hr.

tc h ratio = 0.465 (Ref. from Fig.4 of RBF-16)

1 hr. ratio = 0.42 (Ref. from Fig.4 of RBF-16)

24 hrs. to 1 hr. rainfall Value = 644*0.42 = 270.48 mm

1 hr. PMP value at tc = K*1 hr. rain fall value

(where, K = tc h raio/1 hr. ratio = 0.465/0.42 = 1.107)

= 1.107*270.48 mm = 299.42 mm

I : Rainfall Intensity = PMP at tc/tc = 299.42/1 =299.42 mm/hr.

A = Catchment Area of Upper Dam = 0.25 km^2

Therefore,

Design Flood = 0.278CIA

= 0.278*0.56*299.42*0.25 = 11.65 cumecs

Base flow in this catchment has been considered as 0.019 m^3/s (0.05 m^3/s /km^2) based on "Cl. 3.8, of Flood Estimation report Krishna & Pennar Subzone-3(h)".

Therefore,

Base flow for this catchment = 0.25*0.05 = 0.0125 m^3/s

Total design Flood for Upper Reservoir = 11.65 + 0.0125

= 11.6625 $m^3/s \approx 11.7\ m^3/s$

The PMF of the upper dam works out to 11.7m3/s. The design storm duration is taken as 1.0 Hr. The corresponding volume for upper dam works out to 6.4 MCM (0.226 TMC). The maximum rise in the water level above FRL (EL496 m) in the upper reservoir is negligible. As the volume of flood is very small, the same can be contained in the reservoir itself and hence, no separate spillway provision is provided for the probable maximum flood.

Chapter-7

Alternative Layout Study

7 ALTERNATIVE LAYOUT STUDY

7.1 GENERAL

This chapter covers the studies of alternative locations of various project components and various project layouts developed and considered during preparation of Feasibility report of Chitravathi Pumped Storage Project.

7.2 PREVIOUS ALTERNATIVE STUDIES

Techno-Commercial Feasibility Study Report of the project was prepared by the WAPCOS Limited in May 2020. The study of WAPCOS covers the two alternative locations for the upper reservoir; one is on left bank (named as Option-1) and second is on right bank (named Option-2).

Option-1:

In this option, the upper reservoir is proposed on left bank at geographical co-ordinate N- 14° 34' 26.93" E- 77° 56'2.60" in NW direction of existing lower Reservoir. The highest possible elevation is at EL-500m on the hilltop. At this location the flat surface area is inadequate to create required capacity in reservoir. Therefore, it is proposed to create Pondage through excavating a pit upto desired depth for optimum live storage. The length of water conductor is 810m starting from upper Intake to lower intake. The General Layout Map for Option-1 is presented below:

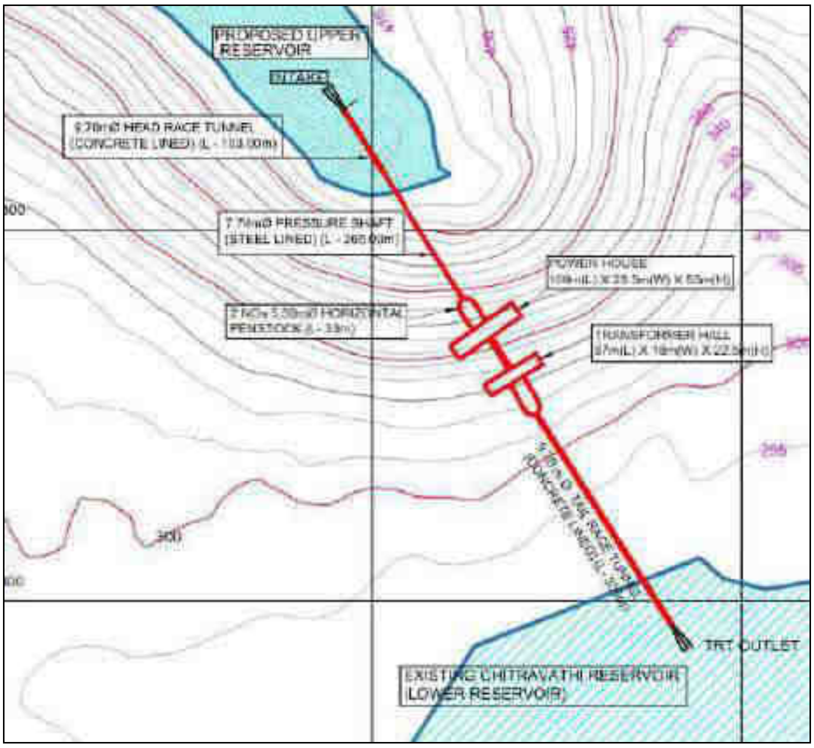


Figure 7-1: General Layout Map- Option-1

Option-2:

In this option, the upper reservoir is proposed on Right bank at geographical co-ordinate N- 14° 31' 38.46" E- 77° 57' 31.09". The highest possible elevation is at EL-500m on the hilltop. At this location the flat surface area is inadequate to create required capacity in reservoir. Therefore, it is proposed to create Pondage through excavating a pit upto desired depth for optimum live storage. The length of water conductor is 2650m starting from upper Intake to lower intake. The General Layout Map for Option-2 is presented below:

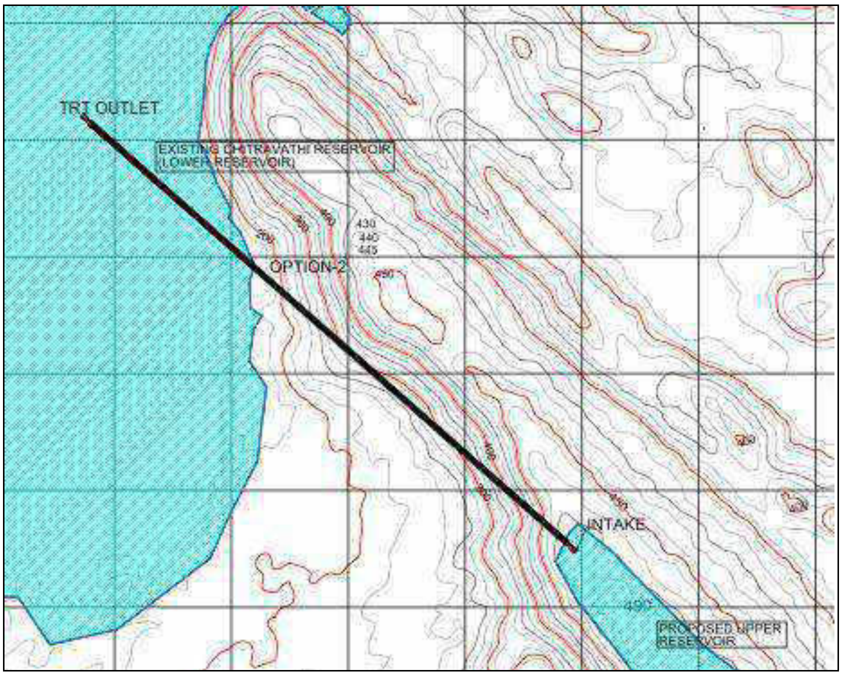


Figure 7-2: General Layout Map- Option-2

A comparative preliminary analysis is presented below:

Table 7-1: Comparative Preliminary Analysis

Chitravathi PSP			
Basic Data		**Basic Data**	
Lower Reservoir (Existing)		**Lower Reservoir (Existing)**	
FRL	298	FRL(m)	298
MDDL	283	MDDL(m)	283
Upper Reservoir (Option-1) –Left Bank		**Upper Reservoir (Option-2) –Right Bank**	
Reservoir Type - Excavated Pit		**Reservoir Type – Excavated Pit**	
FRL	475	FRL(m)	475

MDDL	455	MDDL(m)	455
Head(m)	174.5	Head(m)	174.5
Length(m)	810	Length(m)	2650
L/H Ratio	4.64	L/H Ratio	15.19
Excavated Quantity (Million m3)	**6.32**	Excavated Quantity (Million m3)	**19.949**

As evident from above, L/H ratio in option-1 is much less than Option-2 which is a major criterion from techno economic standpoint. Moreover, the excavation in Option-2 is also more than option- 1. Therefore, Option-1 is more economical and is the preferred option and hence selected at this stage.

The required live storage of upper reservoir for 500 MW generations for about 5 hour and 10 minutes is 6.01 MCM (0.21 TMC)

7.3 PRESENT ALTERNATIVE STUDIES FOR SELECTION OF UPPER RESERVOIR LOCATION

Alternative study on both left bank and right bank has been carried out to find the best optimized location for upper reservoir.

7.3.1 Reservoir Location Optimization on Left Bank

A detailed alternative study has been carried out to find out the best location of upper reservoir on left bank as shown in Figure 7-3. Various alternatives were studied considering construction of reservoir with entire excavation portion and combination of excavation and construction of embankment dam. The selection criteria were to utilise the maximum possible excavated material in filling and storage cost per MCM. Following sections outlines the various combination studied.

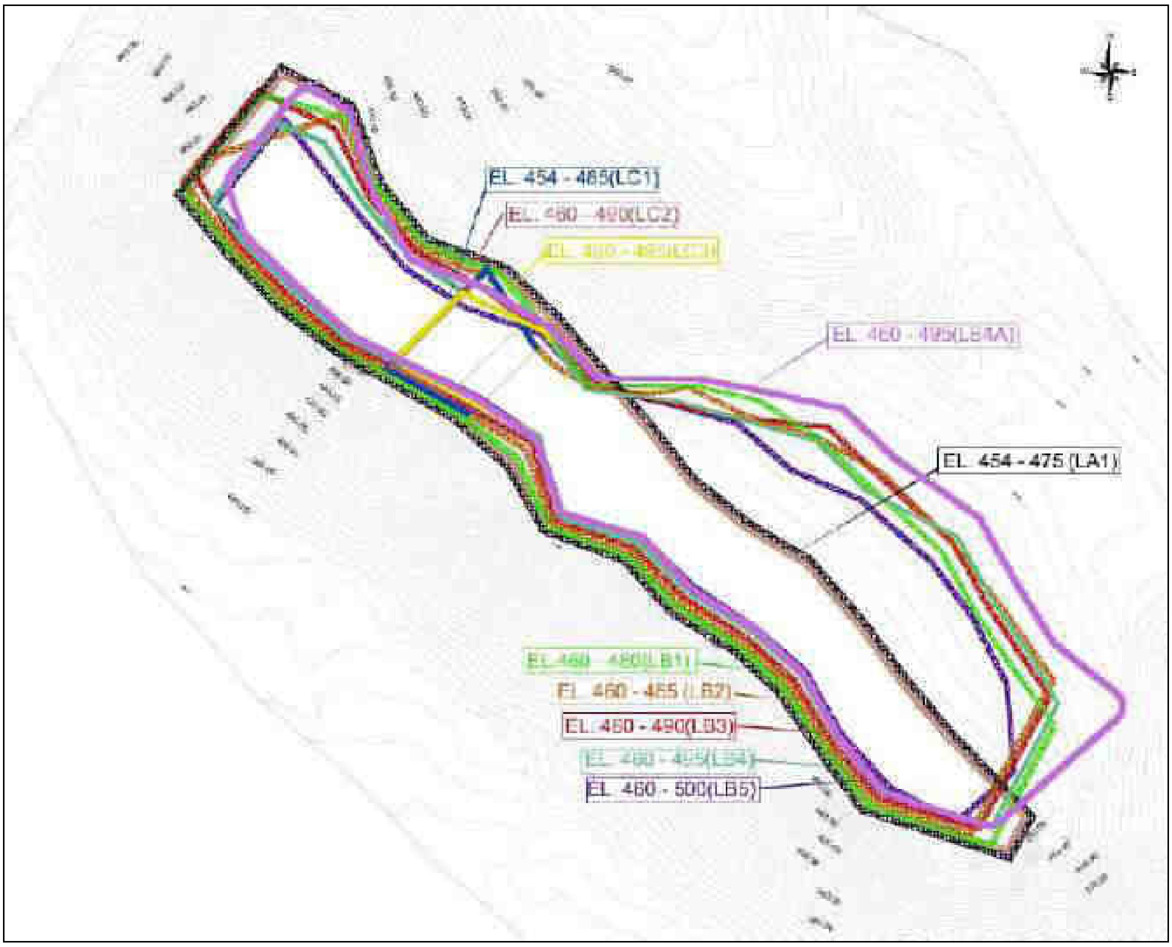


Figure 7-3: Upper Reservoir Alternatives on Left Bank

A. Excavated Pit for Reservoir

In this alternative the upper reservoir is created by excavating a pit for creating desired storage volume.

Alternative: LA-1

Alternative LA-1 comprises of excavating a pit of about 1.5m km long and 0.0.15 km (average) wide for formation of reservoir is excavated to create required Pondage between EL. 454m and EL. 475m. The storage capacity of reservoir is this case works out to be 5.1 MCM.

B. Partial Excavation (Longer Hill) and Bund

Various combinations of cutting and bund formations are explored to arrive at the optimum storage and maximum head which are detailed below:

Alternative: LB-1

- Small portion of reservoir is with Embankment.
- Elevation: EL 460-480
- Storage : 5.90 MCM

Alternative: LB-2

- Same as LB-1 with 5m above reservoir elevation.
- Elevation: EL 460-485
- Storage : 6.40 MCM

Alternative: LB-3

- Same as LB-1 with 10m above reservoir elevation.
- Elevation: EL 460-490
- Storage : 7.79 MCM

Alternative: LB-4

- Same as LB-1 with 15m above reservoir elevation.
- Elevation: EL 460-495
- Storage : 7.78 MCM

Alternative: LB-4A

- Same as LB-1 with shifting the embankment dam downward to increase the storage capacity.
- Elevation: EL 460-495
- Storage : 8.3 MCM

Alternative: LB-5

- Same as LB-1 with 20m above reservoir elevation.
- Elevation: EL 460-500
- Storage : 6.4 MCM

C. Partial Excavation (avoid cutting in Narrow Hill) and Bund

In this alternative required Pondage is created avoiding excavation in narrow part of hill and constructing partial bund.

Alternative: LC-1

- High and narrow part of hill is avoided in cutting
- Bigger part for embankment/bund
- Elevation: EL 454-485
- Storage : 6.3 MCM

Alternative: LC-2

Same as LC-1 with modified elevation.

- High and narrow part of hill is avoided in cutting
- Bigger part for embankment/bund
- Elevation: EL 460-490
- Storage : 5.97 MCM

Alternative: LC-3

Same as LC-1 with modified elevation.

- High and narrow part of hill is avoided in cutting
- Bigger part for embankment/bund
- Elevation: EL 460-495
- Storage : 6.28 MCM

Alternative: LC-4

Same as LC-1 with modified elevation.

- High and narrow part of hill is avoided in cutting
- Bigger part for embankment/bund
- Elevation: EL 460-500
- Storage : 5.23 MCM

7.3.2 Reservoir Location Optimization on Right Bank

A detailed alternative study has been carried out in similar lines as done for left bank to find out the best location of upper reservoir on right bank as shown in Figure 7-4. The details are outlined hereunder.

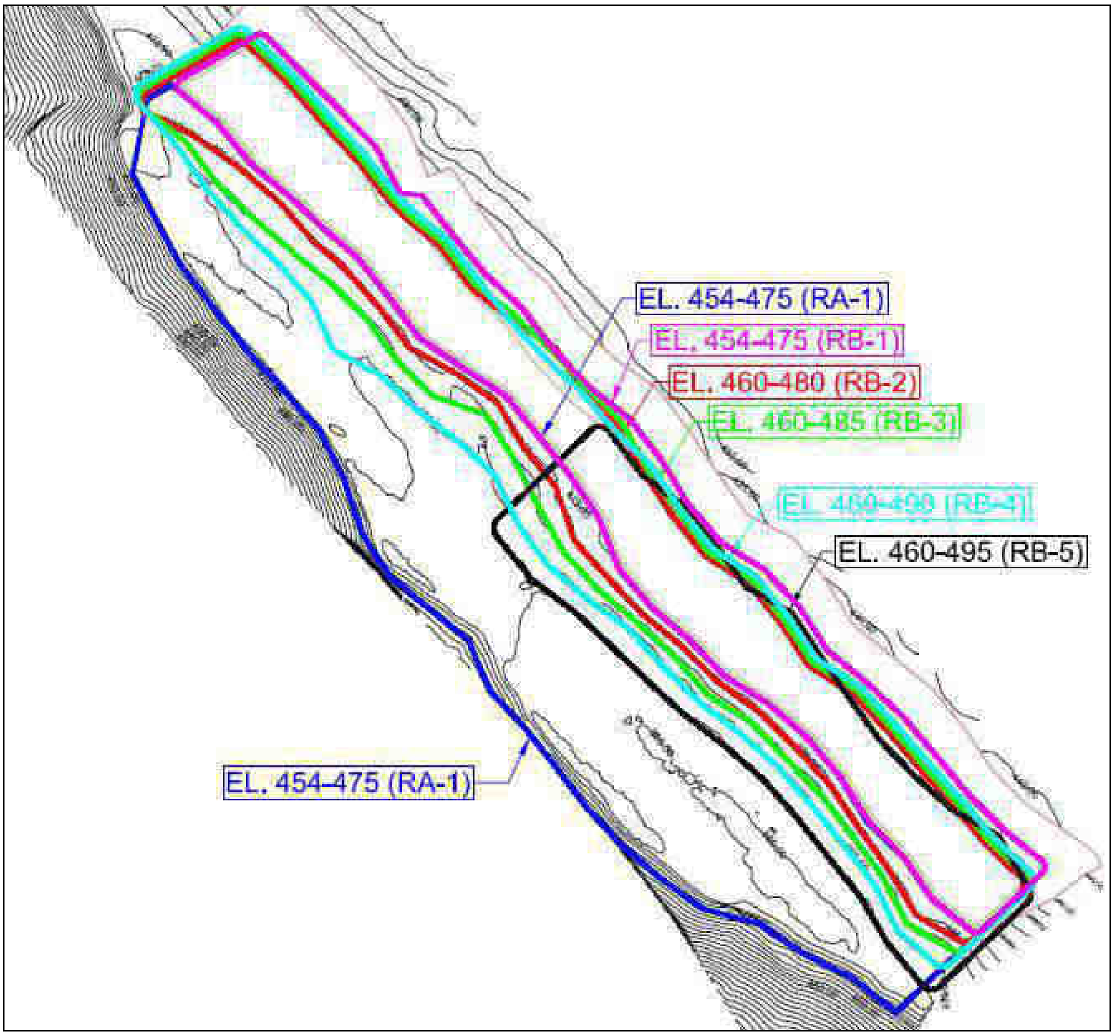


Figure 7-4: Upper Reservoir Alternatives on Right Bank

A. Excavated Pit for Reservoir

Alternative LA-1 comprises of excavating a pit of about 2.4m km long and 0.25 km (average) wide for formation of reservoir to create required Pondage between EL. 454m and El. 475m. The storage capacity of reservoir is this case works out to be 14.27 MCM. However, the quantity of excavation works out to be very high in order of 2.5 cr. cubic meter.

Alternative: RA-1

This Alternative is very similar to the study carried out by WAPCOS as option-2. In this alternative approx. 2.4m km long reservoir is excavated to create required Pondage between EL. 454-475. The storage capacity of reservoir is this case works out to be 14.27 MCM. In this case excavation works out to be very high in order of 2.5 c. cubic meter.

B. Partial Excavation (Longer Hill) and Bund

In this alternative, to avoid huge excavation reservoir is shitted to down to avoid cutting in narrow part of hill. In this case required Pondage is created by excavating whole stretch of hill (Approx. 2.4 km) and constructing embankment/bund.

Alternative: RB-1

- Reservoir length is approx. 2.4 km
- Partial Cutting and filling
- Elevation: EL 454-475
- Storage : 7.86 MCM

Alternative: RB-2

Same as RB-1 with modified elevation.

- Reservoir length is approx. 2.4 km
- Partial Cutting and filling
- Elevation: EL 460-480
- Storage : 7.53 MCM

Alternative: RB-3

Same as RB-1 with modified elevation.

- Reservoir length is approx. 2.4 km
- Partial Cutting and filling
- Elevation: EL 460-485
- Storage : 11.67 MCM

Alternative: RB-4

Same as RB-1 with modified elevation.

- Reservoir length is approx. 2.4 km
- Partial Cutting and filling
- Elevation: EL 460-490
- Storage : 16.12 MCM

Alternative: RB-5

Same as RB-1 with modified elevation.

- Reservoir length is approx. 1.3 km
- Partial Cutting and filling
- Elevation: EL 460-495
- Storage : 8.73 MCM

7.3.3 Assumed Rate for the Costing of Various Alternatives of Upper Reservoir

At this preliminary stage, rates of various items are taken either from State SOR, (2020-21) or from the similar large project in the similar region. These rates are considered for comparison and to find out the best optimal alternative for the upper reservoir and therefore variation in rates will not affect the pattern of selection of alternatives. However, the detailed rate analysis shall be carried out at next phase of studies. The assumed rates are given in Table 7-2.

Table 7-2: Assumed Rate

S.No.	Item	Unit	Rate (Rs)
1	Excavation (Overburden)	m^3	247
2	Excavation (Rock)	m^3	406
3	Rock fill (For Embankment)	m^3	322.95
4	Clay Core (For Embankment)	m^3	419
5	Grouting	Per Bag	656
6	M15 Mass concrete	m^3	3586

7.3.1 Summary of Various Selected Alternatives including Costing

A preliminary costing has been worked out for each alternative considering excavation, filling of embankment dam, grouting and rock support. Summary of result of various alterative on left bank is given in Table 7-3 and for right bank is given in Table 7-4.

Table 7-3: Summary of Various Alternatives of Upper Reservoir location on Left Bank

S.No.	Alternative	Storage (MCM)	Cost in Cr. (INR)		Total Cost in Cr. (INR)	Cost in Cr/MCM	Excavation (m^3)	Embankment Filling (m^3)	Used Excavation Material in Filling %
			Cutting	Filling					
1.	LA-1 (454-475)	5.10	413	0	413	81.1	97,65,761	-	-
2.	LB-1 (460-480)	5.90	346	63	409	69.3	82,49,444	12,53,388	15
3.	LB-2 (460-485)	6.40	325	89	414	64.8	76,60,721	17,80,846	23
4.	LB-3 (460-490)	7.79	305	115	420	53.9	70,17,979	26,11,241	37
5.	LB-4 (460-495)	7.78	254	135	389	50.0	57,08,796	30,58,474	54
6.	LB-4A (460-495)	8.30	254	323	577	69.5	57,08,796	49,02,975	85
7.	LB-5 (460-500)	6.40	200	141	342	53.4	42,52,952	31,08,720	73
8.	LC-1 (454-485)	6.30	228	123	352	55.8	54,04,307	27,92,102	52
9.	LC-2 (460-490)	5.97	186	114	301	50.3	42,92,879	25,92,387	60
10	LC-3 (460-495)	6.28	163	134	297	47.3	36,53,366	30,36,391	83
11	LC-4 (460-500)	5.23	124	158	282	53.9	26,01,536	30,86,275	119

Table 7-4: Summary of Various Alternatives of Upper Reservoir location on Right Bank

S.No.	Alternative	Storage (MCM)	Cost in Cr.		Total Cost in Cr.	Cost in Cr/MCM	Excavation (m^3)	Embankment Filling (m^3)	Used Excavation Material in Filling %
			Cutting	Filling					
1	RA-1 (454-475)	14.27	1036	0	1036	72.63	250,28,702	-	-
2	RB-1 (454-475)	7.86	139	386	525	66.78	29,70,833	53,45,184	180
3	RB-2 (460-480)	7.53	129	385	514	68.24	27,26,238	62,02,883	228
4	RB-3 (460-485)	11.67	190	534	724	62.03	41,46,022	85,42,204	206
5	RB-4 (460-490)	16.12	267	744	1011	62.75	59,58,353	118,95,983	200
6	RB-5 (460-495)	8.73	175	356	532	60.89	39,47,836	55,14,817	140

7.3.1 Optimized Alternative for Upper Reservoir

Based on the review of the alternatives worked out above, right bank alternative seems less favourable in compare to left bank alternative with respect to cost to be incurred per MCM storage capacity. Also in most of cases more filling material is required for the filling of embankment.

From the various alternatives on left bank, Alternative LB-4 and LC-3 seems best optimized alternative with respect to cost to be incurred per MCM storage capacity. However, in view of utilization of excavated material in the filling of embankment/bund, alterative LC-3 seems more suitable alternative for upper reservoir. In view of above **Alternative LC-3** is considered as upper reservoir for further study.

7.4 DETAILED ALTERNATIVE STUDIES FOR SELECTION OF POWER HOUSE LOCATION

Based on the alternative study for upper reservoir as explained above, the left bank is found more suitable for the development of the Chitravathi PSP.

For left bank upper reservoir, following alternative of power houses were studied:

- ❖ Surface power house in the open pit
- ❖ Underground power house- Alternative-1 (refer Figure 7-5)
- ❖ Underground power house Alternative-2 (refer Figure 7-5)

For the planning of power house, following are the governing factors:

- ❖ Lower Reservoir FRL: EL 298.00 m
- ❖ Lower Reservoir MDDL: EL 282.55 m
- ❖ Turbine centre line elevation: EL 245.45 m

7.4.1 Surface Powerhouse in the Open Pit

Maximum bench of 30 m width at EL 230.50 is available for an alternative of location a surface power house. Feasibility of surface power house is studied, but found not suitable mainly due to following reasons:

- ❖ Excavation of more than 60 m deep power house pit adjacent to the operational reservoir.
- ❖ Possibility of very high seepage through the reservoir charged rock mass.
- ❖ Constructability and operation issue related to dewatering of seepage flow.
- ❖ Larger quantities of excavation muck and slope stabilisation measures.
- ❖ Limited space available between reservoir boundary and the toe of the hill and therefore possibility of destabilisation of hill slope for deep excavations.

However, further exploration for Surface powerhouse will be done at DPR stage.

7.4.2 Underground Power house- Alternative-1 and Alternative-2

The underground powerhouse layout alternatives are presented in Figure 7-5.

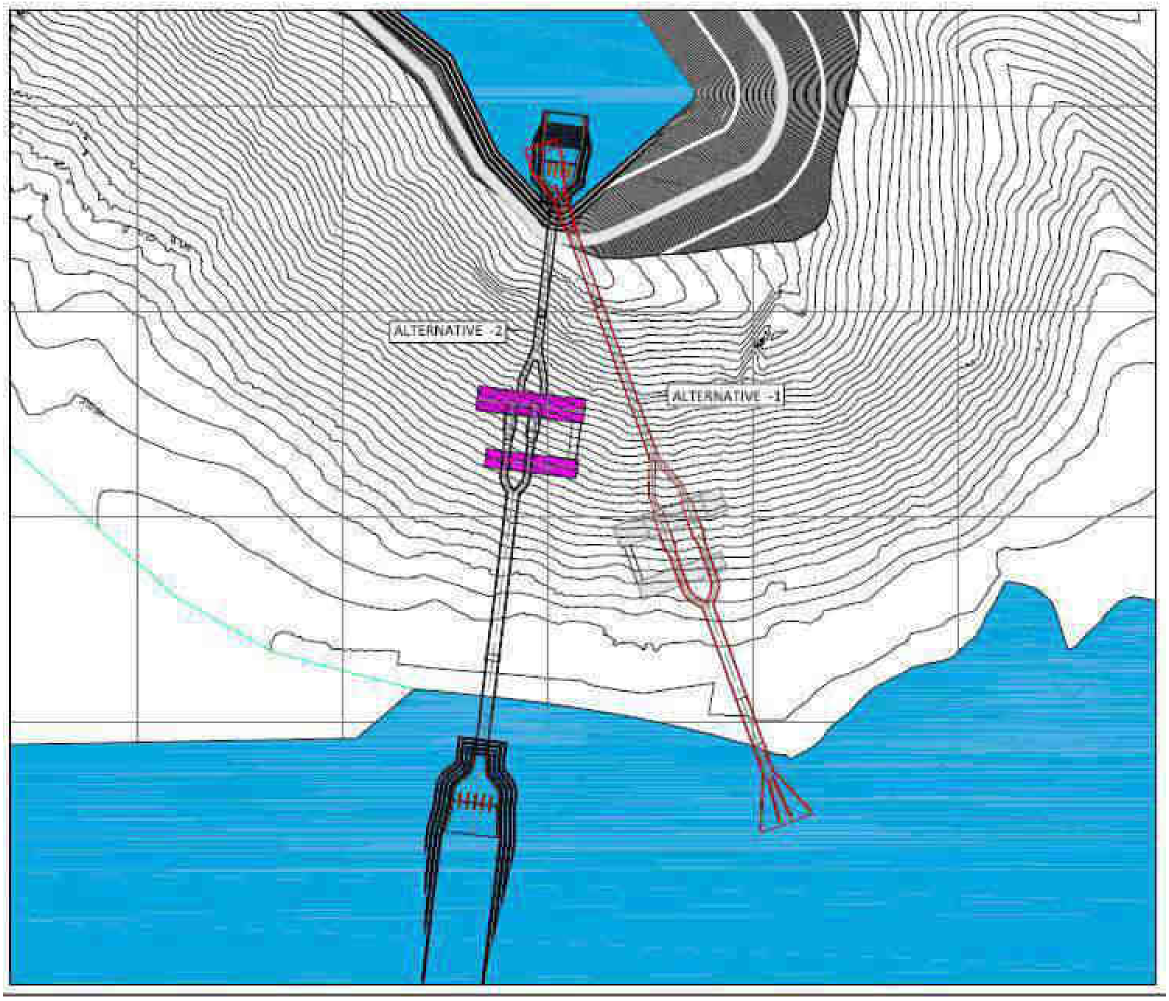


Figure 7-5: Alternative Layouts of Underground Powerhouse

Both the alternative has similar arrangement except minor changes in the length of pressure shaft and TRT. The Alternative-2 provides larger working area and flatter uphill slope. Further, the length of pressure shaft in the Alternative-2 is comparatively 30% less. Therefore underground power house alternative-2 is chosen for the development of the proposed PSP.

7.5 ALTERNATIVE FOR DAM TYPE

Roller compacted concrete, Asphalt Facing Rock fill Dam & Rock fill Dam with central impervious clay core are the three types of dams considered for formation of embankment of upper reservoir. The following aspects were taken into consideration for selecting the type of embankment.

Material costs for construction of embankments

Time spent for construction of embankment viz., total construction time, man-hours, requirement of infrastructure facilities etc.,

Time and cost used for trial tests.

Preparation for construction, e.g., excavation, foundation, diversion and construction of batching and crusher plants.

Roller-Compacted Concrete Dam: Roller-compacted concrete dams have many similarities with conventional gravity concrete dams. The dam is built to required height and depth where it can resist the expected forces from the water by its weight. But instead of using rock-fill or earth fill, RCC Dam consists of concrete which is spread in thin layers and compacted by vibrator rollers. It is important to provide the RCC Dam with sufficient resistance to water leakage (seepage). The method of using a concrete with higher binder close to the upstream face will decrease the permeability by creating a water tight barrier of concrete with higher quality. RCC Dam is much heavier and thus demand better bedrock allowing the stresses produced by the dam weight and the water pressure. If the bedrock is heavily foliated, the foundation will suffer from shearing failure. Before and during construction of RCC Dam, the geological conditions at the site must be investigated much more thoroughly than a Rock fill dam. The cost of construction and the requirement of infrastructure facilities are higher for RCC Dam compared to Rock fill dam.

Asphalt Concrete Facing Rock-fill Dam: Asphalt concrete faced rock-fill dam (AFRD) in which asphaltic concrete acts as upstream impervious facing (as water barrier) for rock-fill embankment dam. AFRD is considered a technically viable option and is also fast in construction in comparison with conventional Rock-fill dam with central impervious clay core. AFRD offers an additionally advantage of possibility of using lower quality rock-fill shell material as there is no direct water contact and moreover placement of material is fast because of homogenous nature of rock-fill shell. Further, asphaltic concrete facing dam is also having advantage from other type of reinforcing concrete facing alternatives as being more flexible and capable of accommodating more reasonable deflection of dam and faster in laying with modern construction equipment and technique.

In the pumped storage scheme generally, drawdown is in order of 20m to 30m and that also in period of 6-9 hours. In such case, upstream impervious facing sealing embankment dam found more appropriate than Rockfill Dam with central impervious clay core sealing as keeping water barrier on the upstream face of the embankment is pore pressure free and is neither subject to steady seepage nor to rapid drawdown effects. Moreover, other additional advantage offered by such type of dam is that after drawdown of the reservoir, the facing is readily accessible for inspection, maintenance and repair. Therefore, in view of the above AFRD appears to be a one of the suitable options because of necessity of rapid drawdown conditions in pumped storage schemes. However, this aspect will be further studied/explored for optimization during detailed design stage.

Rock-fill Dam with central impervious clay core: The main characteristics with the Rock-fill is that the dam type enables usage of local materials excavated from the project components and the compulsory excavations in the rock-fill dam body, as opposed to using expensive material from quarries which may have to be transported a long way etc. However, there are some quality requirements on the aggregates which have to be met in order to be able to use them in the dam body. The quality is mainly determined by the local geology and highlights the importance of good geological surroundings in order to exploit all advantages with the dam type.

Clay for formation of impervious core is available in adequate quantities very near to the project site and excavated materials from the project components being proposed for shell of the Dam, Rock-fill with central impervious clay core is proposed for the Chitravathi Upper Reservoir which is economical and faster to construct comparing to RCC Dam. Moreover, the rock-fill dams have many advantages comparing to RCC Dam. The main advantages are:

- Rock-fill dams can be constructed on any given foundation condition and the excavation for foundation need not be up to rock level, where the bed rock is deep seated. Foundation excavation is negligible in most of the dams.
- Soil/rock materials locally available are used with negligible processing.
- Use of costly manufactured items like cement and steel is eliminated and there is saving on transportation cost also.
- Rock-fill dams are more resistant to seismic forces.
- With modern earth moving machineries, the dam can be completed in less time compared to a rigid dam.

Considering the merits & demerits of Rock-fill dam with different type of sealing arrangements (surface & central core sealing) & RCC Dam options, Rock-fill dam with central impervious clay core is selected for formation of upper reservoir.

Chapter-8

Reservoir

8 RESERVOIR

8.1 GENERAL

The existing Chitravathi Balancing Reservoir project is located near Parnapalli Village in Anantapur district, Andhra Pradesh on the river Chitravathi which is a tributary of the Pennar River. The purpose of this project is to provide irrigation to the two districts namely Kadapa, Anantapur. This reservoir is also known as Sri. Penchikala Basi Reddy Chitravathi Balancing Reservoir.

It is envisaged to utilise the existing Chitravathi Reservoir as Lower pond for the proposed PSP scheme by locating upper pond at a suitable higher location in the vicinity.

The proposed Chitravathi Pumped Storage project envisages utilization of available head between newly constructed upper dam and existing Chitravathi reservoir as lower pond. An Underground Power House (UGPH) will be located in between two reservoirs. Both the reservoirs are interconnected through water conductor and the generator and turbines installed at the power house in between the reservoirs.

This chapter covers the studies of characteristics of existing Chitravathi reservoir and proposed upper reservoir.

8.2 EXISTING RESERVOIR

The Chitravathi Balancing/Existing Reservoir project is located near Parnapalli Village in Anantapur district, Andhra Pradesh on the river Chitravathi which is a tributary of the Pennar River. The purpose of this project is to provide irrigation to the two districts namely Kadapa, Anantapur. This reservoir is also known as Sri. Penchikala Basi Reddy Chitravathi Balancing Reservoir.

The catchment area at the dam site is 5431 sq. km. The reservoir has Gross storage of 283.1 MCM and Dead storage 1.25 MCM (0.044 TMC).

The salient features of Existing reservoir are listed below in Table 8-1. The Area Capacity curve of existing reservoir is given in Figure 8-1.

Table 8-1: Salient Features of Existing Reservoir

Sl. No.	Parameter	Unit	Value
1	Catchment Area of Reservoir	Sq. Km	5431
2	Average Annual Rainfall in the Catchment	mm	710.00
3	Design Flood Discharge	Cumecs	4080
4	Top of Bund (T.B.L)	m	EL + 302.50
5	Max Water Level (MWL)	m	EL +298.00

Sl. No.	Parameter	Unit	Value
6	Full Reservoir Level (FRL)	m	EL +298.00
7	Minimum Draw Down Level (MDDL)	m	EL+ 282.55
8	River Bed Level	m	EL + 277.00
9	Crest Level	m	EL + 289.35
10	Live Storage	TMC	9.956
11	Dead Storage	TMC	0.044
12	Gross Storage	TMC	10.00
13	Total Length of Dam	m	832.75
14	Earth Bund Length	m	360
15	N.O.F Length	m	366
16	Spillway Length	m	106.75
17	Design Head	m	8.65

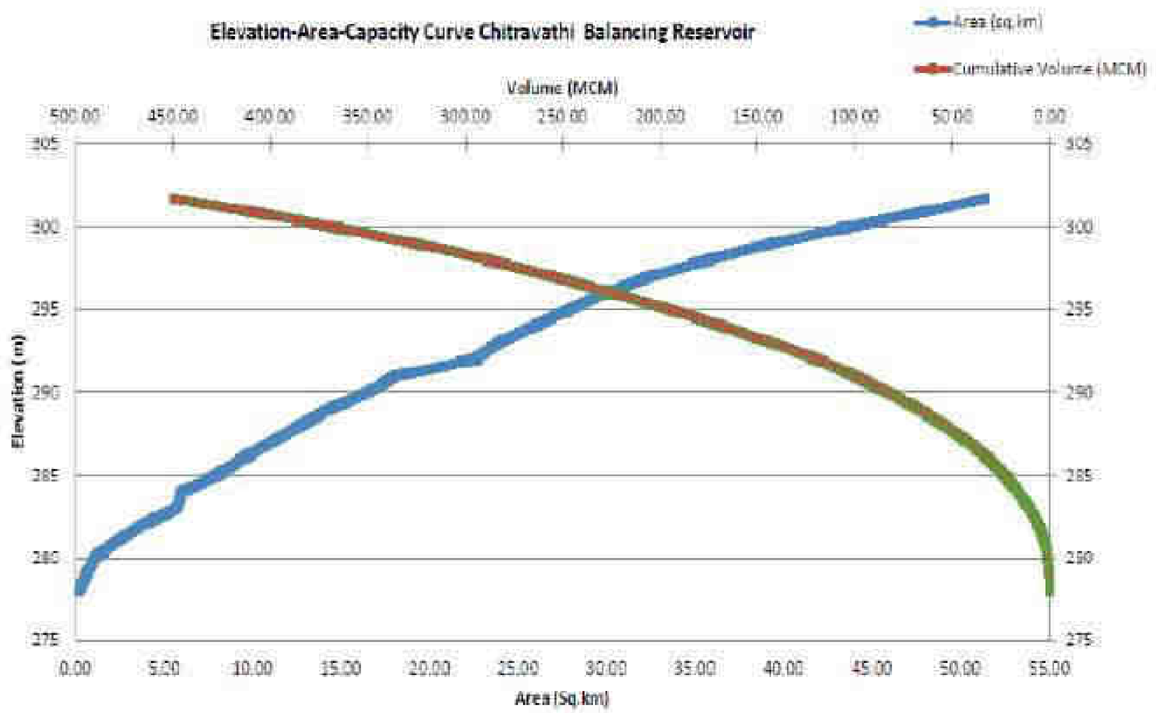


Figure 8-1: Elevation-Area-Capacity Curve of Existing Reservoir

8.3 PROPOSED UPPER RESERVOIR

An upper reservoir is proposed at the top of hill on the left bank of river by excavating a pit between elevation EL 459.00 m (considering 1m of dead storage from MDDL 460.00 m) to EL 495.00 m. A partial embankment/bund is also proposed on the downward side of the reservoir to create required storage. The live storage of reservoir between EL 495 to 460 m is 6.26 MCM (about 2.0% of live storage of Balancing/Existing reservoir).

The reservoir elevation-area-capacity curve has been prepared from the area enclosed within the contours of 1 m elevations. The volume between any two elevations is calculated using the cone formula:

$$V = \frac{H}{3} * \left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$

Where,
V =Volume between two contours
H =Contour interval
A_1 =Area at level of first contour
A_2 =Area at level of second contour
The salient features of the reservoir are listed below:

Full Reservoir Level (FRL)	:	EL 495.00 m
Minimum Draw down Level (MDDL)	:	EL 460.00 m
Gross Storage	:	6.4 MCM (0.226 TMC)
Live Storage	:	6.26 MCM (0.22TMC)
Dead Storage	:	0.14 MCM (0.005TMC)
Length of Embankment Dam	:	1200 m
Maximum Height of Embankment Dam	:	53.0 m

The reservoir elevation-area-capacity computation is given in Table 8-2and in Figure 8-2.

Table 8-2: Elevation-Area-Capacity

EL (m)	Area (Ha.)	Volume bet. EL (MCM)	Cumulative Volume (MCM)
459	13.75	0.00	0.00
460	13.75	0.14	0.14
461	13.85	0.14	0.28
462	13.95	0.14	0.41
463	14.06	0.14	0.55
464	14.17	0.14	0.70

465	14.30	0.14	0.84
466	14.44	0.14	0.98
467	14.59	0.15	1.13
468	14.75	0.15	1.27
469	14.91	0.15	1.42
470	15.08	0.15	1.57
471	15.85	0.15	1.73
472	16.03	0.16	1.89
473	16.22	0.16	2.05
474	16.41	0.16	2.21
475	16.60	0.17	2.38
476	16.80	0.17	2.54
477	17.01	0.17	2.71
478	17.22	0.17	2.88
479	17.44	0.17	3.06
480	18.70	0.18	3.24
481	18.93	0.19	3.42
482	19.16	0.19	3.62
483	19.38	0.19	3.81
484	19.61	0.19	4.00
485	19.85	0.20	4.20
486	20.12	0.20	4.40
487	20.38	0.20	4.60
488	20.64	0.21	4.81
489	20.91	0.21	5.02
490	21.63	0.21	5.23
491	21.91	0.22	5.45
492	23.67	0.23	5.67
493	23.94	0.24	5.91
494	24.48	0.24	6.15
495	24.68	0.25	6.40

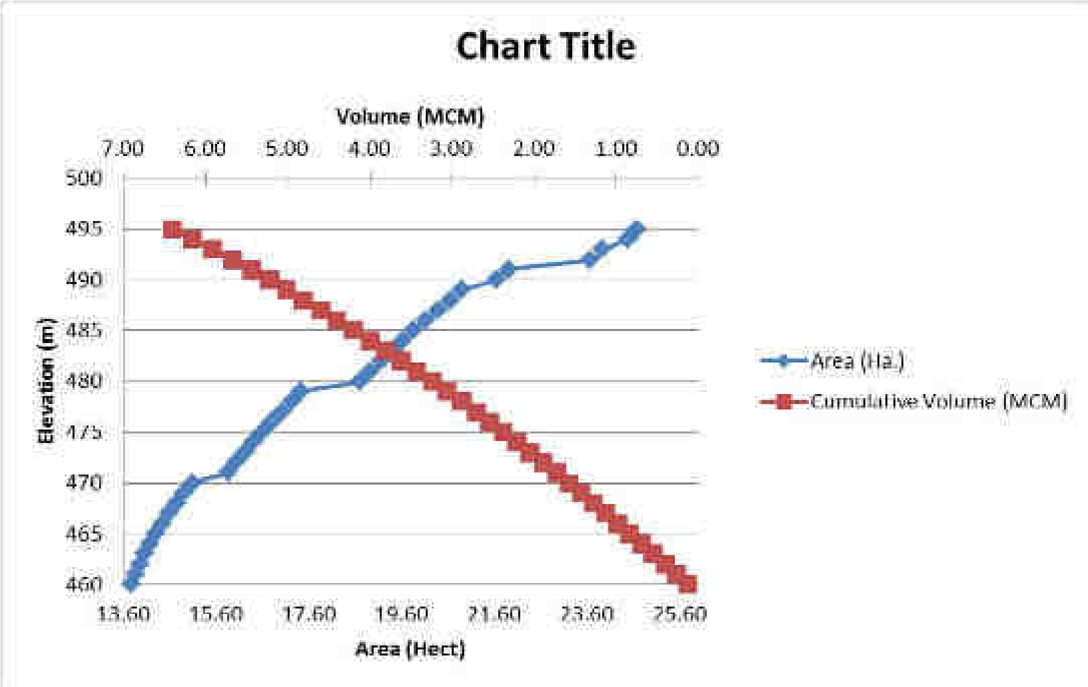


Figure 8-2: Elevation-Area-Capacity Curve of Upper Reservoir

Chapter-9

Power Potential & Installed Capacity

9 POWER POTENTIAL AND INSTALLED CAPACITY

9.1 TYPE OF SCHEME

The Chitravathi PSP is proposed as a pumped storage hydroelectric project and will operate on daily cycle with an installed generating capacity of 500 MW. The assessment of storage requirement in the reservoirs for power generation has been carried out on the basis of daily operation. The Project will generate 500 MW of peak power for about 5.61 hours by utilizing a design discharge of 297.26 Cumec with a rated head of 189.40 m and will utilize 556 MW to pump 0.22 TMC of water to the upper reservoir in 6.61 hours.

9.2 OPTIMISATION OF STORAGE CAPACITY

The existing Chitravathi balancing reservoir is proposed as lower reservoir and as such optimisation studies are not carried out for the existing lower reservoir. The alternative studies carried out for optimization of Upper reservoir is described in detail in Chapter-7 and the details of the final alternative is presented in the subsequent paragraphs.

9.3 LOCATION & RESERVOIR DETAILS

9.3.1 Upper Dam

The geographical coordinates of the proposed upper reservoir are at longitude 77°56'2.6"E & latitude is 14°34'26.93"N. The area capacity characteristics developed for the reservoir at this Upper Dam location are enclosed at Table 8-2. (Refer chapter Hydrology)

The gross storage in the upper reservoir at FRL (EL. 495.00 m) and MDDL (EL. 460.00 m) are 0.226 TMC (6.40 MCM) and 0.005 TMC (0.14 MCM) respectively. The live storage of upper reservoir is 0.221 TMC (6.26 MCM)

The Full Reservoir Level (FRL) of upper dam has been kept in order to achieve the maximum potential at site duly met the required storage capacity and lesser water spread area thereby minimising the evaporation losses.

The Minimum Draw down Level (MDDL) for the upper reservoir has been arrived at from the consideration of silt storage, requirement of water seal above intake and head variations. Considering a sediment rate of 378 cum/sq. km/year, (as a worst case scenario being transported from lower reservoir) the silt volume in 70 years would only be a small proportion of the dead storage and therefore does not influence the selection of MDDL. The MDDL has been fixed for Upper Reservoir at EL +460.0 m from the above considerations and requirement of live Pondage for proposed installation of 500 MW to operate at an average of 5.61 hours.

9.3.2 Lower Dam

The geographical coordinates of the proposed upper reservoir are at longitude 77°56'51"E and 14°33' 31"N. The existing Chitravathi Balancing Reservoir will be used as lower reservoir for the project.

The gross storage in the lower reservoir at FRL (EL. 298.0 m) and MDDL (EL. 282.55 m) are 10.226 TMC (289.6 MCM) and 0.29 TMC (8.24 MCM) respectively. The live storage of lower reservoir is 9.94 TMC (281.85 MCM).

9.4 OPTIMISATION OF INSTALLED CAPACITY AND NUMBER OF UNITS

The installed capacity of the pumped storage hydro power project is dependent on:

- The demand for peak power
- Availability of pumping energy and
- Reservoir storage and head available at the site.

The daily load factor of operation of the scheme, which in turn determines the hours of operation in a day, depends on the power system requirements. The state of Andhra Pradesh had an installed capacity of 25,251.17 MW as on January 2021. Currently the state government has commissioned 8534.21MW of renewable energy as of February 2021 comprising of 4083.57 MW of wind power, 3858.24MW of solar power, 102.6MW of small hydro, 171.25MW from Biomass, 65.45MW from Biomass Energy, 206.95MW with co-generation with Bagasse, 6.15MW from municipal solid waste, 40.01MW with industrial waste.

Government of Andhra Pradesh is also developing solar capacity of 10,000 MW through Andhra Pradesh Green Energy Corporation Ltd. and identified sites to the tune of 17,800 MW under the Renewable Energy Export Policy. This large scale injection of solar power into the grid necessitates the proposals for storage of energy systems

Considering medium and large hydro power projects, a total of 1798 MW of hydro power generating projects have been built across the Krishna, Godavari, sileru & its tributaries. This is only about 7.5% of the total installed capacity.

The PSP is planned to utilize the surplus solar energy during day time effectively for meeting the energy requirement during peak hours and also to utilize these schemes for grid balancing. Owing to highly seasonal/intermittent nature of solar/wind sources, development of suitable energy storage system to supply firm dispatchable renewable power to the Discom is required to be taken up.

As the pumped storage projects are site specific, the optimisation of installed capacity is carried out based on reservoir storage and head available at the site. Details of optimisation of reservoir storage capacity are presented in Chapter-7. Hence, the installed capacity of the power plant is arrived at 500MW with 2 units of 250MW each for 5.61 hours of generation. The net storage required in the reservoirs for generation of 500MW works out to 6.26 MCM.

9.5 DAILY REGULATION AND REQUIRED STORAGE

The plant has been proposed to be operated on daily cycle basis. A detailed study has been carried out to establish the requirement of net storage in the reservoirs. The operation of the scheme in generation or pumping, results in continuous change in the levels of the two reservoirs as also consequently change in the operating head on the machines.

The impact of continuous variations in head is assessed by simulation of operation of the scheme considering shorter time intervals of 10 minutes and presented in Table 9-1 (When the lower reservoir is at 0.22 TMC below FRL).

Generation-Operation Simulation (When the lower Reservoir is at MDDL)

(When the lower reservoir is at MDDL) and Table 9-3 (When the lower reservoir is at average level of FRL & MDDL). The average annual generation considering the three scenarios is shown in Table 9-2. Similarly Pumping simulation is presented in Table 9-4, Table 9-5 and Table 9-6.

The annual energy generation from Chitravathi PSP estimated based on the generation simulation presented in Table 9-2 works out to 963.19 MU. The annual input energy required for pumping water to the upper reservoir based on the pumping simulation presented in Table 9-5 works out to 1274.58 MU. The cycle efficiency of the plant works out to 76.99%.

There will be losses in storage in Upper reservoir due to causes like evaporation, transmission etc., A pumped storage scheme does not require continuous flow of water as in a conventional hydropower plant and stored water in the reservoir is recycled. However, the annual losses in storage in the reservoir due to evaporation etc., need to be recharged during monsoon. There will be progressive reduction in the stored volume of reservoirs due to losses. Therefore, provision for additional storage in the reservoirs will have to be made to facilitate planned operation of the PSP at 5.61 Hrs even at the critical periods, when the storage in the reservoirs is at a minimum. As the provision additional storage in the reservoir will increase the cost of the project and impact the overall viability, it is proposed that the reduction in the storage volume of reservoirs due to losses will be compensated by refilling the loss storage during monsoon periods.

Three scenarios were also considered in working out the average annual energy generation

When the lower reservoir is 0.22 TMC below the FRL: The annual energy generation works out to 924.67 MU by utilizing0.22 TMC of water for 5.33 Hours. Similarly annual energy required to pump

0.22 TMC of water when lower the reservoir is at FRL is 1204.96 MU for duration of 6.3 Hrs. Detailed working tables are presented in Table 9-1and Table 9-3.

When the lower reservoir is at MDDL: The annual energy generation works out to 1011.35 MU by utilizing 0.22 TMC of water for 5.83 Hours. Similarly annual energy required to pump 0.22 TMC of water when lower the reservoir is at MDDL is 1294.93 MU for a duration of 6.8 Hrs. Detailed working tables are presented in Table 9-3 and Table 9-6.

When the lower reservoir is at average level of FRL and MDDL: The annual energy generation works out to 953.56 MU by utilizing 0.22 TMC of water for 5.67 Hours. Similarly annual energy required to pump 0.22 TMC of water when lower the reservoir is at average reservoir level is 1253.15 MU for a duration of 6.67 Hrs. Detailed working tables are presented in Table 9-2 and Table 9-5.

Thus the average annual energy generation and input power required is arrived at average of the three scenarios

Annual Energy Generated = (924.67+953.56+1011.35)/3 = 963.19 MU

Annual Input Power Required = (1204.96+1294.93+1253.15)/3 = 1251.01 MU

Cycle efficiency of the scheme – 76.99%

Table 9-1: Generation – Operation Simulation (When The Lower Reservoir is near to FRL)

Table 9.1: Generation – Operation Simulation (When The Lower Reservoir is near to FRL)																		
Chitravati Upper Reservoir					Chitravati Lower Reservoir													
	EL	Mcum	TMC			EL	Mcum	TMC										
FRL	495.00	6.40	0.226		FRL	298.00	289.59	10.23										
MDDL	460.00	0.14	0.005		Near FRL	297.80	283.33	9.98										
Storage for PSP		6.26	0.221		Storage for PSP		6.26	0.25										
				Chitravati Upper Reservoir						Chitravati Lower Reservoir						500 MW Generation		
Sl.No	Time (Min)	Generation (MW)	Design Discharge for 500 MW (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	500	294.99	495.00	6.40	0.18	6.22	494.20	494.60	297.80	283.33	0.18	283.51	297.80	297.80	6.14	190.66	83.3
2	10	500	296.24	494.20	6.22	0.18	6.04	493.50	493.85	297.80	283.51	0.18	283.69	297.80	297.80	6.19	189.86	83.3
3	10	500	297.41	493.50	6.04	0.18	5.87	492.80	493.15	297.80	283.69	0.18	283.86	297.80	297.80	6.24	189.11	83.3
4	10	500	298.68	492.80	5.87	0.18	5.69	492.00	492.40	297.80	283.86	0.18	284.04	297.80	297.80	6.29	188.31	83.3
5	10	500	300.04	492.00	5.69	0.18	5.51	491.20	491.60	297.80	284.04	0.18	284.22	297.80	297.80	6.35	187.45	83.3
6	10	500	301.43	491.20	5.51	0.18	5.33	490.40	490.80	297.80	284.22	0.18	284.40	297.80	297.80	6.41	186.59	83.3
7	10	500	302.82	490.40	5.33	0.18	5.14	489.60	490.00	297.80	284.40	0.18	284.59	297.80	297.80	6.47	185.73	83.3
8	10	500	304.32	489.60	5.14	0.18	4.96	488.70	489.15	297.80	284.59	0.18	284.77	297.80	297.80	6.53	184.82	83.3
9	10	500	305.92	488.70	4.96	0.18	4.78	487.80	488.25	297.80	284.77	0.18	284.95	297.80	297.80	6.60	183.85	83.3
10	10	500	307.54	487.80	4.78	0.18	4.59	486.90	487.35	297.80	284.95	0.18	285.14	297.80	297.80	6.67	182.88	83.3
11	10	500	309.19	486.90	4.59	0.19	4.41	486.00	486.45	297.80	285.14	0.19	285.32	297.80	297.80	6.74	181.91	83.3
12	10	500	310.85	486.00	4.41	0.19	4.22	485.10	485.55	297.80	285.32	0.19	285.51	297.80	297.80	6.81	180.94	83.3
13	10	500	312.63	485.10	4.22	0.19	4.03	484.10	484.60	297.80	285.51	0.19	285.70	297.80	297.80	6.89	179.91	83.3
14	10	500	314.52	484.10	4.03	0.19	3.85	483.10	483.60	297.80	285.70	0.19	285.89	297.80	297.80	6.97	178.83	83.3
15	10	500	316.44	483.10	3.85	0.19	3.66	482.20	482.65	297.80	285.89	0.19	286.07	297.90	297.85	7.06	177.74	83.3
16	10	500	318.39	482.20	3.66	0.19	3.46	481.20	481.70	297.90	286.07	0.19	286.27	297.90	297.90	7.15	176.65	83.3
17	10	500	320.46	481.20	3.46	0.19	3.27	480.10	480.65	297.90	286.27	0.19	286.46	297.90	297.90	7.24	175.51	83.3
18	10	500	322.57	480.10	3.27	0.19	3.08	479.10	479.60	297.90	286.46	0.19	286.65	297.90	297.90	7.34	174.36	83.3
19	10	500	324.70	479.10	3.08	0.19	2.88	478.00	478.55	297.90	286.65	0.19	286.85	297.90	297.90	7.43	173.22	83.3
20	10	500	327.08	478.00	2.88	0.20	2.69	476.80	477.40	297.90	286.85	0.20	287.04	297.90	297.90	7.54	171.96	83.3
21	10	500	329.61	476.80	2.69	0.20	2.49	475.60	476.20	297.90	287.04	0.20	287.24	297.90	297.90	7.66	170.64	83.3
22	10	500	332.18	475.60	2.49	0.20	2.29	474.40	475.00	297.90	287.24	0.20	287.44	297.90	297.90	7.78	169.32	83.3
23	10	500	334.79	474.40	2.29	0.20	2.09	473.20	473.80	297.90	287.44	0.20	287.64	297.90	297.90	7.90	168.00	83.3
24	10	500	337.46	473.20	2.09	0.20	1.89	472.00	472.60	297.90	287.64	0.20	287.84	297.90	297.90	8.03	166.67	83.3
25	10	500	340.28	472.00	1.89	0.20	1.68	470.70	471.35	297.90	287.84	0.20	288.05	297.90	297.90	8.16	165.29	83.3
26	10	500	343.40	470.70	1.68	0.21	1.48	469.30	470.00	297.90	288.05	0.21	288.25	297.90	297.90	8.31	163.79	83.3
27	10	500	346.71	469.30	1.48	0.21	1.27	467.90	468.60	297.90	288.25	0.21	288.46	297.90	297.90	8.48	162.22	83.3
28	10	500	350.08	467.90	1.27	0.21	1.06	466.50	467.20	297.90	288.46	0.21	288.67	297.90	297.90	8.64	160.66	83.3
29	10	500	353.67	466.50	1.06	0.21	0.85	465.00	465.75	297.90	288.67	0.21	288.88	297.90	297.90	8.82	159.03	83.3
30	10	500	357.47	465.00	0.85	0.21	0.63	463.50	464.25	297.90	288.88	0.21	289.10	297.90	297.90	9.01	157.34	83.3
31	10	500	361.37	463.50	0.63	0.22	0.42	462.00	462.75	297.90	289.10	0.22	289.32	297.90	297.90	9.21	155.64	83.3
32	10	500	365.51	462.00	0.42	0.22	0.20	460.40	461.20	297.90	289.32	0.22	289.53	297.90	297.90	9.42	153.88	83.3
	320					0.22												2666.67
	5.33																	
	Annual Energy Generation =				**2667**	**X 365 X 0.95 /1000 =**			**924.67**	**MU**								
	Total Annual Energy Generation (A)							**=**	**924.67**	**MU**								

Table 9-2: Generation – Operation Simulation (When the Lower Reservoir is at MDDL)

Table 9.2: Generation – Operation Simulation (When the Lower Reservoir is at MDDL)																		
Chitravati Upper Reservoir					**Chitravati Lower Reservoir**													
	EL	Mcum	TMC			EL	Mcum	TMC										
FRL	495.00	6.40	0.23		FRL	298.00	289.59	10.23										
MDDL	460.00	0.14	0.00		MDDL	282.60	28.36	0.30										
Storage for PSP		6.26	0.22		Storage for PSP		261.23	9.93										
				Chitravati Upper Reservoir						Chitravati Lower Reservoir						500 MW Generation		
Sl.No	Time (Min)	Generation (MW)	Design Discharge for 500 MW (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	500	274.02	495.00	6.40	0.16	6.23	494.30	494.65	282.60	28.36	0.16	28.52	285.60	284.10	5.29	205.26	83.3
2	10	500	277.15	494.30	6.23	0.17	6.07	493.60	493.95	285.60	28.52	0.17	28.69	285.60	285.60	5.42	202.93	83.3
3	10	500	278.17	493.60	6.07	0.17	5.90	492.90	493.25	285.60	28.69	0.17	28.86	285.60	285.60	5.46	202.19	83.3
4	10	500	279.19	492.90	5.90	0.17	5.73	492.20	492.55	285.60	28.86	0.17	29.03	285.60	285.60	5.50	201.45	83.3
5	10	500	280.22	492.20	5.73	0.17	5.57	491.50	491.85	285.60	29.03	0.17	29.19	285.60	285.60	5.54	200.71	83.3
6	10	500	281.41	491.50	5.57	0.17	5.40	490.70	491.10	285.60	29.19	0.17	29.36	285.70	285.65	5.58	199.87	83.3
7	10	500	282.68	490.70	5.40	0.17	5.23	489.90	490.30	285.70	29.36	0.17	29.53	285.70	285.70	5.63	198.97	83.3
8	10	500	283.82	489.90	5.23	0.17	5.06	489.20	489.55	285.70	29.53	0.17	29.70	285.70	285.70	5.68	198.17	83.3
9	10	500	285.04	489.20	5.06	0.17	4.89	488.30	488.75	285.70	29.70	0.17	29.87	285.70	285.70	5.73	197.32	83.3
10	10	500	286.35	488.30	4.89	0.17	4.71	487.50	487.90	285.70	29.87	0.17	30.05	285.70	285.70	5.78	196.42	83.3
11	10	500	287.67	487.50	4.71	0.17	4.54	486.70	487.10	285.70	30.05	0.17	30.22	285.80	285.75	5.83	195.52	83.3
12	10	500	289.09	486.70	4.54	0.17	4.37	485.80	486.25	285.80	30.22	0.17	30.39	285.80	285.80	5.89	194.56	83.3
13	10	500	290.52	485.80	4.37	0.17	4.19	484.90	485.35	285.80	30.39	0.17	30.57	285.80	285.80	5.95	193.60	83.3
14	10	500	291.97	484.90	4.19	0.18	4.02	484.00	484.45	285.80	30.57	0.18	30.74	285.80	285.80	6.01	192.64	83.3
15	10	500	293.43	484.00	4.02	0.18	3.84	483.10	483.55	285.80	30.74	0.18	30.92	285.80	285.80	6.07	191.68	83.3
16	10	500	294.99	483.10	3.84	0.18	3.67	482.20	482.65	285.80	30.92	0.18	31.09	285.90	285.85	6.14	190.66	83.3
17	10	500	296.57	482.20	3.67	0.18	3.49	481.30	481.75	285.90	31.09	0.18	31.27	285.90	285.90	6.20	189.65	83.3
18	10	500	298.17	481.30	3.49	0.18	3.31	480.30	480.80	285.90	31.27	0.18	31.45	285.90	285.90	6.27	188.63	83.3
19	10	500	299.79	480.30	3.31	0.18	3.13	479.40	479.85	285.90	31.45	0.18	31.63	285.90	285.90	6.34	187.61	83.3
20	10	500	301.51	479.40	3.13	0.18	2.95	478.30	478.85	285.90	31.63	0.18	31.81	285.90	285.90	6.41	186.54	83.3
21	10	500	303.35	478.30	2.95	0.18	2.77	477.30	477.80	285.90	31.81	0.18	31.99	285.90	285.90	6.49	185.41	83.3
22	10	500	305.30	477.30	2.77	0.18	2.58	476.20	476.75	285.90	31.99	0.18	32.18	286.00	285.95	6.57	184.23	83.3
23	10	500	307.36	476.20	2.58	0.18	2.40	475.10	475.65	286.00	32.18	0.18	32.36	286.00	286.00	6.66	182.99	83.3
24	10	500	309.37	475.10	2.40	0.19	2.21	474.00	474.55	286.00	32.36	0.19	32.55	286.00	286.00	6.75	181.80	83.3
25	10	500	311.50	474.00	2.21	0.19	2.03	472.80	473.40	286.00	32.55	0.19	32.73	286.00	286.00	6.84	180.56	83.3
26	10	500	313.66	472.80	2.03	0.19	1.84	471.70	472.25	286.00	32.73	0.19	32.92	286.00	286.00	6.94	179.31	83.3
27	10	500	315.96	471.70	1.84	0.19	1.65	470.50	471.10	286.00	32.92	0.19	33.11	286.10	286.05	7.04	178.01	83.3
28	10	500	318.49	470.50	1.65	0.19	1.46	469.20	469.85	286.10	33.11	0.19	33.30	286.10	286.10	7.15	176.60	83.3
29	10	500	321.06	469.20	1.46	0.19	1.26	467.90	468.55	286.10	33.30	0.19	33.49	286.10	286.10	7.27	175.18	83.3
30	10	500	323.68	467.90	1.26	0.19	1.07	466.60	467.25	286.10	33.49	0.19	33.69	286.10	286.10	7.39	173.76	83.3
31	10	500	326.46	466.60	1.07	0.20	0.87	465.20	465.90	286.10	33.69	0.20	33.89	286.10	286.10	7.51	172.29	83.3
32	10	500	329.50	465.20	0.87	0.20	0.68	463.80	464.50	286.10	33.89	0.20	34.08	286.20	286.15	7.66	170.69	83.3
33	10	500	332.61	463.80	0.68	0.20	0.48	462.40	463.10	286.20	34.08	0.20	34.28	286.20	286.20	7.80	169.10	83.3
34	10	500	335.68	462.40	0.48	0.20	0.28	461.00	461.70	286.20	34.28	0.20	34.48	286.20	286.20	7.94	167.56	83.3
35	10	500	337.23	461.00	0.28	0.20	0.07	461.00	461.00	286.20	34.48	0.20	34.69	286.20	286.20	8.02	166.78	83.3
	350					0.22												2916.67
	5.83																	
	Annual Energy Generation =				**2917**	**X 365 X 0.95 /1000 =**			**1011.35**	**MU**								
	Total Annual Energy Generation (A)							**=**	**1011.35**	**MU**								

Table 9-3: Operation Simulation (When the Lower Reservoir is at Average Level)

Table 9.3: Generation – Operation Simulation (When the Lower Reservoir is at Average Level)																		
Chitravati Upper Reservoir					Chitravati Lower Reservoir													
	EL	Mcum	TMC			EL	Mcum	TMC										
FRL	495.00	6.40	0.23		FRL	298.00	289.59	10.23										
MDDL	460.00	0.14	0.00		Avg Lvl	290.30	87.98	3.11										
Storage for PSP		6.26	0.22		Storage for PSP		201.61	7.12										
				Chitravati Upper Reservoir						Chitravati Lower Reservoir						500 MW Generation		
Sl.No	Time (Min)	Generation (MW)	Design Discharge for 500 MW (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	500	283.06	495.00	6.40	0.17	6.23	494.30	494.65	290.30	87.98	0.17	88.15	290.30	290.30	5.65	198.70	83.3
2	10	500	284.12	494.30	6.23	0.17	6.06	493.60	493.95	290.30	88.15	0.17	88.32	290.30	290.30	5.69	197.96	83.3
3	10	500	285.19	493.60	6.06	0.17	5.89	492.90	493.25	290.30	88.32	0.17	88.49	290.30	290.30	5.73	197.22	83.3
4	10	500	286.35	492.90	5.89	0.17	5.72	492.10	492.50	290.30	88.49	0.17	88.66	290.30	290.30	5.78	196.42	83.3
5	10	500	287.52	492.10	5.72	0.17	5.54	491.40	491.75	290.30	88.66	0.17	88.84	290.30	290.30	5.83	195.62	83.3
6	10	500	288.69	491.40	5.54	0.17	5.37	490.60	491.00	290.30	88.84	0.17	89.01	290.30	290.30	5.88	194.82	83.3
7	10	500	289.96	490.60	5.37	0.17	5.20	489.80	490.20	290.30	89.01	0.17	89.18	290.30	290.30	5.93	193.97	83.3
8	10	500	291.24	489.80	5.20	0.17	5.02	489.00	489.40	290.30	89.18	0.17	89.36	290.30	290.30	5.98	193.12	83.3
9	10	500	292.61	489.00	5.02	0.18	4.85	488.10	488.55	290.30	89.36	0.18	89.53	290.30	290.30	6.04	192.21	83.3
10	10	500	294.08	488.10	4.85	0.18	4.67	487.30	487.70	290.30	89.53	0.18	89.71	290.40	290.35	6.10	191.25	83.3
11	10	500	295.57	487.30	4.67	0.18	4.49	486.40	486.85	290.40	89.71	0.18	89.89	290.40	290.40	6.16	190.29	83.3
12	10	500	297.07	486.40	4.49	0.18	4.31	485.50	485.95	290.40	89.89	0.18	90.06	290.40	290.40	6.22	189.33	83.3
13	10	500	298.59	485.50	4.31	0.18	4.13	484.60	485.05	290.40	90.06	0.18	90.24	290.40	290.40	6.29	188.36	83.3
14	10	500	300.13	484.60	4.13	0.18	3.95	483.70	484.15	290.40	90.24	0.18	90.42	290.40	290.40	6.35	187.40	83.3
15	10	500	301.69	483.70	3.95	0.18	3.77	482.80	483.25	290.40	90.42	0.18	90.60	290.40	290.40	6.42	186.43	83.3
16	10	500	303.35	482.80	3.77	0.18	3.59	481.80	482.30	290.40	90.60	0.18	90.79	290.40	290.40	6.49	185.41	83.3
17	10	500	305.03	481.80	3.59	0.18	3.41	480.90	481.35	290.40	90.79	0.18	90.97	290.40	290.40	6.56	184.39	83.3
18	10	500	306.73	480.90	3.41	0.18	3.22	479.90	480.40	290.40	90.97	0.18	91.15	290.40	290.40	6.63	183.37	83.3
19	10	500	308.55	479.90	3.22	0.19	3.04	478.90	479.40	290.40	91.15	0.19	91.34	290.40	290.40	6.71	182.29	83.3
20	10	500	310.57	478.90	3.04	0.19	2.85	477.80	478.35	290.40	91.34	0.19	91.53	290.50	290.45	6.80	181.10	83.3
21	10	500	312.72	477.80	2.85	0.19	2.67	476.70	477.25	290.50	91.53	0.19	91.71	290.50	290.50	6.90	179.85	83.3
22	10	500	314.81	476.70	2.67	0.19	2.48	475.60	476.15	290.50	91.71	0.19	91.90	290.50	290.50	6.99	178.66	83.3
23	10	500	317.02	475.60	2.48	0.19	2.29	474.40	475.00	290.50	91.90	0.19	92.09	290.50	290.50	7.09	177.41	83.3
24	10	500	319.37	474.40	2.29	0.19	2.09	473.20	473.80	290.50	92.09	0.19	92.28	290.50	290.50	7.19	176.11	83.3
25	10	500	321.76	473.20	2.09	0.19	1.90	472.00	472.60	290.50	92.28	0.19	92.48	290.50	290.50	7.30	174.80	83.3
26	10	500	324.19	472.00	1.90	0.19	1.71	470.80	471.40	290.50	92.48	0.19	92.67	290.50	290.50	7.41	173.49	83.3
27	10	500	326.77	470.80	1.71	0.20	1.51	469.50	470.15	290.50	92.67	0.20	92.87	290.50	290.50	7.53	172.12	83.3
28	10	500	329.50	469.50	1.51	0.20	1.31	468.20	468.85	290.50	92.87	0.20	93.07	290.50	290.50	7.66	170.69	83.3
29	10	500	332.39	468.20	1.31	0.20	1.11	466.90	467.55	290.50	93.07	0.20	93.26	290.60	290.55	7.79	169.21	83.3
30	10	500	335.45	466.90	1.11	0.20	0.91	465.50	466.20	290.60	93.26	0.20	93.47	290.60	290.60	7.93	167.67	83.3
31	10	500	338.69	465.50	0.91	0.20	0.71	464.00	464.75	290.60	93.47	0.20	93.67	290.60	290.60	8.09	166.06	83.3
32	10	500	342.01	464.00	0.71	0.21	0.50	462.60	463.30	290.60	93.67	0.21	93.87	290.60	290.60	8.25	164.45	83.3
33	10	500	345.40	462.60	0.50	0.21	0.30	461.10	461.85	290.60	93.87	0.21	94.08	290.60	290.60	8.41	162.84	83.3
34	10	500	347.18	461.10	0.30	0.21	0.09	461.10	461.10	290.60	94.08	0.21	94.29	290.60	290.60	8.50	162.00	83.3
	340	5.67				0.223												2833.33
	Annual Energy Generation =				**2833 X 365 X 0.95 /1000 =**				**982.46**	**MU**								
	Total Annual Energy Generation (A)							**=**	**982.46**	**MU**								
Average Annual Energy Generated							=	(924.67+		982.46+		1011.35)/3		=	972.83	MU		
Average Duration of Generation							=	(5.33+		5.67+		5.83)/3		=	5.61	Hrs		

Table 9-4: Operation Simulation (When the lower reservoir is at FRL)

Table 9.4: Pumping – Operation Simulation (When the lower reservoir is at FRL)																		
Chitravati Upper Reservoir					Chitravati Lower Reservoir													
	EL	Mcum	TMC			EL	Mcum	TMC										
FRL	495.00	6.40	0.23		FRL	298.00	289.59	10.23										
MDDL	460.00	0.14	0.00		MDDL	282.60	28.36	0.30										
Storage for PSP		6.26	0.22		Storage for PSP		261.23	9.93										
				Chitravati Lower Reservoir						Chitravati Upper Reservoir						556 MW Pump input		
Sl.No	Time (Min)	Pump Capacity (MW)	Design Discharge For 556 MW Pump (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	556	306.24	298.00	289.59	0.18	289.41	297.90	297.95	460.00	0.14	0.18	0.32	461.30	460.65	6.845	169.55	92.7
2	10	556	304.00	297.90	289.41	0.18	289.23	297.90	297.90	461.30	0.32	0.18	0.50	462.60	461.95	6.746	170.80	92.7
3	10	556	301.87	297.90	289.23	0.18	289.05	297.90	297.90	462.60	0.50	0.18	0.68	463.90	463.25	6.651	172.00	92.7
4	10	556	299.84	297.90	289.05	0.18	288.87	297.90	297.90	463.90	0.68	0.18	0.86	465.10	464.50	6.562	173.16	92.7
5	10	556	297.84	297.90	288.87	0.18	288.69	297.90	297.90	465.10	0.86	0.18	1.04	466.40	465.75	6.475	174.33	92.7
6	10	556	295.87	297.90	288.69	0.18	288.51	297.90	297.90	466.40	1.04	0.18	1.22	467.60	467.00	6.390	175.49	92.7
7	10	556	293.99	297.90	288.51	0.18	288.33	297.90	297.90	467.60	1.22	0.18	1.40	468.80	468.20	6.309	176.61	92.7
8	10	556	292.14	297.90	288.33	0.18	288.16	297.90	297.90	468.80	1.40	0.18	1.57	470.00	469.40	6.230	177.73	92.7
9	10	556	290.38	297.90	288.16	0.17	287.98	297.90	297.90	470.00	1.57	0.17	1.75	471.10	470.55	6.155	178.80	92.7
10	10	556	288.72	297.90	287.98	0.17	287.81	297.90	297.90	471.10	1.75	0.17	1.92	472.20	471.65	6.085	179.83	92.7
11	10	556	287.15	297.90	287.81	0.17	287.64	297.90	297.90	472.20	1.92	0.17	2.09	473.20	472.70	6.019	180.82	92.7
12	10	556	285.59	297.90	287.64	0.17	287.47	297.90	297.90	473.20	2.09	0.17	2.26	474.30	473.75	5.953	181.80	92.7
13	10	556	284.05	297.90	287.47	0.17	287.30	297.90	297.90	474.30	2.26	0.17	2.43	475.30	474.80	5.889	182.79	92.7
14	10	556	282.60	297.90	287.30	0.17	287.13	297.90	297.90	475.30	2.43	0.17	2.60	476.30	475.80	5.829	183.73	92.7
15	10	556	281.16	297.90	287.13	0.17	286.96	297.90	297.90	476.30	2.60	0.17	2.77	477.30	476.80	5.770	184.67	92.7
16	10	556	279.73	297.90	286.96	0.17	286.79	297.90	297.90	477.30	2.77	0.17	2.94	478.30	477.80	5.712	185.61	92.7
17	10	556	278.39	297.90	286.79	0.17	286.62	297.90	297.90	478.30	2.94	0.17	3.11	479.20	478.75	5.657	186.51	92.7
18	10	556	277.13	297.90	286.62	0.17	286.46	297.90	297.90	479.20	3.11	0.17	3.27	480.10	479.65	5.606	187.36	92.7
19	10	556	275.88	297.90	286.46	0.17	286.29	297.90	297.90	480.10	3.27	0.17	3.44	481.00	480.55	5.555	188.21	92.7
20	10	556	274.64	297.90	286.29	0.16	286.13	297.90	297.90	481.00	3.44	0.16	3.60	481.90	481.45	5.506	189.06	92.7
21	10	556	273.41	297.90	286.13	0.16	285.96	297.80	297.85	481.90	3.60	0.16	3.77	482.70	482.30	5.456	189.91	92.7
22	10	556	272.19	297.80	285.96	0.16	285.80	297.80	297.80	482.70	3.77	0.16	3.93	483.60	483.15	5.408	190.76	92.7
23	10	556	271.04	297.80	285.80	0.16	285.64	297.80	297.80	483.60	3.93	0.16	4.09	484.40	484.00	5.362	191.56	92.7
24	10	556	269.98	297.80	285.64	0.16	285.47	297.80	297.80	484.40	4.09	0.16	4.26	485.20	484.80	5.320	192.32	92.7
25	10	556	268.91	297.80	285.47	0.16	285.31	297.80	297.80	485.20	4.26	0.16	4.42	486.00	485.60	5.278	193.08	92.7
26	10	556	267.86	297.80	285.31	0.16	285.15	297.80	297.80	486.00	4.42	0.16	4.58	486.80	486.40	5.237	193.84	92.7
27	10	556	266.82	297.80	285.15	0.16	284.99	297.80	297.80	486.80	4.58	0.16	4.74	487.60	487.20	5.196	194.60	92.7
28	10	556	265.78	297.80	284.99	0.16	284.83	297.80	297.80	487.60	4.74	0.16	4.90	488.40	488.00	5.156	195.36	92.7
29	10	556	264.81	297.80	284.83	0.16	284.67	297.80	297.80	488.40	4.90	0.16	5.06	489.10	488.75	5.119	196.07	92.7
30	10	556	263.85	297.80	284.67	0.16	284.52	297.80	297.80	489.10	5.06	0.16	5.21	489.90	489.50	5.082	196.78	92.7
31	10	556	262.90	297.80	284.52	0.16	284.36	297.80	297.80	489.90	5.21	0.16	5.37	490.60	490.25	5.045	197.50	92.7
32	10	556	262.02	297.80	284.36	0.16	284.20	297.80	297.80	490.60	5.37	0.16	5.53	491.30	490.95	5.011	198.16	92.7
33	10	556	261.14	297.80	284.20	0.16	284.04	297.80	297.80	491.30	5.53	0.16	5.69	492.00	491.65	4.978	198.83	92.7
34	10	556	260.27	297.80	284.04	0.16	283.89	297.80	297.80	492.00	5.69	0.16	5.84	492.70	492.35	4.944	199.49	92.7
35	10	556	259.46	297.80	283.89	0.16	283.73	297.80	297.80	492.70	5.84	0.16	6.00	493.30	493.00	4.914	200.11	92.7
36	10	556	258.72	297.80	283.73	0.16	283.58	297.80	297.80	493.30	6.00	0.16	6.15	493.90	493.60	4.886	200.69	92.7
37	10	556	257.92	297.80	283.58	0.15	283.42	297.80	297.80	493.90	6.15	0.15	6.31	494.60	494.25	4.856	201.31	92.7
38	5	556	257.31	297.80	283.42	0.08	283.35	297.80	297.80	494.60	6.31	0.08	6.39	494.90	494.75	4.833	201.78	46.3
	375	Min				0.221												3475.0
	6.3	Hrs																
	Annual Energy Generation =				3475.0	X 365 X 0.95 /1000 =			1204.96	MU								=
	Total Annual Energy Generation (A)							=	1204.96	MU								=

Table 9-5: Pumping – Operation Simulation (When the lower reservoir is at MDDL)

Table 9.5: Pumping – Operation Simulation (When the lower reservoir is at MDDL)

Chitravati Upper Reservoir	EL	Mcum	TMC	Chitravati Lower Reservoir	EL	Mcum	TMC
FRL	495.00	6.40	0.23	Near MDDL	283.70	14.74	0.50
MDDL	460.00	0.14	0.00	MDDL	282.60	8.48	0.30
Storage for PSP		6.26	0.22	Storage for PSP		6.26	0.20

				Chitravati Lower Reservoir						Chitravati Upper Reservoir						556 MW Pump input		
Sl.No	Time (Min)	Pump Capacity (MW)	Design Discharge For 556 MW Pump (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	556	283.98	283.70	14.74	0.17	14.57	283.60	283.65	460.00	0.14	0.17	0.31	461.20	460.60	5.886	182.84	92.7
2	10	556	282.17	283.60	14.57	0.17	14.40	283.60	283.60	461.20	0.31	0.17	0.48	462.40	461.80	5.811	184.01	92.7
3	10	556	280.44	283.60	14.40	0.17	14.24	283.60	283.60	462.40	0.48	0.17	0.65	463.60	463.00	5.741	185.14	92.7
4	10	556	278.74	283.60	14.24	0.17	14.07	283.60	283.60	463.60	0.65	0.17	0.81	464.80	464.20	5.671	186.27	92.7
5	10	556	277.06	283.60	14.07	0.17	13.90	283.50	283.55	464.80	0.81	0.17	0.98	465.90	465.35	5.603	187.40	92.7
6	10	556	275.39	283.50	13.90	0.17	13.74	283.50	283.50	465.90	0.98	0.17	1.14	467.10	466.50	5.536	188.54	92.7
7	10	556	273.82	283.50	13.74	0.16	13.57	283.50	283.50	467.10	1.14	0.16	1.31	468.20	467.65	5.473	189.62	92.7
8	10	556	272.25	283.50	13.57	0.16	13.41	283.40	283.45	468.20	1.31	0.16	1.47	469.30	468.75	5.410	190.71	92.7
9	10	556	270.71	283.40	13.41	0.16	13.25	283.40	283.40	469.30	1.47	0.16	1.63	470.40	469.85	5.349	191.80	92.7
10	10	556	269.31	283.40	13.25	0.16	13.09	283.40	283.40	470.40	1.63	0.16	1.80	471.40	470.90	5.294	192.79	92.7
11	10	556	267.99	283.40	13.09	0.16	12.93	283.40	283.40	471.40	1.80	0.16	1.96	472.40	471.90	5.242	193.74	92.7
12	10	556	266.62	283.40	12.93	0.16	12.77	283.30	283.35	472.40	1.96	0.16	2.12	473.40	472.90	5.189	194.74	92.7
13	10	556	265.33	283.30	12.77	0.16	12.61	283.30	283.30	473.40	2.12	0.16	2.28	474.30	473.85	5.139	195.69	92.7
14	10	556	264.11	283.30	12.61	0.16	12.45	283.30	283.30	474.30	2.28	0.16	2.43	475.30	474.80	5.092	196.59	92.7
15	10	556	262.84	283.30	12.45	0.16	12.29	283.20	283.25	475.30	2.43	0.16	2.59	476.20	475.75	5.043	197.54	92.7
16	10	556	261.58	283.20	12.29	0.16	12.13	283.20	283.20	476.20	2.59	0.16	2.75	477.20	476.70	4.994	198.49	92.7
17	10	556	260.39	283.20	12.13	0.16	11.98	283.20	283.20	477.20	2.75	0.16	2.91	478.10	477.65	4.949	199.40	92.7
18	10	556	259.28	283.20	11.98	0.16	11.82	283.20	283.20	478.10	2.91	0.16	3.06	479.00	478.55	4.907	200.26	92.7
19	10	556	258.17	283.20	11.82	0.15	11.67	283.10	283.15	479.00	3.06	0.15	3.22	479.80	479.40	4.865	201.12	92.7
20	10	556	257.07	283.10	11.67	0.15	11.51	283.10	283.10	479.80	3.22	0.15	3.37	480.70	480.25	4.824	201.97	92.7
21	10	556	256.04	283.10	11.51	0.15	11.36	283.10	283.10	480.70	3.37	0.15	3.52	481.50	481.10	4.785	202.79	92.7
22	10	556	255.08	283.10	11.36	0.15	11.21	283.10	283.10	481.50	3.52	0.15	3.68	482.30	481.90	4.749	203.55	92.7
23	10	556	254.07	283.10	11.21	0.15	11.05	283.00	283.05	482.30	3.68	0.15	3.83	483.10	482.70	4.712	204.36	92.7
24	10	556	253.12	283.00	11.05	0.15	10.90	283.00	283.00	483.10	3.83	0.15	3.98	483.80	483.45	4.677	205.13	92.7
25	10	556	252.24	283.00	10.90	0.15	10.75	283.00	283.00	483.80	3.98	0.15	4.13	484.60	484.20	4.644	205.84	92.7
26	10	556	251.24	283.00	10.75	0.15	10.60	282.90	282.95	484.60	4.13	0.15	4.28	485.40	485.00	4.608	206.66	92.7
27	10	556	250.32	282.90	10.60	0.15	10.45	282.90	282.90	485.40	4.28	0.15	4.43	486.10	485.75	4.574	207.42	92.7
28	10	556	249.45	282.90	10.45	0.15	10.30	282.90	282.90	486.10	4.43	0.15	4.58	486.90	486.50	4.542	208.14	92.7
29	10	556	248.59	282.90	10.30	0.15	10.15	282.90	282.90	486.90	4.58	0.15	4.73	487.60	487.25	4.511	208.86	92.7
30	10	556	247.74	282.90	10.15	0.15	10.00	282.80	282.85	487.60	4.73	0.15	4.88	488.30	487.95	4.480	209.58	92.7
31	10	556	246.89	282.80	10.00	0.15	9.85	282.80	282.80	488.30	4.88	0.15	5.03	489.00	488.65	4.449	210.30	92.7
32	10	556	246.11	282.80	9.85	0.15	9.71	282.80	282.80	489.00	5.03	0.15	5.18	489.70	489.35	4.421	210.97	92.7
33	10	556	245.33	282.80	9.71	0.15	9.56	282.80	282.80	489.70	5.18	0.15	5.32	490.40	490.05	4.393	211.64	92.7
34	10	556	244.49	282.80	9.56	0.15	9.41	282.70	282.75	490.40	5.32	0.15	5.47	491.10	490.75	4.363	212.36	92.7
35	10	556	243.72	282.70	9.41	0.15	9.27	282.70	282.70	491.10	5.47	0.15	5.62	491.70	491.40	4.336	213.04	92.7
36	10	556	243.06	282.70	9.27	0.15	9.12	282.70	282.70	491.70	5.62	0.15	5.76	492.30	492.00	4.312	213.61	92.7
37	10	556	242.36	282.70	9.12	0.15	8.97	282.60	282.65	492.30	5.76	0.15	5.91	492.90	492.60	4.287	214.24	92.7
38	10	556	241.65	282.60	8.97	0.14	8.83	282.60	282.60	492.90	5.91	0.14	6.05	493.50	493.20	4.262	214.86	92.7
39	10	556	241.00	282.60	8.83	0.14	8.68	282.60	282.60	493.50	6.05	0.14	6.20	494.10	493.80	4.240	215.44	92.7
40	10	556	240.36	282.60	8.68	0.14	8.54	282.60	282.60	494.10	6.20	0.14	6.34	494.70	494.40	4.217	216.02	92.7
41	3	556	239.93	282.60	8.54	0.04	8.50	282.60	282.60	494.70	6.34	0.04	6.38	494.90	494.80	4.202	216.40	27.8
	403	Min				0.221												3734.5
	6.7	Hrs																
	Annual Energy Generation =				**3734.5**	**X 365 X 0.95 /1000**		**=**	**1294.93**	**MU**								=
	Total Annual Energy Generation (A)							**=**	**1294.93**	**MU**								=

Table 9-6: Pumping – Operation Simulation (When the lower reservoir is at Average Level

Table 9.6: Pumping – Operation Simulation (When the lower reservoir is at Average Level)																		
Chitravati Upper Reservoir					**Chitravati Lower Reservoir**													
	EL	Mcum	TMC			EL	Mcum	TMC										
FRL	495.00	6.40	0.23	NearAvg		290.30	87.98	3.11										
MDDL	460.00	0.14	0.00	MDDL		282.60	8.48	0.30										
Storage for PSP		6.26	0.22		Storage for PSP		79.50	2.81										
				Chitravati Lower Reservoir						Chitravati Upper Reservoir						556 MW Pump input		
Sl.No	Time (Min)	Pump Capacity (MW)	Design Discharge For 556 MW Pump (Cumecs)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Initial Level (m)	Initial Storage (Mcum)	Power Draft (Mcum)	Final Storage (Mcum)	Final Level(m)	Average Level (m)	Head Loss (m)	Net Head (m)	Energy Generation (Mwh)
1	10	556	293.91	290.30	87.98	0.18	87.80	290.20	290.25	460.00	0.14	0.18	0.31	461.20	460.60	6.306	176.66	92.7
2	10	556	291.91	290.20	87.80	0.18	87.63	290.20	290.20	461.20	0.31	0.18	0.49	462.50	461.85	6.220	177.87	92.7
3	10	556	290.00	290.20	87.63	0.17	87.45	290.20	290.20	462.50	0.49	0.17	0.66	463.70	463.10	6.139	179.04	92.7
4	10	556	288.19	290.20	87.45	0.17	87.28	290.20	290.20	463.70	0.66	0.17	0.84	464.90	464.30	6.062	180.16	92.7
5	10	556	286.41	290.20	87.28	0.17	87.11	290.20	290.20	464.90	0.84	0.17	1.01	466.10	465.50	5.987	181.29	92.7
6	10	556	284.64	290.20	87.11	0.17	86.94	290.20	290.20	466.10	1.01	0.17	1.18	467.30	466.70	5.914	182.41	92.7
7	10	556	282.89	290.20	86.94	0.17	86.77	290.20	290.20	467.30	1.18	0.17	1.35	468.50	467.90	5.841	183.54	92.7
8	10	556	281.23	290.20	86.77	0.17	86.60	290.20	290.20	468.50	1.35	0.17	1.52	469.60	469.05	5.773	184.62	92.7
9	10	556	279.66	290.20	86.60	0.17	86.43	290.20	290.20	469.60	1.52	0.17	1.68	470.70	470.15	5.709	185.66	92.7
10	10	556	278.11	290.20	86.43	0.17	86.27	290.10	290.15	470.70	1.68	0.17	1.85	471.70	471.20	5.646	186.70	92.7
11	10	556	276.57	290.10	86.27	0.17	86.10	290.10	290.10	471.70	1.85	0.17	2.02	472.80	472.25	5.583	187.73	92.7
12	10	556	275.12	290.10	86.10	0.17	85.93	290.10	290.10	472.80	2.02	0.17	2.18	473.80	473.30	5.525	188.72	92.7
13	10	556	273.75	290.10	85.93	0.16	85.77	290.10	290.10	473.80	2.18	0.16	2.35	474.80	474.30	5.470	189.67	92.7
14	10	556	272.39	290.10	85.77	0.16	85.61	290.10	290.10	474.80	2.35	0.16	2.51	475.80	475.30	5.416	190.62	92.7
15	10	556	271.11	290.10	85.61	0.16	85.44	290.10	290.10	475.80	2.51	0.16	2.67	476.70	476.25	5.365	191.52	92.7
16	10	556	269.84	290.10	85.44	0.16	85.28	290.10	290.10	476.70	2.67	0.16	2.83	477.70	477.20	5.315	192.41	92.7
17	10	556	268.59	290.10	85.28	0.16	85.12	290.10	290.10	477.70	2.83	0.16	3.00	478.60	478.15	5.266	193.32	92.7
18	10	556	267.40	290.10	85.12	0.16	84.96	290.10	290.10	478.60	3.00	0.16	3.16	479.50	479.05	5.219	194.17	92.7
19	10	556	266.23	290.10	84.96	0.16	84.80	290.10	290.10	479.50	3.16	0.16	3.32	480.40	479.95	5.174	195.02	92.7
20	10	556	265.13	290.10	84.80	0.16	84.64	290.10	290.10	480.40	3.32	0.16	3.48	481.20	480.80	5.131	195.83	92.7
21	10	556	264.05	290.10	84.64	0.16	84.48	290.00	290.05	481.20	3.48	0.16	3.63	482.00	481.60	5.089	196.64	92.7
22	10	556	262.90	290.00	84.48	0.16	84.33	290.00	290.00	482.00	3.63	0.16	3.79	482.90	482.45	5.045	197.50	92.7
23	10	556	261.83	290.00	84.33	0.16	84.17	290.00	290.00	482.90	3.79	0.16	3.95	483.70	483.30	5.004	198.30	92.7
24	10	556	260.83	290.00	84.17	0.16	84.01	290.00	290.00	483.70	3.95	0.16	4.11	484.50	484.10	4.966	199.07	92.7
25	10	556	259.83	290.00	84.01	0.16	83.86	290.00	290.00	484.50	4.11	0.16	4.26	485.30	484.90	4.928	199.83	92.7
26	10	556	258.91	290.00	83.86	0.16	83.70	290.00	290.00	485.30	4.26	0.16	4.42	486.00	485.65	4.893	200.54	92.7
27	10	556	257.99	290.00	83.70	0.15	83.55	290.00	290.00	486.00	4.42	0.15	4.57	486.80	486.40	4.858	201.26	92.7
28	10	556	257.01	290.00	83.55	0.15	83.39	290.00	290.00	486.80	4.57	0.15	4.73	487.60	487.20	4.821	202.02	92.7
29	10	556	256.10	290.00	83.39	0.15	83.24	290.00	290.00	487.60	4.73	0.15	4.88	488.30	487.95	4.787	202.74	92.7
30	10	556	255.26	290.00	83.24	0.15	83.08	290.00	290.00	488.30	4.88	0.15	5.03	489.00	488.65	4.756	203.41	92.7
31	10	556	254.31	290.00	83.08	0.15	82.93	289.90	289.95	489.00	5.03	0.15	5.18	489.80	489.40	4.721	204.17	92.7
32	10	556	253.36	289.90	82.93	0.15	82.78	289.90	289.90	489.80	5.18	0.15	5.34	490.50	490.15	4.685	204.94	92.7
33	10	556	252.59	289.90	82.78	0.15	82.63	289.90	289.90	490.50	5.34	0.15	5.49	491.10	490.80	4.657	205.56	92.7
34	10	556	251.83	289.90	82.63	0.15	82.48	289.90	289.90	491.10	5.49	0.15	5.64	491.80	491.45	4.629	206.18	92.7
35	10	556	251.07	289.90	82.48	0.15	82.33	289.90	289.90	491.80	5.64	0.15	5.79	492.40	492.10	4.601	206.80	92.7
36	10	556	250.32	289.90	82.33	0.15	82.18	289.90	289.90	492.40	5.79	0.15	5.94	493.10	492.75	4.574	207.42	92.7
37	10	556	249.57	289.90	82.18	0.15	82.03	289.90	289.90	493.10	5.94	0.15	6.09	493.70	493.40	4.546	208.05	92.7
38	10	556	248.88	289.90	82.03	0.15	81.88	289.90	289.90	493.70	6.09	0.15	6.24	494.30	494.00	4.521	208.62	92.7
39	10	556	248.20	289.90	81.88	0.15	81.73	289.90	289.90	494.30	6.24	0.15	6.39	494.90	494.60	4.496	209.20	92.7
	390	Min				0.221						0.22						3614.0
	6.50	Hrs																
	Annual Energy Generation =				**3614.0**	**X 365 X 0.95 /1000 =**			**1253.15**	**MU**								=
		Total Annual Energy Generation (A)						=	**1253.15**	**MU**								=
Average Annual Energy Required for pumping						=	(1204.96+		1253.15+		1294.93)/3		=	1251.01	MU			-
Average Duration for Pumping						=	(6.25+		6.50+		6.72)/3		=	6.49	Hrs			-

Chapter-10

Design of Civil Structures

10 DESIGN OF CIVIL STRUCTURES

10.1 GENERAL

The existing Chitravathi Balancing Reservoir project is located near Parnapalli Village in Anantapur district, Andhra Pradesh on the river Chitravathi which is a tributary of the Pennar River. The purpose of this project is to provide irrigation to the two districts namely Kadapa, Anantapur. This reservoir is also known as Sri. Penchikala Basi Reddy Chitravathi Balancing Reservoir.

The catchment area at the dam site is 5431 sq. km. The reservoir has Gross storage of 283.1 MCM (10 TMC) and Dead storage 1.25 MCM (0.044 TMC). The Chitravathi dam is having length 832.75m.

It is envisaged to utilise the existing Chitravathi Reservoir as Lower pond for the proposed PSP scheme by locating upper pond at a suitable higher location in the vicinity.

The proposed Chitravathi Pumped Storage project envisages utilization of available head between newly constructed upper dam and existing Chitravathi reservoir as lower pond. An Underground Power House (UGPH) will be located in between two reservoirs. Both the reservoirs are interconnected through water conductor and the generator and turbines installed at the power house in between the reservoirs.

10.2 SELECTION OF LAYOUT GENERAL

The concept of pumped storage Projects are broadly categorized in two types as under: -

- ❖ Closed-loop pumped storage projects are not continuously connected to a naturally-flowing water feature.
- ❖ Open-loop pumped storage projects are continuously connected to a naturally-flowing water feature.

The Proposed scheme is categorized as Open loop Pump Storage type. The Lower reservoir is an existing reservoir namely Chitravathi Balancing Reservoir which is connected to natural Chitravathi river. The Upper reservoir is proposed as an artificial reservoir at higher elevation to gain the available head.

10.3 PROPOSED LAYOUT OF THE PROJECT

Accordingly, the existing Chitravathi Balancing Reservoir has been proposed as lower reservoir for the Pumped storage scheme with Full Reservoir Level of 298 m and Minimum draw down level of 282.55m. An artificial Reservoir is proposed as upper Reservoir which is constructed by excavating a Pit and forming partial embankment/bund at Elevation-495.0m. The live storage capacity for pump storage scheme required is only 6.26 MCM (0.22 TMC). The proposed project will generate 500 MW of power by utilizing net rated head of 189.40 m. The water from the upper reservoir will be diverted through Power House and TRT to the existing lower reservoir. The water will be pumped back to the upper reservoir through TRT-Reversible Turbines-pressure shaft-HRT to upper reservoir.

The project also comprises of a lower intake at the adjacent of existing Chitravathi reservoir to pump the water to upper reservoir.

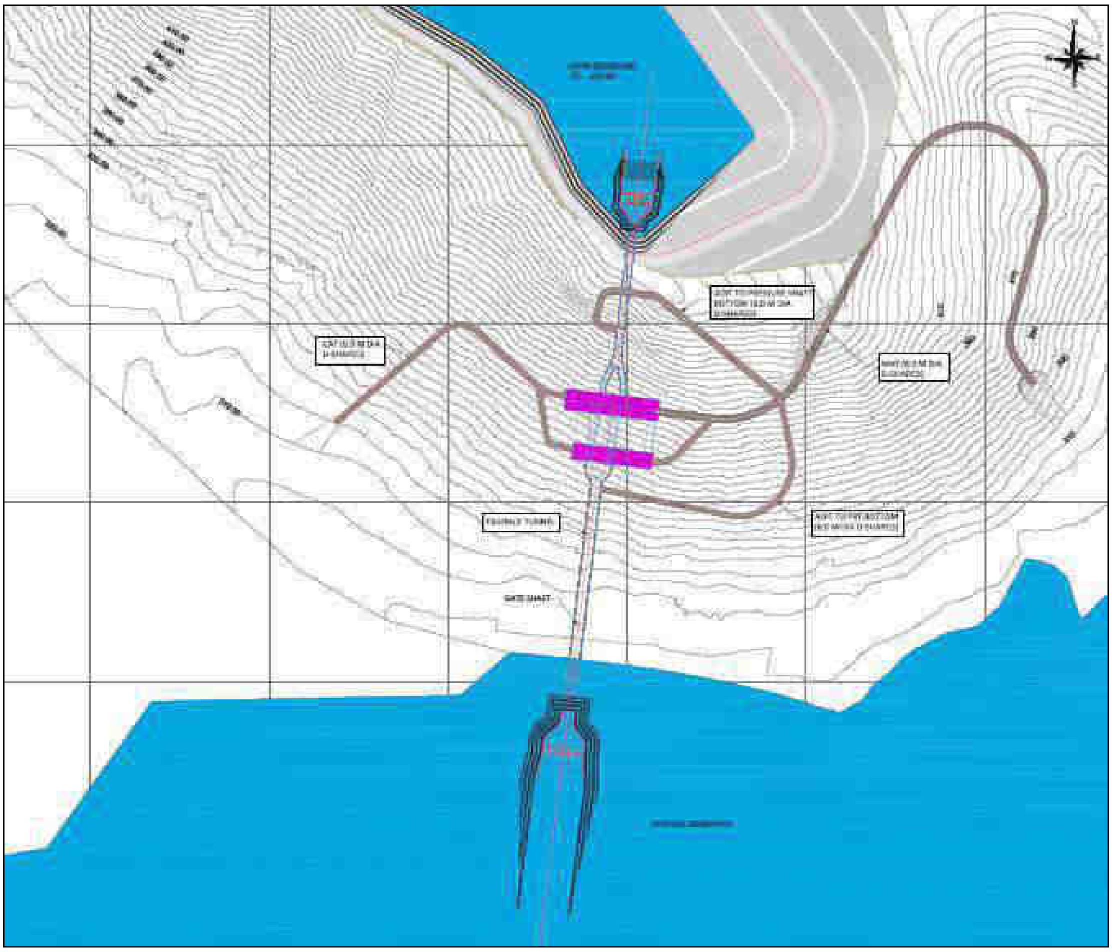


Figure 10-1: Project Layout

The proposed civil components of the project are as follows:

- An artificial upper reservoir including embankment/bund having live storage capacity of 6.26 MCM (0.22 TMC) and elevation varies from FRL 495.00 m and MDDL 460.00 m. The length of embankment dam is order of 1200 m and maximum height is 53.00 m.
- An upper intake with inclined trash rack on the left bank.
- One number 6 m dia. Adit to Pressure shaft comprising of length 294 m.
- One number of circular main penstock of 7.7 m diameter and 312 m long with bifurcates in to 5.5 m diameter and 62.0 m long two branch penstock to feed two turbine units.

- One number of MAT (Main Access Tunnel) with diameter of 8m and length of order of 882.5 m.
- One number of CAT (Cable Access Tunnel) with diameter of 6m and length of order of 373 m.
- An underground power house of 105 m (L) x 23.5 m (W) x 51.5 m (H) housing two vertical shaft reversible Francis turbines and generator unit of 250 MW each.
- Two number of draft tube to feed the water to the Tail race tunnel.
- One number of adit to TRT connected from MAT of diameter 6 m and length of 455 m.
- A number of Circular shaped Tail race tunnel of 10.7 m diameter and 300.60 m long.
- A lower intake adjacent to the existing Chitravathi reservoir to feed to water to TRT to Upper reservoir in pumping mode.
- A diversion arrangement at the lower reservoir (existing Chitravathi reservoir) for the construction of lower intake and for the connection of TRT to existing Chitravathi reservoir.

10.4 UPPER RESERVOIR

The Chitravathi PSP is proposed to utilize the water available in the existing Chitravathi Balancing reservoir located near Lingala village in Tadimarri Taluk of Anantapur/Kadapa District. The upper reservoir is formed to have a live storage capacity of 6.26 MCM (0.22 TMC).

An upper reservoir is proposed at the top of hill on the left bank of river by excavating a pit between elevation EL 459.00 m (considering 1m of dead storage from MDDL 460.00 m) to EL 495.00 m. A partial embankment/bund is also proposed on the downward side of the reservoir to create required storage. Reservoir plan and typical section showing cutting and filling are shown in Figure 10-2 and Figure 10-3.

Since the proposed scheme is a pumped storage scheme and envisages to utilize 6.26 MCM (0.22 TMC) of water from existing Chitravathi Balancing Reservoir, no modification in the operating levels are needed. Moreover, only recycling of water is proposed for Chitravathi PSP operation.

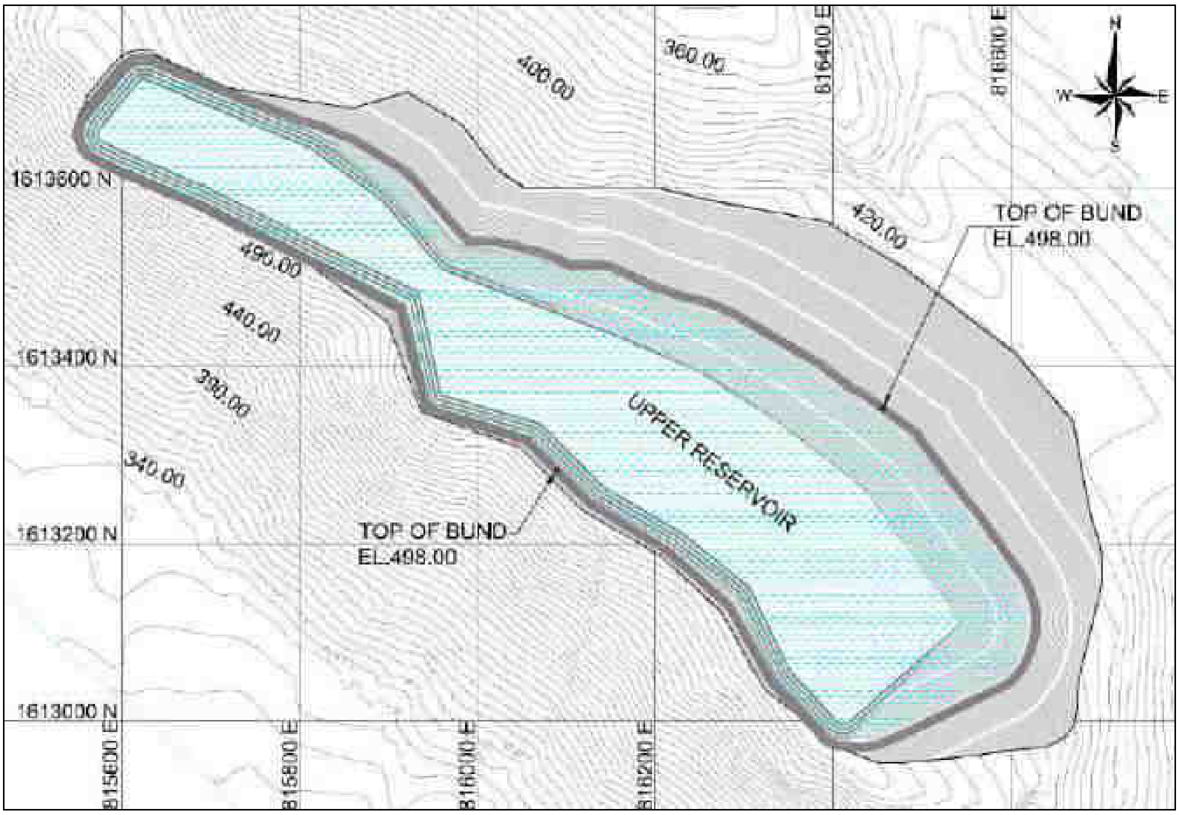


Figure 10-2: Plan of Upper Reservoir

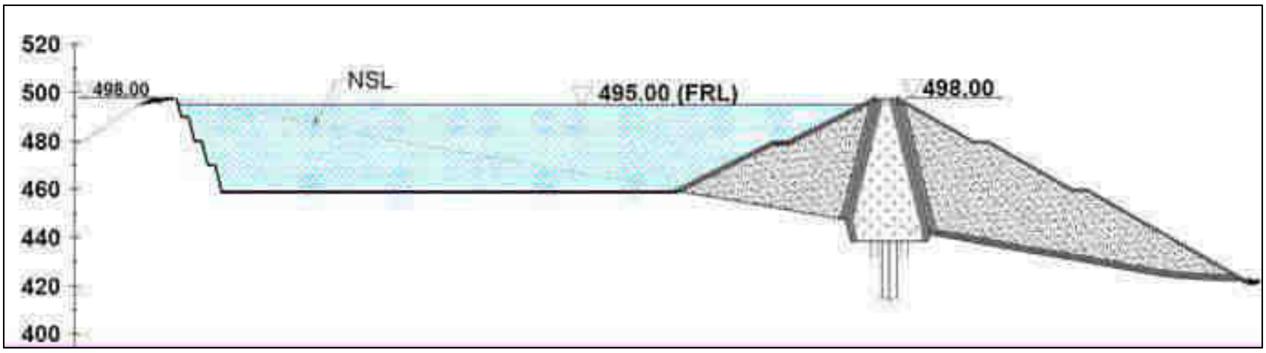


Figure 10-3: Typical Upper Reservoir Section Showing Cutting and Filling

10.4.1 Free Board for Upper Reservoir Embankment/Bund

Free board is the vertical difference in elevation between still water level and the dam crest. Its purpose is to provide protection against waves.

The evaluation of the height of the waves originating in the reservoir as a result of exposure to wind is calculated to arrive at the requirement of free board for Newly Proposed upper reservoir.

The available dam free board and the wave wall height placed on the dam crest were evaluated considering the following aspects:

- Selection of an appropriate wind speed, valid for the studied area and representative of the worst conditions;
- Geographic and effective fetch for the selected dam location and reservoir;

The wind speed was selected as per IS 875-III.

The historical series shows an absolute maximum wind speed of 140.4 Km/h was used to evaluate the wave height.

The effective fetch and wave height are calculated as per IS:10635 "Freeboard requirement in embankment dams – Guidelines"

The effective fetch length is given by the following equation:

Effective fetch length = $\Sigma fi * \cos 2\theta / \Sigma \cos\theta$

where:

fi = distances from the dam centre to the shore

θ = corresponding angles (the centre line is the direction with maximum fetch)

The effective fetch and wave height are calculated as per USBR Design standards No.13.

The following table shows the results of computed free board for the reservoirs.

Table 10-1: Free board of Upper Reservoir

As per IS : 10635 (Free board requirement in Embankment Dams)	
	Upper Reservoir
FRL/MWL	+495.00m
FB	+3.00m
TBL	+498.00m

Free Board for Chitravathi upper reservoir with margin of 2.37m. Hence; Provide TBL For Upper Reservoir = 495.00 + 0.63(Required) + 2.37(Margin) = 498.00 m

10.4.2 Upper Reservoir Surface Treatment

The upper reservoir surface area needs to be treated to prevent erosion of bed material and entering of the material in the water conductor system during its daily depletion (i.e. generation). Accordingly provision has been kept for the surface treatment which could be in the form of surfacing by impervious material/layer, grouting, development of a 3.5 m deep x 10 m wide trench in reservoir bottom and around the intake structure.

10.5 UPPER INTAKE

An upper intake is proposed on the left bank of the river. The function of upper intake structure is to allow the smooth entry of water from the upper reservoir into the water conductor system/penstock. Flow velocity in the reservoir is negligible whereas it would be of the order of 6.38 m/s in the water conductor system/penstock. As per IS Code "Guidelines for design of intakes for hydroelectric projects" generally velocity allowed in penstock are in range of 3 m/s to 6m/s. Though, higher velocities have been allowed.

Intake structures are designed, so as to provide smooth entry with transition from lower velocity to higher velocity, without turbulence and air entrainment into the water conductor system.

10.5.1 Submergence below Minimum Drawdown Level

Required submergence for the intake to avoid air entry due to vortex should be estimated. The minimum draw down level (MDDL) for the operation will be checked accordingly based on submergence required, penstock diameter and dead storage level. Submergence has been estimated based on Gordon's criteria and provision made in IS 9761:1995. These are discussed in the following paragraphs.

As per Gordon's Criteria

$$S = CV\left(\frac{D}{g}\right)^{0.5}$$

where,

s: submergence above tunnel crown

v: velocity through inlet tunnel

c: Gordon's coefficient;

c = 1.7 for symmetrical approach

c = 2.3 for asymmetrical approach

Minimum elevation of centreline and hence the invert, as evaluated from the above two criteria, is adopted for design.

IS Code Criteria

a) For large size intake, if $F_r = \frac{V}{\sqrt{gD}} \leq \frac{1}{3}$

$$\frac{S}{D} = 1\ to\ 1.5$$

b) For medium and small size intakes, if $F_r = \frac{V}{\sqrt{gD}} \geq \frac{1}{3}$

$$\frac{S}{D} = 0.5 + 2F_r$$

Where, s: submergence above intake centre line

D: height of inlet section

As per Gordon's Criteria

Minimum submergence has been evaluated using Gordon's formula considering asymmetrical flow conditions in front of the intake. The invert level as suggested by Gordon works out at EL 437.75 m.

As per IS Code Criteria

The velocity in the penstock, for design discharge of 306.30 Cumec is 6.58 m/s. The Froude number for this flow is estimated to be 0.765. Froude number of more than 0.33 implies that the intake is a medium size installation and submergence is evaluated accordingly. The required invert elevation as per IS Code 9761:1995 is worked out as EL 439.52 m.

To avoid formation of vortices and the entry of air into the water conductor system, the intake invert is proposed at EL 437.00 m**.** This would provide sufficient water seal from the minimum draw down level (MDDL).

10.5.2 Design Computation of Upper Intake

Hydraulic design of intake comprises intake setting, intake dimensioning, and sizing of trash rack structure. The results are presented in subsequent sections.

Input Data:

Full reservoir level (FRL)	:	EL 495.00 m
Minimum drawdown level (MDDL)	:	EL 460.00 m
Design discharge of water conductor system	:	297.26 Cumec
Diameter of Penstock	:	7.7 m

Intake Dimension:

The intake structure comprises of one intake located on the left bank of the river. For provision of gates, the intake structure is proposed with five bays, 4.5 m (W) x 61 m (H) separated by a 3 m thick side per and 2 m thick central pier. Total length of intake structure is 36.50 m. Dimensions of the intake bays have been fixed considering equivalent flow area of penstock. For minimizing losses, profile of the intake roof and sides has been streamlined. Bell mouth entry has been provided as recommended by IS 9761:1995 and USBR. Size of the bell mouth opening works out to be 9.2 m (W) x 12.18 m (H). The intake shall draw water from the trash racks provided above the intake floor at an angle of 10° with the vertical.

10.5.3 Trash rack

The sizing of trash racks has been worked out with following considerations;

a) Flow at MDDL gives minimum depth of flow.
b) Net area of trash rack bars is assumed as 65% of the gross area.
c) Total of 30% of the net area of the trash rack is assumed to be clogged with trash.

The floor level of the intake approach is set at EL 437.0 m having a flow depth of 23.0 m from MDDL. It is proposed to provide 5 trash rack bays of 4.5 m width each. This gives a flow through velocity on net area of 0.63 m/s for design discharge and 1.39 m/s in clogged condition. As per IS 11388:1995, the flow velocity through trash racks shall be limited to 0.75m/s for Manual cleaning of racks and to 1.5 m/s for mechanical cleaning of racks. Hence, the flow through velocity is within the limit even for manual cleaning of the rack.

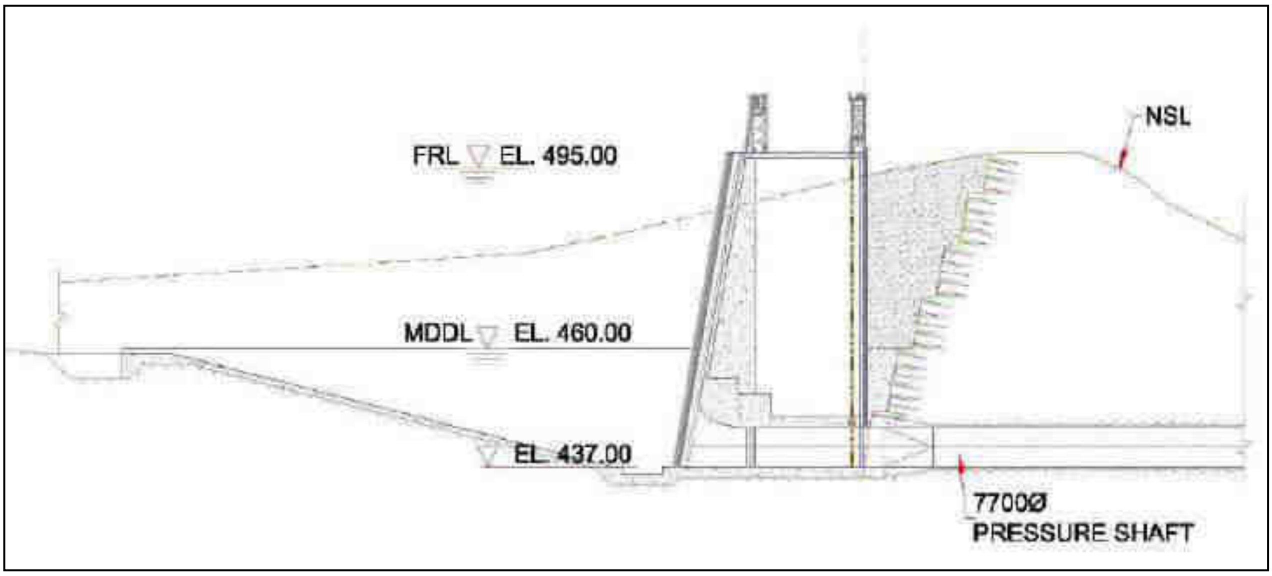


Figure 10-4: L-Section of Upper Intake

Hydraulic design calculation of upper Intake is attached as **Annexure 10-1.**

10.6 WATER CONDUCTOR SYSTEM

Alignment and profile of the waterway is also one of major elements to be optimized in the selection of optimum general layout, because it governs other layouts of structures such as switchyard, access tunnel etc.

Following aspects are considered while finalising the alignment of the waterway from the intake to the tailrace outlet;

- Shortest possible Length of waterway.
- Bends are to be avoided as far as possible.

- Both intake and tailrace outlet are to be aligned in such a way that pumping and generation mode have favourable flow characteristics.

10.6.1 Penstock

The Project is proposed with two generating units, in which water will be feed by one power intakes. Main penstock will be bifurcated near the powerhouse to feed water to the independent generating units. As the flow in penstock is quite high (297.26 Cumec,), the size of the penstock shall be of the order of 7.7 m dia. based on economical diameter calculation. The penstock shall be steel lined penstock and the flow velocity works out to be 6.38 m/s for the design discharge of 297.26 Cumec.

10.6.2 Economical Diameter of Penstock

The length of the main penstock is of the order of 312 m whereas that of the two branch penstock is 62.00 m each. Computation of economical diameter of penstock is worked out as per empirical formula based on IS Code 11625:1986.

The basic parameters and procedure for computation of economical diameter of penstock as per IS 11625 are summarized below.

Cost (Ep): Annual cost is computed based on the total cost of the structure. The annual cost is the sum of (i) annual interest on the total cost, (ii) annual depreciation and (iii) the annual operation and maintenance cost

Benefit (Et): Benefit from revenue from sale of energy against reduction of friction losses in the penstock (larger size penstock will have less velocity and therefore less head losses). The cost and benefits shall be worked out in terms of (d_e), where d_e is required to be optimised. In order to get the optimised (economical) diameter of penstock, the annualized penstock cost (E_p + E_t) is to be differentiated with respect to penstock diameter and equated to zero as below:

$$D_e = \frac{\delta\,(E_p + E_t\,)}{\delta D} = 0$$

The above computation shall be worked out based on the steel thickness required for design head (hoop stress). But in some cases, where design head is comparatively less and the size of penstock is large, the handling thickness will be higher than the designed thickness. Therefore, the optimisation study is required to be checked out for handling thickness criteria also. Both design criteria is adopted for the optimisation study of the size of the penstock.

Based on IS code 11625:1986, economical diameter of main penstock works out to be 7.5 m and 5.5 m for branch penstock. But to restrict the higher velocity in the penstock tunnel diameter of main penstock is provided as 7.7 m.

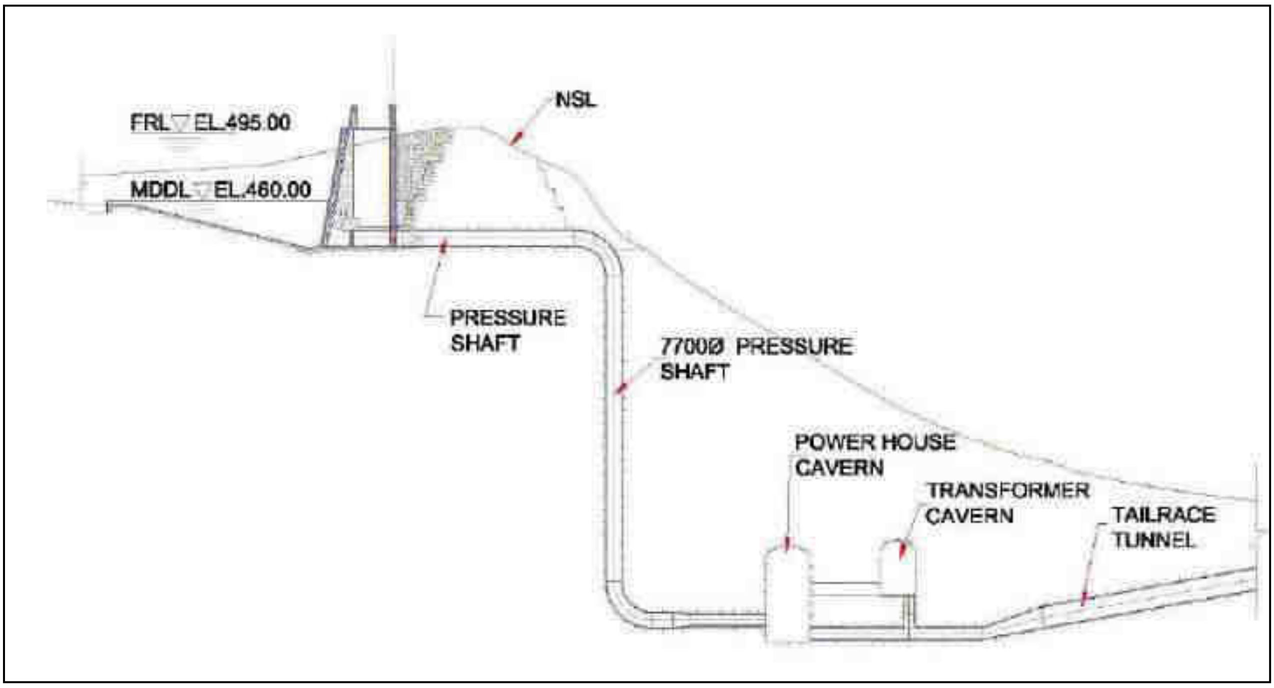


Figure 10-5: L-Section of Penstock

The hydraulic calculation for economic diameter of Main Penstock and Branch penstock is attached as **Annexure 10-2.**

10.6.3 Criteria for Surge Tank

Alternative-1:

This option envisages construction of Powerhouse out falling directly into the lower reservoir. The average ground level at this location is about EL + 460.0m. The layout plan is shown in drawing nos. AAEI/POWER/2376/GEN/005. The proposed alignment is analysed for requirement of surge shaft.

The requirement of surge tank in the water conductor system has been assessed based on the following thumb rule:

- ❖ Criteria for requirement surge tank based on L/H Ratio:
- ❖ Surge tank is not required when L/H ratio is less than 5
- ❖ Surge tank may be required when L/H ratio is in between 5 & 10 to control mass oscillation in Water Conductor System
- ❖ Surge tank is required when L/H ratio exceeds 5

Where,

L = Length of pressurized tunnel

H = Net head for power generation

L/H = 389/189.40 =2.05

Criteria for requirement of surge tank based on Water Acceleration time (TW):

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

$$Ta = \frac{L\,x\,V}{g\,x\,H}$$

Where	L	=	Length of water conductor
	V	=	velocity of flow in water conductor
	H	=	Net head
	g	=	Acceleration due to gravity

In the present case, L = 389 m, H = 189.4 m and V = 6.38 m/s which gives an acceleration time, Ta of 1.33 seconds and hence there is no requirement for a surge shaft.

Alternative-2:

This option envisages construction of Powerhouse out falling directly into the lower reservoir. The average ground level at this location is about EL + 460.0m. The layout plan and L-section are shown in drawing nos. AAEI/POWER/2376/GEN/005.The proposed alignment is analyzed for requirement of surge shaft.

The requirement of surge tank in the water conductor system has been assessed based on the following thumb rule:

- Criteria for requirement surge tank based on L/H Ratio:
- Surge tank is not required when L/H ratio is less than 5
- Surge tank may be required when L/H ratio is in between 5 & 10 to control mass oscillation in Water Conductor System

- Surge tank is required when L/H ratio exceeds 5

Where,

L = Length of pressurized tunnel

H = Net head for power generation

L/H =312/189.40 =1.64

Criteria for requirement of surge tank based on Water Acceleration time (TW):

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

$$Ta = \frac{L\,x\,V}{g\,x\,H}$$

Where	L	=	Length of water conductor
	V	=	velocity of flow in water conductor
	H	=	Net head
	g	=	Acceleration due to gravity

In the present case, L = 312 m, H = 189.4 m and V = 6.38 m/s which gives an acceleration time, Ta of 1.07 seconds and hence there is no requirement for a surge shaft.

10.7 UNDERGROUND POWERHOUSE AND UNDERGROUND TRANSFORMER CAVERN

A water conductor system comprising one number steel lined pressure tunnels bifurcated into 2 unit penstock to feed 2 nos. of vertical shaft reversible Francis turbines, 250 MW each. The units shall be housed in an underground powerhouse cavern located inside left bank of existing reservoir. Water from each machine is led through respective draft tubes to tail race tunnel and then lead the water back to existing reservoir. A transformer cavern is envisaged parallel to the powerhouse cavern for housing transformers and GIS.

10.7.1 Powerhouse Cavern

Powerhouse cavern of length 105m (including service bay and control blocks) and cross-section 23.5m (W) x 51.5m (H) has been provided to house 2 nos. vertical shafts reversible Francis turbines spaced at 22.5m c/c. The centre line of machines has been kept at El. 245.45m. The Main Inlet valves (MIV) shall also be housed inside the cavern with MIV floor at El. 239.50m. The turbine and generator floors shall be at El. 250.60m and El. 255.60m respectively. The powerhouse operating floor shall be at El. 260.60m and powerhouse crown at El. 282.00m.

A dewatering gallery has been provided on the upstream side of the units that runs along the entire length of the powerhouse and leads to drainage sump. The dewatering sump has been provided adjunct to the drainage sumps.

Water from the machines shall be released into tailrace tunnel through draft tubes. The draft tube bottom shall be at El. 232.50m.

Service bay (unloading cum erection bay) of 35m length has been provided at the same level as the operating floor i.e. El. 260.60m on the eastern side of the powerhouse. Two EOT cranes of capacity 400 tonne each, with auxiliary hook of 50/10 tonne have been provided for facilitating erection and maintenance of the equipment with top of crane beams at El. 271.90m.

Control block of 20m length has been provided opposite to the service bay on the western side of the powerhouse to accommodate control room, battery room, electrical & mechanical workshops conference room and office facilities.

10.7.2 Transformer Cavern

Transformer cavern of 90m (L) x 18.5m (W) x 30.0m (H) has been located 36m downstream of powerhouse cavern. Each generating unit at the powerhouse will be directly connected to three single phase generator step-up transformers through isolated phase bus. Total of seven (7) single-phase transformers, including one spare shall be located in the transformer cavern at El. 260.60m. Gas Insulated Switchgear (GIS) shall be housed on the floor above the transformers at El. 275.40m.

10.8 TAIL RACE TUNNEL (TRT)

One no. of 10.7 m diameter and 300.60 m long circular shape concrete lined TRT has been proposed. TRT will be provided with suitable rock support system depending upon the geological strata. Actual support system will be decided after geological investigations and analysis at DPR stage. The economical diameter of TRT works out to be 10.7 m and the calculation for the same is attached below.

Table 10-2: Economical Diameter of TRT

Diameter (m)	Total Cost (Rs)	Annual Charges (Rs)	Head Loss (m)	Net Annual Energy Loss @ Specified PLF (MU)	Annual Cost of Energy Loss (Rs)	Total Cost Annual (Rs)
8.0	86000000	129,00,000	0.64	3.01	225,43,030	354.43

8.3	90500000	135,75,000	0.53	2.48	185,24,325	320.99
8.6	95000000	142,50,000	0.44	2.05	153,28,529	295.79
8.9	99600000	149,40,000	0.36	1.71	127,66,706	277.07
9.2	104300000	156,45,000	0.31	1.43	106,97,701	263.43
9.5	109100000	163,65,000	0.26	1.21	90,15,012	253.80
9.8	114000000	171,00,000	0.22	1.02	76,37,534	247.38
10.1	118900000	178,35,000	0.19	0.87	65,02,967	243.38
10.4	124000000	186,00,000	0.16	0.74	55,63,068	241.63
10.7	129200000	193,80,000	0.14	0.64	47,80,193	241.60
11.0	134400000	201,60,000	0.12	0.55	41,24,753	242.85
11.3	139800000	209,70,000	0.10	0.48	35,73,336	245.43
11.6	145200000	217,80,000	0.09	0.42	31,07,298	248.87
11.9	150800000	226,20,000	0.08	0.36	27,11,701	253.32
12.2	156400000	234,60,000	0.07	0.32	23,74,505	258.35
12.5	162100000	243,15,000	0.06	0.28	20,85,958	264.01
12.8	168000000	252,00,000	0.05	0.25	18,38,114	270.38
13.1	173900000	260,85,000	0.05	0.22	16,24,471	277.09
13.4	179900000	269,85,000	0.04	0.19	14,39,682	284.25
13.7	186000000	279,00,000	0.04	0.17	12,79,330	291.79
14.0	192200000	288,30,000	0.03	0.15	11,39,749	299.70
14.3	198600000	297,90,000	0.03	0.14	10,17,888	308.08
14.6	205000000	307,50,000	0.03	0.12	9,11,193	316.61
14.9	211400000	317,10,000	0.02	0.11	8,17,521	325.28
15.2	218000000	327,00,000	0.02	0.10	7,35,066	334.35
15.5	224800000	337,20,000	0.02	0.09	6,62,303	343.82

					Minimum	241.60
Economical Diameter, D_{eco} =		**10.70**	**m**			
Velocity corresponding to economical diameter, V =			**3.31**	**m/s**		

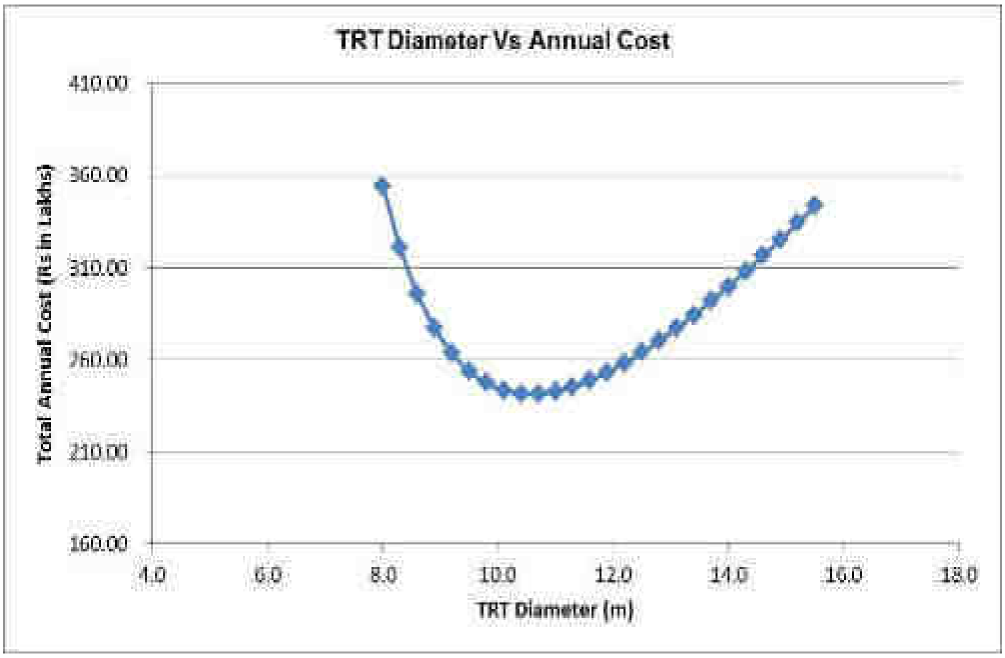


Figure 10-6: Economical Diameter of TRT

10.9 LOWER INTAKE/PUMP INTAKE

A lower intake adjacent to existing reservoir is proposed on the left bank of the river. The function of lower intake structure is to allow the smooth entry of water from the lower reservoir to the upper reservoir. Flow velocity in the reservoir is negligible whereas it would be of the order of 2.73 m/s in the tail race tunnel.

The hydraulic design of lower intake is done in similar lines as of the upper intake (refer Cl.10.5).

10.9.1 Design Computation of Lower Intake

Hydraulic design of intake comprises intake setting, intake dimensioning, and sizing of trash rack structure. The results are presented in subsequent sections.

Data:

Full reservoir level (FRL)	:	EL 298.00 m
Minimum drawdown level (MDDL)	:	EL 282.55 m
Design discharge of water conductor system	:	259.16 Cumec (pump mode)
Diameter of TRT	:	10.7 m
Sill level of Intake	:	EL 263.00 m

Intake Dimension:

The intake structure comprises of one intake located on the left bank of the river adjacent to the existing reservoir. For provision of gates, the intake structure is proposed with six bays, 5.7 m (W) x 35 m (H) separated by a 3 m thick side pier and 2 m thick central pier. Total length of intake structure is 50.50 m. Dimensions of the intake bays have been fixed considering equivalent flow area of TRT. For minimizing losses, profile of the intake roof and sides has been streamlined. Bell mouth entry has been provided as recommended by IS 9761:1995 and USBR. Size of the bell mouth opening works out to be 12.7 m (W) x 16.93 m (H). The intake shall draw water from the trash racks provided above the intake floor at an angle of 10° with the vertical.

10.9.2 Trash rack

The sizing of trash racks has been worked out with following considerations;

d) Flow at MDDL gives minimum depth of flow.
e) Net area of trash rack bars is assumed as 65% of the gross area.
f) Total of 50% of the net area of the trash rack is assumed to be clogged with trash.

The floor level of the intake approach is set at EL 263.0 m having a flow depth of 19.55 m from MDDL. It is proposed to provide 6 trash rack bays of 5.7 m width each. This gives a flow through velocity on net area of 0.72 m/s for design discharge and 1.44 m/s in clogged condition. As per IS 11388:1995, the flow velocity through trash racks shall be limited to 0.75m/s for Manual cleaning of racks and to 1.5 m/s for mechanical cleaning of racks. Hence, the flow through velocity is within the limit even for manual cleaning of the rack.

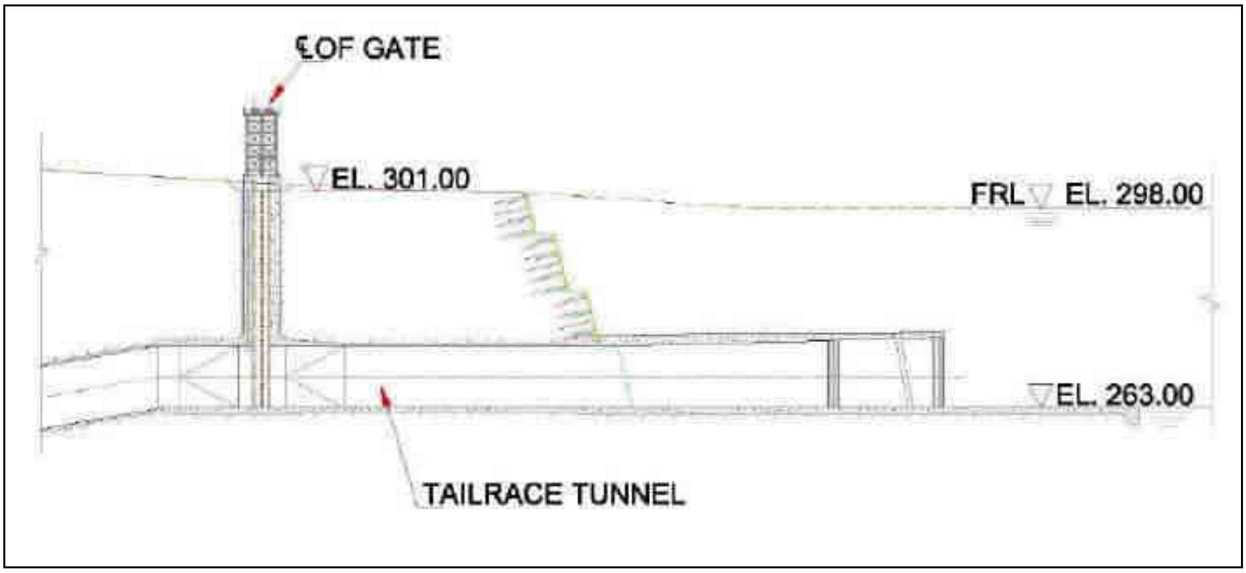


Figure 10-7: L-Section of Lower Intake/Pump Intake

Hydraulic design calculation of upper Intake is attached as **Annexure 10-3.**

10.10 HEAD LOSS IN WATER CONDUCTOR SYSTEM

Head loss in water conductor system is competed as 6.23 m in turbine mode and 4.90 m in pump mode. Hydraulic calculation for Head loss is attached as **Annexure 10-4.**

10.11 DRAWINGS OF CIVIL STRUCTURES

All the preliminary drawings of Civil Structures are appended in Volume-II “Civil Drawings”.

Chapter-11

Design of Hydro-mechanical Equipment's

11 DESIGN OF HYDRO-MECHANICAL EQUIPMENT'S

11.1 GATE COMPONENTS

A gate consists basically of three elements: leaf, embedded parts and operating device. The leaf is movable element that serves as bulkhead to the water passage and consists of skin plate and girders. The shield plate directly responsible for the water thrust is called the skin plate. The seals, components responsible for the water tightness, consist generally of rubber seals screwed on the skin plate. On the gate leaf are also attached the support elements (wheels/bearing plates, guide rollers, lifting brackets and so on).

The embedded parts are the components embedded onto the concrete, which serve to guide and house the leaf, to redistribute to the concrete the forces acting on the gate, acting also as protection to the concrete edges and support element for seal. The basic components of the embedded parts are sill beam, wheel or slide tracks, side guides, counter guides, lintel, seal seats and eventually, slot lining. The operating device is directly responsible for opening and closing of the gate. The main requirement of a gate operating device is to develop a large operating force with low power supply.

11.2 INTAKE TRASH RACKS (UPPER RESERVOIR)

The susceptibility of large inlets to clogging by debris and trash needs to be considered when estimating their hydraulic capacities. In most instances, trash racks will be needed. Trash racks and safety gates are critical elements of inlet structure design and serve several important functions.

Trash shall be cleaned by a travelling trash rack cleaning machine (TRCM).

The salient features of the trash racks are given in Table 11-1

Table 11-1: Salient Features of Intake Trash Racks (Upper Reservoir)

Parameter	Unit	Particulars
Trash Rack Panel Size	m	4.5 (w) x 4.80 (h)
Number of bays	no	5
Total Number of panels	no	15
Sill elevation	m	437.00m
MDDL	m	460.00m
FRL	m	495m
Deck elevation	m	498m
Cleaning of Trash racks		TRCM (with hydraulic grappler)

11.3 INTAKE SERVICE GATE (UPPER RESERVOIR)

Intake Service gate is intended to regulate water through the intake will be lowered during inspection and maintenance of penstock. Fixed wheel gate having downstream skin plate and sealing is proposed for the intake and shall be operated under balanced head condition by means of crack opening. Intake Gate will be operated by adequate capacity of Rope Drum Hoist.

The salient features of the gate are given in Table 11-2

Table 11-2: Salient Features of Intake Service Gate (Upper Reservoir)

Parameter	Unit	Particulars
Clear opening size	m	7.7 (w) x 7.7 (h)
Type of gate		Fixed wheel Gate
Number of vent	no	1
Number of gate	no	1
Sill elevation	m	437.00 m
MDDL	m	460.00m
FRL	m	495.00m
Deck elevation	m	498.00m
Design head	m	58.00m
Type of hoist		Fixed Rope drum hoist
Operating condition		Lowering under flowing water and lifting under balanced head

11.4 Draft Tube Gate

In order to isolate any of the units from tail race side, without affecting installation and operation of the remaining unit 2 nos. of the draft tube gate are provided. The Draft Tube Gates are bonnet type which is operated by the Hydraulic Hoists of adequate capacity. The gates shall be provided with downstream sealing considering flow from the Tail Race side.

The salient features of the tailrace tunnel gate are given in Table 11-3

Table 11-3: Salient Features of Draft Tube Gate

Parameter	Unit	Particulars
Clear opening size	m	5.50 (w) x 5.50(h)
Type of gate		Slide Type
Number of Gate	no	2 (two)
Sill elevation	m	236.81
High flood level	m	298.00
Deck elevation	m	248.41
Design head (max)	m	61.19
Type of hoist		Hydraulic Hoist

Parameter	Unit	Particulars
Operating condition		Unbalanced head

11.5 INTAKE SERVICE GATE (LOWER RESERVOIR)

Intake gate is intended to regulate water through the intake will be lowered during inspection and maintenance of Tail Race Tunnel. Fixed wheel gate having downstream skin plate and sealing is proposed for the intake and shall be operated under balanced head condition by crack opening. The gate will be operated by adequate capacity of rope drum hoist.

The salient features of the gate are given in Table 11-4

Table 11-4: Salient Features of Intake Service Gate

Parameter	Unit	Particulars
Clear opening size	m	10.7 (w) x 10.7 (h)
Type of gate		Fixed wheel Gate
Number of vent	no	1
Number of gate	no	1
Sill elevation	m	263.00 m
MDDL	m	282.50m
FRL	m	298.00m
Deck elevation	m	304.00m
Design head	m	35.00m
Type of hoist		Fixed Rope drum hoist
Operating condition		Lowering under flowing water and lifting under balanced head

11.6 INTAKE MAINTENANCE GATE (LOWER RESERVOIR)

Maintenance gate is mainly intended to undertake maintenance and repair of the Intake gate and used at upstream side. Fixed wheel vertical gate is proposed for the intake with filling valves at the top of the gate. The gate leaf shall consist of upstream skin plate and sealing. The gate shall be operated after balancing the water pressure upstream and downstream side of bulkhead gate by means of adequate capacity of Rope Drum Hoist.

The salient features of the gate are given in Table 11-5

Table 11-5: Salient Features of Intake Service Gate

Parameter	Unit	Particulars
Clear opening size	m	10.7 (w) x 10.7 (h)

Parameter	Unit	Particulars
Type of gate		Fixed wheel Gate
Number of vent	no	1
Number of gate	no	1
Sill elevation	m	263.00 m
MDDL	m	282.50m
FRL	m	298.00m
Deck elevation	m	304.00m
Design head	m	35.00m
Type of hoist		Fixed Rope drum hoist
Operating condition		Balanced water head

11.7 INTAKE TRASH RACKS (LOWER RESERVOIR)

The susceptibility of large inlets to clogging by debris and trash needs to be considered when estimating their hydraulic capacities. In most instances, trash racks will be needed. Trash racks and safety gates are critical elements of inlet structure design and serve several important functions.

The salient features of the trash racks are given in Table 11-6

Table 11-6: Salient Features of Intake Trash Racks

Parameter	Unit	Particulars
Trash Rack Panel Size	m	5.7 (w) x 4.40 (h)
Number of bays	no	6
Total Number of panels	no	18
Sill elevation	m	263.00m
MDDL	m	282.55m
FRL	m	298m
Deck elevation	m	276.00m

11.8 PENSTOCK

A 7700 mm diameter steel lined pressure shaft takes-off from Intake to carry 297.26 m^3/sec discharges to the machine.

Economic diameter studies were carried out for assigning a suitable diameter for the single penstock. The result shows that a 7700mm diameter conduit, steel lined, back filled with concrete is required.

Depending upon the head to be resisted, thickness of the plates varies from 32mm to 50mm. Maximum thickness has been restricted to 50 mm to exclude requirement of stress relieving and for ease in handling. Carbon steel conforming to ASTM A517 Grade F steel plates has been provided.

Length of each ferrule has been restricted to 2.5mtr for ease in handling. All field welded circumferential joint shall be radiographed at the contractor's workshop whereas 10% of the field joints shall be radiographed. The entire field joint shall also be subjected to ultrasonic examination. The elevation of centre line the penstock at intake is at EL 440.85 m and in machine hall EL 245.65 m. At intake there is transition from square of 7.7m x 7.7m to circular of diameter of 7.7m. The length of transit is 7.70m. Penstock diameter will be 7.70m and its length is 312.0 m and it divides into two branches for each unit of diameter 5.5 m and length is 62.0 m each. .

The 7700mm penstock bifurcates into two branches, each of 5500mm diameter feeding two turbine units. An internal sickle-type of reinforcement has been provided for even distribution of stresses in the three conduits at the bifurcation point.

The penstock shall be designed FRL + dynamic head. In machine hall at penstock centre line the static head is 249.35 m and dynamic head is considered as 35% of static head. The penstock is also checked for external pressure and suitable size of stiffeners is provided at the out surface of penstock as the critical pressure is less than the external pressure.

Design calculation of Steel Liner is attached as Annexure 11-1.

All drawings of Hydro mechanical Works are appended in Volume-II "HM Drawings".

<u>Main Technical Parameters</u>

i	No. of generating Units	2
ii	No. of Penstock	1
iii	No. of Bifurcation	1
iv	Discharge in each penstock	297.26 m^3/sec
v	Size of Inlet of transition	Square of 7700mm x 7700mm
vi	Size of outlet of transition	Circular of diameter of 7700mm
vii	Inner diameter of Penstock	77000 mm
Vii	Diameter of branch pipe each	5500 mm
ix	Length of penstock	312 m Main Penstock & 62m each of two branches after bifurcation + 7.7 m (transition)
xi	Thickness of penstock plate	32 mm to 50 mm

xii	FRL	495.00m
xiii	Centre line Penstock at Intake	440.85 m
xiv	Centre line Penstock at machine Hall	245.45 m
xv	Design head	249.35 + 35% pressure rise at turbine CL
xvi	Reference codes	IS 11639 Part 2

Material of Penstock

i	Penstock Plate Material	Carbon steel conforming to ASTM A517 Grade F or equivalent

11.9 Summary of Hydro-Mechanical Equipment

Table 11-7: Summary of Hydro-Mechanical equipment

Particulars	Intake Trash Racks (upper Reservoir)	Intake Service Gate (Upper Reservoir)	Draft Tube Gate	Intake Service Gate (Lower Reservoir)	Intake trash Rack (Lower reservoir)	Intake maintenance gate (Lower Reservoir)
Gate Type		Fixed Wheel Gate	Bonnet Type Slide Type	Fixed wheel Gate	-	Fixed wheel type
number of gates	5 Bay/ 15 Panels	1	2	1	6 Bay/ 18 Panel	1
Size of gates (wxh) in m	4.5 x 4.8 (size of one panel)	7.70 X 7.70	5.50 X 5.50	10.7 X 10.7	5.5 x 4.4 (size of one panel)	10.70 x 10.70
Skin Plate location		Downstream	Upstream (Toward Tail Race Side)	Downstream	-	upstream
Seal location		Downstream	Downstream (Toward Power House Side)	Downstream	-	upstream
Design Head	6.0m-Trash Bars 7.0m-frame	58.00	61.19	35.00	6.0m-Trash Bars 7.0m-frame	35.00

Sill level	437.00	437.00	236.81	263.00	263.00	263.00
opening condition		Balanced Condition	Un-Balanced Condition	Balanced Condition by crack opening	-	Balanced Condition
closing condition		Against flowing water	Unbalanced Condition	Against flowing water		Against flowing water
Type of hoist	Aux. hook of TRCM	Rope Drum Hoist	Hydraulic Hoist	Rope drum hoist	-	Rope Drum Hoist
Hoist capacity (t)	10	1 x 230	2x 120	1 X 320	-	1 x 255
No. X Weight of gate in MT	15x 5.5	1 x 91	2 x 47	1 x 128	18x 5	1 x 128
No. x Weight of EP's	5x 5	1x 28	2 x 15	1 x 38	6 x 5	1 x 38

Chapter-12

Design of Electro-mechanical Equipment's

12 DESIGN OF ELECTRO-MECHANICAL EQUIPMENT'S

12.1 GENERAL

The Chitravathi Pumped Storage Scheme envisages installation of reversible Pump Turbines and Generator–Motors along with associated auxiliaries having capacity matching with the outcome of the power potential studies detailed in Chapter No 9. It is proposed to house these machine units along with auxiliaries in an underground complex comprising of Service Bay, Machine Hall, Transformer cavern, Gas Insulated Switchgear Hall, Control Block etc.

The general arrangement of the powerhouse showing the powerhouse structure, Pothead yard and approach road etc. are shown in the powerhouse complex layout.

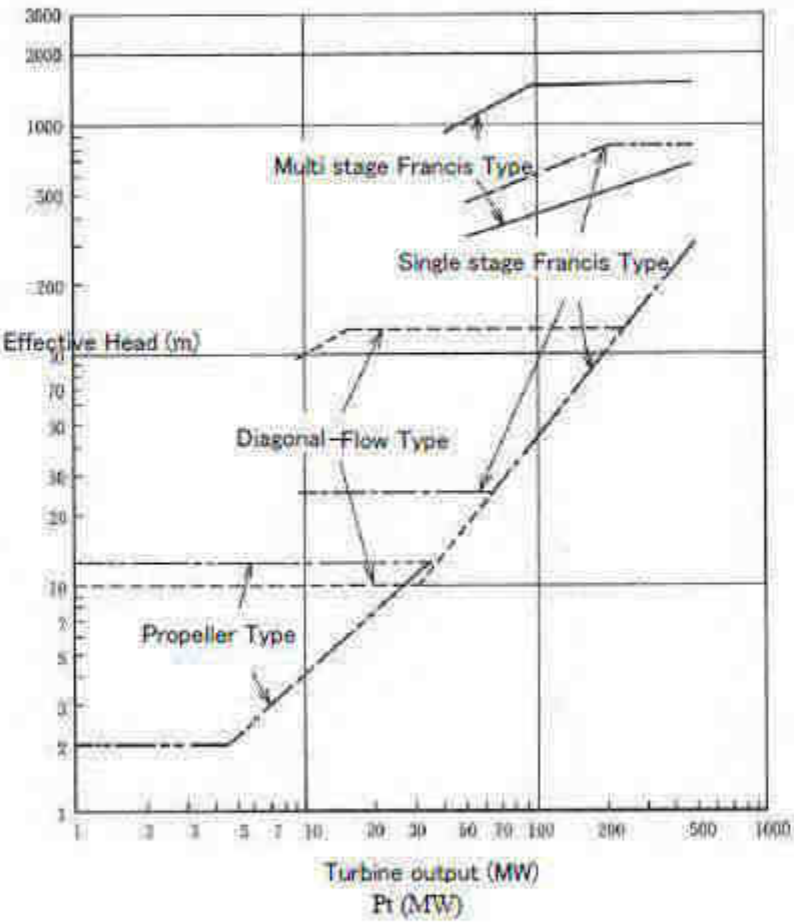
As per the Techno-commercial Feasibility Study carried out by WAPCOS, two (2) Francis type Pump Turbine Units with rated capacity of 250MW was suggested for the Chitravathi Pumped Storage Scheme. The same have been further studied with recent available information/ data and as per the updated Power Potential Study. The configuration of the plant is proposed with installation of two (2) units of Reversible Pump Turbine and Generator Motors in an Underground Powerhouse.

12.2 SIZING AND TECHNICAL SPECIFICATION OF MAIN PLANT EQUIPMENT

12.2.1 Pump-Turbine

Operating Levels & Hydraulic Parameters:

Full Reservoir Level of Upper Reservoir, FRL(U)	495.00	m
Minimum Draw Down Level of Upper Reservoir, MDDL(U)	455.00	m
Full Reservoir Level of Lower Reservoir, FRL(L)	298.00	m
Minimum Draw Down Level of Lower Reservoir, MDDL(L)	282.55	m
Maximum Gross Head, Hg max = FRL(U)-MDDL(L)	**212.45**	m
Minimum Gross Head, Hg min = MDDL(U)-FRL(L)	**162.00**	m
Gross Weighted Average Head, Hgwav = Hgmin+(2/3)*(Hgmax-Hgmin)	**195.63**	m



Based on the gross head range of 157 m to 200 m as well as the unit capacity of 250 MW, the Single stage Francis Type Pump Turbine has been chosen as the most suitable option.

Estimation of Design and Rated Head for Turbine & Pump Operation:

Average Head Losses (Turbine mode)	*HL*	*6.23*	*m*
Average Head Losses (Pump mode)	*HL*	*4.91*	*m*
Gross Minimum Head	Hg_{min}=*MDDL(U)-FRL(L)*	162.00	*m*
Maximum net head for Turbine Mode =Hgmax-HL	*Hnmax(Tur)*	206.22	*m*
Minimum net head for Turbine Mode =Hgmin-HL	*Hnmin(Tur)*	155.77	*m*
Maximum net head for Pump Mode =Hgmax+HL	*Hnmax(Pump)*	218.68	*m*
Minimum net head for Pump Mode =Hgmin+HL	*Hnmin(Pump)*	168.23	*m*
Net Design Head(Turbine)	*Hn(Tur)=Hg-HL*	189.40	*m*
Net Design Head (Pump)	*Hn(Pump)=Hg+HL*	*200.54*	*m*

12.2.2 Pump Turbine Sizing & Dimension

The following input has been used for the Pump Turbine sizing:

Installed Capacity per Unit (Turbine Mode)	250	MW
Installed Capacity per Unit (Pump Mode)	278	MW
Assumed Weighted Average Efficiency of Turbine, η_t	92.00	%
Assumed Weighted Average Efficiency of Generator, η_g	98.50	%
Assumed Weighted Average Efficiency of Pump, η_p	93.00	%
Assumed Weighted Average Efficiency of Motor, η_m	98.50	%
Rated Turbine Unit Discharge	148.63	Cumec
Rated Pump Unit Discharge	129.58	Cumec
No of Units	2	
Acceleration due to gravity, g	9.81	m/s^2

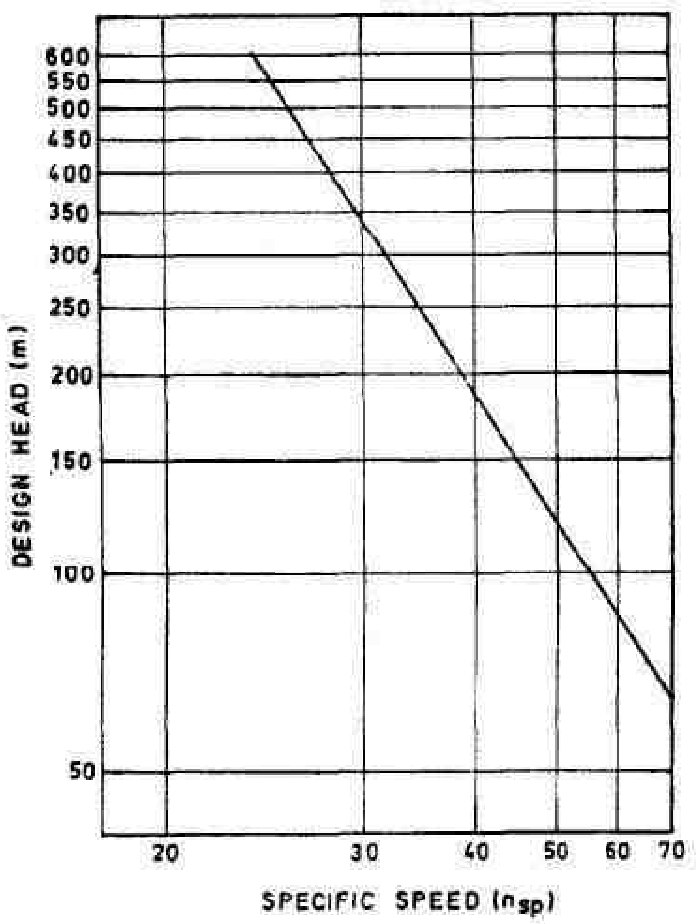
12.2.3 Pump Turbine Rated Speed

The reversible pump turbine speed is a function of specific speed, head and discharge. The upper and lower limits of specific speeds are determined from experience data of existing machines as well as empirical relations of head and specific speed as provided in standards/ guidelines such as IS: 12800-Part II, USBR Monograph EM 39 and JICA's Guidelines. For economic considerations, the trend is towards selection of turbines with higher specific speeds.

The calculated speed is not synchronous speed, therefore nearest synchronous speed is selected to enable matching of the turbine speed with generator speed, which is a function of frequency and pole pairs.

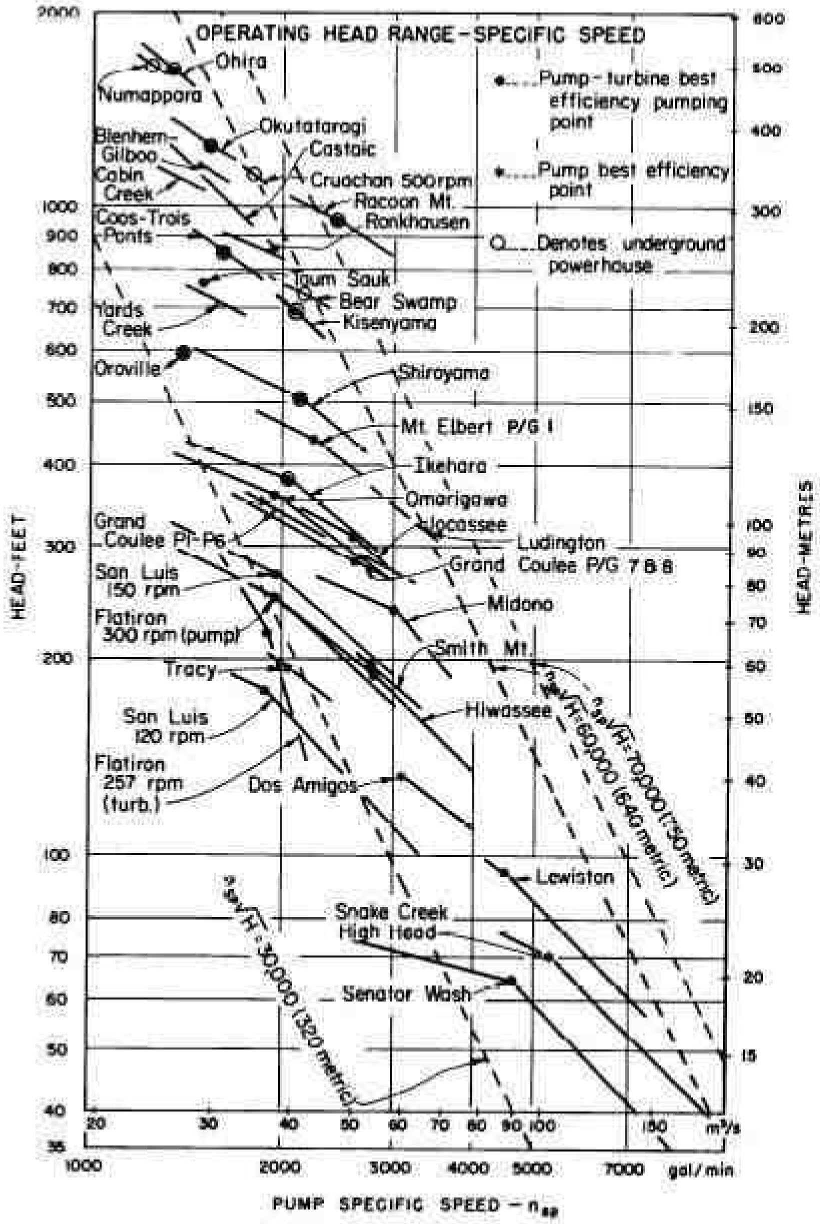
The various speed options are estimated as follows:

As per IS :12800 , corresponding to Pump rated head of 200.54 m the trial specific speed is 38 metric (refer Graph below as extracted from IS :12800)



As per USBR, Engineering Monograph EM 39 for Reversible Pump Turbines

The trial specific speed (nsp) can vary from 320/ √Hn to 750/√Hn and the optimal value being 640/√Hn. Thus the trial specific speed is worked out as 45.19 metric.



As per JICA's Guideline

The trial specific speed (nsp) can be estimated as nsp limit value = 12500/(Hnp+80)+13. Accordingly the Trial Specific Speed works out to be 57.56

An average value of the trial specific speeds as calculated above have been adopted for further study. Thus adopted trial specific speed, nst' = 46.92

The trial synchronous speed (Ns') thus works out to be = $n_{st'}$ x H_n^0.75/Qp^0.5= **219.64 rpm**

The nearest value of synchronous speeds can be 187.5 rpm, 214.3 or 250 rpm for a conventional design of the Synchronous Motor Generator with nearest even number of pair of poles. i.e. 24 poles, 28 poles or 32 poles.

It is imperative to mention that with increased Speed, the cost of the Synchronous Motor Generator is reduced and at the same time, variable speed option is also available which has the following advantages in case of a pumped storage scheme:

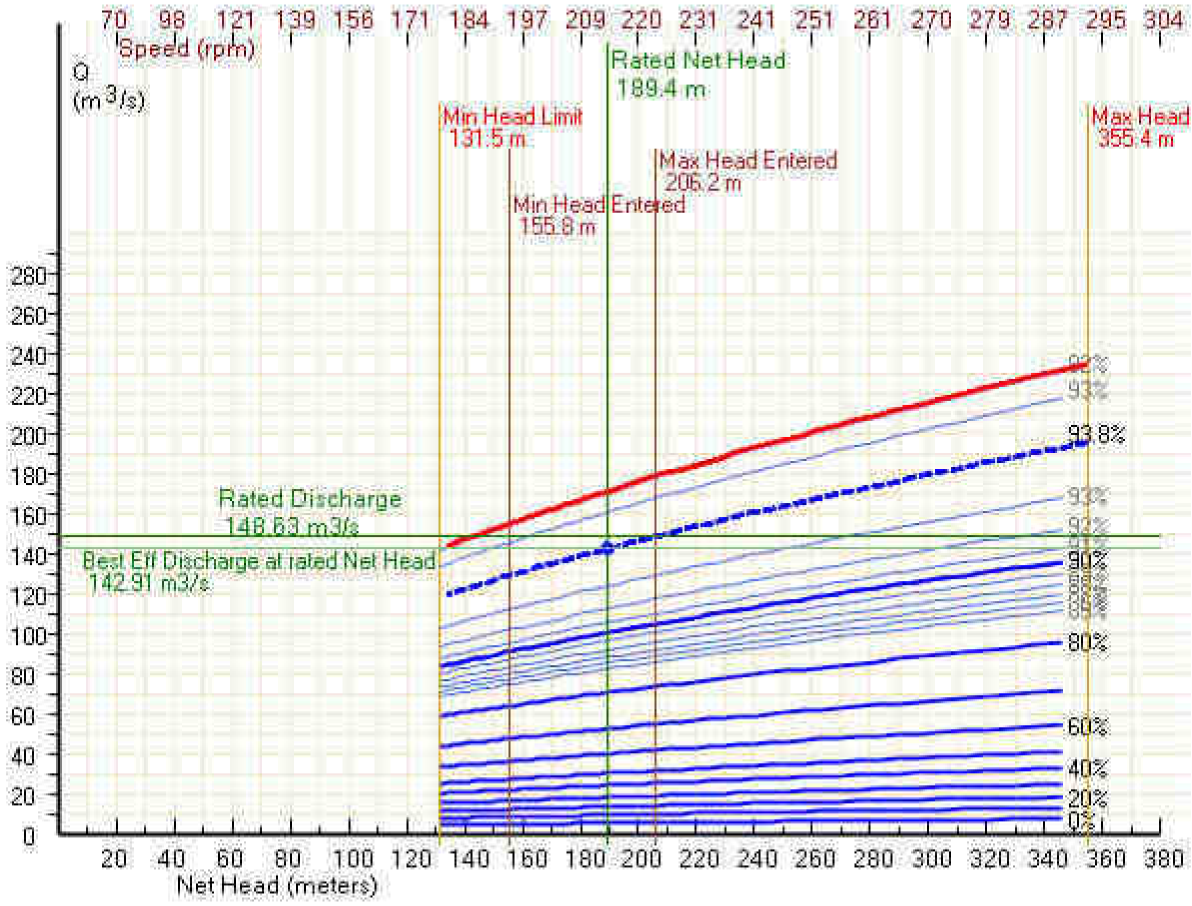
- Higher and flatter generating efficiency curve: The unit is operated at slower speed at part load to improve part load and peak efficiency. Over the typical normal operating range of the unit, this could be about 0.5% to 2.0% improvement in generating efficiency. This also depends on the energy recovery from the wound rotor excitation system; nevertheless, there is some degree of efficiency improvement.
- Pump regulation: Variable-speed operation would permit regulation in the pumping mode. For example, a unit capable of being operated as a pump with a variable-speed of +/- 7% from normal speed could potentially regulate power at +/- 20%. This is the primary advantage of variable-speed; however, at the extremes of pond elevation, it may not be possible to fully utilize this entire range because of generator-motor or pump-turbine limitations.
- Wider generating operating range: A typical generating mode operating range is from about 60% of full load to 100% of full load because of concerns for rough operation and cavitation. Operation at lower speed raises part load efficiency and should allow the unit to operate over a wider range.
- Wider operating head range: The typical head range of a single-speed pump-turbine used for preliminary studies is a minimum operating head of no less than 80% of the maximum operating head. Operation at wider head ranges will result in high cavitation levels or excessive unit submergence. Variable-speed operation allows a wider operating head range without cavitation and/or a higher unit setting as compared to a single-speed machine with a wide head range.
- Easier start-up process: For larger single-speed pump-turbines, it can be problematic to obtain the large block of power necessary for pump starting. A variable-speed pump-turbine can be started at lower speed, reducing the power that is required to bring the pump on line. This advantage is normally only applicable for very large pumps where the input power can affect the grid performance.

The main disadvantage associated with variable-speed technology is the higher equipment costs and the cost of additional civil work to accommodate the physically larger variable-speed units in the powerhouse. The best information at present indicates that the incorporation of variable-speed units roughly doubles the cost of a typical generator-motor and excitation system. Powerhouse size and civil costs will also increase to handle additions to the powerhouse that will be required for the electronic equipment and additional transformers.

Table 12-1: Comparison of Primary Characteristics

Characteristic	Single-Speed	Variable-Speed
Equipment Costs		Approximately 30% to 50% Greater
Powerhouse Size		Approximately 25% to 30% Greater
Powerhouse Civil Costs		Approximately 20% Greater
Project Schedule		Longer - Site Specific
O&M Costs		Greater
Operating Head Range	80% to 100% of Max. Head	70% to 100% of Max. Head
Generating Efficiency		Approximately 0.5% to 2% Greater
Power Adjustment Generation Mode	Approximately 60% to 100%	Approximately 50% to 100%
Power Adjustment Pump Mode	None	+/- 20%
Operating Characteristics		
Idle to Full Generation	Generally Less than 3 Minutes	Generally Less than 3 Minutes
100 Percent Pumping to 100 Percent Generation	Generally Less than 6 to 10 Minutes	Generally Less than 6 to 10 Minutes
100 Percent Generation to 100 Percent Pumping	Generally Less than 6 to 10 Minutes	Generally Less than 6 to 10 Minutes
Load Following	Seconds (i.e., 10 MW per Second)	Seconds (i.e., 10 MW per Second)
Reactive Power Changes	Instantaneously	Instantaneously
Automatic Frequency Control	No	Yes

The choice of Turbine with variable speed option has been further verified with TURBNPRO, which is an internationally accepted software for sizing of Hydro Turbine and the Performance characteristics are as given below:



Taking into account all the aspects as stated above, the speed of the Pump Turbine is adopted as 214.3 rpm being the mid value for sizing of the Pump Turbine under constant speed option. However this aspect will be further validated in consultation with the manufacturer during DPR stage for both constant.

Thus the Design specific speed at Rated Power is worked out as

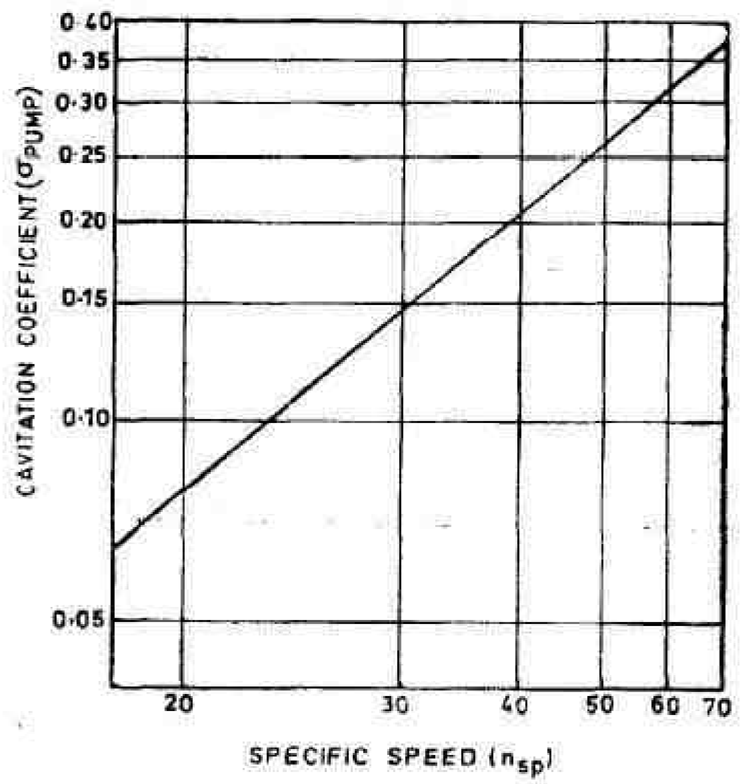
$$Nsd = \frac{N \times \sqrt{Qp}}{Hd^{.75}} = 45.77 \text{metric}$$

12.2.4 Cavitation and Turbine Testing

Cavitation is the formation of water vapour bubbles in areas of the water passage through the Pump Turbine where localized pressure levels fall to or below that of the vapour pressure of water. When these bubbles travel into higher pressure areas they collapse back into liquid. If this occurs adjacent to a pump turbine surface and thus results in pitting.

To avoid cavitation, the absolute pressure within the pump turbine must be such that vapour pressures will not be encountered or created. This is done by keeping the unit elevation sufficiently low relative to Minimum Draw Down Level of the Lower Reservoir to ensure proper absolute pressures. This difference between the Minimum Draw Down Level of the Lower Reservoir elevation and the runner blade centreline elevation is the ‘setting' of the unit.

As per the IS: 12800 –Part 2, the Cavitation Coefficient corresponding to specific speed of 46 as per the below graph is approximately 0.24.



As per the USBR Monograph EM 39, $\sigma = 1.37 * 10^{(-3)} * n_{sp}^{((4/3))}$	0.22	
Normal water temperature =	20.0	°C
Barometric Pressure (Hb-Hv) =	9.47	m WC
Corresponding to Design Head (Hd), Suction Head (hs) = Hb-Hv-σ*hd =	**-35.50**	m
As such Setting firmed up as keeping margin of 1.6 m	**-37.10**	m
Elevation of Pump Turbine Runner Blade Centre Line =	**245.45**	**m**

12.2.5 Estimation of Major Dimensions of the Pump Turbine

The major dimensions of the Pump Turbines have been estimated as per the IS: 12800 (Part-II) and USBR Monograph 39EM. The same have been attached as **Annexure 12-1**.

12.2.6 Specific Design & Quality Requirement

Design Stress Limits

The pump-turbine shall be designed to withstand forces arising under the worst conditions of operation taking also into account superimposed seismic forces.

Under the most severe conditions of loading expected in normal operation, stresses in the materials shall not exceed the values listed below:

Direct or combined steady stresses:

- For materials used in the construction of the equipment, the maximum stress due to maximum normal rated load operating conditions shall not exceed one-third of the minimum yield point or one-fifth of the minimum ultimate strength of the material, whichever is lower. The minimum factor of safety under the worst conditions shall not be less than 1.5 on yield point (YP) or 3 (three) on ultimate tensile strength (UTS).

- Parts subject to water pressure shall be designed to the applicable provisions of the ASME Code and welding shall be as specified herein and in accordance with ASME Boiler and Pressure Vessel code Section 8, Division 2.

Operating Temperature Limits

The guide bearing metal temperature of the pump turbine shall not exceed 70°C.
The guide bearing shall be designed for the following conditions:

- That the normal working metal pad temperature shall not exceed 70°C for turbine operating at all loads up to permitted overloads.
- Continuous operation at any speed from 90% to 110% of rated speed.
- Capability of operating safely at maximum allowed load for a period of fifteen (15) minutes without cooling water supply.
- Safely withstand turbine going to run away speed due to any fault for a period of fifteen (15) minutes with cooling water supply intact and subsequent closing down period without any damage to the guide bearing.
- Withstand safely and without damage the natural retardation from maximum over speed without application of generator brakes.
- Withstand operation at low speed (4-5% of rated speed) for a period of at least Thirty

(30) minutes.

The pump turbines shall be of the plate steel spiral type.

Various components shall be strong and rigid to withstand forces acting upon them under any conditions of operation with safety and without undue deformations. The stay vanes, top cover, bottom ring, discharge ring, draft tube cone & liner, turbine pit-liner etc. shall be amply robust and substantially ribbed. The maximum static pressure acting on the turbine (inlet, scroll casing, guide vanes etc.) will be 1.5 times the maximum static head. The spiral casing and other parts subjected to penstock pressure shall be designed for the maximum pressure, to which it will be subjected under most severe conditions of operation. The forces acting under maximum tail water condition load rejection shall be particularly taken care of in designing top cover.

The head cover shall provide rigid support to the guide bearing housing, shaft seal housing, guide vane upper stems and guide operating ring. The stay ring shall be designed to withstand safely the loads and forces acting upon it. The upper un-embedded portion of the draft tube cone and liner shall be especially strengthened with ribs and other means to avoid undesirable vibrations and limit the same within permissible limits. The guide operating ring and its supporting structures shall be of adequate strength and stiffness to prevent deflection of the ring, guide bearing or the main shaft in the event of the guide operating ring getting subjected to the thrust of only one servomotor with the other servomotor blocked or without oil pressure.

The gate operating mechanism (levers, links etc.) shall be of ample strength to withstand most severe operating conditions. The servomotors and oil piping between servomotors and the governor hydraulic actuator shall be designed and selected respectively to suit this working pressure. All parts that would be embedded in concrete shall be designed assuming no contribution in load sharing by the surrounding concrete. Adequate corrosion and erosion allowance in the wall thickness of embedded parts shall be allowed in the design. This allowance shall be deemed to be not contributing to the strength of the embedded parts.

All identical components of the turbines and the spares shall be interchangeable with one another. Thus at the time of initial site assembly it shall be possible to use the main embedded components of any turbine with similar components of any other turbine.

Heavy and large structural components such as scroll casing, stay ring, bottom ring, top cover, draft tube cone & liner etc. may need to be split, into two or more segments/ sections as necessitated by:

- Inland Transport limits as specified.
- Routine convenience of handling of components during initial site assembly, erection & installation and later for dismantling & removal or maintenance & replacement through stator bore.
- Special provision for dismantling and removal of runner and other under water components affected by silt erosion, for quick maintenance and replacement (necessitated by presence of silt in water)

The various segments/ sections of scroll casing, stay ring, and other components shall have properly machined matching faces to ensure proper matching, circularity and dimensional accuracy during site assembly.

The manufacturing methods/ processes and the suggested materials for various components are tabulated below. The manufacturing process and materials of the construction selected shall be the most appropriate and optimum in respect of the components and the conditions of their operation. Presence of silt shall be taken into account in selection of materials of components susceptible to and affected by silt erosion.

Table 12-2: Main Turbine components, material composition and its relative standards

Sl.No.	Components	Material	Equivalent Standard
1.	Runner	Cast stainless steel (13% Cr. 4% Ni)	ASTM A 743 GR/ CA 6 N or equivalent.
2.	Runner Chamber/ Discharge ring	CS+ SS(13% Cr. 4% Ni)	
3.	Draft Tube & Pit Liner	Carbone Steel	IS : 2062
4.	Guide vane	Cast stainless steel (13% Cr. 4% Ni)	ASTM A 743 GR/ CA 6 N or equivalent.
5.	Guide Vane Stem Bush	Self-Lubricating type	-
6.	Liners for Top Cover & Pivot Ring	WPFS or Cast stainless steel (13% Cr. 4% Ni) or better	ASTM A 743 GR/ CA 6 N or equivalent.
7.	Shaft	Forged carbon steel	ASTM 668 or equivalent

8.	Stay ring	Welded Plate Steel Fabricated Structure or Casting, Stainless Steel Plate	ASTM A537 or equivalent
9.	Spiral casing	Welded Plate Steel Fabricated Structure, Stainless Steel Plate	ASTM A537 or equivalent
10.	Top cover/ bottom ring	Welded Plate Steel Fabricated Structure, Stainless Steel Plate	ASTM A537 or equivalent
11.	GV servomotor cylinder	Carbon steel plates Boiler steel	DIN 17100, St 37-2 St 52-3, ASTM A 283 Grade B ASTM A 287, Grade B
12.	Guide bearing	White metal	-
13.	Shaft Seal	Special Material Resistant to silt abrasion	-
18	Shaft Runner Fasteners	Stainless Steel	AISI420 or equivalent
19	Shaft Liner at Shaft Seal	Stainless Steel	ASTM 743 GR/ CA-6NM or equivalent

12.2.7 Performance Requirement

The pump turbines shall be designed to give satisfactory, quiet and smooth operation, free from excessive noise, vibrations, pressure pulsations, power swings, hunting etc. in the required range of operation of heads and outputs including over load output.

The pump turbine OUTPUT and EFFICIENCY shall be guaranteed parameters. The best efficiency at Design Head under rated conditions is expected to be to be not less than 93%.

Guarantee shall be obtained for the guide vanes, runner, discharge ring and other hydraulic passage of the turbine against excessive pitting caused by cavitation for the first 8000 hours of operation, or not over two calendar years after provisional acceptance of the turbine, whichever is the earlier. The Cavitation Guarantee shall be governed by the IEC 60909.

12.2.8 Governors

The governor stability for the unit shall be established during DPR stage by computing the speed rise and pressure rise under full load rejection as well as acceptance cases taking into account the grid conditions.

12.2.9 Expected Performance Data

The technical particulars of Governor are represented below:

Table 12-3: Technical Particulars of Governor

Sl.No.	Particulars	Value
1.	Wicket gate Servomotor Operating Time	
a)	Opening time adjustable	15 - 30 s
b)	Closing time adjustable (closing in two speed sequence will be required to reduce transient over speed and pressure rise)	8 to 12 s
2.	Range of adjustments	
a)	Speed adjustment at no load	± 10%
b)	Gate limitation	0 – 100%
c)	Permanent speed droop	0 – 10%
d)	Temporary speed droop	0 – 100%
3.	Static Performances	
a)	Dead band of governor (speed sensitivity) (The governor dead band is defined as the smallest relative frequency which can still be perceived to have an appreciable effect on actuator governing the governor main control valve.)	Less than 1/ 1000 of a relative frequency variation.
b)	Dead time (dead time for action on the Guide vanes, following frequency Variation)	Less than 0.2 s

Sl.No.	Particulars	Value
c)	Speed stability at no load	± 1/ 1000
4.	Dynamic performance	
a)	Over speed at full load rejection under most unfavourable load and head conditions	Less than 45%
b)	Max pressure rise at full load rejection under most unfavourable load and head conditions	Less than 35%

Each pump turbine will be provided with a digital, microprocessor type PID governor. The governing system will be connected to and be fully compatible with the power station control and monitoring equipment. It will be possible to control turbines from main control room in auto mode and from unit control board (UCB) in manual as well as auto mode.

The following functions will be included in the governor:

- Speed control at no load operation
- Automatic start and stop sequences including automatic synchronisation
- Power output control
- Frequency regulation
- Load sharing between units in "joint control" mode
- Emergency shutdown on electrical as well as mechanical failures

12.2.10 Main Inlet Valve

Each turbine will be provided with a Spherical type inlet valve installed in the power house upstream of the respective turbine with a nominal diameter matching with the Inlet Diameter of the Spiral casing. The discharge opening of the valve would match the inlet diameter of the scroll case. The valve would be provided with maintenance seal on the upstream and service seal on the downstream. The opening and closing of the valve would normally be done under balanced water condition. The opening of the valve would be done through pressurized oil system. The closing of the valve, however, would be carried out with the help of counter weight. The valve body and valve rotor would be made of cast steel. The material for valve seals will be stainless steel (13% Cr & 4% Ni).

The inlet valve will comprise of valve body and rotor, double acting servomotor(s) for opening and closing operation of the valve, control gear for operation, penstock inlet pipe, outlet pipe with compensator and dismantling joint, and other essential accessories and auxiliaries viz. by-pass valves, sealing valve, air valve, piping with valves, for water, air and oil, master switch, slide valves with electromagnets etc.

A dismantling joint will be provided with MIV on the downstream end to facilitate installation and dismantling of the valve and to permit replacement of the upstream and downstream seals and gaskets.

The Bypass valve would facilitate opening of the MIV under same water pressure at the upstream and downstream ends.

The valve opening and closing time will be adjustable to a closing time range of 50-60 sec. and opening time range of 50-120 sec.

The valve will be designed for automatic control with electric start and stop impulses from the control room. In addition to automatic control, independent manual control system will also be supplied for local operation.

Lugs and Lifting Eyes will be provided for convenience in handling the assembled valve.

12.2.11 Motor- Generators

Two (2) numbers of 327MVA Vertical synchronous motor generators are proposed to be installed in the power house. The Motor-Generators are to be directly coupled to the hydraulic pump turbines to match their speed. The output capacity of the Synchronous Generator is adopted matching with the maximum possible output of the Turbine and standard Power Factor of 0.9 has been adapted in line with generating units of comparable capacity.

The feasibility of installation of Doubly Fed Induction Motor Generator (DFIMG) shall also be studied as an option during the DPR stage. However the present study is limited to Synchronous Type Motor-Generator.

a) Design

The Motor Generator shall be designed to withstand transient situations that can be foreseen during its lifetime without any harmful deformation, displacement or mechanical damage to any of its parts or to the generator foundations, such as but not limited to:

1 Transferred Electric Voltage Surges

2 Short circuit between two or three phases at terminals and external earth faults

3 Multiple disconnections-connections of the connected transmission lines

4 Faulty synchronization

5 Magnetic unbalance due to pole winding failure

6 Runaway conditions.

b) Insulation

Modern motor- generators have an epoxy type insulation system which permits its operation at a class F temperature rise (120°C) as this is defined in IEC 60034-1. Most of the manufacturers have their own patent name for the insulation system, all of which however are very similar.

The long term performance of the insulation system is affected by the maximum operating temperature of the windings. Ageing of the insulation is manifested by partial discharges which increase exponentially and eventually can cause electrical breakdown of the insulation. A convenient method of checking the performance of the insulation is a measurement of partial discharges within regular periods.

In view of increased rate of degradation during operation at high temperature, it is recommended that temperature rise corresponding to class B insulation is adopted for the maximum continuous output under normal conditions. Class B temperature rises are 25°C less than for class F (i.e. 90K).

c) Accessories

Accessories to be provided with the generator shall include braking and jacking system, oil mist collector, brake dust collector device, carbon brush dust collector devices, HS Lubricating System etc. The Motor- generators shall be provided with space heaters to avoid condensation during humid conditions when the generator is not operational.

Cooling water shall be provided for cooling the circulating air inside generator, air coolers shall be provided at the stator frame in the barrel of the generators. Oil coolers for thrust and guide bearings shall be provided and connected with the unit cooling water system.

Further all kind of sensors for monitoring, protection and indications for safe operation of the unit shall be provided.

d) Terminal Voltage

The rated voltage of 15-17.5 kV is appropriate for motor- generators of the proposed size as per the Figure below but the adopted voltage level is 15kV which can be further discussed with the manufacturer during detailed engineering stage.

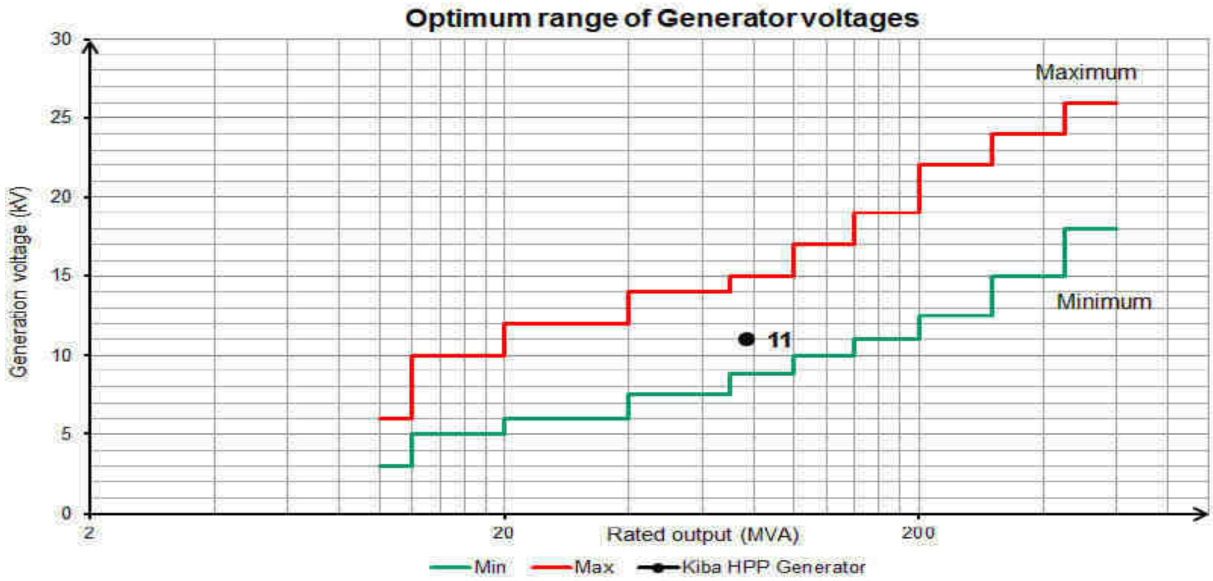


Figure 12-1: Optimum range of Generator voltages

e) Temperature Rise Limit of Windings

Generator stator and rotor winding temperature rise, while delivering maximum output continuously at any voltage and frequency in the specified operating range shall not exceed the following temperature rises over the temperature of the cooling air not exceeding 40 degree C.

Stator 90°C

Rotor 100°C

f) Other Design Parameters

- The motor- generator shall be capable of withstanding a three phase short circuit test at the generator terminals when operating at rated MVA and power factor with 10% over voltage for a period not less than 3 sec.
- The motor-generator shall be capable of withstanding occasional excess current equal to 1.5 times the rated current for not less than 30 seconds each time.
- The motor-generator shall be designed and constructed to be capable of safely withstanding maximum runaway speed for a period of fifteen (15) minutes (with cooling water flow intact) without incurring damage from stresses under such conditions
- Under the most severe conditions of loading expected in normal operation, stresses in the materials shall not exceed the values listed below:

Direct or combined steady stresses:

- For materials used in the construction of the equipment, the maximum stress due to maximum normal rated load operating conditions shall not exceed one-third of the minimum yield point or one-fifth of the minimum ultimate strength of the material, whichever is lower. The minimum factor of safety under the worst conditions shall not be less than 1.5 on yield point (YP) or 3 (three) on ultimate tensile strength (UTS).
- Parts subject to water pressure shall be designed to the applicable provisions of the ASME Code and welding shall be as specified herein and in accordance with ASME Boiler and Pressure Vessel code Section 8, Division 2.

12.2.12 Starting System of the Pump

At the start of pumping operation, a generator motor is started as an Induction motor. After having been synchronized with the power system, pumping is started by synchronous motor operation of a generator motor. To reduce the energy on start-up, the draft water level is depressed by pressurized air to run the runner in the air, and the generator motor is started as a motor using any of the following methods:

Table 12-4: Starting Methods of Pump System

Name	Methods	Features
(a) Half voltage start up (Full voltage start up)	The damper coil of the generator rotor is utilized to start the generator motor as an induction machine.	This method is not suitable for starting a large capacity motor because it imposes great shock on the power system when connected to it as an induction machine.
(b) Synchronous start up (Back-to-Back start up : BTB start up)	Two sets of generators and motors are directly connected in the stationary state, with one set started as a turbine and the other as a generator to drive the generator motor using synchronized force.	The last unit requires a separate device for self starting.
(c) Direct coupling motor start up (Pony motor start up)	Directly connected starting induction motor is mounted coaxially with the generator motor to start the generator motor.	This method requires auxiliary devices, such as a starting motor, a starting transformer, and a liquid resistor for speed control.
(d) Tyristor starter start up	A thyristor starter (frequency converter) is equipped to start the generator motor by applying a low frequency up to the rated frequency.	Two or more pump turbines and generator motors can be effectively utilized on sequential start up. The fewer the units, the higher the cost.

It is considered that based on the size of the Motor Generator units, Thyristor based Static Frequency Converter common for both the Units would be the most suitable option.

12.2.13 Excitation System

The excitation system will be of the fully static type including digital type programmable automatic voltage regulator, Thyristor rectifiers and field suppression equipment. The Excitation System shall conform to IEEE 421 & IEC 60034.The design shall be based on (N-1) principle; if one essential function fails, another shall automatically take over bumplessly and a watch dog function shall be activated.

The ceiling voltage shall not be less than 2 p.u. of the rated excitation voltage. The response of the system shall be very quick and shall be such that when operating at rated MVA output, Terminal Voltage, Power Factor and Speed, the system shall be capable of changing from rated voltage to 90% of Ceiling Voltage within not less than 25 milli seconds for a sustained drop in Generator Terminal Voltage of 5%.

The System shall be complete with all the essential features like protection, Monitoring and Limiters and Power System Stabilisers and comprise of Voltage Regulator Panel, Field Breaker Cubicle with Field Suppression, Thyristor Rectifiers and Excitation Transformers.

12.2.14 Modular Arrangement of Switching Devices Including GCB

PSPP protection schemes include generator circuit breaker, phase reverse disconnector, braking switch, starting and back-to-back switches.

Braking Switch (BS)

The braking switch is designed to perform an electromagnetic braking of the generator by short-circuiting the 3 phases using its high making capability, allowing to reduce the time of shutdown before being able to reverse the operation cycle.

Starting Disconnector Switch (SDS) on Generator Side and Back-to-Back Switch on Transformer Side

Starting disconnector and back to back switches are located on the generator and transformer sides of the GCB. These switches ensure starting in pumping mode instead of production mode and vice-versa, as required. The SDS and BtB switches are designed to withstand the most severe short time currents incurred in PSPP applications.

Generator Circuit Breaker (GCB)

The use of a GCB increases the overall availability of the power plant. It also ensures safe, reliable, economical operation and protection of the power plant. The GCB is the key element for pumped storage power plants, allowing switch off before mode reversing by the disconnectors (from production to pumping or reverse). The main function of a GCB is certainly the protection of the generator and step-up transformer in case of a short circuit.

The technical parameters are as detailed below:

Table 12-5: Technical Particulars of Generator Circuit Breaker

Sl.No.	Particulars	Value/ data
i)	Insulation type	SF6/ Vacuum
ii)	Rated voltage	15kV or above
iii)	Rated current	15000A(Minimum)
iv)	Rated Short Circuit Duty Cycle	CO-30Min-CO
v)	Rated short circuit breaking current	50 KA
vi)	DC component breaking capacity	75%
vii)	Opening time	50 ms
viii)	Rated short time withstand current (effective value) and duration	50 KA
ix)	Short circuit making current (peak value)	137KA
x)	Transient recovery voltage • System side • Generator side	> 3.7kV/ µs, > 3.5kV/ µs

Phase Reverse Disconnector Switch (PRDS)

The phase reversal disconnecting switch serves the purpose of electrical inversion of two phases in a pumped storage power plant after it has been disconnected from the system. Electrical inversion of two phases is mandatory as it allows to reverse the direction of rotation of the generator and so the turbine. It consequently enables the turbine to work either on pumping or generating mode. The PRDS also provides isolating distance of active parts to ensure safety and electrical insulation when in open position.

12.2.15 Online Monitoring Systems

In order to assess the service life of the generators, it is important to monitor the significant parameters of the generator which affect the life of motor-generators. For this purpose it is recommended that the generators should be provided with

- Vibration monitoring,
- Shaft current monitoring,
- Stator winding partial discharge monitoring, and
- Rotor air gap monitoring

12.3 POWER HOUSE SIZING

The dimensions of the power house and tentative layout of the power house have been estimated as per the IS: 12800-Part II and attached as Annexure 12-1.

12.4 AUXILIARY ELECTRICAL SERVICES

12.4.1 Main Step up Transformers

7 (Seven) numbers of 110 MVA, 15/400kV, Single phase generator transformers will be provided for stepping up of generation voltage to Transmission voltage level for synchronization with the grid. Each transformer will be suitable for parallel operation. The transformers will be provided with oil forced water forced (OFWF) type cooling arrangement.

The transformers will be installed at the upstream of the powerhouse on the transformer deck. The transformers will be brought and unloaded in the service bay and will be installed with wheels and put on rails for positioning in their respective positions.

The transformers will be provided with necessary protective and monitoring devices including Buchholz relay, oil temperature and winding temperature indicators, pressure relief device etc.
Lightening impulse voltage for windings shall be as below:

- HV winding – 1425kVp
- LV winding – 95kVp

1 minute power frequency withstand voltages;

- HV winding – 630kVrms
- LV winding – 38kVrms

Transformers will be provided with off circuit tap changer at the HV side, with range of +2.5% to -7.5% in steps of 2.5%.

The transformers will be installed on rails which will provide movement of the transformers from their respective positions to the service bay. Necessary jacking and pulling arrangements will be provided for the transformers. Fire protection wall will be provided between the transformers as per TAC guidelines.

12.4.2 Generator – Transformer Connections

Isolated phase bus ducts conforming to IS 8084 will be provided for connection between the generator and generator step up transformers.

Tentative current rating of the main run bus ducts would be 15000 A. The insulation levels of the bus ducts will be as below:

Table 12-6: Basic Insulation Levels of Bus Duct System

Parameters	Value/ data
Rated voltage	15 kV
Highest voltage	17.5 kV
Power frequency withstand voltage (1min)	38kVrms
Impulse voltage	95kVp

The bus ducts will be naturally air cooled and the temperature rise limits shall be as per IS 8084 and as below:

- Bus duct conductor – Aluminium – 50 °C above ambient temperature
- Bus duct enclosure – Aluminium – 30 °C above ambient temperature

The bus ducts will be complete with continuous type Aluminium enclosure, conductor supported on support insulators with self-aligning arrangement, wall frame assembly, seal off bushing, flexible connections at the termination points, the tap off bus ducts for connection with LAVT cubicle, Excitation Transformer, Unit Auxiliary Transformer etc.

On the neutral side, the bus ducts, after forming star will be connected with the neutral grounding cubicle which will house the grounding transformer and the grounding resistor.

12.4.3 420kv Gas Insulated Switchgear & Pothead Yard

Being Underground Power House, it is proposed to provide a 420kV gas insulated switchgear with Five (5) bays comprising of 2 (Two) generator incomers, 2 (Two) feeder bays and 1 (One) bus coupler bay.

The bus bar scheme adopted is double bus scheme with a bus coupler. The single line diagram indicating generating units, step up transformers, 420kV GIS, transmission line feeders is enclosed as Drawing number AAEI/POWER/2376/EM/A00/001.

The GIS equipment will be located on the floor above the step up transformers in the transformer deck. The connection between the transformers and the GIS bays would be done through 420kV SF6 gas insulated bus ducts (GIBD). Important parameters of the 420kV GIS are as below:

Table 12-7: Technical Parameters of GIS

SI. No.	Technical particulars	Data/ value
i.)	Rated Voltage	420 kV (rms)
ii.)	Rated frequency	50 Hz
iii.)	Grounding	Effectively earthed
iv.)	Rated power frequency withstand Voltage (1min) phase to earth	650 kV (rms)
v.)	Impulse withstand voltage (1.2/ 50/ µs) Line to earth	1425 kVp
vi.)	Switching impulse voltage (phase to earth)	1050
vii.)	Rated short time withstand current (1 sec)	40 kA (rms)
viii.)	Rated peak withstand current	100 kA (peak)
ix.)	Guaranteed maximum gas losses for complete installation as well as for all individual sections in %	As per IEC 62271-203
x.)	Rated normal current, rms	Not less than 2000 A

The metal-enclosed gas insulated switchgear, including the operating devices, accessories and auxiliary equipment forming integral part thereof, will be designed, manufactured, assembled and tested in accordance with the IEC 62271-203 publications including their parts and supplements as amended or revised to date.

12.4.4 420kV XLPE Cables

The connection between the GIS feeder bay and the pothead yard will be made through 420kV grade XLPE cables. Seven (7) runs, three (3) runs each for two (2) outgoing feeders and one (1) run as a spare feeder are proposed. The cables will be 630sq.mm. with Copper conductors with Corrugated Aluminium sheath.

The cables will be laid along a cable duct originating from the powerhouse. The duct will be provided with drain to evacuate any drainage water entering the duct. The cables will be clamped and routed along the duct with support structures designed to bear the cable load and also withstand the short circuit forces.

The cables will be provided with the necessary, sheath voltage limiters and earth boxes, which will be detailed during the detailed engineering stage.

12.4.5 Control and Monitoring System

A SCADA system (Supervisory Control and Data Acquisition) comprising of Distributed digital control, monitoring and information system for the entire power plant will be provided.

The control system will be configured in mainly three control levels:

- The **first level** will be station control level which would comprise a number of functional systems for supervisory control and human machine communication.
- The **second level** will be local control level, which would comprise a number of functional groups such as units, AIS, station service etc.
- The **third level** will be the equipment control level, which can directly and manually control equipment such as governor, DVR etc. and mainly used for testing and adjustment.

The station control level will include functions for overall and centralized control of the station. Typical functions will be supervision and monitoring of the machine conditions, recording the operation/ faults and providing logs and operational information to assist operators. The system will have provision for generation of customized trend reports. There will be a provision for event logging with time stamping at a least count of 1ms.

The local control level will be unit control board, which will be the local control centre for overall sequence of operation of the units. At start up or shut down, it will execute a set of sequence programs. Based on the process criteria, it will generate commands for drive control or functional groups for execution of program. It will check for presence of all required criteria before it issues a particular command. The execution time will also be monitored and if execution time exceeds the stipulated time limit, a trip or an alarm command will be issued. It will be possible to control the unit from the unit control board in fully automatic mode, step by step mode and manual mode.

Equipment, control level will have local control board/ cubicle to control the equipment directly.

The data transmission between the station control level and the local control level will be accomplished by means of LAN with high speed large capacity data bus of optical fibre cables.

A mimic bus diagram board will be provided to depict the status and operational information of the transmission lines, the EHV bus, the generating units and the station service circuits in real time and to operate the equipment with functional switches. Dam water level indicators will also be provided on this board.

The whole system will have a total redundancy in the main CPUs, programmable controllers of the local control units, LAN system and power supply units. Even if one group has a failure, the backup group will instantly succeed the operation seamlessly.

The architecture drawing of control and monitoring system showing the bus topology and tentative equipment connectivity is shown in drawing number AAEI/POWER/2376/EM/A20/001.

12.4.6 Protection System

The electrical protection system for the generators, generator transformers, 420kV GIS, 420kV feeders, auxiliary transformers etc. will be provided with numeric type integrated protection relays, with 100% redundancy.

a) Generators

The following protections will be provided for the generators:

- Differential (87G)
- 95% stator earth fault (64G1)
- 100% stator earth fault (64G2)
- Backup impedance (21G)
- Negative phase sequence (46G)
- Loss of excitation (40G)
- Reverse power (37/ 32G)
- Pole slipping (98G)
- Stator overload (49S)

- Over voltage (59G)
- Under frequency (81G)
- Dead machine (27/ 50G)
- Rotor earth fault (64R)

b) Generator transformers

The following protections will be provided for the generator step up transformers:

- Generator transformer differential (87T)
- Restricted earth fault protection (64T)
- IDMT over current protection (51)
- Neutral grounding back up earth fault protection (51NGT)
- Over fluxing protection (99T)
- Monitoring of insulation of low voltage bushing (59T)
- Buchholtz relay (63)
- Winding temperature protection (49T)
- Oil temperature protection (49)
- Pressure relief valve (PRV)

c) Feeders

The outgoing feeders will be provided with the following protections:

- Distance protection (21)
- Directional instantaneous definite minimum time (IDMT) type earth fault relay
- Two stage over voltage protection

d) Station Auxiliary Transformer

The station auxiliary transformer will be provided with following protections:

- Differential protection (87R)
- Restricted Earth Fault protection (64R)
- Buchholtz relay (63)
- Winding temperature protection (49T)

- ❖ Oil temperature protection (49)
- ❖ Pressure relief valve (PRV)

e) Station Service Transformers and Unit Auxiliary Transformers

The transformers will be provided with the following protections:

- ❖ Restricted earth fault protection (64)
- ❖ Instantaneous and IDMT over current protection on high voltage winding (50/ 51T)
- ❖ Neutral grounding back up earth fault protection (51 NGT)
- ❖ Winding temperature protection (49T)

12.4.7 AC Auxiliary Power System

The station auxiliary power will be supplied through 2 (Two) Nos., 5MVA, 15/ 11kV, Oil filled, ONAN Station Auxiliary Transformers (SAT) located in the transformer deck. The HV side of the transformers will be connected with the tap off connection to the main Bus Ducts of Unit-2 & Unit-4 and the 11kV side of the transformer will be connected with 11kV switchgear through 11kV XLPE cables.

The feeders emanating from the 11kV switchgear are as below;

- ❖ 2 Nos. Station Service Feeders,
- ❖ 1 No. Dam site feeder,
- ❖ 1 No. Colony feeder,
- ❖ 1 No. Valve house feeder and,
- ❖ 2 Nos. Spare feeders.

The station service feeders from the 11kV switchgear will be connected to 2 (two) nos. of Station Service Transformers (SST), 1250MVA, 11/ 0.433kV, Dry type. The LV side of the SSTs will be connected with the Station Service Board (SSB) through 1.1kV, PVC cables.

The SSB will cater to all the station auxiliary loads and will also be interconnected with the Unit Auxiliary Board (UAB) which will dedicatedly feed the unit auxiliaries. Some of the major loads to be connected with the SSB are;

- ❖ Unit Auxiliary Boards 1 and 2,
- ❖ Drainage and dewatering pumps,
- ❖ EOT crane,

- Elevator,
- Illumination system,
- Ventilation and air conditioning,
- DC battery chargers,
- Air Compressor system,
- Workshop and Lab, etc.

The incomings to the SSB will be interlocked and the SSB bus will be provided with bus coupler to avoid charging of the bus with two different sources. The SSB will be located in the Control block at the Service bay floor level.

The UABs will be supplied auxiliary power from the UAT (1250kVA, 11/ 0.433kV, dry type transformer) and also be connected with SSB.

Unit auxiliary board will be provided for each unit and will be installed on the generator floor, below the machine hall. The major loads of the UAB will be;

- Cooling water pumps,
- Oil Pressure Unit/s (Governor and MIV),
- Governor,
- Excitation System,
- Hydrostatic pressure lube oil system,
- Generator transformer oil pump,
- Brake dust fan and carbon dust collector system feeders, etc.

Emergency power will be catered by 2 (Two) no. of 1000kVA, 0.433kV diesel generating sets (1 main and 1 standby) which will be located near the powerhouse at service bay elevation.

Drawings showing the MV and LV schematics are enclosed as drawing number AAEI/POWER/2376/EM/A18/001 and AAEI/POWER/2376/EM/A16/001 respectively.

12.4.8 DC System

It is proposed to install Two (2) sets of 220V, 1000AH capacity battery banks to meet the DC power requirements for control, protection and emergency lighting in the powerhouse. Each battery will be provided with charging equipment comprising of float charger and a float cum boost charger. The cells will be Lead Acid Plant type and will be installed in racks in the powerhouse control block.

The DC distribution board will be provided with adequate number of DC feeders to supply DC power at the required locations.

One (1) set of 220V/ 48V DC – DC Converter/s with DC distribution boards will be provided for Control, communication and other requirements in the powerhouse.

The DC schematic showing the connectivity of the chargers, battery banks and the DC distribution boards is shown in drawing number AAEI/POWER/2376/EM/A19/001.

12.4.9 Earthing System

The earth mat system will comprise of closed circuit conductor grid of steel flats laid over the excavated surface of powerhouse, transformer, switchyard and will extend to the tail race area.

The earthing conductor will be of adequate cross section to safely withstand the system fault current for time duration of fault clearance by the remote/ backup protective system. Sufficient allowances will be provided for corrosion of the embedded conductor on account of chemical properties of soil and also due to galvanic action with other embedded systems.

The earthing system will be designed with the following objectives;

- ❖ To provide low impedance path to fault currents to ensure prompt and consistent operation of protective devices during ground faults.
- ❖ To keep the maximum voltage gradient along the surface inside and around the project complex within safe limits during ground faults.

12.4.10 Power, Control and Instrumentation Cables

11kV XLPE cables will be used for connection between stations auxiliary transformers and the 11kV switchgear, and 11kV switchgear to the station service transformers.

1.1kV grade PVC insulated Al power cables will be used inside the powerhouse for supplying power to various auxiliaries, while for control cables 1.1kV grade PVC insulated Cu cables conforming to IS 1554 will be used. The cables will be Fire Resistant Low smoke type.

The instrumentation cables including fibre optic cables used will be immune to electromagnetic interference. The number of pairs/ cores required will be as per the requirement of the system.

All the accessories like cable glands, ferrules, cable trays, conduits of adequate sizes as required for the installation of cables will be provided.

12.4.11 Illumination System

The indoor illumination scheme will have mainly twin tube light fitting and high pressure metal halide/ mercury vapour lamps. Emergency DC lamps will also be provided in the machine hall, control room, stairways etc. Outdoor illumination will be accomplished through sodium vapour lamps and fluorescent tubes.

The lux levels of the illumination system will be designed in compliance with IS 6665.

Table 12-8: Lux levels in various areas

Nature of area or activity	LUX levels	Quality class of direct glare limitation
Powerhouse machine hall, generator floor, turbine shaft floor, MIV floor, GIS hall etc.	250	2
Powerhouse control block at different elevations	200	2
Control room inside the control block and office areas	300	1
Emergency lighting, all areas	50	3
Outdoor areas like draft tube deck, Pothead Yard and tailrace area	200	

12.4.12 Electrical Workshop

Electrical workshop will be maintained in the powerhouse for testing of various electrical equipment and installations. It will be equipped with testing and measuring instruments like meggers, HV test kit, primary injection relay testing kit, BDV measuring equipment, oil testing kit, portable oscilloscopes etc.

For generator testing, equipment for HV testing, Tan δ measurement, partial discharge measurement, tachometer etc. will also be kept.

12.4.13 Communication System

This project will set up an optical fibre composite overhead ground wire as the main communication channel for transmitting, scheduling, and exchanging users telephone, protection, telecontrol and image information, and set aside trapezoidal modulation channel. SDH optical transmission equipment and PCM multiplex equipment are set at both ends.

Communication system for powerhouse, transformer area, Switchyard and Dam site will consist of internal telephone system and paging system. Paging system will consist of public address system and visual display unit.

The telephone system will consist of an Electronic private automatic branch exchange EPABX along with associated telephone sets.

Possibility of providing Voice over IP (VoIP) phones may be explored during tendering stage.

12.5 AUXILIARY MECHANICAL SERVICES

12.5.1 EOT Crane

2(Two) Electric Overhead Travelling Cranes of 400/50/10 tons capable of operating in tandem with total capacity matching with the heaviest component to be handled is proposed to be installed in the powerhouse for erection and maintenance purpose. The crane will be cabin/ pendant/ radio controlled. The crane will be provided with all accessories including runway rails, down shop leads (DSL), bumpers etc. and will conform to IS 3177. The inching operation will be provided for all motions of the crane. The crane capacity would be reviewed at the detailed engineering stage in consultation with the motor -generator supplier.

One no. of 10 tons EOT Crane is proposed to be installed in the GIS hall for handling the GIS equipment.

12.5.2 Cooling Water System

The cooling water system is provided to cater to the requirements of Generator air coolers, Bearings, Oil Pressure Unit and Step Up Transformers.

The cooling water system will be a single circuit closed loop circulation with heat exchanger placed in the tail water pool to enhance the cooling affect. Hence this type of cooling water system does not require a primary water circuit.

The closed loop circuit of the cooling water system will comprise of pumping systems mainly 3 (three) pumps, 2 main and 1 standby. The pumped water will be routed through a common cooling water header. The water requirements of the units and transformers will be met through this header. The spent water will be collected in the return header of the cooling water and flowed through a heat exchangers (pipe type) immersed in the tail pool. The water after cooling from the heat exchanger will then be pumped back through the pumping system to the common cooling water header. Heat exchanger shall be constructed of Stainless steel SS 316L material and designed considering the water temperature leaving & entering the heat exchanger at a difference of 5°C.

Each Unit shall have independent cooling water circuit.

To compensate the leakages in piping resulting in loss of water, a makeup water system will be installed. This system will pump the water from the tail pool and process it, to remove impurities/ suspended particles from the water using cyclone separator and duplex filter.

To provide water for the shaft seal arrangement, the water will be tapped from the tail pool utilizing small pumps (1 Main & 1 Standby) each having 100% capacity to supply the desired water quantity to the shaft seals of each generating unit. Duplex filters and automatic water filters will have to be installed to obtain the required cleanliness. The filtration capability of the shaft seal filter is expected to be 50 microns.

The drawing showing the schematics of the cooling water system is enclosed as drawing number AAEI/POWER/2376/EM/A51/001.

12.5.3 Drainage and Dewatering Systems

The dewatering system will be provided for emptying the units for inspection/ maintenance. A dewatering sump will be provided between the units and connected with the draft tubes through pipes.

Two submersible pumps will be provided in the sump for pumping out the water to tail pool above the maximum tail water level.

The drainage water will also be collected in a drainage sump located between the units and pumped through 2 submersible pumps to the tail pool above the maximum tail water level.

For automatic operation of the pumps, level controllers will be provided in the dewatering and drainage sumps.

In addition, for protection against flooding, two submersible pumps of adequate capacity along with necessary level sensors for automatic starting will be installed on the MIV floor and the control panels for these pumps will be located in the control block. The drawing showing the schematic of drainage and dewatering system is enclosed as drawing number AAEI/POWER/2376/EM/A52/001.

12.5.4 Fire Protection

Water based fire protection system will comprise of automatic high velocity water spray system for the generator transformers and station auxiliary transformers, and low/ medium pressure fire hydrant system for the Power Station and Switchyard. A microprocessor based fire alarm/ detection system complete with all accessories will be provided for audio/ visual annunciation in case of fire. Water for fire protection system will be obtained by pumping water from tail race to a storage tank by installation of 1 (One) main and 1 (One) standby centrifugal pumps. The fire water storage tank will be placed at an elevation suitable to provide sufficient head/ pressure for the fire protection system.

Water based fire protection system will be supplemented with chemical fire extinguishers. Generators will be provided with CO2 based fire fighting system.

The fire protection system will conform to the NFPA 851 guidelines for fire protection of the hydro generating station.

The schematic of the fire protection system is enclosed as drawing number AAEI/POWER/2376/EM/A53/001.

12.5.5 Ventilation and Air Conditioning

The ventilation and air conditioning system will be sized and configured to provide sufficient air circulation as well as temperature and humidity control for the satisfactory operation of the equipment and comfort of the personnel. Temperature will be controlled by means of air to water heat exchangers.

The air for circulation will be pressurized through blowers in the Fresh Air Unit located on the top floor in the Control block and this treated air will be routed through bus ducts to the lower floors.

Exhaust fans will be provided in the machine hall for maintaining the necessary air changes. Control rooms, office rooms and conference rooms etc. will be provided with air conditioning.

The corrosive/ foul gases from toilets and battery bank room will be exhumed through spark resistant exhaust fans.

Ventilation system will be compliant with IS 4720 and the air duct construction will be as per IS 655. The system will be designed as per ASHRAE guidelines.

12.5.6 Compressed Air System

LP compressed air system comprising of main and standby compressors along with a main receiver and unit receivers will be provided for generator braking and station service purposes.

High pressure compressed air system or Nitrogen bottles shall be provided for hydraulic control of Governor and MIV. The HP compressed air system will be suitably connected with the LP system with pressure reducers for redundancy of the LP system for generator brake operation.

The compressors and receivers will be located in the control block, on the floor below the machine hall. The service air supply to the following floors will be provided through connecting pipes, valves and couplings;

- Machine hall,
- Generator floor,
- Turbine and MIV floor,
- Transformer area,
- Electrical and mechanical workshop.

The compressed air schematic is enclosed as drawing number AAEI/POWER/2376/EM/A55/001.

12.5.7 Electrical Lifts and Elevators

The powerhouse will be equipped with one elevator with sufficient capacity to transport 4 persons between various floors of the powerhouse; the elevator will be located in the Control block of powerhouse.

The elevator will be provided with landing arrangement at various powerhouse floors. It will operate on the following floors;

- Machine hall/ service bay floor,
- Generator floor,
- Turbine floor

12.5.8 Workshop Equipment

A limited workshop facility will be provided in the powerhouse for carrying out the normal operation and maintenance jobs of electro mechanical equipment. The workshop will be equipped with following machine tools:

- Turning machine,
- Mechanical Workbench,
- Power hacksaw,

- Drilling machine,
- Grinding machine,
- Welding set etc.,

12.6 POWER EVACUATION ARRANGEMENT

It is proposed to provide two outgoing bays for evacuating power at 400kV level from Chitravathi PSP. As per Power Evacuation Study, it is recommended to construct 45 Km long double circuit 400 kV line with ACSR Moose conductors from the Project to 400/220 kV Talaricheruvu Substation, near Tadipatri of Ananthapuramu district, Andhra Pradesh.

As per the PFR prepared by WAPCOS, the transmission voltage considered was 220kV. However, considering the quantum of Power to be handled, distance over which it is to be transmitted and also as provided in CEA's Manual on Transmission Planning, 400kV Double circuit Line is proposed which can be further substantiated from the following empirical formula for the most economical voltage for three phase system.

$$V = 5.5 \times \sqrt{\frac{L}{10} + \frac{P}{100}}$$

Where,
V = Line Voltage in kV,
L = Line Length in Kilometres, and
P = Power in Kilowatts

As per proposal, it is estimated that the approximate route length from the project to the nearest Substation would be around 45Km and the optimum plant capacity has been worked out as 500MW.
Based on the above input and the empirical formula, the suitable Line voltage works out to be:

$$V = 5.5 \times \sqrt{\frac{45}{10} + \frac{500000}{100}} = 389\text{kV}$$

Thus the next higher standard system voltage being 400kV, the same has been rightly adopted for Power Transmission System associated with Chitravathi PSP.
However, the various options for evacuation of power from the project shall be further studied in consultation with the Transmission Utilities.

12.7 DRAWINGS

Sl.No.	Title	Drawing Number
1.	Main single line diagram	AAEI/POWER/2376/EM/A00/001

Sl.No.	Title	Drawing Number
2.	MV Schematic	AAEI/POWER/2376/EM/A18/001
3.	LT Schematic	AAEI/POWER/2376/EM/A16/001
4.	Control and monitoring architecture	AAEI/POWER/2376/EM/A20/001
5.	DC Schematic	AAEI/POWER/2376/EM/A19/001
6.	Cooling water Schematic	AAEI/POWER/2376/EM/A51/001
7.	Drainage and dewatering Schematic	AAEI/POWER/2376/EM/A52/001
8.	Fire protection system	AAEI/POWER/2376/EM/A53/001
9.	Compressed air system	AAEI/POWER/2376/EM/A55/001

Chapter-13

Construction Programme and Plant Planning

13 CONSTRUCTION PLANNING, EQUIPMENT PLANNING AND SCHEDULING

13.1 BASIC FOR STUDY

Construction methodology and equipment planning has been devised with an objective to mitigate the adverse impact to surrounding environment during the construction period of the project. The construction cost and construction period depend to a great extent on the method adopted to carry out the works and equipment deployed for the same. As there are alternative methods/equipment, due care has to be exercised in selection of most efficient construction method/equipment so as to optimize construction cost and time. These two factors are inter-related and, generally, any attempt to reduce one results in increasing the other.

This chapter describes the preliminary construction planning and equipment planning of the project. However, detailed construction planning and equipment planning including detailed computation will be done at DPR stage.

Equipment planning depends upon

- Topography of the area
- Accessibility of various working areas
- Speed of construction
- Construction specifications of project components
- Economy of construction
- Optimum utilization of plant
- Shift pattern for continuous working system

The project involves execution of large quantities of excavation, Filling of material and concreting in above ground and underground works. In view of the substantial magnitude and nature of the construction activities, mechanized construction has been considered for all the activities so as to achieve a good quality job at a faster rate for completion of the project within the stipulated time. Special attention has been paid for equipment planning for underground works which entail restricted work space and geological constraints. Before a particular type of equipment and its number are proposed a proper assessment of construction requirements and BOQ of each component of the project is made including the time required to complete the various activities involved.

13.2 MAJOR PROJECT COMPONENTS

The project involves construction of the following major components.

- Upper Reservoir and Embankment/Bund

- Upper Intake
- Penstock
- Powerhouse and Transformer Cavern
- Tailrace Tunnel
- TRT outlet Coffer Dam
- TRT Intake/Lower Intake

13.3 Scheduled Working Hours

Cycle time of operations is the criteria for hourly/daily output of machinery/work force. However, actual progress of work is dependent upon several other factors such as power interruptions, minor break downs, time for meals and other needs of the work force, stray rains etc. It is a general practice to consider 50 minutes as the actual working time per hour (83%). When the work is carried out in more than one shift, there is further reduction in daily production hours due to time required for change in shift and for daily maintenance needs of plant and machinery.

Equipment planning has been done based on the number of working days available. For Equipment planning aspects, as recommended in code IS 11590:1995 and CWC Guidelines for River Valley Projects, following scheduled working hours in a year with 200 working days for all above ground construction activities, has been considered in Table 13-1.

Table 13-1: Scheduled Working Hours

Shift	Working month/yr	Working days/month	Working hr/day	Annual Production Hrs.
Single shift work/day	8	25	6	1200
Two shift work/day	8	25	11	2200
Three shift work/day	8	25	15	3000

13.4 Speed of Trucks and Dumpers

Loaded and empty speed of trucks and dumpers as per CWC recommendations has been considered as under:

Table 13-2: Speed of Trucks and Dumpers

Description	Speed (kmph)	
	Loaded	Empty
Underground Works	15	20
Above Ground Works	20	25

13.5 BASIC FACTORS

As per CWC recommendation, following factors for Excavator and Loader have been adopted.

Table 13-3: Basic Factors for Excavator and Loader

Factors	Value
Sand and Gravel	95.0%
Common Earth	85.0%
Rock well blasted	67.5%
Rock poorly blasted	45.0%

13.6 STAND BY EQUIPMENT

Stand by equipment for various shift working has been considered as under:

Single shift work/day	10%
Two shift work/day	20%
Three shift work/day	30%

13.7 PROJECT IMPLEMENTATION SCHEDULE

It is planned to complete the main construction and commissioning of the project in a period of 48 months including commissioning of two units. The pre-construction period for 9 months has been considered for preparation and award of works and construction of roads & bridges etc.

The proposed construction schedule is appended as **Appendix-A**.

13.8 UPPER RESERVOIR AND EMBANKMENT/BUND FILLING

13.8.1 Excavation and Support of Upper Reservoir

The open cut excavation for the upper reservoir structure would be started after providing access road to upper reservoir location. The excavation to expose sound rock would be started from the top of the cut and taken up in benches. The cut slopes would be protected with rock bolts and shotcrete as per the design, sequentially with the excavation activity. The total volume of open cut excavation would be of the order of 36, 53,366 cum.

Construction Start Date : 10^{th} Month

Construction End Date : 39^{th} Month

Major equipment required for the excavation of Upper reservoir is listed below:

- 3 Cum Excavator
- 35 T Dumper
- Wagon drill
- Dozer
- Rock bolter and Dewatering Pump

13.8.2 Excavation and Filling of Embankment/Bund

The surface stripping of approx. 3.0m depth will be carried out by hydraulic excavator and dumpers. The muck will be disposed off to proposed dumping area. Primary treatment and support shall be done as per the design or as suggested by the site engineer. The stripping of loose material will be done in parallel to the filling of material.

The construction of the Embankment dam has been considered to be done in layers. However the layer thickness and number of static and vibratory passes shall be tested for required parameters before commence of the construction works. The Sequence of Spreading, Compacting, Testing and preparation for the next layer has been considered in the estimation of duration and equipment planning.

For optimized control of equipment and enhanced quality control for the construction works, the sequence of construction shall be by completing the one portion to a certain level and carrying out the construction of the other portion to the same level and further continuing the construction sequence up to the dam construction completion level.

The filling of material of embankment dam will started after the completion of approx. 25% excavation of upper reservoir, to utilize the excavated material for the filling of Embankment.

Construction Start Date : 16^{th} Month

Construction End Date : 41^{th} Month

Major equipment required for the construction of embankment is listed below:

- Hydraulic Excavator
- Dumper

- Dozer
- Drum roller compactor
- Sheep foot roller

13.9 UPPER INTAKE

13.9.1 Excavation of Intake

The open cut excavation for the Power Intake structure would be started after providing access road to Power Intake location. The excavation to expose sound rock would be started from the top of the cut and taken up in benches. The cut slopes would be protected with rock bolts and Shotcrete as per the design, sequentially with the excavation activity.

Construction Start Date : 19th Month

Construction End Date : 24th Month

Major equipment required for the excavation of intake is listed below:

- Hydraulic Excavator
- Dumper
- Wagon drill
- Dozer
- Rock bolter and Dewatering Pump

13.9.2 Concreting of Intake

The concreting of the Power Intake mass foundation would be taken up after the 40th months of the for ease of excavation of penstock and erection of penstock pipe. After placement of concrete in foundation, construction of the piers and abutment walls of the Power Intake structure would be taken up.

Construction Start Date : 41th Month

Construction End Date : 45th Month

Major equipment required for the concreting of intake is listed below:

- Concrete Pump
- Batching and Mixing plant
- Transit mixer

- Rough Terrain crane
- Needle vibrator and form work

13.10 PENSTOCK TUNNEL/PRESSURE SHAFT

13.10.1 Excavation of Adit to Penstock

Before the start of excavation of penstock tunnel, excavation of adit to pressure shaft should be completed.

Tunnel excavation will be achieved by conventional drilling and blasting method for full face. Holes for blasting would be drilled using Single boom drill jumbos with a man basket. Tunnel profile for drilling and other purposes would be marked by installing three laser beams, one each at the springing level and the third at the crown. The lasers would be switched on only when required, and kept switched off for safety reasons. Excavated material shall be loaded by a combination of loader and rear dumpers. As the excavation proceeds, rock support system shall be provided by way of rock bolts, Shotcrete as required. To support the face, sealing Shotcrete shall also be provided if required. Drilling for rock bolts shall also be carried out with single boom drill jumbo.

Instead of the conventional drilling and blasting method which is not always feasible in class V rock types where seepage water is generally encountered, the excavation is proposed to be carried out with the help of a hydraulic breaker mounted on the chassis of a excavator. Fore poles in the arch portion would be installed prior to start of any activity of excavation. The breaker would break the not so hard rock and create a muck pile at the base.

The breaking of the heading rock can be done in two ways, depending upon the strength of the rock and seepage water encountered. In the first case, if the rock is very poor, a one meter wide and 1.5m deep trench along the periphery above springing line may be excavated with the breaker. Before the muck is removed a quick layer of 50 to 75mm thick layer of sealing Shotcrete would be applied under the exposed fore-poles, to control any over break tendency. Some face concreting may also have to be done. In worst cases, face rock bolting may also have to be resorted to. The balance section can then be excavated by the hydraulic breaker and mucking done as the crown would have been secured. In the second case, if the stand-up time is better than in the first case, the entire heading may be excavated with breaker and then sealing Shotcrete layer may be applied. The drilling jumbo would be used to drill and install the fore poles, drill advance probe holes and drainage holes. The excavation of adit will be done from single face.

Construction Start Date	:	17th Month
Construction End Date	:	21st Month

Major equipment required for the excavation of adit is listed below:

- Single boom drill jumbo
- Loader
- Dumper
- Shotcrete machine
- Rock bolter and dewatering pump

13.10.2 Excavation of Top and Bottom Horizontal section of Penstock

The methodology for excavation of top and bottom horizontal section of penstock is similar to the methodology of adit excavation as described in sec 13.10.1.

Construction Start Date	:	22nd Month
Construction End Date	:	24th Month

Major equipment required for the excavation of tunnel is listed below:

- Single boom drill jumbo
- Loader
- Dumper
- Shotcrete machine
- Rock bolter and dewatering pump

13.10.3 Excavation of vertical portion of Penstock

Vertical pressure shafts would be excavated in two stages. In first stage a pilot shaft of 2.5m diameter would be excavated from the bottom to top with the help of Raise Climbers. In second stage the widening of this pilot shaft will be achieved from top to bottom. Mucking will be done from bottom adit. The pressure tunnel leading to the bottom of the pressure shaft would be excavated to make place for the installation of the raise climber.

Raise climbers with 2m diameter platforms with folding extensions would be deployed to carry out the pilot shaft excavation. To deploy the Raise Climber, some preparatory excavation would be needed to allow its entry into the shaft. As per the manufacturer's specifications and the tunnel profile, the excavation in a vertically curved shape would be done to mount the mono-rail track of the machine. Small repeated blasts would be done to make the space for deploying the climber. Once the space is created and the raise climber erected, regular full face shaft driving process would start.

Construction Start Date : 20th Month

Construction End Date : 32nd Month

Major equipment required for the excavation of vertical portion of penstock tunnel is listed below:

- Alimak Raise Climber with stopper drills for excavation of vertical pressure shafts
- Wheel Loader
- Jack Hammers
- Stoppers for vertical drilling in shaft roof
- Dumpers
- Winch
- Hydraulic Platform/Truck Jumbo
- Sand Blasting Equipment

13.10.4 Fabrication and Erection of Ferrules (Steel Liner)

The penstock work involves fabrication of steel liners of 7.7 m and 5.5 m dia. For this purpose, a well-equipped ferrule fabrication workshop will be established at site, with the state-of-the-art plant and equipment. The erection of ferrules shall be started from Intake to bottom of penstock for bottom reach penstock. The stepped concrete pedestals (stairs) shall be provided to facilitate alignment of various pieces of vertical bend. Each piece will be properly aligned before carrying out circumferential widening with the previously erected piece. Before proceeding with erection of next piece the circumferential weld will be checked ultrasonically and defects, if any, will be rectified. Once complete bend is erected, its backfill concreting will be carried out from Intake to bottom of Penstocks. Backing strip will be welded with upper face of ferrule. The strip will help in proper alignment of next ferrule. A clear gap of 3mm will be provided between beveled edges of two ferrules. The circumferential welding will then be carried out. The welding flux will be contained with help of backing strip. After circumferential welding is completed ultrasonic tests will be conducted before carrying out backfill concrete and erection of another ferrule.

Erection of Steel liner of 1 m ferrules would take 1 day.

Construction Start Date : 33rd Month

Construction End Date : 44^{th} Month

13.10.5 Backfilling of Penstock

Concrete for backfilling shall be done for whole reach of the penstock. Concrete shall be transported by transit mixers to the placement point. Concrete pumps shall be used for placing concrete. Contact grouting is done to ensure proper contact of concrete with rock. Contact grouting shall be carried out once the backfill concreting operation is over. Backfill concreting will be done intermittently in 12 months

Construction Start Date : 34^{th} Month

Construction End Date : 45^{th} Month

Major equipment required for backfilling of penstock tunnel is listed below:

- Concrete Pump
- Transit Mixer
- Batching and Mixing Plant

13.11 POWERHOUSE COMPLEX AND TRANSFORMER CAVERN

13.11.1 Excavation of MAT and Cable Access Tunnel (CAT)

The methodology for excavation of MAT and CAT is similar to the methodology of adit excavation as described in sec 13.10.1.

Construction Start Date : 10^{th} Month

Construction End Date : 15^{th} Month for CAT & 20^{th} Month for MAT

Major equipment required for the excavation of tunnel is listed below:

- Single boom drill jumbo
- Loader
- Dumper
- Shotcrete machine
- Rock bolter and dewatering pump

13.11.2 Excavation of Powerhouse

Excavation of Powerhouse will be started after the completion of excavation of CAT. The excavation would be started from right side of powerhouse through CAT to the top of powerhouse. A pilot tunnel of the same size as that of the CAT would be constructed from the right side towards left.

Thereafter, the widening of the section to achieve the final profile up to springing level would be done. Since the final crown of the cavern would get exposed during this cut, the rock reinforcement required for the crown, as per design, would be installed concurrent with the excavation with a lag. After the arch portion is excavated, benching activities would then be taken up to service bay level.

To achieve continuous excavation in the interest of keeping the equipment fully engaged and also because of availability of space, drilling / blasting would be done in half width of the cavern, while mucking would go on simultaneously in the earlier blasted other half. To avoid excessive vibrations due to blasting, cuts more than 3.0m deep would not be taken. The muck would be removed by Backhoes and Dumpers. Concurrently, supporting activity of the final profile exposed during each cut would continue and would be completed up to the level of excavation, since the access to that location would get cut off progressively. Shotcreting would also be completed concurrently.

Construction Start Date : 16^{th} Month

Construction End Date : 26^{th} Month

Major equipment required for the excavation of powerhouse is listed below:

- Two boom drill jumbo
- Hydraulic Excavator for benching
- F.E. Loader
- Dumpers
- Robojet Shotcrete Machine
- Wagon Drills

13.11.3 Excavation of Transformer Cavern

The methodology for excavation of transformer cavern is similar to the methodology of powerhouse excavation as described in sec 13.11.2.

Construction Start Date : 16^{th} Month

Construction End Date : 21st Month

Major equipment required for the excavation of cavern is listed below:

- Two boom drill jumbo
- Hydraulic Excavator for benching
- F.E. Loader
- Dumpers
- Robojet Shotcrete Machine
- Wagon Drills

13.11.4 Concreting of Powerhouse

Concreting activities of the draft tubes would be taken up after access to the lower areas of the powerhouse would no longer be required. The placement of first stage concrete for the powerhouse structure will be done by deploying concrete pumps with placer boom and transit mixers at several locations.

Concreting activities of the draft tubes would be taken up after access to the lower areas of the powerhouse would no longer be required. The placement of first stage concrete for the powerhouse structure will be done by deploying concrete pumps with placer boom and transit mixers at several locations. The construction of the columns and beams for the EOT crane would be taken up. Concreting would be carried out concurrently in lifts. With the help of the EOT crane, the heavy electromechanical equipment would be placed and concreting would be done thereafter. Once the EOT crane would be available it would also be used for concreting with the help of buckets.

Construction Start Date : 28th Month

Construction End Date : 35st Month

Major equipment required for the concreting of powerhouse is listed below:

- Concrete Pump
- Place Boomer
- Transit Mixer
- Batching and Mixing Plant

13.11.5 Concreting of Transformer Cavern

The methodology for concreting of transformer cavern is similar to the concreting of powerhouse.

Construction Start Date : 28th Month

Construction End Date : 35st Month

Major equipment required for the concreting of cavern is listed below:

- Concrete Pump
- Place Boomer
- Transit Mixer
- Batching and Mixing Plant

13.12 TAIL RACE TUNNEL

13.12.1 Excavation and Support of Adit to TRT

The methodology for excavation of adit to TRT is similar to the methodology of adit excavation as described in sec 13.10.1.

Construction Start Date : 26th Month

Construction End Date : 30th Month

Major equipment required for the excavation of tunnel is listed below:

- Single boom drill jumbo
- Loader
- Dumper
- Shotcrete machine
- Rock bolter and dewatering pump

13.12.2 Excavation and Support of TRT

The excavation of the tunnels is proposed to be done by drilling and blasting. The section being large, full face excavation of the tunnels would not be resorted to. Instead, the excavation would be done in stages by dividing the section into three parts viz. heading, benching and invert.

Excavation in heading will be achieved by conventional drilling and blasting method. Holes for blasting would be drilled using three boom drill jumbos with a man basket. Tunnel profile for drilling and other purposes would be set by installing three laser beams, one each at the springing level and the third at the crown.

The breaking of the heading rock can be done in two ways, depending upon the rock and seepage water encountered.

Benching will be done by completing the entire heading excavation and then doing the benching.

Activities of supporting the sides and shotcreting will also be done concurrently. No separate time would be required for bench supporting. Therefore, mucking and side supporting will be carried out sequentially.

While the bench excavation is going on, the drilling and blasting of the rock in the invert would be done in a manner so that no work is interrupted. After blasting, the muck would not be removed. A bulldozer would level out and compact the blasted mass and maintain the horizontal surface of the road for vehicular traffic. The blasted muck would be removed later with a back hoe in a sequential way while doing the concreting of the overt. Hence no separate time would be included in the cycle time.

Construction Start Date	:	31st Month
Construction End Date	:	38th Month

Major equipment required for the excavation of tunnel is listed below:

- Drill jumbo with man basket
- Side dump wheel loader
- Robojet Shotcrete Machine
- Dumpers

13.12.3 Concrete Lining of TRT

The lining of the tunnel comprises of plain cement concrete or reinforced concrete. It is proposed to concrete the overt first and then the invert. Hydraulic collapsible gantries of 12m length are proposed to be deployed for the job. The gantries would travel over rails mounted on concrete kerbs / beams laid at precise level, location and grade. The hydraulic system operating the leaves of the gantry would be used to set and adjust the shell at the desired location in a short time. A timber bulkhead would be erected at the open end to close the annular space between the gantry and the excavated tunnel profile. The concrete placement on both the sides would be done in a manner that the differential level of the concrete on both the sides should nearly be the minimum and never more than 1.00m. This would avoid creation of unequal pressures on the gantry leaves due to large difference of levels between the left and right side green concrete.

Construction Start Date : 39th Month

Construction End Date : 42nd Month

Major equipment required for the concreting of tunnel is listed below:

- Collapsible hydraulic gantry 12 m long for overt concreting
- Concrete pump
- Batching and Mixing Plant
- Transit Mixer
- Backhoe loader

13.13 COFFER DAM (TRT OUTLET)

The construction of coffer dam at TRT outlet should be completed before the start of construction of Pump Intake at TRT outlet. As per preliminary assessment following construction time is worked out..

Construction Start Date : 25th Month

Construction End Date : 36th Month

Major equipment required for the construction of embankment is listed below:

- Hydraulic Excavator
- Dumper
- Dozer
- Drum roller compactor
- Sheep foot roller

13.14 PUMP INTAKE AT TRT OUTLET

The methodology for the construction of pump intake is similar to the methodology of construction of upper intake as described in sec 13.9.

Construction Start Date : 37th Month

Construction End Date : 46th Month

Major equipment required for the excavation of intake is listed below:

- Hydraulic Excavator
- Dumper
- Wagon drill
- Dozer
- Rock bolter and Dewatering Pump
- Concrete Pump
- Batching and Mixing plant
- Transit mixer
- Rough Terrain crane
- Needle vibrator and form work

13.15 SWITCHYARD

The bench for switchyard shall be prepared with excavating, Filling, Levelling & Compaction for placement of switchyard foundations and equipment's.

Construction Start Date	:	35th Month
Construction End Date	:	40th Month

13.16 ERECTION OF ELECTROMECHANICAL EQUIPMENT'S

Methodology for Installation of Electromechanical and Hydro mechanical Works shall be adopted as per the sequence and best practices of the manufacturers.

Erection of Unit-1:

Construction Start Date	:	30th Month
Construction End Date	:	45th Month

Erection of Unit-2:

Construction Start Date	:	31st Month
Construction End Date	:	46th Month

13.17 COMMISSIONING OF UNITS

After completion of all construction activities, the impounding of the reservoir and commissioning will be taken up.

Commissioning of Unit-1	:	47th Month
Commissioning of Unit-2	:	48th Month

Chapter-14

Project Organization

14 PROJECT ORGANIZATION

14.1 CONSTRUCTION ORGANIZATION

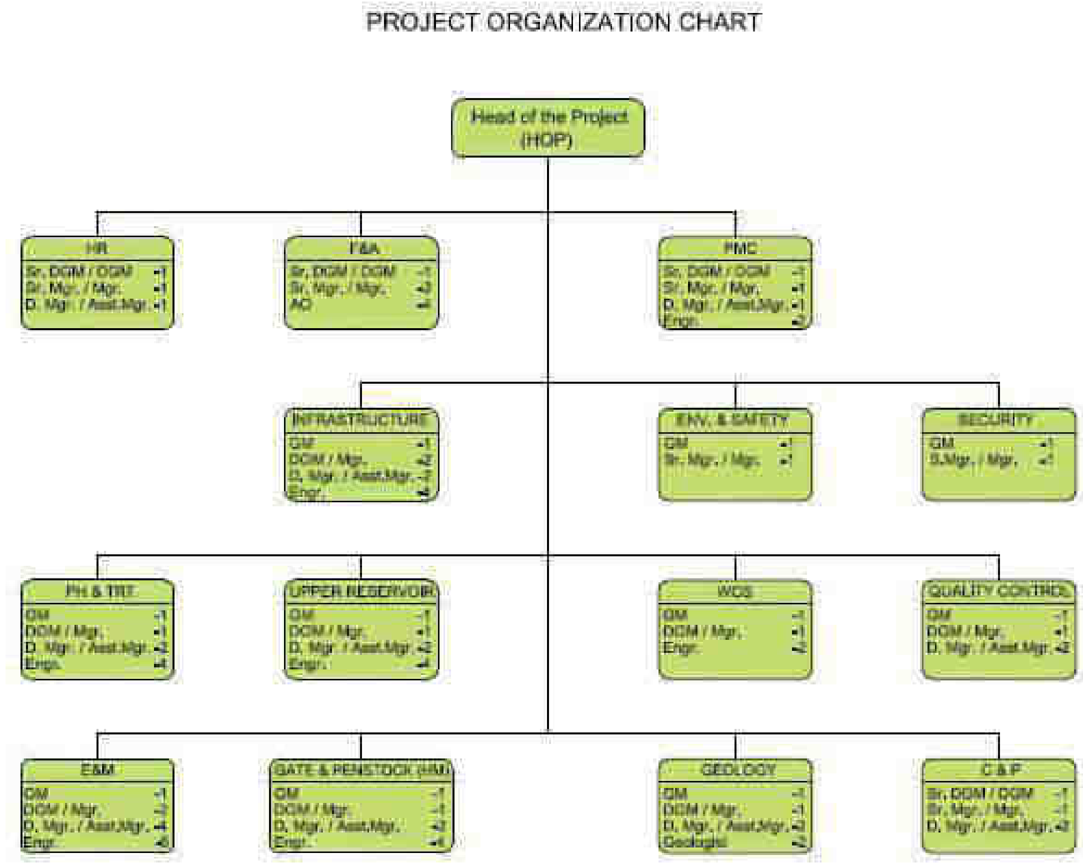
An efficient and result oriented organization will be set up to achieve the objective of constructing the works to a recognized international standards and commissioning the project in a period of 48 months Keeping in view of terrain, very close coordination would be required to avoid cost and time overrun. The project organization will undertake regular review of progress and monitor the works constantly, using latest management information systems. Computer based project management tools using PERT and CPM techniques will be used for overall and day to day planning and monitoring of the project.

The project organization will be headed by Head of Project (HOP) for the overall management of the project. The Head of Project (HOP) would be assisted by several separate teams which will look after construction, material procurement and accounts aspects and coordination with the design consultant of the project. The proposed Organization Chart is appended herewith Figure 14-1.

General Managers for different project components including infrastructure, environment & safety, security, quality control, E&M, gates & penstocks, geology, C&P have been proposed for the project. The financial matters and accounts of the project will be taken care of by a separate accounts department under the charge of a Dy. Manager (Finance). In addition to this HR unit, PMC unit headed by Sr. DGM and Sr. Manager will assist HOP. The unit heads will be supported with different categories of technical and non-technical staff as per requirement.

Besides the above, a Panel of Experts (POE) with eminent Indian / foreign engineers as members could be constituted. The POE will give recommendations on general layout of works, design considerations for major works, and specific design and construction problems as required.

Figure 14-1: Project Organization



TOTAL MANPOWER EXECUTIVES				
Grade Code	Nos.		Category	Nos.
HOP	1		Technical	70
GM	10		F&A	7
SDGM / DGM	4		HR	3
DGM / Mgr.	10		Env. & Safety	2
SM / M	7		Security	2
DM / AM	20			
ENGR	26			
Geologist	2			
AO	4			
			Total	84

Chapter-15

Infrastructure Facilities

15 Infrastructure Facilities

15.1 General

The existing Chitravathi Balancing Reservoir project is located near Parnapalli Village on the river Chitravathi, a tributary of the Pennar River. The purpose of this project is to provide irrigation to the two districts namely Kadapa, Anantapur.

This chapter covers the preliminary studies of infrastructure planning of the project; however detailed infrastructure planning will be done at DPR Stage.

15.2 Project Location

The geographical coordinates of the proposed upper reservoir are at longitude 77°56'2.6"E & latitude is 14°34'26.93"N and that of existing lower reservoir are at 77°56'51"E and 14°33' 31"N. The project lies in border of YSR Kadapa and Ananthapuramu districts. The Chitravathi dam is in YSR Kadapa District and the reservoir is in Ananthapuramu District. The new upper reservoir is proposed on the left bank of Chitravathi Dam, near Peddakotla village.

15.3 Project Access

The Chitravati PSP is proposed on the left bank of Chitravathi Dam, near Peddakotla village. Village is located in Tadimarri Mandal of Ananthapuramu district in Andhra Pradesh, India. It is situated 2 kms away from sub-district headquarter Tadimarri and 10.4 kms away from district headquarter Ananthapuramu. The site is easily approachable by NH-205 from Ananthapuramu. Nearest railway head is Ananthapuramu from where project site is located at around 50 kms away. The nearest international airport is at Tirupati which is about 260 km from the project site and sea port is at Krishnapatnam which is about 295 km from the project site.

15.4 Infrastructure Facilities

15.4.1 Project Office and Colony Area

Project site office(s) shall be constructed in the vicinity of the Project Area. The project site office(s) shall house the office of Construction managers and there support staff.

Suitable plan shall be prepared for this office considering the number of the personnel required for the efficient and effective support, monitoring and control of the construction activities. On the basis of manpower requirement, accommodation and its area has been assessed for Owners and Contractors.

Since the Project is of long duration, appropriate, though limited, family accommodation is also proposed for those who would like to keep their families at Project site. Field hostels/ Bachelor's accommodation is proposed for remaining executives, non-executives and workers.

An area of 15 Ha has been earmarked for permanent office and colony area. Following provision is being kept for construction of offices and residential building at various sites:

- Permanent office building
- Temporary office building
- Temporary site office
- Permanent residential building
- Temporary residential building

Since the Project is of long duration, appropriate, though limited, family accommodation is also proposed for those who would like to keep their families at Project site. Field hostels/ Bachelor's accommodation is proposed for remaining executives, non-executives and workers with following amenities.

Water Supply

Water for construction will be drawn from the existing reservoir. Water tanks of adequate capacity will be constructed at each work location and water will be pumped from reservoir to water tanks. Water tanks of adequate capacity shall be provided/constructed for batching plant, curing of concrete and various construction activities.

Water for project colony and camps shall be drawn from existing reservoir. Water shall be treated for portable use for supply to the colony and camps. Water tank will also be provided at camps & colony considering the total manpower and average daily consumption. Suitable distribution network shall be developed in the camps and colony for supply of water.

Sanitation and Sewage

All Site-offices, workshops, laboratory and other work-sites shall be provided with toilets, water supply and septic tanks.

The Project-colony and camps outside the project-area shall be provided with a properly maintained and operated sewerage system including septic tanks and sewage disposal facilities.

If required Mobile toilets will be provided in the construction area and kept in good condition.

Medical Facilities

In order to cater for the medical care and emergency needs of the project workers, it is proposed to set-up a 4 bedded medical Hospital/dispensary for treatment of construction related injuries, common sickness under the charge of a qualified medical officer supported by sufficient support staff in the Project-colony.

Project site shall also have Emergency Medical Centre with life-saving facilities and medical aids.

Well-equipped ambulances shall also be provided at the Colony-Hospital and also at the construction site.

Adequate medical equipment, stretchers, medical oxygen cylinders etc. shall always be kept in ready to service position. Sufficient stock of medicines shall be kept at these Hospitals.

Communications

A proper communication system is proposed to be established at the site linking the project site activity centres and maintaining communication with the following modes:

- Walkie-Talkies Set
- Telephones
- Public Mobile Phones
- Internet and Emails

Fire Protection

Adequate and appropriate arrangement shall be provided for protection and prevention of fires. Water outlets shall be provided through the pipelines near all offices, workshops camps and other fire prone areas. Wherever, required ABC type fire extinguishers shall be provided in sufficient quantities. If required special extinguisher shall be provided at fuel stations and electrical installations and special warning sign for not using water for extinguishing fire in electrical installations shall be displayed.

Workers shall be given training to use fire extinguishers and tactically handle the situation in case of fire so as to minimize the damage.

15.4.2 Project Roads

The project area is accessible with motor able road via SH 121 Mudigubba Dorigallu Chinnakotla road and also via NH 67. For power house approach tunnel and a new road is to be developed.

The Upper reservoir is not accessible by road network. An approach road shall be constructed connecting lower reservoir to upper reservoir. A total of 10 km of approach road in the project area is envisaged to be constructed. The detailed planning of access to various components shall be done in DPR stage.

15.4.3 Muck Dumping area

As described in the Chapter-7 “Alternative Study” the upper reservoir is planned to be constructed by cutting and filling. The huge excavated material shall be utilised in the construction of embankment dam with processing the excavated material. Moreover the excavated material from underground works of tunnel and powerhouse will also be utilised for processing of aggregates for concrete. Thus about total 14 Lakh cum of excavated muck will be safely dumped in the designated muck dumping yard to mitigate the environmental hazard. An area of 30 Ha has been earmarked downstream of the existing reservoir area.

15.4.4 Batching and Crushing Plant

One set of Batching and crushing plant each will be installed at project site to facilitate the processing of coarse and fine aggregates to be used in concreting works. An area of 10 Ha is earmarked for installation of Batching and Crushing plant.

15.4.5 Project Stores

A project stores shall be constructed in the project area for construction material, consumables, spares and other miscellaneous items.

Cement storage of required capacity shall be provided for storing the cement.

Shaded yard for reinforcing steel and structural steel shall be constructed for stocks and fabrication works. Reinforcing steel cutting and bending yard and Steel fabrication shop shall also be established in the vicinity of steel stock yard.

15.4.6 Explosive Magazine

An explosive magazine of required capacity shall be provided at identified location at project site sufficiently away from the human habitat and working areas. Explosive Magazine shall have an isolated chamber or space for storing Detonators which shall, in no case, be stored in the bare vicinity of gelatine or other explosive material.

The area around the magazines shall be secured by appropriate Boundary wall and fencing with a lockable gate. Round the clock strict security vigil shall be maintained by deploying well trained and capable armed guards.

All the precautions shall be taken while placing in or removing the material to and from the Explosive Magazine in general and as prescribed by the Law of State. Complete record of explosives, detonators and all other such material shall be maintained meticulously which may be demanded by state authorities any time or at the time of filling return for the use of explosive.

Any registration or approval required for establishing explosive magazines as per the Law of the country or state shall be obtained.

15.4.7 Fuel Station

It is necessary to provide a fuel station for catering the fuel and lubricants requirement of the construction activities, two 60kl Fuel station shall be established at the Project site.

In addition to this an area of about 150 m^2 (Equivalent 15 m x 10 m) shall be provided for lubricants for meeting the lubricants requirements of the works.

Further 2 numbers of 10kl Diesel tanker will be provided at site for carrying the diesel from depot to site storage facility. Lubricant drums shall be transported by trucks. In addition, two 2kl diesel bowsers shall be used for filling the equipment and DG sets at work site itself.

15.4.8 Work Shop

a) HM Workshop

A fully equipped self-sufficient heavy equipment workshop shall be established to provide quick repairs and maintenance of heavy construction equipment so that availability of equipment is maintained and the work does not suffer for repairs and maintenance of equipment.

A provision of 50 m x 30 m i.e. about 1500 m^2 has been proposed for HM workshop. This workshop shall be established by the civil contractor. This facility may be transferred to the owner after completion of construction for its use as mechanical workshop and garage during Operation and Maintenance.

b) Light Vehicle Workshop

One light vehicle repairing facility shall also be maintained at the project site in order to provide regular services and repairs to the project vehicles.

A provision of 20 m x 15 m i.e. about 300 m^2 has been proposed for Light vehicle workshop.

c) Electrical Workshop

An electrical workshop shall be established at the Project site to provide services to electrical installations and equipment such as power systems, DG sets, transformers, pumps etc. and also lighting of Project and camp. This will also ensure uninterrupted power supply for construction works.

A provision of 30 m x 15 m i.e. about 450 m^2 has been proposed for Electrical workshop. This workshop shall be established by the civil contractor. This facility may be transferred to the owner after completion of construction for its use during Operation and Maintenance.

15.5 CONSTRUCTION POWER

The power required during the construction stage of the project would be obtained through the available alternatives. However it has been given to understand that due to the availability of grid power in the project area during the construction period of 4 years, it is envisaged to install a new substation to obtain power from Existing grid.

However, if power is required from DG set, it is envisaged to install Diesel Generating sets to power the machineries proposed to be used during that period. The requirement of power for the machineries/ equipment proposed to be used for construction works at various project sites including Upper Reservoir, Powerhouse, project resident colonies & camps, etc. has been worked out as per construction program and planning.

15.6 QUALITY ASSURANCE AND QUALITY CONTROL

In order to assure and maintain quality standards of the construction material and construction works, arrangements will be made to facilitate field laboratory tests as per the applicable standards. For this purpose, a fully equipped laboratory shall be installed for carrying out the prescribed tests on site.

One centralized Quality Control laboratory shall be established near main batching and mixing plant for undertaking various tests and concrete mix design studies etc.

Experienced senior engineers/technicians well versed in various aspects of quality assurance will manage quality assurance and quality control program strictly in accordance with prescribed standards and ensure that the specified tests are carried out and the results interpreted in the manner stipulated in the prescribed project Quality Assurance Manual and standards.

A provision of 45m x 20m i.e. about 900 m^2 has been proposed for quality control laboratory. This laboratory shall be established by the civil contractor. This laboratory shall be established near batching plant area.

The locations of infrastructure facilities as defined above have been shown in drawing no. **AAEI/POWER/2376/CIV/011** "Infrastructure and Construction Facilities - General Layout Plan"

Chapter-16

Environmental & Ecological Aspects

16 ENVIRONMENTAL AND ECOLOGICAL ASPECTS

16.1 INTRODUCTION

Chitravathi pumped storage project is proposed over the Chitravathi balancing reservoir located in Ananthapur district of Andhra Pradesh. Project consists of upper reservoir near pedhakotla village in Tadimarri Mandal of Ananthapur District & the existing Chitravathi balancing reservoir as lower reservoir. The existing Chitravathi reservoir is under operation with a live storage of 9.956TMC. The filling of the proposed upper reservoir will be taken from the Chitravathi balancing reservoir. The total design discharge for the proposed scheme is 297.26cumecs with the rated head of 189.40m. The location of the project is as shown in Figure 16-1.

Regulatory Environmental Clearance (EC) process involves three major steps as stipulated in EIA notification of September 2006, viz. Scoping, Public Consultation and Appraisal.

Water resources development projects will interfere with the environment in the proposed area and its surroundings. Proper assessment of environmental impacts and its mitigation measures during the planning stages of the projects will help in reducing the adverse impacts. A brief description of environmental impacts with the proposed Chitravathi Pumped Storage Project is presented in the chapter. However, detailed EIA & EMP Studies shall be carried out in DPR stage.

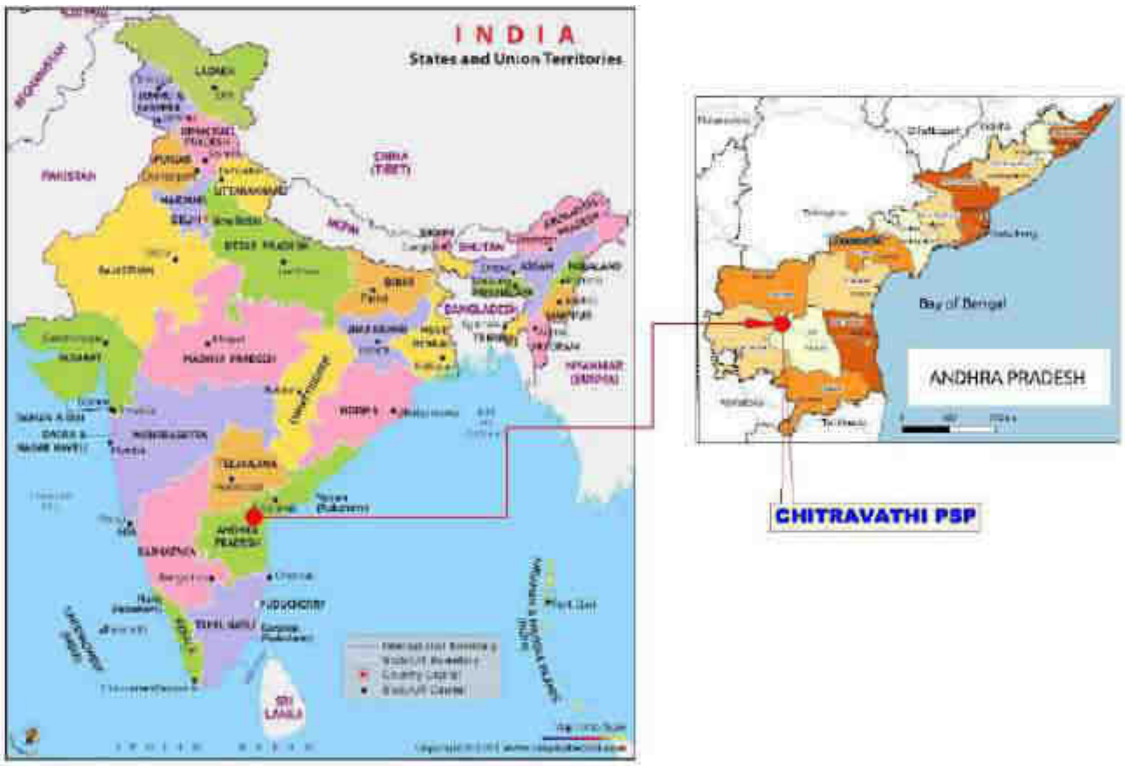


Figure 16-1: Location of the Project

16.2 Study Area of the Project

Study area for environmental study will be delineated as Project area or the direct impact area within 10 km radius of the main project components like Power House, Balancing reservoirs and approach road etc.

16.3 Environmental Baseline Status

Data on the existing environment quality is to be collected to understand the present setting of the environment at the project site. To complete the EIA study, it is important to collect baseline data for various physico-chemical and biological environmental components in the project study area comprising Vegetation Community Structure, Wildlife, Soil Quality, Noise levels, Ambient Air Quality, Traffic density. In the present study, the base line status has been reviewed mainly on the Secondary data that was collected around the project area.

16.3.1 Physiography

The project area is located in the north-eastern part of the Ananthapur district bordering with kadapa district. The project area lies in Pennar basin of Andhra Pradesh. The study area of the proposed project is comprised of moderately sloping, exposed rocks, and scrub vegetation. The study area ranges from El. 287 to 500 m above msl. Parallel drainage system on the linear and strike ridges, parallel drainage system on rounded or domal hills and dendritic drainage pattern on the undulaory terrain has developed

16.3.2 River System

The Chitravathi is an inter-state river in southern India that is a tributary of the Pennar River. The origin of the river is in Karnataka at chikkaballapur & it flows into Andhra Pradesh in the districts of Ananthapur & cuddapah before joining of Pennar river and its basin covers an area of over 5,908 km2. Among the mandals that it drains in the two states are Bagepalli, Gorantla, Hindupur, Bukkapatnam, Dharmavaram, Tadipatri and Kadiri. The river joins the Pennar at Gandikota in Kadapa district.

16.3.3 Geology

The Chitravathi pumped storage project is proposed between the existing Chitravathi balancing reservoir & proposed upper reservoir on left bank of CBR in Ananthapur district. The scheme comprises of upper reservoir, water conducting system, Pressure shaft, Access tunnel, Underground power house & tail race system.

Geological setup of the Project area is unique in terms of Indian Stratigraphy as the site is located in the vast Dharwar Craton which is occupied by igneous and a suite of metavolcanic -metasedimentary rocks (Archaean to PaleoProterozoic Eras) and which are juxtaposed on the eastern side by a spectacular crescent shaped Cuddapaha Basin in which thick pile of sediments were deposited (Meso to Neo Proterozoic Eras). In the project area, Eparachaean unconformity has developed impersistently between granite and thin quartzite horizon. Foliation of Granite gneisses and bedding of quartzite are aligned along N 30-45 W- S30-45 E direction. but foliation dips vary 45 to 70 due S60 -45 W, but quartzite shows 10 -15 due N60-45E. Granite gneisses are represented by hornblende-biotite gneiss, hornblende gneiss, biotite gneiss and older granites and these are classified as Peninsular Gneisses Complex I and II. These, at places, shows migmatitic structures. Younger granites, equivalent to Closepet Granites, are represented by pink or grey granites. These are intruded by three sets of dykes, quartz reefs, aplite, sepidote and quartzofelspathic veins

16.3.4 Seismicity

The project area is located in the border districts of Ananthapur & cuddapah in the rayalseema region of Andhra Pradesh. As per the seismic map zone of India, the Project area lies in the seismic zone-II.

16.3.5 Meteorology

The proposed area of the proposed project lies in Ananthapur district of Rayalaseema region in Andhra Pradesh state. The area lies in the tropical climate zone. The climatic condition of the region can be divided into four seasons. The period from December to February is dry and cool. Summer spreads from March to May followed by south west-west monsoon from June to September. October and November contribute the post-monsoon or retreating monsoon season.

a) Temperature

The average maximum temperature of 40.1˚C was recorded during the month of April over the last twenty years (2000-2020) and average minimum temperature of 18˚C during the month of December & January.

b) Rainfall

Rainfall distribution of Ananthapuram district has been studied for 30 years (1991-2020) precipitation data. From the annual rainfall variation studies it is shown that the maximum rainfall of 978.6 mm occurred in 1996 followed by 2005 (771.30 mm) and minimum rainfall occurred in 2014 of 245.2 mm and that in 2018 (285.7 mm) being the second lowest. The year 1996 is referred as 'wet year' and 2014 as 'dry year' among the study period. It is also shown that the average rainfall for the selected study period of 30 years is 543.5 mm.

c) Relative Humidity

The Relative Humidity is generally high throughout the year, average relative humidity is close to 75% during September to November. Relative humidity is lowest during summer period and ranges from 40 to 45%.

d) Wind Speed

The wind speed is higher during the May to August as compared to the post monsoon and winter period. The average maximum wind speed of 17.4 Kmph is observed during the month of July from January 2000 to December 2020.

16.3.6 Water Quality

The data on surface and ground water shall be collected to evaluate the quality of the water in the proposed area during DPR stage. The water quality in the study area, in general as per physical examination is good. Except for agricultural activities there are no sources of pollution of water bodies in the area. All the samples of surface water shall be collected & tested during the DPR stage as per the Water Quality standards of BIS & CPHEEO.

16.3.7 Flora

The district has very poor forest cover in terms of area & richness of flora. The total area under the forest cover is 1953sq.km constituting 10.2% of the total geographical area of the district. The vegetation in & around the project area comprises of Dry tropical vegetation of tropical thorn forest along with the agricultural crops and weeds. Wide varieties of trees in the area are available such as Phoenix sylvestris, Pongamia pinnata, Acacia nilotica, Azadirachta indica and Tamarindus indica, Adiantum capillus-veneris, Adiantum caudatum, Pteris biaurita and Dryopteris cocheiata. Among byryophytes only Riccia discolor and Plagiochasma sp. List of flora and their status shall be studied during DPR stage.

16.3.8 Wild Life

A detailed description of wildlife in the project area shall be conducted during DPR stage. As per the secondary sources the wild life that are available in the Anathapur, cuddapah region are

a) Mammals

The mammalian species viz; Lepus nigricollis (Common Hare), Herpestes auropunctatus (Samall Indian Mongoose), Semnopithecus entellus (Grey Langur) and Macaca radiata (Bonnet monkey) are sighted mostly in the Ananthapur.

b) Fauna

The most frequently sighted bird species in Ananthapur district are House sparrow, Jungle Babbler, crow, Common Myna, Red-wattled Lapwing and Cattle Egret. List of bird species composition and their conservation status shall be studied during DPR stage

16.4 SOCIO-ECONOMIC PROFILE

The collection of data on the socio-economic status has been delinated with in 10km radius of the main project components such as upper reservoir, lower reservoir, water conducting systems, power house, muck disposal area etc., the proposed area consists of 5 Tehsils of which four are in Annathapur district namely Putlur, Mudigubba, Tadimarri, Yellnur & other in kadapa district namely Lingala tenhsil. Parnapalli & Peddhakotlapalli villages are directly affected by the project activities.

Total households in study area tehsil are 1493. The total population of study area is 5738, of which 2873 are male and 2865 are female. Sex ratio in study area is 997 female per 1000 males. Nearly 14.3% of the population of the Ananthapuramu district area belongs to Scheduled Castes, while the population of Scheduled Tribes is only 3.8%. In study area, 21.7% and 0.9% of the total population belongs to Scheduled Castes and Scheduled Tribes, respectively.

Average literacy rate in in Ananthapuramu district is 63.57% of which 73.62% are males and 53.97% are females. The total literacy rate in the tehsils falling under study area is 61.33%, with 73.64% males and 48.97% females. 52.66_% of the total population of study area is working population. Of this working population 33.63% are main workers and 19.03% are marginal workers. 47.33% of the total population of the study area population is considered as non-workers.

16.5 PREDICTION OF IMPACTS

Majority of the environmental impacts attributed to construction works are temporary in nature, lasting mainly during the construction phase and often do not extend much beyond the construction period. However, as the construction phase of Pumped Storage Project is large and extend upto four years, if these issues are not properly addressed, the impacts can continue even after the construction phase for longer duration. Even though the impacts due to construction are temporary in nature, they need to be reviewed closely as they could be significant due to the nature and intensity of the impacts.

16.5.1 Impact on Land

The impact on the land manly occurs due to the construction works, migration of labours, vehicular & heavy machinery movement in the area. Extension of the construction timeline beyond the scheduled construction may have impact for longer duration although which is temporary in nature.

a) Impacts due to immigration of Construction Workers

At the time of peak construction work in the project, Majority of people are required than the planned persons who have their permanent shelters in nearby villages or temporary homes constructed for the project purpose. Majority of the people will be migrating from other areas. Only the migratory manpower will stay at site camp. Immigration of such a large population for a long duration in remote area can cause serious impact on various environmental resources including socio-economic profile of local population.

The congregation of large number of construction workers during the peak construction phase is likely to create problems of sewage disposal, solid waste management, tree cutting to meet fuel requirement, etc. Appropriate mitigating measures will suggested in EMP, which needs to be implemented to minimize such impacts. This population is expected to reside in the project area at any given time.

b) Impact due to Construction of Main Project Components

For construction of main project components major activities are excavation and concreting. Excavation will have impact in terms of muck generation. Excavation and concreting process will require use of various construction equipment such as batching plants, aggregate processing plants, dumper trucks, excavators, dozers, shotcrete machines, jack hammers, generators, pumps, etc. leading to generation of pollution in terms of emissions, wastewater, noise and solid waste.

c) Operation of Construction Plant and Equipment

During the construction phase, various types of equipment will be brought to the site and construction plants and repair workshops will be set up. These include crushers, batching plant, drillers, earth movers, rock bolters, etc. The siting of this construction equipment would require significant amount of space. In addition, land will also be temporarily acquired, i.e. for the duration of project construction; for storage of the quarried material before crushing, crushed material, cement, steel, etc.

The siting of these construction plant/ equipment's would require clear piece of land. Proper siting of these facilities will reduce the impact due to their location. Their locations have been identified, keeping in view the technical and economic criteria; however, same can be further refined during set up, keeping in view:

- Proximity to the site of use
- Sensitivity of forests in the nearby areas
- Wildlife, if any, in the nearby area
- Proximity from habitations
- Predominant wind direction
- Natural slope and drainage

Such activities are planned on government land and completely avoiding the forest area; to minimize the impacts of tree cutting. Land will be restored once the project construction is complete.

Operation of construction plants and machinery, will have impact on ambient air quality due to fugitive emissions associated with material handling; emission due to operation of DG sets to meet the power requirements and other equipment; impact on water quality due to waste water generation and impact on soil due to solid and hazardous waste generation and impact on soil due to solid and hazardous waste generation. Management of such impacts with operation control and appropriate pollution control equipment is essential to minimize their effect on surrounding environment including local population and wildlife and same is discussed in Environment Management Plan.

d) Muck Disposal

The construction would involve about 4.4 Mcum of soil and rock excavation. About 3 Mcum of excavated muck is expected to be utilized for rockfill and aggregate for construction. Total quantity of muck proposed to be disposed in designated muck disposal area, after considering swelling factor would be 1.4 Mcum. This muck would requires disposal, with minimum environment impacts. Muck, if not securely transported and dumped at pre-designated sites, can have serious environmental impacts, such as:

- Can be washed away into the natural water bodies which can cause negative impacts on surface and ground water quality.
- 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 stabilization measures. In such a scenario, the muck moves along with runoff and creates soil erosion like situations.
- 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.
- A detailed Muck Disposal Plan will be prepared to minimize the impact and addressed in Environmental Management Plan.

e) Road Construction

A network of roads would be required to approach various project components for construction, operation and maintenance. It has been assessed that about 10 km length of new road is required to be constructed to access the power house from the lower reservoir and Upper reservoir. The total land required for the construction of new road is 10 ha. It is proposed to develop the existing cart track for use of project roads. As such, no adverse impact is envisaged with road construction.

f) Impact due to Acquisition of Land

For the development of Chitravathi Pumped storage Project, Approximate land that would be required for construction of project components, reservoir area, muck dumping, construction camps and colony, etc are estimated below. Total land required for the construction of proposed activities is approximately 136 Ha.

Major impact of land acquisition is permanent change of land use, which is unavoidable. Additionally, land acquisition has impacts on local population by way of loss of their agriculture land and hence livelihood and also impact on flora and fauna by way of clearing of vegetation on acquired land. These impacts will be mitigated by implementing Landscaping Restoration and Green Belt Development Plan and Biodiversity Conservation and Wildlife Management Plan, and the detailed study will be taken in EMP studies.

g) Impact on Water Quality

Sewage from Construction Sites due to worker Camps

The disposal of untreated sewage can lead to water pollution, resulting in increase in coliforms and other various pathogens, which can lead to incidence of water borne diseases. Therefore, appropriate measures have to be taken to check such disposal into the natural water bodies. In order to avoid any deterioration in water quality due to disposal of untreated sewage from labour camps, appropriate sewage treatment facilities shall be constructed in the labour camps.

Effluent from Construction Plants and Workshops

Discharge of untreated wastewater will adversely affect the water quality of receiving water body. Turbidity and oil & grease levels will increase substantially in small tributaries, especially, in lean season. To minimize the impact, such effluent needs to be treated in situ before discharge to any water body or for land application.

Disposal of Muck

The major impact on the water quality arises when the muck is disposed along the river bank. The project authorities have identified suitable muck disposal sites which are not located near the river banks.

h) Impact on Terrestrial Flora

Due to the increased level of human interference in and around the project area will have a major impact on the flora. Tree cutting for fuel wood, construction of houses, furniture by the workers to meet their requirements also impact the flora. Normally in such situations, lot of indiscriminate use or wastage of wood is also observed, especially in remote or inaccessible areas. Thus, it is necessary to implement adequate surveillance to mitigate the adverse impacts on terrestrial flora during project construction phase.

i) Impact on Terrestrial Fauna

Disturbance to Wildlife

During the period of construction, large number of machinery and construction workers are mobilized, which results in the disturbance of wildlife population in the vicinity of project area. The operation of various equipment's 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 setting of construction plants, workshops, stores, labour camps etc. could also lead to adverse impact on fauna of the area. 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.

The other major impact could be the blasting to be carried out during construction phase. This impact needs to be mitigated by adopting controlled blasting and strict surveillance regime and the same is proposed to be used in the project. This will reduce the noise level and vibrations due to blasting to a great extent.

j) Impact on Noise Environment

Sources of noise will be from the vehicles, heavy machinery and equipment for excavation and stationary equipment, including concrete batch plant located at the construction sites, explosions, drilling machines and quarrying and crushing activities.

k) Impact on Air Quality

The sources and activities that might affect the air quality in the project area are vehicular movement, dust arising from unpaved village roads and domestic fuel burning. The air environment around project site is free from any significant pollution source. Therefore, ambient air quality is quite good in and around the project area.

l) Traffic Analysis

Traffic analysis shall be carried out to understand the existing load carrying capacity of the roads near to the project site and connecting main roads in the area.

m) Impact on Socio-economic Environment

Positive Impacts on Socio-Economic Environment

The following positive impacts are anticipated on the socio-economic environment of the local people of villages of project area during the project construction and operation phases:

- A number of marginal activities and jobs would be available to the locals during construction phase.
- Developer bringing large scale investment to the area will also invest in local area development and benefit will be reaped by locals. Education, medical, transportation, road network and other infrastructure will improve.
- The availability of alternative resources provided by developer in the rural areas will reduce the dependence of the locals on natural resources such as forest.
- With increased availability of electricity, small-scale and cottage industries are likely to come up in the area.
- The proposed project site is well connected by road. Efforts to be made to develop eco-tourism, which could earn additional revenue.

Negative Impacts on Socio-Economic Environment

Positive impact on socio-economic environment may also bring certain amount of negative impact due to influx of outside population. Workforce will reside in that area for around four years and also there will be influx of drivers and other workers on temporary basis. This influx of people in otherwise isolated area may lead to various social and cultural conflicts during the construction stage. Developers need to take help of local leaders, Panchayat and NGOs to ensure minimum impact on this count.

Increased incidence of Diseases

Large scale activity in the area due to the proposed project may become a cause of spread different types of diseases in the project area due to following reasons:

- Project requires long-term input of labour from outside the area.
- Project requires that significant numbers of project employees be separated from their families for long periods of time
- Project involves the creation of large, temporary construction camp(s).
- Increases mobility of people in and out of the area (job seekers, formal and informal service providers).
- Requires participation / resettlement of the local population.

n) Impact During Operation Phase

On successful completion of the construction, land used for construction activities will be restored. Construction workers will move to another project site. By ensuring all the mitigation and management measures to minimize the impact of construction phase, large part of the area will be restored to pre-construction stage. However, there will be some permanent changes such as reservoir formation, powerhouse and project colony. The project is planned as a clean source of renewable energy as there are no significant pollution generation during project operation. There is no air and water pollution from the project operation. Similarly generation of solid and hazardous waste is also insignificant.

Other impacts of the construction phase include formation of reservoir impacting the water quality, pollution generation from colony and plant and positive as well negative impacts on socio-economic environment mainly due to improved infrastructure in the area.

Proposed Chitravathi pumped storage project consists of artificial upper and an existing lower reservoir and water will remain in circulation from upper to lower during power generation and vice versa during non-generation hours on daily basis. Reservoir water requirement will be met once and thereafter only small quantity will be added to compensate for evaporation losses/leakages.

During the 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 infrastructural facilities, the problems of water pollution due to disposal of sewage are not anticipated. The treated sewage will be reused for gardening and green belt around the colony.

16.6 ENVIRONMENTAL MANAGEMENT PLAN

16.6.1 Biodiversity Conservation & Wildlife Management Plan

In view of the anticipated impacts, the main objectives of biodiversity conservation and wildlife management plan shall be follows:

- ❖ Maintenance of ecological balance through preservation and restoration of wherever it has been disturbed due to project developmental activities,
- ❖ Conservation and preservation of natural habitats in catchment and project area
- ❖ Rehabilitation of critical species (endangered, rare and threatened species), with provisions for in situ or ex situ conservation,
- ❖ Mitigation and control of project induced biotic and/or abiotic pressures/ influences that may affect the natural habitats,

- ❖ Habitat enhancement in project area and catchment area by taking up soil conservation measures,
- ❖ Creating all round awareness regarding conservation and ensuring people's participation in the conservation efforts and minimizing man-animal conflict

16.6.2 Muck Dumping Plan

The project would generate substantial quantity of muck from the excavation of various structures. The total quantity of muck likely to be generated from excavation including construction of roads is about 4.4 Mcum. However after the utilization of muck for different project components and also considering the swell factor total estimated quantity to be disposed of is about 3 MCum. For the disposal of 1.4 MCum of muck an area of 30 Ha has been identified.

16.6.3 Solid waste management from labour camps

The territorial area of the project complex/ colony, shall be responsible for the implementation of the provision of Solid Wastes Management. Facilities for collection, conveyance and disposal of solid waste shall be developed. Any solid waste generated in the project complex/ project colony/ labour colony, shall be managed and handled appropriately. Various aspects of solid waste management include:

- ❖ Reuse/Recycling
- ❖ Storage/Segregation
- ❖ Collection and Transportation
- ❖ Disposal

16.6.4 Public Health Delivery System

Medical services at secondary level play a vital and complimentary role to the tertiary and primary health care systems and together form a comprehensive district based health care system. Following activities are proposed:

- ❖ Ambulances with all the basic Medicare facilities and small DG set, etc. to cater for villages in the project area.
- ❖ Budget for running the ambulances including driver, fuel and maintenance.
- ❖ First aid posts including sheds, furniture and basic equipment.
- ❖ Budget for running the first aid post including cost of medico, para-medico/Nurses and attendant, consumables, etc.
- ❖ Budget for strengthening existing medical facilities.
- ❖ Budget for Health Awareness/ Vaccination Camps.

16.6.5 Energy Conservation Measures

Fuel for cooking and space heating is an essential requirement and in the absence of adequate fuel availability they will resort to tree cutting for use of fuel wood. Therefore, adequate arrangements such as Community kitchen, Supply of Kitchen fuel, efficient cooking facilities and Solar Lantern.

Landscaping, Restoration & Green Belt Development Plan

The proposed project would involve construction of artificial reservoir, power house, adits, residential and staff colonies, roads, batching plants, etc. These activities will result either in the modification or destruction of the existing landscape of the area. Therefore, restoration work should be carried out in these disturbed landscape to similar or near-similar pre-construction conditions and land use.

Green belt development will comprise of plantations at various places like alongside roads, around the periphery of reservoir rim, and at different project offices and colonies.

16.6.6 Air & Water Management Plan

Various mitigation and management measures have been planned to reduce the impacts of air, noise and water pollution and implement safety measures to ensure that impacts on these counts are reduced to minimum possible during the entire construction phase. To implement such measures, it is important to prepare a budget of such measures and include in the project cost so that lack of fund should not constrain their implementation.

Cost for mitigation measures and monitoring of Air, Water and Noise quality in the project area will be covered under Environmental Monitoring Plan.

16.6.7 Environmental Monitoring Plan

Monitoring shall be performed during all stages of the project (namely: construction and operation) to ensure that the impacts are no greater than predicted, and to verify the impact predictions. The monitoring program will indicate where changes to procedures or operations are required, in order to reduce impacts on the environment or local population. The monitoring program for the proposed project will be undertaken to meet the following objectives:

- ❖ To monitor the environmental conditions of the project area and nearby villages;
- ❖ To check on whether mitigation and benefit enhancement measures have actually been adopted and are proving effective in practice;

16.7 COST FOR IMPLEMENTING ENVIRONMENTAL MANAGEMENT PLAN

A Total amount of Rs. 500 lakh has been allocated for the implementation of Environmental Management Plan.

Chapter-17

Cost Estimate

17 Cost Estimate

17.1 General

The existing Chitravathi Balancing Reservoir project is located near Parnapalli Village in Anantapur district, Andhra Pradesh on the river Chitravathi which is a tributary of the Pennar River. The purpose of this project is to provide irrigation to the two districts namely Kadapa, Anantapur. This reservoir is also known as Sri. Penchikala Basi Reddy Chitravathi Balancing Reservoir.

It is envisaged to utilise the existing Chitravathi Reservoir as Lower pond for the proposed PSP scheme by locating upper pond at a suitable higher location in the vicinity.

The proposed Chitravathi Pumped Storage project envisages utilization of available head between newly constructed upper dam and existing Chitravathi reservoir as lower pond. An Underground Power House (UGPH) will be located in between two reservoirs. Both the reservoirs are interconnected through water conductor and the generator and turbines installed at the power house in between the reservoirs.

17.2 Basis of Project Cost

The cost of the project has been worked out on the basis of preliminary designs and drawings as referred and annexed in the present report.

The Civil Cost Estimates of the project has been prepared as per "Guidelines for preparation of estimates for the river valley projects" issued by CWC and Indian Standard IS: 4877 "Guide for Preparation of Estimate for River Valley Projects".

Rates of major items and GST of works have been prepared based on SOR of Andhra Pradesh and local prevailing rates are adopted for the items not covered by the SSR wherever quantification has not been possible at the present stage of design, lump sum provisions have been made based on judgement / experience of other projects.

The estimates of the Hydro Power Scheme has been divided under the following account heads:

A. Direct Cost

I. Works

A - Preliminary

B - Land

C - Works

J - Power Plant Civil Works

K - Buildings

M - Plantation

O - Miscellaneous

P - Maintenance during construction

Q - Special T&P R

R - Communication

X - Environment and Ecology

Y - Losses on stock

S – Power Plant Electrical Works

Total I-Works

Establishment

Tools and Plants

Suspense

Receipt and Recoveries

Total (A) - Direct Cost

B. Indirect Cost

Capitalization of Abatement of Land Revenue

Audit and Account Charges

Total (B) - Indirect Cost

Total Cost (A+B)

17.3 PROJECT COST OF CIVIL AND HM

The project cost estimate is done based on the preliminary design and drawings, "Guidelines for Preparation of Project Estimates for River Valley Projects.

The project cost are likely to undergo changes like additional cost to be incurred due to changes at the detailed design stage specially as a result of hydraulic model studies, variation in the geo-technical parameters which cannot be adjudged precisely at this stage. The cost to completion is also liable to change depending upon the final construction drawings, prevailing rates of materials, equipment & manpower during execution, terms of loan, phasing of expenditure.

The detailed Hard Cost for Civil, Hydro mechanical and Electromechanical Works is attached as **Annexure 17-1**.

Abstract of cost of the Project Hard Cost is given in Table 17-1.

Table 17-1: Abstract of Project Cost

GENERAL ABSTRACT OF PROJECT HARD COST						
Sl No.	Head of A/c	Particulars	Cost of Civil works in Lakhs	Cost of Hydrome-chanical works in Lakhs	Cost of Electrical works in Lakhs	Total Cost in Lakhs
		A. Direct Cost				
	I	**I WORKS**				
	A	Preliminaries: Preliminary Survey	1800.00			1800.00
	B	Land: Lease of Government Land	2000.00			2000.00
	C	Works: Dam and Reservoir Works				
	1	Upper Reservoir Excavation including Embankment/Bund	40800.00			40800.00
	2	TRT outlet Coffer Dam and Associated Channel	1000.00			1000.00
	J	Power Plant Civil Works:				
		Upper Power Intake	5440.00	734.40		6174.40
		TRT Outlet Pump Intake	3330.00	1395.70		4725.70
		Pressure Shafts including Steel Liner	10500.00			10500.00
		Adit to Pressure Shaft Bottom	730.00			730.00
		Adit to TRT Bottom and Transformer Cavern	1000.00			1000.00
		Main Access Tunnel (MAT)	2700.00			2700.00
		Cable Access Tunnel (CAT)	920.00			920.00
		Power House including Transformer Cavern	9900.00	469.30		10369.30
		TRT	3000.00			3000.00
	K	Buildings:	3200.00			3200.00
	M	Plantation: Site Plantations	100.00			100.00
	O	Miscellaneous: Telephone, O & M of inspection vehicles etc.,	1800.00			1800.00
	P	Maintenance: Maintenance charges during construction	900.00			900.00
	Q	Special Tools and Plants	200.00			200.00
	R	Communications: Service Roads	800.00			800.00

	X	Environment & Ecology	500.00			500.00
	Y	Loss on stock: @ 0.25% of C, J	230.00			230.00
	S	Power Plant Electrical Works			69610.00	69610.00
		Transmission Line			11200.00	11200.00
		Total I-Works	**90850.00**			**174259.40**
	II	Establishment Charges, 6% of (I-B) Work	5300.00			5300.00
	III	Tools & Plants @ 0.5% of I-Works less Land	200.00			200.00
	IV	Suspense	NIL			
	V	Receipts & Recoveries: Q – Special Tools & Plants @ 15% of capital cost	-500.00			-500.00
		Sub Total (A)	**95850.00**			179259.40
		B. Indirect Charges				0.00
		Capitalisation of Abatement of Land revenue (5% of cost of culturable Land)	50.00			50.00
		Audit and Accounts @ 0.5% of I Works	450.00			450.00
		Sub Total (B) in Lakh	**96350.00**	**2599.40**	**80810.00**	179759.40
		Total Project Cost in Cr.				**1797.59**

DIRECT CHARGES: INR (95850.00 Lakhs)

I – Works: INR (90850.00 Lakhs)

Under this heading, provision has been made for various components of the Project.

A-Preliminary: INR (1800 Lakhs.)

This head covers the provision for the Surveys and investigations like topographical survey, geological/geotechnical investigations. Construction material availability, route survey, Construction of access roads/paths for investigations, model studies, Consultancy fees for development of project already executed or to be executed in the post DPR phase. This section also covers the consultation fee towards the preparation of bid documents, detailed design & engineering etc. The provision is about 2% of I-works.

B-Land: INR (2000 Lakhs)

The provision under this head covers Acquisition of Land, Interest charges, Solatium charges, demarcation & measurement charges, etc. have been made as per actuals. A provision of 2000 Lakhs has been made under this head.

C– Works: INR (41800 Lakhs.)

This head has provisions for various components of Head works, viz, River diversion works Diversion Tunnel, Coffer Dams etc., and Dam.

J – Power Plant Civil Works: INR (37520 Lakhs.)

This head has provisions for various project components viz., Intake Structure, Headrace Tunnel, Tail Race Tunnel, Pressure Shaft, Powerhouse and Transformer Cavern, Civil works of switchyard.

K – Buildings: INR (3200 Lakhs.)

Buildings, both residential and non-residential have been provided under this head. Under the permanent category only those structures have been included, which will be subsequently utilized for the running and maintenance of the project utilities. The costs are worked out on plinth area basis for the type of construction involved as per prevailing rates in project area.

M – Plantation: INR (100 Lakhs.)

The provision under this head covers the plantation Programme including Gardens etc. required for beautification as considered necessary downstream of Dam and appurtenances around Power House and other important structure. The provision is made on the lump sum basis.

O– Miscellaneous: INR (1800 Lakhs.)

The provision under this head covers the capital cost & maintenance of Electrification, Water supply, Sewage disposal and drainage works, Recreation, Medical, Firefighting equipment's, Inspection vehicles, School bus, Pay van, visit of dignitaries, welfare works etc. A provision of around 2% C-Works, J-Power plant civil works and K-Buildings is made under this head.

P– Maintenance during Construction: INR (900 Lakhs.)

The provision under this head covers the cost of maintenance of all works during the construction period. A provision of 1% of the total cost under the heads of C-Works, J-Power House Civil Works and R-Communication is considered.

Q– Special Tools and Plant: INR (200 Lakhs.)

It is assumed that the work will be carried through Contracts and accordingly provision for general purpose equipment and inspection vehicle only has been made as per CEA/CWC guidelines.

R– Communication: INR (800 Lakhs.)

The cost is based on the construction cost of road and bridges in similar area as of the Project. The road length / location of bridges proposed in this head are tentative and may change during actual construction. Provision under this head covers the cost of construction of main approach roads to all project components, easing of bends/filling deeps/ strengthening of bridges and roads with in project area, widening, strengthen of exiting road.

X– Environment and Ecology: INR (500 Lakhs.)

Provision under this head covers the cost of the Bio-diversity Conservation, Creation of Green Belt, and Restoration of Construction Area, Catchment Area Treatment. A lump sum provision has been kept.

Y- Losses on stock: INR (230.00 Lakhs.)

The provision is made at 0.25% of the total cost of C-Works, J-Power Plant Civil Works and K-Buildings only as per the CEA Guidelines.

II– Establishment: INR (5300 Lakhs.)

Provision for establishment has been made @ 6% of l-works minus B-Land for civil works considering compact size of the project and already in place facilities of existing Chitravathi project.

III– Tools and Plants: INR (200 Lakhs.)

This provision is distinct from that under Q-Special T&P and is meant to cover cost of survey instruments, camp equipment and other small tools and plants. A provision of 2 cr. has been kept as per CWC guideline.

IV– Suspense:

No provision has been made under this head as all the outstanding suspense are expected to be cleared by adjustment to appropriate heads at completion of the project.

V– Receipts and Recoveries: INR (-500 Lakhs Cr.)

Under this head, provision has been made for estimated recoveries by way of resale or transfer temporary buildings and special tools & plants.

INDIRECT CHARGES: INR (500 Lakhs.)

As per the guideline, a provision of 0.5% of the cost of I-Works has been made towards capitalized values of abatement of land revenue (@ 5% of cost of culturable land and audit & accounts charges).

HYDROMECHANICAL WORKS: INR (2599.40 Lakhs.)

This includes cost of all Gates and Valves.

17.4 ELECTRICAL WORKS AND GENERATING PLANT INCLUDING TRANSMISSION LINE

S-INR (80810 Lakhs.)

The cost of generating plant and equipment is based on sources from India. The prices of auxiliary equipment and services are based on prevailing market prices/costs at other ongoing or commissioned projects in India.

17.5 PROJECT COST

The total project cost has been estimated at 179759.40 Lakhs at Mar 2021 price level as given below:

SI. No.	Component	Cost In Lakhs.
1	Civil and HM Works	98949.40
2	E&M Works	80810.00
3	**Total Hard Cost in Lakhs**	**179759.40**
	Total Hard Cost (INR Cr.)	**1797.59**

Chapter-18

Economic Evaluation

18 ECONOMIC EVALUATION

18.1 INTRODUCTION

The economic viability of a project is determined by comparison with the alternative sources at the same place considering therein all elements such as cost of transmission/distribution etc., In isolated areas, it is often compared with diesel or other sources available for affording the same energy benefits. The economics of the project, where existing facility is required to meet the demand could be computed considering system requirements and the ability of the scheme for meeting the demand. When a Hydro Project is to be developed by an Independent producer, he would have to consider returns to him considering all factors such as rate offered to him by third party sale or captive consumption or sale to state electricity boards, any subsidies and concessions available for funding or otherwise.

The economic and financial evaluation of the Chitravathi Pumped Storage Project has been considered as per the standard guidelines issued by Central Electricity Authority and the norms laid down by the Central Electricity Regulatory Commission (CERC) for Hydro and pumped storage projects have been kept in view in this regard.

18.2 GENERATION BENEFITS FROM THE PROJECT

In a year, the planned power generation will be 963.19 MU considering the rate of 5.61 hours per day for 365 days operation @ 95% machine availability.

18.3 ANNUAL REQUIREMENT OF PUMPING ENERGY

The input energy required for pumping works out to 1251MU for 365 days operation @ 95% machine availability.

18.4 PROJECT COST

The total project cost has been estimated at 2027.72 Crore at March 2020 price level as given below:

Cost of Civil Works	:	989.49 Crores
Cost of E&M work including Transmission line	:	808.10 Crores
Interest during Construction	:	230.13 Crores
Total project cost	:	2027.72 Crores

18.5 MEANS OF FINANCE

The project is proposed to be financed through term loans from financial institutions and balance through equity participation or as in practice of Corporation.

Equity: The developer will provide Equity to the extent of 30% of the project cost based on the estimates by adopting a debt equity ratio of 70:30 is borrowed.

Debt: The term loan to the extent of 70% of the project cost (including IDC) based on the estimates will be obtained from the financial institutions.

The analysis has been carried out, considering the rate of interest equal to 10.0% on term loan. As per CERC Terms & Conditions of Tariff Regulations, 2019 (in short, "**CERC Tariff Regulations 2019**"), repayment of loan has been considered equal to the depreciation allowed under these regulations, until the loan is fully paid off. Interest charges have been computed based on average of opening and closing amount of outstanding loan.

18.6 PHASING OF EXPENDITURE

The project is scheduled to be completed in 48 months in all respects. The phasing of the expenditure worked out on the basis of proposed construction programme is summarized in Table 18-1.

Table 18-1: Phasing of Expenditure

6 Monthly Phasing	Capital Expenditure (Cr.)
6	85.132
12	134.311
18	351.744
24	390.900
30	211.013
36	239.675
42	323.211
48	291.737

18.7 INTEREST DURING CONSTRUCTION

Interest charges during construction would depend on phasing of expenditure. IDC has been considered for scheduled completion period of 48 months including preconstruction period. The Interest during Construction period is expected to be Rs.230.13 Cr.

18.8 DEPRECIATION PROVISION

As per CERC Tariff Regulations 2019, Depreciation is considered @5.28% p.a. for the initial period of 14 years and the remaining depreciation to cover 90% depreciable value shall be spread over balance useful life of 40 years of the project.

Land is not a depreciable asset; hence depreciation is to be provided on total cost of the project other than Land.

18.9 VIABLE TARIFF

Following assumptions are made to arrive at the viable tariff, as per CERC Tariff Regulations 2019.

- Operation and maintenance (O & M) Expenses @ 3.5% of the project cost, escalated @ 4.77% per annum.
- Interest on working capital has been arrived as follows: The total working capital is arrived at by considering sum of 15.00% on maintenance of spares, 1-month O&M cost, and 45 days Receivables.
- Discount Factor for the purpose of calculating Levellised tariff has been considered at 10%
- Interest on loan is taken as 10%
- Return on equity – 16.50%
- Auxiliary consumption – 1.20%

Charges for pumping energy	Tariff for first year	Levellised tariff
3.0	8.37	7.82
2.5	7.70	7.15
2.0	7.03	6.48
0.0	4.36	3.81

Detailed Economic Evaluation for base case considering Pumping energy charge as Rs. 3.0 is appended as **Appendix-B**.

18.10 SENSITIVITY ANALYSIS

A sensitivity analysis is carried out to understand the impact of variation of financial parameters on cost of generation. Analysis is done with different combinations of Pumping Power, Interest rates and RoE. The analysis results are appended as **Appendix-C**.

Chapter-19

Conclusion and Recommendation

19 CONCLUSION AND RECOMMENDATION

The present report summarizes the findings and outcome of the Feasibility stage study based on review of previous study and limited field surveys.

- There are hillocks on both the sides of the existing Chitravathi dam, which are considered for proposing upper reservoir. The pump storage scheme will be utilized by utilizing the water from the existing Chitravathi reservoir which has total live storage capacity of the order of 9.956 TMC (281.85MCM). The Chitravathi reservoir is mainly for irrigation and drinking water supply. Based on preliminary alternative study between left bank and right bank, Left bank is found more suitable for upper reservoir.
- The upper reservoir is proposed by excavating the hill top and is envisaged to be constructed partly cutting and partly filling to minimize environmental hazard.
- Optimum live storage of the upper reservoir is worked out as is 6.26 MCM (0.22 TMC). Therefore utilization of water from the existing lower reservoir for the PSP will be 6.26 MCM, which is only 2.21% of the total live storage of the exiting lower reservoir. Thus this requirement of water will be easily met without affecting much on the lower reservoir. Also being close loop pumped project no adverse impact is envisaged in hydrological regime of river.
- The power house is proposed underground and the total water conductor will be of order of 750 m.
- Based on the preliminary geological studies, no adverse geological conditions are envisaged for upper reservoir and underground works.
- Being a compact project with construction of upper reservoir at hillock just adjacent to the existing lower Chitravathi reservoir, the project infrastructure facilities are confined to about 65 Ha. Overall about 136 Ha of project land is estimated to be required. Based on preliminary studies, it is envisaged that the majority of land is unacessed waste land and minimum private land is expected.
- The construction period works out to four years including pre construction activities.
- Based on preliminary engineering and costing the total project cost works out to 179759.40 Lakhs (1797.59 Cr). The per MW cost is approx. 3.59 Cr.

- The Levellised tariff works out to INR 7.82 per unit considering pumping energy charge as Rs. 3.0 and various financial assumptions. However, tariff can be reduced by following ways, which will be explored at next level of study in consultation with the project developer:

  - Possibility of getting interest concession.
  - The developer may spend the equity first and then loan to minimize interest during construction.
  - Possibilities of reduction in interest rate after completion of project as risk reduces thereafter.
  - Reduction of O&M charges
  - Longer loan repayment period
  - Possibility of getting Off-Peak energy for Pumping at Lower Rate by exploring other Non-Conventional/Renewable source.

Following points may also be considered during assessing of the feasibility of the proposed Chitravathi PSP:

- Curtailment/ reduction of energy generation from thermal and fossil fuels to reduce the carbon foot prints considering the climate changes and therefore promoting the renewable energy.
- Pump storage schemes as a renewable source provides ancillary services to stabilize the grid.

Based on the findings of the feasibility study, the project is recommended for further study at Detailed Project Report stage.

ANNEXURES

Annexure 10-1

Chitravathi PSP Upper Intake Design

1.0 Design Inputs:

Normal Operation (100%)	=	297.26	m^3/s
Overloading Operation (110%)	=	326.99	m^3/s
Full Reservoir Level (FRL)	=	495.00	m
Min. Drawdown Level (MDDL)	=	460.00	m
Penstock Diameter, D (Circular)	=	7.70	m
No of Penstock	=	1.00	nos

2.0 Design Calculations:

2.1 Flow Characteristics

Normal Operation (100%)

Total design discharge	=	297.26	m^3/s
Discharge through each Intake	=	297.26 /1	
	=	297.26	m^3/s
Flow velocity in Intake tunnel/HRT	=	6.38	m/s

Overloading Operation (110%)

Total design discharge	=	326.99	m^3/s
Discharge through each Intake	=	326.986 /1	
	=	326.99	m^3/s
Flow velocity in Intake tunnel/HRT	=	7.02	m/s

2.2 Required Bellmouth Opening

Cross sectional area of tunnel, A	=	0.7854 x 7.7^2	
	=	46.57	m^2
Coefficient of contraction, C_c *(as per IS 9761:1995)*	=	0.60	
Inclination of intake (with horizontal), Ø	=	0.00	
Required Opening Area, A_o	=	$A/(C_c . Cos\Phi)$	
	=	46.566 / (0.6 x Cos 0)	
	=	**77.61**	m^2

2.3 Bell Mouth Shape Calculations

Gate Size:

Deeply seated intake structure which subjected to water head of; 58.0 m

Provided Gate Size:

Gate Width, w	=	7.7	m
Gate Height, h	=	7.7	m
Number of bays, n	=	1.0	nos
Area provided at gate section,	=	59.3	m^2

Bellmouth Shapes:

a) Elevation (roof/bottom) = $\left(\frac{x}{a_1}\right)^2 + \left(\frac{y}{b_1}\right)^2 = 1$

a_1	1.1 *h	=	1.1*7.7	m
		=	8.47	m
b_1	0.291 *h	=	0.291 x 7.7	m
			2.2	m

Height of opening, h_e	=	$2*b_1 + h$	
	=	2.241*2 + 7.7	
	=	**12.18**	m

Hence, required width of opening,		=	A_o / he
		=	77.61 / 12.182
		=	**6.37 m**

b) Plan

Sides profile = $\left(\frac{x}{a_2}\right)^2 + \left(\frac{y}{b_2}\right)^2 = 1$

a_2	0.6 *be	=	0.55 x 6.371
		=	3.50 m
b_2	0.2143 *be	=	0.2143 x 6.371
		=	1.40 m
Width of opening,		=	($2*b_2$ + w)
		=	9.171
		=	**9.2** m

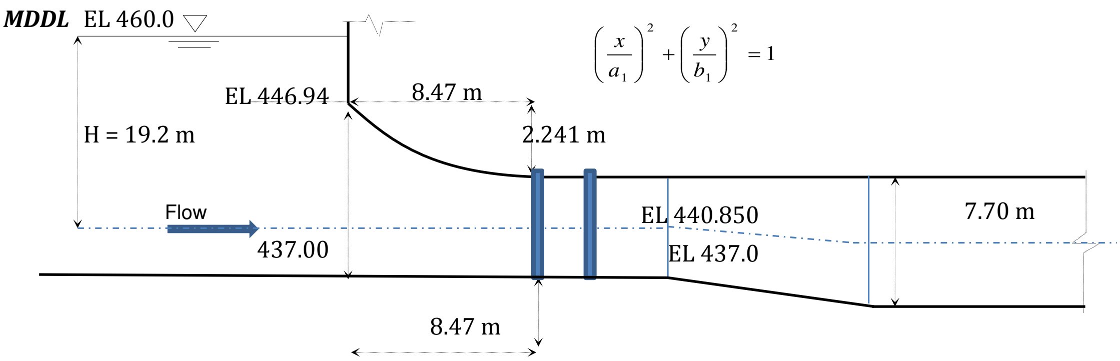
width is more than require hence ok

Hence area provided = **111.721122** *hence ok*

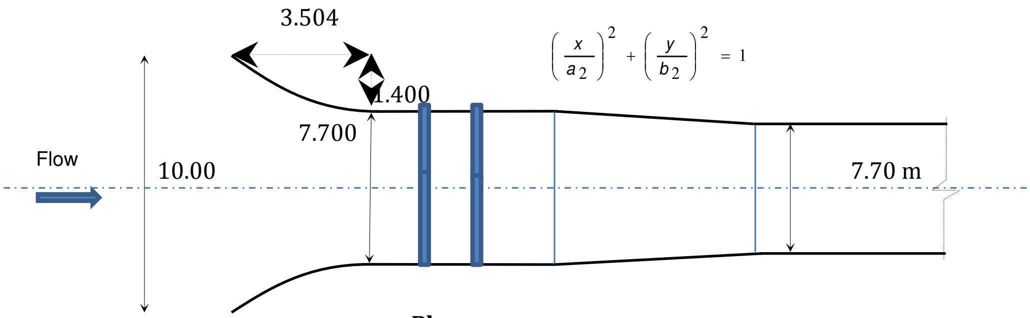
Note: The side profiles for intake have been proposed in reference to IS 9761:1995

2.4 Intake Submergence:

Proposed Intake Sill level	=	437.00 m
Intake approach invert level	=	437.00 m
Center Line Elevation	=	437 + 7.7/2
	=	440.850 m



Elevation



Plan

INTAKE STRUCTURE - GENERAL ARRANGEMENT **[NOT TO SCALE]**

i) As per IS 9761:1995

Submergence depth, *S*	=	460 - 440.85
Hence, S	=	19.15 m
Determination of Froude Number, Fr	=	$V/\sqrt{gD}$
a) Flow Area at Intake Gate	=	(7.7 x 7.7)
	=	59.29 m^2
b) Flow Area at HRT	=	49.17 m^2
Minimum area of above shall governs the submergence.		
Normal Operation (100%)		
Velocity of flow	=	297.26 / 49.17
	=	6.05 m/s
Froude No, Fr	=	6.05 / Sqrt (9.81 x 7.7)
	=	0.696
Overloading Operation (110%)		
Velocity of flow	=	326.986 / 49.17
	=	6.65 m/s
Froude No, Fr	=	6.65 / Sqrt (9.81 x 7.7)
	=	0.765
Since Froud Number 'Fr' is more than 1/3, considered as medium/small size installation		
H/D	=	0.5 + 2Fr
Normal Operation (100%)	=	0.5 + 2 x 0.696
	=	1.89
Overloading Operation (110%)	=	0.5 + 2 x 0.765
	=	2.03
Minimum invert required		
Normal Operation (100%)	=	460 - 1.89 x 7.7 - 7.7/2
Required Invert level	=	441.60 m
Overloading Operation (110%)	=	460 - 2.03 x 7.7 - 7.7/2
Required Invert level	=	440.52 m
Take additional depth for saftey	=	1.00 m(assumed)
Invert level at entrance	=	**439.52** m

ii) As per Gordon Formula

Min. submergence over tunnel crown,	=	$S = C*V*[D/g]^{0.5}$
where,		
Gordon's Coefficient, c	1.7	; for symmetrical approach
	2.3	; for asymmetrical approach
Normal Operation (100%)		
considering asymmetric approach, s	=	2.3 x 6.05 x (7.7 / 9.81)^0.5
	=	12.33 m

Minimum invert required	=	460 - 12.33 - 7.7	
	=	439.97	m
Overloading Operation (110%)			
considering asymmetric approach, s	=	2.3 x 6.65 x (7.7 / 9.81)^0.5	
	=	13.55	m
Minimum invert required	=	460 - 13.55 - 7.7	
	=	438.75	m
Take additional depth for saftey	=	1.00	m(assumed)
Invert level at entrance	=	437.75	
Hence, sill level is adequately provided at elevation;	=	**437.00**	m

2.5 Trash Rack Layout Arrangement

Intake approach floor level	=	437.0	m	
Permissible velocity - Mechanical Cleaning	=	1.50	m/s	
Net area excluding trash rack	=	65%		
Clogging % (for design)	=	30%		
Flow depth at MDDL	=	460 - 437		
	=	23.00	m	
Provide 5 bays of 4.5 m width				
Width provided	=	22.50	m	
Gross area of flow	=	23 x 22.5		
	=	517.50	m^2	
Net area of flow	=	336.38	m^2	
Net area in clogged condition	=	336.375 x (1 - 0.3)		
	=	235.46	m^2	
Check for velocity				
Flow velocity	=	Discharge / Area of flow		
Velocity on gross area	=	326.986 / 517.5		
	=	0.63	m/s	
Velocity on net area	=	0.97	m/s	
Velocity on net area in clogged condition	=	1.39	m/s	
	<	1.50	m/s	***OK***
Trash rack Dimensions				
No of bays	=	5.00		
No of intermediate piers	=	4.00		
Width of Intermediate piers	=	2.00	m	
No. of side pier	=	2.00	m	
Width of side pier	=	3.00	m	
Clear width	=	22.50	m	
Total width provided	=	**36.50**	m	

3.0 Reference:

1. IS 9761:1995 (Reaffirmed 2000), “Hydropower Intakes – Criteria for hydraulic design”.
2. IS 11388:1995 (Reaffirmed 2000), “Recommendation for design of Trash Racks for Intakes”.
3. IS 11570:1985, “Criteria for Hydraulic Design of Irrigation Intake Structures”.

Annexure 10-2

Chitravathi PSP - Economical Diameter of Penstock

Input Data:

Cost of Materials and Energy

Unit cost of Excavation, C_e	4356.000	Rs./cum
Unit cost of Concrete (M15, A40), C_c	7854.000	Rs./cum
Unit cost of Steel, C_s	85.000	Rs./kg
Cost of 1Kwh Energy, C_p	7.5	Rs.

Efficiency

Overall efficiency of Plant, e	0.9160	
Joint efficiency of Penstock, e_j	0.95	
Emergency Water Level, EWL	495.000	
Full Reservoir Level, FRL	495.00	m
Level of the Center line of Penstock	245.65	m
Gross Head = (weighted FRL-Normal TWL) =(MDDL+2/3*(FRL-MDDL)-TWL	212.50	m
Percentage by which Head is increased due to Water Hammer :	35	%
Head on penstock including Water Hammer, H	336.62	m
Percentage by which the steel in penstock is overweight due to provision of stiffeners,Corrosion allowance,etc., i	0.100	
Rugosity coefficient in Manning's formula, n	0.011	
Ratio of annual fixed Operation and maintenance charges to construction cost of penstock (p) :	0.125	
Annual Load factor p_f	0.200	
Design Discharge (100%)	297.26	m^3/sec
No. of WCS	1	Nos
Discharge through penstock, Q	297.26	m^3/sec
Permissible stress for IS 2002-Grade 3 Material, σa	183.33	N/mm^2

From IS 11625-1986, Clause No.6

Economical diameter of Penstock is Given by,

$$D^{\frac{22}{3}} = \frac{2.36 * 10^6 * Q^3 * n^2 * ep_f * Cp}{\left[1.39Ce + 0.6Cc + \frac{121HCs(1+i)}{\sigma_a . e_j}\right]p}$$

$D^{22/3}$ = 2519733 m

D = 7.46 m

Result:

The Economical Diameter of the Penstock is :	=	7.50	m
Provided diameter of Penstcok (to restrict velocity of flow)	=	7.7	m

Annexure 10-3

Chitravathi TRT/Pump Intake Design

1.0	**Design Inputs:**			
	Normal Operation (100%)	=	259.16	m^3/s
	Overloading Operation (110%)	=	285.08	m^3/s
	Full Reservoir Level (FRL)	=	298.00	m
	Min. Drawdown Level (MDDL)	=	282.55	m
	Penstock Diameter, D	=	10.70	m
	No of HRT/Penstock	=	1.00	nos
2.0	**Design Calculations:**			
2.1	**Flow Characteristics**			
	Normal Operation (100%)			
	Total design discharge	=	259.16	m^3/s
	Discharge through each Intake	=	259.16 /1	
		=	259.16	m^3/s
	Flow velocity in Intake tunnel/HRT	=	2.73	m/s
	Overloading Operation (110%)			
	Total design discharge	=	313.58	m^3/s
	Discharge through each Intake	=	313.5836 /1	
		=	313.58	m^3/s
	Flow velocity in Intake tunnel/HRT	=	3.30	m/s
2.2	**Required Bellmouth Opening**			
	Cross sectional area of tunnel, A	=	0.7854 x 10.7^2	
		=	89.92	m^2
	Coefficient of contraction, C_c *(as per IS 9761:1995)*	=	0.60	
	Inclination of intake (with horizontal), Ø	=	0.00	
	Required Opening Area, A_o	=	$A/(C_c . Cos\Phi)$	
		=	89.92 / (0.6 x Cos 0)	
		=	**149.87**	m^2
2.3	**Bell Mouth Shape Calculations**			
	Gate Size:			
	Deeply seated intake structure which subjected to water head of;		263.0	m
	Provided Gate Size:			
	Gate Width, w	=	10.7	m
	Gate Height, h	=	10.7	m
	Number of bays, n	=	1.0	nos
	Area provided at gate section,	=	114.5	m^2
	Bellmouth Shapes:			
a)	**Elevation (roof/bottom)**	=	$\left(\frac{x}{a_1}\right)^2 + \left(\frac{y}{b_1}\right)^2 = 1$	
	a_1 1.1 *h	=	1.1*10.7	m
		=	11.77	m
	b_1 0.291 *h	=	0.291 x 10.7	m
			3.1	m
	Height of opening, h_e	=	$2*b_1 + h$	
		=	3.114*2 + 10.7	
		=	**16.93**	m

Hence, required width of opening,	=	A_o / he
	=	149.867 / 16.928
	=	**8.85 m**

b) Plan

Sides profile = $\left(\frac{x}{a_2}\right)^2 + \left(\frac{y}{b_2}\right)^2 = 1$

a_2	0.6 *be	=	0.55 x 8.854
		=	4.87 m
b_2	0.2143 *be	=	0.2143 x 8.854
		=	1.90 m
Width of opening,		=	(2*b_2 + w)
		=	12.654
		=	**12.7** m

width is more than require hence ok

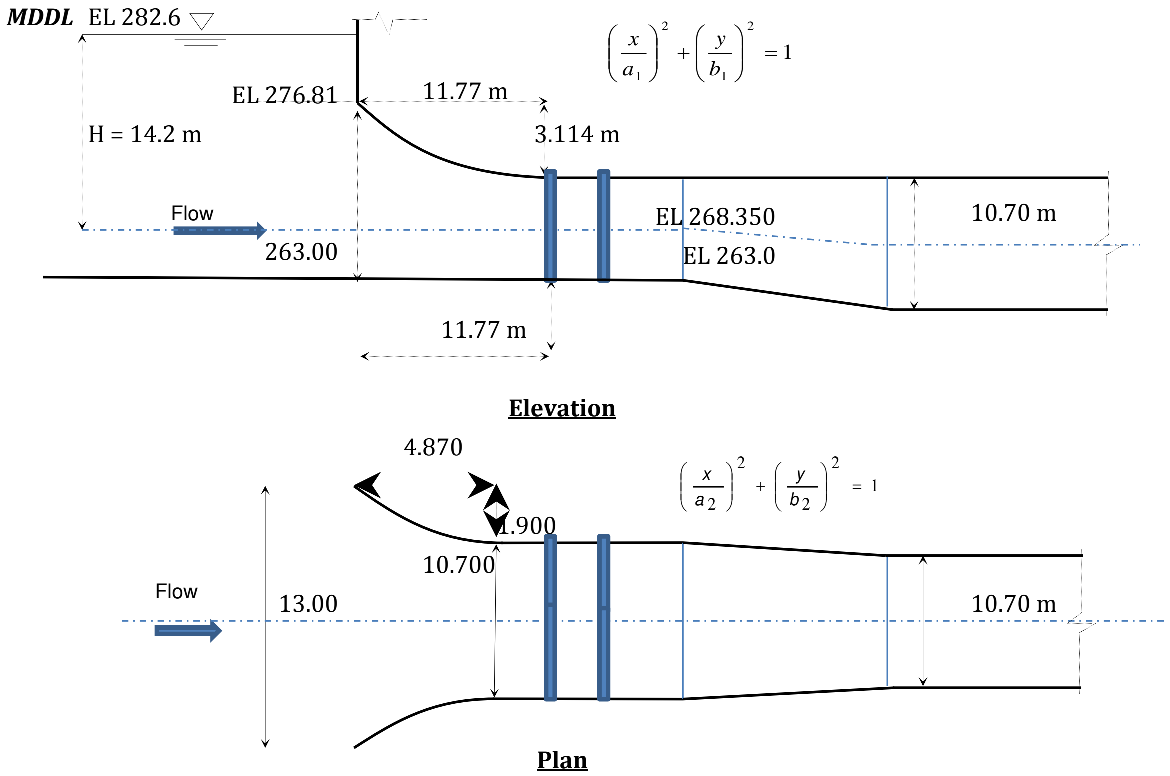
Hence area provided = **214.206912**

hence ok

Note: The side profiles for intake have been proposed in reference to IS 9761:1995

2.4 Intake Submergence:

Proposed Intake Sill level	=	263.00 m
Intake approach invert level	=	263.00 m
Center Line Elevation	=	263 + 10.7/2
	=	268.350 m



INTAKE STRUCTURE - GENERAL ARRANGEMENT **[NOT TO SCALE]**

i) As per IS 9761:1995

Submergence depth, *S*	=	282.55 - 268.35
Hence, S	=	14.20 m
Determination of Froude Number, Fr	=	$V/\sqrt{gD}$
a) Flow Area at Intake Gate	=	(10.7 x 10.7)
	=	114.49 m^2
b) Flow Area at HRT	=	89.93 m^2
Minimum area of above shall governs the submergence.		
Normal Operation (100%)		
Velocity of flow	=	259.16 / 89.93
	=	2.88 m/s
Froude No, Fr	=	2.88 / Sqrt (9.81 x 10.7)
	=	0.281
Overloading Operation (110%)		
Velocity of flow	=	313.5836 / 89.93
	=	3.49 m/s
Froude No, Fr	=	3.49 / Sqrt (9.81 x 10.7)
	=	0.341
Since Froud Number 'Fr' is less than 1/3, considered as Large Size Installation		
H/D	=	0.5 + 2Fr
Normal Operation (100%)	=	0.5 + 2 x 0.281
	=	1.06
Overloading Operation (110%)	=	0.5 + 2 x 0.341
	=	1.18
Minimum invert required		
Normal Operation (100%)	=	282.55 - 1.06 x 10.7 - 10.7/2
Required Invert level	=	265.86 m
Overloading Operation (110%)	=	282.55 - 1.18 x 10.7 - 10.7/2
Required Invert level	=	264.57 m
Invert level at entrance	=	**264.57** m

ii) As per Gordon Formula

Min. submergence over tunnel crown,	=	$S = C*V*[D/g]^{0.5}$
where,		
Gordon's Coefficient, c	1.7	; for symmetrical approach
	2.3	; for asymmetrical approach
Normal Operation (100%)		
considering asymmetric approach, s	=	2.3 x 2.88 x (10.7 / 9.81)^0.5
	=	6.92 m
Minimum invert required	=	282.55 - 6.92 - 10.7
	=	264.93 m

Overloading Operation (110%)		
considering asymmetric approach, s	=	2.3 x 3.49 x (10.7 / 9.81)^0.5
	=	8.38 m
Minimum invert required	=	282.55 - 8.38 - 10.7
	=	263.47 m
Invert level at entrance	=	263.47
Hence, sill level is adequately provided at elevation;	=	**263.00** m

2.5 Trash Rack Layout Arrangement

Intake approach floor level	=	263.0 m	
Permissible velocity - Mechanical Cleaning	=	1.50 m/s	
Net area excluding trash rack	=	65%	
Clogging % (for design)	=	50%	
Flow depth at MDDL	=	282.55 - 263	
	=	19.55 m	
Provide 6 bays of 5.7 m width			
Width provided	=	34.20 m	
Gross area of flow	=	19.55 x 34.2	
	=	668.61 m^2	
Net area of flow	=	434.60 m^2	
Net area in clogged condition	=	434.5965 x (1 - 0.5)	
	=	217.30 m^2	
Check for velocity			
Flow velocity	=	Discharge / Area of flow	
Velocity on gross area	=	313.5836 / 668.61	
	=	0.47 m/s	
Velocity on net area	=	0.72 m/s	
Velocity on net area in clogged condition	=	1.44 m/s	
	<	1.50 m/s	***OK***
Trash rack Dimensions			
No of bays	=	6.00	
No of intermediate piers	=	5.00	
Width of Intermediate piers	=	2.00 m	
No. of side pier	=	2.00 m	
Width of side pier	=	3.00 m	
Clear width	=	34.20 m	
Total width provided	=	**50.20** m	

3.0 Reference:

1. IS 9761:1995 (Reaffirmed 2000), "Hydropower Intakes – Criteria for hydraulic design".
2. IS 11388:1995 (Reaffirmed 2000), "Recommendation for design of Trash Racks for Intakes".
3. IS 11570:1985, "Criteria for Hydraulic Design of Irrigation Intake Structures".

Annexure 10-4

Head Loss Calculations in Water Conductor System in Turbine Mode

Input:

Upper Reservoir Intake:

Discharge (100% discharge) =	297.26	cumecs
Overall Width of Trash Rack =	22.50	m
Overall Height of Trash Rack =	23.00	m
Width of Entrance =	9.20	m
Height of Entrance =	12.18	m
Upstream Main Penstock		
Diameter of Penstock	7.70	m
Length of Penstck	312.01	m
Upstream Branch Penstock		
Diameter of Penstock	5.50	m
Length of Penstck	62.00	m
No. of Penstock	2.00	Nos.
Discharge through each penstock	148.63	cumecs
Diameter after transition (MIV Dia)	3.50	m
Draft Tube Gate		
Height =	5.70	m
Width =	10.90	m
Downstream Branch Penstock		
Diameter of Penstock	5.50	
Length of Penstck	65.50	
No. of Penstock	2.00	
Discharge through each penstock	148.63	
Downstream TRT		
Diameter	10.40	m
Length	300.63	m
Discharge	297.26	
TRT Intake:		
Discharge (100% discharge) =	297.26	cumecs
Overall Width of Trash Rack =	34.20	m
Overall Height of Trash Rack =	19.55	m
Width of Entrance =	12.70	m
Height of Entrance =	16.93	m
Width of gate	10.70	m
Height of gate	10.70	m

1	**Power Intake:**		
a	**Loss at Entry (Clause 4.3 IS : 4880 (Part-III) -1976)**		
	Area, A =	112.06	sqm
	Velocity, V =	2.65	m/s
	where, k_e =	0.16	
	$\mathbf{h_{entrance} = (k_e * V_{intake}^2)/2g}$	**0.057**	**m**
b	**Trash Rack Loss (Clause 4.2 IS : 4880 (Part-III) -1976)**		
i	**Without Clogging:**		
	$k = (1.45 - 0.45R - R^2)$	0.74	
	Gross area of the racks and supports =	517.50	sqm
	Net area through the rack bars =	336.38	sqm
	Velocity through the Trash Rack opening =	0.88	m/s
	R (net area through the rack bars/gross area of the racks and supports)	0.65	
	$h_{Trash\ Rack} = k*V_{TR}^2/(2g)$	**0.029**	m
ii	**With 30% Clogging:**		
	Net Area for 30% clogging =	100.913	sqm
	Velocity =	2.95	m/s
	$h_{Trash\ Rack} = k*V^2/(2g)$	**0.325**	m
	Head loss due to Trash Rack (Min of (i) & (ii)), $\mathbf{h_{Track\ Rack}}$ =	**0.029**	m
c	**Loss due to Intake Stoplog/Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Loss co-efficient due to gate, k_g =	0.10	
	Width	7.70	m
	Height	7.70	m
	Velocity through gate =	5.01	m/s
	Head loss due to gate groove =	**0.128**	**m**
d	**Loss due to Friction at bell mouth (Clause 4.1 IS : 4880 (Part-III) - 1976)**		
	Discharge	297.26	Cumec
	Width at start of bell mouth	9.20	m
	Height at start of bell mouth	12.18	m
	Area at start of bell mouth	112.06	sq. m
	Velocity at start of bell mouth	2.65	m/s
	Width at end of bell mouth	7.70	m
	Height at end of bell mouth	7.70	m
	Area at end of bell mouth	59.29	
	Velocity at end of bell mouth	5.01	m/s

	Average velocity	3.83	m/s
	Perimeter at start of bell mouth	42.76	m
	Perimeter at end of bell mouth	30.80	m
	Average perimeter	36.78	m
	Average area	85.67	sq. m
	Average hydraulic radius, R	2.33	m
	Length of bell mouth	6.00	m
	Mannings coefficient	0.014	
	Loss due to friction, $h_f = (v^2*n^2*L)/R^{4/3}$	**0.0056**	m
e	**Friction loss in gate section (Clause 4.1 IS : 4880 (Part-III) -1976)**		
	Discharge	297.3	Cumec
	Width	7.7	m
	Height	7.7	
	Area	59.3	sq. m
	Perimeter	30.8	m
	Velocity	5.01	m/s
	Hydraulic radius, R	1.9	m
	Mannings coefficient	0.014	
	Length	3.5	m
	Loss due to friction, $h_f = (v^2*n^2*L)/R^{4/3}$	**0.0072**	m
2	**Penstock**		
a	**Loss due to Transition (Gradual Expansion): (Clause 4.4.1 IS : 4880 (Part-III) -1976)**		
	Area of Penstock, A =	46.57	sqm
	Velocity (Penstock), V_1 =	6.38	m/s
	Velocity (Before Transition), V_2 =	5.01	m/s
	K_e =	0.10	
	$h_{expansion} = k_e* (\{V_1^2/2g\}-\{V_2^2/2g\})$	**0.080**	m
b	**Loss due to Friction (Clause 4.4 IS : 11625 -1996)**		
i	**Main Penstock:**		
	Area, A =	46.57	sqm
	Wetted Perimeter, P =	24.19	m
	Velocity, V =	6.38	m/s
	Hydraulic mean radius, R = A/P	1.93	m
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2*n^2*L)/R^{4/3}$	**0.642**	m

ii	**Branch Penstock:**		
	Area, A =	23.76	sqm
	Wetted Perimeter, P =	17.28	m
	Velocity, V =	6.26	m/s
	Hydraulic mean radius, R = A/P	1.38	m
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2 * n^2 * L)/R^{4/3}$	0.175	m
	Loss through one penstock	**0.175**	m
	Total Friction Loss in Penstock =	**0.817**	**m**
iii	**Bifurcation:**		
	Discharge in Branch Penstock, q_b =	148.630	
	Discharge in Main Penstock, q =	297.260	
	q_b/q =	0.500	
	Angle of divergence =	22.000	deg
	Coefficient, k =	0.32	
	$h = (k*V^2/2g)$	**0.665**	**m**
C	**Loss due to Bends (Clause 2.2 IS : 2951 (Part-II) -1965)**		
	Equivalent diameter, D =	7.91	m
	Deflection angle, α =	90.00	deg
	Radius of Curvature of bend, R_b =	23.85	m
	R_b/D =	3.01	
	k =	0.13	
	h_{bend} (= $k*V^2/2g$)	0.260	m
	Loss due to two bend	**0.519**	**m**
3	**Inside the Power House:**		
a	**Loss due to Transition before MIV (Gradual Contraction) (Clause 4.4.1 IS:4880 (Part-III) - 1976)**		
	Velocity (u/s end), V_1 =	6.26	m/s
	Velocity (d/s end), V_2 =	15.45	m/s
	k_c = (as per Clause 4.4.1.1 IS:4880 (Part-III) - 1976)	0.10	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$	**1.02**	**m**
b	**Loss due to Main Inlet Valve (Clause 4.5.4.1 IS:4880 (Part-III) - 1976)**		
	Type of Valve assumed =	Spherical	
	Valve Loss Coefficient, k_v =	0.10	
	$h_{valve} = K_v * V^2/2g$	**1.216**	**m**

c	**Loss due to Draft Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Dimension of Gate =		
	Height =	5.70	m
	Width =	10.90	m
	Area =	62.13	sq m
	Design Discharge per unit =	148.63	cumecs
	Loss co-efficient due to gate, k_g =	0.19	
	Velocity through gate =	2.39	m/s
	Head loss due to gate groove =	**0.055**	**m**
6	**Head loss after power house**		
a	**Transition loss (Draft tube to downstrem Branch Penstock)**		
	Discharge	297.26	Cumec
	Discharge from one draft tube	148.63	Cumec
	Width of draft tube	5.70	m
	Height of draft tube	10.90	m
	Area at start of transition	62.13	sq.m
	Diameter of Downstream branch pressure shaft	5.50	m
	Area at end of transition	23.76	sq.m
	Velocity at start of transition	2.39	m/s
	Velocity at end of transition	6.26	m/s
	K_e	0.10	
	$(\{V_1^2/2g\}-\{V_2^2/2g\})$	1.70	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$, transition loss	0.170	m
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$, due to one draft tube	**0.170**	**m**
7	**Head loss due to Downstream Penstock/Pressure Shaft**		
a	**Loss due to Friction (Clause 4.4 IS : 11625 -1996)**		
	Area, A =	23.76	sqm
	Wetted Perimeter, P =	17.28	m
	Velocity, V =	6.26	m/s
	Hydraulic mean radius, R = A/P	1.38	m
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.203**	m
b	**Loss due to Transition (Gradual Expansion): (Clause 4.4.1 IS : 4880 (Part-III) -1976)**		
	Area of Penstock, A =	23.76	sqm
	Velocity (Penstock), V_1 =	6.26	m/s
	Area of TRT (Horseshoe shape)	89.70	sqm

	Velocity in TRT	3.31	m/s
	Velocity (After Transition), V_2 =	3.31	m/s
	K_e =	0.10	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$	**0.143**	m
c	**Bifurcation:**		
	Discharge in Penstock, q_b =	148.630	
	Discharge in TRT, q =	297.260	
	q_b/q =	0.500	
	Angle of divergence =	34.000	deg
	Coefficient, k =	0.32	
	$h = (k*V^2/2g)$	**0.179**	**m**
8	**Head loss due to Tail Race Tunnel (TRT)**		
a	**Friction Loss**		
	Area, A =	89.70	
	Wetted Perimeter, P =	33.90	
	Velocity, V =	3.31	
	Hydraulic mean radius, R = A/P	2.65	
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2*n^2*L)/R^{4/3}$	**0.109**	
9	**Head loss due to Tail Race Tunnel Intake**		
a	**Friction loss in gate section (Clause 4.1 IS : 4880 (Part-III) -1976)**		
	Discharge	297.3	Cumec
	Width	10.7	m
	Height	10.7	
	Area	114.5	sq. m
	Perimeter	42.8	m
	Velocity	2.60	m/s
	Hydraulic radius, R	2.7	m
	Mannings coefficient	0.014	
	Length	3.5	m
	Loss due to friction, $h_f = (v^2*n^2*L)/R^{4/3}$	**0.0012**	m
b	**Loss due to Friction at bell mouth (Clause 4.1 IS : 4880 (Part-III) - 1976)**		
	Discharge	297.26	Cumec
	Width at start of bell mouth	12.70	m
	Height at start of bell mouth	16.93	m
	Area at start of bell mouth	215.01	sq. m

	Velocity at start of bell mouth	1.38	m/s
	Width at end of bell mouth	10.70	m
	Height at end of bell mouth	10.70	m
	Area at end of bell mouth	114.49	
	Velocity at end of bell mouth	2.60	m/s
	Average velocity	1.99	m/s
	Perimeter at start of bell mouth	59.26	m
	Perimeter at end of bell mouth	42.80	m
	Average perimeter	51.03	m
	Average area	164.75	sq. m
	Average hydraulic radius, R	3.23	m
	Length of bell mouth	6.00	m
	Mannings coefficient	0.014	
	Loss due to friction, $h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.0010**	m
c	**Loss due to Intake Stoplog and Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Loss co-efficient due to gate, k_g =	0.10	
	Width	10.70	m
	Height	10.70	m
	Velocity through gate =	2.60	m/s
	Head loss due to gate groove =	**0.069**	**m**
d	**Trash Rack Loss (Clause 4.2 IS : 4880 (Part-III) -1976)**		
i	**Without Clogging:**		
	$k = (1.45 - 0.45R - R^2)$	0.74	
	Gross area of the racks and supports =	668.61	sqm
	Net area through the rack bars =	434.60	sqm
	Velocity through the Trash Rack opening =	0.68	m/s
	R (net area through the rack bars/gross area of the racks and supports)	0.65	
	$h_{Trash\ Rack} = k*V_{TR}^2/(2g)$	**0.018**	m
ii	**With 50% Clogging:**		
	Net Area for 50% clogging =	217.298	sqm
	Velocity =	1.37	m/s
	$h_{Trash\ Rack} = k*V^2/(2g)$	**0.070**	m
	Head loss due to Trash Rack (Min of (i) & (ii)), $h_{Track\ Rack}$ =	**0.018**	m
e	**Loss at Exit (Clause 4.3 IS : 4880 (Part-III) -1976)**		
	Area, A =	215.01	sqm
	Velocity, V =	1.38	m/s
	where, k_e =	1.00	
	$h_{entrance} = (k_e * V_{intake}^2)/2g$	**0.097**	**m**

	Velocity at start of bell mouth	1.38	m/s
	Width at end of bell mouth	10.70	m
	Height at end of bell mouth	10.70	m
	Area at end of bell mouth	114.49	
	Velocity at end of bell mouth	2.60	m/s
	Average velocity	1.99	m/s
	Perimeter at start of bell mouth	59.26	m
	Perimeter at end of bell mouth	42.80	m
	Average perimeter	51.03	m
	Average area	164.75	sq. m
	Average hydraulic radius, R	3.23	m
	Length of bell mouth	6.00	m
	Mannings coefficient	0.014	
	Loss due to friction, $h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.0010**	m
c	**Loss due to Intake Stoplog and Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Loss co-efficient due to gate, k_g =	0.10	
	Width	10.70	m
	Height	10.70	m
	Velocity through gate =	2.60	m/s
	Head loss due to gate groove =	**0.069**	**m**
d	**Trash Rack Loss (Clause 4.2 IS : 4880 (Part-III) -1976)**		
i	**Without Clogging:**		
	$k = (1.45 - 0.45R - R^2)$	0.74	
	Gross area of the racks and supports =	668.61	sqm
	Net area through the rack bars =	434.60	sqm
	Velocity through the Trash Rack opening =	0.68	m/s
	R (net area through the rack bars/gross area of the racks and supports)	0.65	
	$h_{Trash\ Rack} = k*V_{TR}^2/(2g)$	**0.018**	m
ii	**With 50% Clogging:**		
	Net Area for 50% clogging =	217.298	sqm
	Velocity =	1.37	m/s
	$h_{Trash\ Rack} = k*V^2/(2g)$	**0.070**	m
	Head loss due to Trash Rack (Min of (i) & (ii)), $h_{Track\ Rack}$ =	**0.018**	m

e	**Loss at Exit (Clause 4.3 IS : 4880 (Part-III) -1976)**		
	Area, A =	215.01	sqm
	Velocity, V =	1.38	m/s
	where, k_e =	1.00	
	$h_{entrance}$ = $(k_e*V_{intake}^2)/2g$	**0.097**	**m**
	Head loss up to PH including MIV loss	**5.24**	m
	Head Loss after PH up to TRT intake	**0.99**	m
	Total head loss	**6.23**	m

Head Loss Calculations in Water Conductor System in Pump Mode

Input:

Upper Reservoir Intake:

Discharge (100% discharge) =	259.16	cumecs
Overall Width of Trash Rack =	22.50	m
Overall Height of Trash Rack =	23.00	m
Width of Entrance =	9.20	m
Height of Entrance =	12.18	m
Upstream Main Penstock		
Diameter of Penstock	7.70	m
Length of Penstck	312.01	m
Upstream Branch Penstock		
Diameter of Penstock	5.50	m
Length of Penstck	62.00	m
No. of Penstock	2.00	Nos.
Discharge through each penstock	129.58	cumecs
Diameter after transition (MIV Dia)	3.50	m
Draft Tube Gate		
Height =	5.70	m
Width =	10.90	m
Downstream Branch Penstock		
Diameter of Penstock	5.50	
Length of Penstck	65.50	
No. of Penstock	2.00	
Discharge through each penstock	129.58	
Downstream TRT		
Diameter	10.40	m
Length	300.63	m
Discharge	259.16	
TRT Intake:		
Discharge (100% discharge) =	259.16	cumecs
Overall Width of Trash Rack =	34.20	m
Overall Height of Trash Rack =	19.55	m
Width of Entrance =	12.70	m
Height of Entrance =	16.93	m
Width of gate	10.70	m
Height of gate	10.70	m

1	**Power Intake:**		
a	**Loss at Entry (Clause 4.3 IS : 4880 (Part-III) -1976)**		
	Area, A =	112.06	sqm
	Velocity, V =	2.31	m/s
	where, k_e =	1.00	
	$h_{entrance} = (k_e * V_{intake}^2)/2g$	**0.273**	**m**
b	**Trash Rack Loss (Clause 4.2 IS : 4880 (Part-III) -1976)**		
i	**Without Clogging:**		
	$k = (1.45 - 0.45R - R^2)$	0.74	
	Gross area of the racks and supports =	517.50	sqm
	Net area through the rack bars =	336.38	sqm
	Velocity through the Trash Rack opening =	0.77	m/s
	R (net area through the rack bars/gross area of the racks and supports)	0.65	
	$h_{Trash\ Rack} = k * V_{TR}^2/(2g)$	**0.022**	m
ii	**With 30% Clogging:**		
	Net Area for 30% clogging =	100.913	sqm
	Velocity =	2.57	m/s
	$h_{Trash\ Rack} = k * V^2/(2g)$	**0.247**	m
	Head loss due to Trash Rack (Min of (i) & (ii)), $h_{Track\ Rack}$ =	**0.022**	m
c	**Loss due to Intake Stoplog/Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Loss co-efficient due to gate, k_g =	0.10	
	Width	7.70	m
	Height	7.70	m
	Velocity through gate =	4.37	m/s
	Head loss due to gate groove =	**0.097**	**m**
d	**Loss due to Friction at bell mouth (Clause 4.1 IS : 4880 (Part-III) -1976)**		
	Discharge	259.16	Cumec
	Width at start of bell mouth	9.20	m
	Height at start of bell mouth	12.18	m
	Area at start of bell mouth	112.06	sq. m
	Velocity at start of bell mouth	2.31	m/s
	Width at end of bell mouth	7.70	m
	Height at end of bell mouth	7.70	m
	Area at end of bell mouth	59.29	
	Velocity at end of bell mouth	4.37	m/s
	Average velocity	3.34	m/s

	Perimeter at start of bell mouth	42.76	m
	Perimeter at end of bell mouth	30.80	m
	Average perimeter	36.78	m
	Average area	85.67	sq. m
	Average hydraulic radius, R	2.33	m
	Length of bell mouth	6.00	m
	Mannings coefficient	0.014	
	Loss due to friction, $h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.0043**	m
e	**Friction loss in gate section (Clause 4.1 IS : 4880 (Part-III) -1976)**		
	Discharge	259.2	Cumec
	Width	7.7	m
	Height	7.7	
	Area	59.3	sq. m
	Perimeter	30.8	m
	Velocity	4.37	m/s
	Hydraulic radius, R	1.9	m
	Mannings coefficient	0.014	
	Length	3.5	m
	Loss due to friction, $h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.0055**	m
2	**Penstock**		
a	**Loss due to Transition (Gradual Expansion): (Clause 4.4.1 IS : 4880 (Part-III) -1976)**		
	Area of Penstock, A =	46.57	sqm
	Velocity (Penstock), V_1 =	5.57	m/s
	Velocity (Before Transition), V_2 =	4.37	m/s
	K_e =	0.10	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$	**0.060**	m
b	**Loss due to Friction (Clause 4.4 IS : 11625 -1996)**		
i	**Main Penstock:**		
	Area, A =	46.57	sqm
	Wetted Perimeter, P =	24.19	m
	Velocity, V =	5.57	m/s
	Hydraulic mean radius, R = A/P	1.93	m
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.488**	m

ii	**Branch Penstock:**		
	Area, A =	23.76	sqm
	Wetted Perimeter, P =	17.28	m
	Velocity, V =	5.45	m/s
	Hydraulic mean radius, R = A/P	1.38	m
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2 * n^2 * L)/R^{4/3}$	0.133	m
	Loss through one penstock	**0.133**	m
	Total Friction Loss in Penstock =	**0.621**	**m**
iii	**Bifurcation:**		
	Discharge in Branch Penstock, q_b =	129.580	
	Discharge in Main Penstock, q =	259.160	
	q_b/q =	0.500	
	Angle of divergence =	22.000	deg
	Coefficient, k =	0.32	
	h = $(k*V^2/2g)$	**0.505**	**m**
C	**Loss due to Bends (Clause 2.2 IS : 2951 (Part-II) -1965)**		
	Equivalent diameter, D =	7.91	m
	Deflection angle, α =	90.00	deg
	Radius of Curvature of bend, R_b =	23.85	m
	R_b/D =	3.01	
	k =	0.13	
	$h_{bend\ (}= k*V^2/2g)$	0.197	m
	Loss due to two bend	**0.395**	**m**
3	**Inside the Power House:**		
a	**Loss due to Transition before MIV (Gradual Contraction) (Clause 4.4.1 IS:4880 (Part-III) - 1976)**		
	Velocity (u/s end), V_1 =	5.45	m/s
	Velocity (d/s end), V_2 =	13.47	m/s
	k_c = (as per Clause 4.4.1.1 IS:4880 (Part-III) - 1976)	0.10	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$	**0.77**	**m**
b	**Loss due to Main Inlet Valve (Clause 4.5.4.1 IS:4880 (Part-III) - 1976)**		
	Type of Valve assumed =	Spherical	
	Valve Loss Coefficient, k_v =	0.10	
	$h_{valve} = K_v*V^2/2g$	**0.925**	**m**

c	**Loss due to Draft Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Dimension of Gate =		
	Height =	5.70	m
	Width =	10.90	m
	Area =	62.13	sq m
	Design Discharge per unit =	129.58	cumecs
	Loss co-efficient due to gate, k_g =	0.19	
	Velocity through gate =	2.09	m/s
	Head loss due to gate groove =	**0.04**	**m**
6	**Head loss after power house**		
a	**Transition loss (Draft tube to downstrem Branch Penstock)**		
	Discharge	259.16	Cumec
	Discharge from one draft tube	129.58	Cumec
	Width of draft tube	5.70	m
	Height of draft tube	10.90	m
	Area at start of transition	62.13	sq.m
	Diameter of Downstream branch pressure shaft	5.50	m
	Area at end of transition	23.76	sq.m
	Velocity at start of transition	2.09	m/s
	Velocity at end of transition	5.45	m/s
	K_e	0.10	
	$(\{V_1^2/2g\}-\{V_2^2/2g\})$	1.29	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$, transition loss	0.129	m
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$, due to one draft tube	**0.129**	**m**
7	**Head loss due to Downstream Penstock/Pressure Shaft**		
a	**Loss due to Friction (Clause 4.4 IS : 11625 -1996)**		
	Area, A =	23.76	sqm
	Wetted Perimeter, P =	17.28	m
	Velocity, V =	5.45	m/s
	Hydraulic mean radius, R = A/P	1.38	m
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.154**	m
b	**Loss due to Transition (Gradual Expansion): (Clause 4.4.1 IS : 4880 (Part-III) -1976)**		
	Area of Penstock, A =	23.76	sqm
	Velocity (Penstock), V_1 =	5.45	m/s
	Area of TRT (Horseshoe shape)	89.70	sqm

	Velocity in TRT	2.89	m/s
	Velocity (After Transition), V_2 =	2.89	m/s
	K_e =	0.10	
	$h_{expansion} = k_e * (\{V_1^2/2g\}-\{V_2^2/2g\})$	**0.109**	m
c	**Bifurcation:**		
	Discharge in Penstock, q_b =	129.580	
	Discharge in TRT, q =	259.160	
	q_b/q =	0.500	
	Angle of divergence =	34.000	deg
	Coefficient, k =	0.32	
	$h = (k*V^2/2g)$	**0.136**	**m**
8	**Head loss due to Tail Race Tunnel (TRT)**		
a	**Friction Loss**		
	Area, A =	89.70	
	Wetted Perimeter, P =	33.90	
	Velocity, V =	2.89	
	Hydraulic mean radius, R = A/P	2.65	
	Manning's Coefficient =	0.011	
	Loss due to friction ,$h_f = (v^2*n^2*L)/R^{4/3}$	**0.083**	
9	**Head loss due to Tail Race Tunnel Intake**		
a	**Friction loss in gate section (Clause 4.1 IS : 4880 (Part-III) -1976)**		
	Discharge	259.2	Cumec
	Width	10.7	m
	Height	10.7	
	Area	114.5	sq. m
	Perimeter	42.8	m
	Velocity	2.26	m/s
	Hydraulic radius, R	2.7	m
	Mannings coefficient	0.014	
	Length	3.5	m
	Loss due to friction, $h_f = (v^2*n^2*L)/R^{4/3}$	**0.0009**	m
b	**Loss due to Friction at bell mouth (Clause 4.1 IS : 4880 (Part-III) - 1976)**		
	Discharge	259.16	Cumec
	Width at start of bell mouth	12.70	m
	Height at start of bell mouth	16.93	m
	Area at start of bell mouth	215.01	sq. m
	Velocity at start of bell mouth	1.21	m/s

	Width at end of bell mouth	10.70	m
	Height at end of bell mouth	10.70	m
	Area at end of bell mouth	114.49	
	Velocity at end of bell mouth	2.26	m/s
	Average velocity	1.73	m/s
	Perimeter at start of bell mouth	59.26	m
	Perimeter at end of bell mouth	42.80	m
	Average perimeter	51.03	m
	Average area	164.75	sq. m
	Average hydraulic radius, R	3.23	m
	Length of bell mouth	6.00	m
	Mannings coefficient	0.014	
	Loss due to friction, $h_f = (v^2 * n^2 * L)/R^{4/3}$	**0.0007**	m
c	**Loss due to Intake Stoplog and Gate groove (Clause 4.6 IS : 4880 (Part-III) -1976)**		
	Loss co-efficient due to gate, k_g =	0.10	
	Width	10.70	m
	Height	10.70	m
	Velocity through gate =	2.26	m/s
	Head loss due to gate groove =	**0.052**	**m**
d	**Trash Rack Loss (Clause 4.2 IS : 4880 (Part-III) -1976)**		
i	**Without Clogging:**		
	$k = (1.45 - 0.45R - R^2)$	0.74	
	Gross area of the racks and supports =	668.61	sqm
	Net area through the rack bars =	434.60	sqm
	Velocity through the Trash Rack opening =	0.60	m/s
	R (net area through the rack bars/gross area of the racks and supports)	0.65	
	$h_{Trash\ Rack} = k * V_{TR}^2/(2g)$	**0.013**	m
ii	**With 50% Clogging:**		
	Net Area for 50% clogging =	217.298	sqm
	Velocity =	1.19	m/s
	$h_{Trash\ Rack} = k * V^2/(2g)$	**0.053**	m
	Head loss due to Trash Rack (Min of (i) & (ii)), $h_{Track\ Rack}$ =	**0.013**	m

e	**Loss at Exit (Clause 4.3 IS : 4880 (Part-III) -1976)**		
	Area, A =	215.01	sqm
	Velocity, V =	1.21	m/s
	where, k_e =	0.16	
	$h_{entrance} = (k_e * V_{intake}^2)/2g$	**0.012**	**m**
	Head loss up to PH including MIV loss	**4.21**	m
	Head Loss after PH up to TRT intake	**0.69**	m
	Total head loss	**4.90**	m

Annexure 11-1

Penstock Steel Liner Design

Discharge through penstock	=	297.26 m3/s
Number of units	=	2
Branch flow rate	=	148.63 m3/s
Maximum water level (FRL)	=	495.00 m
Penstock CL elevation at machine hall	=	245.65 m
Penstock CL elevation at Intake	=	440.85 m
Toatal length of penstock (at CL)	=	365.00 m
Corrosion allowance (δ)	=	1.50 mm
Safety stress (σs)	=	3160 kg/cm2
Welding factor (ϕ)	=	0.9
Material Density (γ)	=	7.85 ton/m3
Young's Modulus €	=	2100000 kg/cm2
Poisson's Ratio (v)	=	0.3
Coefficient of thermal expension (ξ)	=	0.000012
Atmosphere Pressurew (Patm)	=	1.00 kg/cm2
External Pressure (Pinj)	=	19.91 kg/cm2
(Intake sill level - Penstock bottom in machine hall)		
Acceleration of grativity (g)	=	9.81 m/s2
Safety Factor (S)	=	1.5
Material	=	ASTM A517 Grade F or equivalent

Allowable Stresses for this material

Hoop Stress	=	3160 kg/cm2
Axial Stress	=	3507 kg/cm2
Combine Stress	=	3976 kg/cm2
Max. Pressure rise at Turbine axis	=	35%
(Taken from Turbine designer)		

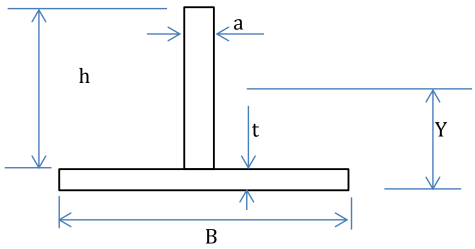
Penstock shell thickness

Penstock diameter (D)	=	7700 mm	mm
tmin	=	(D + 500)/400	
(As per Bureau of Reclamation of USA)	=	20.50 mm	mm
	=	48.00 mm	mm Selected

Material of penstock		ASTM A517 Grade F
Penstock axis static water head (Δht)	=	495-245.65
(at entrance of machine hall)	=	249.35 m
Water hammer (Δh1)	=	249.35 x 0.35
	=	87.27 m
Design head (Ht1)	=	249.35 + 87.2725
	=	336.62 m
Penstock thickness (t)	=	48.00 mm
Internal design pressure (p)	=	33.66 kg/cm2
Internal Pressure stress (σ)	=	(P x D)/(2 x (t - δ) x ϕ)
	=	(33.66225 x 770) / (2 x (4.8 - 0.15) x 0.9)
	=	3096.77 kg/cm2
σ	=	3096.77 < 3160 **SAFE**
Outer Diameter of penstock (D_d)	=	D + 2t = 7796 mm
Critical pressure control (Pk)	=	2 x E x((t - δ)/D_d)^3 /(1 - v^2)
	=	2 x 2100000 x ((48 - 1.5)/7796)^3 / (1 - 0.3^2)
	=	0.979 kg/cm2
Pk	=	0.979 < 24.94 kg/cm2 **Hence stiffeners required**

Spacing of stiffeners (Lt) = 2.59 x E x t^2.5 / (Penj x Dd^1.5 x S)
= 2.59 x 2100000 x 4.65^2.5 / (19.905 x 779.6^1.5 x 1.5)
= 390.20 cm

Lt = 3900 mm Adopted



Moment of inertia of stiffener (Ig) = (1 - v^2) x Dd^3 x Lt x P x S / (24 x E)
= (1 - 0.3^2) x 779.6^3 x 390 x 19.905 x 1.5 / (24 x 2100000)
= 99619.51 cm4

Section of stiffener

a = 35 mm
h = 75 cm
6
rm = D/2 + t/2
rm = 387.40 cm

Pipe effective width (B) = a + 1.56√(rm x t)
= 3.5 + 1.56 x (387.4 x 4.65)^0.5
= 69.71 cm

				Area	Ix		
Aa	=	h x a	=	262.50 cm2	Ix = ha^3/12	=	123046.88 cm4
Ab	=	B x t	=	324.16 cm2	Ix = B(t-δ)^3/12	=	584.09 cm4
A	=	Aa + Ab	=	586.66 cm2			

Centre of Gravity = (Aa x (h/2+(t-δ))+Ab x (t-δ)/2) /A
20.14 cm

Total Inertia = 305630.99 cm4
Ig = 99619.51 < 305630.99 **SAFE**

Support Elastic deformation stress
σTC = ± (1.82 x Aa x P x D)/((Aa + AB) x t x 2)
= 2269.70 kg/cm2

Hoop Stress
σ1 = (P x D0/(2 x (t - δ) x ϕ)
3096.77 kg/cm2

Poisson Stress
σp = v x σ1
929.03 kg/cm2

Temperature difference stress
σTE = ξ x E x ΔT   ΔT = 20
504.00 kg/cm2

Axial Stress
σ1 = ± σp ± σTE ± σTC
5366.46 kg/cm2 > 3507 kg/cm2 **NOT SAFE**

σ2 = ± σp ± σTE ± σTC
-1331.07 kg/cm2 < 3507 kg/cm2 **SAFE**

Combined Stress
σB1 = √(σ^2 + σ1^2 - σ x σ1)
4665.85 kg/cm2 > 3976 kg/cm2 **NOT SAFE**
σB2 = √(σ^2 + σ2^2 - σ x σ2)
3934.94 kg/cm2 < 3976 kg/cm2 **SAFE**

Since the stress level are not within the limits, the thickness of shell will be increased to 48mm

Penstock thickness (t) = 50.00 mm   Adopted higher thickness

Internal design pressure (p) = 33.66 kg/cm2

Internal Pressure stress (σ) = (P x D)/(2 x (t - δ) x ϕ)

= (33.66225 x 770) / (2 x (5 - 0.15) x 0.9)

= 2969.06 kg/cm2

σ = 2969.06 < 3160 kg/cm2   **SAFE**

Outer Diameter of penstock (D_d) = D + 2t = 7800 mm

Critical pressure control (Pk) = 2 x E x((t - δ)/D_d)^3 /(1 - v^2)

= 2 x 2100000 x ((48 - 1.5)/7800)^3 / (1 - 0.3^2)

= 0.978 kg/cm2

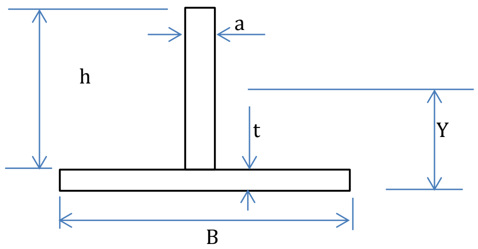
Pk = 0.978 < 24.94 kg/cm2   **Hence stiffeners required**

Spacing of stiffeners (Lt) = 2.59 x E x t^2.5 / (Penj x Dd^1.5 x S)

= 2.59 x 2100000 x 4.85^2.5 / (19.905 x 780^1.5 x 1.5)

= 433.19 cm

Lt = 4300 mm   Adopted



Moment of inertia of stiffener (Ig) = (1 - v^2) x Dd^3 x Lt x P x S / (24 x E)

= (1 - 0.3^2) x 780^3 x 430 x 19.905 x 1.5 / (24 x 2100000)

= 110006.05 cm4

Section of stiffener

a = 35 mm   Keep same size of stiffeners

h = 75 cm

rm = D/2 + t/2

rm = 387.50 cm

Pipe effective width (B) = a + 1.56√(rm x t)

= 3.5 + 1.56 x (387.5 x 4.85)^0.5

= 71.13 cm

				Area	Ix		
Aa	=	h x a	=	262.50 cm2	Ix = ha^3/12	=	123046.88 cm4
Ab	=	B x t	=	344.97 cm2	Ix = B(t-δ)^3/12	=	676.22 cm4
A	=	Aa + Ab	=	607.47 cm2			

Centre of Gravity = (Aa x (h/2+(t-δ))+Ab x (t-δ)/2) /A

19.68 cm

Total Inertia = 309784.61 cm4

Ig = 110006.05 < 309784.61   **SAFE**

Support Elastic deformation stress

σTC = ± (1.82 x Aa x P x D)/((Aa + AB) x t x 2)

= 2101.53 kg/cm2

Hoop Stress

σ1 = (P x D0/(2 x (t - δ) x ϕ)

2969.06 kg/cm2

Poisson Stress

σp	=	v x σ1			
		890.72 kg/cm2			
Temperature difference stress					
σTE	=	ξ x E x ΔT	ΔT = 20		
		504.00 kg/cm2			
Axial Stress					
σ1	=	± σp ± σTE ± σTC			
		3496.25 kg/cm2	<	3507 kg/cm2	**SAFE**
σ2	=	± σp ± σTE ± σTC			
		-1371.54 kg/cm2	<	3507 kg/cm2	**SAFE**
Combined Stress					
σB1	=	√(σ^2 + σ1^2 - σ x σ1)			
		3264.74 kg/cm2	<	3976 kg/cm2	**SAFE**
σB2	=	√(σ^2 + σ2^2 - σ x σ2)			
		3843.00 kg/cm2	<	3976 kg/cm2	**SAFE**

Hence Shell thickness of 50mm is safe & OK

Annexure 12-1

Chitravathi Pump Storage Project(2x250MW)			
Preliminary Dimensions of Power House			
Full reservior Level of Upper Reservoir	*FRL(U)*	*495.00*	*m*
Minimum Draw Down Level of Upper Reservoir	*MDDL(U)*	*460.00*	*m*
Number of Units	*n_u*	*2*	
Design Discharge (for all units)	*Q*	*0.00*	*m^3/sec*
Design Discharge per Unit	*$q = Q/n_u$*	0.00	*m^3/sec*
Full reservior Level of Lower Reservoir	*FRL(L)*	*298.00*	*m*
Minimum Draw Down Level of Lower Reservoir	*MDDL(L)*	*282.55*	*m*
Installed Capacity(Turbine Mode)	*P*	*5,00,000*	*kW*
Installed Capacity per Unit(Turbine Mode)	*$Pg=P/n_u$*	2,50,000.00	*kW/unit*
Installed Capacity(Pump Mode)	*P*	*5,56,000*	*kW*
Installed Capacity per Unit (Pump Mode)	*$Pg=P/n_u$*	2,78,000.00	*kW/unit*
Gross Maximum Head	*Hg_{max}=FRL(U)-MDDL(L)*	212.45	*m*
Average Head Losses (Turbine mode)	*HL*	*6.23*	*m*
Average Head Losses (Pump mode)	*HL*	*4.91*	*m*
Gross Minimum Head	*Hg_{min}=MDDL(U)-FRL(L)*	162.00	*m*
Maximum net head for Turbine Mode =Hgmax-HL	*Hnmax(Tur)*	206.22	*m*
Minimum net head for Turbine Mode =Hgmin-HL	*Hnmin(Tur)*	155.77	*m*
Maximum net head for Pump Mode =Hgmax+HL	*Hnmax(Pump)*	218.68	*m*
Minimum net head for Pump Mode =Hgmin+HL	*Hnmin(Pump)*	168.23	*m*
Net Design Head(Turbine)	*Hn(Tur)=Hg-HL*	189.40	*m*
Net Design Head (Pump)	*Hn(Pump)=Hg+HL*	*200.54*	*m*
Turbine Efficiency	*nt*	*0.92*	
Pump Efficiency	*np*	*0.93*	
Generator Efficiency	*ng*	*0.985*	
Motor Efficiency	*nm*	*0.985*	
Turbine output Power per unit	*$P_t = P_g/ng$*	2,53,807.11	*kW*
Pump Input Power per unit	*Pp=Pm*nm*	2,73,830.00	*kW*
Turbine Unit Discharge	*Qt*	148.63	*Cumec*
Pump Unit Discharge	*Qp*	129.58	*Cumec*

Refer IS: 12800 -(Part 2 /Sec 1)

Trial Turbine specific Speed	n_{st}'=	160.15	
Trial Pump specific Speed	nsp'=	41.77	
		38.00	
Other references			
As per USBR Monograph EM 39	nsp limit value = 640/H^0.5	45.19	
As per JICA's Report	nsp limit value = 12500/(Hnp+80)+13	57.56	
	Adopted Trial Specific Speed =	46.92	
Trial synchronous speed	n'=n_{st} 'Hn^0.75/Qp^ 0.5	219.64	rpm
Trial No of Poles for n'	6000/n'	27.32	
Hence, selected no of poles		28.00	nos.
		14	nos.

Adopted Pair of Poles	Rated Turbine Speed
14	214.29

Final rated speed [for calculations]	n	214.29	rpm
Final Specific Speed (for Calcultion)	nsp	45.77	

Pump Turbine Setting

Refer [***IS:12800 -2 Fig 4]***

The Estimated Cavitation Co-efficient =	s =	0.24	0.26
Refer USBR Monograph EM 39 -Fig 8			
The Estimated Cavitation Co-efficient =	s =	0.22	

Average water temperature **20** °C

[IS:12800-I, Fig 2 page 2]

for an altitude about = *282.55 m*

Temp(° C)	Hb-Hv (m)
0	9.72
10	9.59
15	9.53
20	9.47
30	9.22
40	8.97
60	7.83

(Hb-Hv) = **9.47 m**

Suction Head — *Hs=(Hb-Hv)-s(Hn)*

-35.50 ***m***

Giving a margin of **1.6** m

Since Hs is negative, center line should be kept atleast **37.10** ***m***

below minimum MDDL of of Lower Reservoir

Turbine Distributer Centerline should be set at **EL=TWLmin+Hs**

245.45 ***m***

Runner Dimensions

[IS:12800-II, Fig 6]

For Specific speed	***ns***	**45.77**
Velocity Coefficient	***Ku***	***1.04***
Runner Inlet Diameter		
	D1=60*sqrt(2*g*Hn)*Ku/ **pn**	
		5.815 ***m***

Spiral Casing Dimensions

[IS:12800-II, Fig 8]

The water flow velocity at Inlet of Spiral Casing is considered as 15.75 m/s as per Fig 7 of IS:12800 -Part II

A=		***3.237***	**m**	
B=	***0.97- 1.18***		***D1**	
		B=		**6.205** ***m***
C=	***1.05 - 1.3***		***D1**	
		C=		**6.777** ***m***
D=	***1.1 -1.42***		***D1**	
		D=		**7.256** ***m***
E=	***0.98 - 1.1***		***D1**	
		E=		**6.021** ***m***

The low velocity at Inlet of Spiral Casing is considered as 15.75 m/s as per Fig 7 of IS:12800 -Part II

Draft Tube Dimensions

Depth of draft tube — ***H1+H2=1.82 to 2.4 D1***

			12.323 ***m***
Height from Top of DT Cone to Centre Line	***H1=0.22 to 0.3D1***		**1.519** ***m***
Width of the draft tube (clear width)	***W= 0.9 to 2.4D1***		**9.730** ***m***
Length of the draft tube from turbine axis	***L = 2.85 to 3.7 D1***		**19.122** ***m***
Height of the draft tube at exit	**H3=.8 to 1.175D1**		**5.776** ***m***

Main Parameters of Hydro Generator

Generator rated output		***Pg***	**2,50,000.00** ***kW***
Power factor		***p_f***	***0.9***
Rated MVA of Generator		***$W=Pg/p_f$***	**277.78** ***MVA***
Rated speed of Machine		***n***	**214.29** ***rpm***
No of Pairs of poles		***p***	**14**

[IS:12800-II Fig 12]

Pole pairs	***Vr(m/s)***	***Ko***
5	93.75	5.720
7	88.202	6.000
8	*84.540*	6.125
9	*82.269*	6.236
10	*80.561*	6.309
12	*77.273*	6.407
14	*74.091*	6.519
16	*70.909*	6.630
18	*69.091*	6.722
20	*67.727*	6.778
22	*67.273*	6.852
32	*66.180*	7.125

Maximum Rotor Peripherical Velocity	***Vr***		***74.091*** ***m/s***
Air gap dia	***Dg***	**60*Vr/(pn)**	
			6.6047 ***m***
Outer Core Diameter	***Do***	**Dg(1+π/2p)**	
			7.35 ***m***
Stator frame diamter	***Df***	**(Do+1.2)**	
			8.55 ***m***
	say		***8.60*** ***m***

Inner diamter of generator Barrel		*Db*	(Df+2.3 to 2.8)
		say	(Df+2.55)
			11.15 *m*
Core length of stator		*Lc*	$W*1000/(k_oD_g^2n)$
		Ko=	*6.519*
		Lc=	4.5584 *m*
Lc/Dg ratio			0.69017
Length of stator frame		L_f	Lc + 1.5 to 1.6m
		say	Lc+ 1.5m
			6.06 *m*
Axial Hydraulic thrust		P_H	$k D_1^2Hnmax$
[IS:12800-II, Fig 11]			
		k	0.10625
		P_H	740.99 *Tonnes*
[IS:12800-II, Fig 14]			
Weight of Generator Rotor for Dg=	6.60	Wr=Lc*	178.142
			812.043 *Tonnes*
[IS:12800-II, Fig 10)			
Weight of Turbine Runner		*Wtr*	*62.50* *Tonnes*
Weight of M/C rotating parts	W_r *+Wtr+PH=*		1615.54 *Tonnes*
Height of Load Bearing Bracket hj =			
	k*sqrt(Dg)	umbrella type construction	
	k*sqrt(Df)	suspended type construction	
No of arms of bearing bracket			8
Hence, load per arm of the bracket (Tonnes) Lt			201.942

Lt	k
<50	0.65
50-100	0.75
>100	0.85

Generally 4 to 8 arms of the bracket are taken.

Height of Load Bearing Bracket hj =

		k_b =	0.85	
1. Umbrella type construction	k_b*sqrt(Dg) =		2.18	m
2. Suspended type construction	k_b*sqrt(Df) =		2.49	m

Note: Upto speed of 300rpm, Umbrella type construction should be preferred.

selecting 1 umbrella type		say hj =	2.00	m
Power House Dimensions				
Spiral casing width		C+B+A/2	14.60	m
		D+E	13.28	m
Inner Dia of Generator Barrel		Db	11.15	m

[IS 5496:1993, Cl. 3.3]

no pier for span upto 7m
one pier for span 8-15m
two piers for span more than 16m

pier of minimum 1 m width will be provided

Number of piers according to range Db			1	
Assumed width of one pier		Wpier	1	m
Total width of pier(s)		Wpiert	1	m
Width of Draft tube with pier width **B1 = B+Wpiert**			10.73	m
Outer dia of generator barrel	Do=Db+1.20m		12.35	m
Maximum Dimensions out of above	MaxDim		14.60	m
Unit spacing	Us = MaxDim+Clrnc (2*1.5m)			
			17.60	m
		say	18.00	m
Erection Bay length	L_{eb} = 1 to 1.5 Us			
	say	1.5 Us	27	m
		No of units in a power house	2	
Total length of a Power House =				
		Space for units Us*Nu	36	m
		.+Leb	27.00	m
		.+Space for EOT crane to handle last unit	4	m
		.+space for control bay	20	m
			87.00	m
		say	87.00	m

Width of power house super structure

On upstream side

	Do/2	**6.175**	m
	.+MIV Spacing	**3.5**	m
	.+column width	**1.5**	m
	.+Space of EOT Crane movement	**1.5**	m
	$W_1 =$	**12.675**	***m***
On down stream side			
	Do/2	6.175	m
	.+moving space	1.5	m
	.+clearance for EOT crane movement	1.5	m
	.+column width	1.5	***m***
	$W_2 =$	**10.675**	***m***
Total widht of power house	$W_1 + W_2 =$	**23.35**	***m***
	say	***23.00***	***m***
Total height of machine hall			
	H1	12.32	m
	.+ Depth of concrete	1.5	m
	.+Lf	6.06	m
	.+hj	2.00	m
	.+k	6	m
		27.88	***m***
	say	***28.00***	***m***

Annexure 17-1

GENERAL ABSTRACT OF PROJECT HARD COST						
Sl No.	**Head of A/c**	**Particulars**	**Cost of Civil works in Lakhs**	**Cost of Hydromecha-nical works in Lakhs**	**Cost of Electrical works in Lakhs**	**Total Cost in Lakhs**
		A. Direct Cost				
	I	**I WORKS**				
	A	Preliminaries: Preliminary Survey	1800.00			1800.00
	B	Land: Lease of Government Land	2000.00			2000.00
	C	Works: Dam and Reservoir Works				
	1	Upper Reservoir Excavation including Embankment/Bund	40800.00			40800.00
	2	TRT outlet Coffer Dam and Associated Channel	1000.00			1000.00
	J	Power Plant Civil Works:				
		Upper Power Intake	5440.00	734.40		6174.40
		TRT Outlet Pump Intake	3330.00	1395.70		4725.70
		Pressure Shafts including Steel Liner	10500.00			10500.00
		Adit to Pressure Shaft Bottom	730.00			730.00
		Adit to TRT Bottom and Transformer Cavern	1000.00			1000.00
		Main Access Tunnel (MAT)	2700.00			2700.00
		Cable Access Tunnel (CAT)	920.00			920.00
		Power House including Transformer Cavern	9900.00	469.30		10369.30
		TRT	3000.00			3000.00
	K	Buildings:	3200.00			3200.00
	M	Plantation: Site Plantations	100.00			100.00
	O	Miscellaneous: Telephone, O & M of inspection vehicles etc.,	1800.00			1800.00
	P	Maintenance: Maintenance charges during construction	900.00			900.00
	Q	Special Tools and Plants	200.00			200.00
	R	Communications: Service Roads	800.00			800.00
	X	Environment & Ecology	500.00			500.00
	Y	Loss on stock: @ 0.25% of C, J	230.00			230.00
	S	Power Plant Electrical Works			69610.00	69610.00
		Transmission Line			11200.00	11200.00
		Total I-Works	**90850.00**			**174259.40**
	II	Establishment Charges, 6% of (I-B) Work	5300.00			5300.00
	III	Tools & Plants @ 0.5% of I-Works less Land	200.00			200.00
	IV	Suspense	NIL			
	V	Receipts & Recoveries: Q – Special Tools & Plants @ 15% of capital cost	-500.00			-500.00
		Sub Total (A)	**95850.00**			179259.40
		B. Indirect Charges				0.00
		Capitalisation of Abatement of Land revenue (5% of cost of culturable Land)	50.00			50.00
		Audit and Accounts @ 0.5% of I Works	450.00			450.00
		Sub Total (B) in Lakh	**96350.00**	**2599.40**	**80810.00**	179759.40
		Total Project Cost in Crore				**1797.59**

Upper Reservoir (Cutting and Filling)					
`	Description	Quantity	Unit	Rate, NR	Cost, (INR)
A	**Upper Reservoir -Cutting**				
A.1	Excavation (Overburden)	1,82,668	m3	247	451,19,076
A.2	Excavation (Rock)	34,70,698	m3	406	14091,03,437
A.3	Shotcrete (100 mm)	4,666	m3	8338	389,06,109
A.4	Rock Bolt, 25 dia	64,871	Rm	1609	1043,78,083
A.5	Drilling of Consolidation	23,789	Rm	304	72,31,993
A.6	Drilling for Curtain	47,579	Rm	304	144,63,986
A.7	Consolidation (Bags)	6,330	Bags	656	41,52,480
A.8	Curtain (Bags)	12,660	Bags	656	83,04,960
	Total Cost in Cutting in Cr(INR)				**163**
B	**Upper Reservoir -Embankment Filling**				
B.1	Excavation	1,64,091	m3	247	405,30,536
B.2	Rip Rap	1,85,068	m3	1186	2194,90,506
B.3	Coarse Filter	2,21,407	m3	1062	2351,34,022
B.4	Fine Filter	1,77,339	m3	1062	1883,34,018
B.5	Rockfill	27,97,598	m3	323	9034,84,113
B.6	Clay core	5,73,267	m3	419	2403,70,765
B.7	RR Masonary wall	12,719	m3	3586	456,08,541
B.8	Drilling for Curtain	7,600	Rm	304	23,10,400
B.9	Curtain (Bags)	15200.00	Bags	656	99,71,200
	Total Cost in Cutting in Cr(INR)				**189**
C	Contingencies @ 2 % of cost			2%	**7**
D	Dewatering @ 1 % of cost			1%	**4**
E	Instrumentation @ 1 % of cost			1%	**4**
F	GST				**42**
		Total Cost in Crore			**408**
		Total Cost in Lakhs			**40,800**

Upper Reservoir Power Intake					
`	**Description**	**Quantity**	**Unit**	**Rate, NR**	**Cost, (INR)**
A	**Earth Work and Foundation Treatment**				
A.1	**Site Clearance**	LS			10,00,000
A.2	Excavation in overburden without blasting	4,342	Cum	223	9,67,355
A.3	Excavation in Rock with blasting	82,494	Cum	406	335,29,837
A.4	Plain Shotcerete 100 mm thick	185	Cum	8338	15,45,423
A.5	Rock Anchor , 25 mm	4,502	RM	757.0	34,07,762
A.6	Rock bolt, 25 mm, 4 m long	1,371	Rm	1608.9	22,05,898
B	**Concrete Works and Reinforcement**				
B.3	Reinforced Cement Concrete, M25, A40 Grade	48,980	Cum	4803	2352,71,913
B.4	RR Backfill	2,302	Cum	3586	82,55,222
B.5	Reinforcement in Concrete works Fe 500	2,939	MT	59260	1741,53,164
B.6	Compacted Backfill	20,720	Cum	251	52,00,802
C	**Grouting**				
C.1	Drilling for grouting	611	Rm	304	185458.87
C.2	Cement for Grouting	1,222	Bags	656	801632.00
				Total	**4665,24,467**
				Cost in Crore	**46.65**
E	Contingencies @ 2 % of cost			2%	0.93
F	Dewatering @ 1 % of cost			1%	0.47
G	Instrumentation @ 1 % of cost			1%	0.47
	Total Cost (In Crore)				**48.52**
	GST				5.82
	Say			**Cost in Crore**	**54.40**
				Cost in Lakhs	**5440**

Lower/Pump Intake					
`	**Description**	**Quantity**	**Unit**	**Rate, NR**	**Cost, (NR)**
A	**Earth Work and Foundation Treatment**				
A.1	**Site Clearance**	LS			10,00,000
A.2	Excavation in overburden without blasting	17,750	Cum	223	39,54,700
A.3	Excavation in Rock with blasting	3,37,250	Cum	406	1370,75,263
A.4	Plain Shotcerete 100 mm thick	191	Cum	8338	15,90,557
A.5	Rock Anchor , 25 mm	11,379	RM	757.0	86,13,651
A.6	Rock bolt, 25 mm, 4 m long	1,425	Rm	1608.9	22,92,683
B	**Concrete Works and Reinforcement**				
B.1	Reinforced Cement Concrete, M25, A40 Grade	15,532	Cum	4803	746,04,359
B.2	Reinforcement in Concrete works Fe 500	932	MT	59260	552,23,698
C	**Grouting**				
C.1	Drilling for grouting	544	Rm	304	165122.13
C.2	Cement for Grouting	1,088	Bags	656	713728.00
				Total	**2852,33,760**
				Cost in Crore	**28.52**
E	Contingencies @ 2 % of cost			2%	0.57
F	Dewatering @ 1 % of cost			1%	0.29
G	Instrumentation @ 1 % of cost			1%	0.29
	Total Cost (In Crore)				**29.66**
	GST				3.56
	Say			**Cost in Crore**	**33.30**
				Cost in Lakhs	**3330**

PRESSURE SHAFT					
S.No.	Description	Unit	Qty.	Rate (NR.)	Amount (INR)
A	**Underground Excavation**				
1	Tunnel Excavation including	Cum	22694	4460	101204911.13
2	Overbreak	Cum	2269	579	1314222.76
B	**Rock stabalization and supports**				
1	Steel Ribs	MT	40	118788	4751520.00
2	Lattice Girders	MT	25	66338	1658450.00
3	Precast Lagging	Cum	130	7075	919750.00
4	25mm dia. Rock Bolts	Rm	5350	1609	8607615.00
5	Shotcrete	Sqm	880	8338	733744.00
C	**Concrete**				
1	M20, A20 Concrete Backfill around liner and Adit Portal concrete	Cum	7400	3362	24880280.00
2	Backfill with M20 due to overbreak, A20	Cum	1850	3362	6220070.00
3	Backfill with M15 behind steel ribs and concrete plugging in adit	Cum	800	3121	2496560.00
D	**Drilling and Grouting**				
1	Drilling for Drainage holes	Rm	450	654	294120.00
2	Drilling for Contact Grouting	Rm	450	654	294120.00
3	Contact Grouting @ 2 bag/Rm	Bags	900	630	567000.00
4	Drilling for Consolidation Grouting	Rm	1190	654	777784.00
5	Consolidation Grouting @ 2 bag/Rm	Bags	2380	630	1499400.00
6	Pre Grouting @ 2 bag/RM	Bags	2380	630	1499400.00
F	**Steel Liner**	MT	2926	250000	731442561.34
	SUB TOTAL IN CRORE				**88.92**
F	Instrumentation @ 1% of above item except Lump sum				0.89
G	Contingencies @ 2% of above item except Lump sum				2.67
H	Dewatering @ 1% of above item except Lump sum				0.89
	TOTAL (Civil)-In Cr				**93.40**
	GST				**11.21**
	TOTAL (Civil)-In Cr				**105.00**
	TOTAL (Civil)-In Lakhs				**10500.00**

Adit to Pressure Shaft					
S.No.	**Description**	**Unit**	**Qty.**	**Rate (in Rs.)**	**Amount (INR)**
A	**Site Clearance**	LS			5,00,000.00
B	**Underground Excavation**				
1	Tunnel Excavation	Cum	13905	2790	387,94,950.00
2	Overbreak	Cum	695	579	4,02,619.28
3	Steel Ribs	MT	133	118788	157,79,741.50
8	Shotcrete	Cum	683	8338	56,98,114.66
B	**Concrete and Reinforcement**				
1	M15, A40 Concrete Backfill for ribs	Cum	412	3121	12,84,480.12
	SUB TOTAL				**624,59,905.60**
C	Instrumentation @ 1% of above item except Lump sum				6,24,599.06
D	Contingencies @ 2% of above item except Lump sum				12,49,198.11
E	Dewatering @ 1% of above item except Lump sum				6,24,599.06
	TOTAL (in INR)				**649,58,301.90**
	GST				**77,94,996.23**
	Total (in Crore)				**7.30**
	Total Cost in Lakhs				**730.00**

Adit to TRT Bottom and Transformer Cavern					
S.No.	**Description**	**Unit**	**Qty.**	**Rate (in Rs.)**	**Amount (INR)**
A	**Site Clearance**	LS			5,00,000.00
B	**Underground Excavation**				
1	Tunnel Excavation	Cum	15993	2790	446,20,470.00
2	Overbreak	Cum	579	579	3,35,298.90
2	Steel Ribs	MT	179	118788	212,06,535.64
3	Shotcrete	Cum	911	8338	75,95,806.40
B	**Concrete and Reinforcement**				
1	M15, A40 Concrete Backfill for ribs	Cum	637	3121	19,87,885.90
	SUB TOTAL				**762,45,996.90**
C	Instrumentation @ 1% of above item except Lump sum				7,62,459.97
D	Contingencies @ 2% of above item except Lump sum				15,24,919.94
E	Dewatering @ 1% of above item except Lump sum				7,62,459.97
	TOTAL (INR))				**792,95,836.80**
	GST				**95,15,500.42**
	TOTAL (INR-Cr))				**10.0**
	TOTAL (INR-Lakhs)				**1000.0**

Abstract MAT					
S.No.	**Description**	**Unit**	**Qty.**	**Rate (in Rs.)**	**Amount (INR)**
A	**Site Clearance**	LS			5,00,000.00
B	**Underground Excavation**				
1	Tunnel Excavation	Cum	60694	2790	1693,36,260.00
2	Overbreak	Cum	3035	579	17,57,394.77
3	Steel Ribs	MT	307	118788	365,06,617.13
8	Shotcrete	Cum	2293	8338	191,19,315.76
B	**Concrete and Reinforcement**				
1	M15, A40 Concrete Backfill for ribs	Cum	1412	3121	44,06,428.40
	SUB TOTAL				**2316,26,016.10**
C	Instrumentation @ 1% of above item except Lump sum				23,16,260.16
D	Contingencies @ 2% of above item except Lump sum				46,32,520.32
E	Dewatering @ 1% of above item except Lump sum				23,16,260.16
	TOTAL (INR)				**2408,91,056.80**
	GST				**289,06,926.82**
	Total (in Crore)				**27.00**
	Total (in Lakhs)				**2700**

Abstract CAT					
S.No.	**Description**	**Unit**	**Qty.**	**Rate (in Rs.)**	**Amount (INR)**
A	**Site Clearance**	LS			5,00,000.00
B	**Underground Excavation**				
1	Tunnel Excavation	Cum	18755	2790	523,26,450.00
2	Overbreak	Cum	938	579	5,43,051.03
3	Steel Ribs	MT	125	118788	148,33,633.68
8	Shotcrete	Cum	918	8338	76,57,709.85
B	**Concrete and Reinforcement**				
1	M15, A40 Concrete Backfill for ribs	Cum	734	3121	22,91,842.08
	SUB TOTAL				**781,52,686.70**
C	Instrumentation @ 1% of above item except Lump sum				7,81,526.87
D	Contingencies @ 2% of above item except Lump sum				15,63,053.73
E	Dewatering @ 1% of above item except Lump sum				7,81,526.87
	TOTAL (INR)				**812,78,794.20**
	GST				**97,53,455.30**
	Total (in Crore)				**9.20**
	Total (in Crore)				**920.00**

POWERHOUSE AND TRNASFORMER CAVERN					
S.No.	**Description**	**Unit**	**Qty.**	**Rate (INR.)**	**Amount (INR)**
A	**Site Clearance**	LS			5,00,000
B	**Unedr Ground Excavation**				
a	Caverns	Cum	150400	1900	285759810.00
C	**Concrete and Reinforcement**				
1	Grade M-15 Grade P C C for all Components	M3	413	3121	1289317.21
2	Grade M25 (RCC)	M3	25394	4803	121976386.78
3	Grade M-30 for Second Stage Pockets (RCC)	M3	194	5284	1026049.47
4	Reinforcement Grade Fe-500	MT	2043	59260	121094050.05
D	**Rock Stablisation**				
1	Rock bolts, 25 mm	Rm	75750	1609	121874175.00
2	Plain Shotcrete				
i)	100 Thk.	Cum	9408	8338	78443236.96
ii)	150 Thk.	Cum	533	8338	4446238.50
iii)	200 Thk.	Cum	4340	8338	36186503.10
3	Drainage/Pressure relief holes	Rm	13150	304	3991463.33
4	Lattice Girders	MT	62	118788	7310235.61
5	Pre Grouting	Rm	10395	304	3155229.00
E	**Miscellaneous**				
1	Brick masonry	Cum	760	6117	4648920.00
2	Flooring	Sqm	3100	2779	8614900.00
3	Plastering	Sq. m.	5000	235	1175000.00
F	Other Misc. Item	LS			45000000.00
	SUB TOTAL in Crore				**84.65**
G	Instrumentation @ 1% of above item except Lump sum				0.85
H	Contingencies @ 2% of above item except Lump sum				1.69
I	Dewatering @ 1% of above item except Lump sum				0.85
	TOTAL IN CRORE-INR				88.04
	GST				10.56
	TOTAL IN CRORE				**99.00**
	TOTAL IN LAKHS				**9900.00**

Adit to Pressure TRT					
S.No.	**Description**	**Unit**	**Qty.**	**Rate (in Rs.)**	**Amount (INR)**
A	**Site Clearance**	LS			5,00,000.00
B	**Underground Excavation**				
1	Tunnel Excavation	Cum	38923	3029	1178,93,874.70
2	Overbreak	Cum	1946	579	11,27,015.47
C	**Rock Support**				-
1	Shotcrete	Cum	1076	8338	89,73,958.54
2	Rock anchor (25 mm dia)	Rm	15085	1609	242,70,256.50
1	Steel Ribs	MT	145	118788	172,45,552.75
D	**Concrete**				
	M10	Cum	243	6016	14,61,839.40
	M20	Cum	5913	7227	427,31,477.10
	Reinforcment	MT	406	85027	345,37,117.13
E	**Grouting**				
	Drilling for Consolidation and Contact Grouting	Rm	783	654	5,11,768.80
	Consolidation and contact grouting@ 2bags per Rm	Bags	1566	630	9,86,580.00
	Pressure relief hole	Rm	1992	654	13,01,971.20
	Forepoling	Rm	1320	654	8,62,752.00
	SUB TOTAL				**2524,04,163.60**
C	Instrumentation @ 1% of above item except Lump sum				25,24,041.64
D	Contingencies @ 2% of above item except Lump sum				50,48,083.27
E	Dewatering @ 1% of above item except Lump sum				25,24,041.64
	TOTAL (in INR)				**2625,00,330.20**
	GST				**315,00,039.62**
	Total (in Crore)				**29.40**
					30.00
	Total Cost in Lakhs				**3000**

QUANTITY ESTIMATE							
Hydro Mechanical Works - (Gates and Hoists)							
Item	**Description / Item**	**Unit**	**Qty**	**Unit Weight (MT)**	**UnitRate**	**Total Weight (MT)**	**Total Amount (INR)**
1.0	**Intake Service Gate (Upper Reservoir)**						
1.1	Fixed Wheel Gate	No.	1	91.00	212800.00	91.00	19364800.00
1.2	2nd Stage Embedded parts	Sets	1	28.00	100000.00	28.00	2800000.00
1.3	Rope Drum Hoist-230 Mt	No.	1	230.00	67208.00	230.00	15457840.00
1.4	Rope drum hoist supporting structure	Sets	1	72.00	130636.00	72.00	9405792.00
	Total						**47028432.00**
2.0	**Intake Trash Rack (Upper Reservoir)**						
2.1	Intake Trash Racks	No of Panel	15	5.50	108000.00	82.50	8910000
2.2	2nd Stage Embedded parts	Sets	5	5.00	100000.00	25.00	2500000
2.3	Trash Rack Cleaning Machine complete with rails & fixture	No.	1	-	15000000.00	1.00	15000000
	Total						**26410000**
4.0	**Draft Tube Gate**						
4.1	Slide Gate	No	2	47.00	212800.00	94.00	20003200.00
4.2	Hydraulic Hoists Having capcity 120M	No	2	-	10000000.00	2.00	20000000.00
4.3	2nd Stage Embedded parts	Sets	2	15.00	100000.00	30.00	3000000.00
4.4	Hoist Support Structure	Sets	2	15.00	130636.00	30.00	3919080.00
	Total						**46922280.0**
5.0	**Intake Maintenance Gate (Lower Reservoir)**						
5.1	Fixed wheel Type Bulkhead Gate	No.	1	128.00	212800.00	128.00	27238400.00
5.2	2nd Stage Embedded parts	Sets	1	38.00	100000.00	38.00	3800000.00
5.3	Rope Drum Hoist-255 Mt	No.	1	255.00	67208.00	255.00	17138040.00
5.4	Rope drum hoist supporting structure	No.	1	100.00	130636.00	100.00	13063600.00
	Total						**61240040.0**
6.0	**Intake Service Gate (Lower Reservoir)**						
6.1	Fixed Wheel Gate	No.	1	128.00	212800.00	128.00	27238400.00
6.2	2nd Stage Embedded parts	Sets	1	38.00	100000.00	38.00	3800000.00
6.3	Rope Drum Hoist-320 Mt	No.	1	320.00	67208.00	320.00	21506560.00
6.4	Rope drum hoist supporting structure	Sets	1	100.00	130636.00	100.00	13063600.00
	Total						**65608560.0**
7.0	**Intake Trash Rack (lower Reservoir)**						
7.1	Intake Trash Racks	No of Panel	18	5.00	108000.00	90.00	9720000
7.2	2nd Stage Embedded parts	Sets	6	5.00	100000.00	30.00	3000000
	Total						**12720000**
	Total HM Cost (INR)						**259929312.00**
	Total Cost in Lakhs						**2599.4**

Abstract of Cost Estimate-Electro-Mechanical Works		Annexure S
	Mar 2021, Price Level	
Sl.No	**Item**	**Indian component** (in INR Lakhs)
1	**Preliminary (only cost of model tests)**	200.00
2	**Pump-Turbine plant and equipment.**	
a)	Generator-motor, turbine-pump and accessories - Annex S1.	45,835.00
b)	Auxiliary electrical equipment for power station - Annex S2.	5,859.44
c)	Auxiliary mechanical equipment and services for power station - Annex S3.	1,564.78
d)	Transportation, handling and Insurance charges (@6%) of 2b and 2c.	445.45
e)	Erection and commissioning charges (@8%) of 2b and 2c excluding spares.	589.05
f)	GST on 2 (a), (b), (c), (d) & e	6,515.25
	Sub total (Pump-Turbine plant and equipment)	**61,008.96**
3	**Substation equipment, auxiliary equipment and service of switchyard.**	
a)	Substation equipment, auxiliary equipment and service of switchyard - Annex S4.	1,210.59
b)	Transportation, handling and Insurance charges (@6%) of 3a.	72.64
c)	Erection and commissioning charges (@8%) of 3a excluding spares.	95.60
d)	GST on 3 (a), (b) & (c)	165.46
	Sub total (Substation equipment, auxiliary equipment and service of switchyard)	**1,544.29**
4	**Gas insulated switchgear**	
a)	420kV Gas insulated switchgear - Annex S5.	2,575.00
b)	Erection and commissioning charges @8% of 4a excluding spares.	200.00
c)	GST on 4 (a) & (b)	333.00
	Sub total (GIS and XLPE Cable)	**3,108.00**
5	Contingencies @1% on items 2, 3 and 4.	656.61
6	Tools and plants @0.5% of item 2, 3 and 4.	328.31
7	**Sub total (Item 1 to 6)**	66,646.17
8	Establishment @ 4%	2,626.45
9	**Sub total (Item 7 and 8)**	69,272.62
10	Audit and account charges @ 0.5% of I works	328.31
	Total (E&M works)	69,600.93
	Total (E&M works)-INR Cr	696.10
ATS (Associated Transmission System) Estimates		**(in INR Lakhs)**
12	400kV D/C Transmission Line and Remote substation bay augmentation (2 bays) from Chitravathi project to Talaricheruvu Substation including GST	11,200.00
	GRAND TOTAL-INR Lakh	**80,800.93**
	Grand Total in INR Cr.	808.10

Generator-Motor, Turbine-Pump and Accessories (S-1)						
Sl.No	Item Particulars,	Qty,		Rate (Rs. Lakhs)		Amount (Rs. Lakhs)
1	2	3		4		5
1	**Pump-Turbine Sets**					
a)	Vertical shaft reversible pump turbines with rated generating capacity of 250 MW at a rated net head of 189.4m, 214.3rpm. Max. shaft input power of 278MW in pump mode	2	Nos.			44500.00
b)	Hydrulic and Digital Governor	2	Sets			
c)	Spherical valve	2	Sets			
2	**Motor-Generator Sets**					
a)	Motor- Generator Sets of 327MVA, 15kV, 214.3rpm, 0.9pf complete with static excitation (DC) system	2	Nos.			
b)	Water depression system common for all units with unitized air receivers and motor starting panels	1	Set			
c)	Cooling water system comprising pump sets, valves, piping etc.	1	Lot			
d)	Drainage and dewatering systems	1	Lot	Included in 1 a) above.		
e)	Compressed air system including motor starting panels	1	Set			
3	Common Static Frequency Converter for the starting of units in pump mode with starting bus	1	set			
4	15kV Phase bus ducts & associated auxiliaries for units along with phasereversal disconnector switch	2	Sets			
6	Supervisory control and data acquisition system.	1	Lot			
7	Control and Protection panels	1	Lot			
9	Spares @ 3%	1	Lot	3.0	%	1335.00
	TOTAL					45835.00

	Auxiliary Electrical Equipment for Power Station				S2	
Sl.No	Item Particulars,	Qty,		Rate		Amount
				(Rs. Lakhs)		(Rs. Lakhs)
1	2	3		4		5
A	**Transformers**					
1	Step up transformer (Rating 15/420kV,110MVA, Single phase, ODWF type each with OLTC	7	Nos.	750.00	1 No.	5250.00
1.1	Station Auxiliary Transformer (Rating 15/11kV, 5MVA, ONAN type)	2	Nos.	1010.00	Rs./ kVA	101.00
2	Unit auxiliary transformer, 1250kVA, Dry type	2	Nos.	1800.00	Rs./ kVA	45.00
3	Station service transformers, 1250kVA, Dry type	2	Nos.	1600.00	Rs./ kVA	40.00
4.1	MV AC switchgear (11kV)	10	Bays	3.50	per bay	35.00
4.2	LT AC switchgear (415V SSBs)	1	Lot	55.00		55.00
5	DC batteries, charging equipment, distribution board (220V, 1000AH)	1	Lot	35.00		35.00
6	Diesel generating sets, 1000kVA, 415V	2	Nos.	50.00		100.00
7	Control, Power and Instrumentation cables	1	Lot	115.00		115.00
8	Cable racks and accessories	1	Lot	22.00		22.00
9	Ground mat and earthing for powerhouse	1	Lot	5.50		5.50
10	Illumination of powerhouse and switchyard	1	Lot	11.00		11.00
11	Electrical test lab and generator testing equipment	1	Lot	28.00		28.00
12	Sub total (items 1 to 11)					5842.50
13	Spares @ 3 % on items 1 to 8					16.94
	TOTAL					5859.44

Auxiliary Mechanical Equipment for Power Station (S-3)						
Sl.No	Item Particulars,	Qty,		Rate (Rs. Lakhs)		Amount (Rs. Lakhs)
1	2	3		4		5
1	Electric overhead travelling crane for powerhouse (Capacity 400/ 50/ 30T)	2	Nos.	1.35	L Rs./ MT	1078.66
2	Electric overhead travelling crane for GIS (Capacity 10T)	1	Nos.	2.50	L Rs./ MT	25.00
3	Electric lifts and elevators	1	No.	40.00		40.00
4	Fire fighting equipment with storage tanks, pipes, pumps, valves etc.	1	LS	170.00		170.00
5	Air conditioning, ventilation and heating equipment	1	LS	85.00		85.00
6	Filtered water supply for powerhouse	1	LS	17.00		17.00
7	Oil handling equipment with pipes, valves, tanks, purifiers	1	LS	55.00		55.00
8	Workshop machines and equipment	1	LS	50.00		50.00
9	Sub total (items 1 to 8)					1520.66
10	Spares @ 3% for item no. 1 to 7					44.12
	TOTAL					**1564.78**

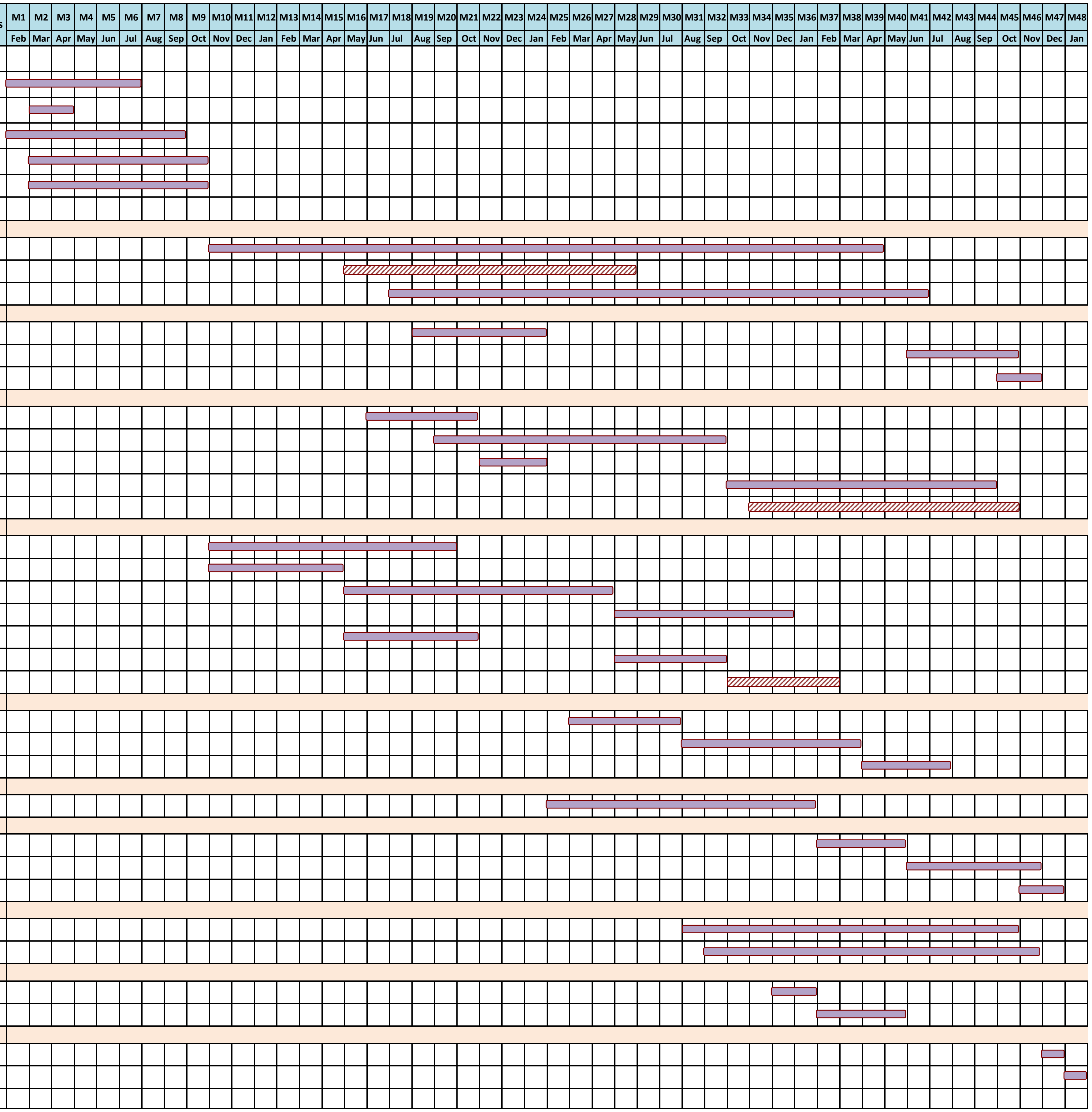
Pothead Yard & auxiliary equipment and its services (S-4)						
Sl.No	Item Particulars,	Qty,		Rate (Rs. Lakhs)		Amount (Rs. Lakhs)
1	2	3		4		5
1	420kV XLPE cables	0.4	Km	185	per Km	74
a)	No of runs	7	Nos.			518
2	420kV cable termination	12	Nos.	40		480
3	420kV, Pothead yard equipment including LAs etc.					
	Current transformers (Rating 420kV, 5 core, 2000-1000/1A, PS, 0.2s, 50VA)	6	Nos.	8.00		48.00
	Voltage Transformers (Rating 420kV, 420kV/ 110V, PS, 0.2s, 50VA)	6	Nos.	4.00		24.00
	Lightening arrestors (Rating 390kV, 20kA, Class III)	6	Nos.	0.80		4.80
4	Bus conductors, hardware and insulators	1	Lot	11.00		11.00
5	DC battery, charger and associated equipment	Included in Annexure S2, Item 5				
6	Fire protection system	Included in Annexure S3, Item 4				
7	PLCC equipment	2	Sets	35.00		70.00
8	Gantry, Foundation for structures and miscellaneous civil work for other equipment	1	LS	12.00		12.00
9	Fencing and security	1	Nos.	1.20		1.20
10	Sub total (items 1 to 9)					1195.00
11	Spares @3% for items 2 and 3					15.59
	TOTAL					**1210.59**

GIS & auxiliary equipment and its services (S-5)						
Sl.No	Item Particulars,	Qty,		Rate (Rs. Lakhs)		Amount (Rs. Lakhs)
1	2	3		4		5
1	**Gas insulated switchgear, GIS**					
a)	420kV Gas insulated switchgear including incomer bays, feeder bays and bus coupler, double bus enclosures, SF6 to air bushings for line connection	5	Bays	500.00	per Bay	2500.00
2	Spares @3%					75.00
3	**TOTAL**					**2575.00**

APPENDICES

APPENDIX-A (CONSTRUCTION SCHEDULE)

Activity Number	Activity	Months
1	**Pre-Construction Activities**	
A	Preliminary Works	**6**
B	Land Acquisition	**2**
C	Tendering Works	**8**
D	Constrcution of Project Roads	**8**
E	Constrcution of Project colonies, and infrastructure facilities	**8**
2	**Main Construction Activities**	
A	**Upper Reservoir and Embankment/Bund**	
A-1	Excavation and Rock support of Upper Reservoir	30
A-2	Stripping of Loose Material for Embankment	4
A-3	Embankment filling/Bund Filling	24
B	**Upper Intake**	
B-1	Excavation and rock support of Intake	6
B-2	Concreting of Intake	5
B-3	Installation of H&M Gates	2
C	**Penstock Tunnel**	
C-1	Excavation and Support of Adit to Pressure Shaft	5
C-2	Excavation and Rock support of Penstock for Vertical Section	13
C-3	Excavation and Rock support of Penstock for Top and Bottom Horizontal Section	3
C-4	Steel Liner Erection	12
C-5	Backfill Concrete of Penstock	12
D	**Powerhouse Complex and Transformer Cavern**	
D-1	Excavation and rock support of MAT	11
D-2	Excavation and rock support of Cable Tunnel cum ventilation tunnel for excvation of PH from Top	6
D-3	Excavation of Powerhouse	12
D-4	Concreting of Powerhouse	8
D-5	Excavation of Transformer Cavern	6
D-6	Concreting of Transformer Cavern	5
D-7	Installation of H&M Equipments	3
E	**TRT**	
E-1	Excavation and Support of Adit to TRT	5
E-2	Excavation and Rock Support of TRT	8
E-3	Concreting of TRT	4
F	**Coffer Dam (TRT Outlet)**	
F-1	Excvation and Filling of Coffer Dam	12
G	**Pump Intake at TRT Outfall**	
G-1	Excavation and rock support of Intake	4
G-2	Concreting of Intake	6
G-3	Installation of H&M Gates	2
H	**Electromechanical Works**	
H-1	Erection of Unit-1	15
H-2	Erection of Unit-2	15
I	**Switchyard Works**	
I-1	Filling, leveling , compaction and Foundation works of Switchyard	2
I-2	Equipment Erection Works of Switchyard	4
J	**Comissioning of Unit**	
J-1	Commissioning of Unit-1	1
J-2	Commissioning of Unit-2	1
	Legend	



FULL TIME INPUT

INTERMITTENT INPUT

APPENDIX-B (ECONOMIC EVALUATION)

NAME OF THE PROJECT : CHITRAVATHI PUMPED STORAGE PROJECT

Cost Of Project	**1797.59**	**Cr**	**Land**	**20.00**
IDC	**230.13**	**Cr**		
Total Cost Of Project	**2027.72**	**Cr**		
Promoters Equity 30 %	**608.32**	**Cr**		
Loan 70 %	**1419.40**	**Cr**		

GENERATION COST AND TARIFF (Rs. In Crores)

Sl.No	Description	UNIT	Year1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
1	Capacity	MW	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
2	Power Generation/annum	Units (in Lakhs)	**9631.90**	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90
3	Auxillary Consumption	%	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
4	Net units available for sale	Units (in Lakhs)	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32
	Fixed Cost																					
5	O & M Expenses @3.5%, escalated @ 4.77% per annum	Rs.in Cr	62.92	65.92	69.06	72.36	75.81	79.42	83.21	87.18	91.34	95.70	100.26	105.04	110.05	115.30	120.80	126.56	132.60	138.93	145.55	152.50
6	Interest on WC Loan	Rs.in Cr	14.74	14.69	14.64	14.61	14.58	14.55	14.53	14.52	14.52	14.52	14.54	14.56	14.59	14.64	13.19	13.42	13.67	13.92	14.19	14.48
7	Interest on loan @10.0 % interest	Rs.in Cr	136.87	126.73	116.59	106.46	96.32	86.18	76.04	65.90	55.76	45.62	35.49	25.35	15.21	5.07	0.00	0.00	0.00	0.00	0.00	0.00
8	Return on equity @16.50% p.a	Rs.in Cr	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37
9	Depreciation @ 5.28% on total cost less land	Rs.in Cr	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	106.01	12.42	12.42	12.42	12.42	12.42	12.42
10	Charges for Pumping Energy	Rs.in Cr	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30
11	**Total Expenses (5 to 10)**	Rs.in Cr	**796.20**	**789.02**	**781.98**	**775.10**	**768.38**	**761.83**	**755.46**	**749.28**	**743.30**	**737.52**	**731.96**	**726.63**	**721.53**	**716.69**	**622.08**	**628.07**	**634.36**	**640.94**	**647.84**	**655.06**
11	Tariff Per Unit (11/2)	Rs per Unit	**8.37**	**8.29**	**8.22**	**8.14**	**8.07**	**8.01**	**7.94**	**7.87**	**7.81**	**7.75**	**7.69**	**7.64**	**7.58**	**7.53**	**6.54**	**6.60**	**6.67**	**6.74**	**6.81**	**6.88**
12	Discount Factor	10.00%	**1.00**	**0.91**	**0.83**	**0.75**	**0.68**	**0.62**	**0.56**	**0.51**	**0.47**	**0.42**	**0.39**	**0.35**	**0.32**	**0.29**	**0.26**	**0.24**	**0.22**	**0.20**	**0.18**	**0.16**
13	Present value of cost	Rs per Unit	**8.37**	**7.54**	**6.79**	**6.12**	**5.51**	**4.97**	**4.48**	**4.04**	**3.64**	**3.29**	**2.97**	**2.68**	**2.42**	**2.18**	**1.72**	**1.58**	**1.45**	**1.33**	**1.22**	**1.13**
14	Levelised tariff for 40 Years	Rs per Unit	**7.82**																			
15	**Working capital**																					
a	Maintenance for spares @15% of O&M	Rs.in Cr	9.437	9.888	10.359	10.853	11.371	11.913	12.482	13.077	13.701	14.354	15.039	15.756	16.508	17.295	18.120	18.985	19.890	20.839	21.833	22.875
b	O&M charges for one month	Rs.in Cr	5.24	5.49	5.76	6.03	6.32	6.62	6.93	7.27	7.61	7.97	8.36	8.75	9.17	9.61	10.07	10.55	11.05	11.58	12.13	12.71
c	Two months receivables	Rs.in Cr	132.70	131.50	130.33	129.18	128.06	126.97	125.91	124.88	123.88	122.92	121.99	121.11	120.26	119.45	103.68	104.68	105.73	106.82	107.97	109.18
d	Total Working Capital	Rs.in Cr	147.38	146.88	146.44	146.07	145.75	145.50	145.33	145.22	145.20	145.25	145.39	145.61	145.93	146.35	131.87	134.21	136.67	139.24	141.94	144.76
e	Interest on WC @10.00%	Rs.in Cr	14.74	14.69	14.64	14.61	14.58	14.55	14.53	14.52	14.52	14.52	14.54	14.56	14.59	14.64	13.19	13.42	13.67	13.92	14.19	14.48

	NAME OF THE PROJECT : CHITRAVATHI PUMPED STORA	
	Cost Of Project	**1797.59**
	IDC	**230.13**
	Total Cost Of Project	**2027.72**
	Promoters Equity 30 %	**608.32**
	Loan 70 %	**1419.40**

GENERATION COST AND TARIFF

Sl.No	Description	UNIT	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30	Year 31	Year 32	Year 33	Year 34	Year 35	Year 36	Year 37	Year 38	Year 39	Year 40
1	Capacity	MW	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00	500.00
2	Power Generation/annum	Units (in Lakhs)	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90	9631.90
3	Auxillary Consumption	%	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
4	Net units available for sale	Units (in Lakhs)	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32	9516.32
	Fixed Cost																					
5	O & M Expenses @3.5%, escalated @ 4.77% per annum	Rs.in Cr	159.77	167.39	175.38	183.74	192.51	201.69	211.31	221.39	231.95	243.01	254.61	266.75	279.47	292.80	306.77	321.40	336.74	352.80	369.63	387.26
6	Interest on WC Loan	Rs.in Cr	14.77	15.08	15.41	15.75	16.10	16.48	16.87	17.28	17.71	18.16	18.63	19.12	19.64	20.18	20.75	21.35	21.97	22.62	23.31	24.03
7	Interest on loan @10.0 % interest	Rs.in Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Return on equity @16.50% p.a	Rs.in Cr	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37	100.37
9	Depreciation @ 5.28% on total cost less land	Rs.in Cr	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42	12.42
10	Charges for Pumping Energy	Rs.in Cr	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30	375.30
11	**Total Expenses (5 to 10)**	Rs.in Cr	**662.63**	**670.56**	**678.87**	**687.58**	**696.70**	**706.26**	**716.27**	**726.76**	**737.75**	**749.26**	**761.32**	**773.96**	**787.20**	**801.08**	**815.61**	**830.84**	**846.79**	**863.51**	**881.02**	**899.37**
11	Tariff Per Unit (11/2)	Rs per Unit	**6.96**	**7.05**	**7.13**	**7.23**	**7.32**	**7.42**	**7.53**	**7.64**	**7.75**	**7.87**	**8.00**	**8.13**	**8.27**	**8.42**	**8.57**	**8.73**	**8.90**	**9.07**	**9.26**	**9.45**
12	Discount Factor	10.00%	**0.15**	**0.14**	**0.12**	**0.11**	**0.10**	**0.09**	**0.08**	**0.08**	**0.07**	**0.06**	**0.06**	**0.05**	**0.05**	**0.04**	**0.04**	**0.04**	**0.03**	**0.03**	**0.03**	**0.02**
13	Present value of cost	Rs per Unit	**1.04**	**0.95**	**0.88**	**0.81**	**0.74**	**0.68**	**0.63**	**0.58**	**0.54**	**0.50**	**0.46**	**0.42**	**0.39**	**0.36**	**0.34**	**0.31**	**0.29**	**0.27**	**0.25**	**0.23**
14	Levelised tariff for 40 Years	Rs per Unit																				
15	**Working capital**																					
a	Maintenance for spares @15% of O&M	Rs.in Cr	23.966	25.109	26.306	27.561	28.876	30.253	31.696	33.208	34.792	36.452	38.191	40.012	41.921	43.921	46.016	48.211	50.510	52.920	55.444	58.089
b	O&M charges for one month	Rs.in Cr	13.31	13.95	14.61	15.31	16.04	16.81	17.61	18.45	19.33	20.25	21.22	22.23	23.29	24.40	25.56	26.78	28.06	29.40	30.80	32.27
c	Two months receivables	Rs.in Cr	110.44	111.76	113.15	114.60	116.12	117.71	119.38	121.13	122.96	124.88	126.89	128.99	131.20	133.51	135.94	138.47	141.13	143.92	146.84	149.90
d	Total Working Capital	Rs.in Cr	147.72	150.82	154.07	157.47	161.03	164.77	168.68	172.78	177.08	181.58	186.30	191.24	196.41	201.83	207.52	213.47	219.70	226.24	233.08	240.26
e	Interest on WC @10.00%	Rs.in Cr	14.77	15.08	15.41	15.75	16.10	16.48	16.87	17.28	17.71	18.16	18.63	19.12	19.64	20.18	20.75	21.35	21.97	22.62	23.31	24.03

NAME OF THE PROJECT : CHITRAVATHI PUMPED STORAGE PROJECT

DEBT REPAYMENT SCHEDULE							
Quarter Number	**Opening Balance**	**Installment**	**Closing Balance**	**Av Loan**	**Interest @ 10.00 %**	**Total Interest**	**Principal**
1	1419.40	25.35	1394.06	1406.73	35.17		
2	1394.06	25.35	1368.71	1381.38	34.53		
3	1368.71	25.35	1343.36	1356.04	33.90		
4	1343.36	25.35	1318.02	1330.69	33.27	136.87	101.39
5	1318.02	25.35	1292.67	1305.34	32.63		
6	1292.67	25.35	1267.33	1280.00	32.00		
7	1267.33	25.35	1241.98	1254.65	31.37		
8	1241.98	25.35	1216.63	1229.31	30.73	126.73	101.39
9	1216.63	25.35	1191.29	1203.96	30.10		
10	1191.29	25.35	1165.94	1178.61	29.47		
11	1165.94	25.35	1140.59	1153.27	28.83		
12	1140.59	25.35	1115.25	1127.92	28.20	116.59	101.39
13	1115.25	25.35	1089.90	1102.57	27.56		
14	1089.90	25.35	1064.55	1077.23	26.93		
15	1064.55	25.35	1039.21	1051.88	26.30		
16	1039.21	25.35	1013.86	1026.53	25.66	106.46	101.39
17	1013.86	25.35	988.51	1001.19	25.03		
18	988.51	25.35	963.17	975.84	24.40		
19	963.17	25.35	937.82	950.49	23.76		
20	937.82	25.35	912.47	925.15	23.13	96.32	101.39
21	912.47	25.35	887.13	899.80	22.50		
22	887.13	25.35	861.78	874.45	21.86		
23	861.78	25.35	836.43	849.11	21.23		
24	836.43	25.35	811.09	823.76	20.59	86.18	101.39
25	811.09	25.35	785.74	798.41	19.96		
26	785.74	25.35	760.39	773.07	19.33		
27	760.39	25.35	735.05	747.72	18.69		
28	735.05	25.35	709.70	722.38	18.06	76.04	101.39
29	709.70	25.35	684.36	697.03	17.43		
30	684.36	25.35	659.01	671.68	16.79		
31	659.01	25.35	633.66	646.34	16.16		
32	633.66	25.35	608.32	620.99	15.52	65.90	101.39
33	608.32	25.35	582.97	595.64	14.89		
34	582.97	25.35	557.62	570.30	14.26		
35	557.62	25.35	532.28	544.95	13.62		
36	532.28	25.35	506.93	519.60	12.99	55.76	101.39
37	506.93	25.35	481.58	494.26	12.36		
38	481.58	25.35	456.24	468.91	11.72		
39	456.24	25.35	430.89	443.56	11.09		
40	430.89	25.35	405.54	418.22	10.46	45.62	101.39
41	405.54	25.35	380.20	392.87	9.82		
42	380.20	25.35	354.85	367.52	9.19		
43	354.85	25.35	329.50	342.18	8.55		
44	329.50	25.35	304.16	316.83	7.92	35.49	101.39
45	304.16	25.35	278.81	291.48	7.29		
46	278.81	25.35	253.46	266.14	6.65		
47	253.46	25.35	228.12	240.79	6.02		
48	228.12	25.35	202.77	215.45	5.39	25.35	101.39
49	202.77	25.35	177.43	190.10	4.75		
50	177.43	25.35	152.08	164.75	4.12		
51	152.08	25.35	126.73	139.41	3.49		
52	126.73	25.35	101.39	114.06	2.85	15.21	101.39
53	101.39	25.35	76.04	88.71	2.22		
54	76.04	25.35	50.69	63.37	1.58		
55	50.69	25.35	25.35	38.02	0.95		
56	25.35	25.35	0.00	12.67	0.32	5.07	101.39
		1419.40					**1419.40**

CHITRAVATHI PSP																				
GENERAL ABSTRACT																				
Head of A/c	Particulars	Cost of Civil works in Lakhs	Cost of Electrical works in Lakhs	Total Cost in Lakhs	INTEREST DURING CONSTRUCTION															
					1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	5th Qtr	6th Qtr	7th Qtr	8th Qtr	9th Qtr	10th Qtr	11th Qtr	12th Qtr	13th Qtr	14th Qtr	15th Qtr	16th Qtr
	A. Direct Cost				**9.77%**				**34.94%**				**22.55%**				**32.75%**			
I	**I WORKS**				**17556.23**				**62806.41**				**40529.24**				**58867.57**			
A	Preliminaries: Preliminary Survey & Investigations	1800.00		1800.00	900	900	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	Land: Lease of Government Land	2000.00		2000.00	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	Upper Reservoir Excavation including Embankment/Bund	40800.00		40800.00	0	0	4080	4080	4080	4080	4080	4080	4080	4080	4080	4080	0	0	0	0
J	Power Plant Civil Works:																			
	Upper Power Intake	6174.40		6174.40	0	0	0	0	0	0	1852	1852	0	0	0	0	0	1235	1235	0
	TRT Outlet Pump Intake	4725.70		4725.70	0	0	0	0	0	0	0	0	709	709	709	709	473	473	473	473
	Pressure Shafts including Steel Liner	10500.00		10500.00	0	0	0	0	0	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	0
	Power House	10369.30		10369.30	0	0	0	0	0	1037	1037	1037	1037	2074	2074	2074	0	0	0	0
	Tail Race Tunnel	3000.00		3000.00	0	0	0	0	0	0	0	0	450	450	450	450	450	450	300	0
	TRT outlet Coffer Dam and Associated	1000.00		1000.00	0	0	0	195	310	250	100	75	50	10	10	0	0	0	0	0
	Adits	5350.00		5350.00	0	0	0	1338	1338	1338	1338	0	0	0	0	0	0	0	0	0
K	Buildings:	3200.00		3200.00	960	640	0	0	0	320	320	320	160	96	384	0	0	0	0	0
M	Plantation: Site Plantations	100.00		100.00	0	0	10	0	10	10	0	0	10	10	10	10	10	10	10	0
O	Miscellaneous: Telephone, O & M of inspection vehicles etc.,	1800.00		1800.00	20	13	82	113	115	162	196	169	151	170	176	168	40	65	62	98
P	Maintenance: Maintenance charges during construction	900.00		900.00	0	0	50	60	60	90	100	90	80	90	90	90	20	40	20	20
Q	Special Tools and Plants	200.00		200.00	0	0	0	0	50	50	0	0	0	0	0	0	0	50	50	0
R	Communications: Service Roads	800.00		800.00	200	200	0	0	100	100	0	0	100	100	0	0	0	0	0	0
X	Environment & Ecology	500.00		500.00	50	50	50	50	25	25	25	25	25	25	25	25	25	25	25	25
Y	Loss on stock: @ 0.25% on total	230.00		230.00	2	2	10	14	14	20	24	21	19	21	22	21	5	10	10	14
S	Power Plant Electrical Works		69610.00	69610.00	0	0	0	0	6961	6961	6961	6961	0	0	0	0	10442	10442	10442	10442
	Transmission Line		11200.00	11200.00	0	0	0	0	0	0	0	0	0	1120	1680	1680	1680	1680	1680	1680
S	Total I-Works	93449.40	80810.00	174259.40																
II	Establishment Charges, 8% of I Work			5300.00	331	331	331	331	331	331	331	331	331	331	331	331	331	331	331	331
III	Tools & Plants @ 0.5% of I-Works less Land			200.00	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Suspense																			
V	Receipts & Recoveries: Q – Special Tools & Plants @ 15% of capital cost			-500.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-500
	Sub Total (A)	93449.40	80810.00	179259.40																
	B. Indirect Charges																			
	Audit and Accounts @ 0.5% of I Works			450.00	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
	Capitalisation of Abatement of Land revenue			50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	25.00
	Sub Total (B)	93449.40	80810.00	179759.40																
	Sub Total '(C)			**179759.40**																
	Sub Total Requirement Per Quarter				**4504.28**	**2176.48**	**4654.08**	**6221.41**	**13434.69**	**15864.49**	**17455.07**	**16052.16**	**8292.50**	**10376.76**	**11131.48**	**10728.50**	**14565.88**	**15900.83**	**15752.83**	**12648.05**
	Equity Per Quarter				1351.28	652.94	1396.22	1866.42	4030.41	4759.35	5236.52	4815.65	2487.75	3113.03	3339.44	3218.55	4369.76	4770.25	4725.85	3794.41
	Loan Per Quarter				3152.99	1523.53	3257.85	4354.98	9404.29	11105.14	12218.55	11236.51	5804.75	7263.73	7792.04	7509.95	10196.11	11130.58	11026.98	8853.63
	Interest During Construction			23012.94	1261.20	571.32	1140.25	1415.37	2821.29	3053.91	3054.64	2528.22	1160.95	1271.15	1168.81	938.74	1019.61	834.79	551.35	221.34
	Total Project Cost			**202772.34**																
	Half Yearly Expenditure				8513.27		13431.10		35174.39		39090.08		21101.36		23967.53		32321.11		29173.56	

C H I T R A V A T H I P S P																					
GENERAL ABSTRACT																					
Sl No.	**Head of A/c**	**Particulars**	**Cost of Civil works in Lakhs**	**Cost of Electrical works in Lakhs**	**Total Cost in Lakhs**	**PHASING OF EXPENDITURE**															
						1st Qtr	**2nd Qtr**	**3rd Qtr**	**4th Qtr**	**5th Qtr**	**6th Qtr**	**7th Qtr**	**8th Qtr**	**9th Qtr**	**10th Qtr**	**11th Qtr**	**12th Qtr**	**13th Qtr**	**14th Qtr**	**15th Qtr**	**16th Qtr**
						3	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**
		A. Direct Cost				**0**				**0**				**0**				**0**			
	I	**I WORKS**				**17556**				**62806**				**40529**				**58868**			
	A	Preliminaries: Preliminary Survey & Investigations	1800.00		1800.00	900	900	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	B	Land: Lease of Government Land	2000.00		2000.00	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	C	Upper Reservoir Excavation including Embankment/Bund	40800.00		40800.00	0	0	4080	4080	4080	4080	4080	4080	4080	4080	4080	4080	0	0	0	0
	J	Power Plant Civil Works:																			
		Upper Power Intake	6174.40		6174.40	0	0	0	0	0	0	1852	1852	0	0	0	0	0	1235	1235	0
		TRT Outlet Pump Intake	4725.70		4725.70	0	0	0	0	0	0	0	0	709	709	709	709	473	473	473	473
		Pressure Shafts including Steel Liner	10500.00		10500.00	0	0	0	0	0	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	0
		Power House	10369.30		10369.30	0	0	0	0	0	1037	1037	1037	1037	2074	2074	2074	0	0	0	0
		Tail Race Tunnel	3000.00		3000.00	0	0	0	0	0	0	0	0	450	450	450	450	450	450	300	0
		TRT outlet Coffer Dam and Associated Channel	1000.00		1000.00	0	0	0	195	310	250	100	75	50	10	10	0	0	0	0	0
		Adits	5350.00		5350.00	0	0	0	1338	1338	1338	1338	0	0	0	0	0	0	0	0	0
	K	Buildings:	3200.00		3200.00	960	640	0	0	0	320	320	320	160	96	384	0	0	0	0	0
	M	Plantation: Site Plantations	100.00		100.00	0	0	10	0	10	10	0	0	10	10	10	10	10	10	10	0
	O	Miscellaneous: Telephone, O & M of inspection vehicles etc.,	1800.00		1800.00	20	13	82	113	115	162	196	169	151	170	176	168	40	65	62	98
	P	Maintenance: Maintenance charges during construction	900.00		900.00	0	0	50	60	60	90	100	90	80	90	90	90	20	40	20	20
	Q	Special Tools and Plants	200.00		200.00	0	0	0	0	50	50	0	0	0	0	0	0	0	50	50	0
	R	Communications: Service Roads	800.00		800.00	200	200	0	0	100	100	0	0	100	100	0	0	0	0	0	0
	X	Environment & Ecology	500.00		500.00	50	50	50	50	25	25	25	25	25	25	25	25	25	25	25	25
	Y	Loss on stock: @ 0.25% on total	230.00		230.00	2	2	10	14	14	20	24	21	19	21	22	21	5	10	10	14
	S	Power Plant Electrical Works		69610.00	69610.00	0	0	0	0	6961	6961	6961	6961	0	0	0	0	10442	10442	10442	10442
		Transmission Line		11200.00	11200.00	0	0	0	0	0	0	0	0	0	1120	1680	1680	1680	1680	1680	1680
		Total I-Works	**93449.40**	**80810.00**	**174259.40**																
	II	Establishment Charges, 8% of I Work	5300.00		5300.00	331	331	331	331	331	331	331	331	331	331	331	331	331	331	331	331
	III	Tools & Plants @ 0.5% of I-Works less Land	200.00		200.00	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	IV	Suspense	NIL	NIL	NIL																
	V	Receipts & Recoveries: Q – Special Tools & Plants @ 15% of capital cost	-500.00	0.00	-500.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-500
		Sub Total (A)	**98449.40**	**80810.00**	**179259.40**																
		B. Indirect Charges																			
		Audit and Accounts @ 0.5% of I Works	450.00	0.00	450.00	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
		Capitalisation of Abatement of Land revenue (5% of cost of culturable Land)	50.00		50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	25.00
		Sub Total (B)	**98949.40**	**80810.00**	**179759.40**																
		Interest During Construction			**23012.94**																
		Total Project Cost			**202772.34**																

APPENDIX-C (SENSITIVITY ANALYSIS)

CHITRAVATHI PUMPED STORAGE PROJECT (2 X 250 MW)

(PROJECT SENSITIVITY ANALYSIS)

REF: Email dated 19-06-2021

Cost of Generation with different combinations of Pumping Power, Interest rates & RoE are Worked out.

The Levellized tariff for 64 combinations are presented in ascending order.

Inputs:

NAME OF THE PROJECT	CHITRAVATHI PUMPED STORAGE PROJECT
COST OF PROJECT (IN CR.):	1797.59
COST OF LAND (IN CR.):	20
IDC (IN CR.):	230.13
TOTAL COST OF PROJECT (IN CR.):	2027.7199999999998
PROMOTER EQUITY (IN %)	30
LOAN (IN %)	70
SELECT NO OF MONTHS FOR REPAYMENT OF LOAN	56
NO OF YEARS FOR TARRIF CALCULATION(IN NO'S)	40
PROJECT CAPACITY (IN MW)	500
POWER GENERATION (IN MWH)	9631.90
AUXILARY CONSUMPTION	1.20

Fixed Costs Inputs:

O AND M EXPENSES(IN %)	3.5
ESCALATION OF O AND M (IN %)	4.77
DEPRICIATION ON TOTALCOST LESS LAND (IN CR.)	5.28
PUMPING CONSUMPTION ENERGY (IN MWH)	12510

Working Capital Inputs:

MAINTENENCE OF SPARES FOR O AND M (IN CR.)	15			
INTERESTING ON WORKING CAPITAL(IN %)	10			
DISCOUNT FACTOR (IN %)	10			
ENTER NO OF SETS TO BE GENERATED	4			
PUMPING CHARGES (IN %)	0	2	2.5	3
RETURN OF EQUITY (IN %)	8	10	12	15.5
INTEREST RATE (IN %)	4	6	8	10.5

Generate Data   Clear

SL.NO	PUMPING CHARGES(IN %)	RATE OF EQUITY(IN %)	INTEREST RATE(IN %)	LEVELLIZED TARIFF(IN RS/-)
1	0	8	4	2.838
2	0	10	4	2.968
3	0	8	6	2.977
4	0	12	4	3.098
5	0	10	6	3.107
6	0	8	8	3.115
7	0	12	6	3.237
8	0	10	8	3.245
9	0	8	10.5	3.29
10	0	15.5	4	3.325
11	0	12	8	3.375
12	0	10	10.5	3.42

13	0	15.5	6	3.463
14	0	12	10.5	3.55
15	0	15.5	8	3.602
16	0	15.5	10.5	3.775
17	2	8	4	5.511
18	2	10	4	5.641
19	2	8	6	5.65
20	2	12	4	5.771
21	2	10	6	5.78
22	2	8	8	5.788
23	2	12	6	5.91
24	2	10	8	5.918
25	2	8	10.5	5.962
26	2	15.5	4	5.999

27	2	12	8	6.048
28	2	10	10.5	6.092
29	2	15.5	6	6.138
30	2.5	8	4	6.18
31	2	12	10.5	6.222
32	2	15.5	8	6.277
33	2.5	10	4	6.31
34	2.5	8	6	6.319
35	2.5	12	4	6.44
36	2.5	10	6	6.449
37	2	15.5	10.5	6.451
38	2.5	8	8	6.457
39	2.5	12	6	6.579

40	2.5	10	8	6.587
41	2.5	8	10.5	6.631
42	2.5	15.5	4	6.668
43	2.5	12	8	6.717
44	2.5	10	10.5	6.761
45	2.5	15.5	6	6.807
46	3	8	4	6.848
47	2.5	12	10.5	6.891
48	2.5	15.5	8	6.944
49	3	10	4	6.978
50	3	8	6	6.987
51	3	12	4	7.108
52	3	10	6	7.117

53	2.5	15.5	10.5	7.12
54	3	8	8	7.126
55	3	12	6	7.247
56	3	10	8	7.256
57	3	8	10.5	7.3
58	3	15.5	4	7.335
59	3	12	8	7.386
60	3	10	10.5	7.43
61	3	15.5	6	7.474
62	3	12	10.5	7.56
63	3	15.5	8	7.614
64	3	15.5	10.5	7.786