BHAKRA BEAS MANAGEMENT BOARD (BBMB)

(A Statutory Body under Ministry of Power, Government of India)

EXPRESSION OF INTEREST (EoI)

Notice No. 10/CS/C-194 **Dated: 16.01.2026**

For Development of 4300 MW Pumped Storage Projects (PSPs) under Tariff Based Competitive Bidding Mode

1. Background

Bhakra Beas Management Board (BBMB) is a statutory body constituted under the Punjab Reorganisation Act, 1966, under the administrative control of the Ministry of Power, Government of India. BBMB is responsible for operation, maintenance and management of major hydroelectric projects including Bhakra, Nangal, Pong and associated reservoirs in the northern region of the country.

In order to support national objectives of renewable energy integration, grid stability and peak power management, Pumped Storage Projects (PSPs) have been identified as a critical infrastructure. BBMB operates two of the largest reservoirs in the country, namely Bhakra Reservoir and Pong Reservoir, which offer significant potential for development of PSPs.

BBMB plans to execute PSPs using these reservoirs as 'Lower Reservoirs' and constructing new reservoirs (Upper Reservoirs) in upper reach of hill adjacent to these reservoirs.

BBMB has identified eight (08) potential PSP sites in the Bhakra–Beas system with an aggregate installed capacity of approximately 13,000 MW, out of which PFR for two sites namely 2800 MW Pumped Storage Project at Pong Reservoir, Distt. Kangra & 1500 MW Pumped Storage Project at Bhakra Reservoir, Distt. Una, in state of Himachal Pradesh, have been prepared. Draft MoU for development of these projects has been prepared and presently under approval of the BBMB Board.

The Ministry of Power (MoP), Government of India, has notified policy guidelines for development of Pumped Storage Projects through Tariff Based Competitive Bidding (TBCB), including development through Special Purpose Vehicle (SPV) mode, under Section 63 of the Electricity Act, 2003.

2. Objective of the EoI

The objective of this Expression of Interest (EoI) is to:

- Assess market interest for development of Pumped Storage Projects under TBCB mode.
- Seek feedback from potential developers, investors and stakeholders.
- Understand technical, commercial and financial perspectives of interested parties.
- Facilitate formulation of an appropriate bid structure for future Request for Proposal (RFP).
- This EoI is not a Request for Proposal (RFP) or tender and does not create any binding obligation on BBMB.

3. Project Details (Indicative)

3.1 Phase-I Projects

a) **Project:** Pumped Storage Project at Pong Reservoir
Proposed Capacity: 2800 MW
Development Mode: Tariff Based Competitive Bidding (TBCB)

b) **Project:** Pumped Storage Project at Bhakra Reservoir
Proposed Capacity: 1500 MW
Development Mode: Tariff Based Competitive Bidding (TBCB)

3.2 Project Reports

Pre-Feasibility Reports (PFRs) of these two projects are attached herewith as a part of EoI, for ready reference of prospective developers.

Indicative tariff worked out in PFRs, in respect of these two PSPs, is attached as **Annexure – A** for reference purpose.

4. Scope of the EoI

The scope of this EoI includes seeking inputs from interested parties on the following aspects:

- Identification of potential developers/investors interested in development of PSPs under TBCB–SPV mode.
- Preferred project capacity configuration, phasing and technical parameters (cycle efficiency, reservoir operation, grid connectivity)
- Feedback on TBCB–SPV development model and concession structure
- Views on tariff structure (capacity charge, energy charge, composite tariff, etc.).
- Suggestions on risk allocation relating to land, geology, hydrology, statutory clearances, financing, construction and off-take arrangements.
- Feedback on implementation timelines and construction strategy.

The responses received shall be used by BBMB solely for planning and structuring of the future competitive bidding process.

5. Proposed Development Framework

The Pumped Storage Project(s) are proposed to be developed under Tariff Based Competitive Bidding mode, broadly involving:

- Selection of developer through transparent competitive bidding under Section 63 of the Electricity Act, 2003
- Project implementation through a Special Purpose Vehicle (SPV), as applicable
- Developer to be responsible for financing, design, construction, operation and maintenance
- Tariff to be discovered through bidding and adopted by the Appropriate Electricity Regulatory Commission
- Concession / PPA structure in line with MoP TBCB Guidelines for Pumped Storage Projects.

6. Eligibility Criteria

Interested parties fulfilling the following eligibility criteria, are eligible to submit EoI:

6.1 Legal Eligibility

- Company incorporated under the Companies Act, 1956 or 2013 (including any amendments)
- Consortium / Joint Venture permitted

6.2 Technical Experience

Experience in development / construction / operation of:

Hydropower projects, or

Pumped storage projects, or

Power generation / transmission / large infrastructure projects

6.3 Financial Capacity

- Minimum Net Worth: INR 1,000 Crore (or equivalent) as on last audited financial year i.e. FY 2024-25.
- Turnover and financial parameters to be detailed at RFP stage.

Note: Detailed eligibility criteria shall be finalised and notified at RFP stage.

7. Timelines and Stakeholder Interaction

Activity	Timeline
Issue of EoI	Day 0 (16.01.2026)
Last date for submission of EoI proposal	Day 11 (27.01.2026)
Stakeholder interaction meeting	Day 14 (30.01.2026)
Venue	Board Secretariat, BBMB, Chandigarh

BBMB reserves the right to modify the above timelines.

During the interaction meeting, the prospective developers shall give detailed presentation regarding their Expression of Interest (EoI), submitted to BBMB.

8. Information to be Submitted by Interested Parties

Interested parties are requested to submit the following information, as a part of EoI: -

i. Covering Letter expressing interest
ii. Details of the Applicant (name, address, legal status)
iii. Brief Organizational Profile
iv. Technical Experience (brief description of relevant projects)
v. Financial Information (Net worth and turnover – indicative)
vi. Brief write-up on proposed development approach
vii. Suggestions on TBCB framework and project structuring
viii. Key Observations / Suggestions on:
  - Project configuration and capacity
  - Tariff structure
  - Risk allocation
  - Concession period
  - Any other relevant aspect
  - The submission may be concise and indicative in nature.

9. Submission of EoI & Contact details

Mode: The EoI must be submitted by due date, through e-mail at dir-consultancy@bbmb.nic.in

Contact details

Director/Consultancy
Bhakra Beas Management Board
Board Secretariat, Sector-19 B, Chandigarh
Tel. No. 0172-5011762
Mobile No. +91-9463998265

10. Rights of BBMB

BBMB reserves the right to:

- Accept or reject any or all EoI submissions without assigning any reason
- Amend or cancel the EoI process at any stage
- Modify the scope, capacity or development framework of the project
- Seek additional information or clarifications from interested parties

11. Confidentiality

Information submitted by interested parties shall be used solely for the purpose of project assessment. BBMB shall not be liable for disclosure of information as required under applicable laws.

12. Important Disclaimers

- This EoI is issued for market assessment and consultation only.
- BBMB is not bound to issue RFP or award any project pursuant to this EoI.
- BBMB reserves the right to modify, cancel or withdraw this EoI at any stage.
- All costs incurred by interested parties in responding to this EoI shall be borne by them
- This EoI is not a Request for Proposal (RFP) or tender and does not create any binding obligation on BBMB.

Director/Consultancy
BBMB, Chandigarh

Annexure-A

Levelized Tariff in respect of 2800 MW Pong PSP

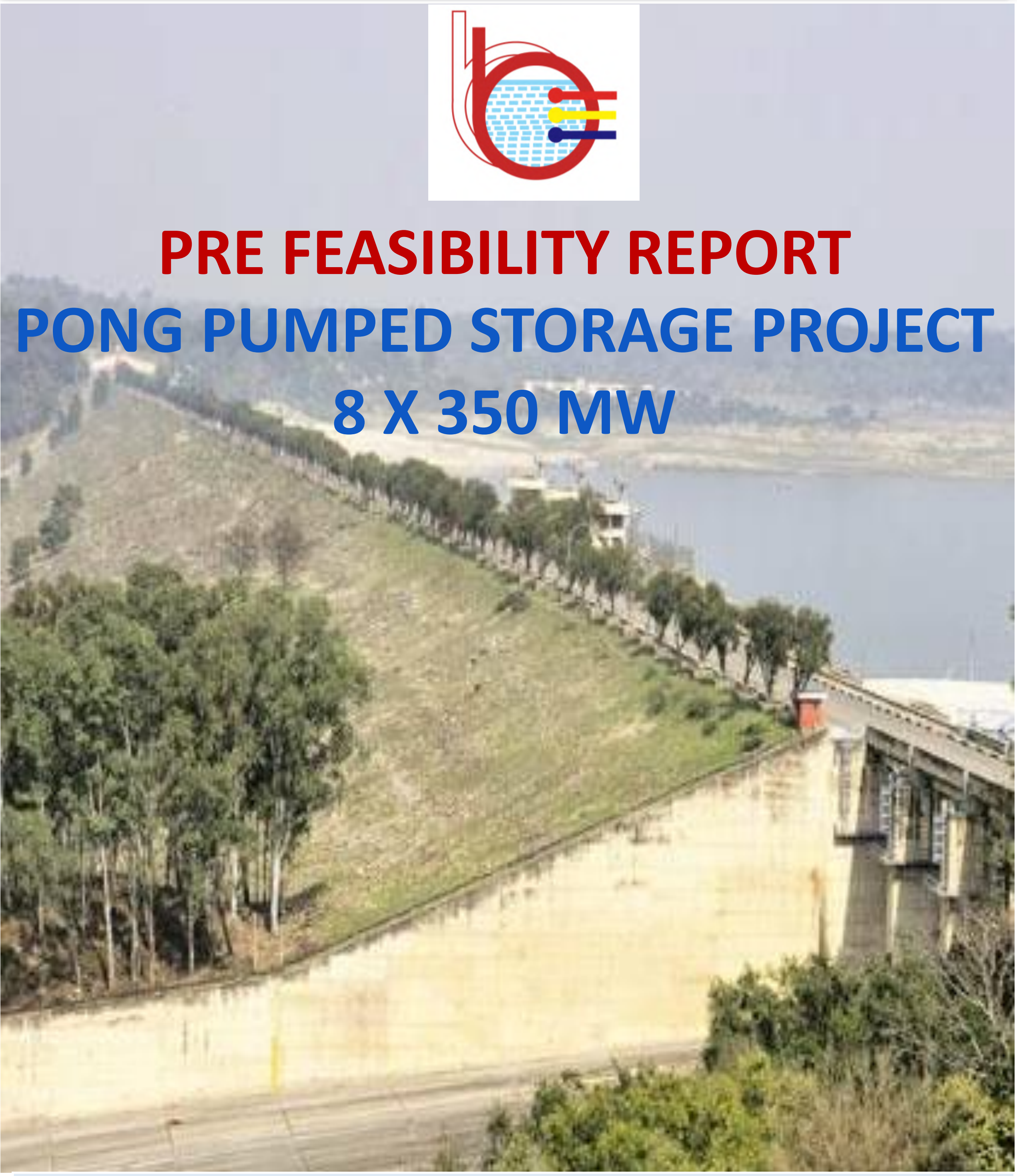
Sr. No.	Off Peak Energy Rate (Rs/kWh)	Levelized Tariff (Rs/kWh)	Conversion Cost of the Project (Rs/kWh)
1.	1	4.66	3.17
2.	1.5	5.41	3.17
3.	2	6.16	3.17
4.	2.5	6.91	3.17

Levelized Tariff in respect of 1500 MW Bhakra PSP

Sr. No.	Off Peak Energy Rate (Rs/kWh)	Levelized Tariff (Rs/kWh)	Conversion Cost of the Project (Rs/kWh)
1.	1	6.54	5.23
2.	1.5	7.20	5.23
3.	2	7.86	5.23
4.	2.5	8.51	5.23

Note: The above tariff has been worked out by BBMB’s consultant based on PFR, considering a single cycle of pumping/generation of about 5.5 hours for Pong PSP and about 5 hours for Bhakra PSP. The DPR is yet to be prepared. The final tariff will depend on the operating cycle time and salient features as per the approved DPR.

BHAKRA BEAS MANAGEMENT BOARD



PRE FEASIBILITY REPORT

PONG PUMPED STORAGE PROJECT

8 X 350 MW

CONSULTANT

WAPCOS LIMITED,
(A GOVERNMENT OF INDIA UNDERTAKING)
76-C, INSTITUTIONAL AREA, SECTOR-18, GURUGRAM,
HARYANA – 122015 INDIA
Email: adv@wapcos.co.in

MARCH 2023

TABLE OF CONTENTS

Drawings Details		
S.No	**Description**	**Drawing Number**
1	General Layout Plan	WAP/Pong-PSP/01
2	Longitudinal section along WCS	WAP/Pong-PSP/02
3	Cross section of PH	WAP/Pong-PSP/03
4	Layout plan of Machine Hall & Transformer Hall floor	WAP/Pong-PSP/04
5	L- section of power house	WAP/Pong-PSP/05
6	SLD for 400kV GIS	WAP/Pong-PSP/06

1. Executive Summary

Chapter-1
Executive Summary

1.1 Preamble

Power is a basic infrastructure for overall development of the nation. It is a necessary input for the economic growth of a country. There has been an ever increasing demand for more and more power generation in the world. India is a fast growing economy through industrialization, irrigation, urbanization, village health to meet the demand of rapidly growing population. And as such the demand for power is much more in India than in developed countries. The chief sources of energy which are now been utilized for generation of electricity are: Fuel in all forms i.e. solid, liquid and gaseous, water energy and nuclear energy. The other sources of energy are sun (solar photo-voltaic etc.), wind and tides.

Hydro-power is a renewable, economical, non-polluting and environmentally benign source of energy. Hydropower stations have inherent ability for instantaneous starting and stopping, to help in improving reliability of power system and to meet the peak demand. Hydroelectric projects have long useful life and help in conserving scarce fossil fuels. In the other ways, because of the inherent source of pollution in thermal generation system, the developed countries are phasing out thermal generation.

Pumped Storage Project is a type of hydroelectric generation plant that stores energy in the form of water, pumped from a lower elevation reservoir to upper elevation reservoir during off-peak period and generates electricity during peak period. This is currently one of the most effective means of storing large amount of electric energy. It helps in grid stability, reliable supply and providing quality power (in terms of voltage and frequency).

The proposed Pong Pumped Storage project envisages utilization of water of Maharana Pratap Sagar Reservoir (one time only) on river Beas. The water released from upstream project Pandoh dam and the inflow from intermediate catchments between Pandoh dam & Pong Dam is impounded by an earthen dam known as Pong Dam and reservoir is known as Maharana Pratap Sagar Reservoir. In present studies lower reservoir would consist of existing Maharana Pratap Sagar reservoir while upper reservoir (Proposed new construction) would be for storage of recycled water. 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.

1.2 Project background

Pong project was considered as the part of the Master plan and was construct to harness the waters of the three eastern rivers through the Satluj, the Beas and the Ravi for irrigation and power-production in an integrated manner. The idea and earlier investigation for storage dam across Beas river at Pong date back to 1926, when Mr.

C.E. Blaker of the Punjab PWD Irrigation Branch first inspected the present site. A committee of Punjab PWD Irrigation Branch was appointed by Punjab Government in 1927 to report on storage scheme for Punjab rivers and their tributaries. Committee on the basis of Mr. C.E. Blaker's report, reported that economical storage is difficult due to high floods which were likely to occur at this site and embankment dam is practical due to foundation conditions. Later on preliminary investigations were initiated in the year 1955 a report was prepared. Later on, after carrying out further detail investigations a more detailed report for the Beas Dam at Pong was prepared and submitted to Punjab Government in 1959. And subsequently under the Chairmanship of Dr. A.N. Kohsla final proposal was formulated that is taken for construction of Pong dam. The full-fledged construction activity for the project started in 1961 after formation of Beas Control Board. And construction of multipurpose project on river beas for irrigation and power generation completed in the 1983. The total catchment area of Beas and its tributaries above Pong is about 12560 sq. km and the mean annual runoff is about 0.95 millon hector meter. The project comprises 132.59 high earthen dam with power houses having an installed capacity of 396 MW. The dam has been named Pong Dam after the village Pong in Kangra District of Himachal Pradesh.

Further, with a view of utilizing storage available in Maharana Pratap Sagar reservoir for Pumped storage Project, BBMB has given the responsibility for formulation of Feasibility Study Report (FSR) for the proposed Pump storage scheme on 04/07/2022 WAPCOS. WAPCOS during preparation of Feasibility studies carried out works of topography, geophysical survey and hydraulic design studies of the project area in upstream of Pong dam to identify & evaluate probable projects sites, alternative layouts with alternate dam locations & water conductor system and minimal utilisation of natural resources.

1.3 Present Studies

With this background, initially WAPCOS started the work of identification of as many as potential sites in July, 2022. Initially field office, identified 15 alternatives for 10 identified sites for upper reservoir (Fig-1.1).

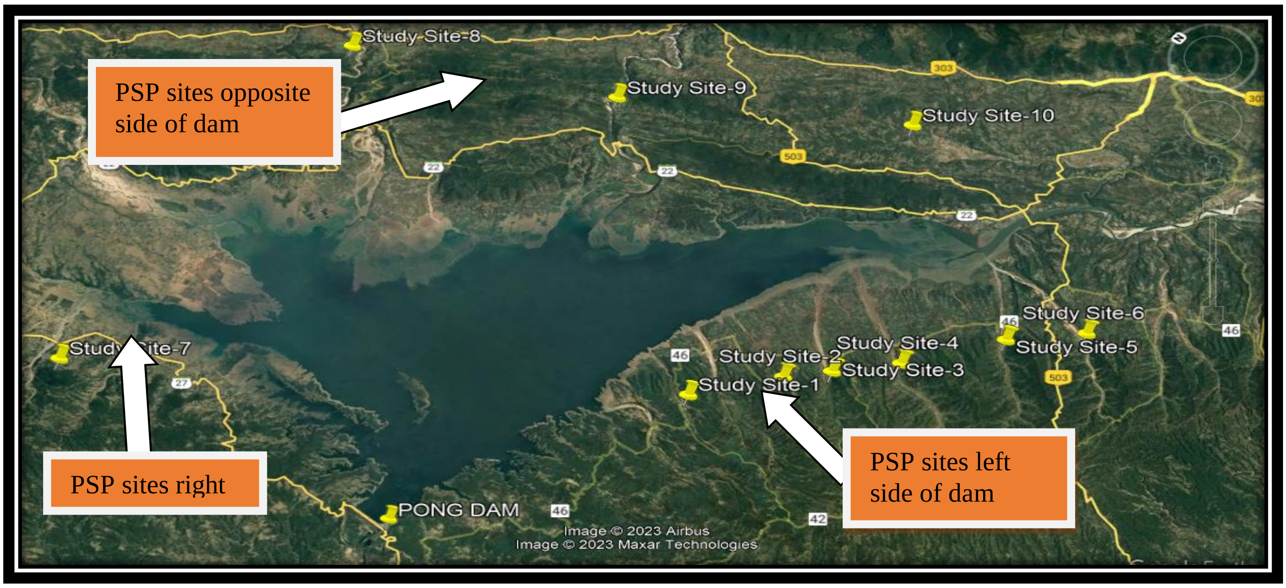


Figure-1.1: Location of 10 identified sites

Later on with further studies for narrowing & project planning of possible sites were carried out during desktop study & various joint site visit by designers, planning experts (HEP) and field staff in between July & August months. After the site visit and thorough planning, designers and experts finally proposed 12 alternatives for feasible 6 site (Fig-1.2) on basis of site works (i.e. topography, geophysical survey & mapping).

Figure-1.2: Location of 6 identified Sites

A comprehensive study and site work was taken simultaneously on these sites and on the basis of survey and feasibility studies finally proposed four (4) possible sites (Fig-1.3). And later Designers & Geologist carried out geological studies of these 4 sites.

And after much technical analysis it is concluded that the sites-1 on left bank will be most favourable from power capacity and techno-economic reasons.

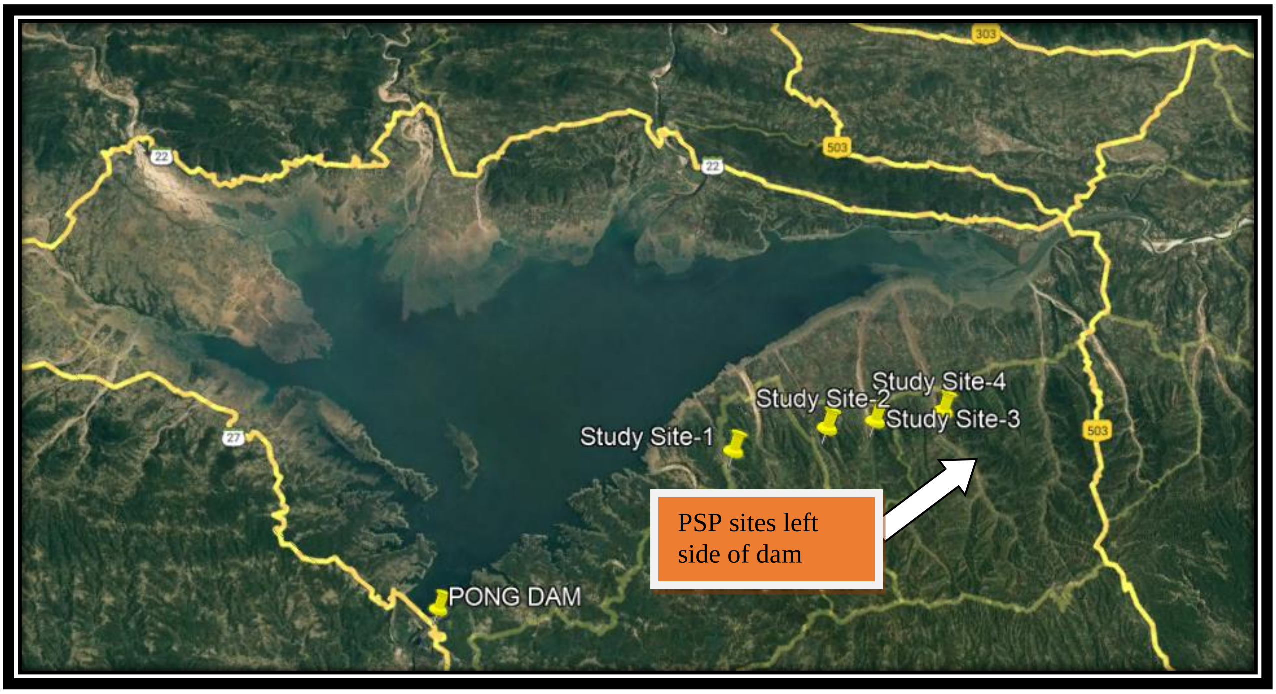


Figure-1.3: Location of 4 identified Sites

Based on the features like gross reservoir capacity, length of the water conductor system and power system, following four alternative were selected for detailed studies for techno-commercial studies and further development in later stages:

i. Dam Axis alternative1 (LB_1_trial 2)
ii. Dam Axis alternative2 (LB_2_Trial 1)
iii. Dam Axis alternative3 (LB_3_Trial 1)
iv. Dam Axis alternative4 (LB_4_Trial 3)

1. Dam axis Alternative1 (LB_1_trial 2)

Upper Dam Axis Alternative-1 (LB_1_trial 2) is located on the left fringe of reservoir near Garial village of Kangra district of Himachal Pradesh. This alternative envisages an upper reservoir having estimated live storage capacity of 22.32 MCM with FRL at EL750m, MDDL at EL700m with the construction of a 70m high and about 856.5m long dam across dada khad that is aligned through Garial village. The design discharge is proposed to be conveyed to an underground powerhouse proposed on the left fringe of reservoir near village gurhala through 5.65 km long water conductor system with the objective of generating 2800 MW of power. The hills around the proposed site were covered with moderately dense vegetation with dense under growth. Primafacie, the site appears suitable for upto 100m high dam. Further detail investigation will be the part of DPR stage.

2. Dam axis alternative 2 (LB_2_Trial 1)

Upper Dam axis alternative-2 (LB_2_Trial 1) is located on the left fringe of Maharana Pratap sagar reservoir on left flank of Pong Dam near balwal village of kangra district of Himachal Pradesh. This alternative envisages an upper reservoir having estimated live storage capacity of 26.52 MCM with FRL at EL750m, MDDL at EL690m with the construction of a 70m high and about 1134m long dam across a bargoalan khad that debouches into Maharana Pratap Sagar reservoir north of Nangal chowk. The design discharge is proposed to be conveyed to a pit/underground powerhouse proposed near village rori kori through a 4.35 km long water conductor system with the objective of generating 2500 MW of power. The hills around the proposed site were covered with moderately dense vegetation.

3. Dam axis alternative 3 (LB_3_Trial 1)

Upper Dam axis alternative 3 (LB_3_Trial 1) alternative is also located on left fringe of reservoir near chaplah village in Kangra district. The studies carried out indicated that it was possible to create a reservoir with FRL at EL 650m, MDDL at EL 610m gross storage capacity of 10.84MCM and live storage capacity of 10.64 MCM generate 900 MW of power.

The site proposed for about 50m high dam near village chaplah across a tributary of chanaur Khad. The hill slopes on both the banks of nala are moderately vegetated with dense under growth. The 4.08km long water conductor system being planned to convey the designed discharge to the lower reservoir.

4. Dam axis alternative 4 (LB_ 4 _Trial 3)

Upper Dam Axis (**LB_ 4 _Trial 3**) alternative located near village dodrah. This alternative envisages an upper reservoir having estimated live storage capacity of 20.10MCM with FRL at EL750m, MDDL at EL730m with the construction of 70m high and about 856m long dam across a tributary of Thor Khad. The 5.64 km long water conductor system being planned to convey the designed discharge to the lower reservoir with the objective of generating 2500MW of power.

As mentioned above, the **Dam axis alternative 1 (LB_1_Trial 2)** had more power potential with comparative water conductor length, has been chosen in the present study on the basis of techno-commercial viability. However, the same may be reviewed at the DPR stage when more subsurface and topographical data is available. This scheme with ultimate capacity of 2800 MW, maximum gross head of 319.6m and

Upper and Lower Reservoirs have effective storage capacity equivalent to Five (5) hours of generation daily at full rated output, possibility to operate the project on daily basis has been considered and finally proposed for PSP Scheme.

1.4 Project Location

The proposed Pong Pumped Storage Project is located near existing Pong Project and approachable from popular Dadasiba village in Kangra district, Himachal, India (**Figure 1.4: Location Map)**. The project falls in the area bounded by N - 31˚ 53’ 24”, E - 76˚ 03’ 54” and N - 31˚57’ 00”, E - 76˚4’ 50”**.**

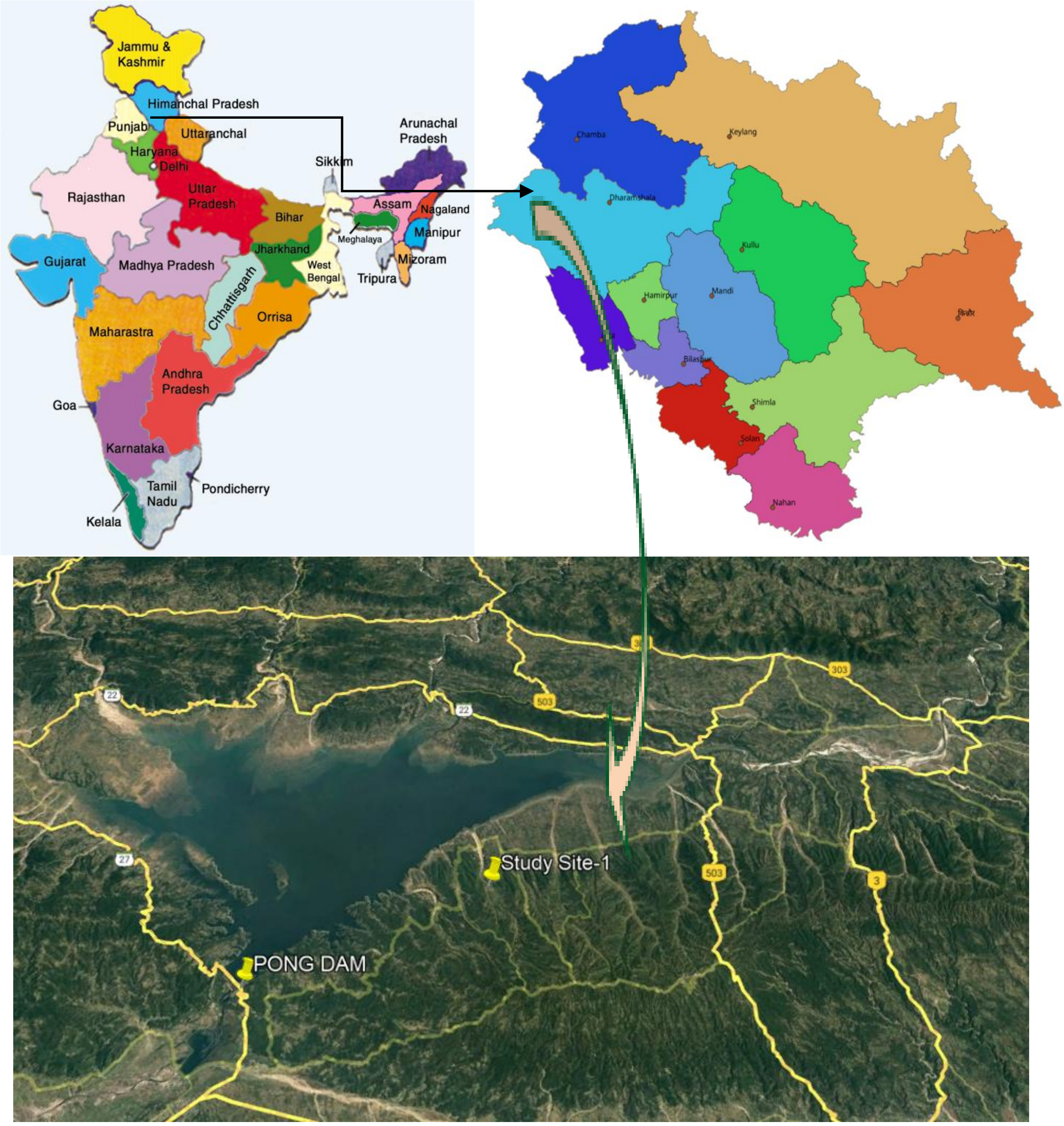


Fig-1.4: Location Map- Dam axis alternative 2 (RB_1_Trial 1)

1.5 Access to the Project:

The project is located about 15 km Left of Pong dam. The nearest rail head is Daulatpur Chowk which is about 30 km from site. Dada Siba village is approachable by about 30 km road from the existing Pong Project. The nearest airport is Amritsar International Airport located in Punjab which is about 160 km away from project site.

1.6 Salient Features:

1. Location	
Country **State** **District**	India Himachal Kangra
River	Beas river
Dam Axis (Upper)	Left Bank: N - 31°53'24.35'', E - 76° 4'2.31" Right Bank: N - 31°53'16.41", E - 76° 4'33.52"
2. Access to the Project	
Road	About 30 km from Talwara town
Airport	Amritsar International Airport, Punjab 160 km away
Railhead (with unloading facilities)	Daultapur Chowk
3. Project	
Type	Pumped Storage Project
Installed Capacity	8 X 350 MW
Peak Operating duration	5 hours daily
4.0 Civil Structure	
4.1 Upper Reservoir	
Max Water Level	750 M
FRL/FRL considered	750 M
MDDL	700 M
Gross Storage capacity	23.2 MCM
Live storage	22.3 MCM

4.2 Lower Reservoir	
FRL	426.72 M
MDDL	384.05 M
Reservoir surface area at FRL	260.00 sq. km
Gross capacity at MWL	8.578 BCM
Live storage	7.291 BCM
4.3 Upper Dam	
Type	Rock fill with central clay core
Top of Dam	EL 752 M
River Bed Elevation	EL 680 M
Total Length of Dam at top	855 m
Max. Height of Dam	72.00 m (from bed level)
Top width of dam	10 m
4.4 Intake Structure	
Type	Trapezoidal type with anti-vortex louver
H x W x L x No. x Line	11 m x 16.36 m x 79.4m 2 no's x 2 line
Dia. Of Tunnel	9.0m
4.5 Headrace Tunnel cum Pressure Shaft (Steel Lined)	
Diameter	9.0 m
Length	150m
No. of Tunnel	2
4.6 Pressure Shaft (Steel Lining)	
D x L x line	-
After Bifurcation	5.5m x 550m x 4 lines
4.7 Tailrace Tunnel (Steel Lined)	
Diameter	11.5 m
Length	5000 m
No. of Tunnel	2
4.8 Powerhouse	
Type	Underground Cavern
Size	314.00 m (L) x 22 m (W) x 57 m (H)

4.9 Transformer Room including Secondary GIS	
Type L x W x H	Underground Cavern including Secondary GIS 229.00 m (L) x 22.00 m (W) x 33.00 m (H)
4.10 Main Access Tunnel (MAT)	
Type W X H	D- shaped, Length – 800m 8.00 m (W) x 8.50 m (H)
5.0 Electromechanical Equipment	
5.1 Pump Turbine	
Turbine	
a) Rated Output at rated net head of 296.84m	355.33 MW
b) Specific Speed	140.95 rpm
c) Rated Speed	250 rpm
d) Centerline of Turbine	EL. 332.00 m
Pump Basic Data	
a) Pump Input at rated net head of 338.84 m	315.01 MW
b) Specific Speed	30 rpm
c) Rated Speed	250 rpm
d) Rated Pump discharge	89.81 cumecs
5.2 Generator-Motor	
Rated Output	350 MW
Power Factor (Generation Mode)	0.85 lagging
Power Factor (Pumping Mode)	0.95 leading
Frequency	50 Hz
Phases	3 (Three)
Speed	250 rpm
Rated Terminal Voltage Between phases	21 kV
Range of frequency	(-) 5 % to (+) 3 %
Bearing arrangement	Semi-Umbrella Type

5.3 Transformers	
Type	Indoor type, oil-immersed, three phase, with on-load tap charger(OLTC) for pumping operation, OFWF Cooled
Number	8+1 (one spare transformer)
Rated Capacity	453 MVA, Three phase
Rated Voltage	Primary; 21 kV Secondary; 765 kV Adjustable range of the secondary voltage: -5% to +5%
Connection	Primary: Delta Secondary: Star
Neutral Grounding System for Secondary Winding	Solidly Grounded
5.4 Gas Insulated Switchgear	
Bus System	Double bus
No. of bays	13
5.5 765 kV XLPE Cable	
Type	Single Core 800 kV cross linked polyethylene insulated type.
Rated Voltage	800 kV
Number of Circuits	4 nos.
5.6 EOT Crane	
Type	Indoor, Electric Overhead Traveling crane
Number of Unit	Two (2) units
Rated Capacity	365 ton (Main hoist), 50 ton and 10 ton
Span	20.00 m

<table>
<tr><td colspan="4">5.7 Project Cost (Price Level Year, 2022)</td></tr>
<tr><td colspan="2">Item</td><td colspan="2">Estimated Cost (Rs. Crore)</td></tr>
<tr><td colspan="2">Civil Works</td><td colspan="2">3775.17 Crores</td></tr>
<tr><td colspan="2">Electro-mechanical Works</td><td colspan="2">4430.06 Crores</td></tr>
<tr><td colspan="2">IDC</td><td colspan="2">653.89 Crores</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">10648.87 Crores</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">5.8 Project Benefits</td></tr>
<tr><td>Sl. No.</td><td>Off Peak Energy Rate (Rs/kWh)</td><td>Levelized Tariff (Rs/kWh)</td><td>Conversion Cost of the Project (Rs/kWh)</td></tr>
<tr><td>1</td><td>1</td><td>4.66</td><td>3.17</td></tr>
<tr><td>2</td><td>1.5</td><td>5.41</td><td>3.17</td></tr>
<tr><td>3</td><td>2</td><td>6.16</td><td>3.17</td></tr>
<tr><td>4</td><td>2.5</td><td>6.91</td><td>3.17</td></tr>
</table>

2. Economic Scene & Power Scenario

Chapter-2

ECONOMIC SCENE & POWER SCENARIO

Power is among the most critical components of infrastructure, crucial for the economic growth and welfare of nations. India power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil, hydro, nuclear to viable non-conventional sources such as Solar, wind, agriculture & domestic waste. Electricity demand in the country has increased rapidly and is expected to rise further in the years to come in order to meet the increasing demand for electricity in the country, massive addition to the installed capacity is requested.

The development of requisite power infrastructure is key for sustained growth of Indian economy. India has witnessed a significant transformation from being an acutely power deficit country to a situation of demand being fully met. India has also made remarkable strides to ensure universal access to electricity for every household.

Over the years the installed capacity of power plants has increased to 399496 MW as on 31.3.2022 from a meager 1362 MW in 1947.

2.1 Power Scenario in Country

	Installed Capacity (As on 31.3.2022)	
Thermal	236108.72	MW
Hydro		
Conventional	42104.55	MW (above 2.5 MW)
Pumped Storage	4745.60	MW
Renewables	109757.75	MW
Total	399496.62	MW

Hydro
Region Wise installed Capacity

As on 31.7.22

Northern	19696.25	MW
Western	7392.00	MW
Southern	11747.15	MW
Eastern	5987.75	MW
North-Eastern	2027.00	MW
Total (All India)	46850.15	MW

Installed Capacity of BBMB

Bhakra Left	4x126 + 1x 108	612	MW
Bhakra Right	5x157	785	MW
Dehar	6x165	990	MW
Pong	6x66	396	MW
Total		2783	MW

Per capita Electricity consumption

The per capita electricity consumption during 2017-22 is summarized as below

Per Capita Electricity Consumption

Year	PER Capita Consumption (kwh)
2017-18	1149
2018-19	1187
2019-20	1208
2020-21	1161

2.2 Demand Assessment

Demand assessment is an essential prerequisite for planning of generation capacity addition and commensurate transmission and distribution system to meet the future electricity requirement. The electricity demand of the country in terms of peak load and energy requirements

For the period from 2022-27 &2027-2032

Projected Region wise electrical energy requirements & Peak electricity demand for the years 2026-27 & 2031-32

Region	Electrical Energy Requirement (MU)		Peak Electricity Demand (MW)	
Northern	2026-27	2031-32	2026-27	2031-32
	564774	762045	86187	117128
Western	573200	792574	84097	114285
Southern	504245	682202	74108	100710
Eastern	200611	266775	31638	42295
North Eastern	31170	44862	5951	8087
All India	1874000	2538458	272000	363188

Note: The electricity demand projection covers electricity demand only for the utility system

The projections do not include the portion of electricity demand of industries and other consumers that would be met from the captive power plants

The electrical energy requirements and peak electricity demand on all-India has been projected at 1874 BU and 272 GW in 2026-27 & 2538 BU and 363 GW in 2031-32 respectively. These projections include impact of solar rooftop, green hydrogen, EV and Energy efficiency measures.

Promotion of Hydro Projects.

For boosting the generation of Hydro Power, the Government of India on 8.3.2019 approved a number of measures of promoting hydropower sector in the country which are as under.

- Declaring Large Hydro .25 MW as Renewable Energy source
- Hydro Purchase obligation (HPO) as a separate entity with Non-Solar Renewable Purchase Obligation (RPO)
- Tariff rationalization measures for bringing down hydropower tariff.
- Budgetary Support for flood moderation/ storage Hydro Electric projects (HEP's)
- Budgetary support to cost of Enabling infrastructure i.e. roads/bridges a) Rs.1.5 Crore per MW for projects upto 200 MQ b) Rs. 1.0 Crore per MW for projects above 200 MW

2.3 Storage System

The next phase of energy transition drives by the large scale deployment of variable renewable energy sources (VREs) like Solar and wind power can be fully realized by Key Technologies of Energy Storage. The grid integration challenges of the intermittent generation sources ensuring quality of supply on real time basis along with the capability to store excess electricity over different time horizons can be achieved by the electricity storage systems. Many Grid scale energy storage systems are commercial available worldwide which include pumped storage plants, Battery energy storage systems etc. However, many other energy storage technologies like green hydrogen are in stage of development.

2.4 Pumped Hydro Storage Systems

While many forms of energy storage systems have been installed globally. Pumped storage plants (PSP) are playing an increasingly significant role in providing peaking power and maintaining system stability in the power system of many countries. Pumped storage resources is the long term technically proven, highly efficient, environmental friendly and flexible way of energy storage on a large scale to store intermittent and variable energy. PAP improve overall economy of power system operation and reduce operational problems of thermal stations during low load period. The other advantages of pumped storage resources are availability of spinning reserve at almost so cost to the system and regulating grid frequency to meet sudden load changes in the network. It also can provide ancillary benefits such as flexible capacity, voltage support and Black start facility etc. pumped storage Resource has advanced significantly since its original introduction and now includes adjustable speed pumped turbines which can quickly shift from motors to generator, to synchronous condenser mode, for easier and more flexible operation of the grid. The concept of off-river PSP is getting popular in recent years due to huge benefits arising out to its fewer capital cost/operations. Currently India is exploring the off-river storage systems which can be executed with lesser cost and at a fast pace.

3. Hydrology

Chapter-3

Hydrology

3.1 Background:

In any Hydroelectric Project (HEP) and Pumped Storage Project (PSP), hydrological inputs play a vital role in planning, execution and operation of these project. Hydrological studies are carried out at all stages of development starting from Pre-feasibility stage, detailed project report (DPR) stage and even during their operation. However, PSP projects are slightly different in a sense that such projects recycle the water between the two reservoir i.e. upper reservoir and lower reservoir. Normally there is no consumptive use of water requirement (except making good for evaporative loss and machine loss). Therefore, PSP projects have negligible impact on hydrological regime and as such the criticality of its impact on hydrology are minimum in case of their proposed installation on existing/ongoing projects.

The Proposed Pong PSP envisages utilisation of water of existing Pong (Maharana Pratap Sagar) reservoir on Beas River having spread in district Kangra of Himachal through installation of 2800 MW power plant, which would be equipped with eight vertical axis reversible type hydro-electric units each comprising of generator-motor and a pump turbine with a generating capacity of 350 MW each. Lower reservoir would consist of existing Maharana Pratap Sagar reservoir while upper reservoir (Proposed new construction) would be for storage of recycled water.

3.2 Objective of the study:

The proposed study aims to harness the various parameters for project planning and design of proposed Pong Pump Storage scheme. Since more than five decades have passed while power generation started at Pong powerhouse and there might be changes in water availability, it is considered necessary to update the hydrology based on recent hydrological data to assess the impact on water availability for existing Maharana Pratap Sagar reservoir for running the proposed PSP scheme utilising the present up to date data.

- To assess the impact of proposed PSP scheme on the release of water for D/s states from existing Maharana Pratap Sagar reservoir.
- To assess additional peaking power generated thereof from the proposed scheme.
- Since Maharana Pratap Sagar reservoir is in existence and meeting the existing demands of irrigation and power; no fresh design flood studies are required.
- To assess the efficacy of combined project in association with existing demands using the existing storage of Maharana Pratap Sagar reservoir i.e. based on recent hydrograph survey (if available).

3.3 Existing Beas river system:

Originally known as Vipasa, Beas has the second largest catchment area in Himachal Pradesh – after Satluj. Beas River was India’s eastern-most part upto which Alexander the Great's conquests in 326 BC were marked. The River is known to have been the biggest hurdle in the way of Alexander's invasion of India. The name of the River 'Beas' is known to have originated from its Sanskrit name 'Vipasha'. The origins of the name are often connected with 'Vyasa' of Veda Vyasa, proving that the river starts from the Vyasa Kund. The Parbati River, the largest tributary of the Beas, has given birth to numerous religious and folk tales that has made the Parbati Valley alluring and sacred for many.

After the completion of the Bhakhra Dam in 1964 on the Satluj River, the attention turned to the utilisation of the waters of the Beas with two major projects – the Pong and Pandoh Dams as a part of the Indus Water Treaty with Pakistan for optimised utilise the waters of the Satluj, Beas and Ravi. The former was constructed in the year 1974, a decade after Bhakhra in Kangra district in a small village called Pong. The dam was to provide irrigation to Punjab, Haryana and Rajasthan. With completion of these two projects in addition to irrigation benefits these project generate electricity at the Dehar Power House and Pong Power house.

Hydropower potential of the Beas basin has been identified to be 5995 MW. On the Beas and it's major tributaries like Parbati, Malana, Sainj, Uhl, Binwa and Neugal, approximately 29 Hydroelectric Projects(HEPs) of more than 6 MW capacity are either commissioned or under construction/planned. A line diagram of existing Beas river system is shown in fig 3.1 below.

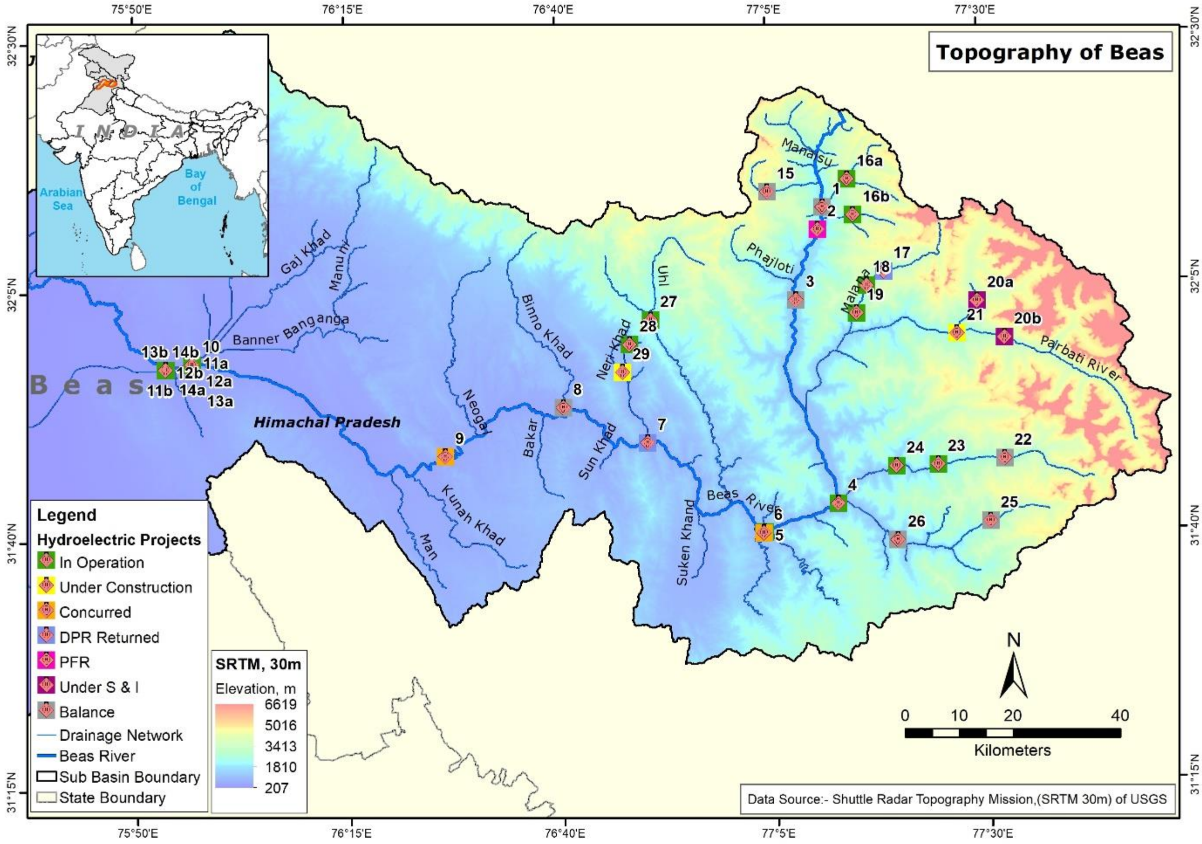


Fig. 3.1: Existing Beas River System (Line Diagram)

3.4 Project Catchment:

The proposed project is planned on tributaries of Beas River and with existing Maharana Pratap Sagar reservoir as lower reservoir, spreads in the district Kangara of Himachal state. The Beas river is the principal tributary of river Satluj originates from Beas Kund at an elevation level (EL) of about 4,000M in Pir Panjal ranges near Rohtang pass and flows in the east-west direction in Himachal Pradesh. The River Beas travels about 230 Kms upto Pong Dam. The river takes a meandering course during its passage. This large river has varying climatic and topographic conditions. The total catchment area is about 12560 Sq. Kms. And out of which area of about 780 Sq. Kms. gets snowfall and an area of about 11780 Sq. Kms only rainfall. The principal tributaries of the Beas River are the Parbati river, Larji river, Sainj river, Suketi khad, Uhl khad, Neogai khad, Man khad, Baner khad, Gaj khad, Dehar khad, and Buhl khad joins Beas river which ultimately joins Satluj river.

The major objective of Pong scheme was to provide irrigation and secondary hydro power generation trough regulated water was ultimately released from power house to irrigate lands in Punjab and Rajasthan. The salient features of existing Pong Dam are as under.

Location	Kangara district of Himachal
Catchment area	12560 km^2
River	Beas in Indus Basin
Gross Capacity	7.29 BCM
Live Capacity	8.57 BCM
Dam type	Earthfill Embankment

3.5 Present study: Pump Storage Project (2800 MW)

The present proposal of pump storage scheme envisages utilisation of already existing and operational Maharana Pratap Sagar reservoir as its Lower reservoir. An Upper reservoir has been proposed at uphill of reservoir by construction of Gravity Dam of approx. 70.0 m height so as to entail a live storage of about 22.32Mm^3. It would act as a balancing reservoir for re-cycling of water.

It is proposed to install eight vertical-axis reversible type hydro-electric units comprising of generator–motor and a pump turbine each having generating capacity of 350 MW (Total installed capacity would be 2800MW). The water thus would be re-cycled between upper proposed reservoir and lower Maharan Pratap Sagar reservoir. Thus the existing set up of hydro-power generation and utilisation from Pong existing reservoir would not be disturbed as enough storage is available in reservoir and it would meet the one-time water requirement of recycling of water for proposed PSP.

A Google map of the existing Maharana Pratap Sagar reservoir including Dam location is at fig.3.2 below.

Fig. 3.2: Google Image of the Project Area

Since no major storage structure is proposed except construction of small upper reservoir, underground/surface power house and appurtenant structures like HRT, pressure shaft, penstock tunnel, TRT, transformer hall etc. and the present scheme would utilize the facilities of existing Pong reservoir to reduce the cost of construction.

3.6 Data Availability:

Satluj River and its tributaries are well gauged along its course. BBMB, Central Water Commission (CWC) and India Meteorological Department (IMD) collect the relevant data on this river.

3.7 Meteorological Data:

The FSR study report prepared for Pong reservoir is based on rainfall data of 20 years (2002-2021), considering rain gauge stations inside the catchment available with BBMB. (Reff -Annexure-3.1).

3.8 Discharge Data

Annually out flow discharge data is available at Pong reservoir site. The project authorities were requested to supply the same including power generation releases data, spills, flood releases, D/s commitments etc. from Pong reservoir. Also there has been no CWC G&D site exists in the neighbourhood of Pong reservoir hence data of project is used for studies.

The FSR appended the annual runoff of Pong catchment (CA= 12562 km^2) for the period 2001 to 2021 (20 years) in report. In absence of daily available runoff data for Pong Catchment, this data has been considered for the present study due to pending collection/supply of relevant data by project authorities.

3.9 Evaporation Data

Evaporation data is available at Maharana Pratap Sagar reservoir. For the same, monthly/daily evaporation rate has been taken from Authorities. The daily evaporation rate in each month is given in Table 3.1 below.

Table- 3.1: Evaporation depths (mm/month)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
mm/ month	33.64	56.1	98.88	158.82	217.42	207.88	128.64	101.92	100.14	89.26	51.3	34.18

3.10 Water Availability

The proposed Pump Storage Project (PSP) aims to utilize the storage of existing Maharana Partap Sagar reservoir and the releases of water for downstream states as per BBMB act for recycling (one time only as water is recycled). Only the surplus storage in the reservoir is proposed to be recycled for operation. As such, the water availability is ensured based on long term inflow & outflow data from the existing Pong reservoir. Accordingly, water availability has been assessed for Pong reservoir using Pong dam annual runoff data. Since monthly flows of Pong dam are available for the period 2001 to 2021, same has been utilised in the study. Since monthly and annual runoff for Pong reservoir catchment are available the same have been considered to conduct the P Tests and F Tests. The Project catchment area map is as below.

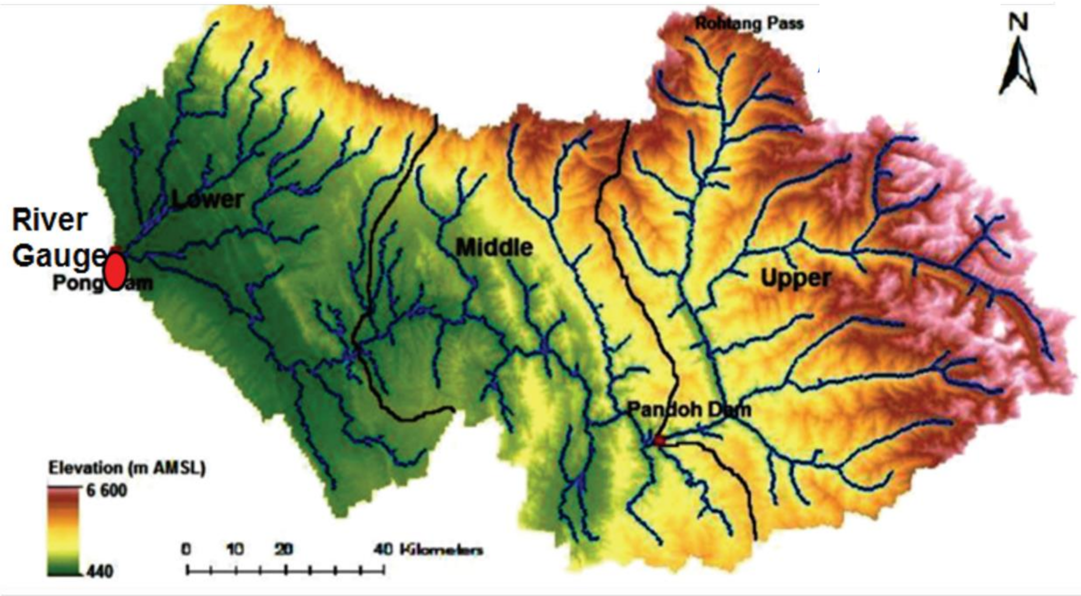


Fig. 3.3: Pong project Catchment area map

3.11 Statistical Tests

T Test and F Tests have been carried out for the observed inflow flows for Pong dam G&D site for the period 2001-2021. The inflow series have been bifurcated in two equal parts while carrying out the relevant tests as detailed in Tables below.

Table 3.2 : Pong Dam G&D Site- F-Test Two-Sample for Variances

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	*8796.667637*	*9797.101904*
Variance	*3722596.901*	*1354730.127*
Observations	*10*	*10*
df	*9*	*9*
F	*2.74785127*	
P(F<=f) one-tail	*0.074098812*	
F Critical one-tail	*3.178893104*	

Table 3.3: Pong Dam G&D Site- t-Test: Paired Two Sample for Means

t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	*8796.667637*	*9797.102*
Variance	*3722596.901*	*1354730*
Observations	*10*	*10*
Pearson Correlation	*-0.220856442*	
Hypothesized Mean Difference	*0*	
df	*9*	
t Stat	*-1.284162856*	
P(T<=t) one-tail	*0.1155777*	
t Critical one-tail	*1.833112933*	
P(T<=t) two-tail	*0.2311554*	
t Critical two-tail	*2.262157163*	

Table 3.4: Pong Dam G&D Site- t-Test: Two-Sample Assuming Equal Variances

t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	Variable 2
Mean	8796.667637	9797.102
Variance	3722596.901	1354730
Observations	10	10

Pooled Variance	2538663.514	
Hypothesized Mean Difference	0	
df	18	
t Stat	-1.404012552	
P(T<=t) one-tail	0.088667003	
t Critical one-tail	1.734063607	
P(T<=t) two-tail	0.177334005	
t Critical two-tail	2.10092204	

Table 3.5: Pong Dam G&D Site- t-Test: Two-Sample Assuming Unequal Variances

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	*8796.667637*	*9797.102*
Variance	*3722596.901*	*1354730*
Observations	*10*	*10*
Hypothesized Mean Difference	*0*	
df	*15*	
t Stat	*-1.404012552*	
P(T<=t) one-tail	*0.090340186*	
t Critical one-tail	*1.753050356*	
P(T<=t) two-tail	*0.180680372*	
t Critical two-tail	*2.131449546*	

An examination of above tables indicates that T-statistics of the two series for both the site are less than the critical values at 95% confidence level for both one tail and two tail. Similarly, F statistics are also less than the critical values at 95% confidence level, thereby indicating better data quality and belong to the same sample. The inflow series at G&D site are homogeneous and the test values are within the permissible critical limits.

3.12 Conclusion

A comparison of result by the above methods viz-a-viz study has been made to assess the series to be adopted for power potential studies which may not affect the functioning of existing Pong project.

3.13 Design flood

The associated dam/reservoir is existing and in operations for the last several decades and have withstood the floods without any Damage to civil structure. Moreover, the proposed scheme is a pumped scheme and do not envisage any change in existing operating levels of the reservoir. No structural modifications/interface are required in existing dam. As such, the spillway provisions are already in place and are in operation successfully. As such design flood re-assessment is not required in the present study.

3.14 Sedimentation

As per recent hydrographic survey carried out for Pong reservoir calculated annual rate of siltation as 1.92 Th.Cu.m./Sq.km./yr. The elevation area capacity curves as available are being recommended for utilization since the quantum of water being used for proposed PSP study is miniscule. And henceforth sedimentation is not an issue at present.

3.15 Limitation of study

The study has been carried out based on the limited available inflow runoff data of Pong Dam.

Annexure-3.1

Sedimentation Studies(Silt Load) for Pong-"LB_1_trial_2" PSP Site

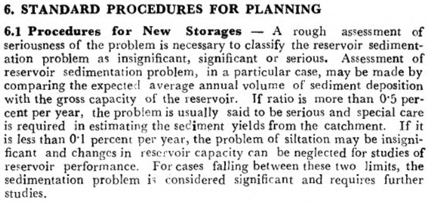
Gross Capacity at F.R.L (C) = 23.191 MCM
Rate of Sedimentation (r) = 1.92 Th.cu.m/sq.km/yr
Rainfed Catchment Area (A) = 10.54 Sq Km
Deepest River B.L at Dam Site = 680.00 m
F.R.L = 750.00 m
Height of the dam = 70.00 m

Elevation - Area - Capacity

S.No	Elevation (m)	Area (Km^2)	Cummulative Capacity M.C.M
1	**680**	0.00	0.0
2	**690**	0.04	0.2
3	**700**	0.10	0.9
4	**710**	0.21	2.4
5	**720**	0.35	5.2
6	**730**	0.50	9.5
7	**740**	0.68	15.4
8	**750**	0.89	23.2

Trap Efficiency (η) = 97.45%
Average Annual Sediment Volume = A xr x η
= 0.0197 M.C.M
R = Annual. Sed. Volume/C = 0.085 % < 0.50%

Clasification of reservoir Sedimentation as per IS code = **Insignificant**



6. STANDARD PROCEDURES FOR PLANNING

6.1 Procedures for New Storages — A rough assessment of seriousness of the problem is necessary to classify the reservoir sedimentation problem as insignificant, significant or serious. Assessment of reservoir sedimentation problem, in a particular case, may be made by comparing the expected average annual volume of sediment deposition with the gross capacity of the reservoir. If ratio is more than 0·5 percent per year, the problem is usually said to be serious and special care is required in estimating the sediment yields from the catchment. If it is less than 0·1 percent per year, the problem of siltation may be insignificant and changes in reservoir capacity can be neglected for studies of reservoir performance. For cases falling between these two limits, the sedimentation problem is considered significant and requires further studies.

4. Geological Studies

Chapter-4

Geological Studies

4.1 Introduction:

The Bhakra Beas Management Board (BBMB), with a view of utilize the water available in Maharana Partap Sagar reservoir that spreads over 260.00 sq. km. of area and has gross storage capacity of 8.578 BCM by constructing a pump storage project (PSP).

On the basis of Survey of India Toposheets 43P/16, 44M/13, 52D/4 and 53A/1, studied the area around Maharana Partap Sagar reservoir and identified 10 probable sites with 15 alternative layouts (Figure-5.1).

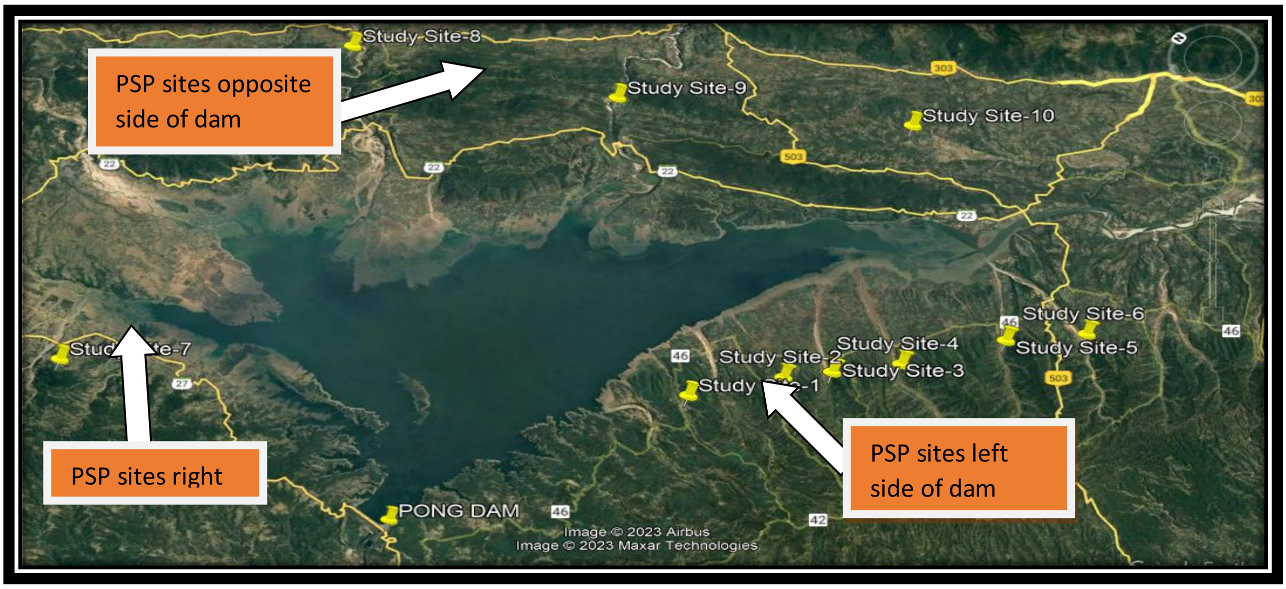


Figure-4.1: Location of 10 identified sites

Subsequently, on the basis of detailed field topographic surveys and techno economic studies including estimated reservoir capacity, length of water conductor system and power potential of different alternatives led to selection of four alternative sites. These are:

i. Dam Axis alternative1 (LB_1_trial 2)

ii. Dam Axis alternative2 (LB_2_Trial 1)

iii. Dam Axis alternative3 (LB_3_Trial 1)

iv. Dam Axis alternative4 (LB_4_Trial 3)

These alternative sites were visited to have preliminary geotechnical assessments of different project sites with a view to select a site that could be taken up for further investigations.

4.2 Geology of The Area

The area under study, bound by latitudes 31 °50'N and 31°15'N and longitudes 75° 55'E and 76 ° 15'E in Survey of India Top sheet nos. 43P/16, 44M/13, 52D/4 and 53A/1, is located in Kangra, district of Himachal Pradesh on the fringes of Bhakra Dam Project reservoir. Beas River is the prime river flowing in the study area and is fed by tributaries like Parbati river, Larji river, Sainj river, Suketi khad, Uhl khad, Neogai khad, Man khad, Baner khad, Gaj khad, Dehar khad, and Buhl khad in upstream areas.

Kangra district lies in the Siwalik lesser Himalayan zone and its topography is well defined by a series of almost parallel hill ranges which rise in height towards North-East. (Geological Map of Kangra District is enclosed –Plate-1) The rocks of Shivalik group occur as several kilometers wide hill ranges with steeper scraps towards the north and can be studied around Ranital, Nurpur, Kotla, Kangra, Jawalamukhi and Dehra Gopipur. The valleys are filled with alluvial sand, slate and recent boulder material. Besides, the rock facies commonly seen in the district are green shales and fossils rich limestone of Subathu formation, shale, clay and sandstone of Siwalik group, gneissic and granatic rock of Dhauladhar group, slate, phyllites, schist, quartzites, basic lava flows and dolomites belonging to Jutogh group of rocks.The sediments of the Dharamshala Group unconformably overlie the Subathu group. These sediments consist of claystone, siltslones, calcareous shales and sandstones.

Beas River and its tributaries Sarhyali Khad and Seer Khad flow mainly along NW-SE direction but towards south-east near village Zakatkhana, Sutlej River takes U- turn and flows along SE-NW direction. The flanks of the hills are moderately dissected by sub-parallel to parallel drainage.

Regionally, the area under study is located in Sub-Himalayan part of Himachal Himalaya. Sub Himalaya is bound by Lesser Himalaya in the north and Indo-Gangetic plains in the south. It is separated from Lesser Himalaya by Main Boundary Thrust (MBT) and from Indo-Gangetic Plains by Himalayan Frontal Thrust (HFT).

The rocks exposed in the Gobind Sagar reservoir rim area belong to Shali Group, Sirmour Group and Siwalik Supergroup. These rocks are characterized by their distinct lithological characters. Shali Group is the oldest rocks exposed in the area overlain by Sirmour Group and Siwalik Supergroup of the rocks ranging in age from Meso-Proterozoic to Pliocene. Rocks belonging to Sirmour group and Siwalik Super group of Tertiary age are separated from those belonging to Sirmour Group by MBT and same thrust both these from Lesser Himalaya Shali Group of rocks. The general litho-stratigraphic sequence of the studied area is given in Table-5.1.

Table -4.1: Litho- Stratigraphic of Siwalik System in Kangra District.

Age	**Super Group**	**Group/Sub-Group**	**Formation**	**Lithology**
Quaternary	**Newer Alluvium**			**Sand, silt, gravel and Pebbles**
Neogene	Siwalik	Upper Siwalik	B	Predominantly massive conglomerate with red and orange clay as matrix and minor sandstone and earthy buff and brown calystone
			A	Sandstone, clay and conglomerate alternation
		Middle	B	Massive Sandstone with minor conglomerate and local variegated claystone

		Siwalik	A	Predominantly medium to coarsegrained sandstone and red clay alternation, soft pebbly with subordinate claystone, locally thick prism of conglomerate.
		Lower Siwalik	B	Alternation of fine to medium grained sporadically pebbly sandstone, calcareous cement and prominent chocolate and medium maroon claystone in the middle part
			A	Red and mauve claystone with thin intercalations of medium to fine grained sandstone

Regional geological map of the area surrounding the project area (Figure-5.2) shows that the study area is located East of the Kashmir–Hazara syntaxis, the Sub-Himalayan Cenozoic sequence of foreland basin attains a maximum width of ~80 km, between the Ravi and Satluj rivers in the Kangra reentrant. The foreland basin is bounded in the north by a narrow, a few km wide, belt of the Panjal Imbricate zone of the Lesser Himalaya along the MBT. The Lesser Himalayan zone itself in turn is overlain along the Panjal Thrust (~MCT), by the Chamba nappe sequence, constituting the Dhauladhar and Pir (Fig. 5.2). CN Chamba Nappe, RW Rampur Window, KW Kishtwar Window, HHC HigherHimalaya Crystalline, MWT Medlicott Wadia Thrust, JT Jawalamukhi Thrust.

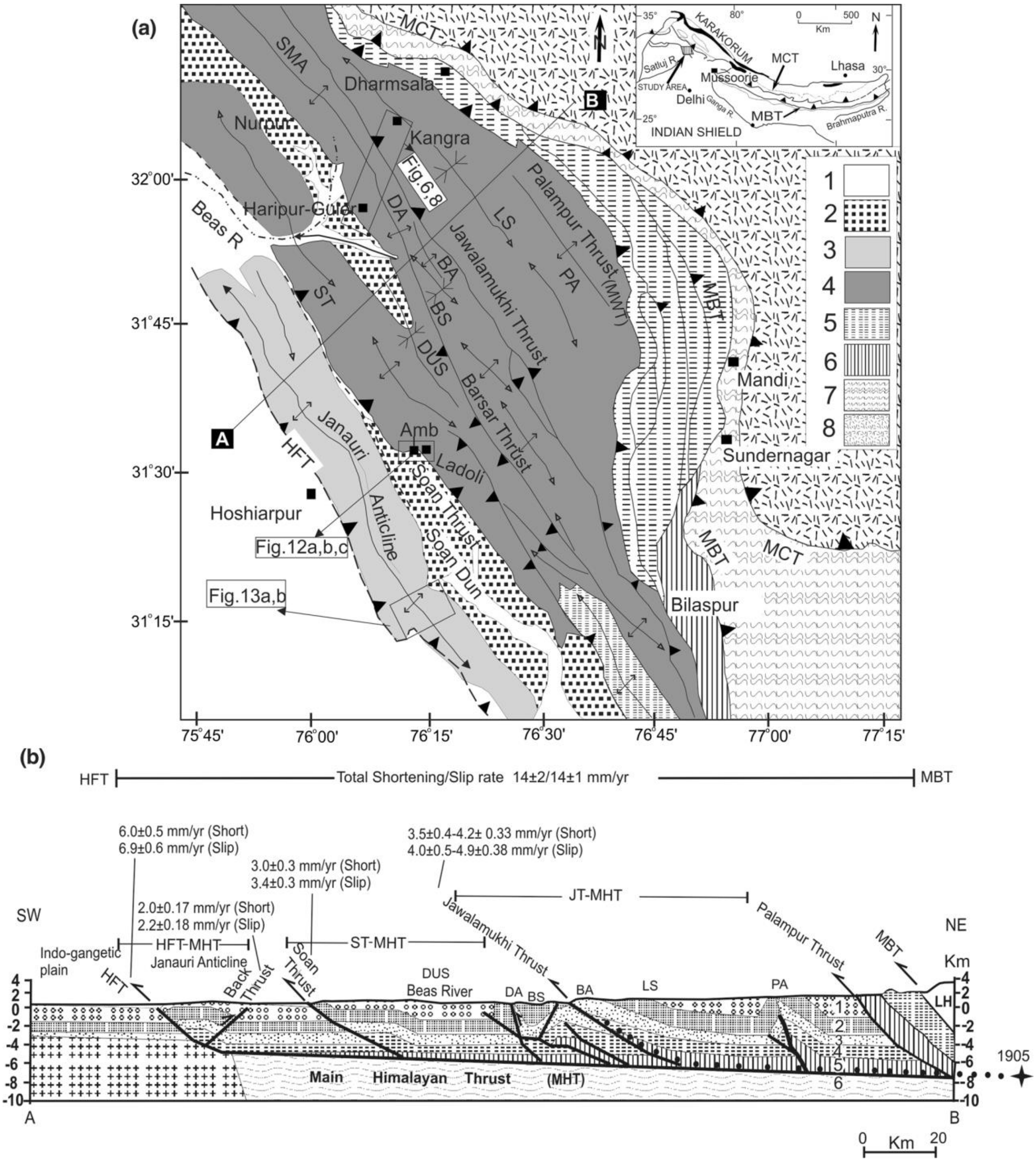


Figure-4.2: Geological Map of the Area around the Area under Study

South of the MBT, the Kangra reentrant constitutes lower Tertiary sequence of the marine Paleocene–Middle Eocene Subathu and the non-marine Late Oligocene-Early Miocene Dharamsala Formations in the northern part. In the northern part, the lower Tertiary sequence is thrust along the PT over a wide belt of the Middle Miocene–Pleistocene (Neogene) Siwalik Group that occupies the central and southern parts of the reentrant (Fig. 5.2). The southern part is characterized by the Soan dun intermontane basin and frontal Janauri anticline. In northern part, the Kangra intermontane basin (dun) is developed between the Dhauladhar range and the Siwalik range over the JT. South of the MBT, the Palampur/Bilaspur Thrust, earlier referred as the Main Boundary Fault by Medlicott (1864) and Wadia (1937), is now renamed as the Medlicott Wadia Thrust (MWT) that extends as an active fault strand of the MBT from Jhelum to Yamuna in NW Himalaya South of the Palampur Thrust (MWT), the Neogene Siwalik Group is characterized into three thrust packages, based on major structural style, of the JT, the ST and the HFT (Fig. 5.2). The JT slab shows fairly uniform 25–35°NE dip becoming nearly horizontal to the north. The slab sequence is folded into a broad open Lambagaon syncline (LS) with 80 km lateral extent and a secondary Paror anticline (PA) with 20 km lateral extent (Fig. 5.2). The JT extends NW–SE along regional strike for more than 200 km. The ST slab shows a large broad monoclinal folding in its southern part. Its northern part, which constitutes the footwall of the JT, is made of fold-thrust system of Balh anticline (BA), Balaru syncline (BS) and Dehra Gopipur anticline (DA) (Fig. 5.2). The HFT thrust slab constitutes the Janauri anticline ridge of frontal Siwalik range and an intermontane synformal depression of the Soan dun. The fold-thrust belt of the Kangra reentrant between the HFT and the MBT is underlain by a decollement. Dhauladhar range (D-range), bordering the northern margin of the foreland basin in the Kangra reentrant, rises abruptly to 4,800–4,000 m above mean sea-level (amsl) altitude from the 700–800 m high Siwalik ranges, constituting a mountain front for focused precipitation. In the adjoining Lahaul area, the southern extent of glacial advance is recorded up to 2,800 m during last glacial cycle and last glacial maximum (LGM) (Owen et al. 1997, 2002). A similar glaciation scenario is envisaged for the D-range. The Kangra basin is late Quaternary intermontane basin,~75 km long and 10–25 km wide, bounded to the north by the D-range and to its south is framed by the Siwalik ranges. The basin was developed as a piggyback basin (Ori and Friend 1984) over the

JT during late Quaternary. The Kangra intermontane basin is predominantly filled by debris flow fans produced by deglaciation in the D-range. 3–8 m thick orange-red paleosol horizons occur at several places within the fan sequence. Paleopedological analysis and OSL dating of paleosols revealed those as pedogenised loess (Srivastava et al. 2009). Loess deposited around ~78–44 ka in the proximal setting and ~30–20 ka in the distal setting during cold-arid conditions as glaciers advanced on the D-range. Wet–humid intervals pedogenised the loess into paleosol. Between Kangra and Guler, width of the deep-cut river channel varies 100–250 m, whereas the individual strath terrace width ranges 400–700 m. The combined channel width of Kangra T3 or Haripur-Guler T2 strath terraces, which occur on both sides of the river as paired terraces, indicates width of the channel ranging between 800 and 1,200 m. The gravel cover of the strath terraces contain (sub) rounded boulders of the Dhauladhar granite in sandy matrix. The peneplanation of wide strath terraces was by deglaciation event in the D-range. Subsequent upthrusting elevated the strath surface with gravel cover. The OSL dates, 32–30 and 17–13 ka, of the strath surfaces represent the abandonment ages of the terraces from the riverbed due to uplift.

4.3 Seismicity

Bhakra dam site and area encompassing Maharana partap Sagar reservoir in its vicinity are located in Kangra seismic block. The frontal thrust-fold belt of Northwest Himalaya encompassing parts of the States of Himachal Pradesh, Uttarakhand and Punjab and the Union Territory of Jammu and Kashmir, constitutes a 36% segment of the 2400 km long great mountain range. It is composed of Palaeogene, Neogene and Quaternary sediments and a few Proterozoic inliers in the western part. The region is drained by several of the mighty rivers of the Indus and Ganga basins that are fed by as many as 8965 glaciers in their upper reached. The frontal belt all through its length is confined between the Main Boundary thrust (MBT) in the north and Himalayan Frontal thrust (HFT) in the south with structural styles varying from emergent thrust to blind thrust fronts and wrench dominant as well as pop-up structures of different amplitudes. This Tertiary pack is thrown into several open folds and riddled with a host of tectonic discontinuities that developed during the terminal phase of the Himalayan orogeny. The regional thrusts imbricate along a detachment plane, which defines the upper surface of the underthrusting Indian plate, dipping at 2°-3° beneath the Indo-Gangetic basin and the sub Himalaya.

The Kangra seismotectonic block, located between Ropar - Sundarnagar fault in the east and Ravi tear in the west, is dissected by several thrusts paralleling the Himalayan trend, the prominent among them being HFT, MBT, Jwalamukhi thrust, Jogindarnagar thrust, Palampur thrust, Gambhar thrust, etc. The regional open folds of this domain include Mastgarh anticline, Dabbar syncline, Deragopipur anticline Drang syncline, Paror anticline, Janauari anticline, etc. This block has experienced a total of 122 seismic events of moment magnitude ≥ 4 in the last 200 years. The strongest earthquake was that of Kangra of 4th April 1905 (Mw 7.8), responsible for 20,000 human fatalities. The earthquakes of 1914, 1945 and 1947 measured more than 6.0 in magnitude. Almost 84% of the seismic events were confined to less than 40 km in depth. The region lies in Zones V and IV of the Seismic Zone map of India (2002).

The Kangra reentrant is drained by three perennial rivers of Ravi, Beas and Sutlej of the Indus basin. Major hydropower projects such as Bhakhra, Pong and Ranjit Sagar have come up in these rivers and changed the economic face of the region in a significant way. Bhakhra dam over Sutlej river, which was commissioned in 1963, is founded over Lower Siwalik Formation. It lies in Seismic Zone IV and has been designed for peak ground acceleration (PGA) of 0.15g. Pong dam that was commissioned in 1974 in Upper Siwaliks was designed for a PGA of 0.12g for concrete section and 0.15g for earth section. Ranjit Sagar dam founded over Lower Siwaliks was commissiond in 2001. It has been designed for a PGA of 0.2g. All these hydropower projects are in operation in the present time.

The Pong Dam, constructed on the Beas River, and the neighbouring area under study are located southwest of the Main Boundary Thrust and the Main Central Thrust in the foothills of the Himalayas.

As per IMD data, All the epicenters of the earthquakes, which occurred during the period October 1977 to September 2002 around Pong dam are plotted in Fig. 5.3. This epicentral map shows that the area in the North and North East of Pong dam is very active. Considering the area within 100 km of the vicinity of the dam, it may be seen that a thick cluster of earthquakes is present on the northeast ward of the dam site. The same was found in the study of Srivastava et al., 1982 and 1990. A total of 894 earthquakes (≥ 2.0) have been recorded by the seismographs in this region

including one having highest magnitude of 5.5 which occurred on 26th April 1986 at a distance of 53 km North-East ward of the Dam. Another earthquake with a magnitude of 5.4 occurred on 14th June 1978 at a distance of 78 km from the dam. There are eighteen earthquakes which occurred within 15 km. from the dam and the nearest one occurred on 15th February 1989 at a distance of 2 km from the dam with a magnitude of 2.8. These indicate that existence of such a large reservoir in the has not impacted the seismicity of the region during last 60 years.

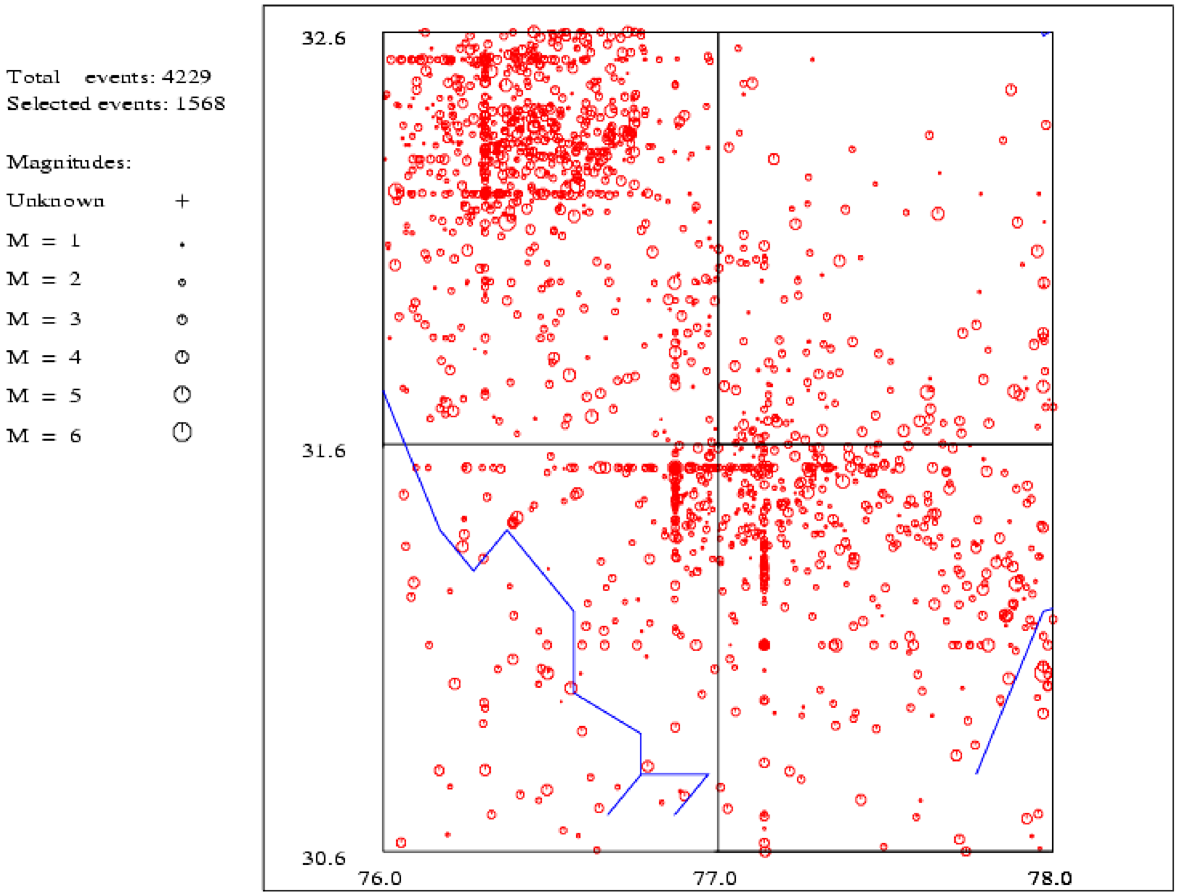


Figure-4.3: Map showing epicenters around Pandoh dam during the period 1977-2002

Keeping in view the location of different alternative sites in Seismic Zone IV as per Seismic Zoning Map of India (2002) and existence of a number of thrust faults in the close vicinity of sites, it is recommended that suitable seismic coefficient may be incorporated into the designs of proposed dam and other appurtenants of the project.

4.4 Geomorphology and Geology of the Project Area

The studies carried out on the fringes of MaharanaPartap Sagar reservoir in Survey of India toposheet Nos. 43P/16, 44M/13, 52D/4 and 53A/1 resulted in identification possible scheme on the banks of the reservoir. The WAPCOS by evaluating existing SOI toposheets and carried out comprehensive study and site work was taken simultaneously on these sites and on the basis of survey and feasibility studies finally proposed four (4) possible sites And later Designers & Geologist carried out geological studies of these 4 sites. And after much technical analysis it is concluded that the sites-1 on left bank will be most favourable from power capacity and techno-economic reasons. And recommended sites that could be taken up for further studies. Salient features of these sites are given in Table-5.2 and locations are shown in Figure-5.4.

Based on the features like gross reservoir capacity, length of the water conductor system and power system, following four alternative were selected for detailed studies with for techno-commercial viability and further development in later stages:

i. Dam Axis alternative1 (LB_1_trial 2)

ii. Dam Axis alternative2 (LB_2_Trial 1)

iii. Dam Axis alternative3 (LB_3_Trial 1)

iv. Dam Axis alternative4 (LB_4_Trial 3)

Geological and geotechnical aspects of these thus selected alternatives are discussed below.

1. Dam axis Alternative1 (LB_1_trial 2)

Upper Dam Axis Alternative-1 (LB_1_trial 2) is located on the left fringe of reservoir near Garial village of Kangra district of Himachal Pradesh. This alternative envisages an upper reservoir having estimated live storage capacity of 22.32 MCM with FRL at EL750m, MDDL at EL700m with the construction of a 70m high and about 856.5m long dam across dada khad that is aligned through Garial village. The design discharge is proposed to be conveyed to an underground powerhouse proposed on the left fringe of reservoir near village gurhala through 5.65 km long water conductor system with the objective of generating 2800 MW of power. The hills around the proposed site were covered with moderately dense vegetation with dense under growth. Primafacie, the site appears suitable for upto 100m high dam. Further detail investigation will be the part of DPR stage.

2. Dam axis alternative 2 (LB_2_Trial 1)

Upper Dam axis alternative-2 (LB_2_Trial 1) is located on the left fringe of Maharana Pratap sagar reservoir on left flank of Pong Dam near balwal village of kangra district of Himachal Pradesh. This alternative envisages an upper reservoir having estimated live storage capacity of 26.52 MCM with FRL at EL750m, MDDL at EL690m with the construction of a 70m high and about 1134m long dam across a bargoalan khad that debouches into Maharana Pratap Sagar reservoir north of Nangal chowk. The design discharge is proposed to be conveyed to a pit/underground powerhouse proposed near village rori kori through a 4.35 km long water conductor system with the objective of generating 2500 MW of power. The hills around the proposed site were covered with moderately dense vegetation.

3. Dam axis alternative 3 (LB_3_Trial 1)

Upper Dam axis alternative 3 (LB_3_Trial 1) alternative is also located on left fringe of reservoir near chaplah village in Kangra district. The studies carried out indicated that it was possible to create a reservoir with FRL at EL 650m, MDDL at EL 610m gross storage capacity of 10.84MCM and live storage capacity of 10.64 MCM generate 900 MW of power.

The site proposed for about 50m high dam near village chaplah across a tributary of chanaur Khad. The hill slopes on both the banks of nala are moderately vegetated with dense under growth. The 4.08km long water conductor system being planned to convey the designed discharge to the lower reservoir.

4. Dam axis alternative 4 (LB_ 4 _Trial 3)

Upper Dam Axis (LB_ 4 _Trial 3) alternative located near village dodrah. This alternative envisages an upper reservoir having estimated live storage capacity of 20.10MCM with FRL at EL750m, MDDL at EL730m with the construction of 70m high and about 856m long dam across a tributary of thor Khad. The 5.64 km long water conductor system being planned to convey the designed discharge to the lower reservoir with the objective of generating 2500MW of power.

As mentioned above, the Dam axis alternative 1 (LB_1_Trial 2) had more power potential with comparative water conductor length, has been chosen in the present study on the basis of techno-commercial viability. However, the same may be reviewed at the DPR stage when more subsurface and topographical data is available. This scheme with ultimate capacity of 2400 MW, maximum gross head of 319.6m and Upper and Lower Reservoirs have effective storage capacity equivalent to Five (5) hours of generation daily at full rated output, possibility to operate the project on daily basis has been considered and finally proposed for PSP Scheme.

4.5 Conclusion and Recommendation

As BBMB proposes to develop a pump storage scheme utilizing the water available in Gobind Sagar reservoir of Bhakra Dam. Recently, the scheme with objective of preparation of FSR was handed over to WAPCOS. WAPCOS on the basis of detailed topographic survey identified ten alternative sites. After identifying the sites, different alternative for all the site were studied and 12 alternatives were selected for further evaluation. Based on different factor like gross reservoir capacity of the proposed reservoir, live storage available, height of the proposed dam, length of water conductor system and power potential of the alternatives, the choice was narrowed down to four alternatives.

The area encompassing these selected sites is located in Himachal Pradesh Sub-Himalaya between MBT separating it from Lesser Himalaya in the north and Himalayan Frontal Thrust demarcating its southern limit. The rocks belonging to Pinjor Formation of upper Siwalik Super Group and Dewal and Mohargarh formations of Middle Siwalik Super Group. These rocks are folded and faulted and are traverswd by Bursar Thrust in the area along which the older nahan formation rocks override the younger Dewal and Mohargarh formation rocks. Seismotectonically the area encompassing the four sites under consideration relocated in Kangra Seismotectonic block bound by Ropar- Sunder Nagar tear in the east and Ravi Tear in the west known for 7.8MW magnitude earthquake of 1905. Keping the seismic acvity in the block and the area surrounding the proposed site, same been kept in Seismic Zone IV as per BIS Seismic Zoning Map of India (2002). Keeping the seismic status of the area and presence of a number of thrust faults in the vicinity of the proposed sites, it is recommended that suitable seismic coefficient may be got determined for the area and in corporateed in the designs of different apurtenants of the project finally adopted.

The comparison of different aspects like geological and tectonic setup, rock types present, gross reservoir capacity, length of water conductor system and estimated power potential of different alternative studied it is suggested that alternative LB_ 1_ Trial 1 could be preferred and taken up for further detailed studies and explorations.

It is also proposed that possibility of shifting the dam axis further downstream to reduce the length of dam and locating chute spillway in the saddle on the right abutment may be looked into at DPR Stage. In that case the dam could be designed as a rock fill dam. It is also suggested that efforts may be made to construct powerhouse in an underground cavern as nearer to dam as possible so that length of pressurized component of the water conductor is minimum and to reduce its cost. Another advantage of this site is that it is located in close vicinity of existing Pong Dam and infrastructure of same can be utilized here.

5. Project Planning and Installed Capacity

CHAPTER - 5

PROJECT PLANNING AND INSTALLED CAPACITY

5.1 Introduction

The Bhakra Beas Management Board (BBMB), with a view of utilize the water available in Maharana Pratap Sagar reservoir that spreads over 260. sq. km. of area and has gross storage capacity of 8.578 BCM by constructing a pump storage project (PSP). The Pong Pumped Storage project is located near District Kangra of Himachal on the Beas river.

5.2 Pong Pump Storage Project

The Proposed Pong PSP envisages utilisation of water of existing Maharana Pratap Sagar reservoir on Beas River having spread in Talwara District of Himachal through installation of 2800 MW power plant, which would be equipped with eight vertical axis reversible type hydro-electric units each comprising of generator-motor and a pump turbine with a generating capacity of 350 MW each. Lower reservoir would consist of existing Maharana Pratap Sagar reservoir while upper reservoir (Proposed new construction) would be for storage of recycled water at the foot -hill.

5.3 Upper Reservoir

The upper reservoir of pumped storage operation of the project. The reservoir has a live storage capacity of 22.32 MCM as under.

Table: 5.1

Particulars	
FRL	EL. 750 m
MDDL	EL. 700 m
Live Storage	**22.32 MCM**

5.4 Lower Reservoir

The lower reservoir of pumped storage operation of the project. The reservoir has a live storage capacity of 8578 MCM as under.

Table: 5.2

Particulars	
FRL	EL. 426.72 m
MDDL	EL. 384.05 m
Live Storage	**7291 MCM**

5.5 Operating Gross Head

Gross operating head on the pumped storage units would vary from 365.95m to 273.28m. The head ratio i.e., ratio of maximum pumping head to minimum pumping head is 1.322. The head loss in the water conductor system has been estimated as 24.0 m in generation mode and 18.0 m in pumping mode.

5.6 Installed Capacity

Considering the availability of the storage capacity in upper reservoir an installation of 2800 MW comprising 8 units of 350 MW has been provided.

5.7 Operation Simulation

The operation simulation of the two reservoirs for pumped storage operation has been carried out considering the storage characteristics. The operation of the scheme in either mode viz. 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. As the lower reservoir i.e., Maharana Pratap Sagar Reservoir has an enormous 260.00 sq. km. of area with live storage of 8578 MCM. Therefore, an outflow of 22.32 MCM shall not have any major impact on the level of Lower reservoir. Therefore, the simulation has been done considering two scenarios i.e.

Scenario 1: The studies have been carried out at the beginning of generating cycle, the Upper reservoir is at FRL i.e., EL. 750.00 m and Lower reservoir is at FRL i.e., EL. 426.72 m

Generation Operation: The impact of such continuous variations in head is best captured by simulation of operation of the scheme considering shorter time intervals of 8 to 9 minutes The detailed preliminary generation operation simulation studies of the Scheme have been carried out to considering 21 time intervals of 9 minutes each, 17 time interval of 8 mins each for 5 hours and 25 minutes hours generating cycle to assess storage requirement for proposed Pong Pumped Storage Scheme for an installed capacity of 2800 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 750.00 m. The reservoir draws down to El. 700.00 m in 5 hours and 25 minutes of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 22.32 million m^3.
- At the start of generation, the Lower reservoir is at its FRL 426.72 and 22.32 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy generation during the period is 15166.67 MWh.

The details of the studies are given at Annexure-5.1.

Pong PSP- Storage Requirement (MCM) for an Installed Capacity of 2800MW & for 5 hours and 25 minutes peaking operation

Pumping Operation: The detailed preliminary pumping operation simulation studies of the Scheme have been carried out to considering 29 time intervals of 11 minutes each, 11 time interval of 12 mins each for 7 hours and 31 minutes hours pumping cycle to assess storage requirement for proposed Pong Pumped Storage Scheme for an installed capacity of 2800 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at MDDL El. 700.00 m. The reservoir recharges to El. 750.00 m in 7 hours and 25 minutes of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 22.32 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 426.72 m and 22.32 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy consumed during the period is 21046.67 MWh.

The details of the studies are given at Annexure-5.2.

Pong PSP- Storage Requirement (MCM) for an Installed Capacity of 2800MW & for 7 hours and 31 minutes pumping operation

Scenario 2: The studies have been carried out at the beginning of generating cycle, the Upper reservoir is at FRL i.e., EL. 750.00 m and Lower reservoir is at FRL i.e., EL. 384.05 m

The impact of such continuous variations in head is best captured by simulation of operation of the scheme considering shorter time intervals of 10 to 11 minutes The detailed preliminary operation simulation studies of the Scheme have been carried out to considering 32 time intervals of 10 minutes each and 6 time interval of 9 mins for 6 hours and 14 minutes hours generating cycle to assess storage requirement for proposed Pong Pumped Storage Scheme for an installed capacity of 2800 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 750.00 m. The reservoir draws down to El. 700.00 m in 6 hours and 14 of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 22.32 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 384.05 m and 22.32 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy generation during the period is 17453.33 MWh.

The details of the studies are given at Annexure-5.3.

Pong PSP- Storage Requirement (MCM) for an Installed Capacity of 2800MW & for 6 hours and 14 minutes peaking operation

Pumping Operation: The detailed preliminary pumping operation simulation studies of the Scheme have been carried out to considering 27 time intervals of 11 minutes each, 18 time interval of 12 mins each for 8 hours and 33 minutes hours pumping cycle to assess storage requirement for proposed Pong Pumped Storage Scheme for an installed capacity of 2800 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 700.00 m. The reservoir recharges to El. 750.00 m in 8 hours and 33 minutes of full load operation representing a drawdown of 50 m.

- The storage utilized for operation is 22.32 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 384.05 m and 22.32 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy consumed during the period is 21140 MWh.

The details of the studies are given at Annexure-5.4

Pong PSP- Storage Requirement (MCM) for an Installed Capacity of 2800MW & for 8 hours and 33 minutes pumping operation

Generator Turbine efficiency

The efficiency of the Turbine-Generator unit during generating mode is adopted as 90% and during the pumping mode is adopted as 91%.

5.8 Losses in the Water Conductor System

The losses in the water conductor system have been considered as 24.0 m during generation and 18.0 m during pumping operation.

ANNEXURE - 5.1

Pong Pumped Storage Project (8 x 350 MW), Himachal Pradesh

Generation Operation Simulation Studies (Starting of year Lower reservoir at FRL)

Operating Levels and Storage available at Existing and new Reservoirs

Upper reservoir				Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)		
FRL		750.00	-	FRL	426.72		
MDDL		700.00	-	MDDL	384.05		
Live Storage			22.32	Live Storage		unlimited	
Head Loss (m)		24.00					

Scenario 1: Operating Levels considered for Operation Simulation

Upper reservoir		Lower reservoir			
	Level (m)			Level (m)	Storage (MCum)
FRL-PS Operation	750.00	FRL-PS Operation		426.72	-
MDDL-PS Operation	700.00	MDDL-PS Operation		426.72	-
Pondage for PS Operation	22.43	Pondage for PS Operation			22.43
Generating mode effficiency	0.90				

				Upper Pond				Lower Pond					
Interval No	**Time Interval (Minutes)**	**Station Output (MW)**	**Discharge (cumecs)**	**Initial Pond Level (m)**	**Outflow from Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Initial Pond Level (m)**	**Inflow into Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Average Net Head (m)**	**Energy Generation (MWh)**
1	9.0	2800.0	1025.40	750.00	0.55	748.76	749.38	426.72	0.55	426.72	426.72	298.66	420.00
2	9.0	2800.0	1061.87	748.76	0.57	747.48	748.12	426.72	0.57	426.72	426.72	297.40	420.00
3	9.0	2800.0	1066.37	747.48	0.58	746.19	746.83	426.72	0.58	426.72	426.72	296.11	420.00
4	9.0	2800.0	1071.01	746.19	0.58	744.89	745.54	426.72	0.58	426.72	426.72	294.82	420.00
5	9.0	2800.0	1075.71	744.89	0.58	743.59	744.24	426.72	0.58	426.72	426.72	293.52	420.00
6	9.0	2800.0	1080.46	743.59	0.58	742.28	742.93	426.72	0.58	426.72	426.72	292.21	420.00
7	9.0	2800.0	1085.29	742.28	0.59	740.97	741.62	426.72	0.59	426.72	426.72	290.90	420.00
8	9.0	2800.0	1090.17	740.97	0.59	739.65	740.31	426.72	0.59	426.72	426.72	289.59	420.00
9	9.0	2800.0	1095.13	739.65	0.59	738.32	738.99	426.72	0.59	426.72	426.72	288.27	420.00
10	9.0	2800.0	1100.15	738.32	0.59	736.99	737.66	426.72	0.59	426.72	426.72	286.94	420.00
11	9.0	2800.0	1105.24	736.99	0.60	735.66	736.33	426.72	0.60	426.72	426.72	285.61	420.00
12	9.0	2800.0	1110.40	735.66	0.60	734.31	734.99	426.72	0.60	426.72	426.72	284.27	420.00
13	9.0	2800.0	1115.64	734.31	0.60	732.96	733.64	426.72	0.60	426.72	426.72	282.92	420.00
14	9.0	2800.0	1120.94	732.96	0.61	731.61	732.29	426.72	0.61	426.72	426.72	281.57	420.00
15	9.0	2800.0	1126.33	731.61	0.61	730.25	730.93	426.72	0.61	426.72	426.72	280.21	420.00
16	9.0	2800.0	1131.79	730.25	0.61	728.88	729.56	426.72	0.61	426.72	426.72	278.84	420.00
17	9.0	2800.0	1137.34	728.88	0.61	727.50	728.19	426.72	0.61	426.72	426.72	277.47	420.00
18	9.0	2800.0	1142.96	727.50	0.62	726.12	726.81	426.72	0.62	426.72	426.72	276.09	420.00
19	9.0	2800.0	1148.67	726.12	0.62	724.73	725.42	426.72	0.62	426.72	426.72	274.70	420.00
20	9.0	2800.0	1154.47	724.73	0.62	723.33	724.03	426.72	0.62	426.72	426.72	273.31	420.00

21	9.0	2800.0	1160.35	723.33	0.63	721.93	722.63	426.72	0.63	426.72	426.72	271.91	420.00
22	8.0	2800.0	1166.33	721.93	0.56	720.67	721.30	426.72	0.56	426.72	426.72	270.58	373.33
23	8.0	2800.0	1172.06	720.67	0.56	719.41	720.04	426.72	0.56	426.72	426.72	269.32	373.33
24	8.0	2800.0	1177.53	719.41	0.57	718.15	718.78	426.72	0.57	426.72	426.72	268.06	373.33
25	8.0	2800.0	1183.08	718.15	0.57	716.88	717.51	426.72	0.57	426.72	426.72	266.79	373.33
26	8.0	2800.0	1188.70	716.88	0.57	715.60	716.24	426.72	0.57	426.72	426.72	265.52	373.33
27	8.0	2800.0	1194.41	715.60	0.57	714.31	714.96	426.72	0.57	426.72	426.72	264.24	373.33
28	8.0	2800.0	1200.20	714.31	0.58	713.02	713.67	426.72	0.58	426.72	426.72	262.95	373.33
29	8.0	2800.0	1206.08	713.02	0.58	711.73	712.37	426.72	0.58	426.72	426.72	261.65	373.33
30	8.0	2800.0	1212.04	711.73	0.58	710.42	711.07	426.72	0.58	426.72	426.72	260.35	373.33
31	8.0	2800.0	1218.10	710.42	0.58	709.11	709.77	426.72	0.58	426.72	426.72	259.05	373.33
32	8.0	2800.0	1224.24	709.11	0.59	707.80	708.45	426.72	0.59	426.72	426.72	257.73	373.33
33	8.0	2800.0	1230.48	707.80	0.59	706.47	707.14	426.72	0.59	426.72	426.72	256.42	373.33
34	8.0	2800.0	1236.81	706.47	0.59	705.14	705.81	426.72	0.59	426.72	426.72	255.09	373.33
35	8.0	2800.0	1243.24	705.14	0.60	703.81	704.48	426.72	0.60	426.72	426.72	253.76	373.33
36	8.0	2800.0	1249.77	703.81	0.60	702.46	703.13	426.72	0.60	426.72	426.72	252.41	373.33
37	8.0	2800.0	1256.41	702.46	0.60	701.11	701.79	426.72	0.60	426.72	426.72	251.07	373.33
38	8.0	2800.0	1263.15	701.11	0.61	699.75	700.43	426.72	0.61	426.72	426.72	249.71	373.33
	325.00				22.43				22.43				15166.67

MCum - Million Cubic Metres

ANNEXURE - 5.2

Pong Pumped Storage Project (8 x 350 MW), Himachal Pradesh

Pumping Operation Simulation Studies (Starting of year Lower reservoir at FRL)

Operating Levels and Storage available at Existing Reservoirs

Upper reservoir				Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)		
FRL		750.00		FRL	426.72		
MDDL		700.00		MDDL	384.05		
Live Storage			22.32	Live Storage		unlimited	
Head Loss (m)		18.00					

Scenario 1: Operating Levels considered for Operation Simulation

Upper reservoir		Lower reservoir		
	Level (m)		Level (m)	Storage (MCum)
FRL-PS Operation	749.99	FRL-PS Operation	426.72	130.59
MDDL-PS Operation	700.00	MDDL-PS Operation	426.72	108.27
Pondage for PS Operation	22.32	Pondage for PS Operation		22.32
Pumping mode effficiency	0.91			

Interval No	Time Interval (Minutes)	Motor-Pump Power (MW)	Pump Discharge (cumecs)	Upper Pond				Lower Pond				Average Net Head (m)	Energy Consumpt--ion (MWh)
				Initial Pond Level (m)	Inflow into Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Initial Pond Level (m)	Outflow from Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)		
1	11.0	2800.0	904.12	700.00	0.60	701.34	700.67	426.72	0.60	426.72	426.72	291.95	513.33
2	11.0	2800.0	889.66	701.34	0.59	702.65	701.99	426.72	0.59	426.72	426.72	293.27	513.33
3	11.0	2800.0	885.64	702.65	0.58	703.96	703.31	426.72	0.58	426.72	426.72	294.59	513.33
4	11.0	2800.0	881.69	703.96	0.58	705.27	704.61	426.72	0.58	426.72	426.72	295.89	513.33
5	11.0	2800.0	877.80	705.27	0.58	706.56	705.91	426.72	0.58	426.72	426.72	297.19	513.33
6	11.0	2800.0	873.96	706.56	0.58	707.86	707.21	426.72	0.58	426.72	426.72	298.49	513.33
7	11.0	2800.0	870.17	707.86	0.57	709.14	708.50	426.72	0.57	426.72	426.72	299.78	513.33
8	11.0	2800.0	866.42	709.14	0.57	710.42	709.78	426.72	0.57	426.72	426.72	301.06	513.33
9	11.0	2800.0	862.73	710.42	0.57	711.70	711.06	426.72	0.57	426.72	426.72	302.34	513.33
10	11.0	2800.0	859.08	711.70	0.57	712.97	712.33	426.72	0.57	426.72	426.72	303.61	513.33
11	11.0	2800.0	855.48	712.97	0.56	714.23	713.60	426.72	0.56	426.72	426.72	304.88	513.33
12	11.0	2800.0	851.92	714.23	0.56	715.49	714.86	426.72	0.56	426.72	426.72	306.14	513.33
13	11.0	2800.0	848.41	715.49	0.56	716.75	716.12	426.72	0.56	426.72	426.72	307.40	513.33
14	11.0	2800.0	844.94	716.75	0.56	718.00	717.37	426.72	0.56	426.72	426.72	308.65	513.33
15	11.0	2800.0	841.51	718.00	0.56	719.24	718.62	426.72	0.56	426.72	426.72	309.90	513.33
16	11.0	2800.0	838.13	719.24	0.55	720.48	719.86	426.72	0.55	426.72	426.72	311.14	513.33
17	11.0	2800.0	834.78	720.48	0.55	721.71	721.10	426.72	0.55	426.72	426.72	312.38	513.33
18	11.0	2800.0	831.48	721.71	0.55	722.94	722.33	426.72	0.55	426.72	426.72	313.61	513.33
19	11.0	2800.0	828.21	722.94	0.55	724.17	723.56	426.72	0.55	426.72	426.72	314.84	513.33
20	11.0	2800.0	824.99	724.17	0.54	725.39	724.78	426.72	0.54	426.72	426.72	316.06	513.33
21	11.0	2800.0	821.80	725.39	0.54	726.60	725.99	426.72	0.54	426.72	426.72	317.27	513.33
22	11.0	2800.0	818.64	726.60	0.54	727.81	727.21	426.72	0.54	426.72	426.72	318.49	513.33
23	11.0	2800.0	815.53	727.81	0.54	729.02	728.42	426.72	0.54	426.72	426.72	319.70	513.33

24	11.0	2800.0	812.44	729.02	0.54	730.22	729.62	426.72	0.54	426.72	426.72	320.90	513.33
25	11.0	2800.0	809.40	730.22	0.53	731.42	730.82	426.72	0.53	426.72	426.72	322.10	513.33
26	11.0	2800.0	806.38	731.42	0.53	732.61	732.01	426.72	0.53	426.72	426.72	323.29	513.33
27	11.0	2800.0	803.41	732.61	0.53	733.80	733.20	426.72	0.53	426.72	426.72	324.48	513.33
28	11.0	2800.0	800.46	733.80	0.53	734.98	734.39	426.72	0.53	426.72	426.72	325.67	513.33
29	11.0	2800.0	797.54	734.98	0.53	736.16	735.57	426.72	0.53	426.72	426.72	326.85	513.33
30	12.0	2800.0	794.66	736.16	0.57	737.44	736.80	426.72	0.57	426.72	426.72	328.08	560.00
31	12.0	2800.0	791.68	737.44	0.57	738.72	738.08	426.72	0.57	426.72	426.72	329.36	560.00
32	12.0	2800.0	788.61	738.72	0.57	739.99	739.35	426.72	0.57	426.72	426.72	330.63	560.00
33	12.0	2800.0	785.57	739.99	0.57	741.26	740.62	426.72	0.57	426.72	426.72	331.90	560.00
34	12.0	2800.0	782.56	741.26	0.56	742.52	741.89	426.72	0.56	426.72	426.72	333.17	560.00
35	12.0	2800.0	779.59	742.52	0.56	743.78	743.15	426.72	0.56	426.72	426.72	334.43	560.00
36	12.0	2800.0	776.66	743.78	0.56	745.03	744.40	426.72	0.56	426.72	426.72	335.68	560.00
37	12.0	2800.0	773.75	745.03	0.56	746.28	745.65	426.72	0.56	426.72	426.72	336.93	560.00
38	12.0	2800.0	770.88	746.28	0.56	747.52	746.90	426.72	0.56	426.72	426.72	338.18	560.00
39	12.0	2800.0	768.04	747.52	0.55	748.76	748.14	426.72	0.55	426.72	426.72	339.42	560.00
40	12.0	2800.0	765.23	748.76	0.55	749.99	749.38	426.72	0.55	426.72	426.72	340.66	560.00
	451.00				22.32				22.32				21046.67

MCum - Million Cubic Metres

ANNEXURE - 5.3

Pong Shah Nehar Pumped Storage Project (8 x 350 MW), Himachal Pradesh

Generation Operation Simulation Studies (Starting of year Lower reservoir at MDDL)

Operating Levels and Storage available at Existing and new Reservoirs — **Scenario 1: Operating Levels considered for Operation Simulation**

Upper reservoir				Lower reservoir				Upper reservoir		Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)				Level (m)			Level (m)	Storage (MCum)
FRL		750.00	-	FRL	426.72			FRL-PS Operation	750.00	FRL-PS Operation		384.05	-
MDDL		700.00	-	MDDL	384.05			MDDL-PS Operation	700.00	MDDL-PS Operation		384.05	-
Live Storage			22.32	Live Storage	unlimited			Pondage for PS Operation	22.35	Pondage for PS Operation			22.35
Head Loss		24.00						Generating mode effficiency	0.90				

				Upper Pond				Lower Pond					
Interval No	Time Interval (Minutes)	Station Output (MW)	Discharge (cumecs)	Initial Pond Level (m)	Outflow from Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Initial Pond Level (m)	Inflow into Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Average Net Head (m)	Energy Generation (MWh)
1	10.0	2800.0	901.08	750.00	0.54	748.79	749.39	384.05	0.54	384.05	384.05	341.34	466.67
2	10.0	2800.0	929.08	748.79	0.56	747.54	748.16	384.05	0.56	384.05	384.05	340.11	466.67
3	10.0	2800.0	932.44	747.54	0.56	746.29	746.91	384.05	0.56	384.05	384.05	338.86	466.67
4	10.0	2800.0	935.88	746.29	0.56	745.03	745.66	384.05	0.56	384.05	384.05	337.61	466.67
5	10.0	2800.0	939.36	745.03	0.56	743.77	744.40	384.05	0.56	384.05	384.05	336.35	466.67
6	10.0	2800.0	942.88	743.77	0.57	742.50	743.13	384.05	0.57	384.05	384.05	335.08	466.67
7	10.0	2800.0	946.44	742.50	0.57	741.23	741.86	384.05	0.57	384.05	384.05	333.81	466.67
8	10.0	2800.0	950.04	741.23	0.57	739.95	740.59	384.05	0.57	384.05	384.05	332.54	466.67
9	10.0	2800.0	953.68	739.95	0.57	738.67	739.31	384.05	0.57	384.05	384.05	331.26	466.67
10	10.0	2800.0	957.37	738.67	0.57	737.38	738.02	384.05	0.57	384.05	384.05	329.97	466.67
11	10.0	2800.0	961.09	737.38	0.58	736.09	736.74	384.05	0.58	384.05	384.05	328.69	466.67
12	10.0	2800.0	964.86	736.09	0.58	734.79	735.44	384.05	0.58	384.05	384.05	327.39	466.67
13	10.0	2800.0	968.68	734.79	0.58	733.49	734.14	384.05	0.58	384.05	384.05	326.09	466.67
14	10.0	2800.0	972.54	733.49	0.58	732.18	732.84	384.05	0.58	384.05	384.05	324.79	466.67
15	10.0	2800.0	976.44	732.18	0.59	730.87	731.53	384.05	0.59	384.05	384.05	323.48	466.67
16	10.0	2800.0	980.40	730.87	0.59	729.55	730.21	384.05	0.59	384.05	384.05	322.16	466.67
17	10.0	2800.0	984.40	729.55	0.59	728.23	728.89	384.05	0.59	384.05	384.05	320.84	466.67
18	10.0	2800.0	988.45	728.23	0.59	726.90	727.57	384.05	0.59	384.05	384.05	319.52	466.67
19	10.0	2800.0	992.55	726.90	0.60	725.57	726.23	384.05	0.60	384.05	384.05	318.18	466.67
20	10.0	2800.0	996.71	725.57	0.60	724.23	724.90	384.05	0.60	384.05	384.05	316.85	466.67

21	10.0	2800.0	1000.91	724.23	0.60	722.88	723.56	384.05	0.60	384.05	384.05	315.51	466.67
22	10.0	2800.0	1005.17	722.88	0.60	721.53	722.21	384.05	0.60	384.05	384.05	314.16	466.67
23	10.0	2800.0	1009.48	721.53	0.61	720.17	720.85	384.05	0.61	384.05	384.05	312.80	466.67
24	10.0	2800.0	1013.85	720.17	0.61	718.81	719.49	384.05	0.61	384.05	384.05	311.44	466.67
25	10.0	2800.0	1018.28	718.81	0.61	717.44	718.13	384.05	0.61	384.05	384.05	310.08	466.67
26	10.0	2800.0	1022.77	717.44	0.61	716.07	716.76	384.05	0.61	384.05	384.05	308.71	466.67
27	10.0	2800.0	1027.31	716.07	0.62	714.69	715.38	384.05	0.62	384.05	384.05	307.33	466.67
28	10.0	2800.0	1031.91	714.69	0.62	713.30	713.99	384.05	0.62	384.05	384.05	305.94	466.67
29	10.0	2800.0	1036.58	713.30	0.62	711.91	712.60	384.05	0.62	384.05	384.05	304.55	466.67
30	10.0	2800.0	1041.31	711.91	0.62	710.51	711.21	384.05	0.62	384.05	384.05	303.16	466.67
31	10.0	2800.0	1046.11	710.51	0.63	709.10	709.81	384.05	0.63	384.05	384.05	301.76	466.67
32	10.0	2800.0	1050.97	709.10	0.63	707.69	708.40	384.05	0.63	384.05	384.05	300.35	466.67
33	9.0	2800.0	1055.91	707.69	0.57	706.41	707.05	384.05	0.57	384.05	384.05	299.00	420.00
34	9.0	2800.0	1060.66	706.41	0.57	705.13	705.77	384.05	0.57	384.05	384.05	297.72	420.00
35	9.0	2800.0	1065.22	705.13	0.58	703.84	704.48	384.05	0.58	384.05	384.05	296.43	420.00
36	9.0	2800.0	1069.84	703.84	0.58	702.55	703.19	384.05	0.58	384.05	384.05	295.14	420.00
37	9.0	2800.0	1074.52	702.55	0.58	701.25	701.90	384.05	0.58	384.05	384.05	293.85	420.00
38	9.0	2800.0	1079.26	701.25	0.58	699.94	700.59	384.05	0.58	384.05	384.05	292.54	420.00
	374.00				22.35				22.35				17453.33

MCum - Million Cubic Metres

ANNEXURE - 5.4

Pong Shah Nehar Pumped Storage Project (8 x 350 MW), Himachal Pradesh

Pumping Operation Simulation Studies (Starting of year Lower reservoir at MDDL)

Operating Levels and Storage available at Existing Reservoirs **Scenario 1: Operating Levels considered for Operation Simulation**

Upper reservoir				Lower reservoir				Upper reservoir		Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)				Level (m)			Level (m)	Storage (MCum)
FRL		750.00		FRL	426.72			FRL-PS Operation	744.55	FRL-PS Operation		384.05	130.59
MDDL		700.00		MDDL	384.05			MDDL-PS Operation	700.00	MDDL-PS Operation		384.05	110.70
Live Storage			22.32	Live Storage		unlimited		Pondage for PS Operation	22.34	Pondage for PS Operation			22.34
Head Loss		18.00						Pumping mode effficiency	0.90				

				Upper Pond				**Lower Pond**					
Interval No	**Time Interval (Minutes)**	**Motor-Pump Power (MW)**	**Pump Discharge (cumecs)**	**Initial Pond Level (m)**	**Inflow into Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Initial Pond Level (m)**	**Outflow from Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Average Net Head (m)**	**Energy Consumpt--ion (MWh)**
1	11.0	2800.0	787.19	700.00	0.52	701.16	700.58	384.05	0.52	384.05	384.05	334.53	513.33
2	11.0	2800.0	776.41	701.16	0.51	702.31	701.74	384.05	0.51	384.05	384.05	335.69	513.33
3	11.0	2800.0	773.74	702.31	0.51	703.46	702.88	384.05	0.51	384.05	384.05	336.83	513.33
4	11.0	2800.0	771.11	703.46	0.51	704.60	704.03	384.05	0.51	384.05	384.05	337.98	513.33
5	11.0	2800.0	768.50	704.60	0.51	705.73	705.16	384.05	0.51	384.05	384.05	339.11	513.33
6	11.0	2800.0	765.92	705.73	0.51	706.86	706.30	384.05	0.51	384.05	384.05	340.25	513.33
7	11.0	2800.0	763.37	706.86	0.50	707.99	707.43	384.05	0.50	384.05	384.05	341.38	513.33
8	11.0	2800.0	760.84	707.99	0.50	709.12	708.56	384.05	0.50	384.05	384.05	342.51	513.33
9	11.0	2800.0	758.34	709.12	0.50	710.24	709.68	384.05	0.50	384.05	384.05	343.63	513.33
10	11.0	2800.0	755.86	710.24	0.50	711.36	710.80	384.05	0.50	384.05	384.05	344.75	513.33
11	11.0	2800.0	753.41	711.36	0.50	712.47	711.91	384.05	0.50	384.05	384.05	345.86	513.33
12	11.0	2800.0	750.97	712.47	0.50	713.58	713.03	384.05	0.50	384.05	384.05	346.98	513.33
13	11.0	2800.0	748.57	713.58	0.49	714.69	714.13	384.05	0.49	384.05	384.05	348.08	513.33
14	11.0	2800.0	746.18	714.69	0.49	715.79	715.24	384.05	0.49	384.05	384.05	349.19	513.33
15	11.0	2800.0	743.82	715.79	0.49	716.89	716.34	384.05	0.49	384.05	384.05	350.29	513.33
16	11.0	2800.0	741.48	716.89	0.49	717.99	717.44	384.05	0.49	384.05	384.05	351.39	513.33
17	11.0	2800.0	739.17	717.99	0.49	719.08	718.53	384.05	0.49	384.05	384.05	352.48	513.33
18	11.0	2800.0	736.87	719.08	0.49	720.17	719.62	384.05	0.49	384.05	384.05	353.57	513.33
19	11.0	2800.0	734.60	720.17	0.48	721.26	720.71	384.05	0.48	384.05	384.05	354.66	513.33
20	11.0	2800.0	732.34	721.26	0.48	722.34	721.80	384.05	0.48	384.05	384.05	355.75	513.33
21	11.0	2800.0	730.11	722.34	0.48	723.42	722.88	384.05	0.48	384.05	384.05	356.83	513.33
22	11.0	2800.0	727.90	723.42	0.48	724.49	723.96	384.05	0.48	384.05	384.05	357.91	513.33

23	11.0	2800.0	725.71	724.49	0.48	725.57	725.03	384.05	0.48	384.05	384.05	358.98	513.33
24	11.0	2800.0	723.54	725.57	0.48	726.64	726.10	384.05	0.48	384.05	384.05	360.05	513.33
25	11.0	2800.0	721.38	726.64	0.48	727.70	727.17	384.05	0.48	384.05	384.05	361.12	513.33
26	11.0	2800.0	719.25	727.70	0.47	728.77	728.23	384.05	0.47	384.05	384.05	362.18	513.33
27	11.0	2800.0	717.13	728.77	0.47	729.83	729.30	384.05	0.47	384.05	384.05	363.25	513.33
28	12.0	2800.0	715.04	729.83	0.51	730.98	730.40	384.05	0.51	384.05	384.05	364.35	560.00
29	12.0	2800.0	712.87	730.98	0.51	732.13	731.55	384.05	0.51	384.05	384.05	365.50	560.00
30	12.0	2800.0	710.62	732.13	0.51	733.28	732.70	384.05	0.51	384.05	384.05	366.65	560.00
31	12.0	2800.0	708.39	733.28	0.51	734.42	733.85	384.05	0.51	384.05	384.05	367.80	560.00
32	12.0	2800.0	706.19	734.42	0.51	735.56	734.99	384.05	0.51	384.05	384.05	368.94	560.00
33	12.0	2800.0	704.01	735.56	0.51	736.69	736.13	384.05	0.51	384.05	384.05	370.08	560.00
34	12.0	2800.0	701.84	736.69	0.51	737.83	737.26	384.05	0.51	384.05	384.05	371.21	560.00
35	12.0	2800.0	699.70	737.83	0.50	738.95	738.39	384.05	0.50	384.05	384.05	372.34	560.00
36	12.0	2800.0	697.58	738.95	0.50	740.08	739.52	384.05	0.50	384.05	384.05	373.47	560.00
37	12.0	2800.0	695.47	740.08	0.50	741.20	740.64	384.05	0.50	384.05	384.05	374.59	560.00
38	12.0	2800.0	693.39	741.20	0.50	742.32	741.76	384.05	0.50	384.05	384.05	375.71	560.00
39	12.0	2800.0	691.32	742.32	0.50	743.43	742.88	384.05	0.50	384.05	384.05	376.83	560.00
40	12.0	2800.0	689.27	743.43	0.50	744.55	743.99	384.05	0.50	384.05	384.05	377.94	560.00
41	12.0	2800.0	687.24	744.55	0.49	745.65	745.10	384.05	0.49	384.05	384.05	379.05	560.00
42	12.0	2800.0	685.23	745.65	0.49	746.76	746.21	384.05	0.49	384.05	384.05	380.16	560.00
43	12.0	2800.0	683.23	746.76	0.49	747.86	747.31	384.05	0.49	384.05	384.05	381.26	560.00
44	12.0	2800.0	681.25	747.86	0.49	748.96	748.41	384.05	0.49	384.05	384.05	382.36	560.00
45	12.0	2800.0	679.29	748.96	0.49	750.06	749.51	384.05	0.49	384.05	384.05	383.46	560.00
	513.00				22.34				22.34				21140.00

MCum - Million Cubic Metres

6. Design of civil structures

Chapter – 6

Design of Civil Structures

6.1 The Scheme

After completion of mammoth multipurpose Bhakra project water of Satluj river stands fully harnessed. Now the attention transfers to utilise water of Beas river for irrigation and power. In order to fully exploit the resources available, the construction of Pong and Pandoh projects are being planned part of the Master plan. The Beas river is one of the three principal eastern tributary (the Satluj, the Beas & the Ravi) of river Indus, originates at Beas Kund at an elevation level (EL) of about 4,000M in Pir Panjal ranges near the Rohtang pass, flowing from North to South west over a distance of 230 km before entering the Pong Reservoir. The total catchment area of Beas and its tributaries above Pong is about 12562 sq. km.

Pong project comprises 132.59 high concrete gravity dam with houses having an installed capacity of 396MW. The dam has been named Pong dam after the village of Pong which was the first to be submerged by the reservoir although it was envisaged in 1926 but preliminary survey & investigation could be started in 1955 and DPR for major irrigation project at the present dam site was prepared. However, later on after carrying out further detail investigations a more detailed report for the Beas Dam at Pong was prepared and submitted to Punjab Government in 1959. The dam was finally constructed is a Earthfill_Embankment type with a maximum height of 132.59m and fully utilises the power potential and water supplies available. This project has been constructed in stages. The dam was constructed in all respect in 1974, and first & sixth generating units of dam toe power house was commissioned in 1978 & 1983 respectively.

6.2 Geological Investigations

The dam is located in the Himalayan foot hills across Beas river. The dam site and the river canyon are underlain by beds of the upper shivalik series including the layers of Pinjore stage featured by alteration of soft sandstone and claystone/siltstone bed terraces on the adjoining ridges bordering the valley.

6.3 Present Proposal

There is continuous increase in demand of energy so like other source we use water as source of renewal energy by cycling the water /pumped storage plant as already have been stated that there is much variation in the inflow of river Beas in a year therefore project authorities' thought of exploring the possibilities of constructing a pumped storage plant and for this they hired the services of WAPCOS as their consultant to for further study.

Under this back ground WAPCOS started their study in the month of July. The present dam has been built on Beas when the river enters in the plains so this existing Pong reservoir has been proposed as a lower reservoir for the pumped storage scheme with maximum operating level of 426.72 m and minimum draw down level of 384.05 m.

6.4 Selection of Layout - General

Identification of locations for upper dam axis have been selected as under: Initially WAPCOS field office identified as many as possible potential sites for upper reservoir (Fig 5.1), later narrowing & identification of proposed sites were carried out during continuous joint site visit of designers, experts and field staff in between July to November months.

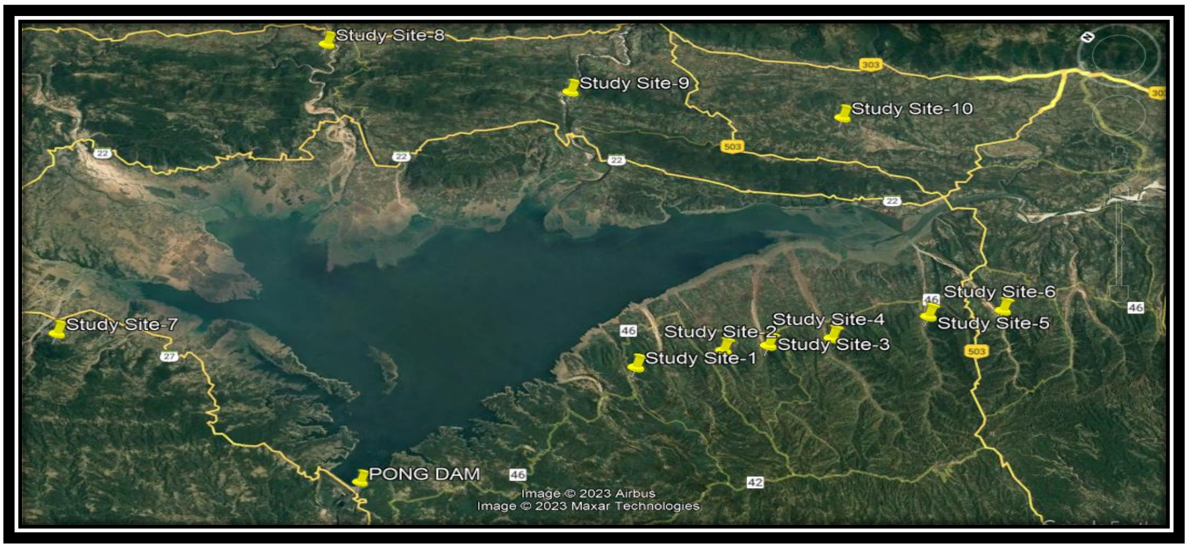
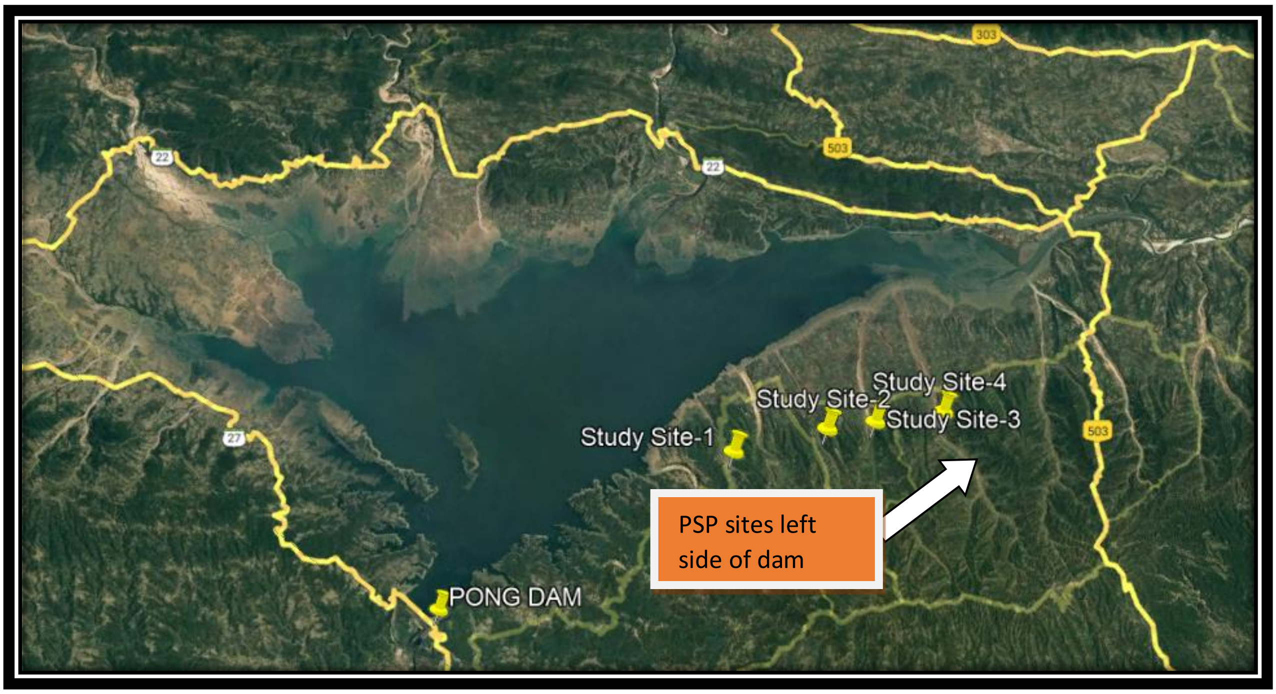


Figure-6.1: Location of 10 identified sites

Further designers & expert finally proposed 6 sites for site survey and topography. A comprehensive study and work was taken on these sites (Fig 5.2) but on the basis of survey and viability studies finally proposed four (4) possible sites. Designers & Geologist carried out geological studies of these 4 sites. And after much technical analysis it is concluded that the site LB_1_trial 2 near Garial village of Kangra district of Himachal Pradesh on left bank will be most favourable from power capacity and techno-economic reasons. Hence, proposing this site for further studies and preparation of detail project report.



PSP sites left side of dam

Figure-6.2: Location of 4 identified Sites

In our various alternative studies, it is concluded the that live storage capacity requirement for the upper reservoir is very much less as compared to its huge storage of existing lower reservoir. As significant head is available for the generation of 900 to 2800 MW power which at this stage we feel is essential for economic viability of the proposal. The live storage capacity for pump storage scheme requirement varies from 10.64 mcm to 26.52 mcm against a live storage of the existing lower reservoir of 7.291 BCM and gross storage capacity is of the tune of 8.578 BCM.

Hence, in present studies, final proposed have power generation capacity of 900 MW to 2800 MW.

Based on the features like gross reservoir capacity, length of the water conductor system and power system, following four alternative including the one evaluated earlier were selected for detailed studies with for techno-commercial viability and further development in later stages:

i. Dam Axis AA (i.e. LB_1_trial 2)

ii. Dam Axis BB (i.e. LB_2_Trial 1)

iii. Dam Axis CC (i.e. LB_3_Trial 1)

iv. Dam Axis DD (i.e. LB_4_Trial 3)

1. Dam axis Alternative1 (Axis A-A)

LB_1_Trial 2 is located on the left fringe of reservoir and old course of beas river near Garial village of Kangra district of Himachal Pradesh in Survey of India Toposheet 53A/1. This alternative envisages an upper reservoir having estimated live storage capacity of 22.3 MCM with FRL at EL750m, MDDL at EL700m with the construction of a 70m high and about 856.5 m long dam across a north easterly flowing nala that is aligned through Garial village. The design discharge is proposed to be conveyed to an underground powerhouse proposed on the left fringe of Maharana Pratap reservoir near village Thatal through 5.65 km long water conductor system with the objective of generating 2800MW of power.

The hills around the proposed site were covered with moderately dense vegatation with dense under growth.

2. Dam axis Alternative2 (Axis B-B):

LB_2_Trial 1 is located on the left fringe of Gobind Sagar reservoir on left flank of Pong Dam near balwal village of kangra district of Himachal Pradesh in Survey of India Toposheet 53A/1. This alternative envisages an upper reservoir having estimated live storage capacity of 26.52MCM with FRL at EL750m, MDDL at EL690m with the construction of a 70m high and about

1134m long dam across a small south northerly flowing nala that debouches into Mahara Pratap Sagar north of Nangal chowk. The design discharge is proposed to be conveyed to a underground powerhouse proposed on the left fringe of Gobind Sagar reservoir near village rori kori through 4.35 km long water conductor system with the objective of generating 2500 MW of power.

The area around the proposed site located on the low lying, moderately bisected hills and shows with medium and trellis pattern. The hills around the proposed site were covered with moderately dense vegetation with dense under growth.

3. Dam axis Alternative3 (Axis C-C):

LB_3_Trial 1 alternative is also located on left fringe of reservoir near chaplah village in Kangra district. The studies carried out indicated that it was possible to create a reservoir with FRL at EL 650m, MDDL at EL 610m gross storage capacity of 10.84MCM and live storage capacity of 10.64 MCM generate 900 MW of power.

The site proposed for about 50m high dam near village chaplah across a north easterly flowing tributary of chanaur Khad. The hill slopes on both the banks of nala are moderately vegetated with dense under growth. The 4.08km long water conductor system being planned to convey the designed discharge to the lower reservoir.

4. Dam axis Alternative4 (Axis D-D):

Upper Dam Axis (LB_ 4 _Trial 3) alternative located near village dodrah. This alternative envisages an upper reservoir having estimated live storage capacity of 20.10MCM with FRL at EL750m, MDDL at EL730m with the construction of 70m high and about 856m long dam across a tributary of thor Khad. The 5.64 km long water conductor system being planned to convey the designed discharge to the lower reservoir with the objective of generating 2500MW of power.

In view of the reduced submergence, less quantity of upper dam and with more power generation etc. as mentioned above, the alternative-1 has been chosen in the present study. However, the same may be reviewed at the DPR stage when more detailed subsurface and topographical data is available.

6.4.1 Type of Structure - Dam

The Rock fill with central clay core type dam structure is considered for creating the upper reservoir of the project.

The basic requirements for an earth and rock-fill dam to be safe and stable under various conditions of operation of the reservoir are to ensure that:

- The dam should comprise materials of sufficient shear strength to satisfy the requirements of stability under the various static and dynamic loading conditions to which the dam and its foundation would be subjected.
- The slopes of the rock-fill dam must be stable during construction and under all conditions of reservoir operation.
- There should be sufficient design flexibility to allow the fullest possible utilization of all required excavation and readily available borrow materials.
- The core material should be sufficiently impermeable to resist seepage through the dam and there should be a general increase in permeability from the core towards the exterior slopes of the dam.
- The Filter requirements between adjacent zones and between the foundation fill materials should be satisfied in order to avoid migration of fine materials into coarser ones.
- Seepage flow through the core, foundation, and abutments must be controlled so that no internal erosion takes place. The amount of water lost through seepage must be controlled and exit gradient at downstream toe of the dam should not be high enough to cause sloughing or piping action.
- Adequate free board must be provided above FRL (Full reservoir level)/MWL (Maximum water level) to guard against overtopping by wave action. Free board must also take into account the settlement of dam under the effect of dynamic loading.

The normal and minimum free board computations shall be based on T. Saville's method as given in IS: 10635. The following factors govern the requirements of free board: -

- Wave characteristics particularly wave height and wave length depends mainly on wind velocity.
- Upstream slope of the embankment and roughness of the pitching.

- Height of wind set up above the still water level which depends on depth of water in the reservoir.

6.4.2 Upper Dam & Spillway

The Location of upper dam axis at PFR Stage will provide required live storage. It is observed that the most suitable location for Dam Axis is at Left Bank N - 31°53'24.35”, E - 76° 4'2.31"and Right Bank N - 31°53'16.41", E - 76° 4'33.52” which can provide the required Live Storage and better geological & other considerations. The FRL and MDDL is kept at EL750 m and EL700.00 m which create required live poundage 22.3 MCM. The maximum height of upper dam is 70m and length 856.5m. A Bottom Outlet has been kept in lower spillway below the MDDL in upper Reservoir for environmental flow.

6.4.3 Design Approach

The basic approach in design of concrete dam shall be to select a dam section analysed by the approach specified in IS Code of practice for Stability Analysis of Gravity Dam. The factors of safety computed for critical combination of external forces will be compared with the minimum factor of safety stipulated in the code. The outer slopes of the dam will be optimized such that the computed factors of safety are higher than, but close to, the minimum desired values under various loading conditions.

6.4.4 Power Intake

Intake structure has been proposed from the upper reservoir on the left bank of Dam. An approach channel has been proposed to guide the flow towards intake mouth. Optimum layout requirements have been considered to suit the alignment of the Water Conductor in fixing the alignment of Power Intake. An intake of size 11 m x 16.36 m x 79.4m 2 no’s x 1 line has been proposed. The intake will be connected to a tunnel of diameter 7m with transition. The maximum discharging capacity of the tunnel will be 600 cumec.

Based on the parameters minimum submergence required has been calculated as per BIS codal practice and Gorden formula for symmetric flow. The center line of the intake has been accordingly fixed at EL 685.0m.

The inlet and outlet is designed in accordance with the guidelines proposed by Central Research Institute of Electric Power Industry in Japan which has been mostly applied to design for intakes and outlets of a lot of pumped storage power station. The main consideration of design criteria are as follows;

Waterway of a pumped storage power plant is pressure one, so an inlet of a pumped storage power plant also comes to pressure type. Considering vertical arrangement of an inlet for a pressure conduit, sufficient water cushion shall be provided for withdrawal of requisite discharge without any vortex formation. Water depth from sill of an inlet to the minimum water level should be 1.5 to 2.0 times as high as internal diameter. Velocity of flow through trash rack shall not be more than 1.0 meter/sec in normal condition and entry through intake shall be stream lined such that head loss is minimum. For fixing the intake level it is also planned that it does not attract much of the silt during withdrawal of water.

An intake of a pumped storage power station has the following characteristics in difference from a conventional hydraulic power station;

- Both an intake and a tailrace outlet are to function as an intake as well as an outlet since directions in generating and pumping modes are exact reverse even though hydraulic feature is quite different between water intake and discharge.
- There is a possibility that vortex easily comes into being for the reason that water depth between a surface to an intake comes to small near the maximum draw-down level.
- It is difficult that water flow discharged from an inlet or outlet evenly diffuses into a reservoir because flow velocity of a pumped storage power station is generally faster than that of a conventional hydraulic power station. As a result, the inlet structure is designed and shown in drawings.

6.4.5 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. Therefore, comparative study on location of the waterway on both banks is conducted and an optimum profile of the waterway is selected through comparative study among various alternatives.

The alignment of the waterway from the intake to the tailrace outlet is studied under the following conditions;

- Length of waterway is tried to be shortest.
- The portion of water way is aligned in such a way that it has a no bends.
- Both intake and tailrace outlet are aligned in such a way that pumping and generation mode have favourable flow characteristics.

- There are two reversible units for which one pressure shaft has been provided.
- Longitudinal axis of the powerhouse cavern is to be aligned so that will make an angle of 43˚-53˚ with the strike of foliations.
- It goes without saying that the powerhouse cavern is to be positioned with enough rock cover on the powerhouse cavern for stability of the cavern. In this regard, the bottom level of the Power house has been kept so that sufficient cover shall be available over Power house cavern. The height of the cavern is 57m. The rock cover on the powerhouse cavern has been kept more than twice of height of the cavern for proper stability of the cavern.

The Longitudinal section along the alignment of the waterway from the intake to the tailrace outlet is shown in drawing. The locations of power intake and tailrace outlet are to be selected in the area where stable topographical and geological conditions can be obtained, so as to be able to ensure the stable and safe water flow.

6.4.6 Head Race Tunnel (Steel Lined) Cum Pressure Shaft

A 550m m long and 9.5 m dia steel lined 2 nos Head Race Tunnel (HRT) has been proposed to carry a max discharge of 1200 cumec. The maximum cover of HRT will be 110m. From HRT, the adit (D-Shaped) of length 200m and dimensions 7m x 7.5m is proposed. The adit is provided to facilitate the construction of pressure shaft. This tunnel will also be provided with suitable rock support system depending upon the geological strata formations enroute. Actual support system will be decided after geological investigations and analysis at DPR stage.

Four horizontal pressure tunnels each bifurcating further into 8 horizontal pressure tunnels have been proposed. The length of horizontal pressure tunnel will be about 200 m & 55 m and 5.5 m & 2.25 m Dia. In general, rock-bolts and lining will be required as support system. Actual support system will be decided after geological investigations and analysis at DPR stage.

Diameter of 5.5 m as proposed for penstock is based on the velocity consideration however economic diameter studies may be done at DPR stage. Plate thickness will be assessed considering both internal water pressure plus increase in head due to water hammer as well as external pressure.

Design criteria

The hydraulic and structural design of pressure shaft/penstock is based on following criteria:

- Steel liner will be designed to take the entire internal pressure independently without any rock participation - Steel liner shall be capable to withstand maximum external pressure under empty condition
- Penstock will be designed for loading condition at mid span and at the supports where additional stresses are developed.
- Sickle plate for penstock manifold should take care of all unbalanced forces at the point of bifurcation.

6.4.7 Underground Power house and Underground Transformer Hall

An underground Power House (UGPH) of size 265mx23mx55m for and a transformer cavern hall of 314.00 m (L) x 22 m (W) x 57 m (H) have been proposed for this project. The power house will have eight Francis type vertical shaft reversible units of 350 MW each. The design head for turbine mode as 306.84 m and pumping mode as 334.84 m has been assessed.

The powerhouse cavern actual orientation will be finalized after large scale geological mapping, 3D logging and in-situ test at the exploratory drift to power house at DPR stage.

6.4.8 Machine Hall Cavern

The machine hall cavern would be 314.0m in length, 22.0m in width and overall height of the power house cavity from the lowest excavation of the turbine pit would be 57m. The generating units would be spaced at 27.0m center to center. The entrance to the Machine hall cavern shall be through Main Access Tunnel (MAT). The auxiliary rooms shall be located at different floors provided on the services bay side of the machine hall cavern.

The penstock for each generating unit would enter the power house horizontally making an angle with the power house longitudinal direction and accommodate the main inlet valve in the machine hall. The penstock for each unit will terminate into a distributor feeding the turbine nozzles. The center line of the horizontal penstocks entering the power house cavity would be El. 332.0m in line with nozzles of the turbines.

The roof of machine hall cavern has been provided with a circular arch shape with crown rise of 7m from the spring level. The roof and walls of the power house cavern are supported by systematic rock bolting and shortcreting

(SFRS), where the rock mass is of poor quality ('Q' value from 1.0 to 2.0), the roof is supported with the combination of shotcrete (SFRS), rock bolts and steel ribs. Provision of drainage holes in regular way has also been made for roof and walls for drainage the rock mass adjoining the cavern.

RCC columns of size 1000mm x 1500mm are proposed for supporting the EOT crane beam. A clearance of about 500mm has been provided between the column edge and excavated rock surface to take care of the convergence of power house walls.

6.4.9 Transformer cavern

The transformer cavern would be 229m long, its width and height being 22m and 33m respectively. It accommodates 8 sets of unit transformers at El. 350.0m. The roof arch of this cavity would be of circular arch shape with 5m rise of crown from the spring level. As in the machine hall cavity, the roof and walls of the transformer cavity are also supported by systematic rock bolting and shotcreting (SFRS), where the rock mass is of poor quality ('Q' value from 1.0 to 2.0), the roof is supported with the combination of shotcrete (SFRS), rock bolts and steel ribs. Provision of drainage holes in regular way has also been made for roof and walls for draining the seepage water adjoining the cavern.

6.4.10 Tail Race Tunnel

A 11.5m dia and 5000m long 2nos TRT has been proposed. The rock cover along TRT will vary from 100m to 350m. TRT will be provided with suitable rock support system depending upon the geological strata. Apart from the rock support system, the TRT will be provided with 600 mm thick reinforced cement concrete lining. Actual support system will be decided after geological investigations and analysis at DPR stage.

6.4.11 Main Access Tunnel (MAT), Cable tunnel and Construction Adits

The details of MAT, Adits etc. are furnished in the following table 6.1:

Table-6.1

S.No.	Type	Length	Dimensions
1	Main Access Tunnel (MAT)	800m	8m x 8.5m

2	TRT Adits	400m	7m x 7.5m
3	Pressure Shaft Adit	300 m	7m x 7.5m
4	Top of transformer Hall (Adit)	250m	7m x 7.5m
5	Top of Power House (Adit)	300m	7m x 7.5m
6	Cable Access tunnel &Ventilation Tunnel	300m	6m x 6.5m
8	HRT Adit	200m	7m x 7.5m

7. Design of Electro-Mechanical Equipments

Chapter – 7

Design of Electro-Mechanical Equipments

The utility of Pumped Storage Project has evolved a long way as one of the power system tools to perform multiple functions. While the fixed speed synchronous generator can meet the peak power demand in quickest possible way, the pumping operation has immense contribution in maintaining frequency at lean hour and maintaining the plant load factor of Thermal generation plants.

With the advent of technological advancement to meet the need of the power system network, variable speed machines are gradually felt necessary because of their many advantages over the conventional fixed speed machines. Specially, with the present trend of development of renewable energy in India, grid management will become critical in future.

In such scenario one of the options in integrated power system management is variable speed pumped storage project. It has some other definite advantages when analysed on long term basis over life cycle of project.

Considering the above the following three options for configuration of the main units has been considered for the basic design of the Electro - Mechanical equipment at present:

Option 1: 8 Fixed speed units

Option 2: 4 Fixed + 4 Variable speed units

Option 3: 8 Variable speed units

Detail analysis will be carried out before final selection of the machine and configuration during preparation of technical specification.

The basic design of E&M equipment in this chapter is based on the Option 1, Option 2 and Option 3 as considered in the Annexure 7.1.

7.1 General

The proposed Pong Pumped Storage Project of 2800 MW is envisaged to have 8 vertical pump-turbine driven generating units each of rating 350 MW and operating under a rated head of 296.84 m (Generation mode) and 338.84 m (Pumping mode) in an underground power house. The generated electric power at 21 kV shall be evacuated through 24 kV Isolated Phase Bus Ducts (IPBDs) passing through 8 Nos. Bus Duct galleries and then terminating on LT side of 8 nos. of three phase step up 21/765/√3kV, 453 MVA, Generator Transformers located in transformer hall cavern. HT side of Transformers shall be connected to 800 kV GIS located above the transformer hall. 765 kV XLPE cables laid in cable tunnel shall be used for interconnecting 800 kV GIS located in underground transformer cavern with outdoor 765kV transmission lines at Pothead yard. Two double circuit 765 kV transmission lines each having twin moose conductor per phase shall transmit power to & from 765 kV Substation at Pong HEP.

7.2 Layout Plan of Electro-Mechanical Equipment

A pumped storage scheme consists of upper reservoir and one lower reservoir by constructing suitable dam complex water conductor system i.e. tow Head Race Tunnels each bifurcating into two pressure shafts, four nos. of pressure shafts each bifurcating into two penstocks, would run between the upper reservoir and eight nos. pump turbine housed in an underground Power House. Further, two tail race from pump turbine would be merge and then the discharge from two pump turbine would be merge together and will be carried by TRT to the lower reservoir.

The unit spacing has been kept 27 m. Straight entry of penstocks at 90^0 in the power house is proposed and main inlet valves shall be located in a separate MIV cavern located 30m upstream side of power house having the size of 150m x 10m x 24m.

The Pong PSP underground power house will have 8 (eight) Pump-Turbine and Generator-Motor units of 350/375 MW each along with all the auxiliary systems such as governors, excitation equipment, SFC starting equipment cooling water system, compressed air system, potable water supply system, fire protection system, ventilation and air conditioning system, illumination system, HT & LT AC and DC systems etc.

The entrance to the Machine hall cavern shall be through Main Access Tunnel (MAT). The machine hall at EL 349.00 m shall be 314.0 m in length (Including service bay and control block) and 22 m in width. The height of machine hall cavern shall be 57 m. The Transformer hall cavern (size 229m x 22m x 33m) shall be located 50m downstream of main power house cavern.

The auxiliary rooms shall be located at different floors provided in the auxiliary and control blocks on the Unit 1 & Unit-8 side of the machine hall. Control room, Model/Conference room, Engineers Room, 220 V DC system, HVAC equipment, electrical equipment testing laboratory and mechanical workshop etc. shall be located in these auxiliary rooms.

Floor wise equipment layout plan is as under:-

Machine Hall at EL 349.00 m

Unit Control Boards (UCBs) and Excitation Panels shall be installed in the machine hall floor. Phase reversal switch along with Generator circuit breaker (GCB) which is provided between Isolated Phase Bus Duct (IPBD) and Generator-Motor shall be installed at this floor.

Generator-Motor floor at EL 343.00 m

Unit Auxiliary Boards (UAB's), LT distribution boards with dry type distribution transformers, Neutral grounding Cubicles, lubrication system etc. shall be installed at this floor.

Pump-Turbine floor at EL 337.00 m

HP & LP compressed air systems, Oil pressure units for governors of each unit and other pump-turbine auxiliaries shall be placed on Pump-turbine floor.

Runner Inspection Floor at EL 327 m

Cooling water pumps, Dewatering & Drainage pumps, flood water pumps and Guide vanes servo motors shall be located on Runner Inspection Floor.

Drainage & Dewatering Gallery floor at EL 318.50 m

Draft tubes shall be connected to dewatering sump through a network of valves & pipes. Seepage and drainage from various floors of power house shall also be collected to the adjacent drainage sump at this floor.

24 kV isolated phase bus ducts shall be laid in individual bus duct gallery of respective unit interconnecting machine hall floor with the Transformer cavern. GCBs, Phase Reversal Switches, LAVT cubicles, Excitation Transformers, Unit Auxiliary Transformers (UATs) and Station Auxiliary Transformers (SATs) shall be installed in these Bus-duct galleries. Beside eight Bus Duct galleries, 2 additional galleries (One extended part of MAT on Service bay side and other on Unit-8 side) shall be provided for interconnecting Machine Hall cavern with Transformer Hall. One cable tunnel of adequate size is also proposed to accommodate 765 kV XLPE cables to transmit power between GIS installed in transformer cavern and overhead transmission lines at pothead yard.

HT, LT, control, protection, signaling cables between various panels in the underground power house and Transformer Hall & Pothead yard shall be laid in the cable tunnel/ trenches/ trays & racks.

The access to turbine pit shall be from pump-turbine floor.

Necessary hatches for material handling and removal of MIV shall be provided at various floors in the machine hall cavern.

The dewatering, drainage & flood water sumps shall be provided at the MIV floor towards Service bay side & far end unit-6 side.

The Main Access Tunnel (MAT) and construction adit tunnel for the power house cavern shall be utilized as ventilation tunnel & exhaust air tunnel afterwards. Suitable ventilation and air conditioning ducts, as required, shall be installed at various locations and floors.

Two nos. of 365/50/10 Tonnes EOT Cranes capable of operating in tandem along with a lifting beam shall be installed in the power house cavern.

One no. of 10 Tonnes EOT Crane shall be installed in the GIS hall for handling the GIS equipment and One (01) number 80 T EOT Crane in transformer hall for handling bonneted type draft tube gates.

7.3 Electro-Mechanical Equipment

7.3.1 Pump-Turbine

The Pump-turbines shall be of vertical shaft Francis type coupled to Generator-Motor of nominal rating of 350 MW each Eight (8) Nos.of the Francis pump-turbine each of 355.83 MW output and 385.00 MW as input operating under rated heads as mentioned below shall be installed.

The details of the hydraulic system of the generating units are as given below:

i. Upper Reservoir levels	
a) Full Reservoir Level (FRL)	750.0 m
b) Minimum Draw Down Level (MDDL)	700.0 m
ii. Lower Reservoir levels	
a) Full Reservoir Level (FRL)	426.72 m
b) Minimum Draw Down Level (MDDL)	384.05 m
iii.Head Loss	

a) Turbine Mode	24 m
b) Pump Mode	18 m
iv. Operating Head Range As Turbine:-	
a) Maximum net head	341.95 m
b) Minimum net head	249.28 m
c) Rated net head	296.84 m
d) Discharge (Generation)	133.55 cumecs
As Pump:-	
a) Maximum net head	383.95 m
b) Minimum net head	291.28 m
c) Rated net head	338.84 m
d) Discharge (Pumping)	89.81 cumecs
v. Turbine Basic Data	
a) Rated Output at rated net head of 296.84m	355.33 MW
b) Specific Speed	140.95 rpm
c) Rated Speed	250 rpm
d) Centerline of Turbine	EL. 332.00 m
vi. Pump Basic Data	
a) Pump Input at rated net head of 338.84 m	324.50 MW
b) Specific Speed	30 rpm
c) Rated Speed	250 rpm

Pump-Turbine runner shall be of 13:4/Cr:Ni stainless steel material. The upper portion of the draft cone liner shall be provided with stainless steel cladding.

7.3.2 Governor for Pump-Turbine machine

The Electro-hydraulic governor shall be of digital type with Combined Proportional Integral and Derivative function (PID) for control and regulating function and a hydraulic part acting as a power amplifying servo unit. The governor shall be suitable for local and remote control, synchronizing, load/frequency control, joint control operation, speed sensing etc.

7.3.3 Main Inlet Valve (MIV)

A main inlet valve of spherical type of diameter 2.7 m for shutting-off pressure water supply from the penstock to the pump-turbine shall be provided complete with necessary piping, control cabinet, upstream and downstream connecting pipes with companion flanges, dismantling joint, bypass valve & air release valve, operating mechanism etc. The valve shall have two oil pressure operated working seals (one service seal and the other maintenance seal). The seals shall be of material having high resistance to silt erosion.

7.3.4 Oil Pressure Systems for Governor and Turbine Inlet Valves

Each Pump-turbine shall be provided with a separate pressure oil system for operation of Pump-turbine wicket gate servomotors through governors, Air separate pressure oil system for the opening of MIV shall be provided.

7.3.5 Generator-Motor

The Generator-Motor will be synchronous and of the vertical shaft type. Each of the eight Generator-Motors shall have the following characteristics:

Rated Output	350 MW
Power Factor	0.85 lagging
Frequency	50 Hz
Phases	3 (Three)
Speed	250 rpm
Rated Terminal Voltage Between phases	21 kV
Range of frequency	(-) 5 % to (+) 3 %
Bearing arrangement	Semi Umbrella Type

Generator-Motor voltage shall operate at 21 kV. The voltage rating shall be optimized during preparation of bidding document/detailed engineering stage.

7.3.6 LAVT and Neutral grounding Cubicles

LAVT Cubicles shall include Surge Capacitors, Lightning Arresters, Voltage Transformers and associated accessories. The Generator Neutral Grounding Cubicle shall include a single phase, Dry type earthing transformer, a secondary loading Disconnecting Switch, a Resistor and associated accessories mounted in a single-ventilated, metal enclosed Cubicle.

7.3.7 Static Excitation System and AVR

Static Excitation system shall have microprocessor based controls. The excitation equipment shall comprise of rectifier, excitation transformers, thyristors, field breaker with discharge resistor, field flashing circuit, automatic voltage regulator and protection and control devices along with accessories to make it a complete system.

7.3.8 Generator-Motor Transformers

Eight (08) numbers three phase split type / 26 nos (including 02 spare) single-phase type 21/765/√3kV (Single phase Transformer or Three Phase Transformer shall be decided during DPR stage after route survey), having total capacity 453 MVA, with OFWF type cooling Power Transformers shall be installed in Transformer cavern. HV terminals of these transformers shall be connected through GIB to the GIS located on the floor above this hall.

7.3.9 800 kV Gas Insulated Switchgear (GIS) & 765 kV XLPE Cables

800 kV GIS shall be installed at the floor above the transformer hall connected to HV side of Power transformers through GIBs. The GIS will have 8 incoming bays, 4 outgoing bay and one bus coupler bay, i.e. total 13 bays. Power from 800 kV GIS would be transmitted to pothead yard through 765kV XLPE cables and further to Pong HEP Sub-stations through 2 nos. double circuit 765 kV transmission lines.

7.3.10 Static Frequency Converter (SFC)

Two (02) set of static frequency converter (SFC) for starting of variable speed as well as variable speed units in pumping mode shall be installed in Machine hall auxiliary floor. The primary circuits of SFC shall be able to be connected to generator-motor buses of variable speed machines through a circuit breaker and disconnecting switches.

The secondary circuit of the SFC is connected to all generator-motors through a circuit breaker and disconnecting switches. Both circuits shall be equipped with current limit reactors to reduce interrupting current of circuit breakers.

Static Frequency Convertor (SFC) is used to accelerate the machine in reverse direction for “pumping operation” upto the rated speed by grid power through 800kV GIS breaker and main generation transformer.

SFC acts as a synchronous link between Machine and Grid, It converts AC supply from grid to DC supply and then inverts this DC supply to required frequency AC supply and is fed to the Machine stator.

SFC plays main role in starting the unit in Pumping mode. During this operation once the unit is synchronized to the grid, SFC gets cutoff. Also when the unit is shut down SFC plays role of electrical breaking (in both mode “Generation” as well as “Pumping” mode) and thus brings unit to standstill faster.

7.3.11 Back to Back Starting Method

Back to back starting system shall also be equipped for all of eight generator-motors. Two machines are required in this method of starting. For starting the units in the pump mode by back to back method, provision is to be made for random coupling of any two of the units in the back to back starting across the 24 kV IPBD. Phase reversal is to be achieved by using DS (M) isolators on generator terminal. However all design requirement and equipment requirement are to be finalized during detail engineering for providing required panel and switching arrangement at main control room and at machine hall for back to back start.

Any one of the 350 MW unit in the power house shall be selected and started as a motor by another 350 MW generator which is located in the same power house. Both units are initially at standstill. The necessary switching is performed to disconnect two machines from 800kV Bus/transmission system by selecting the respective breakers & isolators. Note that the two machines are actually interconnected through 24kV IPBD. The fields of both units are energized and the turbine gates are opened to a predetermined position. Both the generator and the motor will accelerate together. The power generated in the stator winding of Back to back generator machine is phase reversed through switching arrangements and fed directly to the stator winding of back to back Pump machine.

The field excitation is to be build up by Back to Back excitation and then taken over by Main Excitation. The Back to back excitation gets the source from Unit Auxiliary Board. The main excitation gets source from machine output through Excitation Transformer. The back to back excitation will be in service from low speed till 90% of the rated speed and 70% of the rated voltage. Once 90% of the rated speed and 70% of the rated voltage is attained, the back to back excitation cut off and the main excitation get connected to the system.

The Back to back generator machine will be in service until the synchronization of the Back to back Pump machine. After synchronization of the back to back Pump machine, back to back generator machine will return to shutdown status and main static excitation system regulator shall control & protect the machine field.

Control cable connection and interlocking arrangements shall be designed for the above scheme and provision to be made in the control desk and in sequencer panel.

Starting method under dewatered condition is proposed. The draft tube water is depressed by admission of compressed air so that runner rotates in air drawing low power from the generator selection machine. The required blow down arrangement with suitable compressors, blow down tank, valves, and pipe lines has to be arranged by the turbine supplier and necessary control & protection arrangement through sequential control is to be made by the generator supplier.

7.3.12 24kV Generator Circuit Breaker

The circuit breaker on generator-motor side in the power house shall operate at every starting and stopping of the main unit, thus relieving the high voltage GIS circuit breakers from frequent operation. The installation of unit circuit breakers also enables the station service transformers to be located in bus-duct tunnels and be connected to the generator-motor circuit.

7.4 Control and Protection System

7.4.1 Control:-

A supervisory control and data acquisition (SCADA) system will be provided for an efficient and economic plant operation. The control and monitoring system will be built up of distributed control technique with independent control modules in hierarchical control levels and standard open protocol for communication network. All the components and subsystems in the hierarchical control levels of the control system shall be flawlessly & seamlessly integrated to achieve a highly reliable and scalable power plant control system.
The powerhouse will be designed to be operated with three levels of control:

- From local control cubicles of each element located adjacent to the unit.
- From the unit control board located on the machine hall floor.
- From the Central control room.

7.4.2 Protection System

The protection relays will be envisaged for the units including its UAT, Excitation Transformer, Station Auxiliary Transformers as well as for the generator transformers, 765 kV XLPE cables and the 800 kV GIS etc.

The design of the protection scheme will be based on the general philosophy that all the protected equipment has a primary and back-up protection supplementing each other. All protection relays will be high speed and of numerical design.

7.5 Mechanical Auxiliaries

7.5.1 EOT Cranes

Power House

The heaviest equipment / assembly required to be lifted in the power house by the EOT crane shall be the assembled rotor. The assembled rotor weight for the 350MW, 250 rpm generating unit is expected to be of the order of 620 Tonnes. Two cranes each of 365/50/10 tones main and auxiliary hooks are proposed to be provided for handling the assembled rotor along the full length of the powerhouse. Both the EOT cranes shall be used in tandem to handle the rotor. A lifting beam of adequate size /capacity for this purpose shall be provided. One monorail crane of 10T capacity supported beneath the outside girders of both the cranes shall also be provided.

GIS Hall/ Transformer Hall

One EOT crane of 10 Tonnes capacity shall be installed in GIS hall. Also, one no. 80 T EOT Crane shall be installed in the transformer hall for handling of draft tube bonneted gates.

7.5.2 Compressed Air System

Sufficient capability to recharge the compressed air system shall consist of eight compressors, two main tank for water level depression and two auxiliary air tanks for complete air distribution system, valves and other piping system with necessary instrumentation and protection system and control panels etc. for Governor, Inlet valve, Braking and jacking of generator rotor and for operating pneumatic tools.

7.5.3 Dewatering and Drainage System

Two sets of interconnected drainage & dewatering sump and other flood protection sump shall be provided in the power house cavern near Unit-1 & Unit-8. Dewatering system shall be provided in the power house for dewatering of unit for access to underwater parts. The scheme shall comprise of 3 nos. of submersible pumps of sufficient capacity (Two as main and one as standby) installed in the dewatering sump along with valves, piping, and control annunciation provided in the Machine Hall cavern.

The drainage scheme shall comprise of 3 nos. submersible drainage pumps (Two as main and one as standby) installed in the drainage sump along with requisite piping, control panels etc. Both the dewatering and drainage sump would be interconnected by means of pipe with gates & Non return valves.

Provision of Flood water evacuation system has also been made in case of inadvertent flooding of the power house. The system shall comprise of 3 nos. of submersible pumps (Two as main and one as standby) installed in the flood sump along with valves, piping, control annunciation to discharge water outside the power house building and shall have dedicated DG set power supply.

Control Panels for dewatering and drainage pump shall be located at the highest floor level.

7.5.4 Cooling Water System

It is proposed to provide individual cooling water system for each unit to remove heat from generators and bearing oils through heat exchangers. The cooling water shall be taken from the draft tube by set of centrifugal pumps. The cooling water shall be discharged back into the draft tube. Cooling water system shall be connected to a common header to cater cooling water to the unit in case of failure of individual pumps.

7.5.5 Air Conditioning and Ventilation System

The machine and transformer halls shall be provided with ventilation and air-conditioning system as required to maintain the control room, Conference room and other work areas at the required level of temperature, humidity and comfort.

Adequate number of supply & exhaust fans shall be installed at suitable locations to provide the air changes per hour as mentioned in Indian standards.

7.5.6 Oil Handling System

Oil handling system for transformer oil and lubricating oil for generating units will be provided with suitable piping, valves, tanks, purifiers etc. and shall be located such as to conform the requirements of underground power house.

7.5.7 Fire Detection and Protection System

The fire detection & protection system in the underground Power House, Main Access Tunnel, Isolated phase bus duct tunnels, switchyard etc. shall be planned to timely detect the occurrence & quick extinguishing of fire, breakouts, and prevention of spread of fire so as to minimize the extent of damage.

7.5.8 Lifts

2 nos. electrically operated lifts shall be provided in the control and auxiliary blocks on the unit –1 & 8 sides of the Machine hall. The lift shall be designed for approximately a load of 16 persons.

7.5.9 Draft Tube Gates

Individual Bonneted type draft tube gates shall be provided with oil operated servo motors in the transformer hall.

7.5.10 Mechanical Workshop

A Mechanical Workshop will be provided in control block on Unit-1 side in Machine Hall cavern for routine maintenance as required for all works & will be equipped with drilling, welding, milling & lathe machines & other required machine tools.

7.6 Electrical Auxiliaries

7.6.1 AC Electrical Auxiliaries – MV/LV Supply System

The MV/LV AC supply system will be developed to ensure the availability of reliable source to all energy consumers of electrical auxiliaries. The Main AC supply system will be made up from 24kV Isolated phase bus-ducts of the 1st & 8th generating units.

Unit auxiliaries will be fed from the UAB/UAT (Unit Auxiliary Board/Unit Auxiliary Transformer) tapped from the bus ducts of each unit and alternative power supply from station auxiliary board located in machine hall cavern.

Two nos. of 21/11 kV, 6.3 MVA station service transformers will be installed in power house Bus-duct Galleries of Unit-1 & Unit-8 and incoming shall be tapped from IPBD between generator circuit breaker and generator transformer with disconnecting switches. These SATs shall feed power to 11 kV Station. Auxiliary Board located in machine hall cavern. Another 11 kV station Auxiliary Board shall be located in pothead yard which will receive outside 11 kV power from board. Both these SABs shall be inter connected through 11 kV cables to be laid in cable tunnel. Two (02) 11kV DG sets each of 2 MVA rating will be installed in pothead yard and shall feed power to UABs & other SSBs through SABs. 11/0.433 kV distribution transformers (Dry type) will be installed for supplying LT power requirements in different installations of the power house and Dams. The MV & LV power supply scheme and requirement of DG sets shall be modified, if found necessary during DPR stage.

7.6.2 DC Supply System

A 220 V DC system, with two sets of battery banks of 1800 AH rating will provide power for unit control and protection equipment, field flashing, emergency lighting of the power house and for emergency lube oil pumps for generator/turbine bearings etc. In addition to above, two sets of 220V DC systems of adequate ratings along with batteries shall be installed in control rooms of both Dams for control of gates etc. A 48V DC system of adequate rating shall be required for PLCC purpose in pothead yard.

7.6.3 Power, Control & Instrumentation cables and cable trays etc.

11 kV XLPE cables shall be used for connection from and to the 11 switchboards to the11/0.433kV Dry type distribution transformer to be installed at different load centers in power house and pothead yard.

1.1 kV Grade PVC insulated Aluminum Power Cables shall be used in the powerhouse, transformer cavern, pothead yard, TRT outfall & Dam complex for supplying power to various auxiliaries, while for control cables 1.1 kV Grade PVC insulated copper cables will be employed. The Instrumentation Cables including Fiber 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 with cable racks & supporting systems, Conduits etc. of adequate sizes as required for the installation of Cables will be included. All cables will be FRLS& HR type.

7.6.4 Illumination System

Illumination System Design shall be based on the principle of achievement of the desired illumination levels with minimum glare. The design shall result in the most energy-efficient and presentable illumination as per the latest International trends in underground Hydro Power Plants.

The Illumination System shall provide Lighting and Electric Power supply to all Plant areas, dam area, and access road to various locations of the project and pothead yard. In addition, it shall provide Lighting for selected areas during plant emergency conditions.

Suitable scheme/arrangement will be provided for Emergency Lighting during AC supply failure.

7.6.5 PLCC Equipment

PLCC system shall provide efficient sources and reliable information links to meat communication need of protection, voice and data including for SCADA system. It shall provide for distance protection and direct tripping for remote end breaker, signal transmission & speech communication between the powerhouse/substation and data communication to remote places through various frequency channels etc.

7.6.6 Communication & Surveillance System

A suitable communication and surveillance system shall be installed in the powerhouse complex to facilitate the communication and desired security in the powerhouse area. Communication system comprises of the public address system and EPBAX equipment. The surveillance system would comprise of access control system and CCTV system equipment including all spaces of Power House.

7.6.7 Electrical Equipment & Testing Laboratory

Portable Electrical Testing Equipment will be provided to carry out normal testing of Powerhouse equipment. Separate room will be proposed in the power house for Electrical Testing Laboratory for storage of portable equipment and to serve as a base for testing staff. All the testing equipment shall be PC compatible &of latest design.

7.6.8 Grounding MAT

The grounding mat of Copper or MS flat or steel rods, having suitable cross sectional area would be provided in power house complex comprising machine hall and transformer hall caverns, Bus Duct galleries, main access tunnel, tail race tunnel, cable tunnel, pothead yard areas etc. Suitable number of grounding risers would be provided in the machine hall & transformer hall caverns for connection to machinery equipment/ panels/ boards in various auxiliary bay floors, cable tunnel/interconnecting tunnels/ MAT/ GIS floor etc. Earthing of various electrical equipment shall be performed by using at least two earthling conductors/ risers. Separate provision would be made for earthing of various electronic equipments in the power house. All non-current carrying equipment shall also be grounded by using at least 2 earth conductors of adequate sizes which shall finally be connected to the grounding grid. The grounding system would be designed to minimize the touch & step potential within acceptable safe limits.

7.6.9 Construction Power

Construction power of 25 MVA (approx.) rating to be arranged by 3-phase 11 kV AC lines from nearest source.

7.7 Power Evacuation Arrangement

The Pong Pumped Storage Project located in Kangara district of Himachal Pradesh envisages utilization of the waters of the Maharana Pratap Sagar reservoir for peak power generation on a Pumped storage type development. The Project envisages an installation of 2800 MW (8x350 MW) capacity. Evacuation of this generated power or drawl of power for pumping water of Pong Pumped Storage Project needs Transmission lines between the pothead yard and 765kV Pong HEP Substation.

Power house drawings:

Sr. No.	**Drawing No.**	**Title**
1.	WAP/PONG-PSP/03	Cross section of power House
2.	WAP/PONG -PSP/04	Layout Plan of Machine Hall Floor and Transformer Hall Floor at EL. 349.00 M.
3.	WAP/PONG-PSP/05	L- Section of Power House.
4.	WAP/PONG -PSP/06	Single Line Diagram

Annexure 7.1

CONSIDERATION OF VARIABLE SPEED OPTIONS

I Consideration of Variable Speed Options

Following two options for configuration of the main units have been considered for basic design of the electromechanical equipment:

- Option 1: 8 Fixed speed units
- Option 2: 4 Fixed speed units + 4 variable speed units
- Option 3: 8 Variable speed units

i. General Description of Variable speed Machine

A conventional synchronous generator-motor for pumped storage power plant can operate only at a constant rated revolving speed determined by the number of rotor poles and the system frequency.

On the other hand, a variable speed pumped storage system enables revolving speed of the Generator-motor to be controlled within a defined range by adopting doubly- fed asynchronous system.

The generator motor and the excitation system used for the variable speed system is different from that used for the conventional pumped storage system because the variable speed Generator motor is excited by low-frequency alternating current for realizing the rotating field on the rotor. A variable speed pumped storage system has some advantages by continuously changing its revolving speed. It has also some disadvantages, mainly due to necessity of the equipment for AC excitation. These advantages and disadvantages are described below.

ii. Advantages of variable speed system

- Regulating capability of pump input at pumping mode

The pump input of a conventional single speed pumped storage system is fixed to have the best pumping efficiency at each pumping head and cannot be adjusted intentionally. The pump input of a variable speed is nearly proportional with the cube of the revolving speed, therefore a variable speed pumped storage system can contribute to regulate the power system frequency by governor free operation at the pumping mode as well as the generating mode.

In addition, the pump input fluctuation at pump start can be reduced by lowering the synchronous speed, thus the influence on the power system can be minimized.

- Expansion of Operational Range at Generating Mode

The operational range at generating mode can be widened from 20% to 40% compared to the single speed pumped storage system by lowering the minimum output due to the improvement of the turbine efficiency at partial load. This advantage contributes to increase the frequency regulating range.

- Expansion of Head Operational Range

A single speed pumped storage system has some limitation in the operational head range due to the cavitations', vibration and other factors. A variable speed pumped storage system is operable in the wider head range by applying the most suitable revolving speed mitigating those bad effects. This advantage permits the larger water level variation in the upper and lower reservoirs, and this means the bigger storage energy is to be available, so it enables the longer operational hours of the plant.

- Improvement of Power System Stability

Rotor displacement angle can be easily controlled with the high–speed and the high accuracy, so it contributes for keeping the static stability of other connected synchronous generators. Moreover, in system disturbance, the adjustable speed machine can improve the transient stability with the rapid regulation of the excitation system.

iii. Disadvantages of variable speed System

- Larger Installation Space for Variable Speed System

The AC excitation system for a variable speed generator-motor requires much larger installation space compared to the excitation system for an equivalent single speed generator-motor. Additionally, the installation and lifting height of a three-phase wound type rotor are generally higher than that of the equivalent salient type rotor due to the difference of the structure. For these reasons, the size of powerhouse adopting variable speed system is increased.

iv. Purpose for Variable Speed Pumped Storage System for Pong PSP

Adopting of variable speed pumped storage system shall be considered if its advantages are necessary for the sound operation of the project and/or the power system or it is expected to bring benefit to the project.

In case of Pong PSP, the head ratio is coming out to be 1.32

it is assumed that the pump input regulating capability of the fixed speed pumped storage system is assumed to be utilized to compensate the frequency fluctuation of the power system caused by variation of the output from the solar photovoltaic power plants with rated output due to change of the weather condition during off-peak load in daytime.

v. Comparison and Consideration of Each Option

Contribution to Stability of Power System Frequency by Pumping Operation

The adjustable range of the pump input of a variable speed pumped storage system can be fully utilized to regulate the power system frequency. The maximum fluctuation of output from the solar PV plant caused by variations of the weather condition will be approximately 200 MW.

The actual frequency regulation of the power system will be conducted by not only Pong PSP but also some other power plants which are connected to the grid. In case of the frequency fluctuation caused by solar PV, it is supposed to be regulated mainly by governor free operation of the generators of those power plants and Pong PSP in pumping operation. Therefore, the adjustable range of the pump input have to cover 100% of the assumed power fluctuation and therefore, techno commercially option 1 with 8 x 350 MW fixed speed turbines seems to be enough for such purpose.

vi. Other Differences

- Spare Parts and Pump-Turbine Model Test

In case of the option 2, both single speed machine and variable speed machine are installed in one power plant. That means the spare parts for both type will be necessary and the extra cost and the extra storage space for those spare parts will be required. Additionally, regarding the pump-turbine, the design and model testing for both type of turbine will be done separately.

- Black Start Capability

The black start of a variable speed machine is technically possible, but a large capacity emergency DG or another power supply system equivalent of the DG is necessary for the excitation power of the variable speed machine to realize the black start function.

vii. Recommendation

The option 3 has higher capacity for regulating the power system frequency during pumping operation and it can more effectively contribute the stability of the power system as compared to the option 1. Therefore, the Option 3 most cost effective and recommended for Pong PSP.

8. Construction Programme & Schedule-R1

Chapter – 8

Construction Programme and Schedule

8.1 General

Construction of Pong Pumped Storage Scheme including erection of the eight generating units is planned to be completed in a period of five years and six months excluding Pre-construction works of one year for creation of infrastructure facilities viz. additional Investigations, improvement of Road network and colonies.

Two shift working is considered economical for surface works. For underground works which do not follow normal pattern of shift working because of cyclic operations, three shift working with minimum 15 hrs. or upto completion of cycle operations/day has been considered. Opting 25 working days in a month, shift wise scheduled working hours annually are adopted as follows:

Single Shift Work = 25 x 10 x 6 hrs = 1500 hrs
Two Shift Work = 25 x 10x 11hrs = 2750 hrs
Three Shift Work = 25x10 x 15 hrs = 3750 hrs
} for Surface Works

Three Shift Work = 25x10 x 18 hrs = 4500 hrs for Underground.

8.2 Main Components of the Project

8.2.1 Main Structure/ Components

The construction schedule has been detailed for major items of the following main structures/ components.

i. Civil Works

a) Upper Dam with Spillway.

b) Power intake structures.

c) Up Surge Shaft.

d) Tailrace outlet structures.

e) MAT and construction adits.

f) Headrace tunnel cum pressure shaft.

g) Draft Tube and Tailrace tunnel.

h) Switch yard and Cable Tunnel

i) Underground powerhouse, transformer cavern and Downstream Surge Chamber.

ii. Electrical Works

a) E.O.T. cranes

b) Supply and erection of T.G./Pumps sets 6 nos. 250 MW each

c) 400 kv G.I.S. and bays equipment

d) Main power transformers

e) Other auxiliary electro-mechanical equipment

iii. Hydraulic equipment

a) Intake gates

b) Surge shaft gates

c) Tailrace Outlet gates

d) Draft Tube gates at Downstream Surge Chamber

8.2.2 Target Schedule

The total construction period is scheduled as follows.

Pre-construction Period	: 1 year
Construction Period (Main Works)	: 5 ½ years
Total construction period	: 6 ½ years

The Programme is also exhibited in the form of a bar chart and is enclosed as **Annexure 8.1**.

8.3 Infrastructure Facilities

The Pong Pumped Storage Scheme is located in Kangra district of Himachal as shown in the index map. The existing Maharana Pratap Sagar reservoir has been proposed as lower reservoir for this Pumped storage scheme. The present scheme is in between N - 31˚ 53' 24", E - 76˚ 03' 54" and N - 31˚57' 00", E - 76˚4' 50". The altitude of the project area varies between 900m and 400 m. The tail water will be diverted through the tunnel to store water in the upper reservoir created by construction of concrete gravity dam across south northerly flowing khad that debouches into reservoir north of Dada Siba village. The Maharana Partap Sagar reservoir which will be the lower pool of the project is accessible with motor able road via MDR-46 and the tail pool site is near to Chatwal village. For power house approach tunnel, a new road is to be developed.

The project is located near existing Pong Project about 30 km Left of Pong dam. The nearest rail head is Daulatpur Chowk which is about 30 km from site. Dada Siba village is about 35 km from the existing Pong Project. The nearest airport is Amritsar International Airport located in Punjab which is about 160 km away from project site.

Construction of infrastructure works will be taken up in first years. Construction power may be obtained from the existing grid, but a new sub-station need to be developed. Construction/ improvement of project road and upgrading of existing road will be taken up immediately. The construction of office and residential buildings will be started in first year and be completed by second year. Construction of Project road shall be taken up first priority to complete within a year due to short length.

Following provision is being kept for construction of offices and residential building at various sites:

- Permanent Office Buildings
- Temporary Office Buildings
- Temporary Site Offices
- Permanent Residential Buildings
- Temporary Residential Buildings

The construction of project colony, residential and other Non-residential building will be taken up from first year and completed all within second year.

8.4 Lower Dam & Spillway (Existing)

A multipurpose project has been constructed on river Beas in north west India for irrigation and power generation. This project comprises 132.59 high earthen dam with dam toe power houses having an installed capacity of 396MW. The dam constructed utilise fully the power potential and water supplies available. This project has been constructed in stages. The dam was constructed in all respect in 1974, and first & sixth generating units of dam toe power house was commissioned in 1978 & 1983 respectively.

8.5 Upper Dam and Spillway

For care of the khad/nala during construction, stage diversion method is being followed for upper reservoir, so that nala diversion will be treated sequentially following foundation excavation and embankment.

The foundation excavation for the Upper dam is proposed to be started in the 1st month of first year and will be spread over fourteen months upto 4th month of 2nd Year.

Construction of dam in continuation with foundation treatment is to be started in the 1st month of 2nd year and will continue upto 2nd month of 4th year.

Concreting in the spillway in continuation with foundation treatment is planned to be done in the 5th month of second year and completed in 1st month of 4th Year.

8.6 Power Intake

Open Excavation for Intake will start from 1st month of 1st year as an independent activity. However, Concreting of Intake structure can only take place after completion of concrete Lining in 1st Phase of HRT from 3rd month of 4th year. The concreting of Intake may spread over eleven months from 3rd of 4th year to 1st month of 5th year respectively.

8.7 Headrace cum pressure shaft & surge shaft

Excavation of HRT from intake face will be taken up in the 10th month of first year after completing the open excavation of intake. The same will be completed in the 6th month of 3rd year.

The excavation of surge shaft will taken up simultaneously in the 10th month of first year after completing the MAT/Adit excavation. The same will be completed in the 3rd month of 3rd year.

The excavation of vertical pressure shaft will be taken up simultaneously in the 10th month of first year after completing the MAT/Adit excavation. The steel liners will be erected from 3rd month of third year and completed in the 12th month of 4th year. The backfilling, grouting will be taken up simultaneously and completed in the 3rd month of 5th year.

8.8 Tailrace Tunnel/ Outlet

Open Excavation of tailrace outlet will start from 1st month of 2nd year which will be completed in 8th month and construction of Tailrace tunnel will be started in the 9th month of 2nd year which will be completed in 12th month of 4th year. The construction completed within 9th month of fifth year.

8.9 Underground Powerhouse/ Transformer Caverns/Draft tube cum D/s Surge chamber

Access tunnel to power house will be done by 10th month of first year but the top construction adit will be completed in 6th month of second year and then the excavation of the power house cavern will be taken up in the 4th month of the second year and will be completed by 12th month of third year. The concreting will be taken up in the 12th month of the third year and will take 18 months more for completion with commissioning of Mechanical machine and most of Electric instrument and Auxiliary Apparatus.

The excavation of Transformer cavern will taken up simultaneously in the 5th month of 2nd year after completing the MAT/Adit excavation. The same will be completed in the 6th month of 5th year with commissioning of Mechanical machine and most of Electric instrument and Auxiliary Apparatus.

8.10 Electro-Mechanical Works

Action for procurement of EOT cranes is proposed to be initiated in the 1st year itself. The entire process of inviting the tender, placing orders, manufacture, supply, erection and testing is planned to be carried out in the period of 6th month of the 1st year to 6th month of the 5th year.

Pre-manufactured activities such as preparation of specifications, inviting and evaluation of tender etc. can be completed within the 1st year so that the supply orders are placed by the end of the 1st year. The model tests and approval to the supplier's drawings will require nine more months. Installation period for each pump/ turbine and generator/ motor has been considered as twenty-nine months.

8.11 Impounding Schedule

Filling of reservoirs will be based on the following considerations: -

i) Filling would be started during the construction of upper dam.

ii) Filling schedule would follow the construction schedule of dam.

iii) Filling elevation would not be permitted to exceed the height of dam anytime.

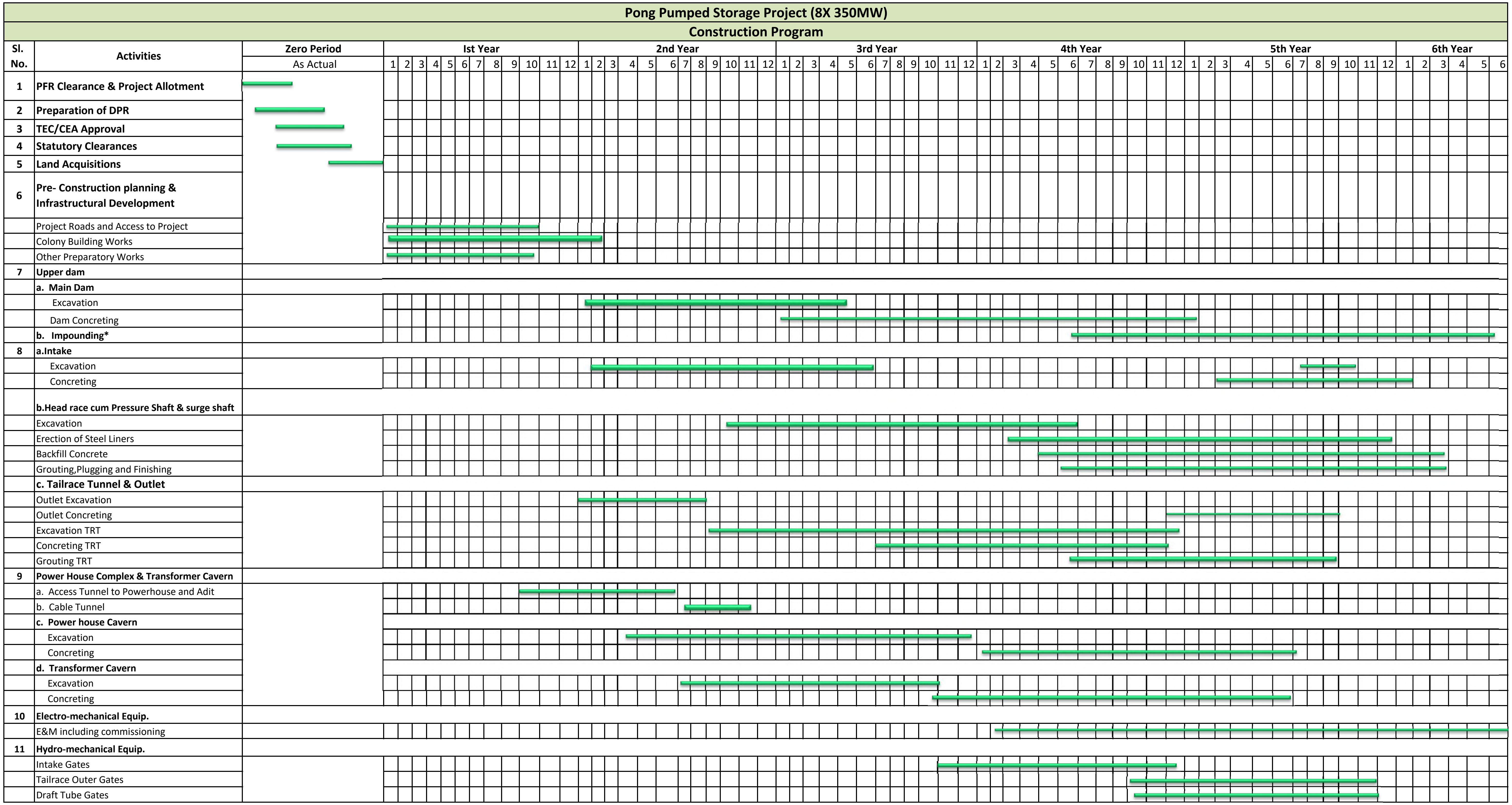
iv) Filling would be restricted to keep the elevation more than 5 m below the dam height during the construction period.

v) In case of exceeding the above clearance, extra water (including flood) would be flown to downstream by pumping or other ways.

Annexure-8.1

Pong Pumped Storage Project (8X 350MW)

Construction Program



Sl. No.	Activities
1	**PFR Clearance & Project Allotment**
2	**Preparation of DPR**
3	**TEC/CEA Approval**
4	**Statutory Clearances**
5	**Land Acquisitions**
6	**Pre- Construction planning & Infrastructural Development**
	Project Roads and Access to Project
	Colony Building Works
	Other Preparatory Works
7	**Upper dam**
	a. Main Dam
	Excavation
	Dam Concreting
	b. Impounding*
8	**a.Intake**
	Excavation
	Concreting
	b.Head race cum Pressure Shaft & surge shaft
	Excavation
	Erection of Steel Liners
	Backfill Concrete
	Grouting,Plugging and Finishing
	c. Tailrace Tunnel & Outlet
	Outlet Excavation
	Outlet Concreting
	Excavation TRT
	Concreting TRT
	Grouting TRT
9	**Power House Complex & Transformer Cavern**
	a. Access Tunnel to Powerhouse and Adit
	b. Cable Tunnel
	c. Power house Cavern
	Excavation
	Concreting
	d. Transformer Cavern
	Excavation
	Concreting
10	**Electro-mechanical Equip.**
	E&M including commissioning
11	**Hydro-mechanical Equip.**
	Intake Gates
	Tailrace Outer Gates
	Draft Tube Gates

9. Cost Estimates

Chapter - 9
Cost Estimate

9.1 Project Cost

A summary of the cost estimate, including direct and indirect charges for the Civil & Electro-mechanical works at year, 2022 Price Level has been worked out as given below:

Item	Estimated Cost (Rs. Lacs)
Civil Works	**377517.00**
Electro-mechanical Works	**443006.00**
Total	**820523.00**

The estimate has been prepared to arrive at the capital cost of Pong Pumped Storage Project, Himachal. The estimate is of Pre-feasibility level and has been prepared on the basis of “Guide Lines for preparation of cost estimates for River Valley Projects” published by Central Water Commission, Govt. of India, New Delhi. The Abstract of Cost is enclosed at in the relevant chapter of this report. The above cost includes the cost of Transmission.

9.2 Basis of Estimate

The estimate for Civil, Hydro-mechanical civil works have been prepared on the basis of following:

I. The rates have been adopted by updation to current price level from the recently approved H.E. Projects having similar parameters and working conditions.
II. The rates of materials are inclusive of GST as applicable.
III. Interest and escalation during construction period not considered.

Quantity estimate have been carried out by calculating the quantities of different work items involved. Unit rate corresponding to major item of works have been worked out by analysis of rate based on prevailing market rates. Some rates of major item of works, lump sum provision have been made based on the other similar projects. The following guidelines have been referred for the preparation of this cost estimate:

1. "Guidelines for preparation of project estimates for River Valley Projects" dated March 1997 by Central Water Commission, Govt. of India.
2. "Guide Lines for preparation of Detailed Project Report of Irrigation and Multipurpose projects" 2010 by Central Water Commission, Govt. of India.

9.3 Classification of Civil Works Into Minor Head/Sub Heads

The cost has been classified into direct and indirect charges and covered under the following minor heads:

Direct Charges

I. Works
II. Establishment
III. Tools and Plants
IV. Receipts and Recoveries on Capital Account

Indirect Charges

I. Capitalized Value of Abatement of Land Revenue
II. Audit and Account Charges

9.4 Direct Charges

9.4.1 I -Works

Current Cost: Rs 353178Lacs

The minor head I-Works has been subdivided in to the following detailed subheads:

9.4.2 A-Preliminary

Current Cost: Rs. 5811.00 Lacs

Under this head provision has been made for surveys and investigations to be conducted at DPR stage and later to arrive at the optimum of the project components. Provision for in-house Design & Engineering and consultancy charges has been kept under this head as 2% of cost of C & J Works.

9.4.3 B-Land

Current Cost: Rs. 14527.00 Lacs

This covers the provision for acquisition of land/lease charges for construction of the project, structures, colonies, offices etc. and the provision for Rehabilitation and Resettlement (R&R) of Project Affected Persons.

9.4.4 C- Works

Current Cost: Rs. 57496.00 Lacs

This sub-head covers the cost of Dykes, Upper Dam and associated Hydro-mechanical equipments.

9.4.5 J- Power Plant Civil Works

Current Cost: Rs. 233034.00 Lacs

This covers the cost of Civil Works of Power Tunnel Intake structures, Head Race Tunnel, Surge Shaft, Pressure Shaft, Power House, Transformer Cavern, D/s Surge Chamber & Tail Race Tunnel etc. along with associated Hydro-mechanical equipment.

9.4.6 K- Buildings

Current Cost: Rs. 11621.00 Lacs

As Talwara township is already existing for Pong project same will also be used for this project. the A provision @ 2% of C-J Works has been made towards temporary and non-residential permanent buildings proposed to be built in colonies for various locations of the project area. The buildings included under the permanent category are all those buildings, which will be subsequently utilized during the state of running and maintenance of the project.

9.4.6.1 M- Plantation

Current Cost: Rs. 70.0 Lacs

The provision under this head includes cost of plantation in colonies, along approach roads, landscaping and improvements of area around powerhouse.

9.4.6.2 O- Miscellaneous

Current Cost: Rs. 5811.00 Lacs

Under this head provision is generally made to cover the cost of the following miscellaneous works:

a) Capital cost of electrification, water supply, sewage disposal, firefighting equipment etc.
b) Repair and maintenance of electrification water supply, sewage disposal, medical assistance, recreation, post office telephone office security arrangements, firefighting, inspection vehicles, schools, transport of labour etc.
c) Other services such as laboratory testing, R&M of Guest House and transit camps, Community center and photographic instruments as well as R&M charges etc.

As the estimate is of Pre-feasibility level, percentage provision @ 2% of C-J works has been considered towards head O- Miscellaneous.

9.4.7 P- Maintenance

Current Cost: Rs.3047.00 Lacs

For maintenance of buildings, roads and other structures during construction period, provision @ 1% of C-works, J-Power Plant civil works, K- buildings R- Communication have been kept.

9.4.8 Q- Special T&P

Current Cost: Rs. 1500.00 Lacs

It is assumed that the work will be carried through Contracts and accordingly nominal provision for procurement of necessary equipment for taking up the work at the earliest by the contractor have been made. The total expenditure towards this will be recovered from the contractors and the same is credited under receipt and recoveries.

Adequate provision is made for inspection vehicles and cost for resale of vehicles is accounted for under receipt and recoveries.

9.4.9 R-Communication

Current Cost: Rs. 2500.00 Lacs

Provision under this head covers the cost of construction of roads and bridges for project works. The provision is Lump sum only at this stage based on preliminary assessments as detailing shall be done later on.

9.4.10 X-Environment and Ecology

Current Cost: Rs. 17000.00 Lacs

Provision under this head covers Bio-diversity Conservation, Creation of green belt, Restoration of Construction Area, Catchment Area Treatment and Compensatory Afforestation etc.

9.4.11 Y-Losses on Stock

Current Cost: Rs.762.00 Lacs

The provision under this head have been made @ 0.25% of the cost of I-Works less A-Preliminary, B-Land, Q-Miscellaneous, M-Plantation, P-Maintenance, Q-Special T&P and Environment and Ecology.

9.4.12 II-Establishment

Current Cost: Rs. 20319.00 Lacs

Provision for establishment including establishment of cost control cell at the project and Head Quarter Level has been made as per “Guide lines for Preparation of Detailed Project Report of Irrigation and Multipurpose Project” by CWC @ 6% of I-Works less B-Land

9.4.12.1 III- Tools &Plants

Current Cost: Rs.500.00 Lacs

The 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 & plants.

9.4.13 IV-Receipt &Recoveries

Current Cost: Rs. 375.00 Lacs

The provision under this head cover the estimated recoveries by way of resale of temporary buildings, transfer of construction equipment, inspection vehicles, generators etc.

9.5 Indirect Charges

Current Cost: Rs.3895.0 Lacs

Provisions under this head have been made for capitalized value of abatement of land revenue. Besides, provision for Audit & Account Charges has been made at 1% of the cost of I-Works.

9.6 Electro-Mechanical Works

Current Cost: Rs. **443006** Lacs

The total cost of Electro-Mechanical works at January, 2020 level works out to be Rs. 443006 lacs, which includes, the cost of main Electro-Mechanical equipment (excluded the transmission system) such as turbines, generators, transformers etc. based on the prevailing market prices in India and abroad. Suitable provision for transportation, erection and commissioning charges, freight and insurance etc. have been adequately made as per general guidelines issued by CEA. Provision for establishment and Audit and Account charges for the electro-mechanical works have also been made under this cost separately.

PONG PUMPED STORAGE PROJECT (8x350 MW)		
GENERAL ABSTRACT OF COST		
Sl. No.	DETAILED HEAD OF WORKS	Amount (Rs. Lacs)
A	**CIVIL WORKS**	
1	**DIRECT CHARGES**	
	I-WORKS	
	A-Preliminary	5811
	B-Land	14527
	C-Works including HM Works	57496
	J-Power Plant Civil Works	233034
	K-Building (4% of C-J Works)	11621
	M-Plantation LS	70
	O-Miscellaneous	5811
	P-Maintenance during construction @1% of I Works-(A+B+O+M+Q+X+Y)	3047
	Q-Special T&P	1500
	R-Communication	2500
	X-Environment & Ecology	17000
	Y-Losses on Stock @0.25% of C,J,K & R	762
	Total of I-Works	**353178**
	II-ESTABLISHMENT @ 6% OF (I-WORKS LESS B LAND)	**20319**
	III-TOOLS & PLANTS LS	**500**
	IV-SUSPENSE	**0**
	V-RECEIPT & RECOVERIES (-)	**-375**
	Total of Direct Charges	**373622**
2	**Indirect Charges**	
	(a) Capitalised value of abatement of land revenue @ 5% of cost of culturable land	**363**
	(b) Audit & Account Charges (@ 1% of I-Works)	**3532**
	Total of Indirect Charges	**3895**
	Total Cost (Direct charges + Indirect Charges)	**377517**
	Total Cost Civil Works	**377517**
A	**Civil Works**	**377517**
B	**Electrical Works**	**443006**
	Total Cost	**820523**

Abstract of Rates for Principal Construction Materials

Sl. No.	Description of item	Unit	Rate (At 2022 price level) in Rs.
1	Loose or unconsidolated excavation other than trenches	cum	261
2	Material excavated from rocky ground through blasting	cum	851
3	Removal of Material arising from overbreak for surface work	cum	370
4	**Concrete of grade M 10 (mass concrete)**	**cum**	5405
5	Concrete- M15	cum	4403
6	**Concrete Lining M15 - Diversion Tunnel**	**cum**	5063
7	Concrete- M 20	cum	5266
8	**Concrete, M20 - Diversion Tunnel**	**cum**	8002
9	Concrete- M25	cum	5616
10	Concrete-M30	cum	6342
11	Concrete- M35	cum	6254
12	**Concrete M 40 (HRT-Lining)**	**cum**	9780
13	Shotcrete Plain	cum	12903
14	Shotcrete with Steel Fibre	cum	24228
15	Fill material Rockfill (Backfill)	cum	450
16	**Fill Material (Gravel)**	**cum**	698
17	Filter material (Gravel)	cum	563
18	Impervious Core Material (Clay)	cum	1288
19	Stone Pitching	cum	1313
20	Rock Bolt more than 5 m depth 36 mm dia.	m	1326
21	Drilling Rock Bolt more than 5 m depth 32 mm dia.	m	1213
22	Rock Bolting-25mm dia 1 to 6m long	m	901
23	**Rock Bolting-32mm dia**	**m**	1356
24	Rock Bolting-25mm dia 4/5/6m long	m	1001
25	Rock Bolting-25mm dia 6m-9m long	m	1088
26	Drilling grout holes upto 5 m depth	m	957
27	Drilling grout holes more than 5 m depth	m	1063
28	Drainage hole	m	1063
29	Reinforcement (Mild steel round and tor steel)	MT	81366
30	ASTM-537 Gr. II Steel Liner for Penstock	MT	185533
31	ASTM-517 Gr. F Steel Liner for Penstock	MT	348317
32	Rock Excavation- Underground	cum	2364
33	Underground Excavation in Power House	cum	2189
34	Contact Grouting	MT	18910
35	Consolidation Grouting	MT	18910
36	PVC Rubber Water Stop	m	538
37	Wire Mesh 2"	sq.m	425
38	Fabrication & Erection - Steel supports	MT	100254
39	Shaft Excavation (Raise Borer)	cum	2364
40	Precast lagging	cum	6854
41	Crushed sand	cum	1401
42	Fabrication and Erection of Trash Rack	MT	100254
43	100 mm dia MS pipe	m	1550
44	Cement	MT	6754

A-PRELIMINARY

Sl. No.	Item	Quantity	Unit	Rate Rs.	Option-I
1	Cost of surveys and investigation including geological investigation, hydrological investigation, preliminary construction materials surveys, access paths and roads etc. at PFR stage	LS @ 2% of the cost of C-J Works			5810.61
2	Topographical & other surveys for HRT, TRT & Powerhouse etc.				
3	Geological Investigation				
4	Drilling & Drifting				
5	Construction Material Survey				
6	Hydrologcal and meteorological observations				
7	Geophysical survey, seimological study				
8	Hydraulic model studies				
9	Charges for prelimanary consultancy & specialists				
10	Training of Engineers during Investigation				
11	Instuments and equipments for S & I works				
12	Stationary, writing of completion report & history of project				
					5810.61

DAM AND APPURTENANT WORKS
I-WORKS

C-WORKS & HM WORKS

ABSTRACT OF COST

Sr. No.	Item	Amount (Rs. Lacs)
1	Upper Dam	50923
2	Spillway Upper Dam	2434
3	HM Works	4140
	Total for Civil & HM Works	**57496**
	Say	**57496**

J-WORKS

ABSTRACT OF COST

Sr. No.	Item	Amount (Rs. Lacs)
1	Intake	19047
2	Intake Gate Shaft (Underground)	923
3	HRT	3166
4	Pressure Shaft	91349
5	Main Access Tunnel	25975
6	Power House	28049
7	Transformer hall	5608
8	Draft Tube	4820
10	Tail race tunnels	40982
12	Tail Race Gate Shaft	1122
13	Outlet	11993
	Total Cost of J-Works	**233034**
	Say	**233034**

DAM AND APPURTENANT WORKS

LOWER DAM

Sl. No.	Items Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	**Site Clearance**	LS			10.00
2	**Open Excavation (Soil)**	262726	cum	261	686.82
3	**Open Excavation (Rock)**	148015	cum	851	1258.95
4	**Drilling holes for consolidation grouting**	17601	RM	957	168.42
5	**Drilling holes for curtain grouting**	26709	RM	1063	283.97
6	**Cement for consolidation grouting**	881	MT	18910	166.57
7	**Cement for curtain grouting**	803	MT	18910	151.80
8	**Impervious Core Material (Clay)**	998430	cum	1288	12863.21
9	**Rockfill material**	4834685	cum	450	21770.34
10	**Coarse Filter**	577945	cum	646	3733.52
11	**Fine Filter**	612836	cum	693	4246.95
12	**Rip Rap**	251397	cum	2057	5171.23
13	**M:15 for parapet**	3494	cum	4403	153.84
14	**Reinforcement for parapet**	35	MT	81366	28.43
15	**Rockbolt @ 32mm dia in slope stabiliztion**	3798	RM	1356	51.51
16	**Shortcrete in abutment slopes-75mm**	586	cum	24228	142.00
17	**Measuring instruments**	LS			20.00
18	**Dewatering**	LS			15.00
				Total	50922.57
				Say	**50923**

SPILLWAY UPPER DAM

Sl. No.	Items Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	**Site Clearance**	LS			5.00
2	**Open Excavation (Soil)**	13636	cum	261	35.65
3	**Open Excavation (Rock)**	54548	cum	851	463.96
4	**Rock bolt for abutment stabilization**	1595	RM	1356	21.63
5	**Shortcrete**	147	cum	12903	18.95
6	**Drilling holes for consolidation grouting**	979	RM	957	9.37
7	**Drilling holes for curtain grouting**	537	RM	1063	5.71
8	**Cement for consoliodation grouting**	27	MT	18910	5.08
9	**Cement for curtain grouting**	21	MT	18910	3.88
10	**DRILLING FOR Drainage holes(75mm)**	474	RM	1063	5.04
11	**M:15**	12379	cum	4403	545.03
12	**M:25**	20109	cum	5616	1129.38
13	**Reinforcement**	201	MT	81366	163.62
14	**100mm dia. M S Pipe**	411	RM	1550	6.36
15	**Measuring instruments**	LS			10.00
16	**Dewatering**	LS			5.00
Total					2433.66
Say					**2434**

Hydro Mechanical Cost

Estimated quantities:

Sl. No	Description	Nos	Width	Height	Des. head	Unit Wt.	Total wt.	Rate /t. (Rs)	Amount (Rs. In Lakh.)
			(m)	(m)	(m)	t	t.		
1	**Power Intake (Upper Reservoir)**								
i.	**Intake gates**								
	Gate leaf	2	6.18	7	39.91	40	80	**243906**	**195.12**
	Embedded parts	2				20	40	**243906**	**97.56**
	Hoist machinary	2				12	24	**268922**	**64.54**
	Hoist Support structure	2				16	32	**212636**	**68.04**
ii.	**Intake Auxiliary gates**								
	Gate leaf	2	6.18	7	39.91	40	80	**243906**	**195.12**
	Embedded parts	2				20	40	**243906**	**97.56**
	Hoist machinary	2				9	18	**268922**	**48.41**
	Hoist Support structure	2				16	32	**212636**	**68.04**
iii.	Liner for Inkake gates	2				20	40	**212636**	**85.05**
2	**Draft Tube gates**								
	Gate leaf	8	5.56	5.56	51.5	30	240	**243906**	**585.37**
	Embedded parts	8				33	264	**243906**	**643.91**
	Hydraulic Hoist	8				LS*		**8755600**	**0.00**
	Liner for gates	8				20	160	**212636**	**340.22**
3	**Tail Race gates (Lower Reservoir)**								
i	**Tail Race Service gates**								
	Gate leaf	2	7.44	9.45	28	70	140	**243906**	**341.47**
	Embedded parts	2				18	36	**243906**	**87.81**
	Hoist machinary	2				18	36	**268922**	**96.81**
	Hoist Support structure	2				19	38	**212636**	**80.80**
ii	**Tail Race Emergency gates**								
	Gate leaf	2	7.44	9.45	28	70	140	**243906**	**341.47**
	Embedded parts	2				18	36	**243906**	**87.81**
	Hoist machinary	2				18	36	**268922**	**96.81**
	Hoist Support structure	2				19	38	**212636**	**80.80**
	Liner for gates	2				25	50	**212636**	**106.32**
4	**MISCELLANEOUS**								
i)	Instrumentation				**4**	**LS***		**6254000**	**250.16**
ii)	D.G Set				**4**	**LS***		**1876200**	**75.05**
iii)	Model studies for groove shape, lip shape,air requirement etc. for gates				**2**	**LS***		**243906**	**4.88**
		Total Quantity in t. =					**1600**	**t**	**4139.15**
		say					**1600**	**t**	**4140**

Total estimated cost for gates = Rs. 41.4 crore

INTAKE					
Sl No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Lakh)**
1	Cleaning, Grubbing & Stripping	116776	m2	17	20
2	Excavation- Soil	174746	cum	261	457
3	Excavation- Rock	1119670	cum	851	9523
4	Banking	36948	cum	851	314
5	Mass concreting- M20	2792	cum	5266	147
6	Intake Structure - (M25)	42340	cum	5616	2378
7	Block out Concrete (M30)	200	cum	6342	13
8	Concreting in Channel (PCC)	5222	cum	4403	230
9	Reinforcement	3387	MT	81366	2756
10	Stone Pitching	8400	cum	1313	110
11	Rock Bolt and Anchor Bolt	157368	m	1326	2086
12	Shortcrete (t=10cm, Wiremesh)	5903	cum	12903	762
13	Trashrack (MT)	250	MT	100254	250
	Total				19047
				Say	**19047**

INTAKE GATE SHAFT					
Sl No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Lakh)**
1	Open Excavation- soil	502	cum	261	1.31
2	Open Excavation- Rock	1170	cum	851	9.95
3	Shaft Excavation- Rock	4686	cum	2364	110.79
4	Non-Core Drilling for Consolidation Grouting	7423	m	957	71.03
5	Grouting Material (Cement)	372	MT	6754	25.10
6	Lining Concrete (M20)	3286	cum	5266	173.02
7	Blockout Concrete (M35)	136	cum	6254	8.50
8	Reinforcing Steel	329	MT	81366	267.33
9	Waterstop	566	m	538	3.05
10	Shotcrete (t=10cm, Wire Mesh)	431	cum	12903	55.55
11	Rockbolt (L=3.0m)	12578	m	901	113.28
13	Other Works		LS		83.89
				Total	922.80
				Say	**923**

HRT					
Sl No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Lakh)**
1	Underground excavation	24293	cum	1869.00	454.03
2	Provision of overbreak	1552	cum	1869.00	29.00
3	Open Excavation	405	cum	439.00	1.78
4	Steel 537	801	MT	152215.22	1218.89
5	Steel 517	319	MT	285766.94	912.22
6	RCC M:25	15	cum	4749.00	0.69
7	Backfilling Concrete M:20	6209	cum	4554.00	282.74
8	Concrete in lagging	145	cum	4117.00	5.97
9	Reinforcement	19	MT	76870.00	14.70
10	Drilling in hard rock for grout holes	4620	m	488.00	22.55
11	Pressure grouting with cement (contact)	10	MT	13751.00	1.36
12	Pressure grouting with cement (cons.)	221	MT	15514.09	34.31
13	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	49	MT	94722.00	46.87
14	Rock bolting 25-mm dia, 5m long	7392	m	759.00	56.11
15	Shotcreting in tunnel	512	cum	6556.00	33.55
16	Drainage holes	2956	m	1109.00	32.78
17	Providing and laying 4 inch dia G.I. pipe	541	m	663.00	3.58
18	Water stoppers	32	m	441.27	0.14
19	Other Works	LS			15.00
	Total				3166.27
	Say				**3166**

Pressure Shaft

SI No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	Underground excavation	121133.34	cum	2364.05	2863.65
2	Provision of overbreak	6056.67	cum	2188.93	132.58
3	Concrete lining	55485.10	cum	9779.50	5426.17
4	Steel reinforcement	435.56	MT	81365.78	354.40
5	Concrete in lagging	968.01	cum	9779.50	94.67
6	Reinforcement in lagging	113.98	MT	81365.78	92.74
7	Backfill concrete in poor rock	3.97	cum	4402.88	0.17
8	Drilling in hard rock for grout holes	12769.53	m	956.88	122.19
9	Pressure grouting with cement (contact)	158.32	MT	18909.88	29.94
10	Pressure grouting with cement (cons.)	480.16	MT	18909.88	90.80
11	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	296.96	MT	100254.40	297.71
12	Rock bolting 25-mm dia, 5m long	164437.26	m	900.59	1480.91
13	Shotcreting in tunnel	4044.80	cum	24228.37	979.99
15	Drainage holes	9744.64	m	1063.20	103.60
16	Providing and laying 4 inch dia G.I. pipe for control cables	5917.43	m	1549.76	91.71
17	Steel Liner 537	8402.88	MT	185532.75	15590.08
18	Steel Liner 517	15874.45	MT	348316.85	55293.37
	Total				83044.67
	Misc.				8304.47
	G.Total				**91349.14**

Power House

Sr. No.	DESCRIPTION OF ITEMS	UNIT	QUANTITY	Rate Rs.	Amount (Rs. Lacs)
1	Excavation	cum	339608	2189	7433.78
2	Provision for overbreak	cum	16980	2189	371.69
3	Shotcrete (machine hall)	cum	4206	24228	1019.05
4	Rockbolts	m	136190	1001	1362.79
6	Mass concreting (M15)	cum	97573	4403	4296.01
7	Concreting in columns, beams, slabs, lift, wells (M25)	cum	5760	6342	365.27
8	Steel reinforcement	MT	16223	81366	13200.16
				TOTAL(A)	**28048.76**

Draft Tube

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs.Lacs)
1	Underground excavation	10559.27	cum	2188.93	231.14
2	Provision of overbreak	529.83	cum	2188.93	11.60
3	Concrete in lagging	109.08	cum	4402.88	4.80
4	Reinforcement in lagging	15.58	MT	81365.78	12.68
5	Supply and erection of steel supports ISMB 200 @650mm c/c	37.40	MT	100254.40	37.50
6	Steel 537	2215.77	MT	185532.75	4110.99
7	Backfill Concrete M20	4593.97	cum	5265.95	241.92
8	Drilling in hard rock for grout holes	2680.33	m	956.88	25.65
9	Pressure grouting with cement (contact)	10.29	MT	18909.88	1.94
10	Pressure grouting with cement (cons.)	123.42	MT	18909.88	23.34
11	Rock bolting 25-mm dia, 5m long	5204.83	m	1000.66	52.08
12	Shotcreting in tunnel	389.58	cum	12903.45	50.27
13	Drainage holes	1483.53	m	1063.20	15.77
14	Providing and laying 4 inch dia G.I. pipe	576.58	m	1549.76	8.94
	Total				4819.67
				G.Total	**4820**

ADIT/MAT

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	Underground excavation	67108	cum	1984	1331.61
2	Provision of overbreak	6711	cum	1984	133.16
3	Shotcrete	3833	cum	15649	599.90
4	Tunnel plug concrete (m15)	3355	cum		0.00
5	Rock bolting - 25 mm	267	m	1059	2.83
6	Supply and erection of steel support	21087	MT	100882	21273.54
7	Drilling for drainage holes	45	m	363	0.17
8	Concrete in lagging (m15)	1752	cum	11191	196.10
9	Backfill concrete in lagging	153	cum	4531	6.91
10	Reinforcement in lagging	101	MT	68814	69.74
				Total	**23613.96**
	Misc.		LS		2361.40
				G. Total	**25975.35**

Transformer Cavern					
Sr. No.	**DESCRIPTION OF ITEMS**	**UNIT**	**QUANTITY**	**Rate Rs.**	**Amount (Rs. Lacs)**
1	**Excavation**	**cum**	138262	2189	3026.46
2	**Provision for overbreak**	**cum**	13826	2189	302.65
3	**Shotcrete**	**cum**	1541	24228	373.45
4	**Rockbolts**	**m**	141171	1001	1412.64
6	**Concreting in columns, beams, slabs, lift, wells**	**cum**	2577	6342	163.41
7	**Steel reinforcement**	**mt**	405	81366	329.16
				TOTAL (A)	**5607.77**

TAIL RACE TUNNELS					
Sl No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Rs. Lacs)**
1	Underground excavation	796563.47	cum	2364	18831.14
2	provision of overbreak	39828.17	cum	2189	871.81
3	Concrete lining (RCC)	104327.56	cum	9780	10202.72
4	Steel reinforcement	818.97	cum	81366	666.36
5	Concrete in lagging	1174.13	cum	9780	114.82
6	reinforcement in lagging	138.25	cum	81366	112.49
7	backfill concrete in poor rock	781.37	m	4403	34.40
8	Drilling in hard rock for grout holes	3028.10	m	957	28.98
9	Pressure grouting with cement (contact)	59.89	mt	18910	11.33
10	Pressure grouting with cement (cons.)	91.52	mt	18910	17.31
11	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	346.89	mt	100254	347.77
12	Rock bolting 25-mm dia, 5m long	111793.89	m	901	1006.80
13	shotcreting in tunnel	19595.51	cum	24228	4747.67
14	Drainage holes	21664.84	m	1063	230.34
15	Providing and laying 4 inch dia G.I. pipe for control cables	2118.34	m	1550	32.83
	Total				37256.78
	Misc.				3725.68
	G. Total				**40982.45**

TRT SURGE CHAMBER

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	Underground Excavation in Rock	69033	cum	#REF!	#REF!
2	Provision of Overbreak in Underground Excavation	6903	cum	#REF!	#REF!
3	Cement Concrete Lining M-20	8997	cum	8001.68	719.92
4	Cement Concrete Lining M-15 Back Fill	79	cum	4402.88	3.49
5	Steel Reinforcement	565	MT	#REF!	#REF!
6	Rock Bolting 32mm dia, 4m long, bolts at 1.5 m c/c	40548	m	1356.50	550.03
7	Shotcreting	1113	cum	#REF!	#REF!
8	Drilling for Consolidation Grouting	396	m	#REF!	#REF!
9	Drilling for Contact Grouting	42	MT	#REF!	#REF!
10	Grouting	22	MT	#REF!	#REF!
11	ISMB 250@ 500 c/c Beam	49	cum	#REF!	#REF!
	G.Total				**#REF!**

TAIL RACE GATE SHAFT					
Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Lakh)
1	Open Excavation- soil	612	cum	261	2
2	Open Excavation- Rock	1428	cum	851	12
3	Shaft Excavation- Rock	5717	cum	2364	135
4	Non-Core Drilling for Consolidation Grouting	9055	m	1063	96
5	Grouting Material (Cement)	453	MT	6754	31
6	Lining Concrete (M20)	4008	cum	5266	211
7	Blockout Concrete (M35)	166	cum	6254	10
8	Reinforcing Steel	401	MT	81366	326
9	Waterstop	691	m	538	4
10	Shotcrete (t=10cm, Wire Mesh)	525	cum	24228	127
11	Rockbolt (L=3.0m)	15344	m	901	138
13	Other Works				30
				Total	1122.46
				Say	1122

TRT Outlet

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	Cleaning, Grubbing & Stripping	LS	m2	LS	10.00
2	Excavation- soil	109960.20	cum	261.42	287.46
3	Excavation - Rock	439840.80	cum	851	3741.10
4	Outlet Structural Concrete (M25)	45360.00	cum	5616	2547.50
5	Banking	39435.58	cum	851	335.42
6	Concreting in Channel (PCC)	1995.00	cum	4403	87.84
7	Reinforcement	3616.20	MT	81366	2942.35
8	Stone Pitching	8967.00	cum	1313	117.77
9	Rock Bolt and Anchor Bolt	83979.00	m	1088	913.87
9	Shortcrete (t=10cm, Wiremesh)	3150.00	cum	24228	763.19
10	Trashrack (MT)	231.00	MT	100254	231.59
11	other works	LS			15.00
	Total				11993.08
	G. Total				**11993**

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
ABSTRACT OF COST ESTIMATES OF E&M WORKS

Sl.No	Item	Amount for Power House (8x350MW) (Rs. Lakhs)
1	**Preliminary (cost of consultancy & model tests)- Annexure S(I)**	3800.00
2	**Generating Plant and Equipment**	
a)	Motor-Generator, Pump-Turbine and accessories- Annexure S(II)	291960.08
b)	Auxiliary electrical equipment for power station - Annex S(III)	40924.92
c)	Auxiliary mechanical equipment and services for power station - Annex S(IV)	11065.14
d)	Custom Duty (as applicable) on 2(a), (b) & (c)	0.00
e)	Transportation,handling and Insurance charges @ 6% of 2(a),(b) & (c)	20637.01
f)	Erection and commissioning charges @ 8 % of 2(a),(b) & (c), excluding spares	26330.07
	Sub-Total (Generating Plant and Equipment)	**390917.22**
3	**Switchyard and Pothead yard Equipment & Service**	
a)	Substation equipment, auxiliary equipment and service of switchyard - Annex S(V)	5450.42
b)	Custom Duty on 3(a)	0.00
c)	Transportation, handling and insurance charges @ 6% of 3(a)	327.03
d)	Erection and commissioning charges @ 8% of 3(a), excluding spares	435.18
	Sub-Total (Substation equipment and auxiliary equipment and service of Switchyard)	**6212.63**
4	**800 kV GIS and XLPE Cable**	
a)	800 KV GIS - **Annex S(VI)**	19887.56
b)	Custom Duty on 4 (a)	0.00
c)	Transportation, handling and insurance charges @ 6% of 3(a)	1193.25
d)	Erection & Commissioning charges @ 8% of 4(a) excluding spares	1551.56
	Sub-Total (GIS)	**22632.37**
5	Contingencies @ 1% in items 2, 3 & 4	4197.62
6	Tools & Plants @ 0.5% of 2, 3 & 4	2098.81
7	**Sub-Total (Item 1 to 6)**	**429858.66**
8	Establishment	12072.88
9	**Sub-Total (Item 7 & 8)**	**441931.54**
10	Audit and account charges @ 0.25% on item 7	1074.65
11	Service Tax on item 1, 2(f), 2(g), 3 (c), 3(d), 4 (c) & 4(d)	0.00
12	**TOTAL (in Lakh Rs.)**	**443006.18**

Annex-S(I)

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
1	Design and Consultancy Charges	LS	3500.00	3500.00	0.00	0.00	3500.00
2	Model test for Pump-Turbine	LS	1000	1000.00	0.00	0.00	1000.00
3	**Total**			**4500.00**			**4500.00**

Annex-S(II)

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

(Rs in lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1 a)	Generating units of 350 MW rated output comprising of Reversible Vertical Francis Pump-Turbine with rated speed of 250 rpm operating under a generation rated head of 306.84 m and pumping rated head of 334.84 m and 21 kV, 0.85 pf motor-generators complete with assoicated equipment such as spherical type MIVs, Governor, AVRs & excitation equipment, water sprinkler fire protection for generators, unit auxiliaries.	8	11200	224000.00	18.00	40320.00	264320.00
			Rs per kW				
c)	Unit control boards	included in (a) above.					
d)	Cooling water system comprising pump sets, valves, piping etc.	included in (a) above.					
e)	Drainage and dewatering systems	included in (a) above.					
f)	LP & HP compressed air system incl. pipes, valves	included in (a)) above.					
g)	Spares @ 5% on item-1a to 1f (incl. one spare runner)			11200	18.00	2016	13216
	Sub Total			235200.00		42336.00	277536.00
2	14000A, 24kV phase Bus Duct for GT connections including starting bus arrangement	8	75	600.00	18.00	108.00	708.00
3	Surge protection & VT cubicles with CTs, PTs, Surge absorber, CBs, fuses etc., Neutral grounding cubicles with grounding transformer resistor	included in item 2 above					
4	Supervisory control and Data acquisition system	LS		1500.00	18.00	270.00	1770.00
5	Unit Control and protection system	8	70	560.00	18.00	100.80	660.80
6	Lubricating oil & Governor oil for first filling	included in 2 (a), 2(b) & 2(c)					
7	21 kV Generator Circuit Breaker & Phase reversing DS	8	748	5984.00	18.00	1077.12	7061.12
8	Static Frequency Convertor	1	3500	3500	18.00	630.00	4130.00
9	Spares @ 3% of item 2 to 7			79.80	18.00	14.36	94.16
10	**Total**			**237939.80**		**42829.16**	**291960.08**

Annex-S(III)

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

(Rs in Lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1	Step up transformers including oil for 1st Filling (453 MVA, 21/765/√3kV, Three phase)	9	2646.15	25720.58	18.00	4629.70	30350.28
			Rs per kVA				
2	Unit Auxiliary transformers 3φ, 21/0.415kV, 1200 kVA Dry type	8	1200	115.20	18.00	20.74	135.94
			Rs per kVA				
3	Station auxiliary transformer (SAT) 3φ, 21/11kV, 8000 kVA dry type	2	1500	240.00	18.00	43.20	283.20
			Rs per kVA				
4(a)	Station Service transformers 11/ 0.415kV, 2000 kVA dry type	8	1200	192.00	18.00	34.56	226.56
			Rs per kVA				
4(b)	Station Service transformers 11/ 0.415kV, 3000 kVA dry type	2	1200	72.00	18.00	12.96	84.96
			Rs per kVA				
4(c)	Station Service transformers 11/ 0.415kV, 1000 kVA dry type	2	1200	24.00	18.00	4.32	28.32
			Rs per kVA				
4(d)	Station Service transformers 11/ 0.415kV, 400 kVA dry type	4	1200	19.20	18.00	3.46	22.66
			Rs per kVA				
5 €	Shunt Reactor, 125 MVAR	1	800	864.00	18.00	155.52	1019.52
6	HT/LT AC Switchgear for aux. Power supply to PH and outdoor switchyard.	LS		1500.00	18.00	270.00	1770.00
7	220V, 2000 MAh batteries, battery chargers, DC distribution board with DC switchgear	2 Sets	200	400.00	18.00	72.00	472.00
8 (a)	DG set (11kV,2000kVA)	2 Sets	100	200.00	18.00	36.00	236.00
8 (b)	DG set (0.415kV,630kVA)	1	25	25.00	18.00	4.50	29.50
9	Control and power cables	LS		1000.00	18.00	180.00	1180.00
10	Cable racks & accessories	LS		150.00	18.00	27.00	177.00
11	CCTV, Survelliance System & Telecommunication Equipments			150.00	18.00	27.00	177.00
12	Ground system for power house, Transformer yard & switchyard & Dam	LS		1000.00	18.00	180.00	1180.00
13	Illumination of power house & switchyard & Dam site	LS		1500.00	18.00	270.00	1770.00
14	Electrical workshop & testing equipment	LS		500.00	18.00	90.00	590.00
15	**Sub Total (Iteam 1 to14)**			**33671.98**			**39732.93**
16	Spares @ 3% (Iteam 15)			1010.16	18.00	181.83	1191.99
17	**Total**			**34682.14**		**6242.78**	**40924.92**

Annex-S(IV)

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

(Rs in Lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1 a)	Electrically operated Overhead travelling crane for PH (capacity 365/50/10T)	2	715.00	1430.00	18.00	257.40	1687.40
b)	Electrically operated Overhead travelling crane for Draft Tube Gates (50T)	1	250.00	250.00	20.00	50.00	300.00
c)	Electrically operated Overhead travelling crane for GIS (10T)	1	40.00	40.00	18.00	7.20	47.20
2	Electric lifts and elevators	2	40.00	80.00	18.00	14.40	94.40
3	Fire protection system with storage tanks, pupms, pipes valves etc.	LS		3000.00	18.00	540.00	3540.00
4	Air conditioinig , venilation and heating equipments	LS		3000.00	18.00	540.00	3540.00
5	Oil handling system with pipes, valves, tanks & purifiers	LS		300.00	18.00	54.00	354.00
6	Portable water supply system for power house	LS		300.00	18.00	54.00	354.00
7	Mechnical workshop equipment	LS		700.00	18.00	126.00	826.00
8	**Sub Total (Item 1 to 7)**			**9100.00**	**0.00**	**1643.00**	**10743.00**
9	**Spares @ 3% (Iteam 1 to 7)**			273.00	18.00	49.14	322.14
10	**Total**			**9373.00**		**1692.14**	**11065.14**

Annex-S(V)

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

(Rs in Lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1	**765 kV Pothead yard Equipments**						
a)	Lightning arrestors	12	5.00	60.00	18.00	10.80	70.80
b)	Capacitance voltage transformers	12	5.00	60.00	18.00	10.80	70.80
c)	Wave Traps	12	15.00	180.00	18.00	32.40	212.40
d)	Current Transformer	12	10.00	120.00	18.00	21.60	141.60
e)	Disconnector	12	20.00	240.00	18.00	43.20	283.20
3	Gantry,Foundation for structures & Miscllaneous civil works for other equipment like sheild wire, lightning mast etc.	LS	350.00	350.00	18.00	63.00	413.00
4	Protection	LS	3000.00	3000.00	18.00	540.00	3540.00
5	PLCC	LS	600.00	600.00	18.00	108.00	708.00
4	**Sub Total (1 to 5)**			**4610.00**		**829.80**	**5439.80**
5	Spares for Item (1) @ 3%			9.00	18.00	1.62	10.62
6	**Total**			**4619.00**		**831.42**	**5450.42**

Pong Pumped Storage Project (8X350 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

(Rs in lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1	800 kV GIS with double bus arrangment comprising of 8 transformer bays, 1 bus coupler bay, & 4 line bays.	15	600.00	9000.00	18.00	1620.00	10620.00
2	765 kV XLPE Cable, 1600 sqmm including associated auxilliaries and support structures	13520	0.55	7436.00	18.00	1338.48	8774.48
3	Spares for above @ 3%			493.08		0.00	493.08
4	**Total**			16929.08		2958.48	19887.56

10. Economic Evaluation

Chapter – 10

Economic Evaluation

10.1 General

The economic and financial evaluation of the Pong Pumped Storage Project, Himachal Pradesh 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 projects have been kept in view in this regard.

10.2 Project Benefits

The scheme would afford on annual peaking period energy generation of 5535.83 GWh annually. For assessing the tariff, design energy generation of 5259.04 GWh, calculated with 95% capacity availability in a normal dependable year, has been adopted. The project would provide 2800 MW of 5 hours daily peaking capacity benefits.

10.2.1 Capital Cost

The project cost has been estimated at ₹ **8205.23 Crores** without IDC at PL Nov 2022. The breakup of cost is as follows:

- Cost of Civil Works - ₹ **3775.17 Crores**
- Cost of E&M Works - ₹ **4430.06 Crores**

10.3 Mode of Financing

The project is proposed to be financed with a debt equity ratio of 70:30. An interest rate of 9% on the loan component has been considered for the financial analysis of the project. The interest on the working capital is taken as 10.50 %.

10.4 Phasing of Expenditure

It is estimated that project shall be completed in 6 years which includes 1 year of pre-construction activities. The phasing of the expenditure worked out on the basis of proposed construction programme is summarized in Table 8.1.

Table – 10.1
Phasing of Expenditure

Year	Capital Expenditure (₹. Crores)
Up-to 1st Half Year	264.26
2nd Half Year	226.51
3rd Half Year	151.01
4th Half Year	188.76
5th Half Year	820.52
6th Half Year	820.52
7th Half Year	820.52
8th Half Year	1079.78
9th Half Year	1636.04
10th Half Year	1376.78
11th Half Year	820.52
Total	**8205.23**

10.5 Financial Analysis

10.5.1 Basic and Normative Parameters

The following normative parameters have been adopted for working out the financial analysis of the project.

i. The estimated capital cost of ₹. 8859.12 Crores including the Interest during Construction as ₹. 653.89 Crores
ii. Annual gross energy generation of 5535.83 GWh considering 365 days generation in a year.
iii. Operation & maintenance expenses (including insurance) @ 3.5% of the project hard cost in the first year with 4.77% escalation every year.

iv. Depreciation allowed @ 5.28 % of the project cost for first 14 years and remaining depreciation is spread over the balance life i.e. 21 years on an average basis keeping 10% salvage value of the assets.
v. Auxiliary consumption i.e. quantum of energy consumed by auxiliary equipment of the generating station and transformer loss @ 1.25 % of the energy generated.
vi. Interest on working capital @ 10.50%.
vii. Interest during construction has been worked out based upon the interest rates @ 9 %. The computations are given in Annexure-1 for present day capital cost.
viii. Return on equity @ 15.50%
ix. Pump-Generation Cycle efficiency @ 72.06%
x. Pumping Energy Required 7682.03 MU
xi. Off-peak Energy Rate (₹/kWh) @ ₹. 1.0/-, 1.5/-, 2.0/- and 2.5/-
xii. MAT @ 17.01 %
xiii. Corporate Tax – 25.17%
xiv. Tax Holiday – 10 Years

10.5.2 Assessment of Tariff

Based upon the parameters given above, the sale rate of energy at bus bar has been computed in **Annexure- 10.3, 10.4, 10.5 & 10.6 respectively.**

The sale rate applicable in the first year and levellised tariff is indicated below.

Sl. No.	**Off Peak Energy Rate for pumping (₹/kWh)**	**Levellized Tariff (₹/kWh)**	**Conversion cost of the project (excluding pumping cost)** **(₹/kWh)**
1	1	4.66	3.17
2	1.5	5.41	3.17
3	2	6.16	3.17

4	2.5	6.91	3.17

Annexure-10.2 may please be referred for Conversion cost of the project (excluding pumping cost).

Annexure-10.1

PONG PUMPED STORAGE PROJECT (8x350=2800 MW)

INTEREST DURING CONSTRUCTION (IDC)

1	**Cost of Civil Works**	**INR**	**3775.17** Cr.	
2	**Cost of E&M Works**	**INR**	**4430.06** Cr.	
1	**Total Cost of the Project**	**INR**	**8205.23** Cr.	
2	**Interst Rate on Loan**		**9.0** %	per annum
3	**Equity**		**30.0** %	
4	**Loan**		**70.0** %	
5	**CERC Gudelines followed**		**2019-24**	

Period	**Expenditure Civil**		**Expenditure E&M**		**Total Expenditure**	**Equity available**	**Equity Used**	**Loan**	**IDC**	**IDC for Loan component**	**IDC for Equity component**	**Outstanding**
	Phasing of expendtiure	**Hard Cost**	**Phasing of expendtiure**	**Hard Cost**								
Half year	**%**	**INR Cr.**	**%**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**
1	7	264.26			264.26	2461.57	264.26	0.00	0.00	0.00	0.00	0.00
2	6	226.51			226.51	2197.31	226.51	0.00	0.00	0.00	0.00	0.00
3	4	151.01			151.01	1970.80	151.01	0.00	0.00	0.00	0.00	0.00
4	5	188.76			188.76	1819.79	188.76	0.00	0.00	0.00	0.00	0.00
5	10	377.52	10.00	443.01	820.52	1631.03	820.52	0.00	0.00	0.00	0.00	0.00
6	10	377.52	10.00	443.01	820.52	810.51	810.51	0.00	0.00	0.00	0.00	0.00
7	10	377.52	10.00	443.01	820.52	0.00	0.00	820.52	18.46	12.92	5.54	833.45
8	11	415.27	15.00	664.51	1079.78	0.00	0.00	1079.78	61.80	43.26	18.54	1956.48
9	14	528.52	25.00	1107.52	1636.04	0.00	0.00	1636.04	124.85	87.40	37.46	3679.92
10	13	490.77	20.00	886.01	1376.78	0.00	0.00	1376.78	196.57	137.60	58.97	5194.31
11	10	377.52	10.00	443.01	820.52	0.00	0.00	820.52	252.21	176.54	75.66	6191.37
	100	**3775.17**	**100**	**4430.06**	**8205.23**		2461.57	5733.65	653.89	457.73	196.17	

Hard Cost	**INR**	**8205.23**	**Cr.**	**Equity**	**INR**	**2657.74**	**Cr.**
IDC	**INR**	**653.89**	**Cr.**	**Loan**	**INR**	**6191.37**	**Cr.**
Total Capital Cost	**INR**	**8859.12**	**Cr.**	**Total Capital Cost**	**INR**	**8849.11**	**Cr.**

Annexure-10.2

PONG PUMPED STORAGE PROJECT (8x350=2800 MW)

S.No	Parameters	Unit	Value		S.No	Parameters		Unit	Value		S.No	Parameters		Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	2800.00		11	ROE		%	15.50		14	Interest rate on W.C		%	10.50	22	Equity	INR in Crs	2657.74
2	Normative availability	%	95.00		12	Working capital					15	O&M Expenses		%	3.50	23	Loan	INR in Crs	6191.37
3	Annual Energy Generation	GWh	5535.83														Total capital cost	INR in Crs	8849.11
4	Annual Energy Generation @ 95% availability	GWh	5259.04			i) Spares(% of O&M)		%	15.00		16	O&M Escalation rate		%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses		Months	1.00		17	Discount Rate		%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables		days	45.00		18	Depreciation Rate		%	5.28	26	Hard Cost	INR in Crs	8205.23
7	Auxiliary Consumption	%	0.70		13	i) MAT			17.01%		19	Max Dep Allowed		INR Cr.	7964.20	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax			25.17%		20	Energy Required for pumping		GWh	7682.03				
9	Free Power	%	0.00			III) Tax holiday		years	10.00		21	Rate for off peak energy		INR	0.00				
10	Net Saleble energy	GWh	5196.12												per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	496.38	287.18	467.23	6191.37	536.20	467.23	1003.43	23.93	43.08	224.08	291.09	30.56	0.00	1817.56	0.00	5196.12	3.50	1.00	3.50
2	496.38	300.88	467.23	5724.14	494.15	467.23	961.38	25.07	45.13	220.58	290.79	30.53	0.00	1789.18	0.00	5196.12	3.44	0.91	3.12
3	496.38	315.23	467.23	5256.91	452.10	467.23	919.33	26.27	47.29	217.17	290.72	30.53	0.00	1761.47	0.00	5196.12	3.39	0.82	2.78
4	496.38	330.27	467.23	4789.67	410.05	467.23	877.28	27.52	49.54	213.84	290.90	30.54	0.00	1734.48	0.00	5196.12	3.34	0.74	2.48
5	496.38	346.02	467.23	4322.44	367.99	467.23	835.23	28.84	51.90	210.60	291.34	30.59	0.00	1708.23	0.00	5196.12	3.29	0.67	2.21
6	496.38	362.53	467.23	3855.21	325.94	467.23	793.18	30.21	54.38	207.46	292.05	30.67	0.00	1682.76	0.00	5196.12	3.24	0.61	1.97
7	496.38	379.82	467.23	3387.97	283.89	467.23	751.13	31.65	56.97	204.42	293.05	30.77	0.00	1658.10	0.00	5196.12	3.19	0.55	1.76
8	496.38	397.94	467.23	2920.74	241.84	467.23	709.07	33.16	59.69	201.49	294.34	30.91	0.00	1634.30	0.00	5196.12	3.15	0.50	1.57
9	496.38	416.92	467.23	2453.51	199.79	467.23	667.02	34.74	62.54	198.67	295.95	31.07	0.00	1611.40	0.00	5196.12	3.10	0.45	1.40
10	496.38	436.81	467.23	1986.28	157.74	467.23	624.97	36.40	65.52	195.96	297.88	31.28	0.00	1589.44	0.00	5196.12	3.06	0.41	1.25
11	550.51	457.64	467.23	1519.04	115.69	467.23	582.92	38.14	68.65	200.13	306.92	32.23	0.00	1623.31	0.00	5196.12	3.12	0.37	1.16
12	550.51	479.47	467.23	1051.81	73.64	467.23	540.87	39.96	71.92	197.67	309.55	32.50	0.00	1603.36	0.00	5196.12	3.09	0.33	1.03
13	550.51	502.35	467.23	584.58	31.59	467.23	498.82	41.86	75.35	195.35	312.56	32.82	0.00	1584.50	0.00	5196.12	3.05	0.30	0.92
14	550.51	526.31	467.23	117.34	5.28	117.34	122.62	43.86	78.95	195.13	317.93	33.38	0.00	1582.72	0.00	5196.12	3.05	0.27	0.84
15	550.51	551.41	54.73	0.00	0.00	0.00	0.00	45.95	82.71	146.16	274.82	28.86	0.00	1185.51	0.00	5196.12	2.28	0.25	0.57
16	550.51	577.71	54.73	0.00	0.00	0.00	0.00	48.14	86.66	149.52	284.32	29.85	0.00	1212.81	0.00	5196.12	2.33	0.22	0.52
17	550.51	605.27	54.73	0.00	0.00	0.00	0.00	50.44	90.79	153.05	294.28	30.90	0.00	1241.41	0.00	5196.12	2.39	0.20	0.49
18	550.51	634.14	54.73	0.00	0.00	0.00	0.00	52.85	95.12	156.75	304.71	31.99	0.00	1271.38	0.00	5196.12	2.45	0.18	0.45
19	550.51	664.39	54.73	0.00	0.00	0.00	0.00	55.37	99.66	160.62	315.64	33.14	0.00	1302.78	0.00	5196.12	2.51	0.17	0.42
20	550.51	696.08	54.73	0.00	0.00	0.00	0.00	58.01	104.41	164.67	327.09	34.34	0.00	1335.67	0.00	5196.12	2.57	0.15	0.39
21	550.51	729.29	54.73	0.00	0.00	0.00	0.00	60.77	109.39	168.92	339.09	35.60	0.00	1370.13	0.00	5196.12	2.64	0.14	0.36
22	550.51	764.07	54.73	0.00	0.00	0.00	0.00	63.67	114.61	173.37	351.66	36.92	0.00	1406.24	0.00	5196.12	2.71	0.12	0.34
23	550.51	800.52	54.73	0.00	0.00	0.00	0.00	66.71	120.08	178.04	364.82	38.31	0.00	1444.07	0.00	5196.12	2.78	0.11	0.31
24	550.51	838.70	54.73	0.00	0.00	0.00	0.00	69.89	125.81	182.92	378.62	39.76	0.00	1483.70	0.00	5196.12	2.86	0.10	0.29
25	550.51	878.71	54.73	0.00	0.00	0.00	0.00	73.23	131.81	188.04	393.07	41.27	0.00	1525.22	0.00	5196.12	2.94	0.09	0.27
26	550.51	920.62	54.73	0.00	0.00	0.00	0.00	76.72	138.09	193.40	408.22	42.86	0.00	1568.73	0.00	5196.12	3.02	0.08	0.25
27	550.51	964.54	54.73	0.00	0.00	0.00	0.00	80.38	144.68	199.02	424.08	44.53	0.00	1614.31	0.00	5196.12	3.11	0.08	0.23
28	550.51	1010.55	54.73	0.00	0.00	0.00	0.00	84.21	151.58	204.91	440.71	46.27	0.00	1662.06	0.00	5196.12	3.20	0.07	0.22
29	550.51	1058.75	54.73	0.00	0.00	0.00	0.00	88.23	158.81	211.08	458.12	48.10	0.00	1712.09	0.00	5196.12	3.29	0.06	0.20
30	550.51	1109.25	54.73	0.00	0.00	0.00	0.00	92.44	166.39	217.54	476.37	50.02	0.00	1764.51	0.00	5196.12	3.40	0.06	0.19
31	550.51	1162.16	54.73	0.00	0.00	0.00	0.00	96.85	174.32	224.31	495.48	52.03	0.00	1819.43	0.00	5196.12	3.50	0.05	0.18
32	550.51	1217.60	54.73	0.00	0.00	0.00	0.00	101.47	182.64	231.41	515.51	54.13	0.00	1876.97	0.00	5196.12	3.61	0.05	0.17
33	550.51	1275.68	54.73	0.00	0.00	0.00	0.00	106.31	191.35	238.84	536.50	56.33	0.00	1937.25	0.00	5196.12	3.73	0.04	0.15
34	550.51	1336.53	54.73	0.00	0.00	0.00	0.00	111.38	200.48	246.63	558.48	58.64	0.00	2000.41	0.00	5196.12	3.85	0.04	0.14
35	550.51	1400.28	54.73	0.00	0.00	0.00	0.00	116.69	210.04	254.78	581.52	61.06	0.00	2066.58	0.00	5196.12	3.98	0.03	0.14
36	550.51	1467.07	54.73	0.00	0.00	0.00	0.00	122.26	220.06	263.33	605.65	63.59	0.00	2135.91	0.00	5196.12	4.11	0.03	0.13
37	550.51	1537.05	54.73	0.00	0.00	0.00	0.00	128.09	230.56	272.29	630.93	66.25	0.00	2208.54	0.00	5196.12	4.25	0.03	0.12
38	550.51	1610.37	54.73	0.00	0.00	0.00	0.00	134.20	241.56	281.67	657.42	69.03	0.00	2284.64	0.00	5196.12	4.40	0.03	0.11
39	550.51	1687.18	54.73	0.00	0.00	0.00	0.00	140.60	253.08	291.50	685.17	71.94	0.00	2364.37	0.00	5196.12	4.55	0.02	0.10
40	550.51	1767.66	54.73	0.00	0.00	0.00	0.00	147.31	265.15	301.80	714.25	75.00	0.00	2447.90	0.00	5196.12	4.71	0.02	0.10
			7964.20			**6191.37**												**10.36**	32.80
	Levellised Tariff (INR/Kwh)=	**3.17**																	

Annexure-10.3

PONG PUMPED STORAGE PROJECT (8x350=2800 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	2800.00		11	ROE	%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2657.74
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	6191.37
3	Annual Energy Generation	GWh	5535.83												Total capital cost	INR in Crs	8849.11
4	Annual Energy Generation @ 95% availability	GWh	5259.04			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	8205.23
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	7964.20	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	7682.03				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	1.00				
10	Net Saleble energy	GWh	5196.12										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	496.38	287.18	467.23	6191.37	536.20	467.23	1003.43	23.93	43.08	320.04	387.04	40.64	768.20	2595.84	0.00	5196.12	5.00	1.00	5.00
2	496.38	300.88	467.23	5724.14	494.15	467.23	961.38	25.07	45.13	316.54	386.74	40.61	768.20	2567.46	0.00	5196.12	4.94	0.91	4.47
3	496.38	315.23	467.23	5256.91	452.10	467.23	919.33	26.27	47.29	313.12	386.67	40.60	768.20	2539.75	0.00	5196.12	4.89	0.82	4.01
4	496.38	330.27	467.23	4789.67	410.05	467.23	877.28	27.52	49.54	309.79	386.85	40.62	768.20	2512.76	0.00	5196.12	4.84	0.74	3.59
5	496.38	346.02	467.23	4322.44	367.99	467.23	835.23	28.84	51.90	306.56	387.29	40.67	768.20	2486.51	0.00	5196.12	4.79	0.67	3.21
6	496.38	362.53	467.23	3855.21	325.94	467.23	793.18	30.21	54.38	303.42	388.01	40.74	768.20	2461.03	0.00	5196.12	4.74	0.61	2.88
7	496.38	379.82	467.23	3387.97	283.89	467.23	751.13	31.65	56.97	300.38	389.00	40.85	768.20	2436.38	0.00	5196.12	4.69	0.55	2.58
8	496.38	397.94	467.23	2920.74	241.84	467.23	709.07	33.16	59.69	297.44	390.29	40.98	768.20	2412.58	0.00	5196.12	4.64	0.50	2.31
9	496.38	416.92	467.23	2453.51	199.79	467.23	667.02	34.74	62.54	294.62	391.90	41.15	768.20	2389.68	0.00	5196.12	4.60	0.45	2.08
10	496.38	436.81	467.23	1986.28	157.74	467.23	624.97	36.40	65.52	291.91	393.83	41.35	768.20	2367.72	0.00	5196.12	4.56	0.41	1.86
11	550.51	457.64	467.23	1519.04	115.69	467.23	582.92	38.14	68.65	296.09	402.87	42.30	768.20	2401.58	0.00	5196.12	4.62	0.37	1.71
12	550.51	479.47	467.23	1051.81	73.64	467.23	540.87	39.96	71.92	293.63	405.50	42.58	768.20	2381.64	0.00	5196.12	4.58	0.33	1.53
13	550.51	502.35	467.23	584.58	31.59	467.23	498.82	41.86	75.35	291.30	408.51	42.89	768.20	2362.78	0.00	5196.12	4.55	0.30	1.38
14	550.51	526.31	467.23	117.34	5.28	117.34	122.62	43.86	78.95	291.08	413.89	43.46	768.20	2361.00	0.00	5196.12	4.54	0.27	1.25
15	550.51	551.41	54.73	0.00	0.00	0.00	0.00	45.95	82.71	242.11	370.77	38.93	768.20	1963.79	0.00	5196.12	3.78	0.25	0.94
16	550.51	577.71	54.73	0.00	0.00	0.00	0.00	48.14	86.66	245.48	380.28	39.93	768.20	1991.09	0.00	5196.12	3.83	0.22	0.86
17	550.51	605.27	54.73	0.00	0.00	0.00	0.00	50.44	90.79	249.00	390.23	40.97	768.20	2019.69	0.00	5196.12	3.89	0.20	0.79
18	550.51	634.14	54.73	0.00	0.00	0.00	0.00	52.85	95.12	252.70	400.66	42.07	768.20	2049.66	0.00	5196.12	3.94	0.18	0.73
19	550.51	664.39	54.73	0.00	0.00	0.00	0.00	55.37	99.66	256.57	411.59	43.22	768.20	2081.05	0.00	5196.12	4.01	0.17	0.67
20	550.51	696.08	54.73	0.00	0.00	0.00	0.00	58.01	104.41	260.62	423.04	44.42	768.20	2113.95	0.00	5196.12	4.07	0.15	0.61
21	550.51	729.29	54.73	0.00	0.00	0.00	0.00	60.77	109.39	264.87	435.04	45.68	768.20	2148.41	0.00	5196.12	4.13	0.14	0.57
22	550.51	764.07	54.73	0.00	0.00	0.00	0.00	63.67	114.61	269.32	447.61	47.00	768.20	2184.52	0.00	5196.12	4.20	0.12	0.52
23	550.51	800.52	54.73	0.00	0.00	0.00	0.00	66.71	120.08	273.99	460.78	48.38	768.20	2222.35	0.00	5196.12	4.28	0.11	0.48
24	550.51	838.70	54.73	0.00	0.00	0.00	0.00	69.89	125.81	278.87	474.57	49.83	768.20	2261.98	0.00	5196.12	4.35	0.10	0.44
25	550.51	878.71	54.73	0.00	0.00	0.00	0.00	73.23	131.81	283.99	489.03	51.35	768.20	2303.50	0.00	5196.12	4.43	0.09	0.41
26	550.51	920.62	54.73	0.00	0.00	0.00	0.00	76.72	138.09	289.36	504.17	52.94	768.20	2347.01	0.00	5196.12	4.52	0.08	0.38
27	550.51	964.54	54.73	0.00	0.00	0.00	0.00	80.38	144.68	294.98	520.04	54.60	768.20	2392.59	0.00	5196.12	4.60	0.08	0.35
28	550.51	1010.55	54.73	0.00	0.00	0.00	0.00	84.21	151.58	300.86	536.66	56.35	768.20	2440.34	0.00	5196.12	4.70	0.07	0.32
29	550.51	1058.75	54.73	0.00	0.00	0.00	0.00	88.23	158.81	307.03	554.07	58.18	768.20	2490.37	0.00	5196.12	4.79	0.06	0.30
30	550.51	1109.25	54.73	0.00	0.00	0.00	0.00	92.44	166.39	313.49	572.32	60.09	768.20	2542.79	0.00	5196.12	4.89	0.06	0.27
31	550.51	1162.16	54.73	0.00	0.00	0.00	0.00	96.85	174.32	320.27	591.44	62.10	768.20	2597.71	0.00	5196.12	5.00	0.05	0.25
32	550.51	1217.60	54.73	0.00	0.00	0.00	0.00	101.47	182.64	327.36	611.47	64.20	768.20	2655.25	0.00	5196.12	5.11	0.05	0.23
33	550.51	1275.68	54.73	0.00	0.00	0.00	0.00	106.31	191.35	334.79	632.45	66.41	768.20	2715.53	0.00	5196.12	5.23	0.04	0.22
34	550.51	1336.53	54.73	0.00	0.00	0.00	0.00	111.38	200.48	342.58	654.43	68.72	768.20	2778.69	0.00	5196.12	5.35	0.04	0.20
35	550.51	1400.28	54.73	0.00	0.00	0.00	0.00	116.69	210.04	350.74	677.47	71.13	768.20	2844.86	0.00	5196.12	5.47	0.03	0.19
36	550.51	1467.07	54.73	0.00	0.00	0.00	0.00	122.26	220.06	359.28	701.60	73.67	768.20	2914.19	0.00	5196.12	5.61	0.03	0.17
37	550.51	1537.05	54.73	0.00	0.00	0.00	0.00	128.09	230.56	368.24	726.88	76.32	768.20	2986.82	0.00	5196.12	5.75	0.03	0.16
38	550.51	1610.37	54.73	0.00	0.00	0.00	0.00	134.20	241.56	377.62	753.37	79.10	768.20	3062.92	0.00	5196.12	5.89	0.03	0.15
39	550.51	1687.18	54.73	0.00	0.00	0.00	0.00	140.60	253.08	387.45	781.13	82.02	768.20	3142.65	0.00	5196.12	6.05	0.02	0.14
40	550.51	1767.66	54.73	0.00	0.00	0.00	0.00	147.31	265.15	397.75	810.20	85.07	768.20	3226.18	0.00	5196.12	6.21	0.02	0.13
			7964.20			**6191.37**												**10.36**	48.32
	Levellised Tariff (INR/Kwh)=	**4.66**																	

PONG PUMPED STORAGE PROJECT (8x350=2800 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	2800.00		11	ROE	%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2657.74
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	6191.37
3	Annual Energy Generation	GWh	5535.83												Total capital cost	INR in Crs	8849.11
4	Annual Energy Generation @ 95% availability	GWh	5259.04			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	8205.23
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	7964.20	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	7682.03				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	1.50				
10	Net Saleble energy	GWh	5196.12										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	496.38	287.18	467.23	6191.37	536.20	467.23	1003.43	23.93	43.08	368.01	435.02	45.68	1152.31	2984.98	0.00	5196.12	5.74	1.00	5.74
2	496.38	300.88	467.23	5724.14	494.15	467.23	961.38	25.07	45.13	364.51	434.72	45.65	1152.31	2956.60	0.00	5196.12	5.69	0.91	5.15
3	496.38	315.23	467.23	5256.91	452.10	467.23	919.33	26.27	47.29	361.10	434.65	45.64	1152.31	2928.89	0.00	5196.12	5.64	0.82	4.62
4	496.38	330.27	467.23	4789.67	410.05	467.23	877.28	27.52	49.54	357.77	434.83	45.66	1152.31	2901.90	0.00	5196.12	5.58	0.74	4.14
5	496.38	346.02	467.23	4322.44	367.99	467.23	835.23	28.84	51.90	354.53	435.27	45.70	1152.31	2875.64	0.00	5196.12	5.53	0.67	3.72
6	496.38	362.53	467.23	3855.21	325.94	467.23	793.18	30.21	54.38	351.39	435.98	45.78	1152.31	2850.17	0.00	5196.12	5.49	0.61	3.34
7	496.38	379.82	467.23	3387.97	283.89	467.23	751.13	31.65	56.97	348.35	436.98	45.88	1152.31	2825.52	0.00	5196.12	5.44	0.55	2.99
8	496.38	397.94	467.23	2920.74	241.84	467.23	709.07	33.16	59.69	345.42	438.27	46.02	1152.31	2801.72	0.00	5196.12	5.39	0.50	2.69
9	496.38	416.92	467.23	2453.51	199.79	467.23	667.02	34.74	62.54	342.59	439.88	46.19	1152.31	2778.82	0.00	5196.12	5.35	0.45	2.41
10	496.38	436.81	467.23	1986.28	157.74	467.23	624.97	36.40	65.52	339.89	441.81	46.39	1152.31	2756.86	0.00	5196.12	5.31	0.41	2.17
11	550.51	457.64	467.23	1519.04	115.69	467.23	582.92	38.14	68.65	344.06	450.85	47.34	1152.31	2790.72	0.00	5196.12	5.37	0.37	1.99
12	550.51	479.47	467.23	1051.81	73.64	467.23	540.87	39.96	71.92	341.60	453.48	47.62	1152.31	2770.78	0.00	5196.12	5.33	0.33	1.79
13	550.51	502.35	467.23	584.58	31.59	467.23	498.82	41.86	75.35	339.28	456.49	47.93	1152.31	2751.91	0.00	5196.12	5.30	0.30	1.61
14	550.51	526.31	467.23	117.34	5.28	117.34	122.62	43.86	78.95	339.06	461.86	48.50	1152.31	2750.13	0.00	5196.12	5.29	0.27	1.45
15	550.51	551.41	54.73	0.00	0.00	0.00	0.00	45.95	82.71	290.09	418.75	43.97	1152.31	2352.93	0.00	5196.12	4.53	0.25	1.12
16	550.51	577.71	54.73	0.00	0.00	0.00	0.00	48.14	86.66	293.45	428.25	44.97	1152.31	2380.23	0.00	5196.12	4.58	0.22	1.03
17	550.51	605.27	54.73	0.00	0.00	0.00	0.00	50.44	90.79	296.98	438.21	46.01	1152.31	2408.83	0.00	5196.12	4.64	0.20	0.94
18	550.51	634.14	54.73	0.00	0.00	0.00	0.00	52.85	95.12	300.67	448.64	47.11	1152.31	2438.80	0.00	5196.12	4.69	0.18	0.86
19	550.51	664.39	54.73	0.00	0.00	0.00	0.00	55.37	99.66	304.54	459.57	48.25	1152.31	2470.19	0.00	5196.12	4.75	0.17	0.79
20	550.51	696.08	54.73	0.00	0.00	0.00	0.00	58.01	104.41	308.60	471.02	49.46	1152.31	2503.09	0.00	5196.12	4.82	0.15	0.73
21	550.51	729.29	54.73	0.00	0.00	0.00	0.00	60.77	109.39	312.85	483.02	50.72	1152.31	2537.55	0.00	5196.12	4.88	0.14	0.67
22	550.51	764.07	54.73	0.00	0.00	0.00	0.00	63.67	114.61	317.30	495.58	52.04	1152.31	2573.66	0.00	5196.12	4.95	0.12	0.61
23	550.51	800.52	54.73	0.00	0.00	0.00	0.00	66.71	120.08	321.96	508.75	53.42	1152.31	2611.48	0.00	5196.12	5.03	0.11	0.56
24	550.51	838.70	54.73	0.00	0.00	0.00	0.00	69.89	125.81	326.85	522.55	54.87	1152.31	2651.12	0.00	5196.12	5.10	0.10	0.52
25	550.51	878.71	54.73	0.00	0.00	0.00	0.00	73.23	131.81	331.97	537.00	56.39	1152.31	2692.64	0.00	5196.12	5.18	0.09	0.48
26	550.51	920.62	54.73	0.00	0.00	0.00	0.00	76.72	138.09	337.33	552.15	57.98	1152.31	2736.15	0.00	5196.12	5.27	0.08	0.44
27	550.51	964.54	54.73	0.00	0.00	0.00	0.00	80.38	144.68	342.95	568.01	59.64	1152.31	2781.73	0.00	5196.12	5.35	0.08	0.40
28	550.51	1010.55	54.73	0.00	0.00	0.00	0.00	84.21	151.58	348.84	584.63	61.39	1152.31	2829.48	0.00	5196.12	5.45	0.07	0.37
29	550.51	1058.75	54.73	0.00	0.00	0.00	0.00	88.23	158.81	355.01	602.05	63.22	1152.31	2879.51	0.00	5196.12	5.54	0.06	0.34
30	550.51	1109.25	54.73	0.00	0.00	0.00	0.00	92.44	166.39	361.47	620.30	65.13	1152.31	2931.93	0.00	5196.12	5.64	0.06	0.32
31	550.51	1162.16	54.73	0.00	0.00	0.00	0.00	96.85	174.32	368.24	639.41	67.14	1152.31	2986.85	0.00	5196.12	5.75	0.05	0.29
32	550.51	1217.60	54.73	0.00	0.00	0.00	0.00	101.47	182.64	375.34	659.44	69.24	1152.31	3044.39	0.00	5196.12	5.86	0.05	0.27
33	550.51	1275.68	54.73	0.00	0.00	0.00	0.00	106.31	191.35	382.77	680.43	71.44	1152.31	3104.67	0.00	5196.12	5.97	0.04	0.25
34	550.51	1336.53	54.73	0.00	0.00	0.00	0.00	111.38	200.48	390.55	702.41	73.75	1152.31	3167.83	0.00	5196.12	6.10	0.04	0.23
35	550.51	1400.28	54.73	0.00	0.00	0.00	0.00	116.69	210.04	398.71	725.44	76.17	1152.31	3234.00	0.00	5196.12	6.22	0.03	0.21
36	550.51	1467.07	54.73	0.00	0.00	0.00	0.00	122.26	220.06	407.26	749.58	78.71	1152.31	3303.33	0.00	5196.12	6.36	0.03	0.20
37	550.51	1537.05	54.73	0.00	0.00	0.00	0.00	128.09	230.56	416.21	774.86	81.36	1152.31	3375.96	0.00	5196.12	6.50	0.03	0.18
38	550.51	1610.37	54.73	0.00	0.00	0.00	0.00	134.20	241.56	425.60	801.35	84.14	1152.31	3452.06	0.00	5196.12	6.64	0.03	0.17
39	550.51	1687.18	54.73	0.00	0.00	0.00	0.00	140.60	253.08	435.43	829.10	87.06	1152.31	3531.79	0.00	5196.12	6.80	0.02	0.16
40	550.51	1767.66	54.73	0.00	0.00	0.00	0.00	147.31	265.15	445.72	858.18	90.11	1152.31	3615.32	0.00	5196.12	6.96	0.02	0.14
			7964.20			**6191.37**												**10.36**	56.08
	Levellised Tariff (INR/Kwh)=	**5.41**																	

Annexure-10.5

PONG PUMPED STORAGE PROJECT (8x350=2800 MW)

S.No	Parameters	Unit	Value		S.No	Parameters		Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	2800.00		11	ROE		%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2657.74
2	Normative availability	%	95.00		12	Working capital					15	O&M Expenses	%	3.50	23	Loan	INR in Crs	6191.37
3	Annual Energy Generation	GWh	5535.83													Total capital cost	INR in Crs	8849.11
4	Annual Energy Generation @ 95% availability	GWh	5259.04			i) Spares(% of O&M)		%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses		Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables		days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	8205.23
7	Auxiliary Consumption	%	0.70		13	i) MAT			17.01%		19	Max Dep Allowed	INR Cr.	7964.20	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax			25.17%		20	Energy Required for pumping	GWh	7682.03				
9	Free Power	%	0.00			III) Tax holiday		years	10.00		21	Rate for off peak energy	INR	2.00				
10	Net Saleble energy	GWh	5196.12											per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	496.38	287.18	467.23	6191.37	536.20	467.23	1003.43	23.93	43.08	415.99	483.00	50.71	1536.41	3374.12	0.00	5196.12	6.49	1.00	6.49
2	496.38	300.88	467.23	5724.14	494.15	467.23	961.38	25.07	45.13	412.49	482.69	50.68	1536.41	3345.74	0.00	5196.12	6.44	0.91	5.83
3	496.38	315.23	467.23	5256.91	452.10	467.23	919.33	26.27	47.29	409.07	482.63	50.68	1536.41	3318.03	0.00	5196.12	6.39	0.82	5.23
4	496.38	330.27	467.23	4789.67	410.05	467.23	877.28	27.52	49.54	405.74	482.81	50.69	1536.41	3291.03	0.00	5196.12	6.33	0.74	4.70
5	496.38	346.02	467.23	4322.44	367.99	467.23	835.23	28.84	51.90	402.51	483.25	50.74	1536.41	3264.78	0.00	5196.12	6.28	0.67	4.22
6	496.38	362.53	467.23	3855.21	325.94	467.23	793.18	30.21	54.38	399.37	483.96	50.82	1536.41	3239.31	0.00	5196.12	6.23	0.61	3.79
7	496.38	379.82	467.23	3387.97	283.89	467.23	751.13	31.65	56.97	396.33	484.95	50.92	1536.41	3214.66	0.00	5196.12	6.19	0.55	3.41
8	496.38	397.94	467.23	2920.74	241.84	467.23	709.07	33.16	59.69	393.39	486.25	51.06	1536.41	3190.86	0.00	5196.12	6.14	0.50	3.06
9	496.38	416.92	467.23	2453.51	199.79	467.23	667.02	34.74	62.54	390.57	487.85	51.22	1536.41	3167.96	0.00	5196.12	6.10	0.45	2.75
10	496.38	436.81	467.23	1986.28	157.74	467.23	624.97	36.40	65.52	387.86	489.78	51.43	1536.41	3146.00	0.00	5196.12	6.05	0.41	2.47
11	550.51	457.64	467.23	1519.04	115.69	467.23	582.92	38.14	68.65	392.04	498.82	52.38	1536.41	3179.86	0.00	5196.12	6.12	0.37	2.26
12	550.51	479.47	467.23	1051.81	73.64	467.23	540.87	39.96	71.92	389.58	501.46	52.65	1536.41	3159.92	0.00	5196.12	6.08	0.33	2.04
13	550.51	502.35	467.23	584.58	31.59	467.23	498.82	41.86	75.35	387.25	504.47	52.97	1536.41	3141.05	0.00	5196.12	6.05	0.30	1.83
14	550.51	526.31	467.23	117.34	5.28	117.34	122.62	43.86	78.95	387.03	509.84	53.53	1536.41	3139.27	0.00	5196.12	6.04	0.27	1.66
15	550.51	551.41	54.73	0.00	0.00	0.00	0.00	45.95	82.71	338.06	466.73	49.01	1536.41	2742.07	0.00	5196.12	5.28	0.25	1.31
16	550.51	577.71	54.73	0.00	0.00	0.00	0.00	48.14	86.66	341.43	476.23	50.00	1536.41	2769.37	0.00	5196.12	5.33	0.22	1.20
17	550.51	605.27	54.73	0.00	0.00	0.00	0.00	50.44	90.79	344.96	486.19	51.05	1536.41	2797.97	0.00	5196.12	5.38	0.20	1.10
18	550.51	634.14	54.73	0.00	0.00	0.00	0.00	52.85	95.12	348.65	496.62	52.14	1536.41	2827.94	0.00	5196.12	5.44	0.18	1.00
19	550.51	664.39	54.73	0.00	0.00	0.00	0.00	55.37	99.66	352.52	507.54	53.29	1536.41	2859.33	0.00	5196.12	5.50	0.17	0.92
20	550.51	696.08	54.73	0.00	0.00	0.00	0.00	58.01	104.41	356.58	519.00	54.49	1536.41	2892.23	0.00	5196.12	5.57	0.15	0.84
21	550.51	729.29	54.73	0.00	0.00	0.00	0.00	60.77	109.39	360.82	530.99	55.75	1536.41	2926.69	0.00	5196.12	5.63	0.14	0.77
22	550.51	764.07	54.73	0.00	0.00	0.00	0.00	63.67	114.61	365.28	543.56	57.07	1536.41	2962.80	0.00	5196.12	5.70	0.12	0.71
23	550.51	800.52	54.73	0.00	0.00	0.00	0.00	66.71	120.08	369.94	556.73	58.46	1536.41	3000.62	0.00	5196.12	5.77	0.11	0.65
24	550.51	838.70	54.73	0.00	0.00	0.00	0.00	69.89	125.81	374.83	570.52	59.90	1536.41	3040.26	0.00	5196.12	5.85	0.10	0.59
25	550.51	878.71	54.73	0.00	0.00	0.00	0.00	73.23	131.81	379.95	584.98	61.42	1536.41	3081.78	0.00	5196.12	5.93	0.09	0.54
26	550.51	920.62	54.73	0.00	0.00	0.00	0.00	76.72	138.09	385.31	600.12	63.01	1536.41	3125.29	0.00	5196.12	6.01	0.08	0.50
27	550.51	964.54	54.73	0.00	0.00	0.00	0.00	80.38	144.68	390.93	615.99	64.68	1536.41	3170.87	0.00	5196.12	6.10	0.08	0.46
28	550.51	1010.55	54.73	0.00	0.00	0.00	0.00	84.21	151.58	396.82	632.61	66.42	1536.41	3218.62	0.00	5196.12	6.19	0.07	0.42
29	550.51	1058.75	54.73	0.00	0.00	0.00	0.00	88.23	158.81	402.98	650.03	68.25	1536.41	3268.65	0.00	5196.12	6.29	0.06	0.39
30	550.51	1109.25	54.73	0.00	0.00	0.00	0.00	92.44	166.39	409.45	668.27	70.17	1536.41	3321.07	0.00	5196.12	6.39	0.06	0.36
31	550.51	1162.16	54.73	0.00	0.00	0.00	0.00	96.85	174.32	416.22	687.39	72.18	1536.41	3375.99	0.00	5196.12	6.50	0.05	0.33
32	550.51	1217.60	54.73	0.00	0.00	0.00	0.00	101.47	182.64	423.31	707.42	74.28	1536.41	3433.53	0.00	5196.12	6.61	0.05	0.30
33	550.51	1275.68	54.73	0.00	0.00	0.00	0.00	106.31	191.35	430.74	728.40	76.48	1536.41	3493.81	0.00	5196.12	6.72	0.04	0.28
34	550.51	1336.53	54.73	0.00	0.00	0.00	0.00	111.38	200.48	438.53	750.39	78.79	1536.41	3556.97	0.00	5196.12	6.85	0.04	0.26
35	550.51	1400.28	54.73	0.00	0.00	0.00	0.00	116.69	210.04	446.69	773.42	81.21	1536.41	3623.14	0.00	5196.12	6.97	0.03	0.24
36	550.51	1467.07	54.73	0.00	0.00	0.00	0.00	122.26	220.06	455.24	797.55	83.74	1536.41	3692.47	0.00	5196.12	7.11	0.03	0.22
37	550.51	1537.05	54.73	0.00	0.00	0.00	0.00	128.09	230.56	464.19	822.84	86.40	1536.41	3765.10	0.00	5196.12	7.25	0.03	0.20
38	550.51	1610.37	54.73	0.00	0.00	0.00	0.00	134.20	241.56	473.57	849.33	89.18	1536.41	3841.20	0.00	5196.12	7.39	0.03	0.19
39	550.51	1687.18	54.73	0.00	0.00	0.00	0.00	140.60	253.08	483.40	877.08	92.09	1536.41	3920.93	0.00	5196.12	7.55	0.02	0.17
40	550.51	1767.66	54.73	0.00	0.00	0.00	0.00	147.31	265.15	493.70	906.16	95.15	1536.41	4004.46	0.00	5196.12	7.71	0.02	0.16
			7964.20			**6191.37**												**10.36**	63.84
	Levellised Tariff (INR/Kwh)=	**6.16**																	

Annexure-10.6

PONG PUMPED STORAGE PROJECT (8x350=2800 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	2800.00		11	ROE	%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2657.74
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	6191.37
3	Annual Energy Generation	GWh	5535.83												Total capital cost	INR in Crs	8849.11
4	Annual Energy Generation @ 95% availability	GWh	5259.04			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	8205.23
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	7964.20	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	7682.03				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	2.50				
10	Net Saleble energy	GWh	5196.12										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	496.38	287.18	467.23	6191.37	536.20	467.23	1003.43	23.93	43.08	463.96	530.97	55.75	1920.51	3763.26	0.00	5196.12	7.24	1.00	7.24
2	496.38	300.88	467.23	5724.14	494.15	467.23	961.38	25.07	45.13	460.46	530.67	55.72	1920.51	3734.87	0.00	5196.12	7.19	0.91	6.51
3	496.38	315.23	467.23	5256.91	452.10	467.23	919.33	26.27	47.29	457.05	530.60	55.71	1920.51	3707.17	0.00	5196.12	7.13	0.82	5.85
4	496.38	330.27	467.23	4789.67	410.05	467.23	877.28	27.52	49.54	453.72	530.78	55.73	1920.51	3680.17	0.00	5196.12	7.08	0.74	5.26
5	496.38	346.02	467.23	4322.44	367.99	467.23	835.23	28.84	51.90	450.48	531.22	55.78	1920.51	3653.92	0.00	5196.12	7.03	0.67	4.72
6	496.38	362.53	467.23	3855.21	325.94	467.23	793.18	30.21	54.38	447.34	531.93	55.85	1920.51	3628.45	0.00	5196.12	6.98	0.61	4.25
7	496.38	379.82	467.23	3387.97	283.89	467.23	751.13	31.65	56.97	444.30	532.93	55.96	1920.51	3603.80	0.00	5196.12	6.94	0.55	3.82
8	496.38	397.94	467.23	2920.74	241.84	467.23	709.07	33.16	59.69	441.37	534.22	56.09	1920.51	3580.00	0.00	5196.12	6.89	0.50	3.43
9	496.38	416.92	467.23	2453.51	199.79	467.23	667.02	34.74	62.54	438.55	535.83	56.26	1920.51	3557.10	0.00	5196.12	6.85	0.45	3.09
10	496.38	436.81	467.23	1986.28	157.74	467.23	624.97	36.40	65.52	435.84	537.76	56.46	1920.51	3535.14	0.00	5196.12	6.80	0.41	2.78
11	550.51	457.64	467.23	1519.04	115.69	467.23	582.92	38.14	68.65	440.01	546.80	57.41	1920.51	3569.00	0.00	5196.12	6.87	0.37	2.54
12	550.51	479.47	467.23	1051.81	73.64	467.23	540.87	39.96	71.92	437.55	549.43	57.69	1920.51	3549.06	0.00	5196.12	6.83	0.33	2.29
13	550.51	502.35	467.23	584.58	31.59	467.23	498.82	41.86	75.35	435.23	552.44	58.01	1920.51	3530.19	0.00	5196.12	6.79	0.30	2.06
14	550.51	526.31	467.23	117.34	5.28	117.34	122.62	43.86	78.95	435.01	557.81	58.57	1920.51	3528.41	0.00	5196.12	6.79	0.27	1.86
15	550.51	551.41	54.73	0.00	0.00	0.00	0.00	45.95	82.71	386.04	514.70	54.04	1920.51	3131.21	0.00	5196.12	6.03	0.25	1.50
16	550.51	577.71	54.73	0.00	0.00	0.00	0.00	48.14	86.66	389.40	524.20	55.04	1920.51	3158.51	0.00	5196.12	6.08	0.22	1.37
17	550.51	605.27	54.73	0.00	0.00	0.00	0.00	50.44	90.79	392.93	534.16	56.09	1920.51	3187.11	0.00	5196.12	6.13	0.20	1.25
18	550.51	634.14	54.73	0.00	0.00	0.00	0.00	52.85	95.12	396.63	544.59	57.18	1920.51	3217.08	0.00	5196.12	6.19	0.18	1.14
19	550.51	664.39	54.73	0.00	0.00	0.00	0.00	55.37	99.66	400.50	555.52	58.33	1920.51	3248.47	0.00	5196.12	6.25	0.17	1.04
20	550.51	696.08	54.73	0.00	0.00	0.00	0.00	58.01	104.41	404.55	566.97	59.53	1920.51	3281.37	0.00	5196.12	6.32	0.15	0.95
21	550.51	729.29	54.73	0.00	0.00	0.00	0.00	60.77	109.39	408.80	578.97	60.79	1920.51	3315.83	0.00	5196.12	6.38	0.14	0.87
22	550.51	764.07	54.73	0.00	0.00	0.00	0.00	63.67	114.61	413.25	591.54	62.11	1920.51	3351.93	0.00	5196.12	6.45	0.12	0.80
23	550.51	800.52	54.73	0.00	0.00	0.00	0.00	66.71	120.08	417.92	604.70	63.49	1920.51	3389.76	0.00	5196.12	6.52	0.11	0.73
24	550.51	838.70	54.73	0.00	0.00	0.00	0.00	69.89	125.81	422.80	618.50	64.94	1920.51	3429.40	0.00	5196.12	6.60	0.10	0.67
25	550.51	878.71	54.73	0.00	0.00	0.00	0.00	73.23	131.81	427.92	632.95	66.46	1920.51	3470.92	0.00	5196.12	6.68	0.09	0.61
26	550.51	920.62	54.73	0.00	0.00	0.00	0.00	76.72	138.09	433.29	648.10	68.05	1920.51	3514.42	0.00	5196.12	6.76	0.08	0.56
27	550.51	964.54	54.73	0.00	0.00	0.00	0.00	80.38	144.68	438.90	663.96	69.72	1920.51	3560.00	0.00	5196.12	6.85	0.08	0.52
28	550.51	1010.55	54.73	0.00	0.00	0.00	0.00	84.21	151.58	444.79	680.59	71.46	1920.51	3607.76	0.00	5196.12	6.94	0.07	0.47
29	550.51	1058.75	54.73	0.00	0.00	0.00	0.00	88.23	158.81	450.96	698.00	73.29	1920.51	3657.79	0.00	5196.12	7.04	0.06	0.43
30	550.51	1109.25	54.73	0.00	0.00	0.00	0.00	92.44	166.39	457.42	716.25	75.21	1920.51	3710.21	0.00	5196.12	7.14	0.06	0.40
31	550.51	1162.16	54.73	0.00	0.00	0.00	0.00	96.85	174.32	464.19	735.37	77.21	1920.51	3765.13	0.00	5196.12	7.25	0.05	0.37
32	550.51	1217.60	54.73	0.00	0.00	0.00	0.00	101.47	182.64	471.29	755.39	79.32	1920.51	3822.67	0.00	5196.12	7.36	0.05	0.34
33	550.51	1275.68	54.73	0.00	0.00	0.00	0.00	106.31	191.35	478.72	776.38	81.52	1920.51	3882.95	0.00	5196.12	7.47	0.04	0.31
34	550.51	1336.53	54.73	0.00	0.00	0.00	0.00	111.38	200.48	486.51	798.36	83.83	1920.51	3946.11	0.00	5196.12	7.59	0.04	0.28
35	550.51	1400.28	54.73	0.00	0.00	0.00	0.00	116.69	210.04	494.66	821.40	86.25	1920.51	4012.28	0.00	5196.12	7.72	0.03	0.26
36	550.51	1467.07	54.73	0.00	0.00	0.00	0.00	122.26	220.06	503.21	845.53	88.78	1920.51	4081.60	0.00	5196.12	7.86	0.03	0.24
37	550.51	1537.05	54.73	0.00	0.00	0.00	0.00	128.09	230.56	512.17	870.81	91.44	1920.51	4154.24	0.00	5196.12	7.99	0.03	0.22
38	550.51	1610.37	54.73	0.00	0.00	0.00	0.00	134.20	241.56	521.55	897.30	94.22	1920.51	4230.34	0.00	5196.12	8.14	0.03	0.21
39	550.51	1687.18	54.73	0.00	0.00	0.00	0.00	140.60	253.08	531.38	925.05	97.13	1920.51	4310.07	0.00	5196.12	8.29	0.02	0.19
40	550.51	1767.66	54.73	0.00	0.00	0.00	0.00	147.31	265.15	541.68	954.13	100.18	1920.51	4393.60	0.00	5196.12	8.46	0.02	0.17
			7964.20			**6191.37**												**10.36**	71.60
	Levellised Tariff (INR/Kwh)=	**6.91**																	

11. Power Evacuation Arrangement

Chapter – 11

POWER EVACUATION ARRANGEMENT

11.1 General

The transmission systems that are in place in the country consist of Inter-State Transmission System (ISTS) and Intra State Transmission System (Intra-STS).

At the time of independence, power systems in the country were essentially isolated systems developed in and around urban and industrial areas. The installed generating capacity in the country was only about 1300 MW and the power system consisted of small generating stations feeding power radially to load centers. The highest transmission voltage was 132 kV. The voltage level of state-sector network grew from 132 kV level during the 50s and 60s to 220 kV during 60s and 70s. Subsequently, 400kV network was also developed in many states (Utter Pradesh, Maharashtra, Madhya Pradesh, Gujarat, Orissa, Andhra Pradesh and Karnataka) for bulk power transfer over long distances. With the development of state grids in most states of the country, the stage was set for development of regional grid

The National Grid consists of the transmission system for evacuation of power from generating stations, the inter-regional links, Inter State transmission system and Intra-State transmission of the STUs. Thus, development of national grid has been an evolutionary process. The National Grid is a large, meshed synchronous transmission grid where all the regional and State grids in them are electrically connected and operate at single frequency

The country has moved from the concept of regional self-sufficiency to bulk inter-regional transfer of power through high capacity AC and HVDC corridors forming an all-India National Grid

11.2 Reliablity Criterion

Criteria for the system

(A) Under the scenario where a contingency N-1 has already happened, the system may be subjected to one of the following subsequent contingencies (called ‘N-1-1’ condition):

a) The system shall be able to survive a permanent single phase to ground fault on a 765 kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

Demand assessment is an essential prerequisite for planning of generation capacity addition and associated transmission infrastructure required to meet the future power requirement of various sectors of our economy. The type and location of power projects to be planned in the system is largely dependent on the magnitude, spatial distribution as well as the variation of demand during the day, seasons and on a yearly basis. Therefore, reliable planning for generation and transmission capacity addition for future is largely dependent on an accurate assessment of the future demand.

In the 19th Electricity Power Survey report (prepared based on inputs from and consultation with Stake-holders in the Power Sector in the country), the demand for electricity both in terms of peak electric load and electrical energy requirement has been projected. As per 19th Electric Power Survey (EPS) Report, the peak electricity demand 2026-27 is given below:

State/UTs	**2026-27**
Northern Region	97182 MW
Western Region	94825 MW
Southern Region	83652 MW
Eastern Region	35674 MW
North- Eastern Region	6710 MW
Total All India (Peak)(MW)	**298632 MW**

All India transmission network is composed of lines of different voltage levels as given below along with the distances .Total distance of covered by transmission lines in India is **367850 km**

Sno	**Voltage Class**	**km**
a	HVDC ± 500kV/ ± 800 kV-	31240 km
b	765 kV	15556 km
c	440kV	157787 km
d	230/220 kV	163268 km
	Total km	**367850 km**

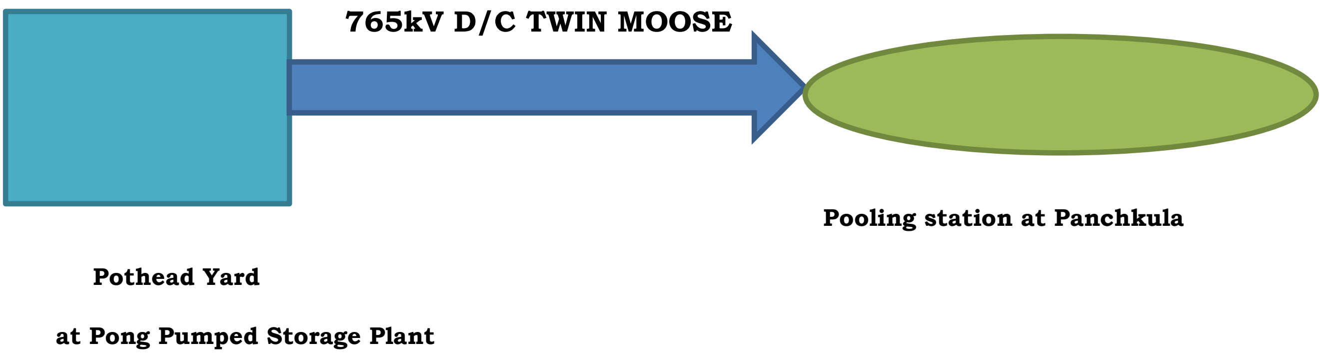
All India power maps is attached as Annexure 1 & 2

BBMB system lies in northern grid. At present power is evacuated from 400 kV, 220 kV, 132 kV & 66 kV system to cater the existing Installed capacity of 2918.73 MW

Now BBMB intends to enhance the existing the existing capacity by making 2800 MW pumped storage hydroelectric power plant at Pong PSP consisting of 8 x 350 MW

Power from 2800 MW pumped storage hydroelectric power plant at Pong PSP would be evacuated through 765 kV D/C transmission line using twin moose or quad conductor lines to Panchkula Pooling station which is approx. 213 km from power house.

Fig .1



BHAKRA BEAS
NATION'S PRIDE

BHAKRA BEAS MANAGEMENT BOARD

An ISO 9001, 14001 Certified Board

Pre Feasibility Study Report

Bhakra Pumped storage Project
(6 x 250 MW)

ISO 9001: 2015

वाप्कोस लिमिटेड
WAPCOS LIMITED
(भारत सरकार का उपक्रम)
जल शक्ति मंत्रालय
(A Government of India Undertaking)
Ministry of Jal Shakti

JANUARY 2023

CONTENTS

TABLE OF CONTENTS

LIST OF DRAWINGS

LIST OF DRAWINGS

Chapter No.	DESCRIPTION	Drawing Number
1.1	General Layout Plan	WAP/BHAKRA-PSP/01
1.2	General Layout Plan (RB-1 Upper Dobar Site)	WAP/BHAKRA-PSP/02
1.3	Longitudinal section along WCS	WAP/BHAKRA-PSP/03
1.4	Cross section of PH	WAP/BHAKRA-PSP/04
1.5	Layout plan of Machine Hall & Transformer Hall floor	WAP/BHAKRA-PSP/05
1.6	L- section of power house	WAP/BHAKRA-PSP/06
1.7	SLD for 400kV GIS	WAP/BHAKRA-PSP/07

1. EXECUTIVE SUMMARY

Chapter-1
Executive Summary

1.1 Preamble

Power is a basic infrastructure for overall development of the nation. It is a necessary input for the economic growth of a country. There has been an ever increasing demand for more and more power generation in the world. India is a fast growing economy through industrialization, irrigation, urbanization, village health to meet the demand of rapidly growing population. And as such the demand for power is much more in India than in developed countries. The chief sources of energy which are now been utilized for generation of electricity are: Fuel in all forms i.e. solid, liquid and gaseous, water energy and nuclear energy. The other sources of energy are sun (solar photo-voltaic etc.), wind and tides.

Hydro-power is a renewable, economical, non-polluting and environmentally benign source of energy. Hydropower stations have inherent ability for instantaneous starting and stopping, to help in improving reliability of power system and to meet the peak demand. Hydroelectric projects have long useful life and help in conserving scarce fossil fuels. In the other ways, because of the inherent source of pollution in thermal generation system, the developed countries are phasing out thermal generation.

Pumped Storage Project is a type of hydroelectric generation plant that stores energy in the form of water, pumped from a lower elevation reservoir to upper elevation reservoir during off-peak period and generates electricity during peak period. This is currently one of the most effective means of storing large amount of electric energy. It helps in grid stability, reliable supply and providing quality power (in terms of voltage and frequency).

The proposed Bhakra Pumped Storage project envisages utilization of water of Gobind Sagar Reservoir (one time only) on river satluj. The water released from upstream project Kol dam and the inflow from intermediate catchments between Koldam Hydropower Station & Bhakra project is impounded by an concert gravity dam known as Bhakra Dam and reservoir is known as Gobind Sagar Reservoir. In present studies lower reservoir would consist of existing Gobind Sagar reservoir while upper reservoir (Proposed new construction) would be for storage of recycled water. 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.

1.2 Project background

The proposal to construct a storage reservoir on the Satluj first time originated in a Note dated 8 November 1908 by Sir Louis Dane indicating Suni and Badu Gorges as being favorable sites for dams for storage and power development. A detailed report on this proposal was submitted in March 1910. And subsequently various revised proposals were prepared for the project. And in 1951, a revised project report was prepared and submitted for final consideration. The full-fledged construction activity started only after April 1952 when team of construction technicians and engineers from America arrived in india. And construction of multipurpose project on river satluj in India for irrigation and power generation completed in the 1963. The total catchment area of Satluj and its tributaries above Bhakra is about 56980 sq. km. the mean annual runoff is about 1.6millon hector meter. The project comprises 225.55 high concrete gravity dam with two power houses having an installed capacity of 1050MW which further has been increased to 1379 MW during course of time by modifying various units still there is proposal to increase the left bank power house capacity from 594 mw to 630 mw. The dam has been named Bhakra Dam after the village of Bhakra which was the first to be submerged by the reservoir.

Further, with a view of utilizing storage available in Gobind Sagar reservoir for Pumped storage Project, preliminary identification studies were carried out by Central Electricity Authority (CEA). In their proposal CEA proposed Majra Pumped Storage scheme with installed capacity of 1800 MW in the vicinity of the Gobind Sagar reservoir of Bhakra Project near Majra village.

Subsequent Water and Power Consultancy Services (WOPCOS) was given the responsibility for formulation of Feasibility Study Report (FSR) for the proposed Pump storage scheme recently by BBMB on 04/07/2022. WAPCOS during preparation of Feasibility studies carried out works of topography, geophysical survey and hydraulic design studies of the project area in upstream of Bhakra dam to identify & evaluate probable projects sites, alternative layouts with alternate dam axis/water conductor system and minimal utilisation of natural resources.

1.3 Present Studies

With this background, initially WAPCOS field office started the work of identification work of as many as potential sites in second week of July, 2022. Initially field office, identified 28 alternatives for 16 identified sites (including CEA identified site Majra) for upper reservoir (Fig-1.1).

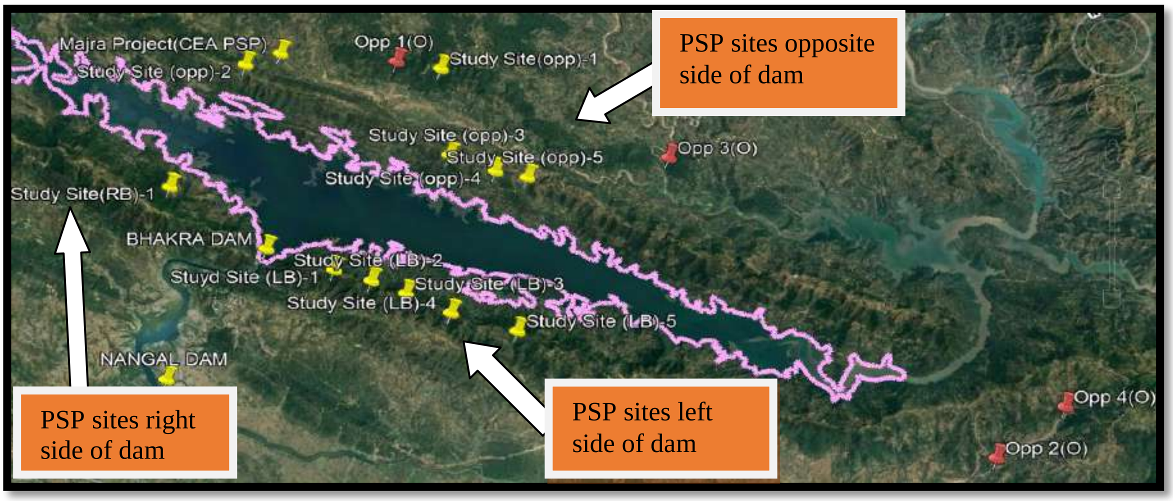


Figure-1.1: Location of 16 identified sites

Later on with further studies for narrowing & project planning of possible sites were carried out during desktop study & various joint site visit by designers, planning experts (HEP) and field staff in between July & August months. After the site visit and thorough planning, designers and experts finally proposed 12 alternatives for feasible 7 site (Fig-1.2) on basis of site works (i.e. topography, geophysical survey & mapping).

Figure-1.2: Location of 7 identified Sites

A comprehensive study and site work was taken simultaneously on these sites and on the basis of survey and feasibility studies finally proposed four (4) possible sites (Fig-1.3). And later Designers & Geologist carried out geological studies of these 4 sites in month of October. And after much technical analysis it is concluded that the sites on right bank will be most favourable from power capacity and techno-economic reasons.

Figure-1.3: Location of 4 identified Sites

Based on the features like gross reservoir capacity, length of the water conductor system and power system, following four alternative including the one identified earlier by CEA were selected for detailed studies for techno-commercial studies and further development in later stages:

i. Dam Axis alternative1 (LB_2_trial 3) near village Lehri.
ii. Dam Axis alternative1 (RB_1_Trial 1) near village Dobar Uparla.
iii. Dam Axis alternative1 (OP_MJ_Trial 5) near village Majra
iv. Dam Axis alternative1 (OP_1(0)_Trial 2) near village Chalaihli/Chhakmoh

1. Lehri PSP Site - Dam axis Alternative1 (LB_2_trial 3)

Upper Dam Axis Alternative-1 (LB_2_trial 3) is located on the left fringe of reservoir and old course of Satluj river near Lehri village uphill Thathal village of Bilaspur district of Himachal Pradesh. This alternative envisages an upper reservoir having estimated live storage capacity of 6 MCM with FRL at EL850m, MDDL at EL770m with the construction of a 100m high and about 600m long dam across a small nala that is aligned through Lehri village. The design discharge is proposed to be conveyed to an underground powerhouse proposed on the left fringe of Gobind Sagar reservoir near village Thatal through 1.58 km long water conductor system with the objective of generating 841 MW of power. The hills around the proposed site were covered with moderately dense vegetation with dense under growth.

2. Dober PSP Site - Dam axis alternative 2 (RB_1_Trial 1)

Upper Dam axis alternative-2 (RB_1_Trial 1) is located on the right fringe of Gobind Sagar reservoir on right flank of Bhakra Dam near Dobar Uparla village of Una district of Himachal Pradesh. This alternative envisages an upper reservoir having estimated live storage capacity of 14.4MCM with FRL at EL750m, MDDL at EL700m with the construction of a 100m high and about 500m long dam across a small nala that debouches into Gobind Sagar reservoir north of Rajpur village. The design discharge is proposed to be conveyed to a pit/underground powerhouse proposed near village Rajpur through. A 1.20 km long water conductor system with the objective of generating 1500 MW of power.

The hills around the proposed site were covered with moderately dense vegetation with dense under growth. Primafacie, the site appears suitable for about 100m high dam.

It is proposed, Shifting the axis towards downstream may make it possible to utilize the saddle on right flank of the proposed dam. If it is possible, this could result in thinking of constructing an earth cum rockfill or rockfill at the site. This possibility is subject to availability of construction material required for an earth dam with further detail investigation for same in DPR stage.

3. Majra PSP Site - Dam axis alternative 3 (OP_MJ_Trial 5)

Upper Dam axis alternative 3 (OP_MJ_Trial 5) alternative is same as that was earlier studied site by CEA. It is located on the opposite bank of the reservoir near Majra village in erstwhile Kangra and now Hamirpur district. The studies carried out then indicated that it was possible to create a reservoir with FRL at EL 720m, MDDL at EL 700m gross storage capacity of 20.2MCM and live storage capacity of 14.9 MCM generate 1800 MW of power through 9 units of 200MW capacity each.

However, the detailed studies carried out at the site by WAPCOS. These studies led to identification of another alternative also i.e. OP_M J_Trial 2. Since the same site as was studied earlier, has been retained as OP_MJ_Trial 5 in the present phase. However, the detailed field topographic surveys carried out at the site indicated substantial reduction in capacity and resultant power generation capacity. The present studies indicated that FRL at EL 720m (same as adopted in earlier studies) and MDDL at EL 690m (10m lower than adopted earlier) the reservoir capacity works out 8.27MCM against 20.2MCM estimated earlier. This resulted in reduction in estimated power generation from 1800MW to 688.22MW. Studies carried out considering another alternative namely OP_MJ_trial 2 with FRL & MDDL levels also indicated that the reservoir capacity reduced to 7.33 MCM and resultant power generation to 662.2 MW.

The site proposed for about 40m high dam near village Singhwa across a tributary of Sarhyali Khad. The hill slopes on both the banks of nala are moderately vegetated with dense under growth. The 1.92km long water conductor system being planned to convey the designed discharge to the lower reservoir.

4. Chhakmoh PSP Site - Dam axis alternative 4 (OP_ 1(0) _Trial 2)

Upper Dam Axis (OP_ 1(0)_Trial2) alternative located near village Chhakmoh on hill range on the foot of which Shah Talai town is located. This alternative envisages an upper reservoir having estimated live storage capacity of 16.31MCM with FRL at EL720m, MDDL at EL680m with the construction of 80m high and about 421m long dam across a small nala that debouches into Sarhyali Khad on on the banks of which Shah Talai town is located. The 3.98 km long water conductor system being planned to convey the designed discharge to the lower reservoir with the objective of generating 1400MW of power.

As mentioned above, the **Dam axis alternative 2 (RB_1_Trial 1)** had lesser length of water conductor system and more power potential has chosen in the present study on the basis of techno-commercial viability. However, the same may be reviewed at the DPR stage when more subsurface and topographical data is available. This scheme with ultimate capacity of 1500 MW, maximum gross head of 304.38m and Upper and Lower Reservoirs have effective storage capacity equivalent to Five (5) hours of generation daily at full rated output, it is possible to operate the project on daily basis has been considered and finally proposed for PSP Scheme.

1.4 Project Location

The proposed Bhakra Pumped Storage Project is located near existing Bhakra Project near Raipur village in Una district, Himachal, India (**Figure 1.4: Location Map)**. The project falls in the area bounded by N - 31˚ 26’ 45”, E - 76˚ 25’ 54” and N - 31˚27’ 37”, E - 76˚25’ 40”**.**

–

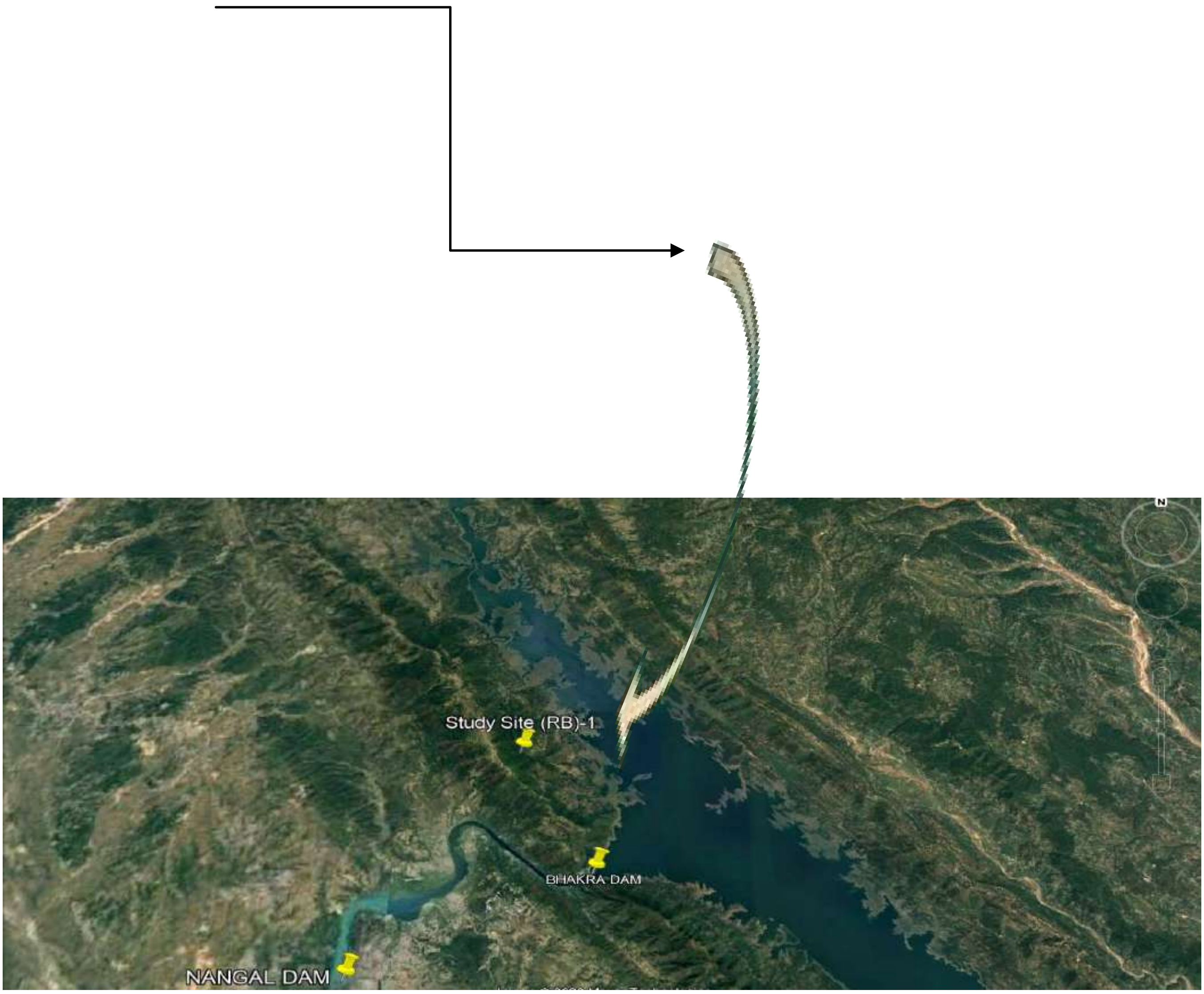


Fig-1.4: Location Map- Dam axis alternative 2 (RB_1_Trial 1)

1.5 Access to the Project

The project is located about 10 km right of Bhakra dam. The nearest rail head is Nangal which is about 20 km from site. Raipur town is about 15 km from the existing Bhakra Project. The nearest airport is Chandigarh International Airport located in Sahibzada Ajit Singh Nagar, Punjab which is about 120 km away from project site.

1.6 Salient Features:

1. Location	
Country **State** **District**	India Himachal Una
River	Satluj river
Dam Axis (Upper)	Left Bank: N - 31˚ 27’ 10.64”, E - 76˚ 25’ 1.97” Right Bank: N - 31˚26’ 51.55”, E - 76˚24’ 59.63”
2. Access to the Project	
Road	20 km from Nangal town
Airport	Chandighar International Airport, Sahibzada Ajit Singh Nagar, Punjab 120 km away
Railhead (with unloading facilities)	Nangal town
3. Project	
Type	Pumped Storage Project
Installed Capacity	6 X 250 MW
Peak Operating duration	5 hours daily
4.0 Civil Structure	
4.1 Upper Reservoir	
Max Water Level	750 M
FRL/FRL considered	750 M
MDDL	700 M
Gross Storage capacity	19.3 MCM
Live storage	14.4 MCM
4.2 Lower Reservoir	
FRL	512.07 M
MDDL	445.62 M
Reservoir surface area at FRL	168.35 sq. km
Gross capacity at MWL	7.04 BCM
Live storage	5.65 BCM

4.3 Upper Dam	
Type	Concrete Gravity
Top of Dam	EL 752 M
River Bed Elevation	EL 650 M
Total Length of Dam at top	500 m
Max. Height of Dam	100.00 m (from bed level)
Top width of dam	10 m
4.4 Intake Structure	
Type	Trapezoidal type with anti-vortex louver
H x W x L x No. x Line	11 m x 16.36 m x 79.4m 2 no's x 1 line
Dia. Of Tunnel	7.0m
4.5 Headrace Tunnel cum Pressure Shaft (Steel Lined)	
Diameter	11.5 m
Length	350m
No. of Tunnel	1
4.6 Pressure Shaft (Steel Lining)	
D x L x line	-
After Bifurcation	4.5m x 150m x 6 lines
4.7 Tailrace Tunnel (Steel Lined)	
Diameter	11.5 m
Length	600 m
No. of Tunnel	1
4.8 Powerhouse	
Type	Underground Cavern
Size	265.00 m (L) x 23 m (W) x 55 m (H)
4.9 Transformer Room including Secondary GIS	
Type	Underground Cavern including Secondary GIS
L x W x H	260.00 m (L) x 18.50 m (W) x 28.00 m (H)
4.10 Main Access Tunnel (MAT)	
Type	D- shaped, Length – 500m
W X H	8.00 m (W) x 8.50 m (H)

5.0 Electromechanical Equipment	
5.1 Pump Turbine	
Turbine	
a) Rated Output at rated net head of 241 m	253.81 MW
b) Specific Speed	132.48 rpm
c) Rated Speed	214.29 rpm
d) Centerline of Turbine	EL. 396.00 m
Pump Basic Data	
a) Pump Input at rated net head of 245.82 m	254.33 MW
b) Specific Speed	34 rpm
c) Rated Speed	214.29 rpm
d) Rated Pump discharge	97.03 cumec
5.2 Generator-Motor	
Rated Output	250 MW
Power Factor (Generation Mode)	0.85 lagging
Power Factor (Pumping Mode)	0.95 leading
Frequency	50 Hz
Phases	3 (Three)
Speed	214.29 rpm
Rated Terminal Voltage Between phases	18 kV
Range of frequency	(-) 5 % to (+) 3 %
Bearing arrangement	Semi Umbrella Type
5.3 Transformers	
Type	Indoor type, oil-immersed, three phase, with on-load tap charger(OLTC) for pumping operation, OFWF Cooled
Number	6+1 (one spare transformer)
Rated Capacity	324 MVA, Three phase
Rated Voltage	Primary; 18 kV Secondary; 400 kV Adjustable range of the secondary voltage: -5% to +5%
Connection	Primary: Delta

	Secondary: Star
Neutral Grounding System for Secondary Winding	Solidly Grounded
5.4 Gas Insulated Switchgear	
Bus System	Double bus
No. of bays	11
5.5 200kV XLPE Cable	
Type	Single Core 420 kV cross linked polyethylene insulated type.
Rated Voltage	420 kV
Number of Circuits	4 nos.
5.6 EOT Crane	
Type	Indoor, Electric Overhead Traveling crane
Number of Unit	Two (2) units
Rated Capacity	300 ton (Main hoist), 50 ton and 10 ton
Span	20.00 m
5.7 Project Cost (Price Level Year, 2022)	
Item	**Estimated Cost (Rs. Crore)**
Civil Works	3241.32
Electro-mechanical Works	3268.68
IDC	668.59
Total	**7178.59**
5.6 Project Benefit's	

Sl. No.	**Off Peak Energy Rate (Rs/kWh)**	**Levelized Tariff (Rs/kWh)**	**Conversion Cost of the Project (Rs/kWh)**
1	1	6.54	5.23
2	1.5	7.20	5.23
3	2	7.86	5.23
4	2.5	8.51	5.23

2. ECONOMIC SCENE AND POWER SCENARIO

Chapter-2

ECONOMIC SCENE & POWER SCENARIO

Power is among the most critical components of infrastructure, crucial for the economic growth and welfare of nations. India power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil, hydro, nuclear to viable non-conventional sources such as Solar, wind, agriculture & domestic waste. Electricity demand in the country has increased rapidly and is expected to rise further in the years to come in order to meet the increasing demand for electricity in the country, massive addition to the installed capacity is requested.

The development of requisite power infrastructure is key for sustained growth of Indian economy. India has witnessed a significant transformation from being an acutely power deficit country to a situation of demand being fully met. India has also made remarkable strides to ensure universal access to electricity for every household.

Over the years the installed capacity of power plants has increased to 399496 MW as on 31.3.2022 from a meager 1362 MW in 1947.

2.1 Power Scenario in Country

	Installed Capacity (As on 31.3.2022)	
Thermal	236108.72	MW
Hydro		
Conventional	42104.55	MW (above 2.5 MW)
Pumped Storage	4745.60	MW
Renewables	109757.75	MW
Total	399496.62	MW

Hydro
Region Wise installed Capacity

	Installed Capacity (As on 31.3.2022)
Northern	19696.25 MW
Western	7392.00 MW
Southern	11747.15 MW
Eastern	5987.75 MW
North-Eastern	2027.00 MW
Total (All India)	46850.15 MW

Installed Capacity of BBMB

Bhakra Left	4x126 + 1x 108	612	MW
Bhakra Right	5x157	785	MW
Dehar	6x165	990	MW
Pong	6x66	396	MW
Total		2783	MW

Per capita Electricity consumption

The per capita electricity consumption during 2017-22 is summarized as below

Per Capita Electricity Consumption

Year	PER Capita Consumption (kwh)
2017-18	1149
2018-19	1187
2019-20	1208
2020-21	1161

2.2 Demand Assessment

Demand assessment is an essential prerequisite for planning of generation capacity addition and commensurate transmission and distribution system to meet the future electricity requirement. The electricity demand of the country in terms of peak load and energy requirements

For the period from 2022-27 &2027-2032

Projected Region wise electrical energy requirements & Peak electricity demand for the years 2026-27 & 2031-32

Region	Electrical Energy Requirement (MU)		Peak Electricity Demand (MW)	
Northern	2026-27	2031-32	2026-27	2031-32
	564774	762045	86187	117128
Western	573200	792574	84097	114285
Southern	504245	682202	74108	100710
Eastern	200611	266775	31638	42295
North Eastern	31170	44862	5951	8087
All India	1874000	2538458	272000	363188

Note: The electricity demand projection covers electricity demand only for the utility system

The projections do not include the portion of electricity demand of industries and other consumers that would be met from the captive power plants

The electrical energy requirements and peak electricity demand on all-India has been projected at 1874 BU and 272 GW in 2026-27 & 2538 BU and 363 GW in 2031-32 respectively. These projections include impact of solar rooftop, green hydrogen, EV and Energy efficiency measures.

Promotion of Hydro Projects.

For boosting the generation of Hydro Power, the Government of India on 8.3.2019 approved a number of measures of promoting hydropower sector in the country which are as under.

- Declaring Large Hydro .25 MW as Renewable Energy source
- Hydro Purchase obligation (HPO) as a separate entity with Non-Solar Renewable Purchase Obligation (RPO)
- Tariff rationalization measures for bringing down hydropower tariff.
- Budgetary Support for flood moderation/ storage Hydro Electric projects (HEP's)
- Budgetary support to cost of Enabling infrastructure i.e. roads/bridges a) Rs.1.5 Crore per MW for projects upto 200 MQ b) Rs. 1.0 Crore per MW for projects above 200 MW

2.3 Storage System

The next phase of energy transition drives by the large scale deployment of variable renewable energy sources (VREs) like Solar and wind power can be fully realized by Key Technologies of Energy Storage. The grid integration challenges of the intermittent generation sources ensuring quality of supply on real time basis along with the capability to store excess electricity over different time horizons can be achieved by the electricity storage systems. Many Grid scale energy storage systems are commercial available worldwide which include pumped storage plants, Battery energy storage systems etc. However, many other energy storage technologies like green hydrogen are in stage of development.

2.4 Pumped Hydro Storage Systems

While many forms of energy storage systems have been installed globally. Pumped storage plants (PSP) are playing an increasingly significant role in providing peaking power and maintaining system stability in the power system of many countries. Pumped storage resources is the long term technically proven, highly efficient, environmental friendly and flexible way of energy storage on a large scale to store intermittent and variable energy. PAP improve overall economy of power system operation and reduce operational problems of thermal stations during low load period. The other advantages of pumped storage resources are availability of spinning reserve at almost so cost to the system and regulating grid frequency to meet sudden load changes in the network. It also can provide ancillary benefits such as flexible capacity, voltage support and Black start facility etc. pumped storage Resource has advanced significantly since its original introduction and now includes adjustable speed pumped turbines which can quickly shift from motors to generator, to synchronous condenser mode, for easier and more flexible operation of the grid. The concept of off-river PSP is getting popular in recent years due to huge benefits arising out to its fewer capital cost/operations. Currently India is exploring the off-river storage systems which can be executed with lesser cost and at a fast pace .

3. HYDROLOGY

Chapter-3

Hydrology

3.1 Background:

In any Hydroelectric Project (HEP) and Pumped Storage Project (PSP), hydrological inputs play a vital role in planning, execution and operation of these project. Hydrological studies are carried out at all stages of development starting from Pre-feasibility stage, detailed project report (DPR) stage and even during their operation. However, PSP projects are slightly different in a sense that such projects recycle the water between the two reservoir i.e. upper reservoir and lower reservoir. Normally there is no consumptive use of water requirement (except making good for evaporative loss and machine loss). Therefore, PSP projects have negligible impact on hydrological regime and as such the criticality of its impact on hydrology are minimum in case of their proposed installation on existing/ongoing projects.

The Proposed Bhakra PSP envisages utilisation of water of existing Bhakra (Gobind Sagar) reservoir on Satluj River having spread in three districts i.e Bilaspur, Hamirpur and Una of Himachal through installation of 1500 MW power plant, which would be equipped with six vertical axis reversible type hydro-electric units each comprising of generator-motor and a pump turbine with a generating capacity of 250 MW each. Lower reservoir would consist of existing Gobind Sagar reservoir while upper reservoir (Proposed new construction) would be for storage of recycled water at the foot-hill.

3.2 Objective of the study:

The proposed study aims to harness the various parameters for project planning and design of proposed Bhakra Pump Storage scheme. Since more than five decades have passed while power generation started at Bhakra powerhouse and there might be changes in water availability, it is considered necessary to update the hydrology based on recent hydrological data to assess the impact on water availability for existing Gobind Sagar reservoir for running the proposed PSP scheme utilising the present up to date data.

- To assess the impact of proposed PSP scheme on the release of water for D/s states from existing Gobind Sagar reservoir.
- To assess additional peaking power generated thereof from the proposed scheme.
- Since Gobind Sagar reservoir is in existence and meeting the existing demands of irrigation and power; no fresh design flood studies are required.
- To assess the efficacy of combined project in association with existing demands using the existing storage of Gobind Sagar reservoir i.e. based on recent hydrograph survey (if available).

3.3 Existing Satluj river system:

The Gobind Sagar reservoir on satluj river constructed earlier envisaged installation of five units of generating sets of 90 MW each (450 MW) at left bank and five units of generating sets of 120 MW each (600 MW) at right bank and proposed for further uprating of these units on both side under Renovation, Modernisation & Uprating (R,M &U) works later. Subsequently after R, M&U on Left Bank and Right Bank power plants in later years, the project authorities raised total installed capacity of project to 1379 MW presently.

Since Bhakra project supplies water to Punjab, Haryana, Rajasthan & Delhi, as such as per initial water power studies the releases from Gobind Sagar reservoir shall be governed by primarily from irrigation considerations, but these studies indicated that generated firm power would be only 62% of the all-time power available for the firm power. Therefore to increase the firm power generation various water power studies were carried out during i. Pre-right bank Plant stage, ii Post-right Bank plant stage & iii Post Beas-Sutluj Link Stage to optimise utilisation of available all-time available firm power.

In fact, Bhakra Power Project forms the second stage of development of Sutlej river development. And the released water of Bhakra power houses & Spillway together with intermediate catchment between Bhakra & Nangal dam are impounded by an concrete dam at Nangal and is called as Nangal Dam. The inflow into Bhakra reservoir is thus shared between the states on basis BBMB reorganisation act. A line diagram of existing Satluj river system is shown in fig 3.1 below.

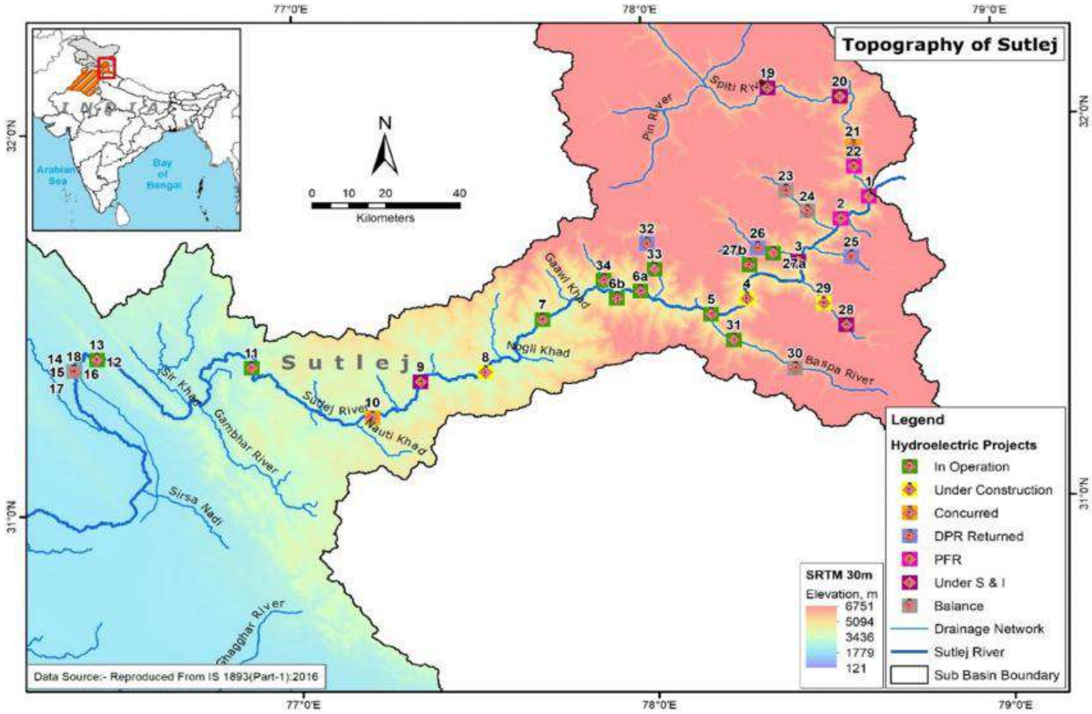


Fig. 3.1: Existing Satluj River System (Line Diagram)

3.4 Project Catchment:

The proposed projects is planned on tributaries of Satluj River and with existing Bhakra reservoir (Gobind Sagar) as lower reservoir, spreads in the districts hamirpur, bilaspur & una in himachal state. The Langqen Zagbo river (called as Satluj river in india downstream) originates near Rakastal which is fed by the lake Mansrover in the Tibetan Plateau at an elevation level (EL) of about 4,572M. The River Sutlej travels about 322 Kms inside the

Tibetan province and then enters India near Shipkilla (Tashigang-village) and further Sutlej River travels about 300 Kms upto Bhakra Dam. The river takes a meandering course during its passage. This large river has varying climatic and topographic conditions. The total catchment area is about 56,980 Sq. Kms, out of which only about 20,000 Sq. Kms lie in India. In the Indian region an area of about 9,000 Sq. Kms. gets only snowfall, an area of about 5,500 Sq. Kms gets both snow and rain and an area of about 5,500 Sq. Kms only rainfall. The important tributaries of the Satluj River are the Soel khad, Alseed khad, Ali khad, Gamrola khad, Ghambhar khad, Seer khad, Sukhar khad, Sarhali khad, and Lunkar khad It joins Sabari River which ultimately joins Godavari River.

The major objective of Bhakra scheme was to provide irrigation and secondary hydro power generation trough regulated water was ultimately released from power house to irrigate 61034ha. The salient features of existing Bhakra Dam are as under.

Location	Bilaspur, Hamirpur and Una district of Himachal
Catchment area	56980 km^2
River	Satluj in Indus Basin
Gross Capacity	7.04 BCM
Live Capacity	5.65 BCM
Dam type	Concrete Gravity Dam

3.5 Present study: Pump Storage Project (1500 MW)

The present proposal of pump storage scheme envisages utilisation of already existing and operational Bhakra reservoir as its Lower reservoir. An Upper reservoir has been proposed at uphill of Bhakra reservoir (Gobind Sagar) by construction of Gravity Dam of approx. 100.0 m height so as to entail a live storage of about 14.14Mm^3. It would act as a balancing reservoir for re-cycling of water.

It is proposed to install two vertical-axis reversible type hydro-electric units comprising of generator–motor and a pump turbine each having generating capacity of 250 MW (Total installed capacity would be 1500MW). The water thus would be re-cycled between upper proposed reservoir and lower Gobind Sagar reservoir. Thus the existing set up of hydro-power generation and utilisation from Bhakra existing reservoir would not be disturbed as enough storage is available in Bhakra reservoir and it would meet the one time water requirement of recycling of water for proposed PSP.

A Google map of the existing Gobind Sagar reservoir including Dam location is at fig.3.2 below.

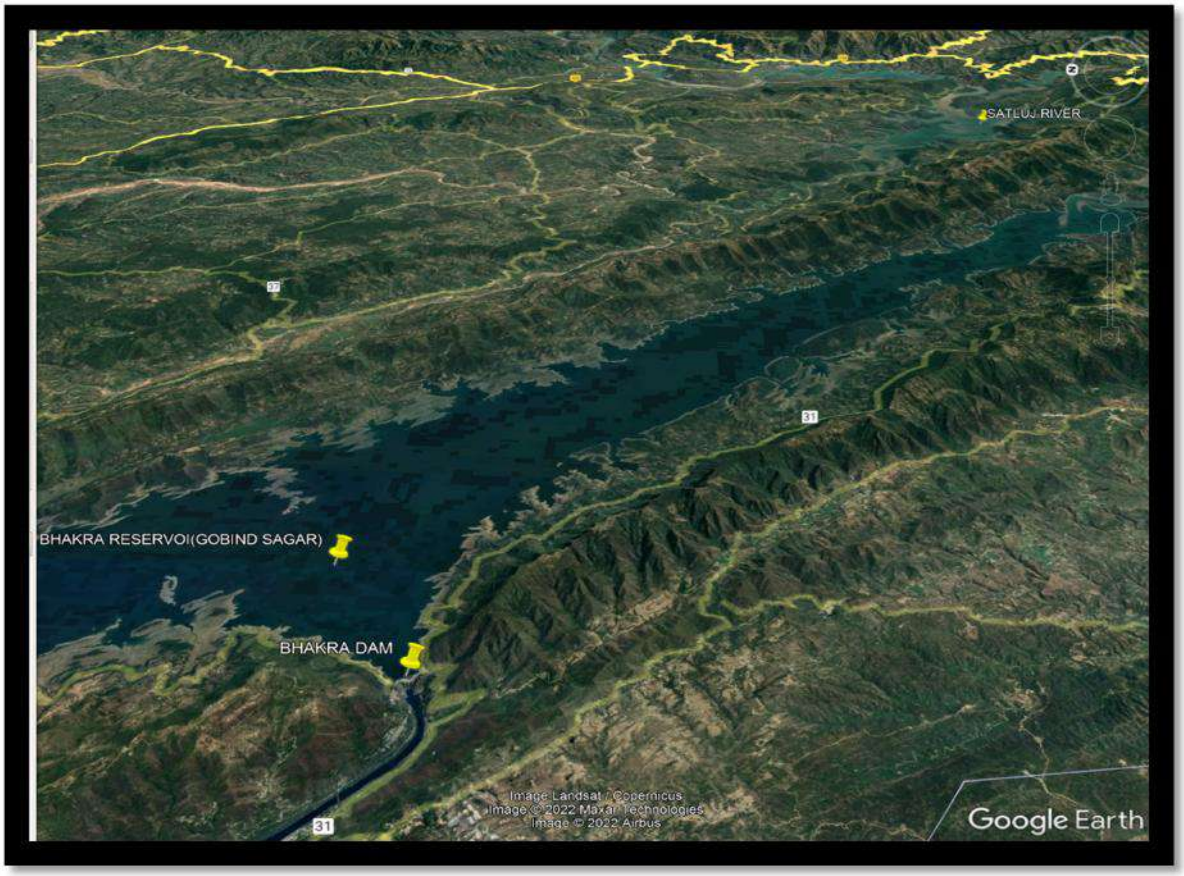


Fig. 3.2: Google Image of the Project Area

Since no major storage structure is proposed except construction of small upper reservoir, underground/surface power house and appurtenant structures like HRT, pressure shaft, penstock tunnel, TRT , transformer hall etc. and the present scheme would utilize the facilities of existing Bhakra reservoir to reduce the cost of construction.

3.6 Data Availability:

Satluj River and its tributaries are well gauged along its course. BBMB, Central Water Commission (CWC) and India Meteorological Department (IMD) collect the relevant data on this river.

3.7 Meteorological Data:

The FSR study report prepared for Bhakra reservoir is based on rainfall data of 20 years (2002-2021), considering four rain gauge stations inside the catchment available with BBMB. (Reff -Annexure-3.1).

3.8 Discharge Data

Annually out flow discharge data is available at Bhakra reservoir site. The project authorities were requested to supply the same including power generation releases data, spills, flood releases etc. from Bhakra reservoir. It has been indicated in earlier para that no CWC G&D site exists in the neighbourhood of Bhakra reservoir.

The FSR appended the annual runoff of Bhakra catchment (CA= 56980 km^2) for the period 2001 to 2021 (20 years) in report. In absence of daily available runoff data for Bhakra Catchment, this data has been considered for the present study due to pending collection/supply of relevant data by project authorities. (Reff -Annexure-3.2)

3.9 Evaporation Data

Evaporation data is available at Bhakra reservoir (Govind Sagar). For the same, monthly/daily evaporation rate has been taken from Authorities. The daily evaporation rate in each month is given in Table 3.1 below.

Table- 3.1: Evaporation depths (mm/month)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
mm/ month	65.73	73.05	109.96	146.05	165.85	175.79	199.33	131.72	171.68	96.68	60.10	48.33

3.10 Water Availability

The proposed Pump Storage Project (PSP) aims to utilize the storage of existing Govind Sagar reservoir and the releases of water for downstream states as per BBMB act for recycling (one time only as water is recycled). Only the surplus storage in the reservoir is proposed to be recycled for operation. As such, the water availability is ensured based on long term inflow & outflow data from the existing Bhakra reservoir. Accordingly water availability has been assessed for Bhakra reservoir using Bhakra dam annual runoff data. Since monthly flows of Bhakra dam are available for the period 2002 to 2021, same has been utilised in the study. Since monthly and annual runoff for Bhakra reservoir catchment (refer annexure 3.2) are available the same have been considered to conduct the P Tests and F Tests. The Project catchment area map is as below.

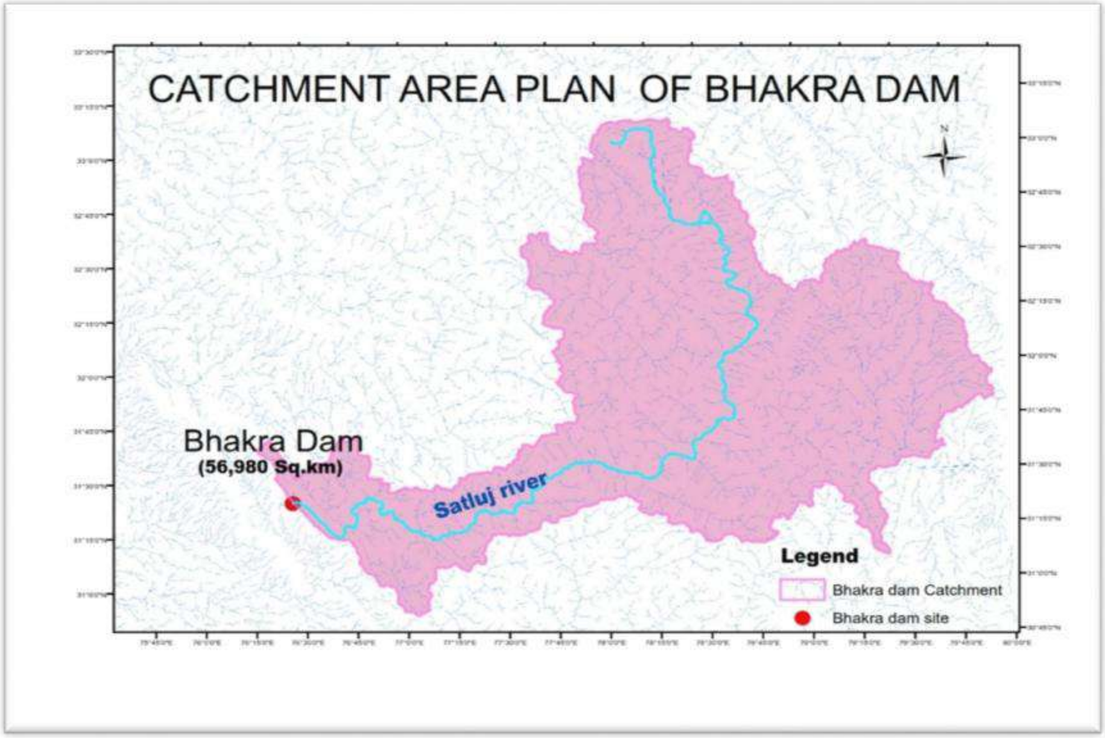


Fig. 3.3: Project Catchment area map

3.11 Statistical Tests

T Test and F Tests have been carried out for the observed inflow flows for Bhakra dam G&D site for the period 2002-2021. The inflow series have been bifurcated in two equal parts while carrying out the relevant tests as detailed in Tables below.

Table 3.2 : Bhakra Dam G&D Site- F-Test Two-Sample for Variances

F-Test Two-Sample for Variances		
	Variable 1	*Variable 2*
Mean	199502.6486	188402.2708
Variance	775874540.9	244107323
Observations	10	10
df	9	9
F	3.178415671	
P(F<=f) one-tail	0.050020973	
F Critical one-tail	3.178893104	

Table 3.3: Bhakra Dam G&D Site- t-Test: Paired Two Sample for Means

t-Test: Paired Two Sample for Means		
	Variable 1	*Variable 2*
Mean	199502.6486	188402.2708
Variance	775874540.9	244107323
Observations	10	10
Pearson Correlation	0.817828507	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.999667529	
P(T<=t) one-tail	0.038296934	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.076593869	
t Critical two-tail	2.262157163	

Table 3.4: Bhakra Dam G&D Site- t-Test: Two-Sample Assuming Equal Variances

t-Test: Two-Sample Assuming Equal Variances		
	Variable 1	*Variable 2*
Mean	199502.6486	188402.2708
Variance	775874540.9	244107323
Observations	10	10
Pooled Variance	509990932	
Hypothesized Mean Difference	0	
df	18	
t Stat	1.09911095	
P(T<=t) one-tail	0.143101851	
t Critical one-tail	1.734063607	
P(T<=t) two-tail	0.286203703	
t Critical two-tail	2.10092204	

Table 3.5: Bhakra Dam G&D Site- t-Test: Two-Sample Assuming Unequal Variances

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	199502.6486	188402.2708
Variance	775874540.9	244107323
Observations	10	10
Hypothesized Mean Difference	0	
df	14	
t Stat	1.09911095	
P(T<=t) one-tail	0.145130947	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.290261894	
t Critical two-tail	2.144786688	

An examination of above tables indicates that T-statistics of the two series for both the site are less than the critical values at 95% confidence level for both one tail and two tail. Similarly, F statistics are also less than the critical values at 95% confidence level, thereby indicating better data quality and belong to the same sample. The inflow series at Bhakra RL 1700 G&D site are homogeneous and the test values are within the permissible critical limits.

3.12 Conclusion

A comparison of result by the above methods viz-a-viz study has been made to assess the series to be adopted for power potential studies which may not affect the functioning of existing Bhakra project.

3.13 Design flood

The associated dam/reservoir is existing and in operations for the last several decades and have withstood the floods without any Damage to civil structure. Moreover, the proposed scheme is a pumped scheme and do not envisage any change in existing operating levels of the reservoir. No structural modifications/interface are required in existing dam. As such, the spillway provisions are already in place and are in operation successfully. As such design flood re-assessment is not required in the present study.

3.14 Sedimentation

No recent hydrographic survey data has been carried out for Bhakra reservoir. The elevation area capacity curves as available are being recommended for utilization since the quantum of water being used for proposed PSP study is miniscule. As such sedimentation is not an issue at present.

3.15 Limitation of study

The study has been carried out based on the limited available inflow runoff data of Bhakra dam.

Annexure -3.1

Daily Rainfall (MM) at Bhakra (RL 1700) Site in Satluj Catchment

Month	Mon-days	Days	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1	1	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	2	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	3	3	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	0.0	0.0	0.0	1.0
1	4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	6.5	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0
1	5	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	6	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	12.0
1	7	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	32.0	0.0	1.2	8.0	8.0
1	8	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.5	0.0	0.0	0.0	0.0	12.9	0.0	0.0	14.0	0.0
1	9	9	0.0	0.0	0.0	0.0	0.0	0.0	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5	0.0
1	10	10	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	11	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	12	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	13	13	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	1.8	0.0	0.0
1	14	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	17.7	0.0
1	15	15	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.5	6.5	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0
1	16	16	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	65.5	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0
1	17	17	0.0	0.0	0.0	3.0	7.5	0.0	1.0	0.0	0.0	0.0	21.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0
1	18	18	8.0	0.0	5.0	0.0	5.0	0.0	14.0	0.5	0.0	0.0	0.0	7.5	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	19	19	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.8	0.0	0.0	5.5	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	20	20	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	21	21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
1	22	22	0.0	0.0	23.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.5	0.0	0.0	0.0	27.5	0.0	0.0
1	23	23	0.0	0.0	48.5	20.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.0	36.0	0.0	0.0	0.0	23.0	0.0	0.0
1	24	24	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	3.0
1	25	25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	26	26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.8	0.0	0.0	0.0	0.0
1	27	27	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	32.5	0.0	0.0	0.0	0.0
1	28	28	0.0	14.5	0.0	21.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0
1	29	29	0.0	26.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	13.5	0.0
1	30	30	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0	0.0	0.0	0.0
1	31	31	0.0	5.5	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1	32	0.0	11.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
2	2	33	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3	34	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4	35	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
2	5	36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	8.4	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
2	6	37	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	5.5	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
2	7	38	0.0	0.0	0.0	28.0	0.0	0.0	5.4	3.5	0.0	1.5	0.0	0.0	15.5	0.0	7.8	0.0	0.0	9.5	0.0	0.0
2	8	39	1.0	0.0	0.0	3.0	0.0	0.0	4.9	0.0	4.5	13.5	0.0	0.0	10.5	0.0	1.0	0.0	0.0	72.2	0.0	0.0
2	9	40	7.5	0.0	0.0	1.0	0.0	0.5	0.0	0.0	16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	10	41	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	11	42	0.0	0.0	0.0	4.9	0.0	50.5	0.0	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	12	43	23.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	13.6	0.0	0.0	0.0
2	13	44	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0	0.0	2.5	1.5	0.0	0.0	0.0	0.0	0.0	19.5	0.0	0.0	0.0
2	14	45	0.0	0.0	0.0	0.0	0.0	10.6	0.0	4.0	0.0	1.5	3.5	0.0	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	15	46	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	22.5	0.0	0.0	10.0	0.0	0.0	0.0	0.0	25.0	0.0	0.0
2	16	47	0.0	0.0	0.0	77.9	0.0	0.0	0.0	0.0	0.0	75.5	0.0	5.2	8.7	2.5	0.0	0.0	0.0	6.0	0.0	0.0
2	17	48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0
2	18	49	0.0	10.5	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	19	50	0.0	34.0	0.4	18.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	11.0	0.0	0.0
2	20	51	0.0	0.0	0.0	21.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.5	7.0	0.0	0.0	0.0	0.0	0.0
2	21	52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	14.0	11.0	0.0	0.0	1.5	1.2	0.0

2	22	53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	12.5	0.0	0.0	0.0	0.0	12.5	0.0	0.0
2	23	54	11.5	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	24	55	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	25	56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0
2	26	57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	0.0	16.0	0.0
2	27	58	0.0	0.0	0.0	0.0	1.6	6.5	0.0	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	9.5	0.0	0.0
2	28	59	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0	0.0	0.0	0.0	6.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	29	60			0.0				0.0				0.0				0.0				2.5	
3	1	61	1.5	29.0	0.0	0.0	0.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	21.0	92.0	0.0	0.0	0.0	0.0	10.0	0.0
3	2	62	8.5	12.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	42.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3	63	10.0	14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.5	0.0	0.0	0.0	0.8	0.0	0.0	0.0	7.0	0.0	0.0
3	4	64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
3	5	65	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
3	6	66	0.0	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	8.0	0.0	0.0	0.0	6.0	0.0
3	7	67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0	0.0	22.0	0.0
3	8	68	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.5	0.0	1.2	0.0	0.0	6.5	6.5
3	9	69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.1	0.0	0.0	0.0	0.0
3	10	70	3.0	0.0	0.0	12.5	1.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0	5.5	0.0	0.0	0.0	0.0
3	11	71	0.0	0.0	0.0	16.4	4.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.5	0.0	0.0	0.0	0.0	0.0
3	12	72	0.0	0.0	0.0	0.0	0.5	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	3.0	28.5	0.0
3	13	73	0.0	0.0	0.0	0.0	0.0	48.5	0.0	0.0	0.0	0.0	2.0	1.8	0.0	0.0	13.8	0.0	0.0	0.0	36.0	0.0
3	14	74	0.0	0.0	0.0	0.0	2.0	44.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.2	0.0	0.0	1.0	25.0	0.0
3	15	75	0.0	0.0	0.0	0.0	100.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	1.0	0.0	0.0	2.2	7.8	0.0
3	16	76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0
3	17	77	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	18	78	0.0	0.0	0.0	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0
3	19	79	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	20	80	0.0	0.0	0.0	2.6	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.7	0.0	0.0
3	21	81	0.0	0.0	0.0	0.5	0.0	1.5	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	22	82	0.0	0.0	0.0	17.5	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	1.0
3	23	83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	2.2	0.0	0.0	0.0	0.0	0.0	0.0	4.5
3	24	84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
3	25	85	1.5	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0
3	26	86	0.0	0.0	0.0	0.0	1.4	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	27	87	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	28	88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.5	1.5	0.0	0.0	0.0	0.0	4.2	0.0
3	29	89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0	13.2	0.0	0.0	0.0	0.0	0.0	0.0
3	30	90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	31	91	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	1	92	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.0	0.0	0.0	0.2	0.0
4	2	93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.5	0.0	0.0	0.0	0.0	0.0	0.0
4	3	94	2.0	0.0	0.0	0.0	0.0	0.0	0.5	6.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
4	4	95	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.4	0.0	0.0	0.0	0.0
4	5	96	0.0	21.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.0
4	6	97	0.0	0.0	0.0	0.0	0.0	0.0	16.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	7	98	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	1.5
4	8	99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.0	1.0	0.0
4	9	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0
4	10	101	0.0	0.0	0.3	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	11	102	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	1.5	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0
4	12	103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.5	0.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0
4	13	104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	14	105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	15	106	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	6.5	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0	0.0
4	16	107	0.0	1.5	0.0	0.0	0.0	0.0	1.5	0.5	0.0	2.6	0.0	0.0	1.5	0.5	0.0	0.0	0.2	0.0	0.0	0.0

4	17	108	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.5	0.4	0.0	0.4	0.0	0.0	0.0	0.0	15.5	0.0	1.5
4	18	109	0.0	0.0	0.0	0.0	0.0	25.7	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	2.5	0.0	0.0	8.0	7.6	2.0
4	19	110	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0
4	20	111	0.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
4	21	112	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	2.5	0.0	0.0	0.0	0.0	5.5	2.5	0.0	3.5	8.5
4	22	113	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0		0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0	1.0
4	23	114	0.0	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.5	0.0	7.5	0.0	0.0	0.0	17.5
4	24	115	8.5	0.0	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5
4	25	116	7.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0
4	26	117	11.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
4	27	118	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0
4	28	119	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	3.2	4.8	0.0	0.0	0.0
4	29	120	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.1	0.0	0.0	0.0
4	30	121	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	2.5	0.0	0.0	0.0	1.0
5	1	122	0.0	0.0	17.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
5	2	123	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	3	124	0.0	0.0	0.0	4.2	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	1.5	0.0	0.0
5	4	125	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	5	126	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	16.2	0.0	0.0	0.0	0.0	0.0
5	6	127	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
5	7	128	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
5	8	129	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	9	130	0.0	0.0	0.0	0.0	20.5	1.2	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	10	131	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	11	132	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.8	20.0	1.5	19.0	0.0	0.0	0.0	0.0	11.0
5	12	133	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.0	1.6	12.8	14.5	0.0	0.0	0.0	0.0	0.0	0.0
5	13	134	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	10.5	0.0	0.0	0.0	0.8	0.0	0.0	1.0
5	14	135	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
5	15	136	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	16	137	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	17	138	0.0	0.0	0.0	0.0	12.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	0.0	0.0
5	18	139	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0
5	19	140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
5	20	141	0.0	0.0	0.0	0.0	22.0	6.0	8.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	21	142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	2.5	0.0	0.0	0.0	0.0
5	22	143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	23	144	0.0	4.0	18.0	0.0	26.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	24	145	0.0	0.0	4.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.0	0.0	0.0	0.6	0.0	0.0
5	25	146	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	26	147	4.5	0.0	0.0	0.0	0.0	0.0	15.4	0.0	0.0	14.5	0.0	3.5	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0
5	27	148	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	28	149	0.0	0.0	2.2	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0
5	29	150	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	2.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
5	30	151	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	0.0	0.0	0.0	0.5
5	31	152	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	1	153	0.0	0.0	0.0	0.0	19.5	0.0	0.0	1.5	0.0	37.5	0.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
6	2	154	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	3.0	0.0	0.0	9.5	7.0	0.0	0.0
6	3	155	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
6	4	156	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	2.4	0.0	0.5
6	5	157	0.0	0.0	0.0	0.0	4.5	0.0	4.5	0.0	4.5	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
6	6	158	0.0	0.0	0.0	0.0	0.0	0.0	7.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	25.8	6.0	0.5	29.0	0.0
6	7	159	0.0	0.0	29.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.5	0.0	0.0	11.2	0.0
6	8	160	0.0	0.0	0.0	2.0	0.0	0.0	3.5	0.0	22.5	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0
6	9	161	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.5	0.0	0.0	0.0	0.0	0.0	3.8	0.0	32.5	0.0	0.0	0.0
6	10	162	0.0	0.0	0.0	0.8	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0

6	11	163	0.0	15.5	9.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0	24.4	0.0	0.0	1.8	0.0	0.0	0.0	0.2	0.0
6	12	164	17.0	0.0	1.0	0.0	0.0	22.5	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7
6	13	165	0.0	0.0	0.0	0.0	0.0	0.0	8.5	0.0	11.2	0.0	0.0	71.5	0.0	0.5	0.0	0.0	0.0	0.0	0.0	25.9
6	14	166	0.0	0.0	0.0	0.0	0.0	19.0	1.6	0.0	10.4	7.5	0.0	30.8	0.3	0.0	0.0	11.5	0.0	0.0	0.0	0.0
6	15	167	0.0	0.0	13.0	0.0	0.0	6.0	79.0	0.0	0.0	31.5	0.0	92.5	0.0	0.0	20.0	0.4	0.0	0.0	0.0	0.0
6	16	168	0.5	0.0	0.0	0.0	1.5	4.0	10.5	11.8	0.0	0.0	0.0	0.0	0.0	0.0	31.7	0.0	16.5	0.0	0.0	6.5
6	17	169	3.0	0.0	0.0	0.0	1.0	0.0	0.0	7.4	0.0	12.0	0.0	6.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	10.7
6	18	170	10.0	15.0	9.0	0.0	0.0	0.0	44.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	2.0	0.0	0.0
6	19	171	0.0	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0	0.0	0.0	0.0	35.0	67.0	0.0	25.5	0.0	0.0	0.0	0.0
6	20	172	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.5	0.0	18.5	0.0	0.0	0.0	3.5
6	21	173	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.1	0.0	0.5
6	22	174	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	0.0	0.0	0.0	0.0	0.0
6	23	175	0.0	70.0	6.5	0.0	0.0	0.0	15.0	0.0	0.0	6.5	0.0	0.0	0.0	1.0	11.8	0.0	0.0	0.0	0.0	0.0
6	24	176	0.0	0.0	0.0	0.0	11.5	11.6	0.0	0.0	28.5	5.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.5	0.0	0.0
6	25	177	0.0	0.0	3.5	0.0	1.0	0.0	4.0	0.0	0.0	2.5	10.5	46.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	14.02.5
6	26	178	0.0	0.0	0.0	2.0	0.0	32.0	0.0	0.0	0.0	5.0	1.0	16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	27	179	17.2	22.0	2.5	0.0	28.0	0.0	24.0	0.0	0.0	2.0	0.0	34.6	0.0	0.0	15.0	0.7	0.0	0.0	0.0	0.0
6	28	180	1.0	12.5	0.0	0.0	11.5	9.5	6.5	0.0	8.5	5.2	0.0	0.5	10.5	0.0	20.0	60.5	90.5	0.0	0.0	0.0
6	29	181	20.0	0.0	0.0	0.0	0.0	0.0	25.5	0.0	0.0	5.2	0.0	8.0	0.0	0.5	0.0	3.0	22.0	0.0	0.0	0.0
6	30	182	7.0	8.0	0.0	27.0	6.0	0.0	14.5	10.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	1	183	10.5	0.0	2.0	11.5	22.6	0.0	0.0	26.5	6.5	0.0	0.0	0.0	71.0	0.0	3.7	0.0	10.0	0.0	0.0	0.0
7	2	184	0.5	0.0	4.5	7.5	0.0	0.0	0.0	0.0	5.5	0.0	0.0	5.0	4.5	1.8	3.9	0.0	0.0	0.0	1.0	0.0
7	3	185	12.5	0.0	0.0	45.0	0.0	42.0	20.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	5.0	12.0	12.5	0.0	0.0	9.0
7	4	186	8.0	0.0	0.0	0.0	0.0	31.5	3.0	0.0	0.0	0.0	0.0	1.5	0.2	0.0	0.0	0.0	8.0	9.0	41.6	0.0
7	5	187	42.5	81.5	23.5	69.0	0.0	0.0	7.5	0.0	6.5	0.0	2.8	4.5	0.0	43.5	0.0	0.0	0.0	14.5	26.5	7.5
7	6	188	0.0	0.0	35.6	26.0	0.0	0.0	9.5	0.0	54.5	0.0	31.5	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	9.5
7	7	189	0.0	21.8	32.0	41.5	0.0	0.0	3.9	0.0	65.5	3.5	13.5	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	8	190	0.0	0.0	30.0	2.0	13.5	1.5	33.5	0.0	43.5	0.5	2.5	6.0	9.0	0.0	0.0	0.0	0.0	0.0	13.5	0.0
7	9	191	0.0	0.0	6.0	0.0	0.0	13.0	2.5	0.0	11.5	19.0	0.0	0.0	0.0	8.9	5.9	0.0	0.0	19.5	10.0	5.5
7	10	192	29.5	9.0	3.0	0.0	1.5	0.0	2.5	0.0	16.5	0.0	0.5	8.0	0.0	100.2	2.5	8.2	0.0	11.0	12.0	0.0
7	11	193	0.0	10.0	0.0	19.0	64.0	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	20.0	0.0	50.0	80.0	0.0	16.0	45.5
7	12	194	0.0	20.5	7.5	8.0	1.0	11.0	34.5	0.0	0.0	0.0	44.0	12.5	0.0	3.0	2.0	0.0	0.0	0.0	17.9	0.5
7	13	195	0.0	0.0	0.0	0.0	21.0	0.0	7.0	23.5	0.0	0.0	0.0	2.0	20.0	0.0	10.0	0.0	0.0	65.0	0.0	15.0
7	14	196	0.0	0.0	8.5	0.0	10.2	53.5	0.0	12.5	0.0	40.0	4.5	2.5	0.0	0.0	6.9	0.0	30.0	14.0	0.0	0.0
7	15	197	0.0	2.0	0.0	20.0	0.0	10.5	0.0	1.0	0.0	35.0	0.0	26.0	27.5	1.0	0.0	7.5	9.8	1.0	2.0	0.5
7	16	198	0.0	10.5	0.5	0.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	11.0	13.5	126.5	0.0	0.0	74.0	6.4	0.0	0.0
7	17	199	0.0	5.5	9.5	10.0	0.0	50.0	3.9	0.0	116.5	0.0	0.0	0.0	23.5	26.0	1.0	0.0	10.0	0.2	0.0	0.0
7	18	200	30.1	42.0	0.0	2.0	0.0	0.0	1.0	26.5	0.0	22.0	0.0	17.2	0.0	20.0	0.0	0.0	0.0	0.0	19.5	0.0
7	19	201	27.5	1.0	0.0	36.0	0.0	0.0	2.0	0.0	1.5	0.0	1.8	34.6	32.5	27.5	0.0	0.0	12.5	20.5	1.0	55.0
7	20	202	22.5	0.0	4.5	31.4	0.0	0.0	3.0	33.5	28.2	0.0	0.0	36.5	0.0	0.0	0.0	0.0	0.0	0.0	12.0	8.0
7	21	203	0.0	6.0	0.0	4.5	70.0	8.5	2.0	5.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	12.6
7	22	204	0.0	0.1	0.0	0.0	4.0	8.5	3.9	5.6	0.0	0.0	0.0	0.0	29.0	11.0	3.0	2.2	0.0	0.0	0.0	0.0
7	23	205	2.0	2.3	0.0	7.5	1.5	0.0	0.0	0.0	7.5	4.0	3.5	0.0	1.0	0.0	25.7	0.5	0.0	0.0	1.5	0.5
7	24	206	0.0	14.0	0.0	11.5	11.5	34.0	7.5	14.0	0.0	1.5	6.0	8.0	10.2	30.5	2.2	0.0	12.0	0.0	1.5	0.0
7	25	207	32.5	0.0	33.5	0.0	1.0	1.0	0.0	2.5	0.0	1.0	4.0	0.0	0.0	38.5	10.2	0.0	7.0	84.5	0.0	0.0
7	26	208	0.0	14.0	0.0	39.5	11.5	4.5	0.0	0.0	0.0	0.0	1.0	2.5	0.0	76.0	0.0	3.4	20.9	38.0	9.0	0.0
7	27	209	33.0	0.0	0.0	0.0	0.5	24.0	2.5	0.0	27.0	24.0	0.0	26.5	6.0	0.3	4.0	0.0	60.0	22.0	0.0	7.0
7	28	210	0.0	0.0	0.0	2.0	14.5	56.5	0.0	20.0	9.0	6.5	9.0	3.5	3.5	10.5	0.0	0.0	1.2	11.0	20.5	22.0
7	29	211	5.5	2.0	0.0	0.0	14.0	0.0	0.0	90.5	0.0	2.0	1.0	0.0	13.0	0.0	0.0	0.0	0.0	2.0	58.0	15.0
7	30	212	0.0	6.0	0.0	9.5	0.0	0.0	0.0	0.0	26.5	0.0	11.0	2.0	0.0	0.0	4.8	0.0	0.0	0.0	26.5	8.0
7	31	213	0.0	44.0	15.5	8.5	0.0	0.0	17.0	0.5	24.5	0.0	1.0	0.0	0.0	28.5	0.0	0.0	0.0	39.0	0.0	17.0
8	1	214	0.0	13.1	0.0	3.0	0.0	0.0	2.5	0.0	0.0	24.0	4.0	0.0	0.0	2.5	88.5	0.0	18.0	10.0	35.2	2.6
8	2	215	0.0	21.5	0.0	0.0	1.0	43.5	0.0	0.0	0.0	2.0	3.0	0.0	0.0	0.0	0.0	20.5	0.0	48.0	11.5	15.4
8	3	216	0.0	0.0	20.0	10.0	2.9	4.0	18.5	0.0	12.5	0.0	3.5	11.0	2.0	0.0	6.0	20	32.5	4.3	0.0	0.0
8	4	217	30.0	7.0	24.5	0.0	2.5	2.5	49.5	20.0	0.0	18.5	18.0	0.0	60.8	0.0	0.0	46	38.5	0.0	0.0	0.0

8	5	218	2.0	38.5	0.0	5.5	13.5	1.5	96.0	0.5	2.5	0.0	4.2	0.0	0.0	0.0	0.0	90.2	0	39.0	0.0	13.0
8	6	219	10.0	11.0	0.5	11.5	24.0	23.0	4.0	51.5	22.5	0.0	1.5	6.5	90.8	56.0	3.6	7.3	54.0	36.2	0.0	7.0
8	7	220	1.5	0.0	0.0	74.0	3.5	1.0	67.0	0.0	0.0	14.5	0.0	0.0	0.2	4.0	29.5	20.2	4.4	0.0	0.0	0.0
8	8	221	0.0	0.0	0.5	0.0	2.0	0.0	37.5	0.0	0.0	16.0	2.0	110.0	7.5	96.0	0.5	29.0	0.0	0.0	0.0	0.0
8	9	222	2.0	0.0	2.0	0.0	8.5	0.0	11.0	1.5	0.0	0.0	0.5	8.5	0.0	7.5	0.0	0.5	0.0	38.0	0.0	35.0
8	10	223	52.5	22.0	0.5	0.0	0.0	0.0	0.0	1.0	2.0	22.5	26.5	0.0	0.0	0.0	40.0	6.3	0.0	7.0	1.5	1.0
8	11	224	14.5	0.0	6.5	10.0	1.0	0.0	0.0	4.0	40.0	0.0	0.0	0.0	22.0	0.0	0.5	10.2	0.0	4.8	16.0	3.0
8	12	225	3.0	0.0	1.5	0.0	0.0	91.0	0.0	0.0	37.5	179.5	0.0	3.5	31.5	0.0	63.0	11.4	45.2	4.6	20.0	0.0
8	13	226	1.0	0.0	32.5	6.0	0.0	172.5	37.0	1.5	1.0	84.0	0.5	0.0	4.5	0.0	0.5	60.2	27.0	12.0	48.2	0.0
8	14	227	13.0	0.0	0.0	0.0	0.0	24.5	54.5	0.5	1.0	13.0	0.0	48.5	0.5	13.5	0.0	41.5	23.0	8.0	11.0	29.0
8	15	228	3.0	4.0	0.0	9.0	4.5	36.5	49.9	0.0	0.0	86.5	6.5	15.5	65.0	18.0	8.5	11.0	0.0	0.0	3.2	4.4
8	16	229	0.0	0.5	13.0	0.0	0.0	21.0	3.0	46.5	56.5	3.5	0.0	31.5	0.0	2.0	0.0	0.0	0.0	0.0	19.0	5.0
8	17	230	0.0	0.0	75.0	23.0	0.0	0.0	1.5	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	3.2	0.0
8	18	231	0.0	0.5	104.5	1.5	0.0	34.5	24.8	0.0	46.5	0.0	39.5	76.5	0.0	0.0	9.5	0.0	0.0	212.0	0.0	0.0
8	19	232	15.5	19.5	0.0	0.0	0.0	16.0	0.0	12.5	1.5	10.5	42.5	0.0	0.0	0.0	0.0	45.1	0.0	5.5	0.0	0.0
8	20	233	0.0	26.5	0.0	0.0	103.5	0.0	0.0	2.5	7.5	0.0	26.0	0.0	0.0	65.0	0.0	7.2	0.0	0.0	28.5	0.5
8	21	234	24.5	0.0	0.0	21.0	0.0	0.0	35.0	0.0	25.0	0.0	1.5	0.0	0.0	20.0	46.9	17.0	9.5	0.0	25.2	0.0
8	22	235	57.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	42.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2	75.0
8	23	236	57.0	0.0	3.5	0.0	61.0	45.2	0.0	0.0	0.0	5.5	3.0	0.0	0.0	0.0	40.2	0.0	26.0	0.0	0.0	1.0
8	24	237	1.0	0.0	3.0	4.5	0.5	0.0	2.0	0.0	0.5	0.0	41.5	0.0	0.0	2.5	1.0	0.8	10.8	0.0	0.0	0.0
8	25	238	0.0	3.5	24.0	5.5	34.5	21.0	6.5	0.0	4.0	0.0	2.0	28.5	0.0	0.0	18.0	0.0	14.8	19.2	10.2	0.0
8	26	239	0.0	0.0	64.0	0.0	31.5	24.0	1.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	20.2	33.0	11.5	4.3	43.0
8	27	240	14.0	69.0	0.0	0.0	15.5	0.0	0.0	0.0	27.5	6.5	0.0	22.5	0.0	0.7	0.0	0.0	0.0	0.0	20.0	0.0
8	28	241	0.0	18.0	0.5	0.0	31.0	0.0	13.0	0.0	0.0	0.0	0.0	45.5	0.0	0.0	19.9	0.0	0.0	0.0	0.0	62.4
8	29	242	24.0	33.5	0.0	5.5	0.0	0.0	4.5	0.0	0.0	0.0	1.5	7.5	0.0	0.0	0.0	0.0	7.0	0.0	0.6	0.0
8	30	243	3.5	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	2.8	0.0	0.0	0.0	0.0	17.0
8	31	244	0.0	18.5	0.0	0.0	3.5	14.0	10.0	64.5	0.0	0.0	5.5	0.0	66.0	0.0	0.7	0.0	3.0	0.0	12.2	0.0
9	1	245	16.5	0.0	0.0	0.0	8.4	0.0	0.0	16.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	46.0	0.0	0.0	0.5	2.8
9	2	246	0.0	1.0	0.0	0.0	43.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.0	43.0	59.2	19.0	0.0	0.0	0.0
9	3	247	0.5	53.0	0.0	0.0	1.5	0.0	1.5	0.0	0.0	0.5	1.0	0.0	1.0	26.0	0.0	1.0	57.0	0.0	5.5	0.0
9	4	248	23.0	0.0	0.0	0.0	0.0	0.0	0.0	43.5	3.5	0.0	0.0	0.0	2.5	0.0	0.0	30.0	0.0	2.0	17.4	6.4
9	5	249	0.0	18.5	0.0	0.0	0.0	1.0	33.0	0.0	0.0	0.0	0.0	0.0	20.5	0.0	0.0	0.0	17.0	18.2	0.0	0.0
9	6	250	0.0	0.0	0.0	0.0	0.0	15.5	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.6
9	7	251	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5	0.0	0.0	0.0	0.0	8.5	0.0	12.0	23.0
9	8	252	63.5	23.5	0.0	0.0	11.0	0.0	0.0	0.0	43.0	15.5	3.0	10.6	48.0	0.0	0.0	36.0	44.0	0.0	0.0	11.0
9	9	253	16.0	0.0	0.0	0.0	12.0	0.0	0.0	12.5	0.0	62.5	2.5	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
9	10	254	0.0	0.0	0.0	4.0	1.0	0.0	0.0	47.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
9	11	255	2.0	6.0	0.0	0.0	1.5	0.0	0.0	18.0	14.5	4.5		0.0	2.7	0.0	0.0	0.0	14.0	0.0	0.0	4.3
9	12	256	0.0	0.0	0.0	2.0	1.2	0.0	0.0	21.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.0	6.2
9	13	257	89.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	35.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	60.0	0.0	2.6
9	14	258	21.5	0.0	0.0	9.0	0.0	0.0	0.0	0.0	20.0	18.0	7.5	0.0	0.0	0.0	10.0	0.0	17.0	0.0	0.0	0.0
9	15	259	0.0	0.0	3.0	5.5	0.0	0.0	0.0	0.0	14.5	9.5	23.0	19.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	16	260	0.0	13.5	36.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	15.0	0.0	0.0
9	17	261	10.0	10.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	44.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.6
9	18	262	0.0	13.0	0.0	1.5	0.0	0.0	0.0	43.0	0.0	0.0	37.5	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	29.4
9	19	263	0.0	0.0	0.0	2.0	13.5	0.0	0.0	0.0	0.0	0.0		0.0	0.0	1.2	0.0	0.0	0.0	6.9	0.0	0.0
9	20	264	0.0	0.0	0.0	0.0	65.9	0.0	0.0	0.0	5.5	0.0	0.0	0.0	32.0	6.7	6.7	0.0	0.0	0.0	0.0	2.8
9	21	265	0.0	0.0	2.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	5.5	0.0	0.0	0.0	0.0	49.4
9	22	266	0.0	0.0	0.0	0.0	0.0	7.0	2.0	0.0	6.5	0.0	0.0	0.0	0.0	33.5	0.0	0.0	0.5	0.0	0.0	7.4
9	23	267	0.0	2.0	0.0	19.5	0.0	13.0	75.5	0.0	10.0	0.0	0.0	0.0	0.0	0.8	11.2	56.0	135.2	0.0	0.0	21.4
9	24	268	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	17.7	0.0	0.0	7.4	37.0	0.0	3.5	41.2
9	25	269	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	98.0	0.0	0.0	0.0
9	26	270	0.5	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	27	271	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	3.0	0.0	20.3	0.0	0.0	0.0	0.0	0.0	29.0	0.0	0.0
9	28	272	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	9.0	0.0	0.0

9	29	273	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
9	30	274	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0
10	1	275	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.2	0.0	0.0
10	2	276	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
10	3	277	0.0	0.0	29.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	4	278	0.0	0.0	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	5	279	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	6	280	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.0	0.0	0.0
10	7	281	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0	0.0	0.0	0.0	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	8	282	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	9	283	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	10	284	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	11	285	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0	0.0
10	12	286	0.0	0.0	78.4	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	13	287	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	14	288	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
10	15	289	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	16	290	0.0	0.0	0.0	0.0	0.0	3.9	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	17	291	0.0	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	18	292	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	19	293	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	20	294	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	21	295	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	22	296	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	23	297	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	24	298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0
10	25	299	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	0.0	0.0	0.0	0.0	0.0	25.4
10	26	300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	27	301	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	28	302	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	29	303	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	30	304	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	31	305	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	1	306	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	2	307	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	3	308	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	3.0
11	4	309	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	5	310	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	6	311	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	7	312	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	8	313	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
11	9	314	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	10	315	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	11	316	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	12	317	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	13	318	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	14	319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	15	320	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	0.0	0.0
11	16	321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0
11	17	322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	18	323	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	19	324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	20	325	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	21	326	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	22	327	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

11	23	328	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	24	329	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	25	330	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	26	331	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	3.0	0.0
11	27	332	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
11	28	333	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	0.0	0.0
11	29	334	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	30	335	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	1	336	0.0	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	2	337	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	3	338	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	4	339	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	5	340	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	6	341	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
12	7	342	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	8	343	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	9	344	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	10	345	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.6	0.0	0.0	0.0	0.0	0.0	0.0
12	11	346	0.0	0.0	0.0	0.0	9.6	18.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
12	12	347	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0	0.0	0.0	0.0	33.0	0.0	0.0	25.0	0.0
12	13	348	0.0	1.5	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	52.5	0.0	0.0	9.0	0.4	16.0	0.0	0.0
12	14	349	0.0	0.4	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	1.0	0.0	11.0	0.0	0.0	0.0	0.0	42.5	0.0	0.0
12	15	350	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	16	351	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	17	352	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	18	353	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	19	354	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	20	355	0.0	0.0	43.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	21	356	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	22	357	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	23	358	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	24	359	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	25	360	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
12	26	361	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0
12	27	362	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	28	363	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.5	0.0
12	29	364	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	30	365	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	31	366	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Statement showing the 10-daily wise In-flows of Bhakra Reservoir (In-cusecs days)

Month	Period	Year									
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	01-10	47082	49324	51579	56346	58334	51632	43849	63873	53423	75328
	11-20	47489	43279	44068	49616	62189	43410	53646	57560	55710	66717
	21-31	57502	48892	70374	54027	59858	50696	51417	59922	51328	65498
February	01-10	41950	47578	52011	55858	57448	43838	36138	57759	55119	64811
	11-20	58541	47730	50159	85084	58132	57461	39826	52641	55785	80774
	21-28/29	38998	44539	51538	53681	46267	40342	31898	41261	46927	51655
March	01-10	88440	82067	53504	77807	52568	72417	53260	47578	63691	90459
	11-20	83453	64168	71564	107235	69069	100084	62250	46808	67205	82273
	21-31	106675	94506	84020	140559	68546	117271	67402	56621	98796	103305
April	01-10	104893	90305	80746	100181	71439	109703	68222	63901	79340	83943
	11-20	120194	142473	72151	107374	82420	127695	88855	66737	106080	106038
	21-30	169142	163767	107004	174473	127926	125506	110215	77575	128306	134933
May	01-10	199673	180918	106608	209290	253074	161444	150098	119600	201242	206473
	11-20	414265	307908	165921	205655	362733	195824	185736	139590	169305	248935
	21-31	368292	433394	213206	188752	457090	194022	251600	267930	254732	337354
June	01-10	381061	534217	182230	215423	311625	167440	287730	253562	253155	255537
	11-20	471065	496639	237672	307865	216256	367097	604339	221402	231714	332477
	21-30	419327	433098	246795	566259	232319	320651	492292	348558	398499	495797
July	01-10	463466	466614	319060	681002	449231	420800	448613	352066	449749	437744
	11-20	408751	434917	286131	702525	418706	331914	452096	406188	409531	414114
	21-31	413222	535278	306616	682981	600058	424957	492063	484880	682090	613791
August	01-10	401338	560746	347974	571357	688585	387852	487680	422186	825363	453458
	11-20	475589	421694	372210	449404	518249	640768	596114	400249	762180	629253
	21-31	466326	435870	317976	388507	512960	436847	443090	316008	651211	514946
September	01-10	370178	387890	208265	313798	236182	320277	259608	290844	469118	420869
	11-20	317293	290321	213516	298087	209798	196257	241774	409277	377985	380260
	21-30	196644	240679	137695	259747	140753	174743	367671	204534	380711	232050
October	01-10	140819	138797	127622	156796	121967	112615	193962	160173	219007	182548
	11-20	120253	112414	137512	123539	118117	92096	152515	116413	157931	131002
	21-31	101861	98500	100315	114753	103509	83543	129150	101596	155557	113740
November	01-10	80901	84549	76433	89246	78641	67887	95958	85554	112423	91287
	11-20	77672	76428	65523	77996	75986	62340	83443	90682	104077	81612
	21-30	67321	68246	57004	69384	71722	61388	75421	72349	92782	74968
December	01-10	57343	63712	58125	65007	65850	55715	76352	64193	80335	73230
	11-20	57116	63832	55021	60857	56373	49018	69951	61972	73938	69374
	21-31	57054	55715	53998	59643	60588	55184	74588	64427	88438	67376

Statement showing the 10-daily wise In-flows of Bhakra Reservoir (In-cusecs days)

Month	Period	Year									
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	01-10	59602	49358	51829	48828	59029	61715	59496	60135	67017	57167
	11-20	72368	59182	62320	49451	60502	56091	50427	58018	75004	56956
	21-31	67495	56119	69958	47246	55142	69796	61832	66750	78077	72782
February	01-10	49317	77888	54712	47999	54361	58340	54523	79911	64379	56208
	11-20	60421	69072	67096	42714	50729	44289	56834	82652	71693	59078
	21-28/29	51621	60461	50687	56725	48921	42361	47561	90795	63024	52068
March	01-10	79158	80037	64058	91213	64756	47273	51568	89217	68507	57168
	11-20	60393	83126	61588	76658	76888	53238	48812	79126	105023	71249
	21-31	94681	121081	98265	115169	78852	72939	59955	113099	110568	72973
April	01-10	112046	104367	108514	135393	92382	106937	63859	150584	99068	70798
	11-20	102737	118992	126667	130081	82814	128543	67145	162546	119163	59612
	21-30	118035	135198	118833	182357	93269	238896	90260	194950	130501	103772
May	01-10	112304	141033	180980	204149	153221	152149	107800	181196	173814	129488
	11-20	158287	204323	194848	286442	241781	255216	113780	195149	194330	137496
	21-31	215794	409563	206958	311356	278046	312970	158102	232614	237030	154381
June	01-10	237776	456508	265411	228582	270786	276933	240753	297165	214150	190712
	11-20	208398	536084	380444	333595	319195	245088	301525	293517	326947	310897
	21-30	347595	542957	388656	390496	359408	314172	208498	301507	440182	264668
July	01-10	375151	619901	438822	417699	369053	411244	282768	468753	454805	364928
	11-20	332937	518848	516251	634502	435036	542027	347371	493969	424569	435235
	21-31	426496	568220	588803	679653	416986	634103	555359	526176	393875	514387
August	01-10	459268	492824	508049	642358	535378	648147	459309	620872	426627	424493
	11-20	417885	504533	495911	622416	492225	441655	609948	710137	496193	332963
	21-31	608571	502289	339044	400808	420025	376744	467143	484656	469250	387545
September	01-10	391315	322621	252429	270783	292227	270683	344055	403226	356813	277178
	11-20	365954	233038	199748	209470	241490	196244	250096	301234	255843	300923
	21-30	212362	191760	169915	184249	195589	222834	355733	226208	212589	268546
October	01-10	149169	157090	137466	126326	160957	151017	192389	159957	148769	183709
	11-20	112037	131294	100310	112496	105379	112747	140524	114582	121795	130556
	21-31	103850	106456	93215	100636	94743	107335	116775	107518	96219	120324
November	01-10	79550	87448	64329	82455	79653	85666	98517	87957	81837	82794
	11-20	73056	80178	58365	77093	67672	72870	88823	85718	76369	75602
	21-30	65307	71414	54158	66130	60812	68699	82202	80607	73292	77231
December	01-10	67338	68843	48289	68101	57397	66208	73124	73024	66086	73462
	11-20	64110	64245	52962	72801	59489	67769	66428	77908	64917	64867
	21-31	58314	66788	50017	62105	60234	64463	69243	73256	73366	71349

Statement showing the 10-daily wise Out-flows of Bhakra Reservoir (In-cusecs days)

Month	Period	Year									
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	01-10	138199	165779	175221	120893	147489	150851	149854	196837	169366	123047
	11-20	153302	163900	182214	120932	166443	158055	133022	188120	152823	156793
	21-31	168368	181030	186938	130927	193015	194540	169350	178488	167021	196567
February	01-10	147844	149299	160458	103380	192965	176342	161708	183313	165382	182631
	11-20	155455	145905	160171	84690	194835	88452	157565	159078	157368	158140
	21-28/29	128320	77915	168299	68102	149765	81951	130475	140427	140375	125958
March	01-10	159514	120719	200314	103340	196004	120314	176492	194768	170613	204386
	11-20	170994	154717	202148	114486	121547	110312	180726	186953	163867	209896
	21-31	204452	185732	199407	98792	140723	158307	175445	161430	160379	214309
April	01-10	164111	133486	141176	137062	132851	175466	114029	119891	88287	165189
	11-20	128175	88372	128466	114072	114146	200027	82681	103660	80248	120142
	21-30	177990	135547	153729	156584	169170	265102	103854	129023	136899	184979
May	01-10	205306	228518	186224	181551	218516	244385	157831	217490	194183	269132
	11-20	227634	229277	203013	183038	221211	232506	183303	227302	215674	307768
	21-31	251594	252584	200888	178428	312253	200113	154081	252592	229202	336005
June	01-10	273632	271153	214788	209906	344247	201084	133839	298772	254168	271827
	11-20	296822	303044	175414	237554	350226	237425	174991	310042	287487	273126
	21-30	315398	306929	195650	257423	286140	215615	227863	264884	305829	290043
July	01-10	326521	327429	190963	318370	234255	229592	254709	272457	248915	300045
	11-20	319602	330172	190084	264416	230677	237413	284288	277667	197684	278372
	21-31	352044	337868	218036	355079	246781	273281	286000	287148	169696	292627
August	01-10	215821	272510	173106	376048	226713	241880	261030	207041	270663	269827
	11-20	209506	270575	152097	319995	237409	195131	287166	179708	359554	254495
	21-31	230545	296728	164628	337647	373731	259954	398316	202344	492413	359262
September	01-10	209754	251043	152730	271969	200834	208986	225244	199752	396489	325901
	11-20	195502	231550	152543	171623	236506	221493	225277	146074	370614	350241
	21-30	208625	225694	133423	234764	202414	203251	302868	162628	382185	262458
October	01-10	187321	168572	121925	176534	182645	182380	239914	139640	225747	247352
	11-20	194650	164569	119990	140959	116154	139374	228511	117842	167638	162528
	21-31	200941	183154	143858	192911	153977	162694	220856	127953	171125	133979
November	01-10	175771	186159	125496	172114	166419	133048	160173	163886	155042	133516
	11-20	172687	174789	139571	152422	159309	143268	138230	147739	154675	135324
	21-30	175000	178772	145161	157358	148392	147941	150000	130695	158753	155923
December	01-10	197484	191385	119470	168275	159876	163216	167365	131404	186006	171375
	11-20	200394	193928	118133	200388	168458	144340	163799	152086	212199	158198
	21-31	243903	213912	152009	203778	174448	180787	186672	179657	177441	173895

Statement showing the 10-daily wise Out-flows of Bhakra Reservoir (In-cusecs days)

Month	Period	Year									
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	01-10	172018	160754	179079	150853	156559	150769	181669	143777	132084	125126
	11-20	166500	158318	181662	140355	148988	139335	175502	158459	119611	128243
	21-31	198373	157818	156994	148965	164582	153539	174889	188374	172318	159108
February	01-10	192368	134629	163345	191432	176818	141283	168613	138418	182342	136300
	11-20	200435	127605	172117	214176	185901	154483	172567	121658	199114	149231
	21-28/29	179528	76311	162641	163556	160449	122122	152519	118356	164686	124494
March	01-10	208591	118976	189517	116299	237144	151764	188639	153365	135909	155098
	11-20	209081	168990	183770	111546	142909	134002	191174	176156	111427	149145
	21-31	220130	224415	165658	130215	140793	143419	180991	187319	165875	146966
April	01-10	187838	163511	128358	101878	122473	87655	122431	134062	149993	115583
	11-20	115306	78628	93469	84583	128054	83262	86584	81154	151388	67718
	21-30	111416	121709	103608	100985	184165	142160	120560	173676	173428	118058
May	01-10	190064	258907	227281	160718	185235	234861	227726	220684	270961	167436
	11-20	210659	239959	246485	230031	200429	223591	223115	268297	343687	165405
	21-31	237600	278466	226258	274959	201572	203312	221742	278571	274665	200619
June	01-10	247125	329963	215812	262358	225027	165354	180930	335183	214434	163701
	11-20	281070	366227	250527	325733	325733	242183	252196	349919	262484	229270
	21-30	295884	314516	262980	340083	337203	293212	320066	324622	303256	260474
July	01-10	292701	358835	255144	260450	312709	255273	235323	342164	343663	298318
	11-20	256265	371208	260669	301333	329578	292852	199779	263381	242187	286210
	21-31	253456	400672	283909	443120	348469	286245	207885	216514	218267	203905
August	01-10	232836	350740	254432	393626	232847	198200	181999	284484	244716	179616
	11-20	225024	311480	288267	454667	232135	244140	164456	419459	246644	210971
	21-31	213154	340767	333400	286573	232765	235462	186322	582039	266200	216243
September	01-10	185318	266964	181203	244317	185352	204905	195893	416841	241475	196944
	11-20	181513	223307	155572	235742	228801	273503	196480	294232	308739	155776
	21-30	167324	217643	232189	141241	209172	214077	116974	259459	304444	150709
October	01-10	206360	181221	216671	190157	210285	206284	116882	198850	265715	160001
	11-20	130981	109498	166282	154336	199029	147193	122427	166700	218950	186530
	21-31	90267	118326	163272	143449	182147	132050	133121	186859	158528	164714
November	01-10	119227	134349	145010	133053	133648	127506	118367	180520	127685	139841
	11-20	154375	144982	137003	137616	126502	129535	97969	126332	132882	135316
	21-30	160386	141472	135477	138523	139467	128571	89013	116083	130124	136450
December	01-10	174060	178989	158739	157036	160948	162360	100759	129175	138041	160064
	11-20	136157	189742	141202	180212	163752	155343	128312	139769	160088	174073
	21-31	162596	177239	152687	188819	170907	195057	177007	161499	202742	161934

Statement showing the levels of Bhakra Reservoir (In-feet)

January

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1593.44	1593.34	1618.02	1560.88	1640.46	1634.88	1611.74	1641.42	1607.42	1653.17	1647.51	1623.80	1647.47	1632.71	1643.44	1602.09	1636.47	1655.43	1644.00	1608.63
2	1592.88	1592.52	1617.22	1560.35	1639.85	1634.26	1610.92	1640.62	1606.70	1653.02	1646.86	1623.14	1646.83	1632.01	1642.89	1601.36	1635.68	1654.87	1643.53	1608.00
3	1592.31	1591.65	1616.39	1559.68	1639.30	1633.64	1610.10	1639.83	1605.88	1652.84	1646.20	1622.46	1646.19	1631.30	1642.33	1600.62	1634.88	1654.38	1643.10	1607.48
4	1591.70	1590.82	1615.56	1559.11	1638.82	1633.02	1609.22	1639.02	1605.05	1652.62	1645.49	1621.75	1645.49	1630.67	1641.76	1599.80	1634.09	1653.89	1642.62	1607.00
5	1591.01	1590.04	1614.74	1558.48	1638.28	1632.40	1608.46	1638.25	1604.22	1652.39	1644.80	1621.02	1644.78	1630.07	1641.16	1599.14	1633.34	1653.40	1642.21	1606.54
6	1590.28	1589.20	1613.93	1557.80	1637.82	1631.76	1607.76	1637.44	1603.41	1652.14	1644.10	1620.30	1644.08	1629.47	1640.58	1598.40	1632.59	1653.00	1641.74	1606.03
7	1589.52	1588.34	1613.10	1557.10	1637.34	1631.06	1607.04	1636.68	1602.60	1651.83	1643.44	1619.52	1643.34	1628.88	1640.02	1597.78	1631.82	1652.63	1641.36	1605.60
8	1588.72	1587.50	1612.28	1556.39	1636.84	1630.45	1606.36	1635.91	1601.77	1651.47	1643.00	1618.73	1642.57	1628.37	1639.44	1597.26	1631.04	1652.28	1641.16	1605.25
9	1587.90	1586.63	1611.42	1556.66	1636.33	1629.88	1605.69	1635.08	1600.93	1651.06	1642.38	1617.98	1641.81	1627.76	1638.90	1596.72	1630.34	1651.82	1641.01	1604.87
10	1587.10	1585.78	1610.54	1554.95	1635.84	1629.31	1605.24	1634.20	1600.08	1650.57	1641.84	1617.26	1641.05	1627.17	1638.34	1596.06	1629.64	1651.37	1640.85	1604.46
11	1586.26	1584.91	1609.66	1554.24	1635.34	1628.71	1604.78	1633.40	1599.20	1650.12	1641.28	1616.51	1640.36	1626.52	1637.76	1595.43	1628.89	1650.93	1640.60	1604.04
12	1585.45	1583.95	1608.71	1553.52	1634.62	1628.09	1604.23	1632.60	1598.42	1649.66	1640.66	1615.78	1639.60	1625.92	1637.16	1594.82	1628.15	1650.43	1640.35	1603.55
13	1584.60	1582.94	1607.76	1552.79	1633.92	1627.43	1603.60	1631.79	1597.69	1649.17	1640.04	1615.05	1638.82	1625.31	1636.54	1594.20	1627.44	1649.93	1640.03	1603.02
14	1583.75	1581.94	1606.84	1552.06	1633.22	1626.73	1602.91	1631.00	1596.96	1648.65	1639.37	1614.32	1638.04	1624.74	1636.00	1593.56	1626.70	1649.44	1639.82	1602.49
15	1582.90	1581.00	1605.91	1551.33	1632.50	1626.01	1602.20	1630.20	1596.22	1648.18	1638.70	1613.57	1637.28	1624.28	1635.48	1592.87	1625.97	1648.93	1639.71	1601.96
16	1582.12	1580.07	1604.96	1550.56	1631.78	1625.29	1601.58	1629.39	1595.44	1647.75	1638.22	1612.80	1636.53	1623.82	1634.95	1592.21	1625.20	1648.29	1639.49	1601.16
17	1581.39	1579.08	1604.00	1549.73	1631.10	1624.56	1601.21	1628.55	1594.64	1647.21	1637.74	1612.01	1635.81	1623.32	1634.43	1591.58	1624.40	1647.68	1639.25	1600.95
18	1580.63	1578.03	1603.03	1548.92	1630.60	1623.81	1600.72	1627.74	1593.88	1646.66	1637.25	1611.25	1635.11	1622.78	1633.92	1590.88	1623.56	1647.10	1638.95	1600.42
19	1579.81	1577.08	1602.07	1548.13	1630.05	1623.03	1600.30	1626.93	1593.12	1646.10	1636.72	1610.80	1634.41	1622.17	1633.38	1590.12	1622.70	1646.48	1638.56	1599.83
20	1578.91	1576.13	1601.11	1547.34	1629.42	1622.25	1599.73	1626.16	1592.31	1645.53	1636.20	1610.30	1633.76	1621.53	1632.85	1589.39	1621.88	1645.75	1638.15	1599.22
21	1578.15	1575.15	1600.16	1546.58	1628.76	1621.48	1599.05	1625.37	1591.54	1644.93	1635.59	1609.78	1633.10	1620.86	1632.30	1588.55	1621.01	1645.05	1637.69	1598.67
22	1577.32	1574.18	1599.24	1545.79	1628.06	1620.63	1598.31	1624.69	1590.81	1644.32	1634.95	1609.18	1632.47	1620.27	1631.71	1587.72	1620.21	1644.47	1637.18	1598.07
23	1576.44	1573.17	1598.46	1545.02	1627.35	1619.77	1597.60	1624.02	1589.98	1643.69	1634.28	1608.56	1632.23	1619.74	1631.09	1586.93	1619.34	1644.11	1636.60	1597.44
24	1575.55	1572.11	1597.95	1544.23	1626.63	1618.86	1596.88	1623.39	1589.15	1643.04	1633.61	1607.92	1631.88	1619.30	1630.45	1586.11	1618.70	1643.68	1636.05	1596.81
25	1574.70	1571.04	1597.30	1543.45	1625.91	1617.97	1596.07	1622.74	1588.30	1642.36	1632.92	1607.26	1631.53	1618.80	1629.82	1585.31	1618.11	1643.37	1635.49	1596.13
26	1573.81	1569.97	1596.46	1542.69	1625.19	1617.10	1595.23	1622.11	1587.44	1641.66	1632.18	1606.62	1631.14	1618.24	1629.19	1584.70	1617.48	1642.86	1634.92	1595.49
27	1572.94	1568.86	1595.62	1541.87	1624.46	1616.22	1594.38	1621.46	1586.58	1640.96	1631.41	1605.96	1630.75	1617.65	1628.59	1584.36	1616.85	1642.32	1634.36	1594.82
28	1572.06	1567.76	1594.80	1541.10	1623.70	1615.33	1593.50	1620.78	1585.72	1640.24	1630.60	1605.24	1630.36	1617.02	1627.98	1584.30	1616.25	1641.55	1633.79	1594.11
29	1571.17	1566.74	1593.96	1540.41	1622.87	1614.42	1592.54	1620.10	1584.84	1639.50	1629.81	1604.56	1629.82	1616.24	1627.30	1583.90	1615.61	1640.65	1633.28	1593.39
30	1570.27	1565.73	1593.13	1539.73	1622.03	1613.50	1591.60	1619.40	1583.95	1638.74	1628.97	1603.89	1629.09	1615.46	1626.70	1583.32	1614.92	1639.72	1632.78	1592.65
31	1569.32	1564.70	1592.36	1538.97	1621.22	1612.59	1590.62	1618.72	1583.04	1638.00	1628.08	1603.16	1628.36	1614.59	1626.06	1582.68	1614.19	1638.83	1632.23	1591.88

Statement showing the levels of Bhakra Reservoir (In-feet)

February

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1568.43	1563.70	1591.70	1538.26	1620.38	1611.66	1589.55	1617.96	1582.12	1637.25	1627.20	1602.38	1627.61	1613.61	1625.30	1582.02	1613.44	1638.21	1631.63	1591.13
2	1567.51	1562.81	1590.98	1537.56	1619.46	1610.75	1588.47	1617.19	1581.14	1636.49	1626.32	1601.58	1626.94	1612.57	1624.61	1581.30	1612.69	1637.66	1631.02	1590.49
3	1566.59	1561.96	1590.18	1536.90	1618.54	1609.86	1587.38	1616.38	1580.13	1635.72	1625.42	1600.76	1626.24	1611.58	1623.87	1580.59	1611.92	1637.13	1630.38	1589.84
4	1565.64	1561.18	1589.36	1536.20	1617.64	1609.00	1586.34	1615.56	1578.98	1634.93	1624.51	1599.95	1625.56	1610.64	1623.11	1579.88	1611.18	1636.54	1629.68	1589.17
5	1564.70	1560.24	1588.48	1535.49	1616.71	1608.14	1585.34	1614.70	1577.88	1634.10	1623.57	1599.44	1624.83	1609.74	1622.32	1579.11	1610.38	1635.99	1628.96	1588.48
6	1563.76	1559.20	1587.62	1534.79	1615.76	1607.23	1584.34	1613.79	1576.77	1633.25	1622.65	1599.55	1624.16	1608.78	1621.54	1578.42	1609.54	1635.49	1628.18	1587.83
7	1562.82	1558.16	1586.73	1534.09	1614.82	1606.27	1583.46	1612.89	1575.65	1632.42	1621.74	1600.05	1623.45	1607.80	1620.73	1577.70	1608.70	1635.16	1627.34	1587.19
8	1561.86	1557.16	1585.86	1533.46	1613.88	1605.30	1582.60	1611.97	1574.58	1631.73	1620.85	1599.88	1622.91	1606.79	1619.90	1576.94	1607.86	1635.56	1626.50	1586.54
9	1561.06	1556.16	1584.96	1533.09	1612.95	1604.38	1581.77	1611.02	1573.56	1631.25	1620.00	1599.51	1622.29	1605.65	1619.04	1576.12	1607.06	1635.43	1625.67	1585.84
10	1560.16	1555.13	1584.10	1532.94	1612.01	1603.44	1580.92	1610.05	1573.03	1630.69	1619.10	1599.06	1621.62	1604.52	1618.26	1575.23	1606.18	1635.20	1624.82	1585.07
11	1559.22	1554.14	1583.23	1532.78	1611.09	1602.95	1580.05	1609.14	1572.35	1630.10	1618.20	1598.60	1620.92	1603.31	1617.43	1574.32	1605.28	1634.85	1623.95	1584.28
12	1558.36	1553.11	1582.38	1532.57	1610.15	1602.80	1579.18	1608.45	1571.43	1629.49	1617.25	1598.10	1620.23	1602.08	1616.54	1573.42	1604.37	1634.49	1623.03	1583.52
13	1557.50	1552.07	1581.49	1532.45	1609.20	1602.76	1578.22	1607.81	1570.49	1628.83	1616.28	1597.46	1619.47	1600.79	1615.63	1572.45	1603.80	1634.12	1622.09	1582.76
14	1556.59	1551.00	1580.61	1532.40	1608.23	1602.64	1577.27	1607.14	1569.48	1628.24	1615.25	1596.77	1618.68	1599.44	1614.68	1571.47	1603.16	1633.77	1621.16	1581.98
15	1555.56	1549.93	1579.74	1532.26	1607.26	1602.45	1576.30	1606.43	1568.53	1627.74	1614.29	1596.19	1618.00	1598.05	1613.75	1570.33	1602.32	1633.61	1620.28	1581.12
16	1554.50	1548.79	1578.80	1532.55	1606.32	1602.24	1575.25	1605.72	1567.60	1627.63	1613.34	1596.65	1617.39	1596.69	1612.78	1569.16	1601.42	1633.60	1619.54	1580.24
17	1553.43	1547.61	1577.88	1533.01	1605.36	1602.02	1574.14	1604.98	1566.60	1627.38	1612.41	1595.27	1616.72	1595.40	1611.85	1567.92	1600.56	1633.50	1618.71	1579.37
18	1552.37	1546.47	1576.97	1533.04	1604.49	1601.78	1573.00	1604.24	1565.52	1626.99	1611.37	1594.97	1615.99	1594.09	1610.85	1566.70	1599.67	1633.26	1617.86	1578.48
19	1551.32	1545.57	1576.06	1533.09	1603.55	1601.54	1571.84	1603.49	1564.40	1626.48	1610.31	1594.64	1615.24	1592.72	1609.80	1565.66	1598.72	1633.05	1617.05	1577.64
20	1550.23	1545.04	1575.14	1532.99	1602.57	1601.30	1570.66	1602.70	1563.24	1625.89	1609.27	1594.37	1614.46	1591.42	1608.77	1564.61	1597.78	1632.78	1616.36	1576.78
21	1549.12	1544.57	1574.13	1532.83	1601.57	1601.04	1569.54	1601.89	1562.04	1625.23	1608.25	1594.00	1613.63	1590.36	1607.87	1563.58	1596.77	1632.38	1615.70	1575.87
22	1548.02	1544.10	1573.02	1532.65	1600.61	1600.80	1568.43	1601.01	1560.72	1624.64	1607.24	1593.55	1612.66	1589.23	1607.10	1562.58	1595.76	1632.20	1614.98	1574.94
23	1546.83	1543.66	1571.87	1532.45	1599.66	1600.44	1567.53	1600.14	1559.42	1624.10	1606.30	1593.25	1611.69	1588.25	1606.31	1561.65	1594.62	1632.33	1614.18	1574.01
24	1545.64	1543.23	1570.74	1532.19	1598.70	1600.06	1566.67	1599.22	1558.20	1623.56	1605.38	1593.20	1610.73	1587.22	1605.48	1560.66	1593.47	1632.21	1613.34	1573.06
25	1544.47	1542.82	1569.60	1531.94	1597.75	1599.62	1565.77	1598.28	1557.00	1622.96	1604.37	1593.25	1609.74	1586.20	1604.62	1559.52	1592.49	1632.02	1612.48	1572.09
26	1543.35	1542.43	1568.45	1531.69	1596.79	1599.18	1564.88	1597.32	1555.66	1622.42	1603.38	1593.17	1608.69	1585.26	1603.74	1558.42	1591.48	1631.75	1611.61	1571.12
27	1542.19	1542.03	1567.30	1531.42	1595.84	1598.68	1563.94	1596.36	1554.31	1621.87	1602.35	1593.05	1607.61	1584.08	1602.86	1557.30	1590.46	1631.44	1610.73	1570.13
28	1541.05	1541.61	1566.18	1531.16	1594.88	1598.24	1562.96	1595.36	1552.86	1621.28	1601.35	1593.10	1606.60	1582.86	1601.90	1556.19	1589.37	1631.07	1609.87	1569.14
29			1565.04				1561.96				1600.29				1600.94				1609.06	

Statement showing the levels of Bhakra Reservoir (In-feet)

March

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1539.87	1541.21	1563.84	1530.94	1593.92	1598.11	1560.86	1594.26	1551.40	1620.64	1599.12	1593.05	1605.60	1581.70	1599.79	1554.94	1588.28	1630.66	1608.53	1568.18
2	1538.62	1540.87	1562.54	1530.60	1592.86	1598.28	1559.66	1593.16	1550.08	1619.74	1598.10	1592.92	1604.83	1580.95	1598.32	1553.60	1587.19	1630.22	1608.00	1567.17
3	1538.02	1540.86	1561.16	1530.24	1591.78	1598.22	1558.51	1592.08	1548.86	1618.81	1596.98	1592.71	1603.93	1581.58	1596.72	1552.25	1586.12	1629.87	1607.42	1566.12
4	1538.08	1540.84	1559.74	1529.90	1590.68	1598.08	1557.46	1590.92	1547.60	1618.20	1595.83	1592.51	1603.05	1581.82	1595.10	1550.96	1585.02	1629.53	1606.81	1565.02
5	1537.26	1540.44	1558.20	1529.58	1589.58	1597.86	1556.35	1589.80	1546.36	1617.67	1594.66	1592.20	1602.18	1581.83	1593.45	1549.55	1583.94	1629.22	1606.25	1564.01
6	1536.34	1539.86	1556.75	1529.24	1588.46	1597.32	1554.88	1588.68	1545.15	1617.00	1593.80	1591.85	1601.26	1581.81	1591.92	1548.16	1582.81	1628.92	1605.69	1562.94
7	1535.40	1539.22	1555.32	1528.87	1587.32	1596.69	1553.28	1587.57	1544.00	1616.15	1593.11	1591.49	1600.36	1581.59	1590.75	1546.76	1581.71	1628.53	1605.20	1561.76
8	1534.40	1538.52	1553.88	1528.54	1586.16	1596.02	1551.83	1586.42	1542.73	1615.25	1592.15	1591.04	1599.37	1581.19	1589.68	1545.41	1580.57	1628.09	1604.94	1560.62
9	1533.27	1537.84	1552.38	1528.21	1584.99	1595.30	1550.55	1585.22	1541.40	1614.31	1591.08	1590.57	1598.43	1581.05	1588.52	1544.39	1579.32	1627.59	1604.92	1559.50
10	1532.11	1537.02	1550.90	1527.92	1583.80	1594.54	1549.22	1583.99	1540.10	1613.45	1589.96	1589.98	1597.48	1580.85	1587.26	1543.72	1578.06	1627.09	1604.22	1558.45
11	1530.92	1536.22	1549.45	1527.80	1582.67	1593.85	1547.90	1582.78	1538.80	1612.58	1588.79	1589.38	1596.45	1580.63	1585.91	1542.97	1576.81	1626.56	1603.81	1557.42
12	1530.04	1535.23	1548.17	1527.51	1582.08	1593.22	1546.61	1581.54	1537.40	1611.65	1587.62	1588.66	1595.61	1580.35	1584.63	1542.21	1575.48	1626.04	1603.53	1556.42
13	1529.06	1534.13	1546.83	1527.11	1581.54	1592.95	1545.44	1580.35	1536.00	1610.67	1586.37	1587.90	1594.97	1580.00	1583.97	1541.42	1574.13	1625.43	1603.54	1555.51
14	1527.94	1532.96	1545.33	1526.68	1581.11	1593.75	1544.11	1579.09	1534.58	1609.71	1585.18	1587.17	1594.17	1579.42	1583.82	1540.52	1572.64	1624.75	1603.93	1554.58
15	1526.75	1531.78	1543.80	1526.34	1581.05	1594.02	1542.67	1577.80	1533.18	1608.82	1583.95	1586.53	1593.16	1578.92	1583.78	1539.52	1571.32	1624.16	1604.29	1553.60
16	1525.48	1530.53	1542.26	1526.23	1581.13	1594.25	1541.23	1576.63	1531.77	1607.90	1582.70	1585.98	1592.04	1578.50	1583.50	1538.41	1569.80	1623.51	1604.36	1552.44
17	1524.24	1529.29	1540.86	1526.28	1580.90	1594.31	1539.83	1575.51	1530.57	1606.98	1581.43	1585.40	1590.85	1578.36	1583.02	1537.16	1568.45	1622.87	1604.30	1551.34
18	1523.07	1528.03	1539.47	1526.35	1580.50	1594.23	1538.36	1574.38	1529.33	1606.16	1580.14	1584.70	1589.66	1578.24	1582.52	1535.87	1567.10	1622.32	1604.20	1550.20
19	1521.92	1526.66	1538.14	1526.46	1580.12	1594.01	1537.14	1573.27	1528.10	1605.31	1578.83	1583.91	1588.69	1578.02	1582.16	1534.57	1565.74	1621.71	1604.00	1549.01
20	1520.76	1525.28	1536.82	1527.00	1579.71	1593.75	1535.93	1572.19	1526.88	1604.49	1577.65	1583.10	1587.69	1577.66	1581.97	1533.21	1564.34	1621.07	1603.76	1547.75
21	1519.73	1523.93	1535.51	1527.41	1579.31	1593.56	1534.77	1571.16	1525.72	1603.67	1576.62	1582.26	1586.62	1577.32	1581.63	1531.75	1563.00	1620.45	1603.48	1546.42
22	1518.61	1522.66	1534.35	1527.97	1578.91	1593.51	1533.58	1570.16	1524.78	1602.84	1575.60	1581.24	1585.61	1577.06	1581.25	1530.58	1561.80	1619.86	1603.26	1545.19
23	1517.46	1521.35	1533.14	1529.04	1578.53	1593.47	1532.32	1569.22	1524.08	1602.05	1574.51	1580.14	1584.76	1576.70	1580.96	1529.54	1560.62	1619.28	1602.75	1544.02
24	1516.16	1520.07	1531.97	1530.01	1578.15	1593.35	1531.02	1568.28	1523.16	1601.24	1573.44	1579.08	1583.85	1576.48	1580.67	1528.53	1559.24	1618.67	1602.18	1543.09
25	1514.87	1518.75	1530.63	1530.78	1577.79	1593.17	1529.72	1567.38	1522.10	1600.41	1572.35	1578.48	1583.21	1576.39	1580.21	1527.65	1557.93	1618.10	1601.61	1542.15
26	1513.48	1517.57	1529.26	1531.18	1577.04	1592.78	1528.42	1566.64	1521.08	1599.60	1571.22	1577.64	1582.86	1576.37	1579.69	1526.78	1556.57	1617.56	1601.12	1541.34
27	1511.91	1516.29	1527.76	1531.46	1576.24	1592.42	1527.22	1565.86	1520.50	1598.83	1570.20	1576.71	1582.71	1576.26	1579.10	1525.88	1555.27	1617.08	1600.72	1540.50
28	1510.29	1514.86	1526.25	1531.74	1575.42	1591.98	1526.02	1565.13	1519.94	1598.09	1569.18	1575.78	1582.56	1576.10	1578.45	1525.02	1554.09	1616.64	1600.34	1539.64
29	1508.65	1513.50	1524.80	1532.02	1574.58	1591.50	1524.78	1564.40	1519.30	1597.36	1568.05	1574.74	1582.43	1576.07	1577.80	1524.19	1554.04	1616.28	1600.23	1538.71
30	1507.02	1512.57	1523.32	1532.20	1573.98	1591.04	1523.50	1563.68	1518.66	1596.87	1566.82	1574.25	1582.48	1576.15	1577.10	1523.74	1551.95	1616.10	1600.06	1537.81
31	1505.44	1512.00	1521.86	1532.30	1573.34	1590.58	1522.22	1562.94	1518.10	1596.23	1565.56	1573.77	1582.29	1576.21	1576.40	1523.56	1550.93	1616.00	1599.75	1536.90

Statement showing the levels of Bhakra Reservoir (In-feet)

April

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1504.32	1511.12	1520.56	1532.36	1572.72	1590.12	1520.96	1562.22	1517.58	1595.50	1564.50	1573.18	1582.14	1576.65	1575.80	1523.60	1550.10	1615.98	1599.26	1535.97
2	1503.00	1509.92	1519.66	1532.15	1572.06	1589.62	1519.80	1561.52	1517.59	1594.70	1563.63	1572.57	1581.93	1577.12	1575.22	1523.71	1549.26	1615.97	1598.88	1535.02
3	1502.00	1508.76	1518.25	1531.82	1571.43	1589.16	1518.60	1560.84	1517.47	1593.77	1562.95	1572.05	1581.71	1577.12	1574.70	1523.93	1548.44	1615.88	1598.50	1534.17
4	1501.03	1507.68	1517.10	1531.45	1570.78	1588.57	1517.50	1560.17	1517.25	1592.96	1562.22	1571.55	1581.49	1577.29	1574.40	1524.12	1547.83	1615.75	1598.08	1533.30
5	1499.96	1506.72	1516.25	1531.16	1570.12	1587.94	1516.69	1559.49	1516.99	1592.37	1561.51	1570.91	1581.11	1577.73	1574.30	1524.24	1547.17	1615.68	1597.86	1532.38
6	1498.93	1506.20	1515.34	1530.84	1569.50	1587.34	1516.23	1558.83	1516.80	1591.83	1560.72	1570.14	1580.69	1578.19	1574.30	1524.30	1546.53	1615.75	1597.50	1531.60
7	1498.08	1505.62	1514.56	1530.15	1569.02	1586.73	1515.97	1558.43	1516.63	1591.18	1559.98	1569.36	1580.37	1578.54	1574.28	1524.49	1545.90	1615.98	1596.98	1530.82
8	1497.30	1505.22	1513.92	1529.20	1568.60	1586.23	1515.83	1558.12	1516.48	1590.51	1559.10	1568.70	1580.12	1578.83	1574.01	1524.80	1545.20	1616.26	1596.42	1530.17
9	1496.46	1505.02	1513.38	1528.40	1568.22	1585.87	1515.64	1557.89	1516.48	1590.02	1558.24	1568.09	1580.32	1579.16	1573.76	1525.50	1544.50	1616.70	1595.93	1529.64
10	1495.67	1505.16	1512.70	1527.62	1567.92	1585.50	1515.46	1557.58	1516.60	1589.72	1557.84	1568.07	1580.70	1579.44	1573.50	1526.20	1543.94	1617.16	1595.42	1529.00
11	1495.11	1505.65	1511.79	1526.60	1567.73	1585.15	1515.34	1557.21	1516.96	1589.42	1557.75	1568.50	1580.91	1579.64	1573.08	1526.53	1543.70	1617.54	1594.92	1528.57
12	1494.60	1506.12	1510.77	1525.79	1567.54	1584.84	1515.22	1556.90	1517.29	1589.20	1557.82	1568.92	1580.72	1579.87	1572.69	1526.95	1543.70	1618.01	1594.42	1528.17
13	1494.05	1506.81	1509.82	1525.53	1567.34	1584.42	1515.22	1556.51	1517.72	1589.01	1557.79	1569.16	1581.10	1580.01	1572.26	1527.30	1543.60	1618.55	1593.96	1527.85
14	1493.80	1507.75	1508.89	1525.60	1567.18	1583.83	1515.37	1556.13	1518.25	1588.89	1557.62	1569.38	1581.63	1580.39	1571.83	1527.68	1543.52	1618.97	1593.57	1527.46
15	1494.01	1508.94	1507.97	1526.08	1566.82	1583.32	1515.47	1555.76	1518.50	1588.77	1557.45	1569.70	1581.98	1580.77	1571.36	1528.25	1543.39	1619.62	1593.44	1527.18
16	1494.32	1510.01	1507.01	1526.30	1566.47	1582.85	1515.38	1555.35	1518.66	1588.50	1557.30	1570.04	1582.21	1581.08	1570.94	1528.95	1543.10	1620.10	1593.30	1527.18
17	1494.61	1511.11	1506.08	1526.52	1566.16	1582.24	1515.74	1554.96	1518.93	1588.27	1557.08	1570.59	1582.45	1581.56	1570.49	1529.72	1542.83	1620.82	1593.07	1527.10
18	1494.79	1512.17	1505.25	1526.67	1565.85	1581.65	1516.12	1554.52	1519.46	1588.27	1556.86	1571.08	1582.83	1582.10	1569.73	1530.40	1542.51	1621.59	1592.97	1527.39
19	1494.65	1512.93	1504.52	1526.71	1565.51	1580.88	1516.31	1554.08	1520.08	1588.43	1556.61	1571.60	1583.10	1582.60	1569.27	1531.23	1542.03	1622.18	1592.86	1527.50
20	1494.28	1513.73	1503.78	1526.77	1565.12	1579.90	1516.45	1553.64	1520.76	1588.59	1556.34	1571.96	1583.36	1583.18	1569.14	1532.40	1541.62	1622.54	1592.68	1527.57
21	1494.20	1514.65	1503.30	1527.02	1564.75	1578.76	1516.54	1553.26	1521.20	1588.50	1556.32	1572.35	1583.73	1583.62	1568.72	1534.03	1541.25	1622.95	1592.40	1527.50
22	1494.12	1515.38	1502.71	1527.35	1563.95	1577.59	1516.62	1553.08	1521.38	1588.36	1556.37	1572.70	1583.98	1584.23	1568.20	1536.01	1540.89	1623.43	1592.04	1527.36
23	1493.64	1515.57	1502.04	1527.91	1563.16	1576.36	1516.90	1552.74	1521.72	1588.01	1556.68	1573.06	1584.23	1585.00	1567.58	1537.13	1540.46	1623.83	1591.67	1527.45
24	1493.23	1515.45	1500.97	1528.45	1562.63	1575.08	1517.10	1552.16	1521.79	1587.43	1556.94	1573.45	1584.50	1585.75	1566.81	1538.67	1539.89	1623.97	1591.27	1527.28
25	1493.02	1515.76	1500.12	1528.68	1562.16	1573.78	1517.38	1551.40	1521.56	1586.92	1557.25	1573.83	1584.76	1586.51	1566.00	1540.36	1539.28	1624.11	1590.92	1527.09
26	1493.31	1516.40	1499.02	1529.08	1561.76	1572.38	1517.89	1550.62	1521.18	1586.27	1557.35	1574.31	1585.12	1587.31	1564.95	1541.91	1538.72	1624.18	1590.65	1526.97
27	1493.92	1517.37	1497.86	1529.34	1561.42	1570.94	1518.12	1549.80	1520.48	1585.76	1557.36	1574.47	1585.45	1587.89	1563.91	1543.37	1538.30	1624.12	1590.51	1526.44
28	1494.10	1518.16	1496.94	1529.37	1561.32	1569.69	1517.86	1549.10	1519.90	1585.32	1557.40	1574.32	1585.52	1588.56	1562.75	1544.36	1537.85	1624.00	1590.18	1526.00
29	1493.62	1518.60	1496.48	1529.28	1561.34	1568.62	1517.62	1548.48	1519.61	1584.96	1557.37	1573.86	1585.08	1589.10	1561.50	1544.68	1537.78	1623.91	1589.61	1525.50
30	1492.74	1518.20	1496.02	1529.04	1561.48	1567.58	1517.47	1548.15	1519.49	1584.58	1557.13	1573.26	1584.58	1589.70	1560.38	1544.92	1537.71	1623.86	1589.03	1525.05

Statement showing the levels of Bhakra Reservoir (In-feet)

May

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1491.74	1517.18	1495.39	1528.56	1561.85	1566.72	1517.30	1547.46	1519.07	1584.20	1556.81	1572.59	1584.14	1590.24	1559.32	1544.58	1536.41	1623.89	1588.68	1524.17
2	1490.70	1516.50	1494.52	1528.13	1562.06	1565.82	1516.76	1546.47	1518.55	1583.77	1556.10	1571.74	1583.60	1590.60	1558.48	1543.39	1534.76	1623.83	1588.08	1523.25
3	1489.88	1516.16	1493.02	1527.84	1562.06	1565.00	1516.35	1545.55	1518.01	1583.33	1555.27	1570.70	1583.10	1591.02	1557.75	1542.28	1533.40	1623.64	1587.55	1522.18
4	1489.13	1515.90	1491.14	1528.10	1561.79	1564.17	1516.07	1544.72	1517.44	1582.74	1554.07	1569.51	1582.52	1591.14	1557.38	1540.89	1532.12	1623.30	1587.10	1521.34
5	1488.64	1514.99	1489.47	1528.43	1561.46	1563.27.	1516.20	1543.67	1517.45	1582.01	1552.79	1568.21	1582.08	1591.17	1557.32	1539.55	1530.93	1622.98	1586.68	1520.68
6	1488.90	1513.74	1487.80	1528.88	1561.00	1562.29	1516.61	1542.58	1518.45	1581.74	1551.60	1566.90	1581.86	1591.24	1557.25	1538.34	1529.20	1622.54	1585.95	1520.40
7	1489.56	1512.63	1486.23	1529.40	1561.15	1561.59	1516.73	1541.43	1519.54	1581.24	1550.45	1565.58	1581.57	1591.48	1556.76	1537.12	1527.13	1622.30	1584.77	1520.12
8	1490.18	1511.59	1484.75	1530.20	1561.98	1561.21	1516.60	1540.17	1520.55	1580.80	1549.40	1564.31	1581.32	1591.85	1556.40	1535.88	1525.10	1622.01	1583.51	1519.59
9	1490.78	1510.80	1483.48	1531.30	1563.20	1560.70	1516.35	1538.73	1520.92	1580.20	1548.56	1563.00	1581.02	1592.44	1556.11	1534.63	1523.27	1621.66	1582.17	1518.84
10	1491.76	1510.66	1482.16	1532.56	1564.53	1560.26	1516.23	1537.27	1520.55	1579.47	1547.85	1561.90	1580.87	1593.18	1556.65	1534.32	1521.29	1621.41	1580.77	1518.24
11	1493.08	1511.00	1480.56	1533.60	1565.85	1559.63	1516.17	1535.69	1520.08	1578.90	1547.28	1561.27	1580.73	1593.53	1557.78	1534.15	1519.36	1621.28	1579.24	1517.45
12	1494.73	1511.96	1478.81	1534.10	1566.97	1559.00	1515.53	1534.20	1519.80	1578.09	1546.72	1560.58	1580.52	1594.06	1559.00	1533.96	1517.07	1621.12	1577.37	1516.87
13	1496.62	1513.15	1477.59	1534.41	1568.00	1558.30	1514.81	1532.62	1519.25	1577.32	1546.14	1560.24	1580.41	1594.84	1559.86	1533.86	1515.00	1620.81	1575.87	1516.26
14	1499.10	1514.66	1476.45	1534.69	1569.12	1557.39	1514.25	1530.92	1518.28	1576.70	1545.59	1559.55	1580.17	1595.48	1559.98	1533.91	1513.69	1620.25	1574.24	1515.92
15	1501.69	1515.46	1475.40	1534.95	1570.25	1556.60	1513.80	1529.34	1517.53	1576.08	1544.90	1558.94	1579.72	1595.62	1560.39	1534.46	1511.56	1619.94	1572.48	1515.78
16	1505.06	1516.04	1474.85	1534.82	1571.53	1556.20	1513.79	1528.01	1516.70	1575.42	1544.08	1558.30	1579.17	1596.02	1560.79	1534.80	1509.77	1619.46	1570.99	1515.49
17	1509.18	1516.78	1474.70	1534.99	1573.10	1556.13.	1514.29	1527.00	1515.68	1574.72	1543.27	1557.66	1578.29	1596.03	1560.92	1535.23	1507.82	1618.69	1569.50	1514.49
18	1513.56	1518.43	1474.89	1535.25	1574.74	1553.12	1515.10	1526.26	1514.80	1574.30	1542.58	1557.30	1577.40	1596.21	1560.92	1536.29	1506.00	1617.84	1568.05	1513.69
19	1518.11	1520.38	1475.23	1535.47	1576.02	1556.08	1515.91	1525.94	1514.00	1573.95	1542.08	1557.45	1576.61	1596.95	1561.12	1537.62	1504.53	1617.15	1566.40	1513.26
20	1521.69	1522.55	1475.45	1535.43	1577.02	1556.40	1516.62	1526.14	1512.90	1573.80	1541.60	1558.10	1576.07	1597.70	1561.28	1538.65	1503.25	1616.46	1565.20	1512.97
21	1524.01	1524.91	1476.28	1535.15	1578.02	1557.34	1517.64	1526.68	1512.00	1573.97	1541.04	1559.15	1575.56	1598.23	1561.88	1539.71	1501.36	1615.88	1563.80	1512.52
22	1525.28	1527.35	1477.54	1535.16	1578.48	1558.14	1518.88	1527.30	1511.20	1574.03	1540.43	1560.28	1575.39	1598.67	1563.28	1540.87	1499.66	1615.35	1562.58	1511.86
23	1526.03	1530.17	1478.64	1535.20	1579.10	1558.52	1519.92	1527.91	1510.68	1573.76	1539.65	1561.90	1575.11	1599.14	1564.24	1541.95	1498.12	1614.98	1561.62	1511.20
24	1527.03	1532.82	1479.70	1535.34	1579.58	1558.68	1521.21	1528.38	1511.15	1573.21	1538.68	1563.72	1574.81	1599.60	1565.53	1543.08	1497.18	1614.68	1561.31	1509.98
25	1528.30	1535.04	1480.40	1535.54	1580.30	1558.62	1522.78	1528.83	1511.48	1572.73	1537.94	1565.72	1574.72	1600.02	1566.57	1544.22	1496.32	1614.70	1561.15	1508.91
26	1529.82	1537.14	1480.44	1535.74	1581.54	1558.38	1524.24	1529.18	1512.00	1572.55	1537.63	1567.46	1574.54	1600.40	1567.56	1545.30	1495.68	1614.56	1561.06	1507.92
27	1531.58	1538.84	1479.92	1535.98	1582.96	1558.02	1525.72	1529.13	1513.04	1572.42	1537.82	1569.07	1574.22	1600.55	1567.66	1546.34	1495.22	1614.34	1561.13	1506.60
28	1533.46	1540.40	1479.56	1536.15	1584.42	1557.60	1526.84	1528.88	1514.40	1572.95	1538.00	1570.56	1573.97	1600.52	1567.47	1547.18	1494.40	1613.94	1561.16	1505.30
29	1534.96	1542.20	1479.00	1536.24	1585.90	1557.04	1527.97	1528.68	1515.85	1573.10	1538.06	1571.22	1573.76	1600.42	1567.62	1548.80	1493.67	1613.58	1561.18	1504.55
30	1535.98	1543.44	1478.32	1536.50	1587.34	1556.47	1528.97	1528.58	1516.87	1573.43	1538.20	1571.30	1573.81	1600.44	1567.99	1550.44	1492.70	1613.15	1561.10	1504.34
31	1536.82	1544.75	1477.86	1536.74	1588.58	1555.75	1529.70	1528.24	1517.18	1573.93	1538.85	1571.10	1574.21	1600.54	1568.65	1551.91	1491.76	1613.16	1561.23	1504.24

Statement showing the levels of Bhakra Reservoir (In-feet)

June

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1537.20	1546.90	1478.00	1536.84	1589.65	1554.95	1530.70	1527.11	1516.18	1574.20	1539.32	1570.65	1574.52	1600.44	1569.00	1553.32	1490.94	1613.08	1561.20	1504.48
2	1537.76	1549.45	1477.54	1536.42	1590.06	1554.20	1531.82	1525.36	1515.58	1574.62	1539.92	1570.83	1574.67	1600.33	1569.40	1554.37	1490.83	1612.93	1561.25	1505.39
3	1538.65	1552.04	1476.75	1536.00	1590.19	1553.52	1533.09	1523.96	1515.85	1574.63	1540.45	1571.80	1574.82	1600.11	1569.89	1555.39	1491.19	1612.44	1561.44	1505.83
4	1539.44	1554.70	1475.86	1535.75	1589.98	1553.07	1534.40	1523.03	1516.58	1574.33	1540.67	1573.51	1574.82	1599.52	1570.63	1556.16	1491.33	1612.25	1561.19	1506.24
5	1540.22	1557.94	1474.87	1535.90	1589.73	1552.60	1535.58	1523.10	1516.94	1573.63	1540.71	1575.10	1574.88	1598.78	1571.34	1557.04	1491.50	1612.15	1561.05	1506.36
6	1541.21	1560.45	1473.70	1536.28	1589.26	1551.97	1537.05	1523.70	1516.50	1573.04	1540.79	1576.85	1575.20	1598.15	1572.36	1558.35	1491.83	1611.96	1560.89	1506.59
7	1542.36	1562.50	1473.19	1536.67	1588.52	1551.51	1539.08	1524.31	1515.95	1572.74	1540.55	1578.56	1575.78	1597.72	1572.95	1559.76	1493.63	1611.77	1560.91	1506.79
8	1543.98	1564.80	1473.01	1537.07	1587.55	1551.32	1541.65	1524.21	1515.34	1572.59	1540.13	1579.87	1576.63	1597.64	1573.10	1561.25	1496.50	1611.50	1560.82	1507.04
9	1546.02	1567.25	1472.74	1537.42	1586.60	1551.51	1544.62	1523.42	1516.18	1572.45	1538.95	1581.07	1577.84	1597.63	1573.04	1562.78	1499.50	1610.98	1560.98	1508.07
10	1548.52	1569.92	1471.49	1537.44	1586.06	1552.16	1547.76	1522.05	1517.01	1572.36	1537.57	1582.74	1578.79	1597.91	1573.06	1564.22	1502.61	1610.43	1561.20	1509.34
11	1551.11	1572.39	1470.12	1537.72	1585.80	1553.22	1550.72	1520.64	1516.97	1572.10	1536.20	1585.12	1579.97	1598.07	1573.11	1565.45	1505.62	1610.07	1561.67	1510.84
12	1553.91	1574.36	1468.64	1538.20	1585.44	1554.60	1554.12	1519.32	1516.22	1571.76	1534.66	1587.46	1580.73	1598.57	1573.11	1566.53	1508.13	1609.76	1561.70	1513.05
13	1556.46	1576.14	1467.14	1539.02	1584.92	1556.11	1558.28	1518.01	1515.19	1571.80	1533.34	1589.05	1581.16	1598.81	1573.08	1567.50	1509.24	1609.43	1562.81	1515.14
14	1558.43	1577.76	1466.11	1539.94	1584.03	1558.09	1562.68	1516.93	1514.16	1572.18	1532.06	1590.44	1581.50	1598.50	1573.11	1567.34	1509.55	1609.20	1563.70	1517.09
15	1559.95	1579.11	1467.26	1540.65	1582.85	1560.26	1566.28	1515.67	1513.16	1572.84	1530.83	1591.29	1581.76	1598.56	1572.91	1566.86	1509.97	1608.74	1564.52	1518.97
16	1561.23	1580.41	1469.66	1541.20	1581.48	1562.16	1570.64	1514.28	1512.02	1573.82	1529.46	1592.77	1582.38	1598.43	1572.58	1566.80	1510.79	1608.14	1565.35	1519.97
17	1562.77	1581.78	1472.45	1542.08	1580.06	1563.41	1574.32	1513.04	1510.94	1574.84	1528.42	1593.50	1583.57	1598.20	1572.19	1566.36	1512.04	1607.78	1565.95	1521.94
18	1564.17	1583.11	1476.00	1542.95	1578.66	1564.12	1578.58	1511.58	1509.98	1576.38	1527.94	1595.04	1585.04	1597.57	1571.92	1565.54	1512.81	1607.42	1566.49	1523.39
19	1564.95	1584.42	1479.65	1543.86	1576.94	1564.62	1583.02	1509.62	1508.66	1577.42	1527.76	1595.96	1587.17	1597.47	1572.15	1564.90	1513.08	1607.02	1567.02	1524.14
20	1565.41	1585.87	1483.39	1545.35	1575.10	1564.96	1586.80	1507.65	1507.66	1578.08	1527.62	1596.35	1589.57	1598.54	1572.43	1564.50	1510.88	1606.38	1568.00	1524.44
21	1565.40	1586.85	1486.62	1547.22	1573.48	1565.36	1589.86	1505.64	1507.66	1578.87	1527.54	1596.75	1591.80	1599.72	1572.56	1564.15	1508.42	1605.59	1569.10	1524.54
22	1565.20	1587.47	1489.00	1549.20	1571.72	1565.68	1592.30	1504.57	1508.42	1579.80	1527.88	1597.13	1594.03	1600.28	1572.88	1564.17	1505.56	1605.08	1570.18	1524.67
23	1565.28	1588.10	1490.79	1551.58	1570.00	1566.10	1594.50	1504.36	1509.68	1580.90	1528.77	1597.54	1595.60	1600.72	1573.16	1564.17	1502.72	1604.64	1570.52	1524.60
24	1565.98	1589.02	1492.04	1554.46	1568.55	1566.90	1596.10	1504.70	1511.28	1582.50	1530.10	1598.37	1596.46	1600.84	1573.27	1564.10	1499.94	1604.28	1571.52	1524.76
25	1567.32	1589.70	1493.18	1557.54	1567.94	1567.62	1597.64	1505.48	1513.60	1584.24	1531.88	1599.92	1596.88	1601.45	1573.37	1564.04	1497.03	1604.21	1573.60	1524.87
26	1568.58	1590.34	1494.01	1560.58	1567.80	1568.72	1599.11	1506.84	1516.06	1586.38	1533.31	1602.16	1597.30	1602.24	1573.45	1563.94	1494.35	1604.22	1575.90	1524.93
27	1570.08	1591.48	1494.04	1564.76	1567.94	1569.96	1600.71	1509.90	1517.27	1588.69	1534.25	1605.13	1597.71	1602.65	1573.57	1564.06	1492.24	1604.36	1577.30	1524.94
28	1571.44	1593.09	1493.65	1568.92	1568.52	1571.33	1602.81	1513.65	1518.65	1590.61	1534.50	1608.01	1598.05	1602.51	1573.87	1564.50	1491.21	1604.47	1578.69	1524.77
29	1573.04	1594.34	1493.08	1572.24	1569.52	1572.81	1605.00	1517.81	1520.50	1592.88	1534.58	1610.53	1598.62	1602.34	1574.16	1565.22	1490.94	1604.58	1580.41	1524.73
30	1574.40	1595.48	1492.63	1575.14	1570.35	1574.23	1606.46	1521.37	1522.61	1594.89	1534.70	1612.84	1599.64	1602.26	1574.57	1566.52	1491.31	1604.72	1581.97	1525.18

Statement showing the levels of Bhakra Reservoir (In-feet)

July

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1575.41	1596.55	1493.15	1577.87	1571.60	1575.58	1607.71	1524.73	1524.96	1596.25	1534.85	1614.67	1600.59	1601.95	1574.76	1567.98	1493.37	1604.76	1582.82	1526.25
2	1576.48	1597.09	1493.87	1581.20	1572.65	1576.99	1608.80	1527.20	1527.03	1597.60	1535.20	1616.24	1601.86	1602.47	1575.05	1569.32	1495.27	1604.90	1583.47	1527.23
3	1577.80	1597.77	1495.34	1583.71	1574.08	1578.95	1609.77	1528.49	1527.92	1598.55	1536.03	1617.72	1603.77	1603.03	1575.86	1570.90	1496.34	1605.33	1584.30	1528.42
4	1579.52	1598.48	1497.09	1586.07	1576.01	1580.91	1611.00	1529.10	1528.60	1599.70	1537.29	1619.02	1605.33	1603.50	1576.22	1572.35	1495.79	1605.94	1585.23	1529.38
5	1581.68	1599.98	1499.25	1588.17	1577.57	1582.33	1612.51	1529.29	1530.18	1600.60	1539.00	1620.28	1606.71	1604.36	1576.54	1574.04	1499.38	1607.80	1586.48	1530.31
6	1583.07	1602.53	1501.93	1592.00	1579.16	1583.49	1613.92	1529.09	1532.51	1601.28	1540.56	1621.78	1607.93	1605.75	1577.75	1575.66	1501.01	1608.57	1588.01	1531.10
7	1583.76	1603.54	1504.38	1597.05	1580.68	1584.68	1615.67	1529.15	1537.06	1602.06	1541.51	1623.85	1609.06	1607.42	1578.80	1577.35	1501.06	1609.24	1588.71	1532.69
8	1584.20	1604.21	1507.30	1599.43	1582.48	1585.82	1617.26	1529.69	1542.56	1602.95	1543.09	1626.14	1610.17	1609.26	1579.61	1578.85	1500.29	1610.45	1589.15	1533.84
9	1584.81	1604.72	1511.36	1601.36	1584.92	1587.95	1618.37	1530.66	1546.19	1604.01	1544.36	1628.32	1611.41	1610.90	1579.83	1580.21	1499.55	1611.91	1590.20	1535.24
10	1585.50	1605.45	1514.00	1603.36	1588.16	1589.72	1619.85	1532.27	1548.81	1605.19	1545.22	1629.87	1612.58	1613.30	1580.00	1581.29	1500.13	1613.81	1591.42	1536.93
11	1586.27	1606.20	1515.77	1605.80	1590.31	1590.88	1620.70	1533.87	1551.43	1606.04	1546.14	1631.10	1613.77	1615.69	1580.35	1583.10	1501.68	1615.27	1593.23	1538.30
12	1587.01	1606.68	1517.10	1608.68	1592.46	1592.11	1621.57	1535.14	1553.98	1606.60	1546.99	1631.98	1615.12	1618.10	1580.68	1584.96	1504.35	1616.84	1594.70	1540.93
13	1587.67	1607.11	1518.38	1611.68	1594.57	1593.25	1622.99	1536.60	1556.40	1607.11	1548.07	1632.79	1616.62	1620.09	1580.77	1586.89	1506.77	1618.71	1596.18	1543.40
14	1588.28	1608.16	1519.69	1614.63	1596.31	1594.24	1624.18	1538.94	1558.06	1607.73	1549.44	1633.60	1618.36	1622.04	1581.00	1588.73	1509.98	1620.91	1597.34	1545.92
15	1588.86	1608.71	1520.92	1618.16	1597.64	1595.10	1624.76	1541.50	1559.40	1608.62	1550.54	1634.32	1620.22	1623.98	1581.29	1590.56	1511.95	1622.67	1598.29	1547.14
16	1589.35	1609.31	1522.21	1621.92	1598.49	1595.58	1625.26	1543.56	1561.16	1610.62	1551.15	1635.35	1622.10	1626.19	1582.07	1592.31	1514.15	1624.18	1599.70	1548.55
17	1589.93	1610.28	1523.53	1625.04	1599.30	1595.96	1626.00	1544.70	1563.07	1611.70	1551.63	1636.44	1624.15	1629.23	1583.02	1594.50	1517.16	1625.61	1601.36	1549.90
18	1590.65	1611.47	1524.83	1627.88	1600.26	1596.24	1627.30	1545.57	1565.80	1612.57	1552.20	1637.30	1625.90	1631.39	1584.13	1596.60	1519.39	1626.79	1602.55	1551.40
19	1591.46	1612.11	1526.11	1630.24	1601.24	1596.58	1629.02	1547.10	1568.20	1613.58	1553.18	1638.17	1627.38	1633.16	1586.11	1598.92	1521.72	1627.82	1604.25	1553.70
20	1592.29	1612.60	1527.44	1632.14	1602.40	1597.02	1630.20	1548.60	1571.38	1614.72	1554.37	1639.03	1629.30	1634.75	1588.45	1601.10	1523.98	1629.07	1605.85	1558.08
21	1593.32	1613.54	1528.42	1634.60	1604.56	1597.66	1631.33	1550.32	1574.88	1615.81	1555.65	1640.55	1630.87	1636.45	1589.47	1603.56	1526.25	1630.09	1607.40	1561.59
22	1594.11	1615.00	1529.08	1636.04	1606.07	1598.44	1632.52	1552.14	1578.67	1617.13	1556.74	1641.40	1632.17	1638.07	1589.75	1605.77	1528.33	1631.22	1608.72	1564.50
23	1594.87	1615.90	1529.72	1637.48	1607.66	1599.37	1633.52	1553.50	1582.21	1618.34	1557.56	1642.36	1633.22	1639.88	1590.40	1607.82	1530.51	1632.46	1610.24	1566.93
24	1595.40	1616.92	1530.31	1639.04	1609.66	1600.54	1634.44	1554.76	1585.14	1619.90	1558.92	1643.28	1634.45	1641.11	1590.99	1609.77	1532.72	1634.08	1611.49	1569.02
25	1595.80	1618.26	1530.54	1640.36	1611.86	1601.64	1635.45	1556.24	1588.03	1621.70	1560.75	1644.36	1635.98	1642.45	1591.32	1612.04	1536.71	1635.69	1612.26	1570.93
26	1596.21	1619.14	1530.90	1641.72	1614.14	1602.75	1636.42	1557.60	1591.45	1625.12	1562.92	1645.34	1637.64	1643.59	1591.57	1614.45	1542.44	1638.13	1612.94	1572.89
27	1596.43	1620.38	1531.74	1643.34	1616.50	1603.93	1637.54	1559.05	1595.49	1628.03	1564.72	1646.09	1639.33	1645.13	1591.86	1616.85	1548.24	1639.92	1613.50	1576.22
28	1596.57	1621.75	1532.98	1645.36	1619.13	1605.21	1638.51	1560.92	1600.60	1630.57	1566.36	1646.70	1641.44	1646.13	1592.10	1618.98	1554.09	1641.88	1614.34	1579.34
29	1596.74	1623.08	1534.58	1647.40	1621.77	1606.28	1639.45	1564.15	1605.40	1632.56	1567.93	1647.23	1643.48	1647.03	1592.39	1620.97	1560.68	1643.59	1615.40	1583.86
30	1596.86	1624.32	1536.72	1649.67	1624.18	1607.10	1640.53	1568.08	1609.10	1634.04	1569.90	1647.87	1645.54	1647.81	1592.72	1622.87	1563.35	1645.28	1617.20	1586.63
31	1596.95	1625.48	1538.68	1651.31	1626.06	1607.81	1642.65	1569.85	1612.17	1635.26	1572.13	1648.50	1647.41	1648.50	1593.94	1624.88	1566.06	1647.61	1618.46	1589.09

Statement showing the levels of Bhakra Reservoir (In-feet)

August

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1597.29	1627.88	1540.77	1652.83	1627.97	1608.54	1644.81	1571.50	1615.76	1636.42	1574.31	1648.98	1649.19	1649.64	1595.46	1627.66	1567.72	1650.20	1619.57	1592.16
2	1598.10	1629.92	1542.39	1654.14	1629.94	1609.36	1645.99	1573.07	1618.52	1637.53	1576.80	1649.53	1650.99	1650.91	1596.78	1631.08	1569.21	1652.55	1620.90	1594.77
3	1599.03	1631.68	1544.04	1655.56	1632.46	1610.37	1647.08	1574.57	1621.73	1638.49	1579.52	1650.19	1652.48	1651.85	1598.77	1633.77	1570.64	1655.37	1621.96	1597.22
4	1600.75	1634.02	1547.28	1656.95	1635.29	1611.78	1648.12	1576.09	1625.34	1639.38	1582.32	1650.93	1653.84	1652.75	1600.62	1636.06	1572.63	1657.00	1623.13	1599.17
5	1602.30	1635.84	1548.14	1658.38	1638.51	1612.88	1649.17	1577.75	1628.69	1640.41	1585.10	1651.43	1655.14	1654.06	1602.00	1638.63	1574.34	1658.23	1624.27	1601.30
6	1603.55	1637.74	1549.34	1659.74	1641.87	1614.00	1650.39	1579.77	1632.85	1641.34	1586.88	1652.09	1656.38	1655.20	1603.46	1641.28	1576.36	1659.49	1625.05	1602.81
7	1604.95	1639.12	1551.10	1660.94	1645.01	1615.09	1651.41	1583.70	1637.44	1642.29	1588.11	1652.94	1657.56	1656.33	1606.30	1645.06	1578.82	1660.69	1625.98	1604.28
8	1606.28	1640.30	1553.14	1661.54	1648.00	1616.06	1652.73	1585.70	1641.24	1643.24	1589.23	1653.68	1658.80	1657.76	1608.84	1648.16	1583.24	1661.92	1626.84	1605.42
9	1607.97	1641.67	1555.46	1661.81	1650.86	1616.99	1654.26	1587.32	1644.28	1644.91	1590.33	1654.88	1660.16	1660.08	1612.16	1649.90	1586.39	1663.40	1628.33	1606.84
10	1609.93	1642.93	1557.55	1662.11	1653.30	1617.89	1655.45	1588.80	1646.76	1646.00	1591.60	1656.45	1661.47	1662.22	1615.93	1651.54	1590.63	1665.94	1630.08	1608.37
11	1612.00	1644.00	1559.29	1662.66	1655.50	1618.96	1656.72	1590.26	1648.50	1647.30	1592.78	1657.38	1662.50	1663.78	1618.67	1653.39	1593.83	1667.17	1631.65	1609.32
12	1614.06	1644.81	1561.05	1663.19	1657.46	1620.46	1657.94	1591.74	1650.60	1648.54	1593.85	1658.30	1663.50	1664.98	1620.96	1654.75	1596.97	1668.53	1633.27	1610.25
13	1615.83	1645.43	1562.81	1663.85	1659.07	1628.66	1659.20	1593.28	1652.98	1650.57	1594.96	1659.45	1664.44	1665.71	1623.45	1656.00	1601.34	1669.80	1635.30	1611.22
14	1617.78	1646.07	1564.51	1664.48	1660.54	1635.20	1662.15	1594.94	1654.88	1654.83	1595.95	1660.51	1665.41	1666.34	1625.45	1657.23	1609.74	1671.18	1637.48	1612.37
15	1620.68	1646.81	1566.14	1665.18	1661.98	1638.52	1665.08	1596.74	1657.12	1656.71	1597.05	1661.74	1667.68	1667.75	1626.94	1658.10	1612.58	1672.68	1638.75	1613.53
16	1622.79	1647.57	1567.80	1665.97	1663.56	1640.76	1667.20	1598.88	1659.43	1658.93	1598.40	1662.79	1669.89	1668.80	1628.46	1658.68	1615.08	1673.88	1640.21	1614.48
17	1624.23	1648.14	1570.07	1667.34	1664.72	1642.18	1669.00	1600.67	1662.14	1662.42	1599.77	1663.83	1671.20	1669.71	1629.59	1659.24	1616.89	1674.54	1641.35	1615.37
18	1625.37	1648.62	1573.06	1668.20	1665.84	1643.32	1670.31	1602.50	1664.50	1664.05	1601.03	1664.72	1671.61	1670.52	1630.52	1659.84	1618.74	1676.93	1642.55	1616.13
19	1626.41	1649.48	1575.70	1668.54	1666.88	1644.08	1671.16	1604.16	1666.56	1665.27	1603.10	1665.73	1671.90	1670.57	1631.70	1660.98	1620.81	1680.80	1643.99	1616.77
20	1627.30	1651.38	1577.40	1668.70	1668.26	1645.10	1671.63	1605.67	1668.53	1666.40	1606.18	1666.66	1672.14	1670.84	1632.54	1662.38	1622.71	1680.82	1645.14	1617.13
21	1628.08	1652.31	1578.85	1668.76	1669.54	1646.18	1672.03	1606.62	1670.83	1667.35	1608.36	1667.48	1672.35	1671.30	1633.59	1663.26	1624.60	1679.49	1646.65	1618.02
22	1628.88	1652.83	1580.06	1668.91	1670.24	1647.34	1672.27	1607.30	1672.13	1668.16	1610.93	1668.56	1672.52	1672.16	1634.36	1664.00	1626.39	1678.06	1648.39	1619.23
23	1629.78	1653.12	1581.31	1668.91	1671.05	1648.30	1672.76	1608.00	1673.16	1668.91	1614.50	1669.50	1672.63	1672.71	1635.37	1664.62	1628.17	1677.54	1649.70	1619.88
24	1630.81	1653.36	1582.64	1669.21	1671.76	1649.28	1673.13	1608.64	1673.55	1669.72	1616.95	1670.36	1672.67	1673.40	1636.36	1665.30	1630.32	1676.85	1650.47	1620.63
25	1631.98	1653.71	1583.80	1669.62	1672.34	1650.32	1673.32	1609.26	1674.06	1670.50	1619.33	1671.24	1672.68	1673.74	1637.27	1666.39	1632.54	1676.13	1651.14	1621.41
26	1633.15	1654.20	1585.44	1669.83	1673.17	1651.52	1673.43	1609.91	1674.53	1671.16	1622.60	1672.09	1672.62	1674.24	1638.26	1667.36	1634.32	1675.89	1651.88	1622.43
27	1634.64	1654.98	1586.51	1670.32	1674.24	1652.39	1673.47	1610.55	1674.80	1671.76	1625.12	1672.85	1672.52	1674.73	1638.98	1668.05	1635.67	1675.64	1652.77	1623.52
28	1636.29	1656.42	1587.41	1670.67	1675.22	1653.22	1673.59	1611.18	1675.22	1672.69	1627.29	1673.45	1672.38	1675.27	1640.13	1668.58	1636.81	1675.54	1653.92	1624.97
29	1638.28	1657.28	1588.20	1670.96	1675.23	1653.92	1673.62	1611.75	1675.72	1673.39	1629.20	1674.10	1672.55	1675.77	1641.13	1668.91	1637.79	1675.47	1655.06	1626.20
30	1640.25	1658.13	1588.92	1671.12	1675.25	1654.50	1673.68	1612.46	1676.19	1673.95	1630.85	1674.55	1672.60	1676.21	1642.38	1669.28	1638.96	1675.60	1655.80	1627.34
31	1641.65	1659.16	1589.57	1671.29	1675.35	1655.09	1673.91	1613.65	1676.69	1674.40	1632.32	1674.96	1672.43	1676.71	1643.75	1669.64	1640.12	1675.88	1656.53	1628.25

Statement showing the levels of Bhakra Reservoir (In-feet)

September

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1642.98	1659.94	1590.19	1671.47	1675.82	1655.86	1674.03	1615.72	1677.29	1674.91	1633.72	1675.57	1672.30	1677.19	1645.00	1669.97	1641.15	1675.92	1657.38	1628.91
2	1644.37	1660.63	1590.66	1671.66	1676.28	1656.61	1674.26	1616.83	1677.93	1675.54	1634.90	1675.98	1672.35	1677.56	1646.34	1670.73	1642.00	1675.88	1658.13	1629.58
3	1645.40	1661.79	1591.07	1671.85	1676.49	1657.63	1674.51	1617.37	1678.59	1676.19	1635.91	1676.18	1672.31	1677.90	1647.31	1671.66	1642.79	1675.76	1658.76	1630.12
4	1646.40	1663.36	1591.46	1672.10	1676.70	1658.51	1674.61	1618.18	1679.40	1676.64	1637.09	1676.42	1672.30	1678.07	1648.04	1672.36	1643.84	1675.46	1659.74	1630.39
5	1647.03	1664.07	1591.87	1672.32	1676.86	1659.39	1674.87	1618.60	1680.05	1676.94	1638.20	1676.59	1672.60	1678.22	1648.63	1672.66	1644.69	1675.27	1660.53	1630.84
6	1647.54	1664.57	1592.25	1672.56	1677.14	1660.01	1675.21	1618.84	1680.34	1677.23	1639.56	1676.73	1673.17	1678.32	1649.06	1672.73	1645.61	1675.24	1661.27	1631.09
7	1647.87	1665.05	1592.65	1672.78	1677.33	1660.60	1675.48	1618.78	1680.55	1677.43	1640.96	1676.90	1673.81	1678.27	1649.23	1672.86	1646.31	1675.00	1662.02	1631.30
8	1648.67	1665.56	1593.04	1672.99	1677.15	1660.94	1675.66	1618.60	1680.80	1677.66	1642.30	1677.13	1674.51	1678.29	1649.41	1673.03	1647.12	1675.01	1662.49	1631.87
9	1650.19	1665.89	1593.42	1673.21	1677.08	1661.17	1675.70	1618.40	1680.95	1678.11	1643.61	1677.67	1675.34	1678.20	1649.58	1673.15	1647.81	1675.12	1662.72	1632.42
10	1650.62	1666.26	1593.86	1673.42	1677.15	1661.24	1675.66	1620.04	1680.39	1679.28	1644.60	1677.82	1676.09	1678.07	1649.73	1673.02	1648.41	1675.18	1662.75	1633.29
11	1650.97	1666.54	1594.36	1673.47	1677.32	1661.28	1675.49	1623.40	1680.14	1679.84	1645.43	1677.93	1676.58	1677.88	1649.89	1672.73	1649.00	1675.14	1662.67	1634.33
12	1651.22	1666.97	1594.88	1673.52	1677.12	1661.24	1675.28	1626.24	1680.16	1680.17	1646.18	1678.00	1677.05	1677.60	1650.06	1672.51	1649.51	1675.03	1662.63	1635.32
13	1652.20	1667.32	1595.40	1673.76	1676.72	1661.08	1675.03	1629.66	1680.19	1680.40	1646.98	1678.16	1677.47	1677.48	1650.40	1672.15	1650.05	1674.91	1662.48	1636.29
14	1653.48	1667.68	1595.86	1674.27	1676.64	1660.86	1674.92	1631.82	1680.92	1680.57	1647.80	1678.29	1677.81	1677.53	1650.70	1671.76	1650.68	1675.27	1662.22	1637.39
15	1654.44	1668.02	1596.38	1674.78	1676.48	1660.70	1674.80	1633.32	1681.08	1680.70	1648.79	1678.32	1678.13	1677.56	1650.76	1671.35	1651.24	1675.51	1661.90	1638.59
16	1655.23	1668.30	1597.46	1675.30	1676.23	1660.46	1674.60	1634.31	1680.77	1680.93	1649.55	1678.45	1678.33	1677.50	1650.73	1670.93	1651.52	1675.79	1661.59	1639.49
17	1655.93	1668.64	1598.02	1676.02	1675.96	1660.18	1674.44	1635.15	1680.28	1681.02	1650.39	1678.55	1678.43	1677.39	1650.68	1670.46	1651.52	1676.04	1661.27	1640.31
18	1656.57	1668.94	1598.39	1677.36	1675.67	1660.08	1674.24	1635.72	1680.03	1681.02	1651.32	1678.50	1678.49	1677.22	1650.63	1669.97	1651.55	1675.96	1660.81	1641.14
19	1657.04	1669.14	1598.46	1678.76	1675.46	1660.01	1674.11	1636.09	1680.29	1680.93	1653.84	1678.39	1678.42	1677.02	1650.57	1669.43	1651.50	1675.80	1660.38	1641.71
20	1657.43	1669.28	1598.57	1679.86	1675.79	1659.95	1676.50	1636.37	1680.74	1680.76	1654.92	1678.32	1678.36	1676.72	1650.44	1669.05	1651.41	1675.54	1660.03	1642.15
21	1657.70	1669.38	1598.66	1680.26	1675.80	1660.04	1680.07	1636.56	1681.10	1680.51	1655.83	1678.19	1678.34	1676.72	1650.38	1668.78	1651.25	1675.34	1659.61	1642.67
22	1657.87	1669.48	1598.80	1680.56	1675.52	1660.05	1680.69	1636.90	1681.18	1680.35	1656.45	1678.11	1678.19	1677.22	1650.38	1668.39	1651.25	1675.11	1659.21	1643.58
23	1657.87	1669.84	1598.94	1680.81	1675.14	1660.22	1680.41	1637.24	1681.53	1680.24	1657.07	1678.01	1677.95	1677.54	1650.51	1668.10	1652.92	1674.84	1658.73	1644.14
24	1657.84	1670.31	1599.08	1680.96	1674.84	1660.12	1680.19	1637.56	1681.11	1680.12	1657.52	1677.86	1677.64	1678.00	1650.57	1668.39	1654.84	1674.37	1658.30	1645.26
25	1657.79	1670.48	1599 07	1681.11	1674.54	1659.89	1680.01	1637.86	1680.59	1679.95	1657.64	1677.60	1677.36	1678.51	1650.53	1668.88	1658.45	1673.96	1657.90	1646.09
26	1657.69	1670.55	1599.03	1681.30	1674.17	1659.58	1680.03	1638.14	1680.47	1679.69	1657.60	1677.35	1677.00	1678.86	1650.31	1669.38	1660.24	1673.68	1657.48	1646.75
27	1657.52	1670.55	1598.99	1681.40	1673.87	1659.30	1679.95	1638.41	1680.44	1679.59	1657.49	1677.23	1676.60	1679.10	1650.16	1669.38	1661.45	1673.49	1657.05	1647.46
28	1657.29	1670.31	1598.89	1681.34	1673.49	1659.05	1679.88	1638.65	1680.61	1679.52	1657.47	1677.04	1676.11	1679.22	1650.04	1669.49	1662.52	1673.76	1656.46	1648.03
29	1657.05	1670.17	1598.86	1681.21	1673.08	1658.69	1679.84	1638.81	1680.67	1679.40	1657.52	1677.01	1675.69	1679.12	1649.77	1669.42	1663.51	1673.70	1655.64	1648.43
30	1656.76	1670.05	1598.90	1680.98	1672.65	1658.34	1679.80	1638.97	1680.67	1679.26	1657.44	1676.99	1675.16	1678.93	1649.68	1669.50	1664.38	1673.83	1654.88	1648.76

Statement showing the levels of Bhakra Reservoir (In-feet)

October

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1656.50	1669.85	1598.73	1680.78	1672.23	1657.94	1679.63	1639.10	1680.63	1679.08	1657.24	1676.87	1674.75	1678.69	1649.47	1669.37	1665.13	1674.24	1654.15	1649.12
2	1656.33	1669.75	1598.61	1680.90	1671.84	1657.49	1679.46	1639.27	1680.63	1678.86	1657.00	1676.67	1674.19	1678.50	1649.18	1669.01	1665.75	1674.41	1653.50	1649.32
3	1656.11	1669.64	1598.67	1680.91	1671.45	1657.06	1679.26	1639.40	1680.61	1678.65	1656.76	1676.42	1673.75	1678.21	1649.11	1668.80	1666.28	1674.41	1652.89	1649.66
4	1655.90	1669.51	1599.03	1680.90	1671.08	1656.61	1679.04	1639.51	1680.63	1678.46	1656.50	1676.27	1673.28	1677.87	1649.00	1668.57	1666.75	1674.11	1652.27	1649.96
5	1655.65	1669.35	1599.43	1680.87	1670.67	1656.14	1678.83	1639.73	1680.60	1678.26	1656.20	1676.17	1672.88	1677.59	1648.77	1668.23	1667.17	1673.83	1651.60	1650.10
6	1655.38	1669.15	1599.65	1680.81	1670.27	1655.74	1678.60	1639.84	1680.56	1677.98	1655.85	1675.99	1672.48	1677.16	1648.68	1667.92	1667.52	1673.51	1650.89	1650.15
7	1655.10	1668.97	1599.61	1680.67	1670.03	1655.34	1678.36	1639.96	1680.46	1677.50	1655.47	1675.88	1672.12	1676.75	1648.41	1667.54	1667.77	1673.13	1650.18	1650.19
8	1654.79	1668.85	1599.55	1680.47	1669.80	1655.00	1678.12	1640.02	1680.32	1676.96	1655.08	1675.79	1671.76	1676.37	1648.05	1667.22	1667.97	1672.71	1649.51	1650.17
9	1654.51	1668.69	1599.46	1680.29	1669.69	1654.68	1677.82	1640.08	1680.33	1676.53	1654.68	1675.71	1671.44	1676.03	1647.61	1666.94	1668.12	1672.22	1648.97	1650.09
10	1654.16	1668.52	1599.34	1680.11	1669.56	1654.40	1677.46	1640.22	1680.35	1675.93	1654.24	1675.75	1671.09	1675.65	1646.92	1666.66	1668.26	1671.83	1648.32	1650.09
11	1653.76	1668.32	1599.28	1679.92	1669.57	1654.10	1677.06	1640.32	1680.31	1675.26	1653.84	1675.80	1670.71	1675.41	1646.32	1666.25	1668.45	1671.33	1647.70	1649.87
12	1653.36	1668.08	1599.88	1679.84	1669.66	1653.84	1676.62	1640.39	1680.29	1674.84	1653.55	1675.90	1670.35	1675.10	1645.70	1666.02	1668.75	1670.92	1647.14	1649.60
13	1653.10	1667.86	1600.36	1679.74	1669.74	1653.57	1676.24	1640.42	1680.25	1674.64	1653.22	1676.07	1670.00	1674.85	1645.08	1665.79	1668.94	1670.59	1646.61	1649.30
14	1652.70	1667.60	1600.66	1679.68	1669.82	1653.30	1675.90	1640.41	1680.14	1674.44	1652.88	1676.22	1669.59	1674.56	1644.60	1665.65	1669.06	1670.28	1646.05	1648.92
15	1652.31	1667.30	1600.72	1679.64	1669.86	1653.03	1675.62	1640.40	1680.00	1674.33	1652.66	1676.37	1669.21	1674.32	1644.10	1665.42	1669.16	1670.03	1645.39	1648.48
16	1651.89	1667.02	1600.78	1679.60	1669.88	1652.80	1675.21	1640.38	1679.92	1674.26	1652.68	1676.49	1668.94	1674.14	1643.52	1665.24	1669.26	1669.81	1644.71	1647.97
17	1651.43	1666.76	1600.82	1679.55	1669.84	1652.57	1674.80	1640.32	1679.93	1674.26	1652.81	1676.62	1668.65	1674.03	1643.04	1665.20	1669.28	1669.61	1644.18	1647.47
18	1650.96	1666.47	1600.78	1679.46	1669.80	1652.32	1674.39	1640.26	1679.88	1674.29	1652.93	1676.72	1668.36	1673.86	1642.54	1665.15	1669.27	1669.48	1643.78	1647.04
19	1650.47	1666.16	1600.72	1679.35	1669.73	1652.05	1674.01	1640.21	1679.88	1674.31	1653.04	1676.80	1668.04	1673.70	1642.16	1665.05	1669.22	1669.28	1643.32	1646.86
20	1650.00	1665.84	1600.62	1679.24	1669.66	1651.73	1673.59	1640.14	1679.88	1674.31	1653.18	1676.87	1667.70	1673.50	1641.68	1664.89	1669.19	1669.15	1642.87	1646.95
21	1649.50	1665.50	1600.48	1679.05	1669.59	1651.35	1673.10	1640.04	1679.86	1674.30	1653.27	1676.84	1667.34	1673.27	1641.19	1664.79	1669.15	1668.90	1642.56	1646.88
22	1649.06	1665.14	1600.25	1678.75	1669.37	1650.87	1672.61	1639.98	1679.84	1674.25	1653.35	1676.81	1666.98	1673.00	1640.66	1664.76	1669.12	1668.57	1642.22	1646.79
23	1648.59	1664.76	1599.94	1678.42	1669.16	1650.41	1672.13	1639.90	1679.94	1674.21	1653.42	1676.80	1666.63	1672.74	1640.06	1664.69	1669.03	1668.32	1641.94	1646.59
24	1648.14	1664.35	1599.60	1678.13	1669.05	1650.01	1671.62	1639.82	1680.00	1674.14	1653.50	1676.76	1666.27	1672.55	1639.30	1664.60	1668.98	1668.02	1641.62	1646.30
25	1647.65	1663.98	1599.32	1677.81	1668.89	1649.61	1671.08	1639.73	1679.95	1674.05	1653.60	1676.71	1665.92	1672.33	1638.72	1664.48	1668.93	1667.64	1641.28	1646.18
26	1647.15	1663.61	1599.03	1677.47	1668.68	1649.21	1670.73	1639.63	1679.84	1673.95	1653.67	1676.67	1665.58	1672.20	1638.22	1664.30	1668.94	1667.24	1640.92	1645.91
27	1646.64	1663.24	1598.72	1677.09	1668.43	1648.77	1670.39	1639.48	1679.72	1673.84	1653.75	1676.64	1665.26	1672.03	1637.76	1664.18	1668.93	1666.82	1640.50	1645.70
28	1646.11	1662.83	1598.43	1676.65	1668.16	1648.37	1670.11	1639.29	1679.58	1673.73	1653.76	1676.55	1664.97	1671.86	1637.43	1664.02	1668.84	1666.45	1640.18	1645.41
29	1645.55	1662.40	1598.08	1676.23	1667.85	1648.00	1669.74	1639.09	1679.41	1673.60	1653.83	1676.44	1664.65	1671.68	1637.16	1663.88	1668.67	1665.97	1639.82	1645.08
30	1645.00	1661.96	1597.72	1675.75	1667.46	1647.64	1669.35	1638.92	1679.25	1673.46	1653.90	1676.36	1664.36	1671.48	1636.80	1663.74	1668.50	1665.50	1639.65	1644.70
31	1644.46	1661.49	1597.33	1675.26	1667.09	1647.26	1668.92	1638.52	1679.08	1673.27	1653.94	1676.26	1664.10	1671.30	1636.44	1663.62	1668.35	1665.07	1639.30	1644.46

Statement showing the levels of Bhakra Reservoir (In-feet)

November

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1643.90	1660.94	1596.92	1674.78	1666.70	1646.88	1668.56	1638.05	1678.89	1673.10	1654.00	1676.20	1663.80	1671.13	1636.10	1663.42	1668.15	1664.63	1638.98	1644.18
2	1643.38	1660.43	1596.52	1674.34	1666.26	1646.49	1668.20	1637.54	1678.69	1672.82	1654.04	1676.10	1663.44	1670.97	1635.84	1663.27	1667.98	1664.15	1638.75	1643.88
3	1642.86	1659.89	1596.06	1673.90	1665.82	1646.17	1667.90	1637.05	1678.48	1672.57	1653.93	1675.87	1663.04	1670.77	1635.58	1663.08	1667.93	1663.51	1638.50	1643.55
4	1642.36	1659.32	1595.75	1673.48	1665.36	1645.84	1667.58	1636.53	1678.28	1672.34	1653.74	1675.59	1662.62	1670.54	1635.26	1662.90	1667.82	1662.98	1638.24	1643.23
5	1641.84	1658.79	1595.40	1673.06	1664.93	1645.48	1667.20	1636.04	1678.04	1672.13	1653.49	1675.40	1662.17	1670.29	1634.98	1662.72	1667.80	1662.39	1637.94	1642.87
6	1641.30	1658.28	1595.03	1672.66	1664.48	1645.12	1666.80	1635.56	1677.83	1671.93	1653.18	1675.04	1661.83	1670.01	1634.62	1662.48	1667.75	1661.83	1637.61	1642.56
7	1640.71	1657.75	1594.70	1672.24	1664.04	1644.76	1666.40	1635.06	1677.60	1671.75	1652.90	1674.68	1661.42	1669.73	1634.22	1662.29	1667.67	1661.23	1637.32	1642.25
8	1640.19	1657.16	1594.30	1671.84	1663.56	1644.38	1666.14	1634.56	1677.39	1671.56	1652.55	1674.38	1660.92	1669.37	1633.85	1662.07	1667.58	1660.77	1637.06	1641.95
9	1639.64	1656.55	1593.90	1671.44	1663.08	1644.00	1665.88	1634.06	1677.14	1671.34	1652.16	1674.15	1660.43	1669.01	1633.45	1661.78	1667.43	1660.50	1636.77	1641.61
10	1639.07	1655.94	1593.54	1671.04	1662.62	1643.58	1665.65	1633.66	1676.89	1671.10	1651.72	1673.85	1659.95	1668.70	1633.09	1661.47	1667.33	1660.31	1636.42	1641.26
11	1638.52	1655.36	1593.12	1670.62	1662.16	1643.11	1665.40	1633.26	1676.63	1670.86	1651.32	1673.55	1659.45	1668.42	1632.68	1661.19	1667.25	1660.13	1636.07	1640.81
12	1637.97	1654.80	1592.54	1670.24	1661.72	1642.65	1665.17	1632.88	1676.40	1670.62	1650.90	1673.26	1658.89	1668.05	1632.32	1660.87	1667.14	1659.91	1635.65	1640.40
13	1637.44	1654.26	1592.00	1669.86	1661.28	1642.20	1664.92	1632.50	1676.18	1670.37	1650.46	1672.98	1658.32	1667.76	1631.92	1660.58	1667.06	1659.70	1635.30	1640.02
14	1636.90	1653.70	1591.44	1669.49	1660.85	1641.73	1664.67	1632.14	1675.91	1670.10	1649.94	1672.67	1657.77	1667.48	1631.56	1660.32	1666.99	1659.47	1634.90	1639.67
15	1636.32	1653.15	1590.89	1669.14	1660.43	1641.25	1664.39	1631.80	1675.64	1669.84	1649.50	1672.33	1657.42	1667.15	1631.16	1659.99	1666.97	1659.25	1634.52	1639.33
16	1635.70	1652.59	1590.28	1668.80	1660.03	1640.80	1664.14	1631.58	1675.37	1669.58	1649.06	1671.97	1657.04	1666.79	1630.81	1659.69	1666.99	1659.02	1632.24	1639.00
17	1635.11	1652.06	1589.71	1668.46	1659.57	1640.34	1663.83	1631.30	1675.07	1669.33	1648.62	1671.60	1656.69	1666.51	1630.48	1659.39	1667.01	1658.78	1633.95	1638.65
18	1634.50	1651.52	1589.04	1668.09	1659.11	1639.88	1663.50	1630.94	1674.83	1669.04	1648.15	1671.27	1656.31	1666.22	1630.13	1659.10	1666.99	1658.55	1633.58	1638.27
19	1633.88	1651.00	1588.46	1667.69	1658.65	1639.40	1663.18	1630.54	1674.56	1668.69	1647.67	1670.91	1655.92	1665.93	1629.81	1658.75	1666.92	1658.27	1633.21	1638.00
20	1633.22	1650.44	1587.82	1667.25	1658.20	1638.92	1662.86	1630.12	1674.29	1668.34	1647.17	1670.52	1655.55	1665.59	1629.44	1658.43	1666.86	1658.06	1632.87	1637.66
21	1632.56	1649.88	1587.17	1666.80	1657.73	1638.43	1662.49	1629.70	1674.01	1668.00	1646.69	1670.16	1655.18	1665.26	1629.01	1658.06	1666.85	1657.85	1632.48	1637.27
22	1631.90	1649.29	1586.57	1666.37	1657.26	1637.90	1662.10	1629.26	1673.70	1667.64	1646.19	1669.84	1654.80	1664.83	1628.55	1657.75	1666.79	1657.59	1632.03	1636.92
23	1631.25	1648.67	1585.86	1665.97	1656.90	1637.38	1661.72	1628.85	1673.38	1667.30	1645.67	1669.49	1654.41	1664.39	1628.12	1657.42	1666.78	1657.39	1631.54	1636.60
24	1630.64	1648.05	1585.17	1665.54	1656.50	1636.87	1661.34	1628.46	1673.08	1666.91	1645.18	1669.13	1653.95	1664.03	1627.65	1657.14	1666.79	1657.17	1631.13	1636.30
25	1629.97	1647.43	1584.49	1665.11	1656.10	1636.36	1660.94	1628.18	1672.75	1666.48	1644.68	1668.79	1653.50	1663.69	1627.18	1656.85	1666.81	1656.97	1630.77	1636.00
26	1629.28	1646.82	1583.81	1664.68	1655.68	1635.83	1660.54	1627.89	1672.42	1666.01	1644.17	1668.43	1653.02	1663.36	1626.66	1656.56	1666.77	1656.80	1630.48	1635.66
27	1628.60	1646.21	1583.12	1664.22	1655.24	1635.30	1660.13	1627.58	1672.07	1665.58	1643.58	1668.08	1652.52	1662.93	1626.15	1656.25	1666.70	1656.57	1630.17	1635.30
28	1627.96	1645.55	1582.41	1663.74	1654.79	1634.76	1659.76	1627.25	1671.70	1665.16	1643.03	1667.74	1652.01	1662.53	1625.63	1655.93	1666.65	1656.37	1629.89	1634.89
29	1627.29	1644.90	1581.72	1663.25	1654.33	1634.24	1659.38	1626.89	1671.32	1664.68	1642.43	1667.34	1651.50	1662.23	1625.13	1655.50	1666.56	1656.15	1629.60	1634.43
30	1626.59	1644.26	1581.01	1662.77	1653.87	1633.59	1658.96	1626.50	1670.90	1664.18	1641.85	1666.92	1651.00	1661.87	1624.56	1655.08	1666.51	1656.07	1629.30	1633.94

Statement showing the levels of Bhakra Reservoir (In-feet)

December

Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1625.80	1643.61	1580.29	1662.28	1653.42	1632.95	1658.50	1626.08	1670.47	1663.66	1641.26	1666.47	1650.48	1661.49	1623.95	1654.61	1666.43	1655.93	1628.94	1633.44
2	1624.95	1642.90	1579.79	1661.78	1652.89	1632.27	1658.04	1625.68	1670.00	1663.16	1640.65	1666.00	1649.95	1661.09	1623.36	1654.13	1666.34	1655.69	1628.58	1632.96
3	1624.10	1642.16	1579.31	1661.28	1652.35	1631.60	1657.60	1625.28	1669.50	1662.63	1640.04	1665.51	1649.34	1660.70	1622.73	1653.61	1666.22	1655.41	1628.20	1632.40
4	1623.25	1641.44	1578.79	1660.73	1651.80	1630.93	1657.14	1624.87	1668.97	1662.10	1639.43	1664.95	1648.70	1660.27	1622.05	1653.06	1666.07	1655.08	1627.82	1631.86
5	1622.38	1640.67	1578.27	1660.16	1651.25	1630.21	1656.60	1624.44	1668.43	1661.56	1638.80	1664.32	1648.10	1659.77	1621.38	1652.45	1665.91	1654.70	1627.43	1631.27
6	1621.49	1639.89	1577.78	1659.58	1650.74	1629.48	1656.03	1624.02	1667.87	1660.95	1638.15	1663.73	1647.42	1659.32	1620.73	1651.88	1665.76	1654.32	1626.97	1630.74
7	1620.61	1639.12	1577.28	1659.00	1650.22	1628.77	1655.46	1623.63	1667.28	1660.40	1637.45	1663.12	1646.75	1658.80	1620.03	1651.29	1665.60	1654.08	1626.46	1630.23
8	1619.68	1638.38	1576.78	1658.42	1649.64	1628.18	1654.90	1623.24	1666.67	1659.92	1636.77	1662.51	1646.13	1658.26	1619.29	1650.73	1665.43	1653.82	1625.95	1629.65
9	1618.70	1637.60	1576.26	1657.83	1649.09	1627.58	1654.36	1622.80	1666.08	1659.51	1636.10	1661.92	1645.49	1657.66	1618.60	1650.23	1665.27	1653.37	1625.35	1629.08
10	1617.74	1636.83	1575.74	1657.24	1648.56	1626.97	1653.82	1622.33	1665.47	1659.06	1635.43	1661.26	1644.82	1657.06	1617.89	1649.70	1665.09	1652.92	1624.78	1628.50
11	1616.80	1636.02	1575.20	1656.65	1648.01	1626.34	1653.31	1621.82	1664.87	1658.65	1634.78	1660.56	1644.11	1656.46	1617.15	1649.10	1664.91	1652.50	1624.21	1627.87
12	1615.84	1635.24	1574.68	1655.87	1647.40	1625.69	1652.81	1621.28	1664.27	1658.19	1634.24	1659.80	1643.37	1656.02	1616.44	1648.72	1664.67	1652.04	1623.69	1627.22
13	1614.88	1634.44	1574.13	1655.07	1646.77	1625.06	1652.30	1620.75	1663.60	1657.71	1633.66	1659.06	1642.72	1655.44	1615.74	1648.34	1664.48	1651.66	1623.18	1626.55
14	1613.91	1633.66	1573.56	1654.28	1646.13	1624.51	1651.80	1620.20	1662.80	1657.26	1633.12	1658.33	1642.28	1654.89	1615.04	1647.93	1664.31	1651.51	1622.62	1625.87
15	1612.92	1632.88	1573.02	1653.46	1645.47	1624.01	1651.28	1619.60	1662.08	1656.80	1632.68	1657.62	1642.08	1654.30	1614.31	1647.49	1664.13	1651.30	1622.04	1625.20
16	1611.92	1632.06	1572.48	1652.65	1644.82	1623.51	1650.73	1618.95	1661.30	1656.29	1632.31	1656.86	1641.70	1653.69	1613.61	1647.01	1663.76	1651.03	1621.45	1624.51
17	1610.94	1631.24	1571.89	1651.85	1644.17	1622.98	1650.19	1618.28	1660.52	1655.76	1631.96	1656.17	1641.27	1653.07	1612.85	1646.48	1663.37	1650.66	1620.87	1623.83
18	1609.95	1630.44	1571.28	1651.03	1643.55	1622.38	1649.65	1617.65	1659.73	1655.20	1631.62	1655.49	1640.80	1652.40	1612.09	1645.97	1662.96	1650.27	1620.08	1623.12
19	1608.96	1629.64	1570.66	1650.19	1642.90	1621.76	1649.09	1617.00	1658.93	1654.66	1631.32	1654.89	1640.34	1651.72	1611.32	1645.41	1662.46	1649.86	1619.35	1622.35
20	1607.96	1628.82	1570.17	1649.36	1642.23	1621.10	1648.52	1616.31	1658.22	1654.09	1630.96	1654.35	1639.87	1651.05	1610.57	1644.80	1661.91	1649.45	1618.63	1621.64
21	1606.89	1627.99	1569.56	1648.51	1641.56	1620.40	1647.98	1615.62	1657.51	1653.56	1630.50	1653.76	1639.35	1650.35	1609.80	1644.17	1661.38	1649.01	1617.94	1620.92
22	1605.70	1627.15	1568.81	1647.76	1640.83	1619.66	1647.50	1614.90	1657.01	1653.03	1630.01	1653.32	1638.81	1649.65	1609.02	1643.54	1660.85	1648.58	1617.14	1620.22
23	1604.60	1626.28	1568.05	1647.02	1640.12	1618.90	1647.08	1614.20	1656.53	1652.53	1629.49	1652.95	1638.28	1648.99	1608.30	1642.98	1660.33	1648.18	1616.33	1619.50
24	1603.39	1625.38	1567.30	1646.27	1639.47	1618.09	1646.64	1613.46	1656.04	1652.00	1628.88	1652.49	1637.72	1648.30	1607.57	1642.33	1659.84	1647.74	1615.48	1618.86
25	1602.19	1624.49	1566.56	1645.56	1638.85	1617.30	1646.12	1612.71	1655.54	1651.49	1628.28	1651.96	1637.14	1647.69	1606.90	1641.64	1659.32	1647.31	1614.58	1618.27
26	1600.90	1623.58	1565.80	1644.85	1638.17	1616.55	1645.58	1611.99	1655.04	1650.93	1627.63	1651.39	1636.56	1647.05	1606.25	1640.94	1658.84	1646.84	1613.60	1617.68
27	1599.68	1622.69	1564.94	1644.13	1637.58	1615.80	1644.98	1611.26	1654.57	1650.37	1627.00	1650.78	1635.96	1646.39	1605.60	1640.19	1658.36	1646.37	1612.56	1617.15
28	1598.39	1621.79	1564.08	1643.40	1637.04	1615.01	1644.38	1610.54	1654.10	1649.82	1626.35	1650.17	1635.36	1645.76	1604.90	1639.45	1657.82	1645.95	1611.58	1616.67
29	1597.13	1620.88	1563.21	1642.68	1636.54	1614.21	1643.70	1609.76	1653.63	1649.26	1625.73	1649.52	1634.75	1645.16	1604.17	1638.71	1657.29	1645.49	1610.47	1616.25
30	1595.86	1619.98	1562.37	1641.95	1635.98	1613.40	1642.96	1608.98	1653.14	1648.70	1625.14	1648.87	1634.42	1644.51	1603.49	1637.97	1656.68	1645.01	1610.00	1615.82
31	1594.65	1618.98	1561.52	1641.24	1635.42	1612.56	1642.19	1608.22	1653.24	1648.13	1624.49	1648.17	1633.50	1643.96	1602.80	1637.22	1656.05	1644.50	1609.34	1615.37

4. GEOLOGICAL STUDIES

Chapter-4

Geological Studies

4.1 Introduction:

The Bhakra Beas Management Board (BBMB), with a view of utilize the water available in Gobind Sagar reservoir that spreads over 168.35 sq. km. of area and has gross storage capacity of 7.04 BCM by constructing a pump storage project (PSP). Earlier Central Electrical Authority (CEA) carried out identification of probable alternative sites for locating the PSP project in late eighties of twentieth century primarily on the basis of topographic studies with the help of Survey of India Toposheets 53A/6 and 53A/7. The studies indicated that it was possible to construct one such scheme with generating capacity of 1800MW near village Majra located on opposite bank of the reservoir in erstwhile Kangra district of Himachal Pradesh. The then studies carried out on Survey of India toposheets indicated that it was possible to create a reservoir with gross storage capacity of 20.2 MCM on Sarhyali Khad by constructing a 60m high dam across it and a design discharge of 1032cumecs from thus created reservoir could be conveyed through a 1.90 km long water conductor system to a semi-underground powerhouse to generate 1800MW of power utilizing a gross head of 221.4m.

Subsequently, the Water and Power Consultancy Services (WOPCOS) was given the responsibility of formulation of Feasibility Study Report (FSR) for the proposed Pump Storage Scheme recently by BBMB. WAPCOS, on the basis of toposheet studies of the area around Gobind Sagar reservoir identified six more probable sites with 11 alternative layouts including one alternate layout for the site near Majra village identified earlier (Figure-4.1 and Table -4.1)

Table 4.1: Details of Alternative Sites identified initially for Bhakra pump Storage project

S. No.	PSP Site Options & trials	Operational Levels				Gross Head (m)	Length of WCS (m)	Estimated Live Storage (MCM)	Estimated Power Potential (MW)
		Upper reservoir FRL (m)	Upper reservoir MDDL (m)	Lower reservoir FRL (m)	Lower reservoir MDDL(m)				
Left Bank (SITES- LB-1, LB-2 & LB-5)									
1	LB_1_trial2	800	710	512.07	445.62	276	1575	5	485
2	LB_2_trial1	790	710	512.07	445.62	271	1800	7	701
3	LB_2_trial3	850	770	512.07	445.62	331	1581	6	841
4	LB_5_trial1	770	660	512.07	445.62	251	1989	5	486
5	LB_5_trial4	790	720	512.07	445.62	241	1936	6	651
Right Bank (SITES- RB-1)									
1	RB_1_trial1	750	700	512.07	445.62	246	1113	14	1461
OPPOSITE (SITES- OP-1, OP-5 &OP-MAJRA)									
1	OP_1(O)_trial1	720.0	700	512.07	445.62	201	4096	13	1096
2	OP_1(O)_trial2	720	680	512.07	445.62	221	3981	16	1358
3	OP_1(O)_trial4_3	720	690	512.07	445.62	181	4334	13	1099
4	OP_5_trial2	650	580	512.07	445.62	136	1112	14	662
5	OP_MJ_trial2	720	690	512.07	445.62	221	1957	7	611

6	OP_MJ_ trial5	720	690	512.07	445.62	221	1921	8	688

Subsequently, on the basis of detailed field topographic surveys and techno economic studies including estimated reservoir capacity, length of water conductor system and power potential of different alternatives led to selection of four alternative sites including one adopted earlier by BBMB for further studies. These are:

i). LB_2_Trial 3 (76027’ 57.54” E :310 22’55”;53A/7)
ii). RB_1_Trial 1 (76024’19” E :31027’00.27” N; 53A/7)
iii). OP_MJ_ Trial 5 (76028’19” E :31029’21.43” N; 53A/7)
iv). OP_1(O)_Trial 2 (76031’35.07” E :38.31” N; 53A/11)

These alternative sites were visited to have preliminary geotechnical assessments of different project sites with a view to select a site that could be taken up for further investigations.

4.2 Geology of The Area

The area under study, bound by latitudes’31023’N and 31029’N and 76024’19”E and longitudes 76024’19”E and 760 31’35.06”E in Survey of India Top sheet nos. 53A/7 is 53A/11, is located in Bilaspur, Hamirpur and Una districts of Himachal Pradesh on the fringes of Bhakra Dam Project reservoir. Satluj River is the prime river flowing in the study area and is fed by tributaries like Karhwin Khad, Lunkhar Khad, Seer Khad, Matla Khad, Gambher Khad, Gambrola Khad, and Ali Khad in upstream areas.

Figure-4.1: Location of various Alternative Sites Identified initially

Geomorphologically, two distinct morphological units have been observed in the study area and around it. One geomorphic unit comprises structural hills-valleys and another is fluvial landform. Structural hills, in this area are of three different types, highly dissected hills, moderately dissected hills and low dissected hills. The structural hills trend NW-SE in general with slopes varying between 15° to 45°. The crests of the hills are sharp to round. Development of steep escarpment usually along the eastern side of the central main ridge has been observed. Sub-trellis to trellis drainage pattern is observed in the area.

Satluj River and its tributaries Sarhyali Khad and Seer Khad flow mainly along NW-SE direction but towards south-east near village Zakatkhana, Sutlej River takes U- turn and flows along SE-NW direction. The flanks of the hills are moderately dissected by sub-parallel to parallel drainage.

Regionally, the area under study is located in Sub-Himalayan part of Himachal Himalaya. Sub Himalaya is bound by Lesser Himalaya in the north and Indo-Gangetic plains in the south. It is separated from Lesser Himalaya by Main Boundary Thrust (MBT) and from Indo-Gangetic Plains by Himalayan Frontal Thrust (HFT).

The rocks exposed in the Gobind Sagar reservoir rim area belong to Shali Group, Sirmour Group and Siwalik Supergroup. These rocks are characterized by their distinct lithological characters. Shali Group is the oldest rocks exposed in the area overlain by Sirmour Group and Siwalik Supergroup of the rocks ranging in age from Meso-Proterozoic to Pliocene. Rocks belonging to Sirmour group and Siwalik Super group of Tertiary age are separated from those belonging to Sirmour Group by MBT and same thrust both these from Lesser Himalaya Shali Group of rocks. The general litho-stratigraphic sequence of the studied area is given in Table-4.2.

Table -4.2: Litho- Stratigraphic Sequence in the Area Around Study Area

Age	**Super Group**	**Group/Sub-Group**	**Formation**	**Lithology**
Holocene	Newer Alluvium		Channel Alluvium	Fine to coarse, micaceous, sand-silt and clay
			Terrace Alluvium	Grey sand, grit & pebbles with lenses of clay
			Fan Alluvium /Bhangal	Brownish grey clay, sand and gravel with boulders
Mid.- Upper Pleistocene	Older Alluvium		Older Alluvium/Dun Gravel	Multi cyclic brown to grey silt, clay with kankar and reddish brown to grey micaeous sand with pebbles
------------------------ Himalayan Frontal Thrust (HFT) ------------------------				
Pliocene to Pleistocene	Siwalik	Upper Siwalik	Kalar	Boulder conglomerate with lenses of mud in lower and sand ind in upper part
			Pinjor	ne grain siltstone in lower part and Earthy mudstone with pebbly layers in upper part
			Saketi (Tatrot)	Alternation of micaceous sandstone and variegated mudstone
Miocene to Pliocene		Middle Siwalik	Dhokpathan/ Mohargarh	Coarse micaceous multistoried sandstone with interbeds of red & grey mudstone
			Nagri/Dewal	Fine to medium grained, rather compact, greyish sandstone and grey to reddish mudstone (almost 50:50).
Miocene		Lower Siwalik	Nahan	Fine to medium grained greenish grey to buff micaceous sandstone with thick red-brown mud alternation, mud dominant in lower part
------------------------ Main Boundary Thrust (MBF) ------------------------				
EarlyMiocene			Kasauli	

Late Eocene to Oligocene		Sirmaur ≡ Dharamshala	Dagshai	Maroon shale with interbeds of sandstone in lower and thick maroon to grey sandstone in upper part
Palaeocene to Mid Eocene			Subathu	Laterite & coal at basal part, dark shale with coquinoid limestone & arenite in lower part, red shale with occasional laterite in mid and splintery Olive green fossiliferous shale, siltstone, sandstone, limestone in upper part.
Meso-Proterozoic		Shali Ξ Deoban	Bandla	Shale, slate, siltstone
			Parnali	Dolomite, limestone
			Makri	Shale, limestone, dolomite
			Tattapani	Cherty dolomite, shale
			Sorgharwari	Limestone
			Khatpul	Dolomite, quartzarenite and shale
			Khaira	Quartzarenite
			Ropri	Shale, siltstone, dolomite

Regional geological map of the area surrounding the project area (Figure4.2) shows that the study area is located almost on the southern margin of Himachal Sub- Himalaya which is bound by Main boundary Thrust (MBT) that separates it from Lesser Himalaya in the north and Himalayan Frontal Thrust (HFT) which separates it from Indo-Gangetic Plains in the south. The rocks belonging to Shali Group of Neo-Proterozoic age are exposed in the north and these override the Sub- Himalayan formation rocks along MBT. The rocks exposed in the Sub –Himalayan part of Himachal Pradesh include the sedimentary rocks belonging to Sirmour Group of Palaeocene to Middle Miocene age and Siwalik Super Group ranging in age from Middle Miocene to lower Pleistocene. These rocks are folded, faulted and traversed by a number of thrust faults.

Shali Group mostly includes limestones and dolomites has been classified into eight formations viz. Ropri, khaira, Khatpul, Sorgharwari, Tattapani, Makri and Bandla formations. Commencing with shale siltstone, dolomites and quartzite lithounits quartzite is succeeded by stromatolitic limestone and dolomite sequence upwardly with subordinate shale parting and occasional basic dykes as intrusive. Based on stromatolite species

(Baicalia, Tungussia, Conophyton, Colonell etc), Middle to Late Mesoproterozoic (Valdiya, 1969) ages has been assigned. The carbonate sequence is overlain by basic volcanics known as Darla/Tattapani vescicular basalt of tholeiitic character. The rocks belonging to Shali Group over ride the Sub- Himalayan litho units belonging to Sirmour Group along MBT.

Rocks belonging to Sirmaur Group ranging in Palaeocene to Mid-Miocene age are exposed south of MBT . These have been divided into Subathu and Dagshai and Kasauli formations.

The Subathu Formation consists mainly of olive green shales, grey shales, grey oyster marls, thin limestone bands and occasional sandstone. They are often traversed by calcite veins. Iron oxide stained quartzite, greenish and carbonaceous shales are observed in the lower part while purple shales occur towards the top. The oyster marl and limestone are the main fossil-bearing horizons which have yielded foraminifera, ostracoda, gastropods, lamellibranchs, and remains of fishes, turtle and marine mammals. In the study area, Kasauli Formation is exposed as small patches only.

Subathu Formation consists mainly of olive green shales, grey shales, grey oyster marls, thin limestone bands and occasional sandstone. They are often traversed by calcite veins. Iron oxide stained quartzite, greenish and carbonaceous shales are observed in the lower part while purple shales occur towards the top. The oyster marl and limestone are the main fossil-bearing horizons which have yielded foraminifera, ostracoda, gastropods, lamellibranchs, and remains of fishes, turtle and marine mammals. In the study area, Kasauli Formation is exposed as small patches only. The Kakara and Subathu Formations are found developed over a wide spectrum of pre-Tertiary rock sequences and possibly indicate an extensive peneplanation (Bhargava et al. 2011).

Dagshai Formation constitutes dominantly brick red, purple, reddish siltstone and mudstone, purple to reddish (greenish-grey at places) fine to medium sandstone, with intra-formational, lensoidal pink mud clast conglomerates. The sandstone is finely laminated to massive in nature. The mudstone shown nodular weathering pattern. The sandstone and mudstone of this formation show fining upward sequence and cyclic nature of the deposition. Fossilized burrow structures have been observed in Dagshai Formation near Dhajwani village. The visual estimation of sandstone and shale/mudstone ratio is about 40:60 respectively. In the study area, this Formation is exposed mostly northern and north-eastern part of Bilaspur town.

The rocks belonging to Kasauli Formation, the youngest formation of the group comprise massive greenish grey sandstone, siltstone, with interbeds of mudstone. The formation is dominated by arenaceous sequence with interbeds of mudstone is considered a fluvial deposit comprising thickly bedded very hard and massive grey to greenish grey coarse, micaceous sandstone with minor proportion of grey to purple claystone. The Dagshai-Kasauli contact is transitional and is marked by the presence of tephra.

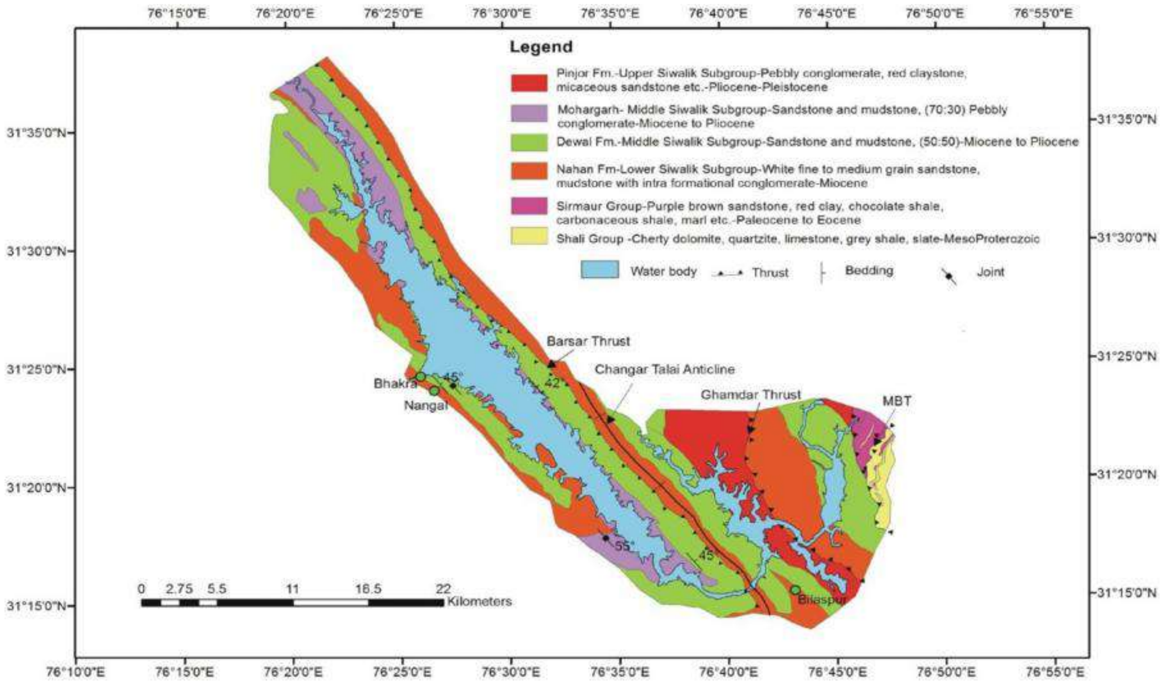


Figure-4.2: Geological Map of the Area around the Area under Study

Based on fossils observed, a late Rupelian–Middle Chattian age for the Kasauli Formation has been suggested. However, the lithounits belonging to Kasauli Formation are exposed as small patches only in the area.

The rocks belonging to Sirmour Group override those belonging to Siwalik Super group along a thrust that merges with MBT further northwest.

The Siwalik belt, a southern most conspicuous arcuate geomorphic belt extends over 2400km from Potwar region of Pakistan in the west to Dibang River valley in Arunachal Pradesh in the east. Approx. 6000m thick mollassic sediments of Siwalik were deposited in a foreland basin as a result of continued uplifts and erosion of the Himalaya. The belt is tectonically overrided by Proterozoic Lesser Himalayan rocks in the north along the MBT (Main Boundary Thrust) and inturn thrust over Late Quaternary sediments of Indo-Gangetic Plain along Himalayan Frontal Thrust (HFT) in the south. Siwaliks on the basis of vertebrate taxa. Ranga Rao (1979), subdivided the lithostratigraphy of Siwaliks into Lower, Middle and Upper subgroups. The Super Group overall, exhibit cyclic riverine deposit with coarsening upward but upward in individual cycle Siwaliks directly overlie the Sirmur Group of rocks at Dharmshala, Sarkaghat and Nalagarh.

As mentioned earlier, the lithounuts belonging to Siwalk Super group on the basis of fossil assemblages discovered in them. These are Lower Siwalik, Middle Siwalik and Upper Siwalik groups. The lithounits belonging to all the three Sub Groups are exposed in the area.

The Lower Siwalik Sub Group in the area are represented by those belonging to Nahan (Chinji) Formation which is represented by thick red mudstone and greenish-buff micaceous sandstone with latter dominated in upper part.

Nahan (=Chinji) Formation comprises an alternate sequence of grey-white, fine to medium grained, hard and compact, micaceous, flaggy sandstone and variegated mudstone with prominent lenses of an intra-formational conglomerate. The reddish- brown mudstone is splintery to nodular at places, mostly calcareous cement and very hard. The calcareous content is very high near the Naina Devi area. The sandstone of Nahan Formation is highly jointed. The Nahan Formation over-rides the Pinjor Formation near Jamli area of Bilaspur District in Himachal Pradesh along the Gambhar Thrust which has caused the deformation of the sandstone. Burnt wood is seen persevered in rocks near Dhrasani village.

The rocks belonging to Nahan formation of Lower Siwalik Sub Group are overlain by those belonging to Middle Siwalik Sub Group in the area. These ranging in age from Middle Siwalik Sub-group: Rocks of Middle Siwalik Sub-group ranging in age from Miocene to Pliocene are exposed extensively in the area parallel to the reservoir. These have been divided in to Dewal or nagri and mohargarh or Dhokpathan Formations on the basis of fossil assemblages observed in them.

The Dewal (Nagri) Formation conformably overlain by Dhokpathan (Mohargarh) Formation with an age range between 10 and 6.7 ma. The Dewal Formation comprises moderately compact, thickly bedded medium to coarse grained planar and trough cross bedded grey micaceous sandstone with reddish brown nodular mudstone. The lenses of quartzite pebble and thin intraformational mud-chip conglomerate horizons are common. The concretionary features are also common. The Dewal Formation shows gradational contact with the underlying Nahan Formation and the overlying younger unit, the Mohargarh Formation. It occasionally shows cross beddings like trough cross beddings as well as tangential cross beddings. On the basis of visual estimation, alternate medium to fine-grained sandstone and mudstone bands, each constitute about 50:50 ratio respectively of the liho-package.

Dewal (Nagri) formation is in turn is succeeded by Mohargarh (Dhokpathan) Formationn, the next younger unit of Middle Siwalik Sub-group through a confomable contact. It comprises buff grey, thickly bedded massive, comparatively less indurate sandstone than the Dewal Formation. The sandstone is medium to coarse- grained, micaceous having salt-pepper appearance (Photo 3. 5). with randomly oriented pebbles of extra-basinal quartzite and lenses or bands of grey to khaki mudstone. The NNW-SSE trending rocks of the Upper Siwalik Subgroup are having gradational contact with underlying Mohargarh Formation.

The Upper Siwaliks Sub Group of Pliocene to Pleistocene age in order of normal stratigraphic disposition is represented by Tatrot (Saketi), Pinjore and Boulder Conglomerate formations at the top. However, this Sub-group is represented by lithounits belonging to Only Pinjor Formation of in the study area.

The Pinjore Formation is mostly fine sand to mud dominated sequence. The Pinjore Formation is mostly in lower part and with frequent pebbly layers in upper part that gradually passes in to the Boulder Conglomerate. This Formation is characterized by an almost equal proportion of alternate conglomerate and sandstone bands. Sandstone is gritty, coarse to medium grained and friable. Minor lenses of variegated grey-pinkish, buff coloured mudstone are observed in sandstone units. The sand body shows massive and thickly bedded geometry. The conglomerate beds are polymictic and matrix supported. Clasts are subrounded to rounded and moderately sorted. Clasts size range from 1 cm to 30 cm. It is well exposed in the southern part of Bilaspur town.

4.3 Structure

The lower Siwalik rocks tending N-S and NNW-SSE dipping 35°-45° towards East are exposed near dam site. These are folded into anticlines and synclibes with fold axs trending NW-SE in general in the area. Of these, Changar Talai anticline aligned along the opposite bank of the

Gobind Sagar is most prominent. Four different joint sets J0: 25°→310°, J1: 70°→120°, J2: 70°→40° J3: 80°→260° are observed in the left bank of the reservoir. Main Boundary Thrust (MBT), Barsar Thrust (BT) and Gambhar Thrust (GT) are passing through the study area. BT and GT, trending NW-SE are parallel to each other whereas Barsar Thrust is dipping towards west while Gambhar Thrust is towards east.

Main Boundary Thrust, locally named as Bilaspur Thrust is more prominent near the Swarghat area. Upper, Middle and Lower Siwalik are repeatedly appearing in the reservoir area due to anticlinal and synclinal folding. One fault has been observed in the southern part of the reservoir, near Naina Devi area. Changar Talai Anticlinal axis tending NW-SE, most prominent anticline, parallel to the Barsar Thrust passes in the Changar Talai area.

Main Boundary Fault (MBF): The Siwalik belt in the eastern part of the study area is delimited by the Main Boundary Fault (MBF). In the north of the study area, it brings rocks of Sirmaur Group over the Pinjor Formation (at places Kalar Formation). It is northerly dipping (>25°) and is locally known as the Palampur Thrust. The deformed clasts of the conglomerates are the indicator of this tectonic plane. The Sirmaur Group of rocks exposed along the hanging wall of the MBF, shows more deformation as compared to the Pinjor Formation.

Gambhar Thrust: It is a regional thrust which has brought the Nahan Formation over the younger lithostratigraphic unit. In the study area, the Nahan Formation over- rides the Pinjor Formation. The Nahan Formation along the hanging wall is highly deformed as compared to the Pinjor Formation. Thrust related brittle shear fractures, micro to mesoscale faults, fault zone rocks like gouge and breccia, shattering of rocks, tilted or sub-vertical beds have been reported in the area.

Barsar Thrust: The Barsar thrust has been observed in northwestern part of the study area. It joins with MBT in Swarghat area. Along with this thrust, the Nahan Formation overrides the Dewal Formation of the Middle Siwalik Subgroup while in its northern continuity it has brought the Nahan Formation over the Mohargarh Formation.

4.4 Seismicity

Bhakra dam site and area encompassing Gobind Sagar reservoir in its vicinity are located in Kangra seismic block. The frontal thrust-fold belt of Northwest Himalaya encompassing parts of the States of Himachal Pradesh, Uttarakhand and Punjab and the Union Territory of Jammu and Kashmir, constitutes a 36% segment of the 2400 km long great mountain range. It is composed of Palaeogene, Neogene and Quaternary sediments and a few Proterozoic inliers in the western part. The region is drained by several of the mighty rivers of the Indus and Ganga basins that are fed by as many as 8965 glaciers in their upper reached. The frontal belt all through its length is confined between the Main Boundary thrust (MBT) in the north and Himalayan Frontal thrust (HFT) in the south with structural styles varying from emergent thrust to blind thrust fronts and wrench dominant as well as pop-up structures of different amplitudes. This Tertiary pack is thrown into several open folds and riddled with a host of tectonic discontinuities that developed during the terminal phase of the Himalayan orogeny. The regional thrusts imbricate along a detachment plane, which defines the upper surface of the underthrusting Indian plate, dipping at 2°-3° beneath the Indo-Gangetic basin and the sub Himalaya.

The Kangra seismotectonic block, located between Ropar - Sundarnagar fault in the east and Ravi tear in the west, is dissected by several thrusts paralleling the Himalayan trend, the prominent among them being HFT, MBT, Jwalamukhi thrust, Jogindarnagar thrust, Palampur thrust, Gambhar thrust, etc. The regional open folds of this domain include Mastgarh anticline, Dabbar syncline, Deragopipur anticline Drang syncline, Paror anticline, Janauari anticline, etc. This block has experienced a total of 122 seismic events of moment magnitude ≥ 4 in the last 200 years. The strongest earthquake was that of Kangra of 4th April

1905 (Mw 7.8), responsible for 20,000 human fatalities. The earthquakes of 1914, 1945 and 1947 measured more than 6.0 in magnitude. Almost 84% of the seismic events were confined to less than 40 km in depth. The region lies in Zones V and IV of the Seismic Zone map of India (2002).

The Kangra reentrant is drained by three perennial rivers of Ravi, Beas and Sutlej of the Indus basin. Major hydropower projects such as Bhakhra, Pong and Ranjit Sagar have come up in these rivers and changed the economic face of the region in a significant way. Bhakhra dam over Sutlej river, which was commissioned in 1963, is founded over Lower Siwalik Formation. It lies in Seismic Zone IV and has been designed for peak ground acceleration (PGA) of 0.15g. Pong dam that was commissioned in 1974 in Upper Siwaliks was designed for a PGA of 0.12g for concrete section and 0.15g for earth section. Ranjit Sagar dam founded over Lower Siwaliks was commissiond in 2001. It has been designed for a PGA of 0.2g. All these hydropower projects are in operation in the present time.

The Bhakra Dam, constructed on the Satluj River, and the neighbouring area under study are located southwest of the Main Boundary Thrust and the Main Central Thrust in the foothills of the Himalayas.

As per IMD data, a total of 608 earthquakes of magnitude 2.0 have occurred within 100 km of the Bhakra dam between October 1977 and September 2002, (Figire-4.3). It has been observed that the majority of earthquakes, were associated with the Main Boundary Thrust. One earthquake of magnitude 5.5 was recorded on 26th April 1986 at a distance of 81 km from the dam in the northeast direction and another earthquake having magnitude 5.4 was recorded on 14th June 1978 towards the north at a distance of 90 km from the Bhakra dam. Three earthquakes, occurred within 15 km from the dam.

The nearest earthquake occurred on 12th December 1979 with a magnitude of 2.9 at a distance of 10 km from the dam, towards the south-west side. 85 earthquake of magnitude >2<4.9 have been recorded 50 km away from the reservoir during 2012 to 2018. Three earthquakes of magnitude≥5 have been recorded 100 km away from the Bhakra Dam at Chamba on 18th November 2014 and at J&K on 8th February 2013. Only one earthquake of magnitude 3 has been observed within 50 km of the reservoir, near Rupnagar, Punjab on 25.09.2013. These indicate that existence of such a large reservoir in the has not impacted the seismicity of the region during last 60 years.

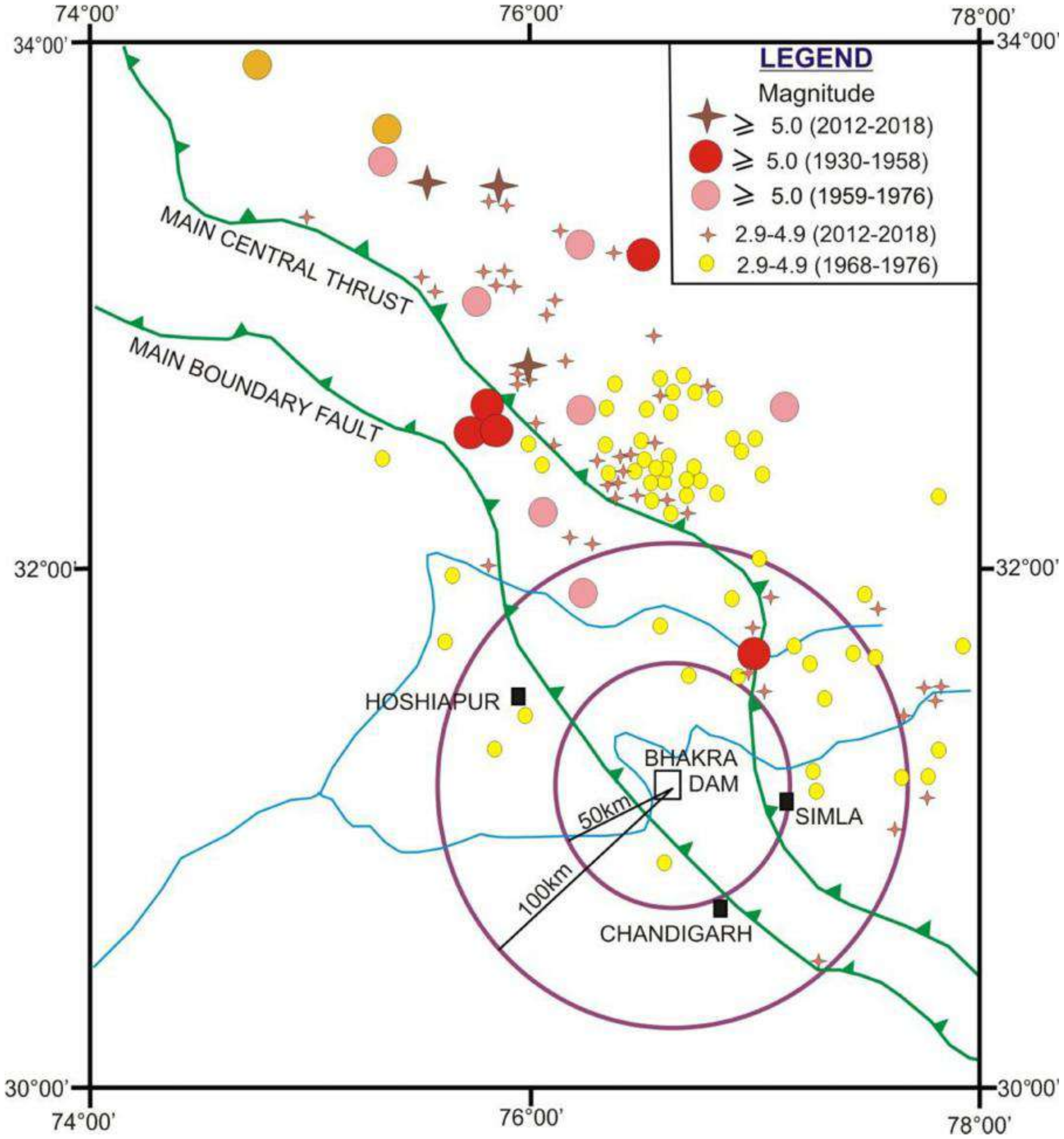


Figure-4.3: Epicenter distribution of earthquakes near Bhakra Dam (for the period 1930 to 1976 and 2012 to 2018).

Keeping in view the location of different alternative sites in Seismic Zone IV as per Seismic Zoning Map of India (2002) and existence of a number of thrust faults in the close vicinity of sites, it is recommended that suitable seismic coefficient may be incorporated into the designs of proposed dam and other appurtenants of the project.

4.5 Geomorphology and Geology of the Project Area

Earlier CEA carried out topographical studies with a view to develop a pump storage scheme by utilizing the storage available in Gobind sagar reservoir. The studies carried out on the fringes of Gobind Sagar reservoir in Survey of India toposheet Nos. 53A/6 and 53A/7 resulted in identification one such possible scheme on the opposite bank of the reservoir near Majra village in erstwhile Kangra and now Hamipur district. The studies carried out then indicated that it was possible to create a reservoir with FRL at EL 720m, MDDL at EL 700m. gross storage capacity of 20.2MCM and live storage capacity of 14.9MCM by constructing about 60m high dam in the upper reaches of Sarhyali Khad which joins Gobind Sagar reservoir near village Lag. It was envisaged to convey 1032 cumecs through a 1.9 km long water conductor system. Combination of 1.6 km long HRTs and 03 km long TRTs to semi-underground/ underground powerhouse proposed on the banks of Lower reservoir i.e. Gobind Sagar reservoir with a view to generate 1800 MW of power through 9 units of 200MW capacity each.

Recently the work was assigned to WAPCOS by BBMB to carry out further studies and prepare the final Feasibility Study Report. The WAPCOS on the basis of evaluation of the existing SOI toposheets and detailed field surveys identified eleven potential alternative sites that could be taken up for further studies. Salient features of these sites are given in Table-4.1 and locations are shown in Figure-4.1. It is observed from Table-4.1 and Figure-4.1 that five of the alternative are located on the left bank, one on right bank and six, including that identified by the CEA earlier on the opposite bank.

Based on the features like gross reservoir capacity, length of the water conductor system and power system, following four alternative including the one evaluated earlier were selected for detailed studies with for techno-commercial viability and further development in later stages:

i. LB_2_trial 3
ii. RB_1_Trial 1
iii. OP_MJ_Trial 5
iv. OP_1(0)_Trial 2

Geological and geotechnical aspects of these thus selected alternatives are discussed below.

LB_2_Trial 3 is located on the left fringe of reservoir and old course of Satluj river near Lehri village uphill Thathal village of Bilaspur district of Himachal Pradesh. in Survey of India Toposheet 53A/7. It is learnt that initially on the five alternative sites on the left bank were identified on the basis of topographic survey and finally based on the site features like reservoir caoacity, length of water conductor system and power potential etc site two was preferred and was adopted for further studies. Based on detailed survey, three alternatives even at this site were considered and finally LB_2_Trial 3 was preferred. This alternative envisages an upper reservoir having estimated live storage capacity of 6MCM with FRL at EL850m, MDDL at EL770m with the construction of a 100m high and about 600m long dam across a small south westerly flowing nala that is aligned through Lehri village. The design discharge is prpoposed to be conveyed to an underground powerhouse proposed on the left fringe of Gobind Sagar reservoir near village Thathal through A 1.58km long water conductor system with the objective of generating 841MW of power.

The area around the proposed site located on the low lying, moderately bisected hills and shows with medium and trellis pattern. The hills around the proposed site were covered with moderately dense vagatation with dense under growth. One of the reasons for same could be due to the reason coukd be that the site was visited immediately after rainy season.The area at higher elevation expose sedimentary lithounits belonging to Nahan Formation of Lower Siwalik group. These comprises an alternate sequence of grey-white, fine to medium grained, hard and compact, micaceous, flaggy sandstone and variegated mudstone with prominent lenses of an intra-formational conglomerate. The reddish-brown mudstone is splintery to nodular at places, mostly calcareous cement and very hard. These strike in general in NW- SE direction and have low to moderate dios towards NE. These traversed by three sets of joints in addition to those oriented along the strike.

The middle and lower reaches of the ridge are occupied by the rocks belonging to Dewal Formation of Middle Siwalik Sub-Group. The rocks belonging to Dewal Formation comprise moderately compact, sparsely cemented thick bedded medium to coarse grained planar and trough cross bedded grey micaceous sandstone with reddish brown nodular mudstone. The lenses of quartzite pebble and thin intra formational mud-chip conglomerate horizons are common. The concretionary features are also common. The Dewal Formation shows gradational contact with the underlying Nahan Formation and the overlying younger unit, the Mohargarh Formation. On the basis of visual estimation, alternate medium to fine-grained sandstone and mudstone bands, each constitute about 50:50 ratio respectively of the litho-package. These are also moderately jointed.

The proposed dam and other appurtenant of the scheme , if developed at this site, are likely to encounter the sedimentary sequence belonging to Dewal Formation of Middle Siwalik Sub-Group and same has to be kept in view while designing various components of the project.

2) RB_1_Trial 1 is located on the right fringe of Gobind Sagar reservoir on right flank of Bhakra Dam near Dobar Uparla village of Una district of Himachal Pradesh in Survey of India Toposheet 53A/7. This alternative envisages an upper reservoir having estimated live storage capacity of 14.4MCM with FRL at EL750m, MDDL at EL700m with the construction of a 100m high and about 500m long dam across a small south northerly

flowing nala that debouches into Gobind Sagar north of Rajpur village. The design discharge is proposed to be conveyed to a pit/ underground powerhouse proposed on the left fringe of Gobind Sagar reservoir near village Rajpur through A 1.12km long water conductor system with the objective of generating 1500 MW of power.

The area around the proposed site located on the low lying, moderately bisected hills and shows with medium and trellis pattern. The hills around the proposed site were covered with moderately dense vegetation with dense under growth. One of the reasons for same could be due to the reason could be that the site was visited immediately after rainy season. The area at higher elevation expose sedimentary litho units belonging to Nahan Formation of Lower Siwalik group. These comprises an alternate sequence of grey-white, fine to medium grained, hard and compact, micaceous, flaggy sandstone and variegated mudstone with prominent lenses of an intra-formational conglomerate. The reddish- brown mudstone is splintery to nodular at places, mostly calcareous cement and very hard. These strike in general in NW- SE direction and dip towards NE with low to moderate dips. These traversed by three sets of joints in addition to those oriented along the strike.

The middle and lower reaches of the ridge are occupied by the rocks belonging to Dewal Formation of Middle Siwalik Sub-Group that unconformably overlies the litho units belonging to those belonging to Nahan Formation of Lower Siwalik Sub-Group . The The rocks belonging to Dewal Formation comprise moderately compact, sparsely cemented thickbedded medium to coarse grained planar and trough cross bedded grey micaceous sandstone with reddish brown nodular mudstone. The lenses of quartzite pebble and thin intraformational mud-chip conglomerate horizons are common. The concretionary features are also common. The Dewal Formation shows gradational contact with the underlying Nahan Formation and the overlying younger unit, the Mohargarh Formation. On the basis of visual estimation, alternate medium to fine-grained sandstone and mudstone bands, each constitute about 50:50 ratio respectively of the litho-package. These are also moderately jointed.

The proposed dam at this site is likely to encounter the sedimentary sequence belonging to Nahan Formation of Upper Siwalik Sub-Group and thst comprises an alternate sequence of grey-white, fine to medium grained, hard and compact, micaceous, flaggy sandstone and variegated mudstone with prominent lenses of an intra-formational conglomerate. The reddish- brown mudstone is splintery to nodular at places, mostly calcareous cement and very hard. The lithounits at the strike in NNW- SSE direction with shallow to moderate dips towards ENE. These characteristics of the foundation have to be kept in view while designing the dam. The ame has to be kept in view while designing various components of the project. The proposed dam axis at the alternative site is oriented in almost N-S direction. Primafacie, the site appears suitable for about 100m high dam. It is however suggested that if the possibility of shifting towards downstream may be looked into as it could lead to reduction of length of dam although the height of dam may increase. Shifting the axis towards could downstream may make it possible to utilize the saddle on right flank of the proposed dam. If it is possible, this could result in thinking of constructing an earth cum rockfill or rockfill at the site. This possibility can thought of subject to availability of construction material required for an earth dam with further investigation for same in later stages.

The 1.12km long water conductor system that includes HRT, penstocks and tailrace tunnel will encounter alternate bands of sandstone and siltstone/shale belonging to Nahan Formation of lower Siwalik Sub-Group initially and then followed by thick sandstone bands with clay shale band. The rocks are jointed. These may prove to be fair to good tunneling media of tunneling is done carefully following the excavation and supporting cycles.

The topographic setup of the site indicates that powerhouse will either be deep seated involving high cut slopes that would require massive treatment or could be envisaged as an underground. It is suggested that if depending upon the detailed explorations, the underground option is adopted, it may be located as near to dam as possible in order to assure adequate cover over the cavern and could also impact the cost of same.

3) OP_MJ_Trial 5 alternative is same as that was earlier studied by CEA. It is located on the opposite bank of the reservoir near Majra village in erstwhile Kangra and now Hamirur district. The studies carried out then indicated that it was possible to create a reservoir with FRL at EL 720m, MDDL at EL 700m gross storage capacity of 20.2MCM and live storage capacity of 14.9 MCM generate 1800 MW of power through 9 unis of 200MW capacity each. However, the detailed studies also carried out at the site. These studies led to identification of another alternative i.e. OP_M J_Trial 2 Since the same site in was studied earlier, has been retained as OP_MJ_Trial 5 in the present phase. However, the detailed field topographic surveys carried out at the site indicated substantial reduction in capacity and resultant power generation capacity. The present studies indicated that FRL at EL 720m (same as adopted in earlier studies) and MDDL at EL 690m (10m lower than adopted earlier) the reservoir capacity works out 8.27MCM against 20.2MCM estimated earlier. This resulted in reduction in estimated power generation from 2000MW to 688.22MW. Studies carried out considering another alternative namely OP_MJ_trial 2 with FRL & MDDL levels also indicated that the reservoir capacity reduced to 7.33MCM and resultant power generation to 662.2 MW.

The site proposed for about 40m high dam near village Singhwa across a southeasterly flowing tributary of Sarhyali Khad that flows through a narrow channel. The hill slopes no both the banks of nala are moderately vegetated with dense under growth. Both the abutments rise at moderate slopes above nala bed. The proposed dam axis oriented in N400E – S400W direction. The proposed site exposes grey coloured, medium grained, weakly cemented and moderately compacted micaceous sandstone belonging to Dewal Formation of Middle Siwalik Sub-Group. these atrike in NNW to NW- SSEto SE direction with moderate dips towards NE due to location of site in the vicinity of Changar Talai Anticline and Bursar Thrust, a small landslide with crown located about 30m above the nala bed and slide toe of the slide at nala bed that is occupied by slide debris up to 5m height. The 1.920km long water conductor system being planned to convey yhe designed discharhe proposed on opposite bank of Gobjnd Sagar, the lower reservoir will encounter the sandstone and shale belonging to Dewal Formation. The topographical set of the area indicates that the proposed powerhouse will either have to be located in a deep pit with very high cut slopes or housed in an underground cavern. Considering the nature of rock and height of slope cut that will require implementation of slope protection measures on massive scale, it is suggested that possibility of locating the powerhouse in an underground cavern may be considered.

Considering the location of the site in the vicinity of Bursar Thrust, length of water conductor system and substantially reduced power generation capacity, it does not appear to be attractive.

4) OP_ 1(0)_Trial 2 alternative located Survey of India toposheet 53A/11on the southwestern slopes of a NW – SE aligned hill range on the foot of which Shah Talai town is located. This alternative envisages an upper reservoir having estimated live storage capacity of 16.31MCM with FRL at EL720m, MDDL at EL680m with the construction of a 80m high and about 421m long dam across a small south easterly flowing nala that debouches into Sarhyali Khad on on the banks of which Shah Talai town is located. The design discharge is proposed to be conveyed to a pit/ underground powerhouse proposed on the left fringe of Gobind Sagar reservoir through a 3.98 km long water conductor system with the objective of generating 1400MW of power.

This site is located on the NE limb of NW- SE oriented Changar Talai anticline that exposes sedimentary rocks belonging to Nahan Formation of Lower Siwalik Sub-Group in the core portion and those belonging to Dewal Formation of Middle Siwalik on the limbs. The rocks belonging to Nahan Formation of Lower Siwalik Sub-Group and occupying the core of the anticline include an alternate sequence of grey-white, fine to medium grained, hard and compact, micaceous, flaggy sandstone and variegated mudstone with prominent lenses of an intra-formational conglomerate. The reddish- brown mudstone is splintery to nodular at places, mostly calcareous cement and very hard. The lithounits at the strike in NW- SE direction with shallow to moderate dips towards NE and SW due to folding. The rocks exposed on the limbs include those belonging to Dewal Formation of Middle Siwalik Sub-Group comprise moderately compact, sparsely cemented thickbedded medium to coarse grained planar and trough cross bedded grey micaceous sandstone with reddish brown nodular mudstone. The lenses of quartzite pebble and thin intraformational mud-chip conglomerate horizons are common. The concretionary features are also common. The Dewal Formation shows gradational contact with the underlying Nahan Formation. On the basis of visual estimation, alternate medium to fine-grained sandstone and mudstone bands, each constitute about 50:50 ratio respectively of the litho-package. These are also moderately jointed. However, on the southern limb the rocks of Nahan Formation override on those of Dewal Formation of Middle Siwalik Sub-Group along Bursar Thrust that is aligned on the southwestern limb of the Changar talai anticline. Both these features are aligned in NW-SE direction.

The site proposed for about 80m high dam with FRL at EL720m is located on left bank tributary of Sahyali Khad N of Shah Talai town. The narrow nala the the site proposed for the dam flows towards in southwest direction, The axis of the proposed dam is oriented in almost NE –SE direction. The site exposes moderately compact, sparsely cemented thickbedded medium to coarse grained planar and trough cross bedded grey micaceous sandstone with reddish brown nodular mudstone. The lenses of quartzite pebble and thin intraformational mud-chip conglomerate horizons are common. The concretionary features are also common. On the basis of visual estimation, alternate medium to fine-grained sandstone and mudstone bands, each constitute about 50:50 ratio respectively of the litho-package. These are also moderately jointed. The characteristic of the bedrock likely to occur in the foundation and same has to be kept in view while designing the foundation. The proposed 3.981km long water conductor system aligned in NNE-SSW direction is expected to encounter sequence of rocks belonging to Nahan Formation folded into an anticline in the central portion in the core of the anticline and those belonging to Dewal Formation in the limbs flanking them. Another prominent feature likely to be encountered by the water conductoer system on the southern limb of this Changar Talai anticline is Bursar Thrust along which the rcks belonging to Nahan Formation over ride those belonging to those of Dewal Formation. Possibility of encountering poor to very poor rock mass zone can not be ruled out at this stage same will have to be explored through detailed explorations. A 1357.97MW installed capacity Powerhouse is envisaged on the opposite fringe of reservoir extending into Sarhyali Khad. The topographical set of the area indicates that the proposed powerhouse will either have to be located in a deep pit with very high cut slopes or housed in an underground cavern. Considering the nature of rock and height of slope cut that will require implementation of slope protection measures on massive scale, it is suggested that possibility of locating the powerhouse in an underground cavern may be considered.

4.6 Conclusion and Recommendation

As BBMB proposes to develop a pump storage scheme utilizing the water available in Gobind Sagar reservoir of Bhakra Dam. Earlier CEA identified one site located near Majra village on opposite bank of Bhakra reservoir. The major appurtenant of the scheme included a 60m high dam on a tributary of Sarhyali Khad, resulting in creation of an upper reservoir with live gross storage of 20.2MCM, a 1.9km long water conductor system and a 1800 MW installed capacity surface or underground powerhouse located on the fringe of reservoir.

Recently, the scheme with the objective of preparation of FSR was handed over to WAPCOS. WAPCOS on the basis of detailed topographic survey identified five alternative sites including one identified earlier by CEA. After identifying the sites, different alternative for all the site were studied and 12 alternatives were selected for further evaluation. It is seen that five of these alternative are located on the left bank, one on right bank and six on opposite bank. Based on different factor like gross reservoir capacity of the proposed reservoir, live storage available, height of the proposed dam, length of water conductor system and power potential of the alternatives, the choice was narrowed down to four alternatives including that earlier selected by CEA.

The area encompassing these selected sites is located in Himachal Pradesh Sub-Himalaya between MBT separating it from Lesser Himalaya in the north and Himalayan Frontal Thrust demarcating its southern limit. The Sub- exposes rocks belonging to Sirmour Group that have been divided into three sub- in the north and those belonging to Siwalik Group in the south. The rocks belonging to Nahan Formation of Lower Siwalik Super Group and Dewal and Mohargarh formations of Middle Siwalik Super Group. These rocks are folded and faulted and are traverswd by Bursar Thrust in the area along which the older nahan formation rocks override the younger Dewal and Mohargarh formation rocks. Seismotectonically the area encompassing the four sites under consideration relocated in Kangra Seismotectonic block bound by Ropar- Sunder Nagar tear in the east and Ravi Tear in the west known for 7.8MW magnitude earthquake of 1905. Keping the seismic acvity in the block and the area surrounding the proposed site, same been kept in Seismic Zone IV as per BIS Seismic Zoning Map of India (2002). Keeping the seismic status of the area and presence of a number of thrust faults in the vicinity of the proposed sites, it is recommended that suitable seismic coefficient may be got determined for the area and in corporateed in the designs of different apurtenants of the project finally adopted.

The comparison of different aspects like geological and tectonic setup, rock types present, gross reservoir capacity, length of water conductor system and estimated power potential of different alternative studied it is suggested that alternative RB_ 1_ Trial 1 could be preferred and taken up for further detailed studies and explorations.

It is also proposed that possibility of shifting the dam axis further downstream to reduce the length of dam and locating chute spillway in the saddle on the right abutment may be looked into at DPR Stage. In that case the dam could be designed as a rock fill dam. It is also suggested that efforts may be made to construct powerhouse in an underground cavern as nearer to dam as possible so that length of pressurized component of the water conductor is minimum and to reduce its cost. Another advantage of this site is that it is located in close vicinity of existing Bhakra Dam and infrastructure of same can be utilized here.

5. PROJECT PLANNING AND INSTALLED CAPACITY

CHAPTER - 5

5 PROJECT PLANNING AND INSTALLED CAPACITY

5.1 Introduction

The Bhakra Beas Management Board (BBMB), with a view of utilize the water available in Gobind Sagar reservoir that spreads over 168.35 sq. km. of area and has gross storage capacity of 7.04 BCM by constructing a pump storage project (PSP). The Bhakra Pumped Storage project is located near Bilaspur District Himachal on the Sutlej river.

5.2 Bhakra Pump Storage Project

The Proposed Bhakra PSP envisages utilisation of water of existing Bhakra (Gobind Sagar) reservoir on Sutlej River having spread in three districts i.e Bilaspur, Hamirpur and Una of Himachal through installation of 1500 MW power plant, which would be equipped with six vertical axis reversible type hydro-electric units each comprising of generator-motor and a pump turbine with a generating capacity of 250 MW each. Lower reservoir would consist of existing Gobind Sagar reservoir while upper reservoir (Proposed new construction) would be for storage of recycled water at the foot -hill.

5.3 Upper Reservoir

The upper reservoir of pumped storage operation of the project. The reservoir has a live storage capacity of 14.4 MCM as under.

Table: 6.1

Particulars	
FRL	EL. 750 m
MDDL	EL. 700 m
Live Storage	**14.4 MCM**

5.4 Lower Reservoir

The lower reservoir of pumped storage operation of the project. The reservoir has a live storage capacity of 7191 MCM as under.

Table: 6.2

Particulars	
FRL	EL. 512.07 m
MDDL	EL. 445.62 m
Live Storage	7191

5.5 Operating Gross Head

Gross operating generation head on the pumped storage units would vary from 304.38m to 185.52 m. Gross operating pumping head on the pumped storage units would vary from 306.79 m to 190.34 m The head ratio i.e., ratio of maximum pumping head to minimum pumping head is 1.61. The head loss in the water conductor system has been estimated as 2.41 m.

5.6 Installed Capacity

Considering the availability of the storage capacity in upper reservoir an installation of 1500 MW comprising 6 units of 250 MW has been provided.

5.7 Operation Simulation

The operation simulation of the two reservoirs for pumped storage operation has been carried out considering the storage characteristics. The operation of the scheme in either mode viz. 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. As the lower reservoir i.e., Govind Sagar Reservoir has an enormous 168.35 sq. km. of area with live storage of 7191 MCM. Therefore, an outflow of 14.4 MCM shall not have any major impact on the level of Lower reservoir. Therefore, the simulation has been done considering two scenarios i.e.,

Scenario 1: The studies have been carried out at the beginning of generating cycle, the Upper reservoir is at FRL i.e., EL. 750.00 m and Lower reservoir is at FRL i.e., EL. 502.07 m

Generation Operation: The impact of such continuous variations in head is best captured by simulation of operation of the scheme considering shorter time intervals of 8 to 12 minutes The detailed preliminary generation operation simulation studies of the Scheme have been carried out to considering 36 time intervals of 8 minutes each, 2 time interval of 4 mins each for 4 hours and 56 minutes hours generating cycle to assess storage requirement for proposed Bhakra Pumped Storage Scheme for an installed capacity of 1500 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 750.00 m. The reservoir draws down to El. 700.00 m in 4 hours and 56 minutes of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 14.40 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 512.07m and 14.4 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy generation during the period is 7400 MWh.

The details of the studies are given at Annex-5.1.

Bhakra PSS- Storage Requirement (MCM) for an Installed Capacity of 1500MW & for 4 hours and 56 minutes peaking operation

Pumping Operation: The detailed preliminary pumping operation simulation studies of the Scheme have been carried out to considering 19 time intervals of 10 minutes each, 21 time interval of 9 mins each for 6 hours and 19 minutes hours pumping cycle to assess storage requirement for proposed Bhakra Pumped Storage Scheme for an installed capacity of 1500 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 700.00 m. The reservoir recharges to El. 750.00 m in 6 hours and 19 minutes of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 14.40 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 512.07m and 14.4 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy consumed during the period is 9475 MWh.

The details of the studies are given at Annex-5.2.

Bhakra PSS- Storage Requirement (MCM) for an Installed Capacity of 1500MW & for 6 hours and 19 minutes peaking operation

Scenario 2: The studies have been carried out at the beginning of generating cycle, the Upper reservoir is at FRL i.e., EL. 750.00 m and Lower reservoir is at MDDL i.e., EL. 445.62 m

The impact of such continuous variations in head is best captured by simulation of operation of the scheme considering shorter time intervals of 8 to 12 minutes The detailed preliminary operation simulation studies of the Scheme have been carried out to considering 25 time intervals of 10 minutes each and 13 time interval of 11 mins for 6 hours and 55 minutes hours generating cycle to assess storage requirement for proposed Bhakra Pumped Storage Scheme for an installed capacity of 1500 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 750.00 m. The reservoir draws down to El. 700.00 m in 6 hours and 55 of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 14.40 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 445.62 m and 14.4 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy generation during the period is 9825 MWh.

The details of the studies are given at Annex-5.3.

Bhakra PSS- Storage Requirement (MCM) for an Installed Capacity of 1500MW & for 6 hours and 55 peaking operation

Pumping Operation: The detailed preliminary pumping operation simulation studies of the Scheme have been carried out to considering 32 time intervals of 12 minutes each, 8 time interval of 13 mins each for 8 hours and 8 minutes hours pumping cycle to assess storage requirement for proposed Bhakra Pumped Storage Scheme for an installed capacity of 1500 MW.

The simulation studies have been carried out for the initial reservoir levels as under.

- At the beginning of the generation, the upper reservoir is at FRL El. 700.00 m. The reservoir recharges to El. 750.00 m in 8 hours and 8 minutes of full load operation representing a drawdown of 50 m.
- The storage utilized for operation is 14.40 million m^3.
- At the start of generation, the Lower reservoir is at its MDDL 445.62m and 14.4 MCM shall have very minor impact on the level of Lower reservoir due to very large area of the reservoir.

The energy consumed during the period is 12200 MWh.

The details of the studies are given at Annex-5.4.

Bhakra PSS- Storage Requirement (MCM) for an Installed Capacity of 1500MW & for 8 hours and 8 minutes peaking operation

Generator Turbine efficiency

The efficiency of the Turbine-Generator unit during generating mode is adopted as 90% and during the pumping mode is adopted as 91%.

5.7.1 Losses in the Water Conductor System

The losses in the water conductor system have been considered as 2.41 m during generation and 4.82 during pumping operation.

ANNEXURE - 5.1

Bhakra Pumped Storage Project H.E. Project, Himachal Pradesh

Generation Operation Simulation Studies (Starting of year Lower reservoir at FRL)

Operating Levels and Storage available at Existing and new Reservoirs

Upper reservoir				Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)		
FRL		750.00	-	FRL	512.07		
MDDL		700.00	-	MDDL	445.62		
Live Storage			14.40	Live Storage	unlimited		

Scenario 1: Operating Levels considered for Operation Simulation

Upper reservoir		Lower reservoir			
	Level (m)			Level (m)	Storage (MCum)
FRL-PS Operation	750.00	FRL-PS Operation		512.07	-
MDDL-PS Operation	700.00	MDDL-PS Operation		512.07	-
Pondage for PS Operation	14.39	Pondage for PS Operation			14.39

				Upper Pond				Lower Pond					
Interval No	Time Interval (Minutes)	Station Output (MW)	Discharge (cumecs)	Initial Pond Level (m)	Outflow from Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Initial Pond Level (m)	Inflow into Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Average Net Head (m)	Energy Generation (MWh)
1	8.0	1500.0	723.44	750.00	0.39	748.65	749.32	512.07	0.39	512.07	512.07	234.84	200.00
2	8.0	1500.0	727.42	748.65	0.35	747.43	748.04	512.07	0.35	512.07	512.07	233.56	200.00
3	8.0	1500.0	731.22	747.43	0.35	746.21	746.82	512.07	0.35	512.07	512.07	232.34	200.00
4	8.0	1500.0	735.09	746.21	0.35	744.99	745.60	512.07	0.35	512.07	512.07	231.12	200.00
5	8.0	1500.0	739.03	744.99	0.35	743.75	744.37	512.07	0.35	512.07	512.07	229.89	200.00
6	8.0	1500.0	743.03	743.75	0.36	742.51	743.13	512.07	0.36	512.07	512.07	228.65	200.00
7	8.0	1500.0	747.10	742.51	0.36	741.26	741.89	512.07	0.36	512.07	512.07	227.41	200.00
8	8.0	1500.0	751.24	741.26	0.36	740.00	740.63	512.07	0.36	512.07	512.07	226.15	200.00
9	8.0	1500.0	755.45	740.00	0.36	738.74	739.37	512.07	0.36	512.07	512.07	224.89	200.00
10	8.0	1500.0	759.73	738.74	0.36	737.47	738.10	512.07	0.36	512.07	512.07	223.62	200.00
11	8.0	1500.0	764.09	737.47	0.37	736.19	736.83	512.07	0.37	512.07	512.07	222.35	200.00
12	8.0	1500.0	768.53	736.19	0.37	734.90	735.54	512.07	0.37	512.07	512.07	221.06	200.00
13	8.0	1500.0	773.05	734.90	0.37	733.60	734.25	512.07	0.37	512.07	512.07	219.77	200.00
14	8.0	1500.0	777.65	733.60	0.37	732.30	732.95	512.07	0.37	512.07	512.07	218.47	200.00
15	8.0	1500.0	782.33	732.30	0.38	730.99	731.64	512.07	0.38	512.07	512.07	217.16	200.00
16	8.0	1500.0	787.10	730.99	0.38	729.67	730.33	512.07	0.38	512.07	512.07	215.85	200.00
17	8.0	1500.0	791.96	729.67	0.38	728.34	729.00	512.07	0.38	512.07	512.07	214.52	200.00
18	8.0	1500.0	796.92	728.34	0.38	727.00	727.67	512.07	0.38	512.07	512.07	213.19	200.00
19	8.0	1500.0	801.96	727.00	0.38	725.66	726.33	512.07	0.38	512.07	512.07	211.85	200.00
20	8.0	1500.0	807.11	725.66	0.39	724.30	724.98	512.07	0.39	512.07	512.07	210.50	200.00

21	8.0	1500.0	812.36	724.30	0.39	722.94	723.62	512.07	0.39	512.07	512.07	209.14	200.00
22	8.0	1500.0	817.70	722.94	0.39	721.56	722.25	512.07	0.39	512.07	512.07	207.77	200.00
23	8.0	1500.0	823.16	721.56	0.40	720.18	720.87	512.07	0.40	512.07	512.07	206.39	200.00
24	8.0	1500.0	828.73	720.18	0.40	718.79	719.49	512.07	0.40	512.07	512.07	205.01	200.00
25	8.0	1500.0	834.41	718.79	0.40	717.39	718.09	512.07	0.40	512.07	512.07	203.61	200.00
26	8.0	1500.0	840.21	717.39	0.40	715.98	716.69	512.07	0.40	512.07	512.07	202.21	200.00
27	8.0	1500.0	846.13	715.98	0.41	714.56	715.27	512.07	0.41	512.07	512.07	200.79	200.00
28	8.0	1500.0	852.17	714.56	0.41	713.13	713.85	512.07	0.41	512.07	512.07	199.37	200.00
29	8.0	1500.0	858.35	713.13	0.41	711.69	712.41	512.07	0.41	512.07	512.07	197.93	200.00
30	8.0	1500.0	864.66	711.69	0.42	710.24	710.97	512.07	0.42	512.07	512.07	196.49	200.00
31	8.0	1500.0	871.10	710.24	0.42	708.78	709.51	512.07	0.42	512.07	512.07	195.03	200.00
32	8.0	1500.0	877.70	708.78	0.42	707.31	708.05	512.07	0.42	512.07	512.07	193.57	200.00
33	8.0	1500.0	884.43	707.31	0.42	705.83	706.57	512.07	0.42	512.07	512.07	192.09	200.00
34	8.0	1500.0	891.33	705.83	0.43	704.34	705.09	512.07	0.43	512.07	512.07	190.61	200.00
35	8.0	1500.0	898.38	704.34	0.43	702.84	703.59	512.07	0.43	512.07	512.07	189.11	200.00
36	8.0	1500.0	905.59	702.84	0.43	701.33	702.09	512.07	0.43	512.07	512.07	187.61	200.00
37	4.0	1500.0	911.09	701.33	0.22	700.57	700.95	512.07	0.22	512.07	512.07	186.47	100.00
38	4.0	1500.0	914.81	700.57	0.22	699.82	700.20	512.07	0.22	512.07	512.07	185.72	100.00
	296.00				14.39				14.39				7400.00

MCum - Million Cubic Metres

ANNEXURE - 5.2

Bhakra Pumped Storage Project H.E. Project, Himachal Pradesh

Pumping Operation Simulation Studies (Starting of year Lower reservoir at FRL)

Operating Levels and Storage available at Existing Reservoirs

Upper reservoir				Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)		
FRL		750.00		FRL	512.07		
MDDL		700.00		MDDL	445.62		
Live Storage			14.40	Live Storage		unlimited	

Scenario 1: Operating Levels considered for Operation Simulation

Upper reservoir		Lower reservoir		
	Level (m)		Level (m)	Storage (MCum)
FRL-PS Operation	749.94	FRL-PS Operation	512.07	130.59
MDDL-PS Operation	700.00	MDDL-PS Operation	512.07	115.95
Pondage for PS Operation	14.64	Pondage for PS Operation		14.64

				Upper Pond				**Lower Pond**					
Interval No	**Time Interval (Minutes)**	**Motor-Pump Power (MW)**	**Pump Discharge (cumecs)**	**Initial Pond Level (m)**	**Inflow into Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Initial Pond Level (m)**	**Outflow from Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Average Net Head (m)**	**Energy Consumpt--ion (MWh)**
1	10.0	1500.0	716.34	700.00	0.43	700.58	700.29	512.07	0.43	512.07	512.07	193.04	250.00
2	10.0	1500.0	720.80	700.58	0.43	702.08	701.33	512.07	0.43	512.07	512.07	194.08	250.00
3	10.0	1500.0	716.93	702.08	0.43	703.58	702.83	512.07	0.43	512.07	512.07	195.58	250.00
4	10.0	1500.0	711.44	703.58	0.43	705.06	704.32	512.07	0.43	512.07	512.07	197.07	250.00
5	10.0	1500.0	706.07	705.06	0.42	706.53	705.79	512.07	0.42	512.07	512.07	198.54	250.00
6	10.0	1500.0	700.82	706.53	0.42	707.99	707.26	512.07	0.42	512.07	512.07	200.01	250.00
7	10.0	1500.0	695.68	707.99	0.42	709.44	708.72	512.07	0.42	512.07	512.07	201.47	250.00
8	10.0	1500.0	690.66	709.44	0.41	710.88	710.16	512.07	0.41	512.07	512.07	202.91	250.00
9	10.0	1500.0	685.74	710.88	0.41	712.31	711.59	512.07	0.41	512.07	512.07	204.34	250.00
10	10.0	1500.0	680.93	712.31	0.41	713.73	713.02	512.07	0.41	512.07	512.07	205.77	250.00
11	10.0	1500.0	676.22	713.73	0.41	715.13	714.43	512.07	0.41	512.07	512.07	207.18	250.00
12	10.0	1500.0	671.61	715.13	0.40	716.53	715.83	512.07	0.40	512.07	512.07	208.58	250.00
13	10.0	1500.0	667.09	716.53	0.40	717.92	717.23	512.07	0.40	512.07	512.07	209.98	250.00
14	10.0	1500.0	662.66	717.92	0.40	719.30	718.61	512.07	0.40	512.07	512.07	211.36	250.00
15	10.0	1500.0	658.31	719.30	0.39	720.68	719.99	512.07	0.39	512.07	512.07	212.74	250.00
16	10.0	1500.0	654.06	720.68	0.39	722.04	721.36	512.07	0.39	512.07	512.07	214.11	250.00
17	10.0	1500.0	649.88	722.04	0.39	723.39	722.72	512.07	0.39	512.07	512.07	215.47	250.00
18	10.0	1500.0	645.78	723.39	0.39	724.74	724.06	512.07	0.39	512.07	512.07	216.81	250.00
19	10.0	1500.0	641.76	724.74	0.39	726.07	725.41	512.07	0.39	512.07	512.07	218.16	250.00
20	9.0	1500.0	637.82	726.07	0.34	727.27	726.67	512.07	0.34	512.07	512.07	219.42	225.00
21	9.0	1500.0	634.14	727.27	0.34	728.46	727.87	512.07	0.34	512.07	512.07	220.62	225.00
22	9.0	1500.0	630.71	728.46	0.34	729.64	729.05	512.07	0.34	512.07	512.07	221.80	225.00
23	9.0	1500.0	627.34	729.64	0.34	730.82	730.23	512.07	0.34	512.07	512.07	222.98	225.00

24	9.0	1500.0	624.02	730.82	0.34	731.99	731.40	512.07	0.34	512.07	512.07	224.15	225.00
25	9.0	1500.0	620.75	731.99	0.34	733.15	732.57	512.07	0.34	512.07	512.07	225.32	225.00
26	9.0	1500.0	617.54	733.15	0.33	734.31	733.73	512.07	0.33	512.07	512.07	226.48	225.00
27	9.0	1500.0	614.37	734.31	0.33	735.46	734.89	512.07	0.33	512.07	512.07	227.64	225.00
28	9.0	1500.0	611.25	735.46	0.33	736.61	736.04	512.07	0.33	512.07	512.07	228.79	225.00
29	9.0	1500.0	608.19	736.61	0.33	737.75	737.18	512.07	0.33	512.07	512.07	229.93	225.00
30	9.0	1500.0	605.16	737.75	0.33	738.88	738.32	512.07	0.33	512.07	512.07	231.07	225.00
31	9.0	1500.0	602.18	738.88	0.33	740.01	739.45	512.07	0.33	512.07	512.07	232.20	225.00
32	9.0	1500.0	599.25	740.01	0.32	741.14	740.57	512.07	0.32	512.07	512.07	233.32	225.00
33	9.0	1500.0	596.35	741.14	0.32	742.25	741.70	512.07	0.32	512.07	512.07	234.45	225.00
34	9.0	1500.0	593.50	742.25	0.32	743.37	742.81	512.07	0.32	512.07	512.07	235.56	225.00
35	9.0	1500.0	590.69	743.37	0.32	744.47	743.92	512.07	0.32	512.07	512.07	236.67	225.00
36	9.0	1500.0	587.92	744.47	0.32	745.58	745.03	512.07	0.32	512.07	512.07	237.78	225.00
37	9.0	1500.0	585.19	745.58	0.32	746.67	746.13	512.07	0.32	512.07	512.07	238.88	225.00
38	9.0	1500.0	582.49	746.67	0.31	747.77	747.22	512.07	0.31	512.07	512.07	239.97	225.00
39	9.0	1500.0	579.84	747.77	0.31	748.85	748.31	512.07	0.31	512.07	512.07	241.06	225.00
40	9.0	1500.0	577.22	748.85	0.31	749.94	749.39	512.07	0.31	512.07	512.07	242.14	225.00
	379.00				14.64				14.64				9475.00

MCum - Million Cubic Metres

ANNEXURE 5.3

Bhakra Pumped Storage Project H.E. Project, Himachal Pradesh

Generation Operation Simulation Studies (Ending of year Lower reservoir at MDDL)

Operating Levels and Storage available at Existing and new Reservoirs **Scenario 1: Operating Levels considered for Operation Simulation**

Upper reservoir				Lower reservoir				Upper reservoir		Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)				Level (m)			Level (m)	Storage (MCum)
FRL		750.00	-	FRL	512.07			FRL-PS Operation	750.00	FRL-PS Operation		445.62	-
MDDL		700.00	-	MDDL	445.62			MDDL-PS Operation	700.00	MDDL-PS Operation		445.62	-
Live Storage			14.40	Live Storage	unlimited			Pondage for PS Operation	14.40	Pondage for PS Operation			14.40

				Upper Pond				Lower Pond					
Interval No	Time Interval (Minutes)	Station Output (MW)	Discharge (cumecs)	Initial Pond Level (m)	Outflow from Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Initial Pond Level (m)	Inflow into Pond (MCum)	Final Pond Level (m)	Average Pond Level (m)	Average Net Head (m)	Energy Generation (MWh)
1	10.0	1500.0	564.82	750.00	0.34	748.82	749.41	445.62	0.34	445.62	445.62	301.38	250.00
2	10.0	1500.0	563.72	748.82	0.34	747.65	748.24	445.62	0.34	445.62	445.62	300.21	250.00
3	10.0	1500.0	565.93	747.65	0.34	746.47	747.06	445.62	0.34	445.62	445.62	299.03	250.00
4	10.0	1500.0	568.15	746.47	0.34	745.29	745.88	445.62	0.34	445.62	445.62	297.85	250.00
5	10.0	1500.0	570.41	745.29	0.34	744.10	744.69	445.62	0.34	445.62	445.62	296.66	250.00
6	10.0	1500.0	572.69	744.10	0.34	742.90	743.50	445.62	0.34	445.62	445.62	295.47	250.00
7	10.0	1500.0	575.00	742.90	0.34	741.71	742.31	445.62	0.34	445.62	445.62	294.28	250.00
8	10.0	1500.0	577.33	741.71	0.35	740.50	741.11	445.62	0.35	445.62	445.62	293.08	250.00
9	10.0	1500.0	579.70	740.50	0.35	739.30	739.90	445.62	0.35	445.62	445.62	291.87	250.00
10	10.0	1500.0	582.09	739.30	0.35	738.08	738.69	445.62	0.35	445.62	445.62	290.66	250.00
11	10.0	1500.0	584.51	738.08	0.35	736.87	737.47	445.62	0.35	445.62	445.62	289.44	250.00
12	10.0	1500.0	586.97	736.87	0.35	735.64	736.25	445.62	0.35	445.62	445.62	288.22	250.00
13	10.0	1500.0	589.45	735.64	0.35	734.42	735.03	445.62	0.35	445.62	445.62	287.00	250.00
14	10.0	1500.0	591.97	734.42	0.36	733.18	733.80	445.62	0.36	445.62	445.62	285.77	250.00
15	10.0	1500.0	594.52	733.18	0.36	731.94	732.56	445.62	0.36	445.62	445.62	284.53	250.00
16	10.0	1500.0	597.10	731.94	0.36	730.70	731.32	445.62	0.36	445.62	445.62	283.29	250.00
17	10.0	1500.0	599.72	730.70	0.36	729.45	730.07	445.62	0.36	445.62	445.62	282.04	250.00
18	10.0	1500.0	602.37	729.45	0.36	728.19	728.82	445.62	0.36	445.62	445.62	280.79	250.00
19	10.0	1500.0	605.05	728.19	0.36	726.93	727.56	445.62	0.36	445.62	445.62	279.53	250.00
20	10.0	1500.0	607.78	726.93	0.36	725.67	726.30	445.62	0.36	445.62	445.62	278.27	250.00

21	10.0	1500.0	610.54	725.67	0.37	724.40	725.03	445.62	0.37	445.62	445.62	277.00	250.00
22	10.0	1500.0	613.33	724.40	0.37	723.12	723.76	445.62	0.37	445.62	445.62	275.73	250.00
23	10.0	1500.0	616.17	723.12	0.37	721.83	722.48	445.62	0.37	445.62	445.62	274.45	250.00
24	10.0	1500.0	619.04	721.83	0.37	720.55	721.19	445.62	0.37	445.62	445.62	273.16	250.00
25	10.0	1500.0	621.96	720.55	0.37	719.25	719.90	445.62	0.37	445.62	445.62	271.87	250.00
26	11.0	1500.0	624.92	719.25	0.41	717.82	718.53	445.62	0.41	445.62	445.62	270.50	275.00
27	11.0	1500.0	628.07	717.82	0.41	716.38	717.10	445.62	0.41	445.62	445.62	269.07	275.00
28	11.0	1500.0	631.42	716.38	0.42	714.93	715.65	445.62	0.42	445.62	445.62	267.62	275.00
29	11.0	1500.0	634.82	714.93	0.42	713.48	714.20	445.62	0.42	445.62	445.62	266.17	275.00
30	11.0	1500.0	638.29	713.48	0.42	712.01	712.74	445.62	0.42	445.62	445.62	264.71	275.00
31	11.0	1500.0	641.80	712.01	0.42	710.54	711.28	445.62	0.42	445.62	445.62	263.25	275.00
32	11.0	1500.0	645.38	710.54	0.43	709.06	709.80	445.62	0.43	445.62	445.62	261.77	275.00
33	11.0	1500.0	649.02	709.06	0.43	707.58	708.32	445.62	0.43	445.62	445.62	260.29	275.00
34	11.0	1500.0	652.71	707.58	0.43	706.08	706.83	445.62	0.43	445.62	445.62	258.80	275.00
35	11.0	1500.0	656.48	706.08	0.43	704.58	705.33	445.62	0.43	445.62	445.62	257.30	275.00
36	11.0	1500.0	660.30	704.58	0.44	703.06	703.82	445.62	0.44	445.62	445.62	255.79	275.00
37	11.0	1500.0	664.20	703.06	0.44	701.54	702.30	445.62	0.44	445.62	445.62	254.27	275.00
38	11.0	1500.0	668.16	701.54	0.44	700.01	700.78	445.62	0.44	445.62	445.62	252.75	275.00
	415.00				14.40				14.40				9825.00

MCum - Million Cubic Metres

ANNEXURE 5.4

Bhakra Pumped Storage Project H.E. Project, Himachal Pradesh

Pumping Operation Simulation Studies (Starting of year Lower reservoir at FRL)

Operating Levels and Storage available at Existing Reservoirs | **Scenario 1: Operating Levels considered for Operation Simulation**

Upper reservoir				Lower reservoir				Upper reservoir		Lower reservoir			
		Level (m)	Storage (MCum)		Level (m)				Level (m)			Level (m)	Storage (MCum)
FRL		750.00		FRL	512.07			FRL-PS Operation	749.99	FRL-PS Operation		445.62	130.59
MDDL		700.00		MDDL	445.62			MDDL-PS Operatior	700.00	MDDL-PS Operation		445.62	116.19
Live Storage			14.40	Live Storage		unlimited		Pondage for PS Ope	14.40	Pondage for PS Operation			14.40

				Upper Pond				Lower Pond					
Interval No	**Time Interval (Minutes)**	**Motor-Pump Power (MW)**	**Pump Discharge (cumecs)**	**Initial Pond Level (m)**	**Inflow into Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Initial Pond Level (m)**	**Outflow from Pond (MCum)**	**Final Pond Level (m)**	**Average Pond Level (m)**	**Average Net Head (m)**	**Energy Consumpt--ion (MWh)**
1	12.0	1500.0	534.52	700.00	0.38	701.34	700.67	445.62	0.38	445.62	445.62	259.87	300.00
2	12.0	1500.0	535.44	701.34	0.39	702.67	702.01	445.62	0.39	445.62	445.62	261.21	300.00
3	12.0	1500.0	532.70	702.67	0.38	704.01	703.34	445.62	0.38	445.62	445.62	262.54	300.00
4	12.0	1500.0	529.99	704.01	0.38	705.33	704.67	445.62	0.38	445.62	445.62	263.87	300.00
5	12.0	1500.0	527.32	705.33	0.38	706.65	705.99	445.62	0.38	445.62	445.62	265.19	300.00
6	12.0	1500.0	524.69	706.65	0.38	707.96	707.31	445.62	0.38	445.62	445.62	266.51	300.00
7	12.0	1500.0	522.10	707.96	0.38	709.27	708.61	445.62	0.38	445.62	445.62	267.81	300.00
8	12.0	1500.0	519.55	709.27	0.37	710.57	709.92	445.62	0.37	445.62	445.62	269.12	300.00
9	12.0	1500.0	517.04	710.57	0.37	711.86	711.21	445.62	0.37	445.62	445.62	270.41	300.00
10	12.0	1500.0	514.56	711.86	0.37	713.14	712.50	445.62	0.37	445.62	445.62	271.70	300.00
11	12.0	1500.0	512.12	713.14	0.37	714.43	713.78	445.62	0.37	445.62	445.62	272.98	300.00
12	12.0	1500.0	509.71	714.43	0.37	715.70	715.06	445.62	0.37	445.62	445.62	274.26	300.00
13	12.0	1500.0	507.34	715.70	0.37	716.97	716.33	445.62	0.37	445.62	445.62	275.53	300.00
14	12.0	1500.0	505.00	716.97	0.36	718.23	717.60	445.62	0.36	445.62	445.62	276.80	300.00
15	12.0	1500.0	502.69	718.23	0.36	719.49	718.86	445.62	0.36	445.62	445.62	278.06	300.00
16	12.0	1500.0	500.41	719.49	0.36	720.74	720.11	445.62	0.36	445.62	445.62	279.31	300.00
17	12.0	1500.0	498.17	720.74	0.36	721.98	721.36	445.62	0.36	445.62	445.62	280.56	300.00
18	12.0	1500.0	495.95	721.98	0.36	723.22	722.60	445.62	0.36	445.62	445.62	281.80	300.00
19	12.0	1500.0	493.76	723.22	0.36	724.46	723.84	445.62	0.36	445.62	445.62	283.04	300.00
20	12.0	1500.0	491.60	724.46	0.35	725.69	725.07	445.62	0.35	445.62	445.62	284.27	300.00
21	12.0	1500.0	489.47	725.69	0.35	726.91	726.30	445.62	0.35	445.62	445.62	285.50	300.00
22	12.0	1500.0	487.37	726.91	0.35	728.13	727.52	445.62	0.35	445.62	445.62	286.72	300.00

23	12.0	1500.0	485.30	728.13	0.35	729.34	728.74	445.62	0.35	445.62	445.62	287.94	300.00
24	12.0	1500.0	483.25	729.34	0.35	730.55	729.95	445.62	0.35	445.62	445.62	289.15	300.00
25	12.0	1500.0	481.22	730.55	0.35	731.75	731.15	445.62	0.35	445.62	445.62	290.35	300.00
26	12.0	1500.0	479.22	731.75	0.35	732.95	732.35	445.62	0.35	445.62	445.62	291.55	300.00
27	12.0	1500.0	477.25	732.95	0.34	734.14	733.55	445.62	0.34	445.62	445.62	292.75	300.00
28	12.0	1500.0	475.30	734.14	0.34	735.33	734.74	445.62	0.34	445.62	445.62	293.94	300.00
29	12.0	1500.0	473.38	735.33	0.34	736.52	735.92	445.62	0.34	445.62	445.62	295.12	300.00
30	12.0	1500.0	471.47	736.52	0.34	737.69	737.11	445.62	0.34	445.62	445.62	296.31	300.00
31	12.0	1500.0	469.60	737.69	0.34	738.87	738.28	445.62	0.34	445.62	445.62	297.48	300.00
32	12.0	1500.0	467.74	738.87	0.34	740.04	739.45	445.62	0.34	445.62	445.62	298.65	300.00
33	13.0	1500.0	465.90	740.04	0.36	741.30	740.67	445.62	0.36	445.62	445.62	299.87	325.00
34	13.0	1500.0	464.02	741.30	0.36	742.56	741.93	445.62	0.36	445.62	445.62	301.13	325.00
35	13.0	1500.0	462.07	742.56	0.36	743.81	743.18	445.62	0.36	445.62	445.62	302.38	325.00
36	13.0	1500.0	460.16	743.81	0.36	745.05	744.43	445.62	0.36	445.62	445.62	303.63	325.00
37	13.0	1500.0	458.27	745.05	0.36	746.30	745.67	445.62	0.36	445.62	445.62	304.87	325.00
38	13.0	1500.0	456.40	746.30	0.36	747.53	746.91	445.62	0.36	445.62	445.62	306.11	325.00
39	13.0	1500.0	454.55	747.53	0.35	748.76	748.15	445.62	0.35	445.62	445.62	307.35	325.00
40	13.0	1500.0	452.73	748.76	0.35	749.99	749.38	445.62	0.35	445.62	445.62	308.58	325.00
	488.00				14.40				14.40				12200.00
MCum - Million Cubic Metres													

6. DESIGN OF CIVIL STRUCTURES

Chapter – 6

Design of Civil Structures

6.1 The Scheme

A mammoth multipurpose project has been constructed on river satluj in north west India for irrigation and power generation. The river Satluj tributary of river Indus, rises from the Mansarovar Lake in the Tibetan plateau situated at elevation of about 4500m above mean sea level. It flows a distance of 320 Km in Tibet before entering the Indian territory near Shipki. In India it cuts through successive Himalayan ranges carving out beautiful gorges and enters the plains. Its length in India upto Bhakra is 260km. The total catchment area of Satluj and its tributaries above Bhakra is about 56980 sq. km. the mean annual runoff is about 1.6millon hector metre. The river drops to 100 cumecs in cold weather and rises to a steady flow of about 1400 cumecs in June.

This project comprises 225.6 high concrete gravity dam with two power houses having an installed capacity of 1050MW which further has been increased to 1379 MW during course of time by modifying various units still there is proposal to increase the left bank power house capacity from 594 mw to 630 mw.

The dam has been named Bhakra Dam after the village of Bhakra which was the first to be submerged by the reservoir although it was envisaged in 1908 but survey could be started in 1916 and DPR for major irrigation project for 120 .4 m high dame at the present dam site was prepared. However, the project did not materialize, a severe famine occurred in south west Punjab due to drought in 1938 and then project investigations were revived in 1939.The dam was finally constructed is a straight gravity concrete structure with a maximum height of 225.6m and utilises fully the power potential and water supplies available. This project has been constructed in stages. The dam was constructed in all respect in 1963, except grouting of the deep curtain although left power house was constructed in 1961 and the right side power house was constructed in 1968.

6.2 Geological Investigations

The dam is located in the outer hills of Himalayas, called Shivalik Hills. The dam site and the river canyon are underlain by rocks, chiefly the Shivalik formation of sandstone and clay beds with thick conglomerate forming upper portion of the stratigraphic column.

6.3 Present Proposal

There is continuous increase in demand of energy so like other source we use water as source of renewal energy by cycling the water /pumped storage plant as already have been stated that there is much variation in the inflow of river Sutlej from 100 cumecs to 1400 cumecs in a year project authorities' thought of exploring the possibilities of constructing a pumped storage plant and for this they hired the services of WABCOS as their consultant to for further study

Under this back ground WAPCOS started their study in the month of July. The present dam has been built on Satluj when the river enters in the plains so this existing Bhakra reservoir has been proposed as a lower reservoir for the pumped storage scheme with maximum operating level of 512 .07 m and minimum draw down level of 445.62m.

6.4 Earlier studies by CEA

Earlier Central Electrical Authority (CEA) carried out identification of probable alternative sites for locating the PSP project in late eighties of twentieth century primarily on the basis of topographic studies with the help of Survey of India Toposheets 53A/6 and 53A/7. The studies indicated that it was possible to construct one such scheme with generating capacity of 1800MW near village Majra located on opposite bank of the reservoir in erstwhile Kangra district of Himachal Pradesh. The then studies carried out on Survey of India Toposheets indicated that it was possible to create a reservoir with gross storage capacity of 20.2 MCM on Sarhyali Khad by constructing a 60m high dam across it and a design discharge of 1032cumecs from thus created reservoir could be conveyed through a 1.90 km long water conductor system to a semi-underground powerhouse to generate 1800MW of power utilizing a gross head of 221.4m.

6.5 Selection of Layout - General

Identification of locations for upper dam axis have been selected as under:

Initially WAPCOS field office identified as many as possible potential sites for upper reservoir (annexure-1), later narrowing & identification of proposed sites were carried out during continuous joint site visit of designers, experts and field staff in between July & August months. Further designers & expert finally proposed 12 sites for site survey and topography. A comprehensive study and work was taken on these sites (annexure 2) but on the basis of survey and viability studies finally proposed four (4) possible sites. Designers & Geologist carried out geological studies of these 4 sites in month of October. And after much technical analysis it is concluded that the sites on right bank will be most favourable from power capacity and techno-economic reasons. Hence, proposing this site for further studies and preparation of detail project report.

In our various alternative studies, it is concluded the that live storage capacity requirement for the upper reservoir is very much less as compared to its huge storage of existing lower reservoir. As significant head is available for the generation of 800 to 14000 mw power which at this stage we feel is essential for economic viability of the proposal. The live storage capacity for pump storage scheme requirement varies from 6.41 mcm to 16 31 mcm against a live storage of the existing lower reservoir of 5.65 BCM and gross storage capacity is of the tune of 7.04BCM.

Hence, in present studies, final proposed have power generation capacity of 800 MW to 1500 MW.

Based on the features like gross reservoir capacity, length of the water conductor system and power system, following four alternative including the one evaluated earlier were selected for detailed studies with for techno-commercial viability and further development in later stages:

i. Dam Axis AA (i.e. LB_2_trial 3)

ii. Dam Axis BB (i.e. RB_1_Trial 1)

iii. Dam Axis CC (i.e. OP_MJ_Trial 5)

iv. Dam Axis DD (i.e. OP_1(0)_Trial 2)

1. Dam axis Alternative1 (Axis A-A)

LB_2_Trial 3 is located on the left fringe of reservoir and old course of Satluj river near Lehri village uphill Thathal village of Bilaspur district of Himachal Pradesh. in Survey of India Toposheet 53A/7. This alternative envisages an upper reservoir having estimated live storage capacity of 6MCM with FRL at EL850m, MDDL at EL770m with the construction of a 100m high and about 600m long dam across a small south westerly flowing nala that is aligned through Lehri village. The design discharge is proposed to be conveyed to an underground powerhouse proposed on the left fringe of Gobind Sagar reservoir near village Thatal through 1.58km long water conductor system with the objective of generating 841MW of power.

The hills around the proposed site were covered with moderately dense vegatation with dense under growth. One of the reasons for same could be due to the reason could be that the site was visited immediately after rainy season.

2. Dam axis Alternative2 (Axis B-B):

RB_1_Trial 1 is located on the right fringe of Gobind Sagar reservoir on right flank of Bhakra Dam near Dobar Uparla village of Una district of Himachal Pradesh in Survey of India Toposheet 53A/7. This alternative envisages an upper reservoir having estimated live storage capacity of 14.4MCM with FRL at EL750m, MDDL at EL700m with the construction of a 100m high and about 500m long dam across a small south northerly flowing nala that debouches into Gobind Sagar north of Rajpur village. The design discharge is proposed to be conveyed to a pit/underground powerhouse proposed on the left fringe of Gobind Sagar reservoir near village Rajpur through A 1.12km long water conductor system with the objective of generating 1500 MW of power.

The area around the proposed site located on the low lying, moderately bisected hills and shows with medium and trellis pattern. The hills around the proposed site were covered with moderately dense vegetation with dense under growth. One of the reasons for same could be due to the reason could be that the site was visited immediately after rainy season. Primafacie, the site appears suitable for about 100m high dam.

It is proposed, Shifting the axis towards downstream may make it possible to utilize the saddle on right flank of the proposed dam. If it is possible, this could result in thinking of constructing an earth cum rockfill or rockfill at the site. This possibility is subject to availability of construction material required for an earth dam with further investigation for same in DPR stage.

3. Dam axis Alternative3 (Axis C-C):

OP_MJ_Trial 5 alternative is same as that was earlier studied by CEA. It is located on the opposite bank of the reservoir near Majra village in erstwhile Kangra and now Hamirur district. The studies carried out then indicated that it was possible to create a reservoir with FRL at EL 720m, MDDL at EL 700m gross storage capacity of 20.2MCM and live storage capacity of 14.9 MCM generate 1800 MW of power through 9 unis of 200MW capacity each.

However, the detailed studies carried out at the site by WAPCOS. These studies led to identification of another alternative i.e. OP_M J_Trial 2. Since the same site in was studied earlier, has been retained as OP_MJ_Trial 5 in the present phase. However, the detailed field topographic surveys carried out at the site indicated substantial reduction in capacity and resultant power generation capacity. The present studies indicated that FRL at EL 720m (same as adopted in earlier studies) and MDDL at EL 690m (10m lower than adopted earlier) the reservoir capacity works out 8.27MCM against 20.2MCM estimated earlier. This resulted in reduction in estimated power generation from 1800MW to 688.22MW. Studies carried out considering another alternative namely OP_MJ_trial 2 with FRL & MDDL levels also indicated that the reservoir capacity reduced to 7.33MCM and resultant power generation to 662.2 MW.

The site proposed for about 40m high dam near village Singhwa across a southeasterly flowing tributary of Sarhyali Khad that flows through a narrow channel. The hill slopes on both the banks of nala are moderately vegetated with dense under growth. The 1.920km long water conductor system being planned to convey the designed discharge proposed on opposite bank of Gobjnd Sagar, the lower reservoir. The topographical set of the area indicates that the proposed powerhouse will either have to be located in a deep pit with very high cut slopes or housed in an underground cavern. Possibility of locating the powerhouse in an underground cavern may be considered.

4. Dam axis Alternative4 (Axis D-D):

OP_ 1(0) _Trial 2 alternative located Survey of India toposheet 53A/11 on hill range on the foot of which Shah Talai town is located. This alternative envisages an upper reservoir having estimated live storage capacity of 16.31MCM with FRL at EL720m, MDDL at EL680m with the construction of 80m high and about 421m long dam across a small south easterly flowing nala that debouches into Sarhyali Khad on on the banks of which Shah Talai town is located. The design discharge is proposed to be conveyed to a pit/ underground powerhouse proposed on the left fringe of Gobind Sagar reservoir through a 3.98 km long water conductor system with the objective of generating 1400MW of power.

In view of the reduced submergence, lesser length of HRT, less quantity of lower dam etc. as mentioned above, the alternative-3 has been chosen in the present study. However, the same may be reviewed at the DPR stage when more subsurface and topographical data is available.

6.5.1 Type of Structure - Dam

The Concrete Gravity type dam structure is considered for creating the upper reservoir of the project.

The basic requirements for an earth and rock-fill dam to be safe and stable under various conditions of operation of the reservoir are to ensure that:

The normal and minimum free board computations shall be based on T. Saville’s method as given in IS: 10635. The following factors govern the requirements of free board: -

- Wave characteristics particularly wave height and wave length depends mainly on wind velocity.
- Upstream slope of the embankment and roughness of the pitching.
- Height of wind set up above the still water level which depends on depth of water in the reservoir.

6.5.2. Upper Dam & Spillway

The Location of upper dam axis at PFR Stage will provide required live storage. It is observed that the most suitable location for Dam Axis is at Left Bank N - 31° 27’ 10.64”, E - 76° 25’ 1.97” and Right Bank N - 31°26’ 51.55”, E - 76°24’ 59.63” which can provide the required Live Storage and better geological & other considerations. The Rock-fill with Clay core type has been chosen on cost consideration over concrete which may increase the project cost. The FRL and MDDL is kept at EL750 m and EL700.00 m which create required live poundage 14.4 MCM. The maximum height of upper dam is 100m and length 500.00m. A Bottom Outlet has been kept in lower spillway below the MDDL in upper Reservoir for environmental flow.

6.5.3 Design Approach

The basic approach in design of concrete dam shall be to select a dam section analysed by the approach specified in IS Code of practice for Stability Analysis of Gravity Dam. The factors of safety computed for critical combination of external forces will be compared with the minimum factor of safety stipulated in the code. The outer slopes of the dam will be optimized such that the computed factors of safety are higher than, but close to, the minimum desired values under various loading conditions.

6.5.4 Power Intake

Intake structure has been proposed from the upper reservoir on the right bank of Dam. An approach channel has been proposed to guide the flow towards intake mouth. Optimum layout requirements have been considered to suit the alignment of the Water Conductor in fixing the alignment of Power Intake. An intake of size 11 m x 16.36 m x 79.4m 2 no's x 1 line has been proposed. The intake will be connected to a tunnel of diameter 7m with transition. The maximum discharging capacity of the tunnel will be 1007 cumec.

Based on the parameters minimum submergence required has been calculated as per BIS codal practice and Gorden formula for symmetric flow. The center line of the intake has been accordingly fixed at EL 650.0m.

The inlet and outlet is designed in accordance with the guidelines proposed by Central Research Institute of Electric Power Industry in Japan which has been mostly applied to design for intakes and outlets of a lot of pumped storage power station. The main consideration of design criteria are as follows;

Waterway of a pumped storage power plant is pressure one, so an inlet of a pumped storage power plant also comes to pressure type. Considering vertical arrangement of an inlet for a pressure conduit, sufficient water cushion shall be provided for withdrawal of requisite discharge without any vortex formation. Water depth from sill of an inlet to the minimum water level should be 1.5 to 2.0 times as high as internal diameter. Velocity of flow through trash rack shall not be more than 1.0 meter/sec in normal condition and entry through intake shall be stream lined such that head loss is minimum. For fixing the intake level it is also planned that it does not attract much of the silt during withdrawal of water.

An intake of a pumped storage power station has the following characteristics in difference from a conventional hydraulic power station;

- Both an intake and a tailrace outlet are to function as an intake as well as an outlet since directions in generating and pumping modes are exact reverse even though hydraulic feature is quite different between water intake and discharge.
- There is a possibility that vortex easily comes into being for the reason that water depth between a surface to an intake comes to small near the maximum draw-down level.
- It is difficult that water flow discharged from an inlet or outlet evenly diffuses into a reservoir because flow velocity of a pumped storage power station is generally faster than that of a conventional hydraulic

power station. As a result, the inlet structure is designed and shown in drawing no. 2.

6.5.5 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. Therefore, comparative study on location of the waterway on both banks is conducted and an optimum profile of the waterway is selected through comparative study among various alternatives.

The alignment of the waterway from the intake to the tailrace outlet is studied under the following conditions;

- Length of waterway is tried to be shortest.
- The portion of water way is aligned in such a way that it has a no bends.
- Both intake and tailrace outlet are aligned in such a way that pumping and generation mode have favorable flow characteristics.
- There are two reversible units for which one pressure shaft has been provided.
- Longitudinal axis of the powerhouse cavern is to be aligned so that will make an angle of 43°-53° with the strike of foliations.
- It goes without saying that the powerhouse cavern is to be positioned with enough rock cover on the powerhouse cavern for stability of the cavern. In this regard, the bottom level of the Power house has been kept so that sufficient cover shall be available over Power house cavern. The height of the cavern is 55m. The rock cover on the powerhouse cavern has been kept more than twice of height of the cavern for proper stability of the cavern.

The Longitudinal section along the alignment of the waterway from the intake to the tailrace outlet is shown in drawing no 2. The locations of power intake and tailrace outlet are to be selected in the area where stable topographical and geological conditions can be obtained, so as to be able to ensure the stable and safe water flow.

6.5.6 Head Race Tunnel (Steel Lined) Cum Pressure Shaft

A 200m m long and 11.5 m dia Steel lined Head Race Tunnel (HRT) has been proposed to carry a max discharge of 1007 cumec. The maximum cover of HRT will be 100m. From HRT, the adit (D-Shaped) of length 200m and dimensions 7m x 7.5m is proposed. The adit is provided to facilitate the construction of pressure shaft. This tunnel will also be provided with suitable rock support system depending upon the geological strata formations enroute. Apart from the rock support system, the headrace tunnel will be provided with steel lining to reduce the head loss due to friction. Actual support system will be decided after geological investigations and analysis at DPR stage.

six horizontal pressure tunnels have been proposed. The length of horizontal pressure tunnel will be about 130 m and 4.5m Dia. In general, rock-bolts and lining will be required as support system. Actual support system will be decided after geological investigations and analysis at DPR stage.

Steel lining has been proposed for the entire length of HRT. The thickness of steel lining will be assessed keeping in view the internal pressure including water hammer and external pressure acting in the event of sudden dewatering of Tunnel. The typical support details of HRT and Pressure Shaft is shown in L-section Drawing.

Diameter of 11.5 m as proposed for penstock is based on the velocity consideration however economic diameter studies may be done at DPR stage. Plate thickness will be assessed considering both internal water pressure plus increase in head due to water hammer as well as external pressure.

Design criteria

The hydraulic and structural design of pressure shaft/penstock is based on following criteria:

- Steel liner will be designed to take the entire internal pressure independently without any rock participation - Steel liner shall be capable to withstand maximum external pressure under empty condition
- Penstock will be designed for loading condition at mid span and at the supports where additional stresses are developed.
- Sickle plate for penstock manifold should take care of all unbalanced forces at the point of bifurcation.

6.5.7 Underground Power house and Underground Transformer Hall

An underground Power House (UGPH) of size 265mx23mx55m for and a transformer cavern hall of 260mx18.5mx28.0m have been proposed for this project. The power house will have six Francis type vertical shaft reversible units of 250 MW each. The design head for turbine mode as 241.0 m and pumping mode as 245.82 m has been assessed.

The powerhouse cavern actual orientation will be finalized after large scale geological mapping, 3D logging and in-situ test at the exploratory drift to power house at DPR stage.

6.5.8 Machine Hall Cavern

The machine hall cavern would be 265.0m in length, 23.0m in width and overall height of the power house cavity from the lowest excavation of the turbine pit would be 55m. The generating units would be spaced at 24.0m center to center. The entrance to the Machine hall cavern shall be through Main Access Tunnel (MAT). The auxiliary rooms shall be located at different floors provided on the services bay side of the machine hall cavern.

The penstock for each generating unit would enter the power house horizontally making an angle with the power house longitudinal direction and accommodate the main inlet valve in the machine hall. The penstock for each unit will terminate into a distributor feeding the turbine nozzles. The center line of the horizontal penstocks entering the power house cavity would be El. 396.5m in line with nozzles of the turbines.

The roof of machine hall cavern has been provided with a circular arch shape with crown rise of 7m from the spring level. The roof and walls of the power house cavern are supported by systematic rock bolting and shortcreting (SFRS), where the rock mass is of poor quality (‘Q’ value from 1.0 to 2.0), the roof is supported with the combination of shotcrete (SFRS), rock bolts and steel ribs. Provision of drainage holes in regular way has also been made for roof and walls for drainage the rock mass adjoining the cavern.

RCC columns of size 1000mm x 1500mm are proposed for supporting the EOT crane beam. A clearance of about 500mm has been provided between the column edge and excavated rock surface to take care of the convergence of power house walls.

6.5.9 Transformer cavern

The transformer cavern would be 260m long, its width and height being 18.5m and 28.0m respectively. It accommodates 7 sets of unit transformers at El. 409.0m. The roof arch of this cavity would be of circular arch shape with 5m rise of crown from the spring level. As in the machine hall cavity, the roof and walls of the transformer cavity are also supported by systematic rock bolting and shotcreting (SFRS), where the rock mass is of poor quality (‘Q’ value from 1.0 to 2.0), the roof is supported with the combination of shotcrete (SFRS), rock bolts and steel ribs. Provision of drainage holes in regular way has also been made for roof and walls for draining the seepage water adjoining the cavern.

6.5.10 Tail Race Tunnel

A 11.5m dia and 500m long TRT has been proposed. The rock cover along TRT will vary from 100m to 210m. TRT will be provided with suitable rock support system depending upon the geological strata. Apart from the rock support system, the TRT will be provided with 600 mm thick reinforced cement concrete lining. Actual support system will be decided after geological investigations and analysis at DPR stage.

6.5.11 Main Access Tunnel (MAT), Cable tunnel and Construction Adits

The details of MAT, Adits etc. are furnished in the following table 6.1:

Table-6.1

S.No.	Type	Length	Dimensions
1	Main Access Tunnel (MAT)	500m	8m x 8.5m
2	TRT Adit	300m	7m x 7.5m
3	Pressure Shaft Adit	250 m	7m x 7.5m
4	Top of transformer Hall (Adit)	250m	7m x 7.5m
5	Top of Power House (Adit)	500m	7m x 7.5m

6	Cable Access tunnel &Ventilation Tunnel	300m	6m x 6.5m
8	HRT Adit	200m	7m x 7.5m

7. DESIGN OF ELECTRO-MECHANICAL EQUIPMENTS

Chapter – 7
Electro-Mechanical Equipment's

The utility of Pumped Storage Project has evolved a long way as one of the power system tools to perform multiple functions. While the fixed speed synchronous generator can meet the peak power demand in quickest possible way, the pumping operation has immense contribution in maintaining frequency at lean hour and maintaining the plant load factor of Thermal generation plants.

With the advent of technological advancement to meet the need of the power system network, variable speed machines are gradually felt necessary because of their many advantages over the conventional fixed speed machines. Specially, with the present trend of development of renewable energy in India, grid management will become critical in future.

In such scenario one of the options in integrated power system management is variable speed pumped storage project. It has some other definite advantages when analysed on long term basis over life cycle of project.

Considering the above the following three options for configuration of the main units has been considered for the basic design of the Electro - Mechanical equipment at present:

Option 1: 6 Fixed speed units

Option 2: 3 Fixed + 3 Variable speed units

Option 3: 6 Variable speed units

Detail analysis will be carried out before final selection of the machine and configuration during preparation of technical specification.

The basic design of E&M equipment in this chapter is based on the Option 1, Option 2 and Option 3 as considered in the Annexure 7.1.

7.1 General

The proposed Bhakra Pumped Storage Project of 1500 MW is envisaged to have 6 vertical pump-turbine driven generating units each of rating 250 MW and operating under a rated head of 241.0 m (Generation mode) and 245.82 m (Pumping mode) in an underground power house. The generated electric power at 18 kV shall be evacuated through 24 kV

Isolated Phase Bus Ducts (IPBDs) passing through 6 Nos. Bus Duct galleries and then terminating on LT side of 6 nos. of three phase step up 18/400/√3kV, 324 MVA, Generator Transformers located in transformer hall cavern. HT side of Transformers shall be connected to 420 kV GIS located above the transformer hall. 400 kV XLPE cables laid in cable tunnel shall be used for interconnecting 420 kV GIS located in underground transformer cavern with outdoor 400kV transmission lines at Pothead yard. Two double circuit 400 kV transmission lines each having twin moose conductor per phase shall transmit power to & from 400 kV Substation at Bhakra HEP.

7.2 Layout Plan of Electro-Mechanical Equipment

A pumped storage scheme consists of upper reservoir and one lower reservoir by constructing suitable dam complex water conductor system i.e. three nos. of pressure shafts each bifurcating into two penstocks, would run between the upper reservoir and six nos. pump turbine housed in an underground Power House. Further, two tail race from pump turbine would be merge and then the discharge from two pump turbine would be merge together and will be carried by TRT to the lower reservoir. The Bhakra underground power house will have 6(six) Pump-Turbine and Generator-Motor units of 250/246 MW each along with all the auxiliary systems such as governors, excitation equipment, SFC starting equipment cooling water system, compressed air system, potable water supply system, fire protection system, ventilation and air conditioning system, illumination system, HT & LT AC and DC systems etc.

The entrance to the Machine hall cavern shall be through Main Access Tunnel (MAT). The machine hall at EL 409.00 m shall be 253.0 m in length (Including service bay and control block) and 23 m in width. The height of machine hall cavern shall be 51 m. The Transformer hall cavern (size 260m x 18.5m x 28m) shall be located 45m downstream of main power house cavern.

The auxiliary rooms shall be located at different floors provided in the auxiliary and control blocks on the Unit 1 & Unit-6 side of the machine hall. Control room, Model/Conference room, Engineers Room, 220 V DC system, HVAC equipment, electrical equipment testing laboratory and mechanical workshop etc. shall be located in these auxiliary rooms.

Floor wise equipment layout plan is as under:-

Machine Hall at EL 409.00 m

Unit Control Boards (UCBs) and Excitation Panels shall be installed in the machine hall floor. Phase reversal switch along with Generator circuit breaker (GCB) which is provided between Isolated Phase Bus Duct (IPBD) and Generator-Motor shall be installed at this floor.

Generator-Motor floor at EL 404.00 m

Unit Auxiliary Boards (UAB's), LT distribution boards with dry type distribution transformers, Neutral grounding Cubicles, lubrication system etc. shall be installed at this floor.

Pump-Turbine floor at EL 399.50 m

HP & LP compressed air systems ,Oil pressure units for governors of each unit and other pump-turbine auxiliaries shall be placed on Pump-turbine floor.

Main Inlet Valve (MIV) floor at EL 392.50 m

Cooling water pumps, Dewatering & Drainage pumps, flood water pumps and MIV servomotors shall be located on MIV floor.

Drainage & Dewatering gallery floor at EL 382.50 m

Draft tubes shall be connected to dewatering sump through a network of valves & pipes. Seepage and drainage from various floors of power house shall also be collected to the adjacent drainage sump at this floor.

24 kV isolated phase bus ducts shall be laid in individual bus duct gallery of respective unit interconnecting machine hall floor with the Transformer cavern. GCBs, Phase Reversal Switches, LAVT cubicles, Excitation Transformers, Unit Auxiliary Transformers (UATs) and Station Auxiliary Transformers (SATs) shall be installed in these Bus-duct galleries. Beside six Bus Duct galleries, 2 additional galleries (One extended part of MAT on Service bay side and other on Unit-6 side) shall be provided for interconnecting Machine Hall cavern with Transformer Hall. One cable tunnel of adequate size is also proposed to accommodate 400 kV XLPE cables to transmit power between GIS

installed in transformer cavern and overhead transmission lines at pothead yard.

HT, LT, control, protection, signaling cables between various panels in the underground power house and Transformer Hall & Pothead yard shall be laid in the cable tunnel/ trenches/ trays & racks.

The access to turbine pit shall be from pump-turbine floor.

Necessary hatches for material handling and removal of MIV shall be provided at various floors in the machine hall cavern.

The dewatering, drainage & flood water sumps shall be provided at the MIV floor towards Service bay side & far end unit-6 side.

The Main Access Tunnel (MAT) and construction adit tunnel for the power house cavern shall be utilized as ventilation tunnel & exhaust air tunnel afterwards. Suitable ventilation and air conditioning ducts, as required, shall be installed at various locations and floors.

Two nos. of 300/50/10 Tonnes EOT Cranes capable of operating in tandem along with a lifting beam shall be installed in the power house cavern.

One no. of 10 Tonnes EOT Crane shall be installed in the GIS hall for handling the GIS equipment and One (01) number 50 T EOT Crane in transformer hall for handling bonneted type draft tube gates .

7.3 Electro-Mechanical Equipment

7.3.1 Pump-Turbine

The Pump-turbines shall be of vertical shaft Francis type coupled to Generator-Motor of nominal rating of 250 MW each Six (6) Nos.of the Francis pump-turbine each of 253.81 MW output and 254.33 MW as input operating under rated heads as mentioned below shall be installed.

The details of the hydraulic system of the generating units are as given below:

i. Upper Reservoir levels	
a) Full Reservoir Level (FRL)	750.0 m
b) Minimum Draw Down Level (MDDL)	700.0 m
ii. Lower Reservoir levels	
a) Full Reservoir Level (FRL)	512.07 m
b) Minimum Draw Down Level (MDDL)	445.62 m
iii.Head Loss	
a) Turbine Mode	2.41 m
b) Pump Mode	2.41 m
iv. Operating Head Range As Turbine:-	
a) Maximum net head	301.97 m
b) Minimum net head	185.52 m
c) Rated net head	241.00 m
d) Discharge (Generation)	117.49 cumecs
As Pump:-	
a) Maximum net head	306.79 m
b) Minimum net head	185.52 m
c) Rated net head	245.82 m
d) Discharge (Pumping)	97.03 cumecs
v. Turbine Basic Data	
a) Rated Output at rated net head of 362m	253.81 MW
b) Specific Speed	132.48 rpm
c) Rated Speed	214.29 rpm
d) Centerline of Turbine	EL. 396.00 m
vi. Pump Basic Data	
a) Pump Input at rated net head of 245.82 m	254.33 MW
b) Specific Speed	34 rpm
c) Rated Speed	214.29 rpm
d) Rated Pump discharge	97.03 cumec

Pump-Turbine runner shall be of 13:4/Cr:Ni stainless steel material. The upper portion of the draft cone liner shall be provided with stainless steel cladding.

7.3.2 Governor for Pump-Turbine machine

The Electro-hydraulic governor shall be of digital type with Combined Proportional Integral and Derivative function (PID) for control and regulating function and a hydraulic part acting as a power amplifying servo unit. The governor shall be suitable for local and remote control, synchronizing, load/frequency control, joint control operation, speed sensing etc.

7.3.3 Main Inlet Valve (MIV)

A main inlet valve of spherical type of diameter 3.00 m for shutting-off pressure water supply from the penstock to the pump-turbine shall be provided complete with necessary piping, control cabinet, upstream and downstream connecting pipes with companion flanges, dismantling joint, bypass valve & air release valve, operating mechanism etc. The valve shall have two oil pressure operated working seals (one service seal and the other maintenance seal). The seals shall be of material having high resistance to silt erosion.

7.3.4 Oil Pressure Systems for Governor and Turbine Inlet Valves

Each Pump-turbine shall be provided with a separate pressure oil system for operation of Pump-turbine wicket gate servomotors through governors, Air separate pressure oil system for the opening of MIV shall be provided.

7.3.5 Generator-Motor

The Generator-Motor will be synchronous and of the vertical shaft type. Each of the six Generator-Motors shall have the following characteristics:

Rated Output	250 MW
Power Factor	0.85 lagging
Frequency	50 Hz
Phases	3 (Three)
Speed	214.29 rpm

Rated Terminal Voltage Between pha	18 kV
Range of frequency	(-) 5 % to (+) 3 %
Bearing arrangement	Semi Umbrella Type

Generator-Motor voltage shall operate at 18 kV. The voltage rating shall be optimized during preparation of bidding document/detailed engineering stage.

7.3.6 LAVT and Neutral grounding Cubicles

LAVT Cubicles shall include Surge Capacitors, Lightning Arresters, Voltage Transformers and associated accessories. The Generator Neutral Grounding Cubicle shall include a single phase, Dry type earthing transformer, a secondary loading Disconnecting Switch, a Resistor and associated accessories mounted in a single-ventilated, metal enclosed Cubicle.

7.3.7 Static Excitation System and AVR

Static Excitation system shall have microprocessor based controls. The excitation equipment shall comprise of rectifier, excitation transformers, thyristors, field breaker with discharge resistor, field flashing circuit, automatic voltage regulator and protection and control devices along with accessories to make it a complete system.

7.3.8 Generator-Motor Transformers

Six (06) numbers three phase split type/19 nos (including 01 spare) single-phase type 18.0/400/√3kV (Single phase Transformer or Three Phase Transformer shall be decided during DPR stage after route survey), having total capacity 324 MVA, with OFWF type cooling Power Transformers shall be installed in Transformer cavern. HV terminals of these transformers shall be connected through GIB to the GIS located on the floor above this hall.

7.3.9 420 kV Gas Insulated Switchgear (GIS) & 400 kV XLPE Cables

420 kV GIS shall be installed at the floor above the transformer hall connected to HV side of Power transformers through GIBs. The GIS will have 6 incoming bays, 4 outgoing bay and one bus coupler bay, i.e. total 11 bays. Power from 420 kV GIS would be transmitted to pothead

yard through 400kV XLPE cables and further to Bhakra HEP Sub-stations through 2 nos. double circuit 400 kV transmission lines.

7.3.10 Static Frequency Converter (SFC)

One (01) set of static frequency converter (SFC) for starting of fixed speed as well as variable speed units in pumping mode shall be installed in Machine hall auxiliary floor. The primary circuits of SFC shall be able to be connected to generator-motor buses of fixed speed machines through a circuit breaker and disconnecting switches.

The secondary circuit of the SFC is connected to all generator-motors through a circuit breaker and disconnecting switches. Both circuits shall be equipped with current limit reactors to reduce interrupting current of circuit breakers.

Static Frequency Convertor (SFC) is used to accelerate the machine in reverse direction for “pumping operation” upto the rated speed by grid power through 420kV GIS breaker and main generation transformer.

SFC acts as a synchronous link between Machine and Grid, It converts AC supply from grid to DC supply and then inverts this DC supply to required frequency AC supply and is fed to the Machine stator.

SFC plays main role in starting the unit in Pumping mode. During this operation once the unit is synchronized to the grid, SFC gets cutoff. Also when the unit is shut down SFC plays role of electrical breaking (in both mode “Generation” as well as “Pumping” mode) and thus brings unit to standstill faster.

7.3.11 Back to Back Starting Method

Back to back starting system shall also be equipped for all of six generator-motors. Two machines are required in this method of starting. For starting the units in the pump mode by back to back method, provision is to be made for random coupling of any two of the units in the back to back starting across the 24 kV IPBD. Phase reversal is to be achieved by using DS (M) isolators on generator terminal. However all design requirement and equipment requirement are to be finalized during detail engineering for providing required panel and switching arrangement at main control room and at machine hall for back to back start.

Any one of the 250 MW unit in the power house shall be selected and started as a motor by another 250 MW generator which is located in the same power house. Both units are initially at standstill. The necessary switching is performed to disconnect two machines from 420kV Bus/transmission system by selecting the respective breakers & isolators. Note that the two machines are actually interconnected through 24kV IPBD/XLPE cables. The fields of both units are energized and the turbine gates are opened to a predetermined position. Both the generator and the motor will accelerate together. The power generated in the stator winding of Back to back generator machine is phase reversed through switching arrangements and fed directly to the stator winding of back to back Pump machine.

The field excitation is to be build up by Back to Back excitation and then taken over by Main Excitation. The Back to back excitation gets the source from Unit Auxiliary Board. The main excitation gets source from machine output through Excitation Transformer. The back to back excitation will be in service from low speed till 90% of the rated speed and 70% of the rated voltage. Once 90% of the rated speed and 70% of the rated voltage is attained, the back to back excitation cut off and the main excitation get connected to the system.

The Back to back generator machine will be in service until the synchronization of the Back to back Pump machine. After synchronization of the back to back Pump machine, back to back generator machine will return to shutdown status and main static excitation system regulator shall control & protect the machine field.

Control cable connection and interlocking arrangements shall be designed
for the above scheme and provision to be made in the control desk and in sequencer panel.

Starting method under dewatered condition is proposed. The draft tube water is depressed by admission of compressed air so that runner rotates in air drawing low power from the generator selection machine. The required blow down arrangement with suitable compressors, blow down tank, valves, and pipe lines has to be arranged by the turbine supplier and necessary control & protection arrangement through sequential control is to be made by the generator supplier.

7.3.12 24kV Generator Circuit Breaker

The circuit breaker on generator-motor side in the power house shall operate at every starting and stopping of the main unit, thus relieving the high voltage GIS circuit breakers from frequent operation. The installation of unit circuit breakers also enables the station service transformers to be located in bus-duct tunnels and be connected to the generator-motor circuit.

7.4 Control and Protection System

7.4.1 Control:-

A supervisory control and data acquisition (SCADA) system will be provided for an efficient and economic plant operation. The control and monitoring system will be built up of distributed control technique with independent control modules in hierarchical control levels and standard open protocol for communication network. All the components and subsystems in the hierarchical control levels of the control system shall be flawlessly & seamlessly integrated to achieve a highly reliable and scalable power plant control system.

The powerhouse will be designed to be operated with three levels of control:

- From local control cubicles of each element located adjacent to the unit.
- From the unit control board located on the machine hall floor.
- From the Central control room.

7.4.2 Protection System

The protection relays will be envisaged for the units including its UAT, Excitation Transformer, Station Auxiliary Transformers as well as for the generator transformers, 400 kV XLPE cables and the 420 kV GIS etc.

The design of the protection scheme will be based on the general philosophy that all the protected equipment has a primary and back-up protection supplementing each other. All protection relays will be high speed and of numerical design.

7.5 Mechanical Auxiliaries

7.5.1 EOT Cranes

Power House

The heaviest equipment / assembly required to be lifted in the power house by the EOT crane shall be the assembled rotor. The assembled rotor weight for the 250MW, 214.29 rpm generating unit is expected to be of the order of 510 Tonnes. Two cranes each of 300/50/10 tones main and auxiliary hooks are proposed to be provided for handling the assembled rotor along the full length of the powerhouse. Both the EOT cranes shall be used in tandem to handle the rotor. A lifting beam of adequate size /capacity for this purpose shall be provided. One monorail crane of 10T capacity supported beneath the outside girders of both the cranes shall also be provided.

GIS Hall/ Transformer Hall

One EOT crane of 10 Tonnes capacity shall be installed in GIS hall. Also, one no. 50 T EOT Crane shall be installed in the transformer hall for handling of draft tube bonneted gates.

7.5.2 Compressed Air System

Sufficient capability to recharge the compressed air system shall consist of six compressors, two main tank for water level depression and two auxiliary air tanks for complete air distribution system, valves and other piping system with necessary instrumentation and protection system and control panels etc. for Governor, Inlet valve, Braking and jacking of generator rotor and for operating pneumatic tools.

7.5.3 Dewatering and Drainage System

One set of interconnected drainage & dewatering sump and other flood protection sump shall be provided in the power house cavern near Unit-1 & Unit-6. Dewatering system shall be provided in the power house for dewatering of unit for access to underwater parts. The scheme shall comprise of 3 nos. of submersible pumps of sufficient capacity (Two as main and one as standby) installed in the dewatering sump along with valves, piping, and control annunciation provided in the Machine Hall cavern.

The drainage scheme shall comprise of 3 nos. submersible drainage pumps (Two as main and one as standby) installed in the drainage sump along with requisite piping, control panels etc. Both the dewatering and drainage sump would be interconnected by means of pipe with gates & Non return valves.

Provision of Flood water evacuation system has also been made in case of inadvertent flooding of the power house. The system shall comprise of 3 nos. of submersible pumps (Two as main and one as standby) installed in the flood sump along with valves, piping, control annunciation to discharge water outside the power house building and shall have dedicated DG set power supply.

Control Panels for dewatering and drainage pump shall be located at the highest floor level.

7.5.4 Cooling Water System

It is proposed to provide individual cooling water system for each unit to remove heat from generators and bearing oils through heat exchangers. The cooling water shall be taken from the draft tube by set of centrifugal pumps. The cooling water shall be discharged back into the draft tube. Cooling water system shall be connected to a common header to cater cooling water to the unit in case of failure of individual pumps.

7.5.5 Air Conditioning and Ventilation System

The machine and transformer halls shall be provided with ventilation and air-conditioning system as required to maintain the control room, Conference room and other work areas at the required level of temperature, humidity and comfort.

Adequate number of supply & exhaust fans shall be installed at suitable locations to provide the air changes per hour as mentioned in Indian standards.

7.5.6 Oil Handling System

Oil handling system for transformer oil and lubricating oil for generating units will be provided with suitable piping, valves, tanks, purifiers etc. and shall be located such as to conform the requirements of underground power house.

7.5.7 Fire Detection and Protection System

The fire detection & protection system in the underground Power House, Main Access Tunnel, Isolated phase bus duct tunnels, switchyard etc. shall be planned to timely detect the occurrence & quick extinguishing of fire, breakouts, and prevention of spread of fire so as to minimize the extent of damage.

7.5.8 Lifts

2 nos. electrically operated lifts shall be provided in the control and auxiliary blocks on the unit –1 &6 sides of the Machine hall. The lift shall be designed for approximately a load of 16persons.

7.5.9 Draft Tube Gates

Individual Bonneted type draft tube gates shall be provided with oil operated servo motors in the transformer hall.

7.5.10 Mechanical Workshop

A Mechanical Workshop will be provided in control block on Unit-1 side in Machine Hall cavern for routine maintenance as required for all works & will be equipped with drilling, welding, milling & lathe machines & other required machine tools.

7.6 Electrical Auxiliaries

7.6.1 AC Electrical Auxiliaries – MV/LV Supply System

The MV/LV AC supply system will be developed to ensure the availability of reliable source to all energy consumers of electrical auxiliaries. The Main AC supply system will be made up from 24kV Isolated phase bus-ducts of the 1st & 6th generating units.

Unit auxiliaries will be fed from the UAB/UAT (Unit Auxiliary Board/Unit Auxiliary Transformer) tapped from the bus ducts of each unit and alternative power supply from station auxiliary board located in machine hall cavern.

Two nos. of 18/11 kV, 6.3 MVA station service transformers will be installed in power house Bus-duct Galleries of Unit-1 & Unit-6 and incoming shall be tapped from IPBD between generator circuit breaker and generator transformer with disconnecting switches. These SATs shall feed power to 11 kV Station. Auxiliary Board located in machine hall cavern. Another 11 kV station Auxiliary Board shall be located in pothead yard which will receive outside 11 kV power from board. Both these SABs shall be inter connected through 11 kV cables to be laid in cable tunnel. Two (02) 11kV DG sets each of 2 MVA rating will be installed in pothead yard and shall feed power to UABs & other SSBs through SABs. 11/0.433 kV distribution transformers (Dry type) will be installed for supplying LT power requirements in different installations of the power house and Dams. The MV & LV power supply scheme and requirement of DG sets shall be modified, if found necessary during DPR stage.

7.6.2 DC Supply System

A 220 V DC system, with two sets of battery banks of 1800 AH rating will provide power for unit control and protection equipment, field flashing, emergency lighting of the power house and for emergency lube oil pumps for generator/turbine bearings etc. In addition to above, two sets of 220V DC systems of adequate ratings along with batteries shall be installed in control rooms of both Dams for control of gates etc. A 48V DC system of adequate rating shall be required for PLCC purpose in pothead yard.

7.6.3 Power, Control & Instrumentation cables and cable trays etc.

11 kV XLPE cables shall be used for connection from and to the 11 switchboards to the11/0.433kV Dry type distribution transformer to be installed at different load centers in power house and pothead yard.

1.1 kV Grade PVC insulated Aluminum Power Cables shall be used in the powerhouse, transformer cavern, pothead yard, TRT outfall & Dam complex for supplying power to various auxiliaries, while for control cables 1.1 kV Grade PVC insulated copper cables will be employed. The Instrumentation Cables including Fiber 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 with cable racks & supporting systems, Conduits etc. of adequate sizes as required for the installation of Cables will be included. All cables will be FRLS& HR type.

7.6.4 Illumination System

Illumination System Design shall be based on the principle of achievement of the desired illumination levels with minimum glare. The design shall result in the most energy-efficient and presentable illumination as per the latest International trends in underground Hydro Power Plants.

The Illumination System shall provide Lighting and Electric Power supply to all Plant areas, dam area, and access road to various locations of the project and pothead yard. In addition, it shall provide Lighting for selected areas during plant emergency conditions.

Suitable scheme/arrangement will be provided for Emergency Lighting during AC supply failure.

7.6.5 PLCC Equipment

PLCC system shall provide efficient sources and reliable information links to meat communication need of protection, voice and data including for SCADA system. It shall provide for distance protection and direct tripping for remote end breaker, signal transmission & speech communication between the powerhouse/substation and data communication to remote places through various frequency channels etc.

7.6.6 Communication & Surveillance System

A suitable communication and surveillance system shall be installed in the powerhouse complex to facilitate the communication and desired security in the powerhouse area. Communication system comprises of the public address system and EPBAX equipment. The surveillance system would comprise of access control system and CCTV system equipment including all spaces of Power House.

7.6.7 Electrical Equipment & Testing Laboratory

Portable Electrical Testing Equipment will be provided to carry out normal testing of Powerhouse equipment. Separate room will be proposed in the power house for Electrical Testing Laboratory for storage of portable equipment and to serve as a base for testing staff. All the testing equipment shall be PC compatible &of latest design.

7.6.8 Grounding MAT

The grounding mat of Copper or MS flat or steel rods, having suitable cross sectional area would be provided in power house complex comprising machine hall and transformer hall caverns, Bus Duct galleries, main access tunnel, tail race tunnel, cable tunnel, pothead yard areas etc. Suitable number of grounding risers would be provided in the machine hall & transformer hall caverns for connection to machinery equipment/ panels/ boards in various auxiliary bay floors, cable tunnel/interconnecting tunnels/ MAT/ GIS floor etc. Earthing of various electrical equipment shall be performed by using at least two earthling conductors/ risers. Separate provision would be made for earthing of various electronic equipments in the power house. All non-current carrying equipment shall also be grounded by using at least 2 earth conductors of adequate sizes which shall finally be connected to the grounding grid. The grounding system would be designed to minimize the touch & step potential within acceptable safe limits.

7.6.9 Construction Power

Construction power of 25 MVA (approx.) rating to be arranged by 3-phase 11 kV AC lines from nearest source.

7.7 Power Evacuation Arrangement

The Bhakra Pumped Storage Project located in Bilaspur district of Himachal Pradesh envisages utilization of the waters of the Gobind Sagar reservoir for peak power generation on a Pumped storage type development. The Project envisages an installation of 1500 MW (6x250 MW) capacity. Evacuation of this generated power or drawl of power for pumping water of Bhakra Pumped Storage Project needs Transmission lines between the pothead yard and 400kV Bhakra HEP Substation.

Power house drawings:

Sr. No.	Drawing No.	Title
1.	WAP/BHAKRA-PSP/03	Cross section of power House
2.	WAP/BHAKRA-PSP/04	Layout Plan of Machine Hall Floor and Transformer Hall Floor at EL.234.00 M.
3.	WAP/BHAKRA-PSP/05	L- Section of Power House.
4.	WAP/BHAKRA-PSP/06	Single Line Diagram

ANNEXURE 7.1

1. Consideration of Variable Speed Options

Following two options for configuration of the main units have been considered for basic design of the electromechanical equipment:

- Option 1: 6 Fixed speed units
- Option 2: 3 Fixed speed units + 3 variable speed units
- Option 3: 6 Variable speed units

2. General Description of Variable speed Machine

A conventional synchronous generator-motor for pumped storage power plant can operate only at a constant rated revolving speed determined by the number of rotor poles and the system frequency.

On the other hand, a variable speed pumped storage system enables revolving speed of the Generator-motor to be controlled within a defined range by adopting doubly- fed asynchronous system.

The generator motor and the excitation system used for the variable speed system is different from that used for the conventional pumped storage system because the variable speed Generator motor is excited by low-frequency alternating current for realizing the rotating field on the rotor. A variable speed pumped storage system has some advantages by continuously changing its revolving speed. It has also some disadvantages, mainly due to necessity of the equipment for AC excitation. These advantages and disadvantages are described below.

3. Advantages of variable speed system

- Regulating capability of pump input at pumping mode

The pump input of a conventional single speed pumped storage system is fixed to have the best pumping efficiency at each pumping head and cannot be adjusted intentionally. The pump input of a variable speed is nearly proportional with the cube of the revolving speed, therefore a variable speed pumped storage system can contribute to regulate the power system frequency by governor free operation at the pumping mode as well as the generating mode.

In addition, the pump input fluctuation at pump start can be reduced by lowering the synchronous speed, thus the influence on the power system can be minimized.

- Expansion of Operational Range at Generating Mode

The operational range at generating mode can be widened from 20% to 40% compared to the single speed pumped storage system by lowering the minimum output due to the improvement of the turbine efficiency at partial load. This advantage contributes to increase the frequency regulating range.

- Expansion of Head Operational Range

A single speed pumped storage system has some limitation in the operational head range due to the cavitations', vibration and other factors. A variable speed pumped storage system is operable in the wider head range by applying the most suitable revolving speed mitigating those bad effects. This advantage permits the larger water level variation in the upper and lower reservoirs, and this means the bigger storage energy is to be available, so it enables the longer operational hours of the plant.

- Improvement of Power System Stability

Rotor displacement angle can be easily controlled with the high–speed and the high accuracy, so it contributes for keeping the static stability of other connected synchronous generators. Moreover, in system disturbance, the adjustable speed machine can improve the transient stability with the rapid regulation of the excitation system.

4. Disadvantages of variable speed System

- Larger Installation Space for Variable Speed System

The AC excitation system for a variable speed generator-motor requires much larger installation space compared to the excitation system for an equivalent single speed generator-motor. Additionally, the installation and lifting height of a three-phase wound type rotor are generally higher than that of the equivalent salient type rotor due to the difference of the structure. For these reasons, the size of powerhouse adopting variable speed system is increased.

5. Purpose for Variable Speed Pumped Storage System for Bhakra PSP

Adopting of variable speed pumped storage system shall be considered if its advantages are necessary for the sound operation of the project and/or the power system or it is expected to bring benefit to the project.

In case of Bhakra PSP, the head ratio is coming out to be 1.62

it is assumed that the pump input regulating capability of the fixed speed pumped storage system is assumed to be utilized to compensate the frequency fluctuation of the power system caused by variation of the output from the solar photovoltaic power plants with rated output due to change of the weather condition during off-peak load in daytime.

6. Comparison and Consideration of Each Option

Contribution to Stability of Power System Frequency by Pumping Operation

The adjustable range of the pump input of a variable speed pumped storage system can be fully utilized to regulate the power system frequency. The maximum fluctuation of output from the solar PV plant caused by variations of the weather condition will be approximately 200 MW.

The actual frequency regulation of the power system will be conducted by not only Bhakra PSP but also some other power plants which are connected to the grid. In case of the frequency fluctuation caused by solar PV, it is supposed to be regulated mainly by governor free operation of the generators of those power plants and Bhakra PSP in pumping operation. Therefore, the adjustable range of the pump input have to cover 100% of the assumed power fluctuation and therefore, techno commercially option 1 with 6 x 250 MW fixed speed turbines seems to be enough for such purpose.

7. Other Differences

- Spare Parts and Pump-Turbine Model Test

In case of the option 2, both single speed machine and variable speed machine are installed in one power plant. That means the spare parts for both type will be necessary and the extra cost and the extra storage space for those spare parts will be required. Additionally, regarding the pump-turbine, the design and model testing for both type of turbine will be done separately.

- Black Start Capability

The black start of a variable speed machine is technically possible, but a large capacity emergency DG or another power supply system equivalent of the DG is necessary for the excitation power of the variable speed machine to realize the black start function.

8. Recommendation

The option 3 has higher capacity for regulating the power system frequency during pumping operation and it can more effectively contribute the stability of the power system as compared to the option 1.

Therefore, the Option 3 most cost effective and recommended for Bhakra PSP.

8. CONSTRUCTION PROGRAMME AND SCHEDULE

Chapter – 8

Construction Programme and Schedule

8.1 General

Construction of Bhakra Pumped Storage Scheme including erection of the six generating units is planned to be completed in a period of four years and six months excluding Pre-construction works of one year for creation of infrastructure facilities viz. additional Investigations, improvement of Road network and colonies.

Two shift working is considered economical for surface works. For underground works which do not follow normal pattern of shift working because of cyclic operations, three shift working with minimum 15 hrs. or upto completion of cycle operations/day has been considered. Opting 25 working days in a month, shift wise scheduled working hours annually are adopted as follows:

Single Shift Work = 25 x 10 x 6 hrs = 1500 hrs
Two Shift Work = 25 x 10x 11hrs = 2750 hrs } for Surface Works
Three Shift Work = 25x10 x 15 hrs = 3750 hrs

Three Shift Works = 25x10 x 18 hrs = 4500 hrs for Underground.

8.2 Main Components of the Project

8.2.1 Main Structure/ Components

The construction schedule has been detailed for major items of the following main structures/ components.

i. Civil Works

a) Upper Dam with Spillway
b) Power intake
c) Tailrace outlet structures
d) MAT and construction Adits
e) Headrace tunnel cum pressure shaft.
f) Draft Tube and Tailrace tunnel.
g) Switch yard and Cable Tunnel

h) Underground powerhouse and transformer cavern.

ii. Electrical Works

a) E.O.T. cranes

b) Supply and erection of T.G./Pumps sets 6 nos. 250 MW each

c) 400 kv G.I.S. and bays equipment

d) Main power transformers

e) Other auxiliary electro-mechanical equipment

iii. Hydraulic equipment

a) Intake gates

b) Tailrace Outlet gates

c) Draft Tube gates

8.2.2 Target Schedule

The total construction period is scheduled as follows.

Pre-construction Period : 1 year

Construction Period (Main Works) : 4+1/2 years

Total construction period : 5+1/2 years

The Programme is also exhibited in the form of a bar chart and is enclosed as **Annexure 8.1**.

8.3 Infrastructure Facilities

The Bhakra Pumped Storage Scheme is located in Una district of himachal as shown in the index map. The existing Gobind Sagar Reservoir has been proposed as an lower reservoir for this Pumped storage scheme. The present scheme is in between N - 31° 26’ 45”, E - 76° 25’ 54” and N - 31°27’ 37”, E - 76°25’ 40”. The altitude of the project area varies between 760m and 500 m. The tail water will be diverted through the tunnel to store water in the upper reservoir created by construction of an Concret gravity dam across small south northerly flowing nala that debouches into Gobind Sagar reservoir north of Rajpur village. The Gobind Sagar reservoir which will be the lower pool of the project is accessible with motor able road via MDR-31 and the tail pool site is near to Raipur village. For power house approach tunnel, a new road is to be developed.

The project is located near existing Bhakra Nangal Project about 7 to 10 km right of Bhakra dam. The nearest rail head is Nangal which is about 20 km from site. Raipur town is about 5 km from the existing Bhakra Project. The nearest airport is Chandighar International Airport located in Sahibzada Ajit Singh Nagar, Punjab which is about 120 km away from project site.

Construction of infrastructure works will be taken up in first years. Construction power may be obtained from the existing grid, but a new sub-station need to be developed. Construction/ improvement of project road and upgrading of existing road will be taken up immediately. The construction of office and residential buildings will be started in first year and be completed by second year. Construction of Project road shall be taken up first priority to complete within a year due to short length.

Following provision is being kept for construction of offices and residential building at various sites:

- Permanent Office Buildings
- Temporary Office Buildings
- Temporary Site Offices
- Permanent Residential Buildings
- Temporary Residential Buildings

The construction of project colony, residential and other Non-residential building will be taken up from first year and completed all within second year.

8.4 Lower Dam & Spillway (Existing)

A mammoth multipurpose project has been constructed on river satluj in north west India for irrigation and power generation. The river drops to 100 cumecs in cold weather and rises to a steady flow of about 1400 cumecs in June.

This project comprises 225.6 high concrete gravity dam with two power houses having an installed capacity of 1050MW which further has been increased to 1379 MW during course of time by modifying various units still there is proposal to increase the left bank power house capacity from 594 mw to 630 mw. The dam was finally constructed is a straight gravity concrete structure with a maximum height of 225.6m and utilises fully the power potential and water supplies available. This project has been constructed in stages. The dam was constructed in all respect in 1963, except grouting of the deep curtain although left power house was constructed in 1961 and the right side power house was constructed in 1968.

8.5 Upper Dam and Spillway

For care of the nala during construction, stage diversion method is being followed for upper reservoir, so that nala diversion will be treated sequentially following foundation excavation and embankment.

The foundation excavation for the Upper dam is proposed to be started in the 1st month of first year and will be spread over fourteen months upto 4th month of 2nd Year.

Construction of embankment in continuation with foundation treatment is to be started in the 1st month of 2nd year and will continue upto 4th month of 4th year.

Concreting in the spillway in continuation with foundation treatment is planned to be done in the 5th month of second year and completed in 1st month of 4th Year.

Foundation Excavation	**Bank Volume(Cum)**	**Concrete**	**Quantity Cum**
Common Excavation	166416	M:15	9676
Rock Excavation	122431	M:25	12304

8.6 Power Intake

Open Excavation for Intake will start from 1st month of 1st year as an independent activity. However, Concreting of Intake structure can only take place after completion of concrete Lining in 1st Phase of HRT from 3rd month of 4th year. The concreting of Intake may spread over eleven months from 3rd of 4th year to 1st month of 5th year respectively.

8.7 Headrace cum pressure shaft

Excavation of HRT from intake face will be taken up in the 10th month of first year after completing the open excavation of intake. The same will be completed in the 6th month of third year.

The excavation of vertical pressure shaft will be taken up simultaneously in the 10th month of first year after completing the adit excavation. The steel liners will be erected from 1st month of third year and completed in the 6th month of fourth year. The backfilling, grouting will be taken up simultaneously and completed in the 11th month of fourth year.

8.8 Tailrace Tunnel/ Outlet

Open Excavation of tailrace outlet will start from 1st month of year 2 which will be completed in 8th month and construction of Tailrace tunnel will be started in the 9th month of 1st year which will be completed in 12th month of 2nd year. The construction completed within 8th month of fourth year.

8.9 Underground Powerhouse/ Transformer Caverns

Access tunnel to power house will be done by 10th month of first year but the top construction adit will be completed in 12th month of first year and then the excavation of the power house cavern will be taken up in the 1st month of the second year and will be completed by 8th month of year 3. The concreting will be taken up in the 9th month of the third year and will take 18 months for completion.

8.10 Electro-Mechanical Works

Action for procurement of EOT cranes is proposed to be initiated in the 1st year itself. The entire process of inviting the tender, placing orders, manufacture, supply, erection and testing is planned to be carried out in the period of July of the 1st year to end of the 3rd year.

Pre-manufactured activities such as preparation of specifications, inviting and evaluation of tender etc. can be completed within the 1st year so that the supply orders are placed by the end of the 1st year. The model tests and approval to the supplier's drawings will require nine more months. Installation period for each pump/ turbine and generator/ motor has been considered as twenty nine months.

8.11 Impounding Schedule

Filling of reservoirs will be based on the following considerations: -

i) Filling would be started during the construction of embankment at the upper dam.

ii) Filling schedule would follow the embankment schedule of dam.

iii) Filling elevation would not be permitted to exceed the height of embankment anytime.

iv) Filling would be restricted to keep the elevation more than 5 m below the embankment during the construction period.

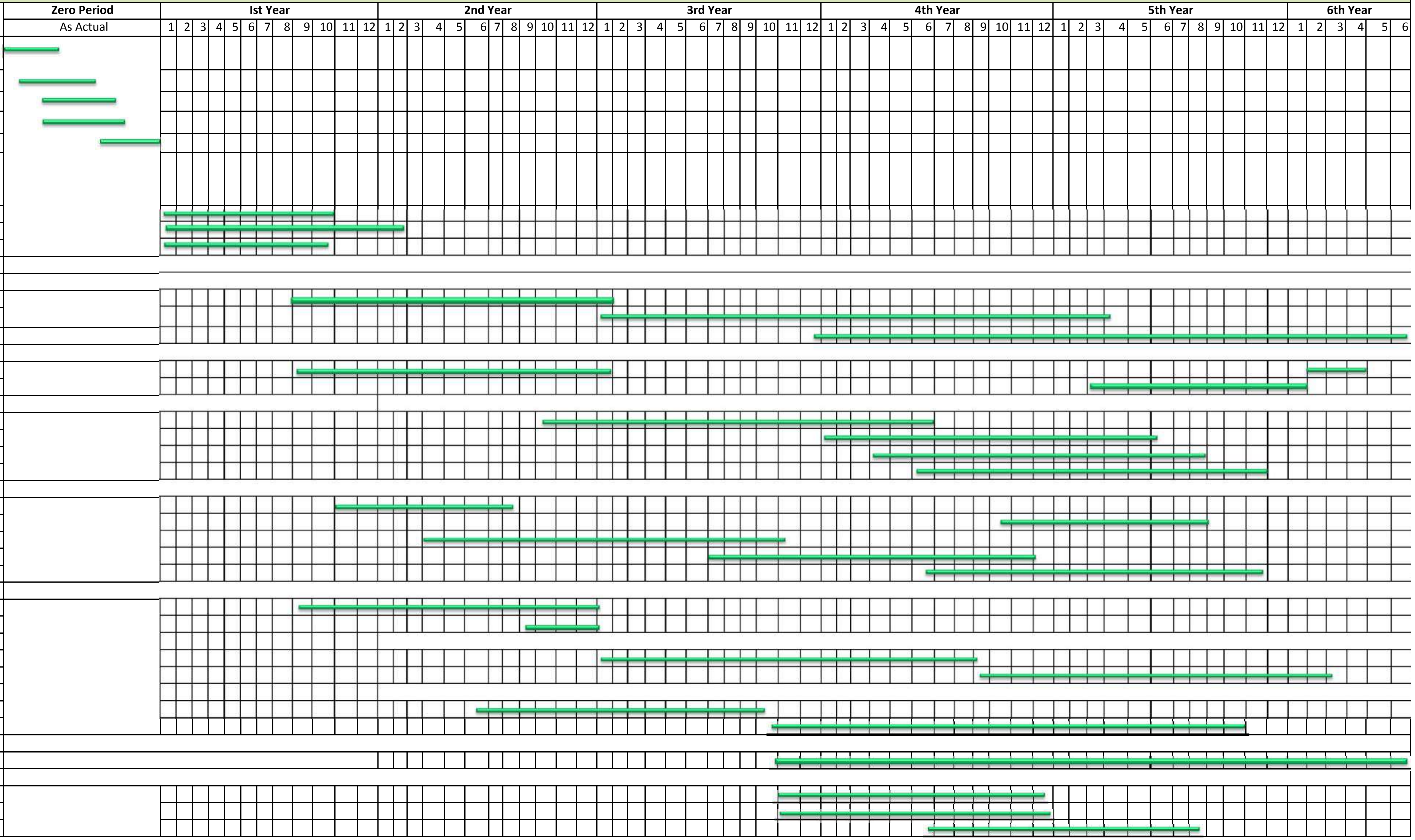
v) In case of exceeding the above clearance, extra water (including flood) would be flown to downstream by pumping or other ways.

Annexure-8.1

Bhakra Pumped Storage Project (6X 250MW)

Construction Program

Sl. No.	Activities
1	**PFR Clearance & Project Allotment**
2	**Preparation of DPR**
3	**TEC/CEA Approval**
4	**Statutory Clearances**
5	**Land Acquisitions**
6	**Pre- Construction planning & Infrastructural Development**
	Project Roads and Access to Project
	Colony Building Works
	Other Preparatory Works
7	**Upper dam**
	a. Main Dam
	Excavation
	Dam Concreting
	b. Impounding*
8	**a.Intake**
	Excavation
	Concreting
	b.Head race cum Pressure Shaft
	Excavation
	Erection of Steel Liners
	Backfill Concrete
	Grouting,Plugging and Finishing
	c. Tailrace Tunnel & Outlet
	Outlet Excavation
	Outlet Concreting
	Excavation TRT
	Concreting TRT
	Grouting TRT
9	**Power House Complex & Transformer Cavern**
	a. Access Tunnel to Powerhouse and Adit
	b. Cable Tunnel
	c. Power house Cavern
	Excavation
	Concreting
	d. Transformer Cavern
	Excavation
	Concreting
10	**Electro-mechanical Equip.**
	E&M including commissioning
11	**Hydro-mechanical Equip.**
	Intake Gates
	Tailrace Outer Gates
	Draft Tube Gates

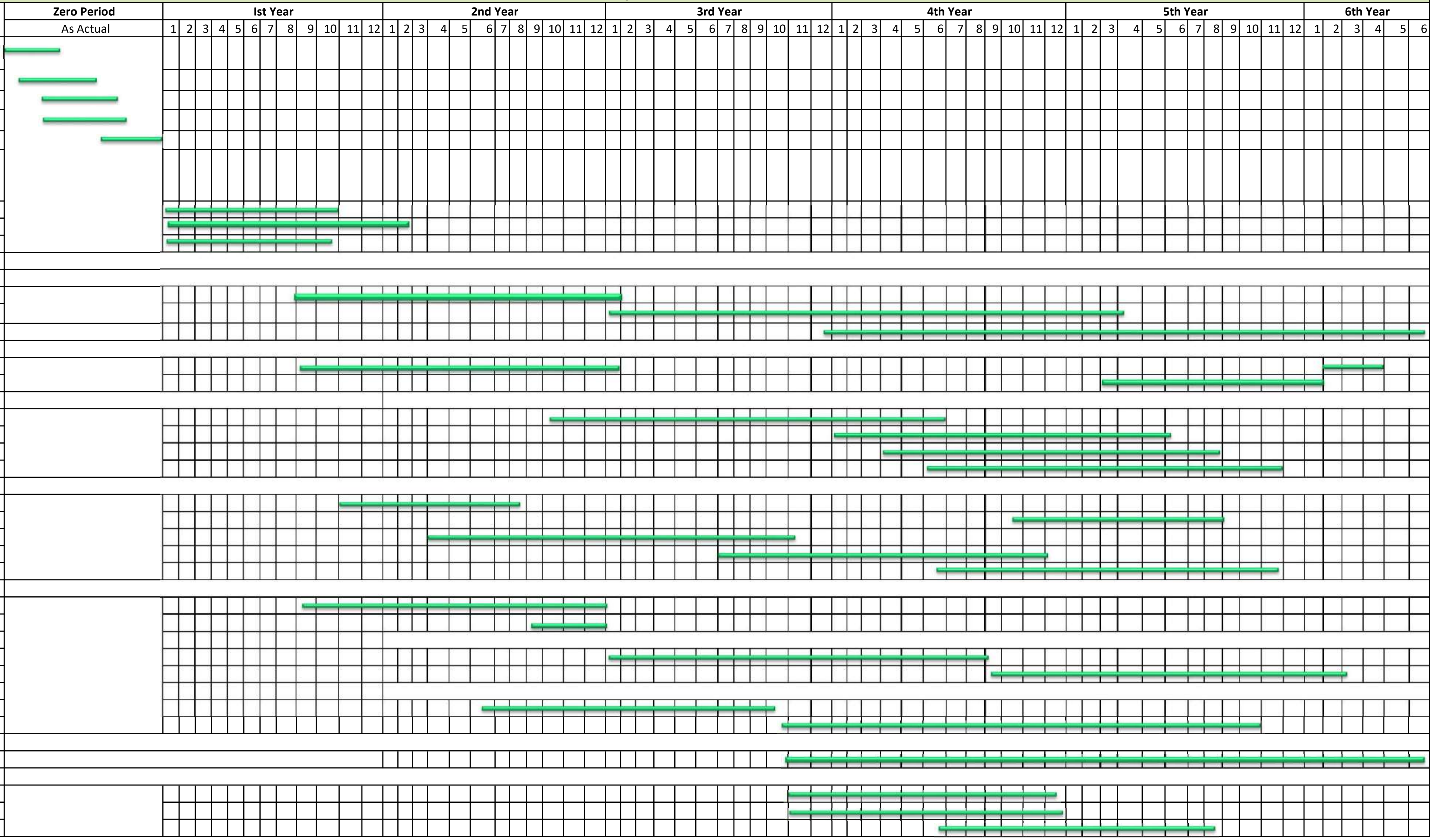


Annexure-8.1

Bhakra Pumped Storage Project (6X 250MW)

Construction Program

Sl. No.	Activities
1	**PFR Clearance & Project Allotment**
2	**Preparation of DPR**
3	**TEC/CEA Approval**
4	**Statutory Clearances**
5	**Land Acquisitions**
6	**Pre- Construction planning & Infrastructural Development**
	Project Roads and Access to Project
	Colony Building Works
	Other Preparatory Works
7	**Upper dam**
	a. Main Dam
	Excavation
	Dam Concreting
	b. Impounding*
8	**a.Intake**
	Excavation
	Concreting
	b.Head race cum Pressure Shaft
	Excavation
	Erection of Steel Liners
	Backfill Concrete
	Grouting,Plugging and Finishing
	c. Tailrace Tunnel & Outlet
	Outlet Excavation
	Outlet Concreting
	Excavation TRT
	Concreting TRT
	Grouting TRT
9	**Power House Complex & Transformer Cavern**
	a. Access Tunnel to Powerhouse and Adit
	b. Cable Tunnel
	c. Power house Cavern
	Excavation
	Concreting
	d. Transformer Cavern
	Excavation
	Concreting
10	**Electro-mechanical Equip.**
	E&M including commissioning
11	**Hydro-mechanical Equip.**
	Intake Gates
	Tailrace Outer Gates
	Draft Tube Gates



9. COST ESTIMATE

Chapter - 9

Cost Estimate

9.1 Project Cost

A summary of the cost estimate, including direct and indirect charges for the Civil & Electro-mechanical works at August, 2022 Price Level has been worked out as given below:

Item	Estimated Cost (Rs. Lacs)
Civil Works	324132
Electro-mechanical Works	326868.04
Total	651000.04

The estimate has been prepared to arrive at the capital cost of Bhakra Pumped Storage Project, Himachal. The estimate is of Pre-feasibility level and has been prepared on the basis of “Guide Lines for preparation of cost estimates for River Valley Projects” published by Central Water Commission, Govt. of India, New Delhi. The Abstract of Cost is enclosed at in the relevant chapter of this report. The above cost includes the cost of Transmission.

9.2 Basis of Estimate

The estimate for Civil, Hydro-mechanical civil works have been prepared on the basis of following:

I. The rates have been adopted by updation to current price level from the recently approved H.E. Projects having similar parameters and working conditions.
II. The rates of materials are inclusive of GST as applicable.
III. Interest and escalation during construction period not considered.

Quantity estimate have been carried out by calculating the quantities of different work items involved. Unit rate corresponding to major item of works have been worked out by analysis of rate based on prevailing market rates. Some rates of major item of works, lump sum provision have been made based on the other similar projects. The following guidelines have been referred for the preparation of this cost estimate:

1. "Guidelines for preparation of project estimates for River Valley Projects" dated March 1997 by Central Water Commission, Govt. of India.
2. "Guide Lines for preparation of Detailed Project Report of Irrigation and Multipurpose projects" 2010 by Central Water Commission, Govt. of India.

9.3 Classification of Civil Works Into Minor Head/Sub Heads

The cost has been classified into direct and indirect charges and covered under the following minor heads:

Direct Charges

I. Works
II. Establishment
III. Tools and Plants
IV. Receipts and Recoveries on Capital Account

Indirect Charges

I. Capitalized Value of Abatement of Land Revenue
II. Audit and Account Charges

9.4 Direct Charges

9.4.1 I -Works

Current Cost: Rs. 303401.0 Lacs

The minor head I-Works has been subdivided in to the following detailed subheads:

9.4.2 A-Preliminary

Current Cost: Rs. 5215.0 Lacs

Under this head provision has been made for surveys and investigations to be conducted at DPR stage and later to arrive at the optimum of the project components. Provision for in-house Design & Engineering and consultancy charges has been kept under this head as 2% of cost of C & J Works.

9.4.3 B-Land

Current Cost:Rs. 13038.0 Lacs

This covers the provision for acquisition of land/lease charges for construction of the project, structures, colonies, offices etc. and the provision for Rehabilitation and Resettlement (R&R) of Project Affected Persons.

9.4.4 C- Works

Current Cost: Rs. 183711.0 Lacs

This sub-head covers the cost of Dykes, Upper Dam and associated Hydro-mechanical equipments.

9.4.5 J- Power Plant Civil Works

Current Cost: Rs. 77058.0 Lacs

This covers the cost of Civil Works of Power Tunnel Intake structures, Head Race Tunnel, Pressure Shaft, Power House, Transformer Cavern & Tail Race Tunnel etc. along with associated Hydro-mechanical equipment.

9.4.6 K- Buildings

Current Cost: Rs. 10431.0 Lacs

A provision @ 4% of C-J Works has been made towards temporary and permanent buildings (both residential and non-residential) proposed to be built in colonies for various locations of the project area. The buildings included under the permanent category are all those buildings, which will be subsequently utilized during the state of running and maintenance of the project.

9.4.6.1 M- Plantation

Current Cost: Rs. 50.0 Lacs

The provision under this head includes cost of plantation in colonies, along approach roads, landscaping and improvements of area around powerhouse.

9.4.6.2 O- Miscellaneous

Current Cost: Rs. 5215.0 Lacs

Under this head provision is generally made to cover the cost of the following miscellaneous works:

a) Capital cost of electrification, water supply, sewage disposal, firefighting equipment etc.
b) Repair and maintenance of electrification water supply, sewage disposal, medical assistance, recreation, post office telephone office security arrangements, firefighting, inspection vehicles, schools, transport of labour etc.
c) Other services such as laboratory testing, R&M of Guest House and transit camps, Community center and photographic instruments as well as R&M charges etc.

As the estimate is of Pre-feasibility level, percentage provision @ 2% of C-J works has been considered towards head O- Miscellaneous.

9.4.7 P- Maintenance

Current Cost: Rs.2737.0 Lacs

For maintenance of buildings, roads and other structures during construction period, provision @ 1% of C-works, J-Power Plant civil works, K- buildings R- Communication have been kept.

9.4.8 Q- Special T&P

Current Cost: Rs. 1000.00 Lacs

It is assumed that the work will be carried through Contracts and accordingly nominal provision for procurement of necessary equipment for taking up the work at the earliest by the contractor have been made. The total expenditure towards this will be recovered from the contractors and the same is credited under receipt and recoveries.

Adequate provision is made for inspection vehicles and cost for resale of vehicles is accounted for under receipt and recoveries.

9.4.9 R-Communication

Current Cost: Rs. 2500.0 Lacs

Provision under this head covers the cost of construction of roads and bridges for project works. The provision is Lump sum only at this stage based on preliminary assessments as detailing shall be done later on.

9.4.10 X-Environment and Ecology

Current Cost: Rs. 1760.00 Lacs

Provision under this head covers Bio-diversity Conservation, Creation of green belt, Restoration of Construction Area, Catchment Area Treatment and Compensatory Afforestation etc.

9.4.11 Y-Losses on Stock

Current Cost: Rs.684 Lacs

The provision under this head have been made @ 0.25% of the cost of I-Works less A-Preliminary, B-Land, Q-Miscellaneous, M-Plantation, P-Maintenance, Q-Special T&P and Environment and Ecology.

9.4.12 II-Establishment

Current Cost: Rs. 17422.0 Lacs

Provision for establishment including establishment of cost control cell at the project and Head Quarter Level has been made as per “Guide lines for Preparation of Detailed Project Report of Irrigation and Multipurpose Project” by CWC @ 6% of I-Works less B-Land

9.4.12.1 III- Tools &Plants

Current Cost: Rs.200.00 Lacs

The 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 & plants.

9.4.13 IV-Receipt &Recoveries

Current Cost: Rs. 250.00 Lacs

The provision under this head cover the estimated recoveries by way of resale of temporary buildings, transfer of construction equipment, inspection vehicles, generators etc.

9.4.14 Indirect Charges

Current Cost: Rs.3360.0 Lacs

Provisions under this head have been made for capitalized value of abatement of land revenue. Besides, provision for Audit & Account Charges has been made at 1% of the cost of I-Works.

9.4.15 Electro-Mechanical Works

Current Cost: Rs. 326868.04 Lacs

The total cost of Electro-Mechanical works at January, 2021 level works out to be Rs. 326868.04 Lacs, which includes, the cost of main Electro-Mechanical equipment (excluded the transmission system) such as turbines, generators, transformers etc. based on the prevailing market prices in India and abroad. Suitable provision for transportation, erection and commissioning charges, freight and insurance etc. have been adequately made as per general guidelines issued by CEA. Provision for establishment and Audit and Account charges for the electro-mechanical works have also been made under this cost separately.

Annexure 9.1

BHAKARA PUMPED STORAGE PROJECT (1500 MW)		
GENERAL ABSTRACT OF COST		
Sl. No.	**DETAILED HEAD OF WORKS**	**Amount (Rs. Lacs)**
A	**CIVIL WORKS**	
1	**DIRECT CHARGES**	
	I-WORKS	
	A-Preliminary	5215
	B-Land	13038
	C-Works including HM Works	183711
	J-Power Plant Civil Works	77058
	K-Building	10431
	M-Plantation LS	50
	O-Miscellaneous	5215
	P-Maintenance during construction @1% of I Works	2737
	Q-Special T&P	1000
	R-Communication	2500
	X-Environment & Ecology	1760
	Y-Losses on Stock @0.25% of C,J,K & R	684
	Total of I-Works	**303401**
	II-ESTABLISHMENT @ 6% OF (I-WORKS LESS B LAND)	**17422**
	III-TOOLS & PLANTS LS	**200**
	IV-SUSPENSE	**0**
	V-RECEIPT & RECOVERIES (-)	**-250**
	Total of Direct Charges	**320772**
2	**Indirect Charges**	
	(a) Capitalised value of abatement of land revenue @ 5% of cost of culturable land	**326**
	(b) Audit & Account Charges (@ 1% of I-Works)	**3034**
	Total of Indirect Charges	**3360**
	Total Cost (Direct charges + Indirect Charges)	**324132**
	Total Cost Civil Works	**324132**
A	**Civil Works**	**324132**
B	**E&M Works**	**326868**
	Total Cost	**651000**

Abstract of Rates for Principal Construction Materials			
Sl. No.	**Description of item**	**Unit**	**Rate (At 2022 price level) in Rs.**
1	Loose or unconsidolated excavation other than trenches	cum	**261**
2	Material excavated from rocky ground through blasting	cum	**851**
3	Removal of Material arising from overbreak for surface work	cum	**370**
4	Concrete- M15	cum	**4403**
5	Concrete- M 20	cum	**5266**
8	Concrete- M25	cum	**5616**
9	Concrete-M30	cum	**6342**
10	Concrete- M35	cum	**6254**
13	Shotcrete Plain	cum	**12903**
14	Shotcrete with Steel Fibre	cum	**24228**
15	Fill material Rockfill (Backfill)	cum	**450**
16	Filter material (Gravel)	cum	**563**
17	Impervious Core Material (Clay)	cum	**1288**
18	Stone Pitching	cum	**1313**
21	Rock Bolting-25mm dia 1 to 6m long	m	**901**
23	Rock Bolting-25mm dia 4/5/6m long	m	**1001**
24	Rock Bolting-25mm dia 6m-9m long	m	**1088**
25	Drilling grout holes upto 5 m depth	m	**957**
26	Drilling grout holes more than 5 m depth	m	**1063**
27	Drainage hole	m	**1063**
28	Reinforcement (Mild steel round and tor steel)	MT	**81366**
29	ASTM-537 Gr. II Steel Liner for Penstock	MT	**185533**
30	ASTM-517 Gr. F Steel Liner for Penstock	MT	**348317**
31	Rock Excavation- Underground	cum	**2364**
32	Underground Excavation in Power House	cum	**2189**
33	Contact Grouting	MT	**18910**
34	Consolidation Grouting	MT	**18910**
35	PVC Rubber Water Stop	m	**538**
36	Wire Mesh 2"	sq.m	**425**
37	Fabrication & Erection - Steel supports	MT	**100254**
38	Shaft Excavation (Raise Borer)	cum	**2364**
41	Precast lagging	cum	**6854**
44	Crushed sand	cum	**1401**
46	Fabrication and Erection of Trash Rack	MT	**100254**
47	100 mm dia MS pipe	m	**1550**
48	Cement	MT	**6754**

A-PRELIMINARY					
Sl. No.	**Item**	**Quantity**	**Unit**	**Rate Rs.**	**Option-I**
1	Cost of surveys and investigation including geological investigation, hydrological investigation, preliminary construction materials surveys, access paths and roads etc. at PFR stage	LS @ 2% of the cost of C-J Works			5215.39
2	Topographical & other surveys for HRT, TRT & Powerhouse etc.				
3	Geological Investigation				
4	Drilling & Drifting				
5	Construction Material Survey				
6	Hydrologcal and meteorological observations				
7	Geophysical survey, seimological study				
8	Hydraulic model studies				
9	Charges for prelimanary consultancy & specialists				
10	Training of Engineers during Investigation				
11	Instuments and equipments for S & I works				
12	Stationary, writing of completion report & history of project				
					5215.39

DAM AND APPURTENANT WORKS
I-WORKS

C-WORKS & HM WORKS

ABSTRACT OF COST

Sr. No.	Item	Amount (Rs. Lacs)
1	Lower Dam	182195
3	HM Works	1516
	Total for Civil & HM Works	**183711**
	Say	**183711**

J-WORKS

ABSTRACT OF COST

Sr. No.	Item	Amount (Rs. Lacs)
1	Intake	9523
2	Intake Gate Shaft (Underground)	434
3	HRT	18897
4	Pressure Shaft	5466
5	Main Access Tunnel	1706
6	Power House	20101
7	Transformer hall	2791
8	Draft Tube	3615
9	Adit Power House	3491
10	Tail race tunnels	4457
12	Tail Race Gate Shaft	571
13	Otlet	6004
	Total Cost of J-Works	**77058**
	Say	**77058**

DAM AND APPURTENANT WORKS

Upper DAM

Sl. No.	Items Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	**Site Clearance**	LS			30.00
2	**Open Excavation (Soil)**	356951	cum	261	933.14
3	**Open Excavation (Rock)**	214170	cum	851	1821.64
4	**Drilling holes for consolidation grouting**	23436	RM	957	224.26
5	**Drilling holes for curtain grouting**	46872	RM	1063	498.34
6	**Cement for consolidation grouting**	9374	MT	18910	1772.70
7	**Cement for curtain grouting**	93745	MT	18910	17726.99
8	**DRILLING FOR Drainage holes(75mm)**	3281	RM	1063	34.88
9	**M:15**	183226	cum	4403	8067.22
10	**M:25**	1832259	cum	5616	102902.92
11	**Reinforcement**	54968	MT	81366	44724.96
12	**Rockbolt slope stabiliztion**	11249	RM	901	101.31
13	**Shortcrete**	25311	cum	12903	3266.00
14	**100mm dia. M S Pipe**	2625	RM	1550	40.68
15	**Measuring instruments**	LS			30.00
16	**Dewatering**	LS			20.00
					182195.05
				Say	**182195**

BHAKARA Pumped Storage Project (1500 MW)									
Hydro Mechanical Cost									
Sl. No	Estimated quantities:								
	Description	Nos	Width	Height	Des. head	Unit Wt.	Total wt.	Rate /t. (Rs)	Amount (Rs. In Lakh.)
			(m)	(m)	(m)	t	t.		
1	**Power Intake (Upper Reservoir)**								
i.	**Intake gates**								
	Gate leaf	1	6.18	7	39.91	40	40	**243906**	**97.5624**
	Embedded parts	1				20	20	**243906**	**48.7812**
	Hoist machinary	1				12	12	**268922**	**32.27064**
	Hoist Support structure	1				16	16	**212636**	**34.02176**
ii.	**Intake Auxiliary gates**								
	Gate leaf	1	6.18	7	39.91	40	40	**243906**	**97.5624**
	Embedded parts	1				20	20	**243906**	**48.7812**
	Hoist machinary	1				9	9	**268922**	**24.20298**
	Hoist Support structure	1				16	16	**212636**	**34.02176**
iii.	Liner for Inkake gates	1				20	20	**212636**	**34**
2	**Draft Tube gates**								
	Gate leaf	6	5.56	5.56	51.5	30	180	**243906**	**117**
	Embedded parts	6				33	198	**243906**	**128.7**
	Hydraulic Hoist	6				LS*		**8755600**	**140**
	Liner for gates	6				20	120	**212636**	**68**
3	**Tail Race gates (Lower Reservoir)**								
i	**Tail Race Service gates**								
	Gate leaf	1	7.44	9.45	28	70	70	**243906**	**136.5**
	Embedded parts	1				18	18	**243906**	**35.1**
	Hoist machinary	1				18	18	**268922**	**38.7**
	Hoist Support structure	1				19	19	**212636**	**32.3**
ii	**Tail Race Emergency gates**								
	Gate leaf	1	7.44	9.45	28	70	70	**243906**	**136.5**
	Embedded parts	1				18	18	**243906**	**35.1**
	Hoist machinary	1				18	18	**268922**	**38.7**
	Hoist Support structure	1				19	19	**212636**	**32.3**
	Liner for gates	1				25	25	**212636**	**42.5**
6	**MISCELLANEOUS**								
i)	Instrumentation				**1**	**LS***		**6254000**	**50**
ii)	D.G Set				**2**	**LS***		**1876200**	**30**
iii)	Model studies for groove shape, lip shape,air requirement etc. for				**1**	**LS***		**243906**	**2.43906**
		Total Quantity in t. =					**966**	**t**	**1515.0434**
		say					**970**	**t**	**1516**

Total estimated cost for gates = 15.16 crore

INTAKE					
SI No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Lakh)**
1	Cleaning, Grubbing & Stripping	58388	m2	17	10
2	Excavation- Soil	87373	cum	261	228
3	Excavation- Rock	559835	cum	851	4762
4	Banking	18474	cum	851	157
5	Mass concreting- M20	1396	cum	5266	74
6	Intake Structure - (M25)	21170	cum	5616	1189
7	Block out Concrete (M30)	100	cum	6342	6
8	Concreting in Channel (PCC)	2611	cum	4403	115
9	Reinforcement	1694	MT	81366	1378
10	Stone Pitching	4200	cum	1313	55
11	Rock Bolt and Anchor Bolt	78684	m	1326	1043
12	Shortcrete (t=10cm, Wiremesh)	2951	cum	12903	381
13	Trashrack (MT)	125	MT	100254	125
	Total				9523
				Say	**9523**

INTAKE GATE SHAFT

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Lakh)
1	Open Excavation- soil	251	cum	261	0.66
2	Open Excavation- Rock	585	cum	851	4.98
3	Shaft Excavation- Rock	2343	cum	2364	55.39
4	Non-Core Drilling for Consolidation Grouting	3712	m	957	35.51
5	Grouting Material (Cement)	186	MT	6754	12.55
6	Lining Concrete (M20)	1643	cum	5266	86.51
7	Blockout Concrete (M35)	68	cum	6254	4.25
8	Reinforcing Steel	164	MT	81366	133.67
9	Waterstop	283	m	538	1.52
10	Shotcrete (t=10cm, Wire Mesh)	215	cum	12903	27.78
11	Rockbolt (L=3.0m)	6289	m	901	56.64
13	Other Works		LS		15.00
				Total	434.45
				Say	434

HRT (11.5 m, Length- 350 m)

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Lakh)
1	Underground excavation	117990	cum	2364.05	2789.33
2	Provision of overbreak	7536	cum	2364.05	178.16
3	Open Excavation	1966	cum	850.56	16.73
4	Steel 537	3889	MT	185532.75	7215.91
5	Steel 517	1550	MT	348316.85	5400.43
6	RCC M:25	109	cum	5616.18	6.15
7	Backfilling Concrete M:20	30155	cum	5265.95	1587.95
8	Concrete in lagging	705	cum	4402.88	31.03
9	Reinforcement	143	MT	81365.78	116.50
10	Drilling in hard rock for grout holes	22439	m	1063.20	238.57
11	Pressure grouting with cement (contact)	48	MT	18909.88	9.09
12	Pressure grouting with cement (cons.)	1074	MT	18909.88	203.13
13	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	240	MT	100254.40	240.96
14	Rock bolting 25-mm dia, 5m long	35903	m	900.59	323.34
15	Shotcreting in tunnel	2485	cum	12903.45	320.71
16	Drainage holes	14355	m	1063.20	152.63
17	Providing and laying 4 inch dia G.I. pipe	2626	m	1549.76	40.69
18	Water stoppers	157	m	537.85	0.85
19	Other Works	LS			25.00
	Total				18897.15
				Say	**18897**

Pressure shaft (4.5m, 100m including Bifurcation)

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	Underground excavation	5852.98	cum	2364.05	138.37
2	Provision of overbreak	292.28	cum	2364.05	6.91
3	Backfilling Concrete	2553.83	cum	4402.88	112.44
4	Steel 517	1451.78	MT	348316.85	5056.79
5	Drilling in hard rock for grout holes	1519.87	m	956.88	14.54
6	Pressure grouting with cement (contact)	5.85	MT	18909.88	1.11
7	Pressure grouting with cement (cons.)	70.15	MT	18909.88	13.26
8	Concrete in lagging	62.11	cum	4402.88	2.73
9	Reinforcement in lagging	7.31	MT	81365.78	5.95
10	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	21.92	MT	100254.40	21.98
11	Rock bolting 25-mm dia, 5m long	2899.09	m	900.59	26.11
12	Shotcreting in tunnel	211.91	cum	12903.45	27.34
13	Drainage holes	818.39	m	1063.20	8.70
14	Providing and laying 4 inch dia G.I. pipe for control cables	321.51	m	1549.76	4.98
	Other Works	LS			25.00
	Total				5466.22
				Say	**5466**

MAIN ACCESS TUNNEL(8 x 8.5m, Length-600m)					
SI No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Rs. Lacs)**
1	Cleaning, grubbing and stripping.	LS			5.00
2	Underground excavation including 10% Overbreak	44352	cum	2364	1048.50
3	Open Excavation(Soil)	381	cum	261	1.00
4	Open Excavation (Rock)	890	cum	850.56	7.57
5	PCC - M15	1152	cum	4403	50.72
6	RCC- M25	44	cum	5616	2.44
7	Concrete in lagging	450	cum	4403	19.83
8	Reinforcement	62	MT	81366	50.57
9	Backfill concrete in poor rock	299	m	4403	13.18
10	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	120	MT	100254	120.08
11	Rock bolting 25-mm dia, 5m long	8812	m	901	79.36
12	shotcreting in tunnel	2034	cum	12903	262.44
13	Drainage holes	963	m	1063	10.24
14	Providing and laying 4 inch dia G.I. pipe for control cables	963	m	1550	14.93
15	Miscellaneous such as additional support measures, dewatering etc.	LS			20.00
				Total	**1705.86**
	G. Total				**1706**

Power House

Sr. No.	DESCRIPTION OF ITEMS	QUANTITY	UNIT	Rate Rs.	Amount (Rs. Lacs)
1	Excavation	**284098**	**cum**	**2189**	**6218.71**
2	Provision for overbreak	**13291**	**cum**	**2189**	**290.92**
3	Shotcrete (machine hall)	**3681**	**cum**	**24228**	**891.77**
4	Rockbolts	**198948**	**m**	**1088**	**2164.98**
5	Mass concreting (M15)	**54197**	**m**	**4403**	**2386.24**
6	Concreting in columns, beams, slabs, lift, wells (M25)	**6174**	**cum**	**5616**	**346.75**
7	Steel reinforcement	**9478**	**cum**	**81366**	**7712.11**
21	**Measuring Instruments**	**L.S**			**30**
22	**Other Works**	**L.S**			**60**
	Total				**20101.49**
	Say				**20101**

Transformer Cavern					
Sr. No.	DESCRIPTION OF ITEMS	QUANTITY	UNIT	Rate Rs.	Amount (Rs. Lacs)
1	Excavation	61524	cum	2189	1346.73
2	Provision for overbreak	6152	cum	2189	134.67
3	Shotcrete	1037	cum	12903	133.81
4	Rockbolts	59671	cum	1088	649.34
5	Concreting in columns, beams, slabs, lift, wells	2701	cum	5616	151.70
6	Steel reinforcement	424	cum	81366	345.05
7	Other Works	LS			30
	Total				2791.30
	Say				2791

Draft Tube (5.56m, 90m)

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs.Lacs)
1	Underground excavation	7919.45	cum	2188.93	173.35
2	Provision of overbreak	397.38	cum	2188.93	8.70
3	Concrete in lagging	81.81	cum	4402.88	3.60
4	Reinforcement in lagging	11.69	MT	81365.78	9.51
5	Supply and erection of steel supports ISMB 200 @650mm c/c	28.05	MT	100254.40	28.12
6	Steel 537	1661.83	MT	185532.75	3083.24
7	Backfill Concrete M20	3445.48	cum	5265.95	181.44
8	Drilling in hard rock for grout holes	2010.25	m	956.88	19.24
9	Pressure grouting with cement (contact)	7.71	MT	18909.88	1.46
10	Pressure grouting with cement (cons.)	92.57	MT	18909.88	17.50
11	Rock bolting 25-mm dia, 5m long	3903.63	m	1000.66	39.06
12	Shotcreting in tunnel	292.19	cum	12903.45	37.70
13	Drainage holes	1112.65	m	1063.20	11.83
14	Providing and laying 4 inch dia G.I. pipe	432.44	m	1549.76	6.70
	Total				3614.75
	G.Total				**3615**

Adits & Cable Tunnels and switch yard					
Sl No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Rs. Lacs)**
1	Underground excavation	60035	cum	2189	1314.13
2	Provision of overbreak	6003	cum	2189	131.40
3	Open Excavation	2250	cum	851	19.14
4	PCC-M15 for invert concrete	673	cum	4403	29.63
5	RCC-M25 for pedestal and supporting structures for cable tray	250	cum	5616	14.04
6	Concrete in lagging	815	cum	4403	35.88
7	Reinforcement in lagging	103	cum	81366	83.81
8	Backfill concrete in poor rock	540	m	4403	23.78
9	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	216	mt	100254	216.55
10	Rock bolting 25-mm dia, 5m long	24681	m	1001	246.97
11	shotcreting in tunnel	3657	cum	12903	471.88
12	Drainage holes (75mm)	1687	m	1063	17.94
13	Providing and laying 4 inch dia G.I. pipe for control cables	1687	m	1550	26.14
14	switch yard cost for civil works				860.00
	Total				3491.28
	G. Total				**3491**

A) TAIL RACE TUNNEL(Dia-11.5m, Length-600m)					
Sl No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Rs. Lacs)**
1	Underground excavation	82109	cum	2364	1941.09
2	provision of overbreak	8210	cum	2364	194.09
4	Concrete lining (RCC)	16332	cum	5266	860.01
5	Reinforcement	301	MT	81366	244.51
6	Concrete in lagging	512	cum	4403	22.56
7	reinforcement in lagging	53	MT	81366	42.88
8	backfill concrete in poor rock	8034	m	4403	353.73
10	Drilling in hard rock for grout holes	10219	m	1063	108.65
11	Pressure grouting with cement (contact)	16	MT	18910	3.12
12	Pressure grouting with cement (cons.)	494	MT	18910	93.51
13	Supply and erection of steel supports ISMB 200 @750c/c and 500 c/c	150	MT	100254	150.63
14	Rock bolting 25-mm dia, 5m long	20517	m	1001	205.31
15	shotcreting in tunnel	1422	cum	12903	183.54
16	Drilling for Drainage holes	751	m	1063	7.99
17	Providing and laying 4 inch dia G.I. pipe for control cables	1764	m	1550	27.33
18	Water Stopper	718	m	441	3.16
19	Other work	LS			15.00
	Total				4457.12
	Say				**4457**

TAIL RACE GATE SHAFT					
SI No.	**Item Details**	**Quantity**	**Unit**	**Rate Rs.**	**Amount (Lakh)**
1	Open Excavation- soil	306	cum	261	1
2	Open Excavation- Rock	714	cum	851	6
3	Shaft Excavation- Rock	2858	cum	2364	68
4	Non-Core Drilling for Consolidation Grouting	4528	m	1063	48
5	Grouting Material (Cement)	227	MT	6754	15
6	Lining Concrete (M20)	2004	cum	5266	106
7	Blockout Concrete (M35)	83	cum	6254	5
8	Reinforcing Steel	200	MT	81366	163
9	Waterstop	346	m	538	2
10	Shotcrete (t=10cm, Wire Mesh)	263	cum	24228	64
11	Rockbolt (L=3.0m)	7672	m	901	69
13	Other Works	LS			25
				Total	571.23
				Say	571

B) TRT Outlet

Sl No.	Item Details	Quantity	Unit	Rate Rs.	Amount (Rs. Lacs)
1	Cleaning, Grubbing & Stripping	LS	m2	LS	5.00
2	Excavation- soil	54980.10	cum	261.42	143.73
3	Excavation - Rock	219920.40	cum	851	1870.55
4	Outlet Structural Concrete (M25)	22680.00	cum	5616	1273.75
5	Banking	19717.79	cum	851	167.71
6	Concreting in Channel (PCC)	997.50	cum	4403	43.92
7	Reinforcement	1808.10	MT	81366	1471.17
8	Stone Pitching	4484	cum	1313	58.88
9	Rock Bolt and Anchor Bolt	41990	m	1088	456.94
9	Shortcrete (t=10cm, Wiremesh)	1575	cum	24228	381.60
10	Trashrack (MT)	115.50	MT	100254	115.79
11	other works		LS		15.00
	Total				6004.04
	G. Total				**6004**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh

ABSTRACT OF COST ESTIMATES OF E&M WORKS

Sl.No	Item	Amount for Power House (6x250MW) (Rs. Lakhs)
1	**Preliminary (cost of consultancy & model tests)- Annexure S(I)**	3800.00
2	**Generating Plant and Equipment**	
a)	Motor-Generator, Pump-Turbine and accessories- Annexure S(II)	205108.90
b)	Auxiliary electrical equipment for power station - Annex S(III)	28273.83
c)	Auxiliary mechanical equipment and services for power station - Annex S(IV)	13693.62
d)	Custom Duty (as applicable) on 2(a), (b) & (c)	0.00
e)	Transportation,handling and Insurance charges @ 6% of 2(a),(b) & (c)	14824.58
f)	Erection and commissioning charges @ 8 % of 2(a),(b) & (c), excluding spares	18925.35
	Sub-Total (Generating Plant and Equipment)	**280826.28**
3	**Switchyard and Pothead yard Equipment & Service**	
a)	Substation equipment, auxiliary equipment and service of switchyard - Annex S(V)	5450.42
b)	Custom Duty on 3(a)	0.00
c)	Transportation, handling and insurance charges @ 6% of 3(a)	327.03
d)	Erection and commissioning charges @ 8% of 3(a), excluding spares	435.18
	Sub-Total (Substation equipment and auxiliary equipment and service of Switchyard)	**6212.63**
4	**420 kV GIS and XLPE Cable**	
a)	420 KV GIS - **Annex S(VI)**	17811.20
b)	Custom Duty on 4 (a)	0.00
c)	Transportation, handling and insurance charges @ 6% of 3(a)	1068.67
d)	Erection & Commissioning charges @ 8% of 4(a) excluding spares	1389.57
	Sub-Total (GIS)	**20269.44**
5	Contingencies @ 1% in items 2, 3 & 4	3073.08
6	Tools & Plants @ 0.5% of 2, 3 & 4	1536.54
7	**Sub-Total (Item 1 to 6)**	**315717.97**
8	Establishment	10360.77
9	**Sub-Total (Item 7 & 8)**	**326078.74**
10	Audit and account charges @ 0.25% on item 7	789.29
11	Service Tax on item 1, 2(f), 2(g), 3 (c), 3(d), 4 (c) & 4(d)	0.00
12	**TOTAL (in Lakh Rs.)**	**326868.04**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Preliminary Works)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
1	Design and Consultancy Charges	LS	3500.00	3500.00	0.00	0.00	3500.00
2	Model test for Pump-Turbine	LS	1000	1000.00	0.00	0.00	1000.00
3	**Total**			**4500.00**			**4500.00**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh
DETAILED ESTIMATES FOR E&M EQUIPMENTS
(Motor-Generator, Pump-Turbine and Accessories)

(Rs in lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1 a)	Generating units of 250 MW rated output comprising of Reversible Vertical Francis Pump-Turbine with rated speed of 214.29 rpm operating under a generation rated head of 241.00 m and pumping rated head of 245.82 m and 18 kV, 0.85 pf motor-generators complete with assoicated equipment such as spherical type MIVs, Governor,AVRs & excitation equipment, water sprinkler fire protection for generators, unit auxiliaries.	6	10400	156000.00	18.00	28080.00	184080.00
			Rs per kW				
c)	Unit control boards	included in (a) above.					
d)	Cooling water system comprising pump sets, valves, piping etc.	included in (a) above.					
e)	Drainage and dewatering systems	included in (a) above.					
f)	LP & HP compressed air system incl. pipes, valves	included in (a)) above.					
g)	Spares @ 5% on item-1a to 1f (incl. one spare runner)			7800	18.00	1404	9204
	Sub Total			163800.00		29484.00	193284.00
2	14000A, 24kV phase Bus Duct for GT connections including starting bus arrangement	6	75	450.00	18.00	81.00	531.00
3	Surge protection & VT cubicles with CTs, PTs, Surge absorber, CBs, fuses etc., Neutral grounding cubicles with grounding transformer resistor	included in item 2 above					
4	Supervisory control and Data acquisition system	LS		1500.00	18.00	270.00	1770.00
5	Unit Control and protection system	6	70	420.00	18.00	75.60	495.60
6	Lubricating oil & Governor oil for first filling	included in 2 (a), 2(b) & 2(c)					
7	18 kV Generator Circuit Breaker & Phase reversing DS	6	680	4080.00	18.00	734.40	4814.40
8	Static Frequency Convertor	1	3500	3500	18.00	630.00	4130.00
9	Spares @ 3% of item 2 to 7			71.10	18.00	12.80	83.90
10	**Total**			**166241.10**		**29923.40**	**205108.90**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh
Auxiliary Electrical Equipment & services for Power Station

(Rs in Lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1	Step up transformers including oil for 1st Filling (324 MVA, 18/420/√3kV, Single phase)	7	2035.5	15388.38	18.00	2769.91	18158.29
			Rs per kva				
2	Unit Auxiliary transformers 3φ, 18/0.415kV, 1200 kVA Dry type	6	1200	86.40	18.00	15.55	101.95
			Rs per kva				
3	Station auxiliary transformer (SAT) 3φ, 18/11kV, 8000 kVA dry type	2	1500	240.00	18.00	43.20	283.20
			Rs per kva				
4(a)	Station Service transformers 11/ 0.415kV, 2000 kVA dry type	6	1200	144.00	18.00	25.92	169.92
			Rs per kva				
4(b)	Station Service transformers 11/ 0.415kV, 3000 kVA dry type	2	1200	72.00	18.00	12.96	84.96
			Rs per kva				
4(c)	Station Service transformers 11/ 0.415kV, 1000 kVA dry type	2	1200	24.00	18.00	4.32	28.32
			Rs per kva				
4(d)	Station Service transformers 11/ 0.415kV, 400 kVA dry type	4	1200	19.20	18.00	3.46	22.66
			Rs per kva				
5 €	Shunt Reactor, 125 MVAR	1	800	864.00	18.00	155.52	1019.52
6	HT/LT AC Switchgear for aux. Power supply to PH and outdoor switchyard.	LS		1500.00	18.00	270.00	1770.00
7	220V, 2000 MAh batteries, battery chargers, DC distribution board with DC switchgear	2 Sets	200	400.00	18.00	72.00	472.00
8 (a)	DG set (11kV,2000kVA)	2 Sets	100	200.00	18.00	36.00	236.00
8 (b)	DG set (0.415kV,630kVA)	1	25	25.00	18.00	4.50	29.50
9	Control and power cables	LS		1000.00	18.00	180.00	1180.00
10	Cable racks & accessories	LS		150.00	18.00	27.00	177.00
11	CCTV, Survelliance System & Telecommunication Equipments			150.00	18.00	27.00	177.00
12	Ground system for power house, Transformer yard & switchyard & Dam	LS		1000.00	18.00	180.00	1180.00
13	Illumination of power house & switchyard & Dam site	LS		1500.00	18.00	270.00	1770.00
14	Electrical workshop & testing equipment	LS		500.00	18.00	90.00	590.00
15	**Sub Total (Iteam 1 to14)**			**23262.98**			**27450.32**
16	Spares @ 3% (Iteam 15)			697.89	18.00	125.62	823.51
17	**Total**			**23960.87**		**4312.96**	**28273.83**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh
Auxiliary Mechanical Equipment & Services for Power Station

(Rs in Lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1 a)	Electrically operated Overhead travelling crane for PH (capacity 300/50/10T)	2	715.00	1430.00	18.00	257.40	1687.40
2 a)	Electrically operated Overhead travelling crane for PH (capacity 300/50/10T)	3	715.00	2145.00	19.00	407.55	2552.55
b)	Electrically operated Overhead travelling crane for Draft Tube Gates (50T)	1	250.00	250.00	20.00	50.00	300.00
c)	Electrically operated Overhead travelling crane for GIS (10T)	1	40.00	40.00	18.00	7.20	47.20
2	Electric lifts and elevators	2	40.00	80.00	18.00	14.40	94.40
3	Fire protection system with storage tanks, pupms, pipes valves etc.	LS		3000.00	18.00	540.00	3540.00
4	Air conditioinig , venilation and heating equipments	LS		3000.00	18.00	540.00	3540.00
5	Oil handling system with pipes, valves, tanks & purifiers	LS		300.00	18.00	54.00	354.00
6	Portable water supply system for power house	LS		300.00	18.00	54.00	354.00
7	Mechnical workshop equipment	LS		700.00	18.00	126.00	826.00
8	**Sub Total (Item 1 to 7)**			**11245.00**	**0.00**	**2050.55**	**13295.55**
9	**Spares @ 3% (Iteam 1 to 7)**			337.35	18.00	60.72	398.07
10	**Total**			**11582.35**		**2111.27**	**13693.62**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh
(400 kV Pothead yard Equipments)

(Rs in Lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1	**420 kV Pothead yard Equipments**						
a)	Lightning arrestors	12	5.00	60.00	18.00	10.80	70.80
b)	Capacitance voltage transformers	12	5.00	60.00	18.00	10.80	70.80
c)	Wave Traps	12	15.00	180.00	18.00	32.40	212.40
d)	Current Transformer	12	10.00	120.00	18.00	21.60	141.60
e)	Disconnector	12	20.00	240.00	18.00	43.20	283.20
3	Gantry,Foundation for structures & Miscllaneous civil works for other equipment like sheild wire, lightning mast etc.	LS	350.00	350.00	18.00	63.00	413.00
4	Protection	LS	3000.00	3000.00	18.00	540.00	3540.00
5	PLCC	LS	600.00	600.00	18.00	108.00	708.00
4	**Sub Total (1 to 5)**			**4610.00**		**829.80**	**5439.80**
5	Spares for Item (1) @ 3%			9.00	18.00	1.62	10.62
6	**Total**			**4619.00**		**831.42**	**5450.42**

Bhakra Pumped Storage Project (6X250 MW), Himachal Pradesh
(400 KV GIS, Equipments and XLPE Cable)

(Rs in lakhs)

Sl. No	Item Particulars	Qty.	Rate	Amt.	GST		Total
					Rate %	Amount	
1	420 kV GIS with double bus arrangment comprising of 8 transformer bays, 1 bus coupler bay, 2 nos. of VT bays & 4 line bays.	15	600.00	9000.00	18.00	1620.00	10620.00
2	400 kV XLPE Cable, 1600 sqmm including associated auxilliaries and support structures	10400	0.55	5720.00	18.00	1029.60	6749.60
3	Spares for above @ 3%			441.60		0.00	441.60
4	**Total**			15161.60		2649.60	17811.20

10. ECONOMIC EVALUATION

Chapter – 10

Economic Evaluation

10.1 General

The economic and financial evaluation of the Bhakra Pumped Storage Project, Himachal Pradesh 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 projects have been kept in view in this regard.

10.2 Project Benefits

The scheme would afford on annual peaking period energy generation of 2699.18 GWh annually. For assessing the tariff, design energy generation of 2564.22 GWh, calculated with 95% capacity availability in a normal dependable year, has been adopted. The project would provide 1500 MW of 5 hours daily peaking capacity benefits.

10.3 Capital Cost

The project cost has been estimated at **6510.00 Crores** without IDC at PL Nov 2022. The breakup of cost is as follows:

- Cost of Civil Works - **3241.32 Crores**
- Cost of E&M Works - **3268.68 Crores**

10.4 Mode of Financing

The project is proposed to be financed with a debt equity ratio of 70:30. An interest rate of 9% on the loan component has been considered for the financial analysis of the project. The interest on the working capital is taken as 10.50 %.

10.5 Phasing of Expenditure

It is estimated that project shall be completed in 6 years which includes 1 year of pre-construction activities. The phasing of the expenditure worked out on the basis of proposed construction programme is summarized in Table 10.1.

Table – 10.1
Phasing of Expenditure

Year	**Capital Expenditure (₹. Crores)**
Up-to 1st Half Year	**226.89**
2nd Half Year	**194.48**
3rd Half Year	**129.65**
4th Half Year	**129.65**
5th Half Year	**390.33**
6th Half Year	**618.59**
7th Half Year	**651.00**
8th Half Year	**846.85**
9th Half Year	**1270.95**
10th Half Year	**1075.11**
11th Half Year	**651.00**
12th Half Year	**325.50**
Total	**6510.00**

10.6 Financial Analysis

10.6.1 Basic and Normative Parameters

The following normative parameters have been adopted for working out the financial analysis of the project.

i. The estimated capital cost of ₹. 7178.59 Crores including the Interest during Construction as ₹. 668.59 Crores
ii. Annual gross energy generation of 2699.18 GWh considering 365 days generation in a year.
iii. Operation & maintenance expenses (including insurance) @ 3.5% of the project hard cost in the first year with 4.77% escalation every year.
iv. Depreciation allowed @ 5.28 % of the project cost for first 14 years and remaining depreciation is spread over the balance life i.e. 21 years on an average basis keeping 10% salvage value of the assets.

v. Auxiliary consumption i.e. quantum of energy consumed by auxiliary equipment of the generating station and transformer loss @ 1.25 % of the energy generated.
vi. Interest on working capital @ 10.50%.
vii. Interest during construction has been worked out based upon the interest rates @ 9 %. The computations are given in Annexure10.1 for present day capital cost.
viii. Return on equity @ 15.50%
ix. Pump-Generation Cycle efficiency @ 78%
x. Pumping Energy Required 3285.46 MU
xi. Off-peak Energy Rate (₹/kWh) @ ₹. 1.0/-, 1.5/-, 2.0/- and 2.5/-
xii. MAT @ 17.01 %
xiii. Corporate Tax – 25.17%
xiv. Tax Holiday – 10 Years

10.6.2 Assessment of Tariff

Based upon the parameters given above, the sale rate of energy at bus bar has been computed in **Annexure- 2, 3, 4 & 5 respectively.**

The sale rate applicable in the first year and levellised tariff is indicated below.

Sl. No.	**Off Peak Energy Rate for pumping (₹/kWh)**	**Levellized Tariff (₹/kWh)**	**Conversion cost of the project (excluding pumping cost) (₹/kWh)**
1	1	6.54	5.23
2	1.5	7.20	5.23
3	2	7.86	5.23
4	2.5	8.51	5.23

Annexure-10.1 may please be referred for Conversion cost of the project (excluding pumping cost).

Annexure-10.1

BHAKRA PUMPED STORAGE PROJECT (6x250=1500 MW)

INTEREST DURING CONSTRUCTION (IDC)

1	**Cost of Civil Works**	**INR**	**3241.32**	Cr.	
2	**Cost of E&M Works**	**INR**	**3268.68**	Cr.	
1	**Total Cost of the Project**	**INR**	**6510.00**	Cr.	
2	**Interst Rate on Loan**		**9.0**	%	per annum
3	**Equity**		**30.0**	%	
4	**Loan**		**70.0**	%	
5	**CERC Gudelines followed**		**2019-24**		

Period	**Expenditure Civil**		**Expenditure E&M**		**Total Expenditure**	**Equity available**	**Equity Used**	**Loan**	**IDC**	**IDC for Loan component**	**IDC for Equity component**	**Outstanding**
	Phasing of expendtiure	**Hard Cost**	**Phasing of expendtiure**	**Hard Cost**								
Half year	**%**	**INR Cr.**	**%**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**	**INR Cr.**
1	7	226.89			226.89	1953.00	226.89	0.00	0.00	0.00	0.00	0.00
2	6	194.48			194.48	1726.11	194.48	0.00	0.00	0.00	0.00	0.00
3	4	129.65			129.65	1531.63	129.65	0.00	0.00	0.00	0.00	0.00
4	4	129.65			129.65	1401.98	129.65	0.00	0.00	0.00	0.00	0.00
5	7	226.89	5.00	163.43	390.33	1272.32	390.33	0.00	0.00	0.00	0.00	0.00
6	9	291.72	10.00	326.87	618.59	882.00	618.59	0.00	0.00	0.00	0.00	0.00
7	10	324.13	10.00	326.87	651.00	263.41	263.41	387.59	8.72	6.10	2.62	393.69
8	11	356.55	15.00	490.30	846.85	0.00	0.00	846.85	36.77	25.74	11.03	1266.28
9	14	453.78	25.00	817.17	1270.95	0.00	0.00	1270.95	85.58	59.91	25.67	2597.14
10	13	421.37	20.00	653.74	1075.11	0.00	0.00	1075.11	141.06	98.74	42.32	3770.99
11	10	324.13	10.00	326.87	651.00	0.00	0.00	651.00	184.34	129.04	55.30	4551.03
12	5	162.07	5.00	163.43	325.50	0.00	0.00	325.50	212.12	148.48	63.64	5025.02
	100	**3241.32**	**100**	**3268.68**	**6510.00**		1953.00	4557.00	668.59	468.02	200.58	

Hard Cost	**INR**	**6510.00**	**Cr.**	**Equity**	**INR**	**2153.58**	**Cr.**
IDC	**INR**	**668.59**	**Cr.**	**Loan**	**INR**	**5025.02**	**Cr.**
Total Capital Cost	**INR**	**7178.59**	**Cr.**	**Total Capital Cost**	**INR**	**7178.59**	**Cr.**

Annexure-10.2

BHAKRA PUMPED STORAGE PROJECT (6x250=1500 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	1500.00		11	ROE	%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2153.58
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	5025.02
3	Annual Energy Generation	GWh	2699.18												Total capital cost	INR in Crs	7178.59
4	Annual Energy Generation @ 95% availability	GWh	2564.22			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	6510.00
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	6460.73	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	3285.46				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	0.00				
10	Net Saleble energy	GWh	2533.54										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	402.22	227.85	379.03	5025.02	435.20	379.03	814.22	18.99	34.18	181.10	234.26	24.60	0.00	1468.89	0.00	2533.54	5.80	1.00	5.80
2	402.22	238.72	379.03	4645.99	401.08	379.03	780.11	19.89	35.81	178.23	233.93	24.56	0.00	1445.62	0.00	2533.54	5.71	0.91	5.17
3	402.22	250.11	379.03	4266.96	366.97	379.03	746.00	20.84	37.52	175.42	233.78	24.55	0.00	1422.87	0.00	2533.54	5.62	0.82	4.60
4	402.22	262.04	379.03	3887.93	332.86	379.03	711.89	21.84	39.31	172.69	233.83	24.55	0.00	1400.70	0.00	2533.54	5.53	0.74	4.10
5	402.22	274.53	379.03	3508.90	298.74	379.03	677.77	22.88	41.18	170.03	234.09	24.58	0.00	1379.11	0.00	2533.54	5.44	0.67	3.66
6	402.22	287.63	379.03	3129.87	264.63	379.03	643.66	23.97	43.14	167.44	234.56	24.63	0.00	1358.14	0.00	2533.54	5.36	0.61	3.26
7	402.22	301.35	379.03	2750.84	230.52	379.03	609.55	25.11	45.20	164.94	235.25	24.70	0.00	1337.82	0.00	2533.54	5.28	0.55	2.91
8	402.22	315.72	379.03	2371.81	196.41	379.03	575.44	26.31	47.36	162.52	236.18	24.80	0.00	1318.18	0.00	2533.54	5.20	0.50	2.59
9	402.22	330.78	379.03	1992.78	162.29	379.03	541.32	27.57	49.62	160.18	237.36	24.92	0.00	1299.25	0.00	2533.54	5.13	0.45	2.31
10	402.22	346.56	379.03	1613.75	128.18	379.03	507.21	28.88	51.98	157.94	238.80	25.07	0.00	1281.07	0.00	2533.54	5.06	0.41	2.07
11	446.08	363.09	379.03	1234.72	94.07	379.03	473.10	30.26	54.46	161.27	246.00	25.83	0.00	1308.10	0.00	2533.54	5.16	0.37	1.91
12	446.08	380.41	379.03	855.69	59.96	379.03	438.99	31.70	57.06	159.23	247.99	26.04	0.00	1291.52	0.00	2533.54	5.10	0.33	1.71
13	446.08	398.56	379.03	476.66	25.84	379.03	404.87	33.21	59.78	157.29	250.29	26.28	0.00	1275.80	0.00	2533.54	5.04	0.30	1.53
14	446.08	417.57	379.03	97.63	4.39	97.63	102.02	34.80	62.64	157.04	254.48	26.72	0.00	1273.80	0.00	2533.54	5.03	0.27	1.38
15	446.08	437.49	44.40	0.00	0.00	0.00	0.00	36.46	65.62	117.25	219.33	23.03	0.00	951.00	0.00	2533.54	3.75	0.25	0.93
16	446.08	458.36	44.40	0.00	0.00	0.00	0.00	38.20	68.75	119.92	226.87	23.82	0.00	972.66	0.00	2533.54	3.84	0.22	0.86
17	446.08	480.22	44.40	0.00	0.00	0.00	0.00	40.02	72.03	122.71	234.77	24.65	0.00	995.35	0.00	2533.54	3.93	0.20	0.80
18	446.08	503.13	44.40	0.00	0.00	0.00	0.00	41.93	75.47	125.65	243.04	25.52	0.00	1019.13	0.00	2533.54	4.02	0.18	0.74
19	446.08	527.13	44.40	0.00	0.00	0.00	0.00	43.93	79.07	128.72	251.71	26.43	0.00	1044.04	0.00	2533.54	4.12	0.17	0.69
20	446.08	552.27	44.40	0.00	0.00	0.00	0.00	46.02	82.84	131.93	260.80	27.38	0.00	1070.13	0.00	2533.54	4.22	0.15	0.64
21	446.08	578.61	44.40	0.00	0.00	0.00	0.00	48.22	86.79	135.31	270.31	28.38	0.00	1097.48	0.00	2533.54	4.33	0.14	0.59
22	446.08	606.21	44.40	0.00	0.00	0.00	0.00	50.52	90.93	138.84	280.29	29.43	0.00	1126.12	0.00	2533.54	4.44	0.12	0.55
23	446.08	635.13	44.40	0.00	0.00	0.00	0.00	52.93	95.27	142.54	290.73	30.53	0.00	1156.14	0.00	2533.54	4.56	0.11	0.51
24	446.08	665.42	44.40	0.00	0.00	0.00	0.00	55.45	99.81	146.41	301.68	31.68	0.00	1187.58	0.00	2533.54	4.69	0.10	0.48
25	446.08	697.17	44.40	0.00	0.00	0.00	0.00	58.10	104.57	150.48	313.15	32.88	0.00	1220.53	0.00	2533.54	4.82	0.09	0.44
26	446.08	730.42	44.40	0.00	0.00	0.00	0.00	60.87	109.56	154.73	325.16	34.14	0.00	1255.04	0.00	2533.54	4.95	0.08	0.41
27	446.08	765.26	44.40	0.00	0.00	0.00	0.00	63.77	114.79	159.19	337.75	35.46	0.00	1291.21	0.00	2533.54	5.10	0.08	0.38
28	446.08	801.76	44.40	0.00	0.00	0.00	0.00	66.81	120.26	163.86	350.94	36.85	0.00	1329.09	0.00	2533.54	5.25	0.07	0.36
29	446.08	840.01	44.40	0.00	0.00	0.00	0.00	70.00	126.00	168.75	364.76	38.30	0.00	1368.79	0.00	2533.54	5.40	0.06	0.33
30	446.08	880.08	44.40	0.00	0.00	0.00	0.00	73.34	132.01	173.88	379.23	39.82	0.00	1410.38	0.00	2533.54	5.57	0.06	0.31
31	446.08	922.06	44.40	0.00	0.00	0.00	0.00	76.84	138.31	179.25	394.40	41.41	0.00	1453.95	0.00	2533.54	5.74	0.05	0.29
32	446.08	966.04	44.40	0.00	0.00	0.00	0.00	80.50	144.91	184.88	410.29	43.08	0.00	1499.60	0.00	2533.54	5.92	0.05	0.27
33	446.08	1012.12	44.40	0.00	0.00	0.00	0.00	84.34	151.82	190.78	426.94	44.83	0.00	1547.43	0.00	2533.54	6.11	0.04	0.25
34	446.08	1060.40	44.40	0.00	0.00	0.00	0.00	88.37	159.06	196.96	444.38	46.66	0.00	1597.54	0.00	2533.54	6.31	0.04	0.24
35	446.08	1110.98	44.40	0.00	0.00	0.00	0.00	92.58	166.65	203.43	462.66	48.58	0.00	1650.04	0.00	2533.54	6.51	0.03	0.22
36	446.08	1163.97	44.40	0.00	0.00	0.00	0.00	97.00	174.60	210.21	481.80	50.59	0.00	1705.04	0.00	2533.54	6.73	0.03	0.21
37	446.08	1219.49	44.40	0.00	0.00	0.00	0.00	101.62	182.92	217.32	501.86	52.70	0.00	1762.67	0.00	2533.54	6.96	0.03	0.19
38	446.08	1277.66	44.40	0.00	0.00	0.00	0.00	106.47	191.65	224.76	522.88	54.90	0.00	1823.05	0.00	2533.54	7.20	0.03	0.18
39	446.08	1338.61	44.40	0.00	0.00	0.00	0.00	111.55	200.79	232.56	544.90	57.21	0.00	1886.30	0.00	2533.54	7.45	0.02	0.17
40	446.08	1402.46	44.40	0.00	0.00	0.00	0.00	116.87	210.37	240.73	567.97	59.64	0.00	1952.58	0.00	2533.54	7.71	0.02	0.16
			6460.73			**5025.02**												**10.36**	54.20
	Levellised Tariff (INR/Kwh)=	**5.23**																	

BHAKRA PUMPED STORAGE PROJECT (6x250=1500 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	1500.00		11	ROE	%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2153.58
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	5025.02
3	Annual Energy Generation	GWh	2699.18												Total capital cost	INR in Crs	7178.59
4	Annual Energy Generation @ 95% availability	GWh	2564.22			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	6510.00
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	6460.73	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	3285.46				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	1.00				
10	Net Saleble energy	GWh	2533.54										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	402.22	227.85	379.03	5025.02	435.20	379.03	814.22	18.99	34.18	222.13	275.30	28.91	328.55	1801.75	0.00	2533.54	7.11	1.00	7.11
2	402.22	238.72	379.03	4645.99	401.08	379.03	780.11	19.89	35.81	219.26	274.96	28.87	328.55	1778.47	0.00	2533.54	7.02	0.91	6.35
3	402.22	250.11	379.03	4266.96	366.97	379.03	746.00	20.84	37.52	216.46	274.82	28.86	328.55	1755.73	0.00	2533.54	6.93	0.82	5.68
4	402.22	262.04	379.03	3887.93	332.86	379.03	711.89	21.84	39.31	213.73	274.87	28.86	328.55	1733.55	0.00	2533.54	6.84	0.74	5.08
5	402.22	274.53	379.03	3508.90	298.74	379.03	677.77	22.88	41.18	211.06	275.12	28.89	328.55	1711.96	0.00	2533.54	6.76	0.67	4.54
6	402.22	287.63	379.03	3129.87	264.63	379.03	643.66	23.97	43.14	208.48	275.59	28.94	328.55	1691.00	0.00	2533.54	6.67	0.61	4.06
7	402.22	301.35	379.03	2750.84	230.52	379.03	609.55	25.11	45.20	205.97	276.29	29.01	328.55	1670.68	0.00	2533.54	6.59	0.55	3.63
8	402.22	315.72	379.03	2371.81	196.41	379.03	575.44	26.31	47.36	203.55	277.22	29.11	328.55	1651.04	0.00	2533.54	6.52	0.50	3.25
9	402.22	330.78	379.03	1992.78	162.29	379.03	541.32	27.57	49.62	201.22	278.40	29.23	328.55	1632.11	0.00	2533.54	6.44	0.45	2.91
10	402.22	346.56	379.03	1613.75	128.18	379.03	507.21	28.88	51.98	198.98	279.84	29.38	328.55	1613.92	0.00	2533.54	6.37	0.41	2.60
11	446.08	363.09	379.03	1234.72	94.07	379.03	473.10	30.26	54.46	202.31	287.03	30.14	328.55	1640.96	0.00	2533.54	6.48	0.37	2.40
12	446.08	380.41	379.03	855.69	59.96	379.03	438.99	31.70	57.06	200.27	289.03	30.35	328.55	1624.38	0.00	2533.54	6.41	0.33	2.15
13	446.08	398.56	379.03	476.66	25.84	379.03	404.87	33.21	59.78	198.33	291.32	30.59	328.55	1608.65	0.00	2533.54	6.35	0.30	1.92
14	446.08	417.57	379.03	97.63	4.39	97.63	102.02	34.80	62.64	198.08	295.51	31.03	328.55	1606.65	0.00	2533.54	6.34	0.27	1.74
15	446.08	437.49	44.40	0.00	0.00	0.00	0.00	36.46	65.62	158.28	260.36	27.34	328.55	1283.85	0.00	2533.54	5.07	0.25	1.26
16	446.08	458.36	44.40	0.00	0.00	0.00	0.00	38.20	68.75	160.95	267.90	28.13	328.55	1305.51	0.00	2533.54	5.15	0.22	1.16
17	446.08	480.22	44.40	0.00	0.00	0.00	0.00	40.02	72.03	163.75	275.80	28.96	328.55	1328.21	0.00	2533.54	5.24	0.20	1.07
18	446.08	503.13	44.40	0.00	0.00	0.00	0.00	41.93	75.47	166.68	284.08	29.83	328.55	1351.98	0.00	2533.54	5.34	0.18	0.98
19	446.08	527.13	44.40	0.00	0.00	0.00	0.00	43.93	79.07	169.75	292.75	30.74	328.55	1376.89	0.00	2533.54	5.43	0.17	0.91
20	446.08	552.27	44.40	0.00	0.00	0.00	0.00	46.02	82.84	172.97	301.83	31.69	328.55	1402.99	0.00	2533.54	5.54	0.15	0.84
21	446.08	578.61	44.40	0.00	0.00	0.00	0.00	48.22	86.79	176.34	311.35	32.69	328.55	1430.33	0.00	2533.54	5.65	0.14	0.77
22	446.08	606.21	44.40	0.00	0.00	0.00	0.00	50.52	90.93	179.87	321.32	33.74	328.55	1458.98	0.00	2533.54	5.76	0.12	0.71
23	446.08	635.13	44.40	0.00	0.00	0.00	0.00	52.93	95.27	183.57	331.77	34.84	328.55	1488.99	0.00	2533.54	5.88	0.11	0.66
24	446.08	665.42	44.40	0.00	0.00	0.00	0.00	55.45	99.81	187.45	342.72	35.99	328.55	1520.44	0.00	2533.54	6.00	0.10	0.61
25	446.08	697.17	44.40	0.00	0.00	0.00	0.00	58.10	104.57	191.51	354.18	37.19	328.55	1553.38	0.00	2533.54	6.13	0.09	0.56
26	446.08	730.42	44.40	0.00	0.00	0.00	0.00	60.87	109.56	195.77	366.20	38.45	328.55	1587.90	0.00	2533.54	6.27	0.08	0.52
27	446.08	765.26	44.40	0.00	0.00	0.00	0.00	63.77	114.79	200.23	378.79	39.77	328.55	1624.06	0.00	2533.54	6.41	0.08	0.48
28	446.08	801.76	44.40	0.00	0.00	0.00	0.00	66.81	120.26	204.90	391.98	41.16	328.55	1661.95	0.00	2533.54	6.56	0.07	0.45
29	446.08	840.01	44.40	0.00	0.00	0.00	0.00	70.00	126.00	209.79	405.79	42.61	328.55	1701.64	0.00	2533.54	6.72	0.06	0.41
30	446.08	880.08	44.40	0.00	0.00	0.00	0.00	73.34	132.01	214.92	420.27	44.13	328.55	1743.23	0.00	2533.54	6.88	0.06	0.38
31	446.08	922.06	44.40	0.00	0.00	0.00	0.00	76.84	138.31	220.29	435.44	45.72	328.55	1786.80	0.00	2533.54	7.05	0.05	0.36
32	446.08	966.04	44.40	0.00	0.00	0.00	0.00	80.50	144.91	225.92	451.33	47.39	328.55	1832.45	0.00	2533.54	7.23	0.05	0.33
33	446.08	1012.12	44.40	0.00	0.00	0.00	0.00	84.34	151.82	231.82	467.98	49.14	328.55	1880.28	0.00	2533.54	7.42	0.04	0.31
34	446.08	1060.40	44.40	0.00	0.00	0.00	0.00	88.37	159.06	237.99	485.42	50.97	328.55	1930.39	0.00	2533.54	7.62	0.04	0.29
35	446.08	1110.98	44.40	0.00	0.00	0.00	0.00	92.58	166.65	244.47	503.69	52.89	328.55	1982.89	0.00	2533.54	7.83	0.03	0.27
36	446.08	1163.97	44.40	0.00	0.00	0.00	0.00	97.00	174.60	251.25	522.84	54.90	328.55	2037.90	0.00	2533.54	8.04	0.03	0.25
37	446.08	1219.49	44.40	0.00	0.00	0.00	0.00	101.62	182.92	258.35	542.90	57.00	328.55	2095.52	0.00	2533.54	8.27	0.03	0.23
38	446.08	1277.66	44.40	0.00	0.00	0.00	0.00	106.47	191.65	265.80	563.92	59.21	328.55	2155.90	0.00	2533.54	8.51	0.03	0.21
39	446.08	1338.61	44.40	0.00	0.00	0.00	0.00	111.55	200.79	273.59	585.94	61.52	328.55	2219.16	0.00	2533.54	8.76	0.02	0.20
40	446.08	1402.46	44.40	0.00	0.00	0.00	0.00	116.87	210.37	281.77	609.01	63.95	328.55	2285.43	0.00	2533.54	9.02	0.02	0.19
			6460.73			**5025.02**												**10.36**	67.81
	Levellised Tariff (INR/Kwh)=	**6.54**																	

Annexure-10.4

BHAKRA PUMPED STORAGE PROJECT (6x250=1500 MW)

S.No	Parameters	Unit	Value		S.No	Parameters		Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	1500.00		11	ROE		%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2153.58
2	Normative availability	%	95.00		12	Working capital					15	O&M Expenses	%	3.50	23	Loan	INR in Crs	5025.02
3	Annual Energy Generation	GWh	2699.18													Total capital cost	INR in Crs	7178.59
4	Annual Energy Generation @ 95% availability	GWh	2564.22			i) Spares(% of O&M)		%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses		Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables		days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	6510.00
7	Auxiliary Consumption	%	0.70		13	i) MAT			17.01%		19	Max Dep Allowed	INR Cr.	6460.73	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax			25.17%		20	Energy Required for pumping	GWh	3285.46				
9	Free Power	%	0.00			III) Tax holiday		years	10.00		21	Rate for off peak energy	INR	1.50				
10	Net Saleble energy	GWh	2533.54											per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	402.22	227.85	379.03	5025.02	435.20	379.03	814.22	18.99	34.18	242.65	295.82	31.06	492.82	1968.18	0.00	2533.54	7.77	1.00	7.77
2	402.22	238.72	379.03	4645.99	401.08	379.03	780.11	19.89	35.81	239.78	295.48	31.03	492.82	1944.90	0.00	2533.54	7.68	0.91	6.95
3	402.22	250.11	379.03	4266.96	366.97	379.03	746.00	20.84	37.52	236.98	295.34	31.01	492.82	1922.16	0.00	2533.54	7.59	0.82	6.22
4	402.22	262.04	379.03	3887.93	332.86	379.03	711.89	21.84	39.31	234.24	295.39	31.02	492.82	1899.98	0.00	2533.54	7.50	0.74	5.56
5	402.22	274.53	379.03	3508.90	298.74	379.03	677.77	22.88	41.18	231.58	295.64	31.04	492.82	1878.39	0.00	2533.54	7.41	0.67	4.98
6	402.22	287.63	379.03	3129.87	264.63	379.03	643.66	23.97	43.14	229.00	296.11	31.09	492.82	1857.42	0.00	2533.54	7.33	0.61	4.46
7	402.22	301.35	379.03	2750.84	230.52	379.03	609.55	25.11	45.20	226.49	296.81	31.16	492.82	1837.10	0.00	2533.54	7.25	0.55	3.99
8	402.22	315.72	379.03	2371.81	196.41	379.03	575.44	26.31	47.36	224.07	297.74	31.26	492.82	1817.46	0.00	2533.54	7.17	0.50	3.58
9	402.22	330.78	379.03	1992.78	162.29	379.03	541.32	27.57	49.62	221.74	298.92	31.39	492.82	1798.54	0.00	2533.54	7.10	0.45	3.20
10	402.22	346.56	379.03	1613.75	128.18	379.03	507.21	28.88	51.98	219.50	300.36	31.54	492.82	1780.35	0.00	2533.54	7.03	0.41	2.87
11	446.08	363.09	379.03	1234.72	94.07	379.03	473.10	30.26	54.46	222.83	307.55	32.29	492.82	1807.39	0.00	2533.54	7.13	0.37	2.64
12	446.08	380.41	379.03	855.69	59.96	379.03	438.99	31.70	57.06	220.78	309.55	32.50	492.82	1790.80	0.00	2533.54	7.07	0.33	2.37
13	446.08	398.56	379.03	476.66	25.84	379.03	404.87	33.21	59.78	218.85	311.84	32.74	492.82	1775.08	0.00	2533.54	7.01	0.30	2.12
14	446.08	417.57	379.03	97.63	4.39	97.63	102.02	34.80	62.64	218.60	316.03	33.18	492.82	1773.08	0.00	2533.54	7.00	0.27	1.92
15	446.08	437.49	44.40	0.00	0.00	0.00	0.00	36.46	65.62	178.80	280.88	29.49	492.82	1450.28	0.00	2533.54	5.72	0.25	1.42
16	446.08	458.36	44.40	0.00	0.00	0.00	0.00	38.20	68.75	181.47	288.42	30.28	492.82	1471.94	0.00	2533.54	5.81	0.22	1.31
17	446.08	480.22	44.40	0.00	0.00	0.00	0.00	40.02	72.03	184.27	296.32	31.11	492.82	1494.63	0.00	2533.54	5.90	0.20	1.20
18	446.08	503.13	44.40	0.00	0.00	0.00	0.00	41.93	75.47	187.20	304.60	31.98	492.82	1518.41	0.00	2533.54	5.99	0.18	1.10
19	446.08	527.13	44.40	0.00	0.00	0.00	0.00	43.93	79.07	190.27	313.27	32.89	492.82	1543.32	0.00	2533.54	6.09	0.17	1.02
20	446.08	552.27	44.40	0.00	0.00	0.00	0.00	46.02	82.84	193.49	322.35	33.85	492.82	1569.42	0.00	2533.54	6.19	0.15	0.94
21	446.08	578.61	44.40	0.00	0.00	0.00	0.00	48.22	86.79	196.86	331.87	34.85	492.82	1596.76	0.00	2533.54	6.30	0.14	0.86
22	446.08	606.21	44.40	0.00	0.00	0.00	0.00	50.52	90.93	200.39	341.84	35.89	492.82	1625.41	0.00	2533.54	6.42	0.12	0.79
23	446.08	635.13	44.40	0.00	0.00	0.00	0.00	52.93	95.27	204.09	352.29	36.99	492.82	1655.42	0.00	2533.54	6.53	0.11	0.73
24	446.08	665.42	44.40	0.00	0.00	0.00	0.00	55.45	99.81	207.97	363.24	38.14	492.82	1686.86	0.00	2533.54	6.66	0.10	0.68
25	446.08	697.17	44.40	0.00	0.00	0.00	0.00	58.10	104.57	212.03	374.70	39.34	492.82	1719.81	0.00	2533.54	6.79	0.09	0.62
26	446.08	730.42	44.40	0.00	0.00	0.00	0.00	60.87	109.56	216.29	386.72	40.61	492.82	1754.32	0.00	2533.54	6.92	0.08	0.58
27	446.08	765.26	44.40	0.00	0.00	0.00	0.00	63.77	114.79	220.75	399.31	41.93	492.82	1790.49	0.00	2533.54	7.07	0.08	0.53
28	446.08	801.76	44.40	0.00	0.00	0.00	0.00	66.81	120.26	225.42	412.49	43.31	492.82	1828.38	0.00	2533.54	7.22	0.07	0.49
29	446.08	840.01	44.40	0.00	0.00	0.00	0.00	70.00	126.00	230.31	426.31	44.76	492.82	1868.07	0.00	2533.54	7.37	0.06	0.45
30	446.08	880.08	44.40	0.00	0.00	0.00	0.00	73.34	132.01	235.44	440.79	46.28	492.82	1909.66	0.00	2533.54	7.54	0.06	0.42
31	446.08	922.06	44.40	0.00	0.00	0.00	0.00	76.84	138.31	240.81	455.96	47.88	492.82	1953.23	0.00	2533.54	7.71	0.05	0.39
32	446.08	966.04	44.40	0.00	0.00	0.00	0.00	80.50	144.91	246.44	471.85	49.54	492.82	1998.88	0.00	2533.54	7.89	0.05	0.36
33	446.08	1012.12	44.40	0.00	0.00	0.00	0.00	84.34	151.82	252.33	488.49	51.29	492.82	2046.71	0.00	2533.54	8.08	0.04	0.33
34	446.08	1060.40	44.40	0.00	0.00	0.00	0.00	88.37	159.06	258.51	505.94	53.12	492.82	2096.82	0.00	2533.54	8.28	0.04	0.31
35	446.08	1110.98	44.40	0.00	0.00	0.00	0.00	92.58	166.65	264.98	524.21	55.04	492.82	2149.32	0.00	2533.54	8.48	0.03	0.29
36	446.08	1163.97	44.40	0.00	0.00	0.00	0.00	97.00	174.60	271.77	543.36	57.05	492.82	2204.32	0.00	2533.54	8.70	0.03	0.27
37	446.08	1219.49	44.40	0.00	0.00	0.00	0.00	101.62	182.92	278.87	563.42	59.16	492.82	2261.95	0.00	2533.54	8.93	0.03	0.25
38	446.08	1277.66	44.40	0.00	0.00	0.00	0.00	106.47	191.65	286.31	584.44	61.37	492.82	2322.33	0.00	2533.54	9.17	0.03	0.23
39	446.08	1338.61	44.40	0.00	0.00	0.00	0.00	111.55	200.79	294.11	606.45	63.68	492.82	2385.58	0.00	2533.54	9.42	0.02	0.21
40	446.08	1402.46	44.40	0.00	0.00	0.00	0.00	116.87	210.37	302.28	629.52	66.10	492.82	2451.86	0.00	2533.54	9.68	0.02	0.20
			6460.73			**5025.02**												**10.36**	74.62
	Levellised Tariff (INR/Kwh)=	**7.20**																	

Annexure-10.5

BHAKRA PUMPED STORAGE PROJECT (6x250=1500 MW)

S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	1500.00		11	ROE	%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2153.58
2	Normative availability	%	95.00		12	Working capital				15	O&M Expenses	%	3.50	23	Loan	INR in Crs	5025.02
3	Annual Energy Generation	GWh	2699.18												Total capital cost	INR in Crs	7178.59
4	Annual Energy Generation @ 95% availability	GWh	2564.22			i) Spares(% of O&M)	%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses	Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables	days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	6510.00
7	Auxiliary Consumption	%	0.70		13	i) MAT		17.01%		19	Max Dep Allowed	INR Cr.	6460.73	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax		25.17%		20	Energy Required for pumping	GWh	3285.46				
9	Free Power	%	0.00			III) Tax holiday	years	10.00		21	Rate for off peak energy	INR	2.00				
10	Net Saleble energy	GWh	2533.54										per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	402.22	227.85	379.03	5025.02	435.20	379.03	814.22	18.99	34.18	263.17	316.34	33.22	657.09	2134.60	0.00	2533.54	8.43	1.00	8.43
2	402.22	238.72	379.03	4645.99	401.08	379.03	780.11	19.89	35.81	260.30	316.00	33.18	657.09	2111.32	0.00	2533.54	8.33	0.91	7.54
3	402.22	250.11	379.03	4266.96	366.97	379.03	746.00	20.84	37.52	257.50	315.85	33.16	657.09	2088.58	0.00	2533.54	8.24	0.82	6.76
4	402.22	262.04	379.03	3887.93	332.86	379.03	711.89	21.84	39.31	254.76	315.90	33.17	657.09	2066.41	0.00	2533.54	8.16	0.74	6.05
5	402.22	274.53	379.03	3508.90	298.74	379.03	677.77	22.88	41.18	252.10	316.16	33.20	657.09	2044.82	0.00	2533.54	8.07	0.67	5.42
6	402.22	287.63	379.03	3129.87	264.63	379.03	643.66	23.97	43.14	249.52	316.63	33.25	657.09	2023.85	0.00	2533.54	7.99	0.61	4.86
7	402.22	301.35	379.03	2750.84	230.52	379.03	609.55	25.11	45.20	247.01	317.33	33.32	657.09	2003.53	0.00	2533.54	7.91	0.55	4.35
8	402.22	315.72	379.03	2371.81	196.41	379.03	575.44	26.31	47.36	244.59	318.26	33.42	657.09	1983.89	0.00	2533.54	7.83	0.50	3.90
9	402.22	330.78	379.03	1992.78	162.29	379.03	541.32	27.57	49.62	242.26	319.44	33.54	657.09	1964.96	0.00	2533.54	7.76	0.45	3.50
10	402.22	346.56	379.03	1613.75	128.18	379.03	507.21	28.88	51.98	240.01	320.88	33.69	657.09	1946.78	0.00	2533.54	7.68	0.41	3.14
11	446.08	363.09	379.03	1234.72	94.07	379.03	473.10	30.26	54.46	243.35	328.07	34.45	657.09	1973.81	0.00	2533.54	7.79	0.37	2.88
12	446.08	380.41	379.03	855.69	59.96	379.03	438.99	31.70	57.06	241.30	330.07	34.66	657.09	1957.23	0.00	2533.54	7.73	0.33	2.59
13	446.08	398.56	379.03	476.66	25.84	379.03	404.87	33.21	59.78	239.36	332.36	34.90	657.09	1941.50	0.00	2533.54	7.66	0.30	2.32
14	446.08	417.57	379.03	97.63	4.39	97.63	102.02	34.80	62.64	239.12	336.55	35.34	657.09	1939.51	0.00	2533.54	7.66	0.27	2.10
15	446.08	437.49	44.40	0.00	0.00	0.00	0.00	36.46	65.62	199.32	301.40	31.65	657.09	1616.71	0.00	2533.54	6.38	0.25	1.59
16	446.08	458.36	44.40	0.00	0.00	0.00	0.00	38.20	68.75	201.99	308.94	32.44	657.09	1638.37	0.00	2533.54	6.47	0.22	1.45
17	446.08	480.22	44.40	0.00	0.00	0.00	0.00	40.02	72.03	204.79	316.84	33.27	657.09	1661.06	0.00	2533.54	6.56	0.20	1.33
18	446.08	503.13	44.40	0.00	0.00	0.00	0.00	41.93	75.47	207.72	325.12	34.14	657.09	1684.84	0.00	2533.54	6.65	0.18	1.23
19	446.08	527.13	44.40	0.00	0.00	0.00	0.00	43.93	79.07	210.79	333.79	35.05	657.09	1709.75	0.00	2533.54	6.75	0.17	1.13
20	446.08	552.27	44.40	0.00	0.00	0.00	0.00	46.02	82.84	214.01	342.87	36.00	657.09	1735.84	0.00	2533.54	6.85	0.15	1.03
21	446.08	578.61	44.40	0.00	0.00	0.00	0.00	48.22	86.79	217.38	352.39	37.00	657.09	1763.19	0.00	2533.54	6.96	0.14	0.95
22	446.08	606.21	44.40	0.00	0.00	0.00	0.00	50.52	90.93	220.91	362.36	38.05	657.09	1791.83	0.00	2533.54	7.07	0.12	0.88
23	446.08	635.13	44.40	0.00	0.00	0.00	0.00	52.93	95.27	224.61	372.81	39.14	657.09	1821.85	0.00	2533.54	7.19	0.11	0.81
24	446.08	665.42	44.40	0.00	0.00	0.00	0.00	55.45	99.81	228.49	383.75	40.29	657.09	1853.29	0.00	2533.54	7.32	0.10	0.74
25	446.08	697.17	44.40	0.00	0.00	0.00	0.00	58.10	104.57	232.55	395.22	41.50	657.09	1886.24	0.00	2533.54	7.45	0.09	0.68
26	446.08	730.42	44.40	0.00	0.00	0.00	0.00	60.87	109.56	236.81	407.24	42.76	657.09	1920.75	0.00	2533.54	7.58	0.08	0.63
27	446.08	765.26	44.40	0.00	0.00	0.00	0.00	63.77	114.79	241.26	419.82	44.08	657.09	1956.91	0.00	2533.54	7.72	0.08	0.58
28	446.08	801.76	44.40	0.00	0.00	0.00	0.00	66.81	120.26	245.93	433.01	45.47	657.09	1994.80	0.00	2533.54	7.87	0.07	0.54
29	446.08	840.01	44.40	0.00	0.00	0.00	0.00	70.00	126.00	250.83	446.83	46.92	657.09	2034.50	0.00	2533.54	8.03	0.06	0.50
30	446.08	880.08	44.40	0.00	0.00	0.00	0.00	73.34	132.01	255.96	461.31	48.44	657.09	2076.09	0.00	2533.54	8.19	0.06	0.46
31	446.08	922.06	44.40	0.00	0.00	0.00	0.00	76.84	138.31	261.33	476.47	50.03	657.09	2119.66	0.00	2533.54	8.37	0.05	0.42
32	446.08	966.04	44.40	0.00	0.00	0.00	0.00	80.50	144.91	266.96	492.36	51.70	657.09	2165.31	0.00	2533.54	8.55	0.05	0.39
33	446.08	1012.12	44.40	0.00	0.00	0.00	0.00	84.34	151.82	272.85	509.01	53.45	657.09	2213.14	0.00	2533.54	8.74	0.04	0.36
34	446.08	1060.40	44.40	0.00	0.00	0.00	0.00	88.37	159.06	279.03	526.46	55.28	657.09	2263.25	0.00	2533.54	8.93	0.04	0.34
35	446.08	1110.98	44.40	0.00	0.00	0.00	0.00	92.58	166.65	285.50	544.73	57.20	657.09	2315.75	0.00	2533.54	9.14	0.03	0.31
36	446.08	1163.97	44.40	0.00	0.00	0.00	0.00	97.00	174.60	292.28	563.88	59.21	657.09	2370.75	0.00	2533.54	9.36	0.03	0.29
37	446.08	1219.49	44.40	0.00	0.00	0.00	0.00	101.62	182.92	299.39	583.94	61.31	657.09	2428.38	0.00	2533.54	9.58	0.03	0.27
38	446.08	1277.66	44.40	0.00	0.00	0.00	0.00	106.47	191.65	306.83	604.95	63.52	657.09	2488.75	0.00	2533.54	9.82	0.03	0.25
39	446.08	1338.61	44.40	0.00	0.00	0.00	0.00	111.55	200.79	314.63	626.97	65.83	657.09	2552.01	0.00	2533.54	10.07	0.02	0.23
40	446.08	1402.46	44.40	0.00	0.00	0.00	0.00	116.87	210.37	322.80	650.04	68.25	657.09	2618.28	0.00	2533.54	10.33	0.02	0.21
			6460.73			**5025.02**												**10.36**	81.43
	Levellised Tariff (INR/Kwh)=	**7.86**																	

Annexure-10.6

BHAKRA PUMPED STORAGE PROJECT (6x250=1500 MW)

S.No	Parameters	Unit	Value		S.No	Parameters		Unit	Value		S.No	Parameters	Unit	Value	S.No	Parameters	Unit	Value
1	Installed Capacity	MW	1500.00		11	ROE		%	15.50		14	Interest rate on W.C	%	10.50	22	Equity	INR in Crs	2153.58
2	Normative availability	%	95.00		12	Working capital					15	O&M Expenses	%	3.50	23	Loan	INR in Crs	5025.02
3	Annual Energy Generation	GWh	2699.18													Total capital cost	INR in Crs	7178.59
4	Annual Energy Generation @ 95% availability	GWh	2564.22			i) Spares(% of O&M)		%	15.00		16	O&M Escalation rate	%	4.77	24	Interest on Loan	%	9.00
5	Secondary Energy	GWh	0.00			ii) O&M expenses		Months	1.00		17	Discount Rate	%	10.46	25	Repay Period	Yrs	14.00
6	Transformation losses	%	0.50			iii) Receivables		days	45.00		18	Depreciation Rate	%	5.28	26	Hard Cost	INR in Crs	6510.00
7	Auxiliary Consumption	%	0.70		13	i) MAT			17.01%		19	Max Dep Allowed	INR Cr.	6460.73	27	Project Life	Years	**40**
8	Transmission losses	%	0.00			II) Tax			25.17%		20	Energy Required for pumping	GWh	3285.46				
9	Free Power	%	0.00			III) Tax holiday		years	10.00		21	Rate for off peak energy	INR	2.50				
10	Net Saleble energy	GWh	2533.54											per unit				

Year	ROE	O&M	Depreciation	Outstanding Principal	Intt on Loan	Loan Principle Paid	Loan Installment	W.C				Intt on	Charges for Pumping	Annual	Energy		Tarrif	Discount	Discounted
								O&M	Spares	Recievables	Total	W.C		Expenses	Free	Sold		Factor	Tariff
	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	INR in Cr.	GWh	GWh	INR/KWh		INR/KWh
1	402.22	227.85	379.03	5025.02	435.20	379.03	814.22	18.99	34.18	283.69	336.85	35.37	821.36	2301.03	0.00	2533.54	9.08	1.00	9.08
2	402.22	238.72	379.03	4645.99	401.08	379.03	780.11	19.89	35.81	280.82	336.52	35.33	821.36	2277.75	0.00	2533.54	8.99	0.91	8.14
3	402.22	250.11	379.03	4266.96	366.97	379.03	746.00	20.84	37.52	278.02	336.37	35.32	821.36	2255.01	0.00	2533.54	8.90	0.82	7.29
4	402.22	262.04	379.03	3887.93	332.86	379.03	711.89	21.84	39.31	275.28	336.42	35.32	821.36	2232.83	0.00	2533.54	8.81	0.74	6.54
5	402.22	274.53	379.03	3508.90	298.74	379.03	677.77	22.88	41.18	272.62	336.68	35.35	821.36	2211.25	0.00	2533.54	8.73	0.67	5.86
6	402.22	287.63	379.03	3129.87	264.63	379.03	643.66	23.97	43.14	270.03	337.15	35.40	821.36	2190.28	0.00	2533.54	8.65	0.61	5.26
7	402.22	301.35	379.03	2750.84	230.52	379.03	609.55	25.11	45.20	267.53	337.84	35.47	821.36	2169.96	0.00	2533.54	8.56	0.55	4.72
8	402.22	315.72	379.03	2371.81	196.41	379.03	575.44	26.31	47.36	265.11	338.78	35.57	821.36	2150.32	0.00	2533.54	8.49	0.50	4.23
9	402.22	330.78	379.03	1992.78	162.29	379.03	541.32	27.57	49.62	262.77	339.96	35.70	821.36	2131.39	0.00	2533.54	8.41	0.45	3.80
10	402.22	346.56	379.03	1613.75	128.18	379.03	507.21	28.88	51.98	260.53	341.40	35.85	821.36	2113.21	0.00	2533.54	8.34	0.41	3.41
11	446.08	363.09	379.03	1234.72	94.07	379.03	473.10	30.26	54.46	263.87	348.59	36.60	821.36	2140.24	0.00	2533.54	8.45	0.37	3.12
12	446.08	380.41	379.03	855.69	59.96	379.03	438.99	31.70	57.06	261.82	350.58	36.81	821.36	2123.66	0.00	2533.54	8.38	0.33	2.81
13	446.08	398.56	379.03	476.66	25.84	379.03	404.87	33.21	59.78	259.88	352.88	37.05	821.36	2107.93	0.00	2533.54	8.32	0.30	2.52
14	446.08	417.57	379.03	97.63	4.39	97.63	102.02	34.80	62.64	259.64	357.07	37.49	821.36	2105.93	0.00	2533.54	8.31	0.27	2.28
15	446.08	437.49	44.40	0.00	0.00	0.00	0.00	36.46	65.62	219.84	321.92	33.80	821.36	1783.13	0.00	2533.54	7.04	0.25	1.75
16	446.08	458.36	44.40	0.00	0.00	0.00	0.00	38.20	68.75	222.51	329.46	34.59	821.36	1804.79	0.00	2533.54	7.12	0.22	1.60
17	446.08	480.22	44.40	0.00	0.00	0.00	0.00	40.02	72.03	225.31	337.36	35.42	821.36	1827.49	0.00	2533.54	7.21	0.20	1.47
18	446.08	503.13	44.40	0.00	0.00	0.00	0.00	41.93	75.47	228.24	345.63	36.29	821.36	1851.26	0.00	2533.54	7.31	0.18	1.35
19	446.08	527.13	44.40	0.00	0.00	0.00	0.00	43.93	79.07	231.31	354.30	37.20	821.36	1876.17	0.00	2533.54	7.41	0.17	1.24
20	446.08	552.27	44.40	0.00	0.00	0.00	0.00	46.02	82.84	234.53	363.39	38.16	821.36	1902.27	0.00	2533.54	7.51	0.15	1.13
21	446.08	578.61	44.40	0.00	0.00	0.00	0.00	48.22	86.79	237.90	372.91	39.16	821.36	1929.61	0.00	2533.54	7.62	0.14	1.04
22	446.08	606.21	44.40	0.00	0.00	0.00	0.00	50.52	90.93	241.43	382.88	40.20	821.36	1958.26	0.00	2533.54	7.73	0.12	0.96
23	446.08	635.13	44.40	0.00	0.00	0.00	0.00	52.93	95.27	245.13	393.33	41.30	821.36	1988.27	0.00	2533.54	7.85	0.11	0.88
24	446.08	665.42	44.40	0.00	0.00	0.00	0.00	55.45	99.81	249.01	404.27	42.45	821.36	2019.72	0.00	2533.54	7.97	0.10	0.81
25	446.08	697.17	44.40	0.00	0.00	0.00	0.00	58.10	104.57	253.07	415.74	43.65	821.36	2052.66	0.00	2533.54	8.10	0.09	0.74
26	446.08	730.42	44.40	0.00	0.00	0.00	0.00	60.87	109.56	257.32	427.75	44.91	821.36	2087.18	0.00	2533.54	8.24	0.08	0.69
27	446.08	765.26	44.40	0.00	0.00	0.00	0.00	63.77	114.79	261.78	440.34	46.24	821.36	2123.34	0.00	2533.54	8.38	0.08	0.63
28	446.08	801.76	44.40	0.00	0.00	0.00	0.00	66.81	120.26	266.45	453.53	47.62	821.36	2161.23	0.00	2533.54	8.53	0.07	0.58
29	446.08	840.01	44.40	0.00	0.00	0.00	0.00	70.00	126.00	271.35	467.35	49.07	821.36	2200.92	0.00	2533.54	8.69	0.06	0.54
30	446.08	880.08	44.40	0.00	0.00	0.00	0.00	73.34	132.01	276.47	481.83	50.59	821.36	2242.51	0.00	2533.54	8.85	0.06	0.49
31	446.08	922.06	44.40	0.00	0.00	0.00	0.00	76.84	138.31	281.85	496.99	52.18	821.36	2286.09	0.00	2533.54	9.02	0.05	0.46
32	446.08	966.04	44.40	0.00	0.00	0.00	0.00	80.50	144.91	287.47	512.88	53.85	821.36	2331.74	0.00	2533.54	9.20	0.05	0.42
33	446.08	1012.12	44.40	0.00	0.00	0.00	0.00	84.34	151.82	293.37	529.53	55.60	821.36	2379.56	0.00	2533.54	9.39	0.04	0.39
34	446.08	1060.40	44.40	0.00	0.00	0.00	0.00	88.37	159.06	299.55	546.97	57.43	821.36	2429.67	0.00	2533.54	9.59	0.04	0.36
35	446.08	1110.98	44.40	0.00	0.00	0.00	0.00	92.58	166.65	306.02	565.25	59.35	821.36	2482.17	0.00	2533.54	9.80	0.03	0.33
36	446.08	1163.97	44.40	0.00	0.00	0.00	0.00	97.00	174.60	312.80	584.40	61.36	821.36	2537.18	0.00	2533.54	10.01	0.03	0.31
37	446.08	1219.49	44.40	0.00	0.00	0.00	0.00	101.62	182.92	319.91	604.46	63.47	821.36	2594.80	0.00	2533.54	10.24	0.03	0.29
38	446.08	1277.66	44.40	0.00	0.00	0.00	0.00	106.47	191.65	327.35	625.47	65.67	821.36	2655.18	0.00	2533.54	10.48	0.03	0.26
39	446.08	1338.61	44.40	0.00	0.00	0.00	0.00	111.55	200.79	335.15	647.49	67.99	821.36	2718.44	0.00	2533.54	10.73	0.02	0.24
40	446.08	1402.46	44.40	0.00	0.00	0.00	0.00	116.87	210.37	343.32	670.56	70.41	821.36	2784.71	0.00	2533.54	10.99	0.02	0.23
			6460.73			**5025.02**												**10.36**	88.24
	Levellised Tariff (INR/Kwh)=	**8.51**																	

11. POWER EVACUATION ARRANGEMENT

Chapter – 11

POWER EVACUATION ARRANGEMENT

11.1 General

The transmission systems that are in place in the country consist of Inter-State Transmission System (ISTS) and Intra State Transmission System (Intra-STS).

At the time of independence, power systems in the country were essentially isolated systems developed in and around urban and industrial areas. The installed generating capacity in the country was only about 1300 MW and the power system consisted of small generating stations feeding power radially to load centres. The highest transmission voltage was 132 kV. The voltage level of state-sector network grew from 132 kV level during the 50s and 60s to 220 kV during 60s and 70s. Subsequently, 400kV network was also developed in many states (Utter Pradesh, Maharashtra, Madhya Pradesh, Gujarat, Orissa, Andhra Pradesh and Karnataka) for bulk power transfer over long distances. With the development of state grids in most states of the country, the stage was set for development of regional grid

The National Grid consists of the transmission system for evacuation of power from generating stations, the inter-regional links, Inter State transmission system and Intra-State transmission of the STUs. Thus, development of national grid has been an evolutionary process. The National Grid is a large, meshed synchronous transmission grid where all the regional and State grids in them are electrically connected and operate at single frequency

The country has moved from the concept of regional self-sufficiency to bulk inter-regional transfer of power through high capacity AC and HVDC corridors forming an all-India National Grid

11.2 Reliability Criterion

Criteria for the system

(A) Under the scenario where a contingency N-1 has already happened, the system may be subjected to one of the following subsequent contingencies (called 'N-1-1' condition):

a) The system shall be able to survive a permanent single phase to ground fault on a 400kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

Demand assessment is an essential prerequisite for planning of generation capacity addition and associated transmission infrastructure required to meet the future power requirement of various sectors of our economy. The type and location of power projects to be planned in the system is largely dependent on the magnitude, spatial distribution as well as the variation of demand during the day, seasons and on a yearly basis. Therefore, reliable planning for generation and transmission capacity addition for future is largely dependent on an accurate assessment of the future demand.

In the 19th Electricity Power Survey report (prepared based on inputs from and consultation with Stake-holders in the Power Sector in the country), the demand for electricity both in terms of peak electric load and electrical energy requirement has been projected. As per 19th Electric Power Survey (EPS) Report, the peak electricity demand 2026-27 is given below:

State/UTs	**2026-27**
Northern Region	97182 MW
Western Region	94825 MW
Southern Region	83652 MW
Eastern Region	35674 MW
North- Eastern Region	6710 MW
Total All India (Peak)(MW)	**298632 MW**

All India transmission network is composed of lines of different voltage levels as given below along with the distances .Total distance of covered by transmission lines in India is **367850 km**

S No.	**Voltage Class**	**Km**
a	HVDC ± 500kV/ ± 800 kV	31240 km
b	765 kV	15556 km
c	440 kV	157787 km
d	230/220 kV	163268 km
	Total km	**367850 km**

All India power maps is attached as Annexure 1 & 2

BBMB system lies in northern grid. At present power is evacuated from 400kV, 220kV, 132 kV & 66 kV system to cater the existing Installed capacity of 2918.73 MW

Now BBMB intends to enhance the existing the existing capacity by making 1500MW pumped storage hydroelectric power plant at Bhakra consisting of 6x250 MW

Power from 1500MW pumped storage hydroelectric power plant at Bhakra PSP would be evacuated through 400KV D/C transmission line using twin moose or quad conductor lines to Panchkula Pooling station which is approx. 90 km from power house.

Fig .1