SJVN Limited

(A Joint Venture of Govt. of India & Govt. of Himachal Pradesh)

PRE-FEASIBILITY REPORT

ON

LUHRI HYDRO ELECTRIC

PROJECT STAGE-I (219 MW)

MAY'2015

Contents Page No.

Multi stage development of Luhri HEP (Alternative Studies)

1. **Introduction: -** Luhri Hydroelectric project located in Shimla, Mandi and Kullu districts of Himachal Pradesh was proposed in single stage to harness the hydel potential between tail water of Rampur Hydro Electric Project and Full Reservoir Level of Kol Dam Hydro Electric Project. The commercial viability of the project was accorded by CEA on dated 04/12/2006. Detailed Project Report of the Luhri HEP (775MW) with design discharge of 480 m^3/sec was submitted to CEA in March'07. Subsequently, MOU between GOHP and SJVN was signed on 27/10/2008 for the execution of Luhri HEP (775 MW) on river Satluj.

   Further, as per the recommendations of the Expert Advisory Committee, the environmental releases were modified which in turn resulted in reduction of design discharge from 480 m^3/sec to 380 m^3/sec. After incorporating the new environmental releases, revised DPR of Luhri HEP (577+ 24MW) having 10.5 m dia, 38 km long Head Race Tunnel with design discharge of 380 m^3/sec was submitted to CEA on March 2013.

   In the detailed project report, in regard to surge arrangement two alternatives were provided. One was having vertical surge shaft of about 35m diameter which needed construction of 41m diameter dome. The rock conditions at the location were from fair to poor and as such it was practically infeasible to construct a vertical surge shaft having dome of about 41m. The option of constructing a surge shaft open to sky was also not feasible at that location. Other alternative was to construct surge galleries of 10.5m diameter, about 1.5km long and having expansion galleries across the main surge gallery. In order to ascertain whether these surge galleries would be capable of absorbing upsurge as well as down surge and to obviate the apprehension of separation of water in down surge when machines were put on, it was decided to get mathematical modeling carried out. The mathematical modeling was got done through CWPRS, Pune which was one dimensional only. During examination, it was felt that this modeling was not true representation of the actual situation which may arise. As such, HCD Directorate, CWC vide letter dated 11/03/15 advised SJVN to review the layout planning of the project (Copy of CWC letter is attached as Annex-I).

   Further, Government of Himachal Pradesh vide letter dated 11/03/15 had requested SJVN to explore the possibility of executing the Luhri HEP as multi stage project instead of present single stage on account of social and environmental/ecological concerns since single stage development of the project consists of a long tunnel of 38km length (Copy of GoHP letter is attached as Annex-II).

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In view of the above, SJVN explored the possibilities for multistage development of Luhri HE project.

2. Alternative studies for Multi Stage Development of Luhri HEP:- The following alternative studies were carried out to explore the feasibility of executing Luhri Hydro electric project in multi stages

2.1 Alternative-A: Development of project in two stages. The layout plan is attached as Plate-A.

2.1.1 Stage-I (265+24 MW) :-

Location	–	Dam at Nirath village and Power House at Khegsu Village.
Surge Shaft Dia.	–	55m
HRT	–	10.5m dia, 9.0 km long
Installed Capacity	–	265 +24 MW
Generation	–	1142 MU
Cost with IDC	–	3716 Cr.
(Jan'13 Price level)		
1st Year Tariff	–	Rs. 8.2 /kWH
Levelised Tarrif	–	Rs. 7.2 /kWH

2.1.2 Stage-II (342 MW):-

Location	–	Dam at Nathan and Power House at Marola Village.
Surge Shaft Dia	–	49m
HRT	–	10.5m dia, 15.5 km long
Installed Capacity	–	342 MW
Generation	–	1344 MU
Cost with IDC	–	4395 Cr.
(Jan'13 Price level)		
1st Year Tariff	–	Rs. 8.2 /kWH
Levelised Tarrif	–	Rs. 7.2 /kWH

2.2 Alternative B: Development of project in three stages. The conceptual layout plan of three stage development of Luhri HEP is attached as Plate-B.

2.2.1 Stage-I (209.5 +9.5 MW):-

Location	–	Dam with Toe Power House at Nirath.
Installed Capacity	–	219 MW.
Generation	–	868.9 MU.
Cost (with IDC)	–	2274 Cr.
(Jan'13 PL)		

1st Year Tariff – Rs. 6.5 /kWh

Levelised Tarrif – Rs. 5.8/ kWh.

2.2.2 Stage-II:-

a) Alternative- II-A (146+24 MW) with twin tunnels

Location – Dam at Kepu and Power House at Chewati.

HRT – Twin tunnels 5km long, 7.25 m dia each.

Installed Capacity – 170 MW (146MW +24 MW).

Generation – 680 MU.

Cost with IDC (Jan'13 PL) – 2604Cr.

1st Year Tariff – Rs. 9.6 /kWh

Levelised Tarrif – Rs. 8.44/ Kwh

b) Alternative- II-B (143 MW) : -

Location – Dam with toe power house at Kepu.

Installed Capacity – 143MW.

Generation – 569 MU.

Cost with IDC (Jan'13 PL) – 1809 Cr.

1st Year Tariff – Rs. 7.88 /kWh

Levelised Tarrif – Rs. 7.01/ kWh

2.2.3 Stage-III (326+13 MW) :-

Location – Dam and Toe Power House at Khaira Village.

Installed Capacity – 339 MW.

Generation – 1358 MU.

Cost (with IDC) (Jan'13 PL) – 2942 Cr.

1st Year Tariff – Rs. 5.4 /kWh

Levelised Tarrif – Rs. 4.8/kWh

3. Conclusion -:

3.1 Alternative-A:- Two stage development of Luhri HEP has been ruled out due to following reasons:-

3.1.1 It involves construction of 24.5km HRT (9km in Stage-I and 15.5 km in Stage-II), which does not resolve the concerns of local people regarding drying up of long stretch of river Satluj.

3.1.2 Surge shafts of diameter about 55m and 49m have been envisaged in Stage-I and Stage-II respectively, which may be difficult to construct in given geological conditions.

3.1.3 In stage-II, 12km state highway was to be submerged out which 8km was on right bank & 4 km was on left bank of the river.

3.1.4 Relatively high cost & levelised tariff in both stages.

3.2 Alternative-B: - Three stage development of Luhri HEP has been adopted on the basis of techno economical & social/environmental reasons**.**

3.2.1 Stage-I: - The Dam axis & reservoir of Stage-I have been kept same, as it was provided in single stage development of Luhri HEP. The detailed investigations of the dam area have already been done and no additional investigations may be required.

3.2.2 Stage-II: - The Alternative-II-B i.e. Dam with toe power house at kepu has been found more economical as compared to Alternative-II-A, hence adopted. In Stage-II detailed site investigations and geological investigations are required for DPR stage in addition to Environment, Forest and other statutory clearances.

3.2.3 Stage-III: - For Stage-III detailed site investigations and geological investigations are required for DPR stage in addition to Environment, Forest and other statutory clearances.

In view of the above, detailed description of Luhri HEP: Stage-I (209.5+9.5 MW) is given herein.

GENERAL LAYOUT

STAGE-I

2. GENERAL LAYOUT

2.1 General: -

Luhri Hydroelectric project Stage –I is located in Shimla district of Himachal Pradesh is a run of river type development proposed to harness the hydel potential of river Satluj. The project envisages construction of a 86m high concrete gravity dam at Nirath with one toe Power House on right bank (200MW) and another toe Power house at left bank (19MW).

Based on Preliminary design calculations civil components has been worked out , however dam has been kept same as in earlier DPR with minor modifications ,the sluices and overflow spillway have been rearranged in order to accommodate to power houses with minimum cutting of hill slopes. Diversion system shall remain same as was provided in single stage scheme of Luhri HEP (577 MW).

Detail design calculation shall be submitted at the DPR stage.

2.2 Main Components of the Project:-

2.2.1. River Diversion Works:

Two no's concrete lined, 10m diameter tunnels each having length of 2680 m have been envisaged for river diversion works. The requirement for the diversion tunnels is to pass up to 1,000m3/s in the construction stage and for passing surplus flows around the lower part of reservoir during operation.

2.2.2. Diversion Dam:

The 86 m high concrete gravity dam from deepest foundation EL 780 m , with an integral gated spillway has been provided. Spillway requirement of being able to discharge 13,462 m3/s.The design discharge requirement for the spillway is 13,462 m3/s. The radial gates 14 m high x 8m wide have been selected to keep the overflow section of the structure within the river channel. A total no. of 5 gates are required to pass the design discharge of 13,462 m3/s at the maximum reservoir level of El 862.9 m and one spare gate is provided in line with IS 11223. The top of dam is proposed as 866m, FRL as 862.9 m & MDDL as 860m. The length of the dam at top shall be 231.5 m consisting of 16 blocks in all (Refer Plates-C,D and E).

The proposed dam is divided in 16 blocks as follows.

Sl.No.	Description	Total length (m)	No. of blocks	Block no.	Remarks
1.	NOF section on left bank	66.9	4	1to 4	Total no. of Blocks = 16
2.	Intake blocks	81	5	3 to 4 &11,12,14	
3.	Over flow blocks	72	6	5 to 10	
4.	NOF section on right bank	92.6	6	11 to 16	

2.2.3. Intake Structure:

The intake structure comprising of five no. intakes, proposed in the dam body itself with a row of trash rack piers having trash racks up to FRL is proposed to be provided in front of intake blocks.

On the right side 3 No. Intakes with C/L EL 846.5 m has been provided in NOF blocks to pass discharge of 515 Cumecs with opening size of 9.5m x 7.2m .

On the left side 2 No. Intakes with C/L EL 852.0 m has been provided in NOF blocks to pass discharge of 50 Cumecs with opening size of 7m x 5m.

2.2.4. Pressure Shaft:

Five nos. of pressure shaft, proposed in the dam body itself. 3 No. Pressure shafts on the right side has been provided in NOF blocks to pass discharge of 515 Cumecs, having length 95m and dia. 6m each. 2 No. Pressure shafts on the left side has been provided in NOF blocks to pass discharge of 50 Cumecs ,having length 95m and dia. 1.9m each (Refer Plates-I&J).

2.2.5. Power House:

Surface toe power houses with size of machine hall as 107.5 m (L) x 45.5 m (W) x 60 m (h) and 40 m (L) x 16 m (W) x 39.5 m (h) on right and left bank has been provided for installed capacity of 200 MW (3 x 66.67 MW) and 19 MW (2 x 9.5 MW) respectively (Refer Plates – K to O).

Detailed description has been provided in the electromechanical chapter.

2.2.6. Tailrace Channel: -

Tail race channels have been envisaged in both the banks to rout the tail water from both the power situated on the right & left banks of the river Satluj respectively.

2.3 Salient Features Stage- I

2.3.1 Location

State	Himachal Pradesh
District	Shimla
River	Satluj
Vicinity	Dam & surface toe power house near Nirath on NH-22.

2.3.2 Hydrology

Catchment area at Dam site	51600 Sq.km
Design Flood (PMF)	13462 cumecs

2.3.3 River Diversion Works

Diversion Tunnel Dia/Length	10.0 m/ 2680 m
No. Of tunnels	2
Coffer Dam	2 No's
Type	Rock fill with cut off wall

2.3.4 Reservoir

FRL	EL 862.9 m
MDDL	EL 860.0 m
Gross Storage	35 MCM
Length	7 km
Area of reservoir	153.05 ha

2.3.5 Diversion Dam

Type	Concrete Gravity
Top of dam	EL 866.0 m
Height from deepest foundation	86 m
Total length at top	231.5m
Min river bed level at dam axis	EL 811.2 m
Deepest foundation level	EL 780.0 m

2.3.6 Sedimentation Arrangement

Particle size to be excluded	+ 0.1mm
Type of arrangement	Reservoir sedimentation with bye pass tunnels

Flushing discharge	500 cumecs- 1500 cumecs

2.3.7 Pressure Shafts

No. & type	5 nos (3 x 6 m dia + 2 x 1.9m dia) vertical
Type of lining	Steel lined
Length	95 m (approx.) each

2.3.8 Power Station Complex

Type	Surface toe power houses
Installed Capacity	200 MW (3 x 66.67) + 19 MW (2 x9.5)
Size of Power House (R/B)	107.5 m (L) x 45.5 m (W) x 60 m (h)
Size of Power House (L/B)	40 m (L) x 16 m (W) x 39.5 m (h)
Turbines	5 Nos, Francis turbines

2.3.9 Power Generation

90% dependable year with 95% machine availability – 868.93 MU (789.25 MU + 79.68 MU).

2.3.10 Cost of Project

Cost of civil works	1978 Crore
Cost of Electromechanical works	397.7 Crore
IDC & FC	301 Crore
Total cost with IDC	2274 Crore
Cost per MW	10.38 Crore

2.3.11 Tariff

First year tariff (Rs./Unit)	6.54 Rs./kWh
Levellised tariff (Rs./Unit)	5.78 Rs./kWh

GEOLOGICAL ASPECTS

STAGE-I

3. GEOLOGICAL ASPECTS

3.1. General: -

Luhri Hydro Electric Project Stage-I is located on the Satluj River in the districts of Shimla and Kullu Districts of Himachal Pradesh. The project is located in the Inner Lesser Himalaya between Dhauladhar range in the south and higher Himalaya in the north. The project envisage construction of a concrete gravity dam 86m high from deepest foundation level across river Satluj near Nirath village (31°19'N; 77°20'E), one power house (200 MW) on the right bank and another power house (19 MW) on the left bank.

3.2. Accessibility: -

The project site is located about 210 km from the nearest rail head at Kalka in Haryana and can be approached by NH- 22 via Shimla, Narkanda and Sainj.

3.3. Physiography and Geomorphology: -

The project lies in the Inner Lesser Himalaya between the Dhauladhar Range in the south and the Higher Himalayan Range in the north. The Satluj River is the main drainage in the catchment area with headwaters located in the highlands of Tibet. Geomorphologically the area is located in a young mountain chain which is characterized by rapid down-cutting. Hence, most of the valley slopes are steep and the Satluj River is confined within narrow V-shaped valleys with little or no flat areas close to the river bed. The only exception to this is several kilometres upstream of Nirath where the valley opens out due to more rapid erosion of softephyllitic rock units this reach is the designated reservoir area of the project.

3.4. Regional Geology: -

The project area lies in Inner Lesser Himalayas SSW of main central thrust. The stratigraphy established for the Lesser Himalayas of the Satluj Valley is given below.

Stratigraphy for Lesser Himalaya in Satluj Valley along Satluj River		
Geological age	Group	Lithology
Holocene	Newer Alluvium	Boulder, pebbles, coarse sands-younger terraces (T1) and river channels.
Middle to Upper Pleistocene	Older Alluvium	Boulder, pebbles, coarse sands- older terraces (T2)
Palaeoceneto Early Eocene	Subathu (Kakara)	Bansal pisolitic laterite, quartz arenite, variegated shales & massive to thin bedded limestone
Mesoproterozoic to Neoproterozoic (II)	Jutogh (Kullu)	Carbonaceous to graphitic schist and phyllite with lenticular limestone & quartzite; quartzite, quartz schist; garnetiferous schist & quartzite with bands of marble & locally porphyroblastic gneiss, amphibolite;
	Shimla	Quartzite-shale-limestone at the base, shale siltstone alternations with limestone inter beds shale & siltstone alternations with orthoquartzite & greywacke; conglomerate, arkosic sandstone, protoquartzite, grey & purple shale at top
Paleoproterozoic	Rampur	Quartzite with penecontemporaneous mafic meta-volcanics intruded by Bandal Granitoid Gneiss
	Shali/Larji	Qrthoquartzite-carbonate sequence
	Sunder Nagar	Quartzite with penecontempraneous mafic volcanic (Mandi-Darla Volcanic)
Archaean	Zeori-Wangtu Granitoid Gneiss	Augen gneisses, mylonitic gneiss, porphyroblastic biotite gneiss with intercalated biotite, garnet, kyanite, sillimanite bearing schist bands intruded by prorpyritic and tourmaline granite, pegmatite and aplite.

3.5. Tectonics: -

Four distinct patterns of folding are identifiable in the vicinity of the project area. Chamba Syncline and Rampur Anticline are main structure features where as Main Central Thrust and Jutogh Thrust are major thrusts in the vicinity.

3.6. Geological studies at project site:-

3.6.1. Geological Mapping: -

The dam & power house site has been mapped on 1:2000 scale covering up to 1.5 Km d/s of the dam axis. The geological map & section along dam axis are appended as Plate-Q & R, whereas geological section along longer axis of right bank & left bank power house is appended as Plate-P.

3.6.2. Exploratory Drilling: - Dam & power house site have been explored by core drilling for a total depth of 2010.85 m. The details are as follows:

Drill Hole No. [Old Number]	Component	Location	El. (m)	Depth (m)	Remarks
DVH-1 [DH-2]	Dam Axis	On the right abutment along Dam Axis (Top of the Dam)	865.62	75.20	
DVH-2 [DH-1]	Dam Axis	On the left bank along Dam Axis (Top of the Dam).	869.14	70.20	
DVH-3 [DH-3]	Dam Axis	On the left abutment along Dam Axis.	843.38	100.10	Inclined 62^{O} towards river bed.
DVH-4 [DH-4]	Dam Axis	In the center of river bed along dam axis.	814.55	50.00	
DVH-5	Dam Axis	On the right bank along Dam Axis.	833.68	50.50	
DVH-6	Dam Axis	On the right bank of river in the river bed.	832.91	90.05	Inclined 52^{O} towards river.
DVH-7	Dam	Plunge Pool Area ±100 m d/s of Dam Axis on the right bank.	815.26	50.30	
DVH-10	Dam Axis	In the river bed at dam axis between DVH-4 & DVH-5	817.65	50.00	
DVH-11	Dam body	Located at right bank 40m d/s of Dam Axis.	835.27	50.10	
DVH-12	U/s Coffer Dam.	380 m U/s of Dam Axis on left bank.	815.20	50.00	
DVH-13	D/S Coffer Dam	160 m D/s of Dam Axis.	810.15	50.50	
DVH-14	U/s Coffer Dam.	1600 m U/s of Dam Axis.	822.13	50.50	
DVH-15	Overflow Section.	75 m U/s of Dam Axis in the river bed.	812.60	117.70	
DVH-16	Overflow Section.	80 m D/s of Dam Axis in the river bed.	811.50	117.00	
DVH-17	Overflow Section.	150 m U/s of Dam Axis in the river bed.	813.20	118.80	
DVH-18	Non-overflow Section.	150 m U/s of Dam Axis on right bank.	826.55	132.00	
DVH-19	Non-overflow Section.	70 m U/s of Dam Axis on the right bank.	829.17	135.70	
DVH-21	Non-overflow Section.	150 m D/s of Dam Axis on the right bank.	831.85	137.50	
DVH-22	Non-overflow Section.	250 m D/s of Dam Axis, along Block No.15 on the right bank.	835.00	140.50	
DT-V1	Diversion Tunnel-I	Located on the Inlet Portal of DT-I 600 m U/S of Dam Axis.	885.51	86.50	
DT-H1	Diversion Tunnel-I	Located on the Inlet Portal of DT-I- 1600 m U/S of Dam Axis.	829.78	50.50	Horizontal
DT-V2	Diversion Tunnel-II	Located on the Inlet Portal of DT-II- 1600 m U/S of Dam Axis.	±884.5	86.20	
DT-H2	Diversion Tunnel-II	Located on the Inlet Portal of DT-II- 1600 m U/S of Dam Axis.	830.77	50.30	Horizontal
DT-V3	Diversion Tunnel	Located on the center of the two outlet portals of DT± 216 m D/S of Dam Axis.	846.53	50.50	
DT-H3	Diversion Tunnel	Located on the center of the two outlet portals of DT ± 216 m D/S of Dam Axis.	833.76	50.20	Horizontal
		TOTAL DRILLING- 2010.85 M			

Location of these drill holes is shown in Plate-P.

3.6.3. Exploratory Drifting: -

The dam abutments have been explored by 2 drifts (50 m each) of 1.8 x 1.8m, one each on each bank for a total length of 100m. The details of drifts are as follows:

3.6.3.1. Right Bank Drift (DT-1):-

50m long drift is located 30m downstream of dam axis at an El. 833m and is driven in N50ºW direction. The rock in the drift is also augen gneiss. This augen gneiss at places contains feldspathic rich patches, which after being intersected by joints give rise to pulverized and crushed rock material consisting of loose quartz and clayey minerals. In addition to foliation which is dipping inside the hill at gentle angle, two other joint sets have been recorded.

No major shear zones have been recorded in this drift except 5-6 Nos. shear seams of less than 10cm thickness. The general rock conditions fair to good and the drift is self supporting in nature. The drift has encountered dry condition in general except some drifting at places.

3.6.3.2. Left Bank Drift (DT-2):-

50m long drift is located 15m downstream of the dam axis at El. +827m and is driven in S50OE direction. The rock in the drift is augen gneiss, wherein well developed augens of about 1cm to >5cm could be recorded at site. The rock is hard and compact & with signs of either nil or very feeble alternation. In addition to foliation which is dipping inside the hill at a gentle angle, there are two other steeper joint sets.

No shear zone / seams in this drift have been recorded except 2-3 shattered rock zones at Rd. ±41 and 48m. Fair to good rock conditions have been encountered in this drift and the drift is self supporting. At the time of logging, the drift was dry to moist up to 13.50m. Heavy dripping between 13.50 to 17.00m was noticed and rest of the length has encountered moist to dry rock conditions.

3.6.4. Geophysical Survey: -

Geophysical Survey at the project site include a total of 13 number vertical electrical soundings out of which 4 nos. were at dam axis on right bank, 3 nos. along an axis at 100m downstream to dam axis at right bank, 2 nos. upstream to dam axis at right bank and 4 nos. on left bank in upstream from dam axis. Studies indicate that the thickness of overburden on dam axis varies from 7.4 to 18.1m, and at 100m downstream along dam axis at right bank varies from 14.7 to 32.4m. In general the observed resistivity values along dam axis indicate the presence of

competent nature of the bedrock except at along two sounding located on right bank in which a conductive zone at the depth of 26.8 & 16.7m (resistivity range 180-460 ohm- m) respectively has been noticed. This conductive zone may correspond to a highly fractured / jointed rock. Such conductive zone has not been found in downstream but it is very much present in the upstream (right bank). It seems that this is the same zone which has been encountered in the drill holes done at right abutment of the dam (DVH-1, 5 & 11). The electrical soundings & seismic refraction survey have been conducted at four places on left bank in the upstream of dam axis. The compact rock in the upstream of dam axis at left bank has been found to vary from RL 686.8 to RL 793.6m and deepest being U/s of dam axis. The overburden material and thick column of highly jointed / sheared rock having resistivity of the order of 200 ohm are overlying the inferred compact rock. The P-wave velocity of 4500 m/sec for the compact rock and around 3000m/sec for sheared rock has been observed.

3.6.5. Laboratory Tests & Petrography: -

Ten numbers of rock & core samples were collected form exploratory drifts and drill holes & laboratory tests & Petrography studies were done for 6 samples.

3.6.6. In Situ Tests: -

Tests (In-situ shear test and plate load tests) have been carried out to determine the deformability and shear strength parameters in the right & left bank drifts near dam axis.

3.7. Geology of Dam & Power House: -

The 86m high dam at Nirath would be located across Satluj River 24m d/s of existing Foot Bridge. The river Satluj at Dam site flows from NE-SW at approximately 810 mad (Meters above Datum). The valley at dam site is wide with gentle slopes. Rock exposed on the both abutments is augen gneiss of Jutogh Group. The foliation on right bank strikes E-W to NE-SW and dipping N to N30°-40°W with an amount of 20°-25° whereas on the left bank the foliation strikes NW-SE to N17°E-S17°W dipping N-E to Easterly with an amount of 10°-20°forming an anticline along the river. Such anticlinal valleys are common in Himalayas. Augen gneiss is massive & strong forming sound abutments. Two prominent joint sets recorded are: a) Dip of 70° to 80° in S30°-40°W Direction & b) Dip of 80° in N35°E Direction. The foliation on the both abutments is favorable for dam foundation.

The main power house (200 MW) is located on the right bank with its central line 94 m D/S of Dam Axis where as a second Power house (19 MW) is purposed on the left bank to utilize environmental discharge with its central line ± 83.5 m D/S of Dam

Axis. The left bank was explored by one vertical and one inclined drill hole. The drilling on the left bank (DVH-2 & DVH-3) revealed competent bedrock comprising of augen gneiss.

The lugeon values for drill holes DVH-2 & DVH-3 located on left abutment computed from water percolation ranges from 1.17 to 19.14 & .86 to 4.34 respectively.Right bank have been explored by 3 holes (DVH-1, DVH-5 & DVH-6) at the dam axis & by one downstream hole (DVH-11). Hole DVH-1drilled from the top of dam at an El 865.624 encountered 9 m of RBM and a 10-13m thick soft and sheared zone (between El. 813.125 to 800.125m) with very poor recoveries. The remaining depth of the hole encountered good augen gneisses. A soft zone have also been recorded (partial thickness) in the drill hole DVH-5 (between El 828.6 to 825.1m & 811.6 to 810.1m) done on right bank of dam axis at an El 833.6m. To know the strike extension of this soft & sheared zone, a vertical drill hole (DVH-11) was done at 45m downstream of dam axis on right bank at an El. 835.27m as per CEA / GSI advice. A soft, sheared/ shattered zone was recorded between El. 803.77 to 796.27 m depth in DVH-11 which appears to be another shattered zone. It seems that these shattered zone/low RQD zones are parallel to foliation. The lugeon values of drill holes DVH-5 &DVH-6 drilled on the right abutment computed from water percolation tests ranges from 0.69 to 2.25 & 0.76 to 4.99 respectively.

The river channel have been explored by hole DVH4 & DVH-10 the drill hole DVH-4 has recorded 28.5 m of river deposits underlain by sound bedrock (augen gneiss) at an El. 784.5 m. The lugeon values computed from water percolation test in the hole DVH-4 ranges from 0.032 to 3.07. Another hole DVH-10 drilled in the river channel towards right bank along the dam axis (located between hole DVH-4 & DVH-5) has encountered 15m river deposit underlain by sound bed rock comprising of augen gneiss. This hole (DVH-10) was done to know the exact configuration of rock overburden contact in the river channel as per CEA / GSI advice.

A drill hole (DVH-7) located 80 m downstream of dam axis in the plumb pool area (towards right bank) in the river channel have encountered river deposit for 29m depth followed by bed rock consisting of augen gneisses upto total drill depth i.e. 50.30m.

4 No. holes (DVH-18 to 19 & DVH-21 to DVH-22) done for Non-Overflow Section on the right bank have encountered gneiss for its entire length with closely jointed zones possibly parallel to foliation, 3 No. Drill Holes (DVH-15 to DVH-17) have been done along overflow section in the river bed. The rock in general in fresh augen gneiss with few weathered patches except for a shattered/closely jointed zone in one of the holes.

The inlet portals of diversion tunnels located approximately 2000m upstream of dam on right bank have been explored by two vertical holes (DT-V1 & DT-V2) and 2 horizontal holes (DTH-1 & DTH-2) two each on each portal. Holes have indicated fresh Augen gneisses. Similarly, outlet portal of DT have been explored by one vertical holes (DT-V3 & on two horizontal holes (DT-H3) indicating from Augen Gneisses rock.

Centreline of the main toe power house lies on the right bank ± 95m D/S of the Dam axis. As it is just on the toe of the dam, the same geological conditions will be encountered. The main rock will be augen gneisses quite strong. The foliation dips inside the hill at gentle angle with moderate to steeper joints dipping towards the valley.

The small power house (19 MW) located on the left bank also has its centreline at ± 95m D/S from Dam Axis. The rock exposed is augen gneiss quite strong. On this bank foliation dips inside the hill at gentle angle besides one steeper joint dipping towards the valley.

3.8. Geological assessment of the Dam: -

The Dam site is located in augen gneiss rock and the river course is along a gentle anticlinal axis with foliation joint dipping inside the hill on both the banks at a gentle angle (10°-25°). The maximum overburden depth in the river channel along the dam axis is 28.5m at the center of the river and 15 m towards the right bank as indicated by drill holes. The river bed level is at ± 813. The deepest rock overburden at El. 784.50. The foundation grade rock at the center of the river along dam axis is expected between elevation 777 m- 778 m overburden in the river towards the d/s of dam axis (around 80 m D/s) is of the order of 29 m. Fracturing and weak shattered zones may be encountered during foundation excavation besides pot holes.

This may require additional treatment during foundation concreting contain some pockets of feldspathic/micaceous minerals bounded by joint and other weak zones are also expected in the foundation. This may give impression of fractured/shattered zones and may also be water saturated at places. The rock based on Q-value broadly comes under “Fair” to “Good” category. Soft and sheared one encountered in the drill holes in the right abutment, (dipping inside the right abutment) as well as observed during geophysical studies will be exposed during the excavation of right abutment of dam & will require treatment.

On the right bank gentle, long continuity joints (and alike shears) dipping into the valley are predominate. Left bank has good augen gneiss rock. 3-D Geological Log of drifts at both banks show open joints of order of 2-15cm filled with rock fragments

and clayey material. These seem to be glide cracks and they may require proper slope stabilization treatment during excavation of dam abutment. The rock in the drifts on both the banks being Fair to Good the depth of stripping is as per the design requirement which is 8 m on the left abutment and 10 m on the right abutment. Both the coffer Dams have been explored by one drill hole each. The depth of RBM in the river at U/S coffer dam is 42 m & at D/S coffer dam it is 31.50 m.

Two numbers Diversion Tunnel-cum-Desilting Tunnel of 2.6 Km length located at right bank have an average over cover of about 227m and will encounter augen gneiss. The foliation joints are dipping 35º: S30ºE direction in the vicinity of inlet portal and towards NW in the downstream side till outlet portal. Other two joint sets are dipping 76º: S50ºE and 88º: S24ºW. Fair to good tunneling condition are expected in general with some poor to very poor patches along the soft and sheared zone encountered in the holes done on the right abutment of dam which is likely to intersect the diversion tunnels.

At the outlet portals of both the diversion tunnels thick overburden is expected. It is proposed that during construction of tunnel from outlet portal initially open channel will be made with gentle side slopes of 30°–35° (where rock is very deep) followed by cut and cover in the area where rock is at shallow depth (5-6m) till the original rock is encountered.

3.9. Reservoir: -

The area likely to be submerged by the proposed project is about 153.05 ha, which is mainly under agriculture, settlements and degraded forest. The vegetation of the submergence area is sparse and is comprises of Tropical dry deciduous forest. From dam axis upto an aerial extent of ~2.30 Km upstream the reservoir valley slopes are of Garh- Manjrot Formation. The Garh-Manjrot Formation is an intrusive body into the Kulu Group. It is a quartzose, banded and streaky gneiss, pale greyish green with alternate beds of schist, quartzite and carbonaceous phyllite. It is strongly foliated and mylonitised with elongated augens of feldspars and coarse grains of bluish quartz standing out prominently.

Minor shear bands to the order of 5 -10cm thick rails on either bank to an extent of ~ 2 km along the narrow valley with 35/25°-30°→310˚ plunge towards upstream. The shear bands have ~2.5cm open shear joints, dry condition. The loose gouge is weathered out.

3.9.1. Right bank: -

The right bank slope from dam axis upto the thrusted contact has modified slope varying from rocky cliff to steep slope and moderately steep slope. The rocky cliff exposed at the top followed by steep slope and moderately steep slope towards the valley. The moderately steep slope face has debris cover of 0.60 - 2m on average. The lower slope face close to the river is exposed with in situ parent rock that confirms the sound rock condition at the slope toe.

From river bed up to an elevation of 900m slope is covered with thin debris cover of 0.5m and sparse vegetation. Debris material composed of angular rock block size ~1m which are slided from uphill slope. Rest is RBM and terrace material 6-10m thick with sand pockets at places. RBM showing grading at different elevations. Beside foliation, 2-3 sets of joints have been identified.

3.9.2. Left bank:-

The left bank slope is comparatively moderately steep with the absence of rocky cliffs. The slope is modified with varying slope angles, varying from 30˚- 40˚ -55˚& 60˚. Moderately steep slope generally on average covered with 1- 2m of debri, followed by gentle to moderately steep slope with agricultural terrace and settlements. Beside Foliation there are 2 sets of joints and a random joint.

The gnessic rocks exposed the right bank hill slope is hard compacted rock mass. At the dam site are the rockmass is compact and provide suitable foundation condition. The attitude of foliations provides stable abutment conditions and suitable reservoir conditions. As a common natural phenomenon the hill slope will experience subsidence and sinking during the initial impounding stage. The slope under submerged condition may suffer stability problem during drawdown condition which can't be ruled out. But provided the hills slope is covered with less debris and presence of insitu rocks at the river bed level, right bank slope of reservoir on gneissic formation is stable. Study is going on far left bank slopes.

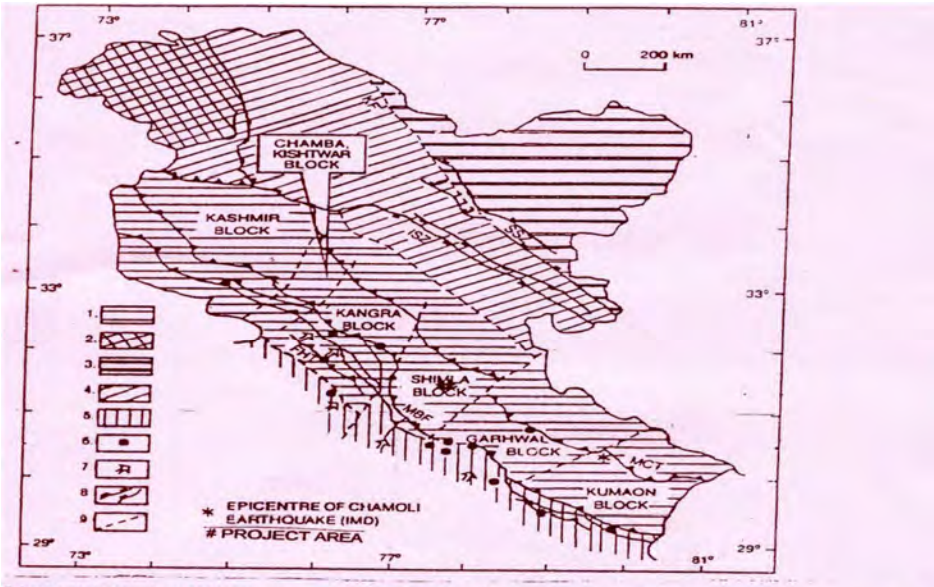
3.10. Geotechnical Assessment of Power House and TRT: -

A geological section along the longer axis of both the power house is enclosed as Drg. No. SJVN/LHEP (Stage-I)- INCEPT/GEO/03/15. The holes done for dam body, overflow & non overflow section indicate presence of hard augen gneiss at the proposed invert of the main power house (Elevation 802 ±) closely/highly jointed zone of low RQD rock Inside the longer axis of the power house on indicated by the drill holes in the vicinity of the power house. The hill slopes behind the power house which will be 40-50 m high needs to be excavated very carefully with concurrent

support on the valley dipping joints may destabilize the slopes during excavation. The TRT Channel of the main power house will initially lie in over burden and subsequently in the rock. A closely jointed zone may cross the TRT Channel at acute angle.

3.11. Seismicity: -

Himachal Pradesh falls in the Himalayan region, which is one of the more seismically active regions in the world. The Project area lies in the Shimla Block of the Main Himalayan Seismic Zone domain of NW Himalayan seismic belt (Narula et al. (2000) the project falls in Earthquake Zone V in accordance with the Seismic Map of India (IS:1893:1984). It is demarcated by the Main Central Thrust in the north and the Main Boundary Fault/Thrust (MBF/MBT) in the south, and limited in east and west by interpretative fundamental transverse faults. The Kangra Block lies to its west and the Garhwal Block in the east.



Seismotectonic domains of NW Himalayan seismic belt. 1. Main Himalayan Seismic Zone (MHSZ); 2. Kashmir Svantaxial Seismic Zone (KSSZ); 3. High Plateau Seismic Zone (HPSZ); 4. High Himalayan Seismic Zone (HHSZ); 5. Foot Hill Seismic Zone (FHSZ); 6. Specific locations where neotectonic activity has been recorded; 7. Direction of crustal shortening during Quaternary; 8. Suture Zone; 9. Block boundary based on geological/geophysical/tectonic flux attributes. SSZ- Shyok Suture Zone; ISZ- Indus Suture Zone; KF- Karakorum Fault; MCT- Main Central Thrust; MBF- Main Boundary Fault; FHT- Foot Hill Thrust. (After Narula et al. 2000)

HYDROLOGY

STAGE-I

4. HYDROLOGY

4.1. General:-

The climatic conditions of the Satluj River basin are strongly influenced by orthographic effects. The boundary between areas receiving mostly precipitation in the form of rain and those receiving mostly snow is at an elevation of (approximately) 1,525m. The catchment covers approximately 51,600 km^2 and 70% of this is largely snow bound.

The catchment receives precipitation due to the South-West monsoon as well as the western disturbances that pass over the north-west part of the country during winter. The South-West monsoon generally lasts from June to September, but may occasionally extend up to early October. During this period rainfall is generally not heavy but at times snowmelt contributes significantly to flood runoff, with maximum flows occurring between June and August. The winter precipitation falls either as rain or snow depending upon altitude and other meteorological conditions and may be very heavy on occasions but does not usually contribute directly to river discharge significantly and mostly goes to feed the snow glacier bound areas of the catchment.

A map of the Satluj River basin is shown in Figure 4-1.

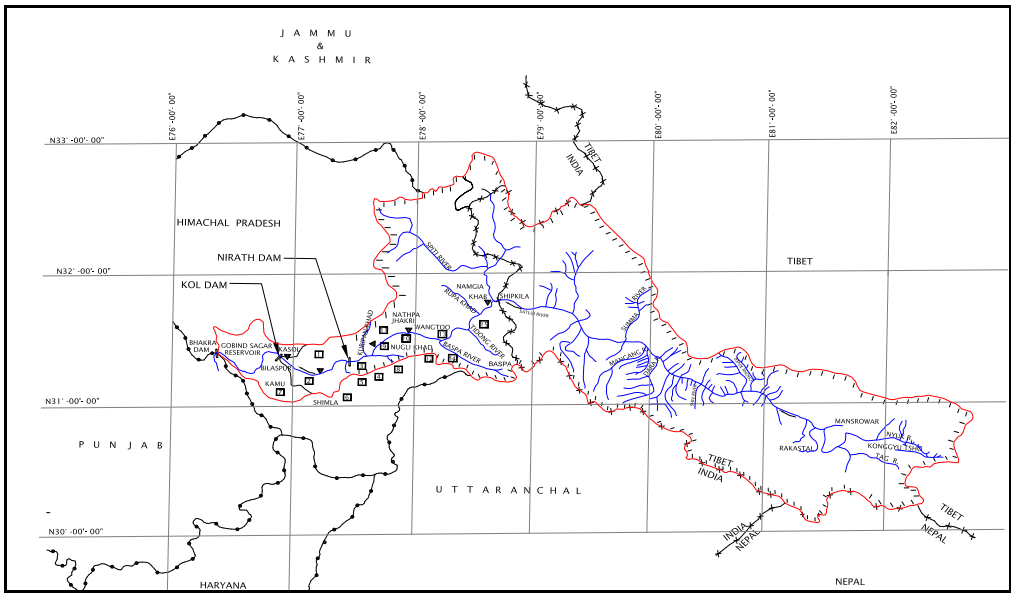


Figure 4-1 Satluj Catchment

4.2. Hydrometeorology data

Data are available for the Satluj catchment within India for the following recording stations:

- Precipitation – stations at Purbani, Kalpa, Sangla, Kilba, Nichar and Rampur (long term rainfall records and snow observations from 1984).
- 20 rain gauge stations in the catchment of the Satluj River upstream of Bhakra.
- Temperature observations at Kalpa and Jeori from 1984.
- River gauging stations on the Satluj River at Bhakra Kasol, Sunni (1963 to 2006)[1], Rampur (1962 to 2006)1, Wangtu, Karcham, Thopan and Khab.
- River gauging stations on several of the tributaries of the Satluj including the Spiti, Baspa, Bhaba, Sholding, Ghanvi, Sir, Sukar and Sari Hydli Khad.
- Locations of the stations in the Satluj Catchment are shown on Figure (stations on the adjacent Beas Catchment are also shown in this figure).
- No data are available for the part of the catchment within Tibet for this part of the study. This area receives its precipitation largely in the form of snow.

Figure 4-2 Hydro meteorological Stations in Satluj - Beas Catchment

[1] Established by Bhakra Beas Management Board (BBMB)

4.3. Precipitation: -

There are at present twenty rain gauge stations in the catchment of Satluj River upstream of Bhakra, at which long term records are available. The relevant details of these stations are given in **Table 4-1**

Table 4-1 Details of Rain Gauge Stations

	Name of Station	Year of Commencement	Altitude	Average Rainfall
			m	mm
1	Bilaspur (Sadar)	1954	580	1104
2	Bilaspur (Obs)	1957	587	1226
3	Ghumarwin	1958	637	1215
4	Arki	1951	1219	1228
5	Suni	1956	510	978
6	Shimla	1956	2065	320
7	Karsog	1951	1890	978
8	Theog	1958	2286	1040
9	Shillaru	1952	2590	1280
10	Kotgarh	1955	1828	963
11	Kumarsain	1951	1388	813
12	Khadrala	1951	2957	1974
13	Rampur	1951	1067	924
14	Fancha	1951	2071	2291
15	Nichar	1951	2195	997
16	Kilba	1951	1707	823
17	Baspa	1974	2550	760
18	Sangla	1951	1986	820
19	Kalpa	1951	2771	673
20	Purbani	1951	2195	580

48% of the annual precipitation occurs during the Indian summer monsoon from June to September. During this period the rainfall is some 40% more between Rampur and Bhakra than above Rampur. For the remainder of the year there is more precipitation above Rampur. This annual distribution of the rainfall is illustrated in **Table 4-2.**

Table 4-2 Annual Distribution of Rainfall

Catchment	Average Rainfall (mm)				
	June-Sep	Oct-Nov	Dec-Feb	Mar-May	Total
	4 Months	2 months	3 months	3 months	12 months
Bhakra to Rampur	670	52	190	149	1061
Rampur to Shipkilla	470	60	220	220	970

4.4. Temperature: -

Maximum and minimum daily temperatures are being recorded by a number of agencies in the Satluj Catchment as shown in **Table 4-3.** Temperature observations have also been started at Kalpa and Jeori from 1984. The maximum and minimum temperatures recorded at four of those stations are given in **Table 4-4.**

Table 4-3 Temperature Observing Stations

Station	Altitude	Year of Commencement
Bhakra	400 m	1946
Bilaspur	580 m	1956
Rampur	930 m	1967
Wangtu	1525 m	1971
Powari	1990 m	1971
Sumdo	3245 m	1973

Table 4-4 Maximum and Minimum Temperatures

Station	Maximum Temperature ° C	Minimum Temperature ° C	Years
Shimla	30	-7.2	1956-70
Bilaspur	45	-2	1956-70
Kalpa	27	-9.5	1984-85
Jeori	40	-3	1984-85

4.5. Evaporation: -

No evaporation measurements are available in the catchment above Rampur. However, observations have been made at Bhakra. The average monthly evaporation based on 10 year observations is given in **Table 4-5**. It is understood that these evaporation rates are based on standard USA open pan-evaporimeters.

Table 4-5 Evaporation Data

Month	Evaporation (mm)
Jan	50
Feb	60
Mar	110
Apr	190
May	260
Jun	230
Jul	130
Aug	100
Sep	110
Oct	100
Nov	70
Dec	50
Total	1460
Mean	120

4.6. River Flows:-

There are seven river gauge and discharge sites on the main stem of the Satluj River up to Bhakra dam; their details (catchment area and period of data availability) are shown in **Table 4-6.**

The longest period of record is from 1909 at Onlinda (Bhakra) (no.7). However, the discharge observations from 1960 onwards are made from Gobind Sagar level fluctuations and releases through the power house unit and through spillway/irrigation outlets.

A gauging station was established in 1966 at Kasol (no.6), upstream of Bhakra. Initially the observations were made by float, but current meter observations commenced in 1984. The gauging site at Rampur (no.4), maintained by BBMB, was established in June 1963. The stream flow data were initially measured using a current meter and subsequently using floats.

No Central Water Commission discharge observation site is available in the catchment above the Rampur project site.

Table 4-6 Gauge and Discharge Sites

Location	Catchment Area (km^2)			Availability of Data
	Tibet	India	Total	
1. Satluj at Khab	34505	150	34655	1972 to 2002
2. Spiti at Khab	2395	7085	9480	1972 to 2002
3. Wangtoo/ Nathpa Dam site	36900	12920	49820	1966 to 2004
4. Rampur	36900	13980	50880	1963 to 2006
5. Sunni	36900	16015	52915	1963 to 2006
6. Kasol	36900	16870	53700	1963 to 2006
7. Onlinda / Bhakra Dam	36900	19975	56875	1909 to 1965

Since 1970 state Government staff have regularly measured the discharge of Shoulding Khad, which has a catchment area of 86 km^2 and joins the Satluj River between Nathpa and Jhakri power house on the left bank. However, since 1987 CWC have disregarded discharge data from this point, as they were inconsistent and inaccurate.

A gauge was established at the Nirath site by SJVN in March 2005 when that site was identified for the project. Whilst there are no long term flow records for Nirath there are four gauging stations on the Satluj River with catchments of a similar size (within 5%) to Nirath **(see Table 4-7**). The closest, at Rampur, has a catchment which is 1.4% smaller.

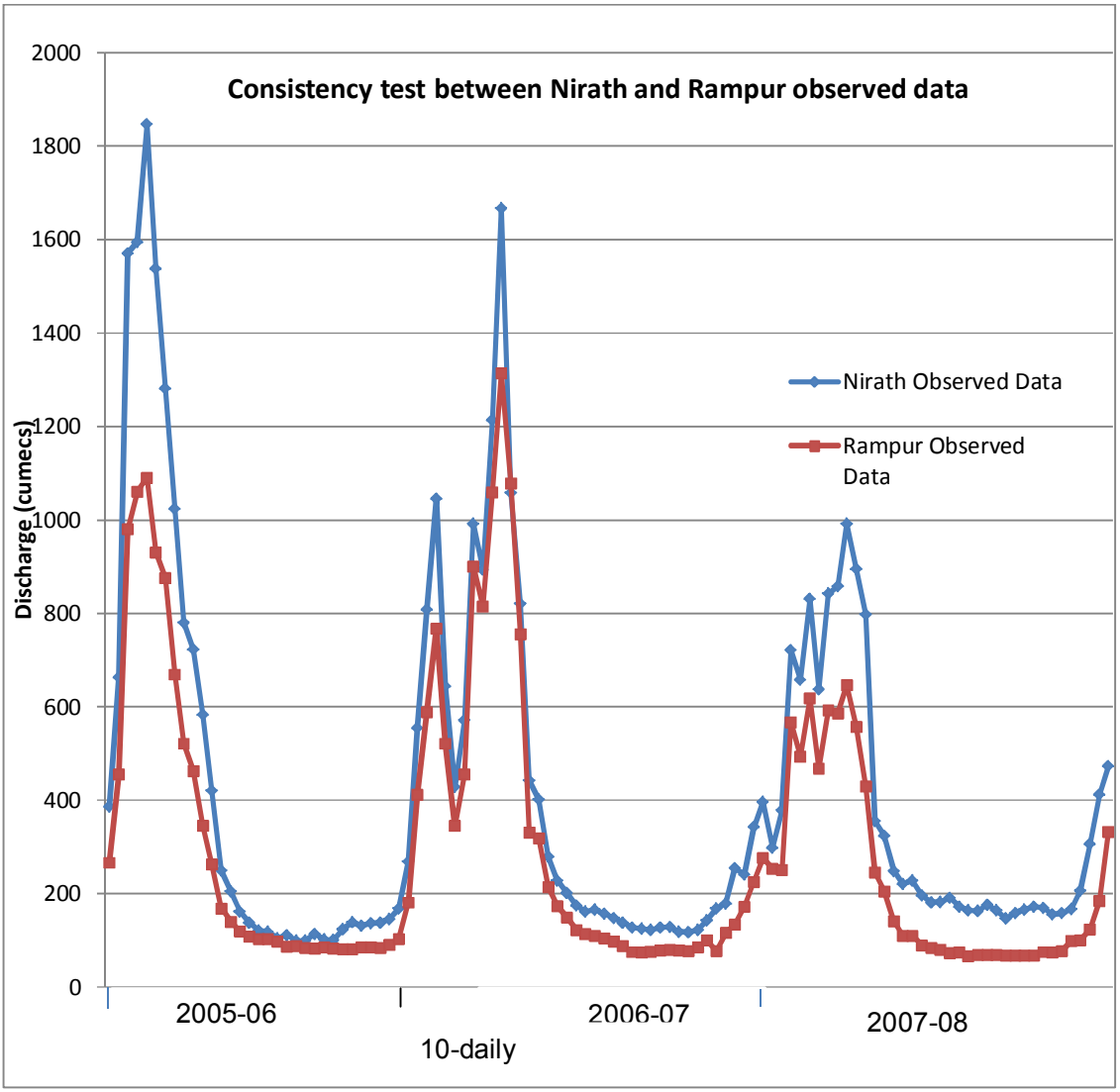
Table 4-7 Catchment Areas

Gauging Station	Catchment Area	Ratio to Catchment Area at Nirath
Nathpa	49820 km^2	0.966
Rampur	50880 km^2	0.986
Nirath	51600 km^2	1
Sunni	52915 km^2	1.025
Kasol	53700 km^2	1.041
Kol	53770 km^2	1.042

4.7. Water availability for generation:-

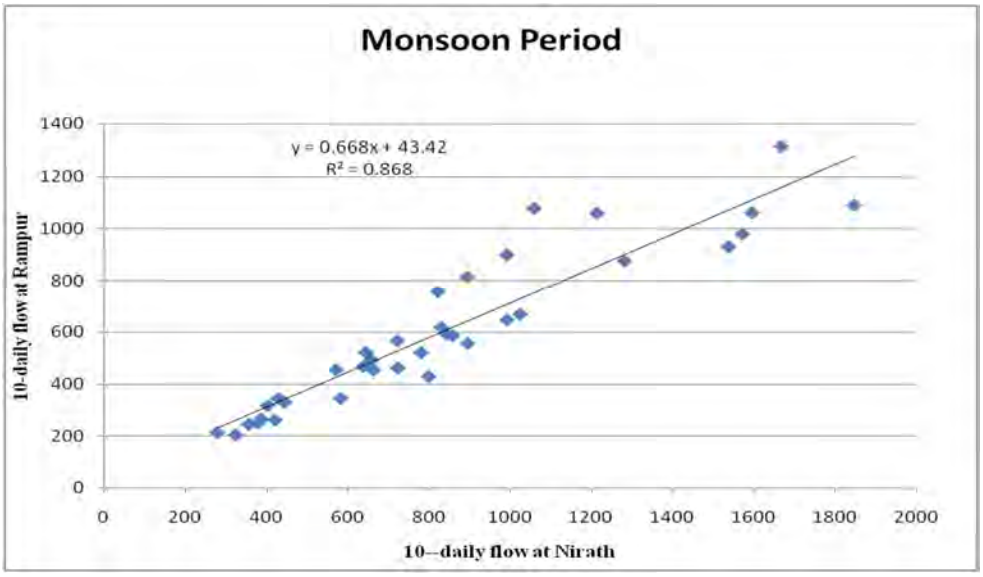
The water availability series for dam site at Nirath from year 1972 to 2008 was developed based on the methodology suggested by CWC (refer Annex-III) using Rampur & Khab data and the same has already been approved by CWC (refer Annex-III). However, the water availability series at Nirath has been updated up to year 2014 using following methodology.

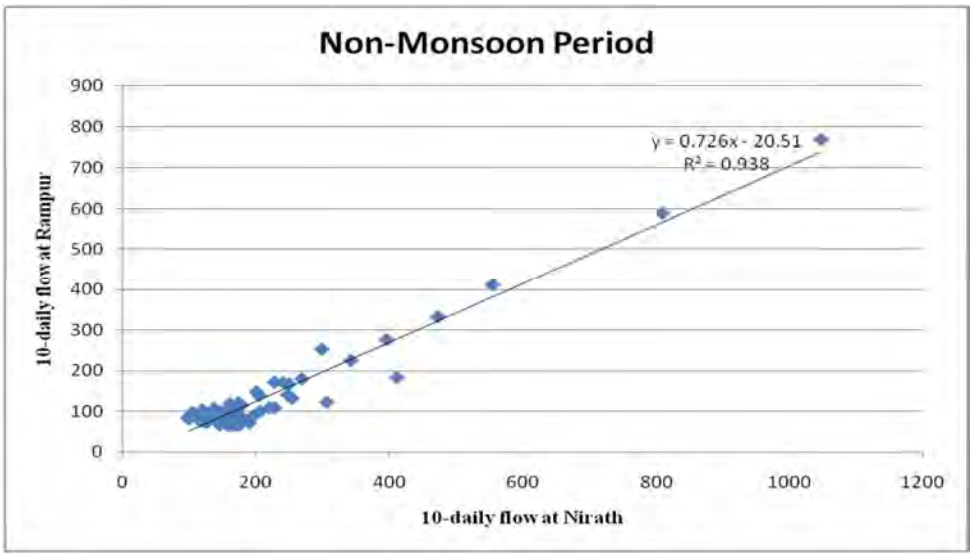
- From year 2005 to 2008, the discharge data was available for Rampur and Nirath. Consistency check has been carried out between Rampur & Nirath data and the same has been found consistent.



- Subsequently, regression analysis has been carried out based on the Nirath data available from year 2005 to 2008.

Regression analysis and consistency check between Nirath and Rampur Discharges							
Month	**Ten Daily**	**2005-06**		**2006-07**		**2007-08**	
		Nirath Observed Discharge	**Rampur Observed Discharge**	**Nirath Observed Discharge**	**Rampur Observed Discharge**	**Nirath Observed Discharge**	**Rampur Observed Discharge**
		m^3/sec	**m^3/sec**	**m^3/sec**	**m^3/sec**	**m^3/sec**	**m^3/sec**
June	I	386	267	644	521	378	252
	II	663	455	429	345	722	567
	III	1571	980	571	455	658	494
July	I	1595	1061	992	900	831	618
	II	1847	1090	894	815	638	468
	III	1538	931	1214	1059	843	593
August	I	1281	876	1668	1314	858	587
	II	1024	669	1059	1078	992	647
	III	781	521	822	757	894	557
September	I	723	463	443	332	799	430
	II	583	346	402	319	355	246
	III	420	263	279	215	323	206
October	I	250	168	229	173	248	142
	II	205	140	202	149	221	110
	III	162	120	175	123	229	110
November	I	138	109	162	114	196	90
	II	121	104	165	110	181	85
	III	119	103	156	105	183	81
December	I	105	98	148	98	191	73
	II	111	87	138	88	172	74
	III	100	88	128	76	164	67
January	I	99	84	125	74	163	69
	II	114	83	122	77	176	69
	III	102	86	127	79	165	70
February	I	101	83	129	81	147	68
	II	124	82	118	79	158	68
	III	139	82	117	78	166	68
March	I	132	85	122	85	172	68
	II	136	85	143	100	169	75
	III	138	84	168	78	155	74
April	I	146	91	179	116	159	78
	II	169	103	255	134	168	99
	III	269	181	241	172	207	101
May	I	554	412	343	226	307	124
	II	808	589	396	277	412	184
	III	1046	768	299	254	473	333





- Based on the above analysis, water availability series at Rampur was extended from the year 2008 to 2014 and is enclosed as Annex-IV.
- In India the hydropower potential of the scheme is based on the 90% dependability year expressed in terms of the annual run-off.
- The 50% dependability year has been indicated in addition to the 90% year. The tables show the years arranged in descending order of annual runoff. The probability of exceedence is determined using Weibull's plotting position m/ (N+1).

90% and 50% Dependable Year

Energy	Year	Ranking	Probability of Exceedence m/(N+1)*100%
1566.8	2010-11	1.0	2.3
1539.0	1978-79	2.0	4.7
1506.0	1975-76	3.0	7.0
1499.8	1973-74	4.0	9.3
1478.3	1998-99	5.0	11.6
1457.0	1994-95	6.0	14.0
1449.9	2013-14	7.0	16.3
1442.4	1983-84	8.0	18.6
1430.2	1982-83	9.0	20.9
1389.8	1991-92	10.0	23.3
1375.3	1990-91	11.0	25.6
1367.3	1979-80	12.0	27.9
1361.5	2011-12	13.0	30.2
1352.0	1977-78	14.0	32.6
1347.6	1987-88	15.0	34.9
1333.3	2012-13	16.0	37.2
1332.4	1980-81	17.0	39.5
1331.1	1986-87	18.0	41.9
1327.5	1972-73	19.0	44.2
1322.6	1989-90	20.0	46.5
1300.2	1996-97	21.0	48.8
1284.3	**1988-89**	**22.0**	**51.2**
1221.3	1981-82	23.0	53.5
1217.8	1995-96	24.0	55.8
1201.0	1992-93	25.0	58.1
1179.1	2002-03	26.0	60.5
1168.6	2009-10	27.0	62.8
1154.4	2005-06	28.0	65.1
1135.2	1985-86	29.0	67.4
1126.1	1976-77	30.0	69.8
1108.8	1974-75	31.0	72.1
1098.2	1984-85	32.0	74.4
1086.1	1999-00	33.0	76.7
1069.9	2003-04	34.0	79.1
1039.9	1993-94	35.0	81.4
1036.3	2006-07	36.0	83.7
1020.2	1997-98	37.0	86.0
1013.4	2008-09	38.0	88.4
977.1	**2001-02**	**39.0**	**90.7**
946.9	2000-01	40.0	93.0
794.9	2007-08	41.0	95.3
740.7	2004-05	42.0	97.7

- Based on the above the 90% dependable year works out to be year 2001-02.

Table - Discharge at Nirath – 90% Dependable Year

Month	Period	Nirath Dam Discharge (m^3/s)
June	I	322.00
	II	449.00
	III	417.00
July	I	566.00
	II	651.00
	III	714.00
August	I	653.00
	II	768.00
	III	592.00
September	I	452.00
	II	288.00
	III	201.00
October	I	159.00
	II	147.00
	III	138.00
November	I	138.00
	II	128.00
	III	110.00
December	I	98.00
	II	92.00
	III	89.00
January	I	88.00
	II	83.00
	III	82.00
February	I	81.00
	II	85.00
	III	83.00
March	I	98.00
	II	108.00
	III	122.00
April	I	132.00
	II	156.00
	III	224.00
May	I	316.00
	II	825.00
	III	616.00

4.8. Probable Maximum Flood: - The design flood studies were approved and conveyed by CWC on dated 08/06/12 (refer Annex-V). The recommended value of PMF is **13462 Cumecs.**

POWER POTENTIAL
STAGE-I

5. POWER POTENTIAL

5.1. Introduction

The power and energy studies have been conducted to determine the potential benefits of the scheme, using an in-house spreadsheet based model that allows various alternative schemes to be analysed in detail. The model is sufficiently detailed and allows the optimisation of various components of the project. For this report, the model has been used to determine the effect of changes in main scheme parameters such as the installed capacity, reservoir capacity.

5.2. Discharge Data

Flow data has been provided for the 42 year period 1972 to 2014 arranged as a hydrological year starting in June. The average flow in the river for each hydrological year has been provided for 42 periods each nominally of 10 days duration. The length of the final period of each month is adjusted in length to suit the individual month. The discharge data utilized for this study is given in Hydrology chapter. The 90% dependable year have been identified as 2001-02. The ten daily flow series for these years is Tabulated below:

Table-5-1: 10 Daily Discharge Data for 90% Dependable Year(2001-02)

Month	Period	Discharge at Nirath (in cumecs)	Month	Period	Discharge at Nirath (in cumecs)
JUNE	I	322	DECEMBER	I	98
	II	449		II	92
	III	417		III	89
JULY	I	566	JANUARY	I	88
	II	651		II	83
	III	714		III	82
AUGUST	I	653	FEBRUARY	I	81
	II	768		II	85
	III	592		III	83
SEPTEMBER	I	452	MARCH	I	98
	II	288		II	108
	III	201		III	122
OCTOBER	I	159	APRIL	I	132
	II	147		II	156
	III	138		III	224
NOVEMBER	I	138	MAY	I	316
	II	128		II	825
	III	110		III	616

Table-5-2: 10 Daily Discharge Data for 50% Dependable Year(1988-89)

Month	Period	Discharge at Nirath (in cumecs)	Month	Period	Discharge at Nirath (in cumecs)
JUNE	I	599	DECEMBER	I	135
	II	601		II	131
	III	1013		III	132
JULY	I	1003	JANUARY	I	131
	II	1040		II	125
	III	1159		III	114
AUGUST	I	1087	FEBRUARY	I	112
	II	896		II	110
	III	672		III	108
SEPTEMBER	I	535	MARCH	I	114
	II	408		II	120
	III	500		III	130
OCTOBER	I	286	APRIL	I	131
	II	216		II	144
	III	173		III	142
NOVEMBER	I	158	MAY	I	169
	II	148		II	304
	III	142		III	530

The CEA guidelines require that the performance of hydropower schemes should be determined for a 90% dependable year on an energy basis. The 90% dependable year for these studies has been found to be 2001-02 for the chosen flow series at Nirath and this year has been used throughout.

5.3. Fixation of various levels

The various levels & other parameters have been fixed as follows for power studies.

FRL	=	862.9m
MDDL	=	860m
Normal TWL	=	817m
Gross head	=	44.9m
Net head	=	42.73m
Design discharge	=	565 cumecs
Combined efficiency	=	92.59%

5.4. Environmental Discharges

The environmental discharge that will be released from the dam will be 24.67 m^3/sec. It is proposed that the environmental release is used to generate electricity in an appropriately sized turbines situated in toe-powerhouse. The gross head for the turbine is approximately 44.90 m. With an overall efficiency of 92.59%, the turbine would have an approximate installed capacity of 9.5 MW.

5.5. Fixation of Installed Capacity

Incremental energy plot has been develop confirms the installed capacity which give fall in incremental energy at 220MW installed capacity with design discharge of 567m^3/sec. However, discharge of 567m^3/sec shall give 2.87 hr peaking with average lean period 90% dependable year discharges. Hence 209.5 MW installed capacity has been adopted with design discharge of 540m^3/sec keeping in view of 3 hrs minimum peaking and as well as live storage available between FRL & MDDL i.e.5.8MCM between EL. 862.9m and El. 860.0m. From the 90% dependable year discharge table, it is derived that the probability of exceedence of design discharge is about 22%.

Figure 5-1: Incremental Energy Curve

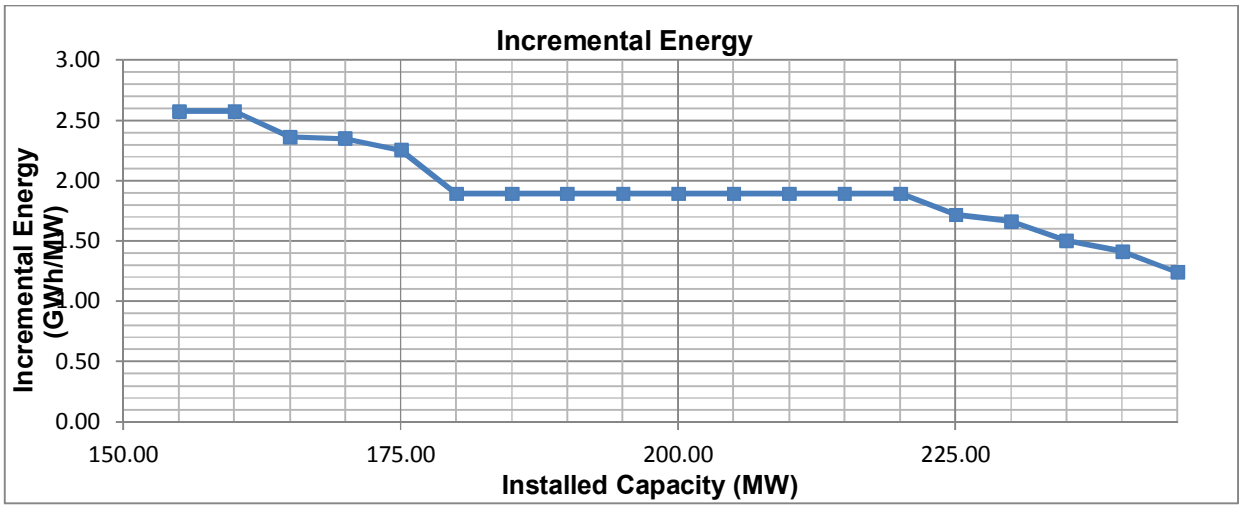
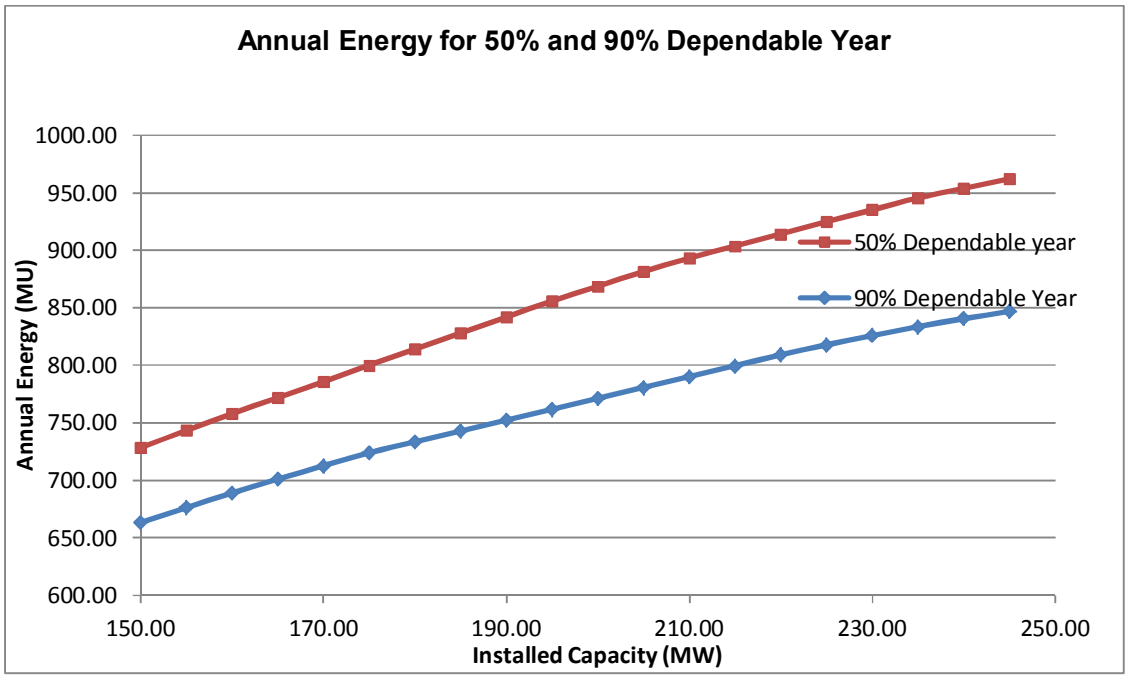


Table-5-3: Installed Capacity, Design Discharge and Energy with 90% dependable year

Power Capacity (MW)	Discharge (cumecs)	Energy (Gwh)	Annual Load Factor (%)
150.00	386	663.37	52.03
155.00	399	676.26	51.30
160.00	412	689.14	50.58
165.00	425	700.95	49.90
170.00	438	712.69	49.12
175.00	451	723.96	48.36
180.00	464	733.42	47.65
185.00	477	742.88	46.98
190.00	490	752.35	46.34
195.00	502	761.81	45.73
200.00	515	771.27	45.16
205.00	528	780.73	44.61
209.5	540	789.41	44.13
210.00	541	790.19	44.09
215.00	554	799.66	43.53
220.00	567	809.12	43.00
225.00	580	817.70	42.42
230.00	593	826.03	41.86
235.00	605	833.54	41.27
240.00	618	840.61	40.70
245.00	631	846.82	40.12

The installed capacity v/s Annual Energy Generation graph has been depicted in Fig-5.2

Figure 5.2: Annual Energy Available for 50% and 90% Dependable Years



5.6. Annual Energy for 90% and 50% dependable year

Annual energy generation has been calculated in Table 4&5 for 90% & 50% dependable years. The energy generation for environmental unit has been calculated in table-6. Also plant availability of 95% has been kept as per CEA guidelines. The annual design energy for 90% dependable year and 50% dependable year is shown in table-5.7.

Table 5.4: Power Generation in a 90 % Dependable Year

FRL	862.9 m
Combined Efficiency	0.926
Net Head	42.730 m
Installed Capacity	209.50 MW
Design Discharge	540.00 Cumecs
Station Availability	95.00 %
Annual Energy Generation	789.25 GWH
Water to be released d/s of dam	

MONTH	PERIOD	INFLOWS IN CUMECS		POWER/ENERGY GENERATION					
				UNRESTRICTED		RESTRICTED (100% AVAILABILITY)		RESTRICTED TO 95% OF INSTALLED CAPACITY	
		SATLUJ AT NIRATH DAM	SATLUJ AT NIRATH DAM after deducting minimum release	POWER MW	ENERGY GWH	POWER MW	ENERGY GWH	POWER MW	ENERGY GWH
JUNE	I	322.00	297.33	115.40	27.70	115.40	27.70	115.40	27.70
	II	449.00	424.33	164.69	39.53	164.69	39.53	164.69	39.53
	III	417.00	392.33	152.27	36.55	152.27	36.55	152.27	36.55
JULY	I	566.00	541.33	210.10	50.42	209.50	50.28	199.03	47.77
	II	651.00	626.33	243.09	58.34	209.50	50.28	199.03	47.77
	III	714.00	689.33	267.54	70.63	209.50	55.31	199.03	52.54
AUGUST	I	653.00	628.33	243.87	58.53	209.50	50.28	199.03	47.77
	II	768.00	743.33	288.50	69.24	209.50	50.28	199.03	47.77
	III	592.00	567.33	220.19	58.13	209.50	55.31	199.03	52.54
SEPTEMBER	I	452.00	427.33	165.86	39.81	165.86	39.81	165.86	39.81
	II	288.00	263.33	102.20	24.53	102.20	24.53	102.20	24.53
	III	201.00	176.33	68.44	16.42	68.44	16.42	68.44	16.42
OCTOBER	I	159.00	134.33	52.14	12.51	52.14	12.51	52.14	12.51
	II	147.00	122.33	47.48	11.39	47.48	11.39	47.48	11.39
	III	138.00	113.33	43.99	11.61	43.99	11.61	43.99	11.61
NOVEMBER	I	138.00	113.33	43.99	10.56	43.99	10.56	43.99	10.56
	II	128.00	103.33	40.10	9.63	40.10	9.63	40.10	9.63
	III	110.00	85.33	33.12	7.95	33.12	7.95	33.12	7.95
DECEMBER	I	98.00	73.33	28.46	6.83	28.46	6.83	28.46	6.83
	II	92.00	67.33	26.13	6.27	26.13	6.27	26.13	6.27
	III	89.00	64.33	24.97	6.59	24.97	6.59	24.97	6.59
JANUARY	I	88.00	63.33	24.58	5.90	24.58	5.90	24.58	5.90
	II	83.00	58.33	22.64	5.43	22.64	5.43	22.64	5.43
	III	82.00	57.33	22.25	5.87	22.25	5.87	22.25	5.87
FEBRUARY	I	81.00	56.33	21.86	5.25	21.86	5.25	21.86	5.25
	II	85.00	60.33	23.42	5.62	23.42	5.62	23.42	5.62
	III	83.00	58.33	22.64	4.35	22.64	4.35	22.64	4.35
MARCH	I	98.00	73.33	28.46	6.83	28.46	6.83	28.46	6.83
	II	108.00	83.33	32.34	7.76	32.34	7.76	32.34	7.76
	III	122.00	97.33	37.78	9.97	37.78	9.97	37.78	9.97
APRIL	I	132.00	107.33	41.66	10.00	41.66	10.00	41.66	10.00
	II	156.00	131.33	50.97	12.23	50.97	12.23	50.97	12.23
	III	224.00	199.33	77.36	18.57	77.36	18.57	77.36	18.57
MAY	I	316.00	291.33	113.07	27.14	113.07	27.14	113.07	27.14
	II	825.00	800.33	310.62	74.55	209.50	50.28	199.03	47.77
	III	616.00	591.33	229.51	60.59	209.50	55.31	199.03	52.54
TOTAL					**893.23**		**810.11**		**789.25**

AVERAGE ANNUAL LOAD FACTOR = 44.14 %
POTENTIAL UTILISATION = 88.36 %
ENERGY WITH FULL DISCHARGE= 789.25 MU

Table 5.5: Power Generation in a 50 % Dependable Year

FRL	862.9 m
Combined Efficiency	0.926
Net Head	42.730 m
Installed Capacity	209.5 MW
Design Discharge	540.00 Cumecs
Station Availability	95.00 %
Annual Energy Generation	892.23 GWH
Water to be released d/s of dam	

MONTH	PERIOD	INFLOWS IN CUMECS		POWER/ENERGY GENERATION					
				UNRESTRICTED		RESTRICTED (100% AVAILABILITY)		RESTRICTED TO 95% OF INSTALLED CAPACITY	
		SATLUJ AT NIRATH DAM	SATLUJ AT NIRATH DAM after deducting minimum release	POWER MW	ENERGY GWH	POWER MW	ENERGY GWH	POWER MW	ENERGY GWH
JUNE	I	599	574.33	222.91	53.50	209.50	50.28	199.03	47.77
	II	601	576.33	223.69	53.68	209.50	50.28	199.03	47.77
	III	1013	988.33	383.59	92.06	209.50	50.28	199.03	47.77
JULY	I	1003	978.33	379.71	91.13	209.50	50.28	199.03	47.77
	II	1040	1015.33	394.07	94.58	209.50	50.28	199.03	47.77
	III	1159	1134.33	440.26	116.23	209.50	55.31	199.03	52.54
AUGUST	I	1087	1062.33	412.31	98.95	209.50	50.28	199.03	47.77
	II	896	871.33	338.18	81.16	209.50	50.28	199.03	47.77
	III	672	647.33	251.24	66.33	209.50	55.31	199.03	52.54
SEPTEMBER	I	535	510.33	198.07	47.54	198.07	47.54	198.07	47.54
	II	408	383.33	148.78	35.71	148.78	35.71	148.78	35.71
	III	500	475.33	184.49	44.28	184.49	44.28	184.49	44.28
OCTOBER	I	286	261.33	101.43	24.34	101.43	24.34	101.43	24.34
	II	216	191.33	74.26	17.82	74.26	17.82	74.26	17.82
	III	173	148.33	57.57	15.20	57.57	15.20	57.57	15.20
NOVEMBER	I	158	133.33	51.75	12.42	51.75	12.42	51.75	12.42
	II	148	123.33	47.87	11.49	47.87	11.49	47.87	11.49
	III	142	117.33	45.54	10.93	45.54	10.93	45.54	10.93
DECEMBER	I	135	110.33	42.82	10.28	42.82	10.28	42.82	10.28
	II	131	106.33	41.27	9.90	41.27	9.90	41.27	9.90
	III	132	107.33	41.66	11.00	41.66	11.00	41.66	11.00
JANUARY	I	131	106.33	41.27	9.90	41.27	9.90	41.27	9.90
	II	125	100.33	38.94	9.35	38.94	9.35	38.94	9.35
	III	114	89.33	34.67	9.15	34.67	9.15	34.67	9.15
FEBRUARY	I	112	87.33	33.89	8.13	33.89	8.13	33.89	8.13
	II	110	85.33	33.12	7.95	33.12	7.95	33.12	7.95
	III	108	83.33	32.34	6.21	32.34	6.21	32.34	6.21
MARCH	I	114	89.33	34.67	8.32	34.67	8.32	34.67	8.32
	II	120	95.33	37.00	8.88	37.00	8.88	37.00	8.88
	III	130	105.33	40.88	10.79	40.88	10.79	40.88	10.79
APRIL	I	131	106.33	41.27	9.90	41.27	9.90	41.27	9.90
	II	144	119.33	46.31	11.12	46.31	11.12	46.31	11.12
	III	142	117.33	45.54	10.93	45.54	10.93	45.54	10.93
MAY	I	169	144.33	56.02	13.44	56.02	13.44	56.02	13.44
	II	304	279.33	108.41	26.02	108.41	26.02	108.41	26.02
	III	530	505.33	196.13	51.78	196.13	51.78	196.13	51.78
TOTAL					**1200.40**		**915.35**		**892.23**

AVERAGE ANNUAL LOAD FACTOR = 49.88 %
POTENTIAL UTILISATION = 74.33 %
ENERGY WITH FULL DISCHARGE = 892.23 MU

Table 5.6: Power Generation using environmental discharge

FRL	862.9 m
Combined Efficiency	0.926
Net Head	42.730 m
Installed Capacity	9.5 MW
Design Discharge	24.67 Cumecs
Station Availability	95.00 %
Annual Energy Generation	79.64 GWH
Water to be released d/s of dam	

MONTH	PERIOD	INFLOWS IN CUMECS	POWER/ENERGY GENERATION					
		Environment releases	UNRESTRICTED		RESTRICTED (100% AVAILABILITY)		RESTRICTED TO 95% OF INSTALLED CAPACITY	
			POWER MW	ENERGY GWH	POWER MW	ENERGY GWH	POWER MW	ENERGY GWH
JUNE	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.30	9.5	2.30	9.09	2.18
JULY	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
AUGUST	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
SEPTEMBER	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.30	9.5	2.30	9.09	2.18
OCTOBER	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
NOVEMBER	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.30	9.5	2.30	9.09	2.18
DECEMBER	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
JANUARY	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
FEBRUARY	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	1.84	9.5	1.84	9.09	1.75
MARCH	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
APRIL	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.30	9.5	2.30	9.09	2.18
MAY	I	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	II	24.67	9.5	2.30	9.5	2.30	9.09	2.18
	III	24.67	9.5	2.53	9.5	2.53	9.09	2.40
TOTAL				**83.88**		**83.83**		**79.64**

AVERAGE ANNUAL LOAD FACTOR = 100.00 %
POTENTIAL UTILISATION = 94.95 %
ENERGY WITH FULL DISCHARGE = 79.64 MU

5.7. Potential Utilisation and Annual Load Factor

The potential utilisation and annual load factors are depicted in Table 5.7.

Table 5.7: Annual Load Factor and Potential Utilization

Scheme	Annual Energy (MU)	Annual Load Factor (%)	Potential Utilization (%)
Main Machine (90% dependable year)	789.25	44.14	88.36
Main Machine (50% dependable year)	892.23	49.88	74.33

ELECTRICAL & MECHANICAL DESIGN

STAGE-I

6. Electro Mechanical Works

6.1. Right Bank Power House (200 MW)

6.1.1 Electro-Mechanical Equipments

6.1.1.1 Installed Capacity

On the basis of the power potential studies it has been proposed to have a Dam Toe Power House with an installed capacity of 200 MW i.e. 3 units each of 66.67 MW capacity on right bank of River Satluj. The turbine generators shall be of vertical, semi-umbrella type. The tentative Layout (cross section and plan) of power house is indicated in Plates.

Following are main floors for accommodating various Electro-Mechanical Equipments:-

Sr.No	Floor	Elevation
1	Service Bay Floor	El.830.50 m
2	Machine Hall	El.823.00 m
3	Generator Floor	El.817.50 m
4	Turbine Floor	El.813.0 m
5	Centre Line of Distributer	El. 809.00 m
6	MIV / Runner Removal Floor	El.804.0 m
7	DT Bottom including concreting	El. 791.80 m
8	Transformer Deck, Pothead Yard and GIS	El. 830.50 m

6.1.1.2 Turbine, Governor and Main Inlet Valve

The upstream levels, tailrace level and head available for power generation are indicated below:

i) Upstream Level

FRL	EL 862.9M
MDDL	EL 860.0 M

ii) Tailrace Levels

Minimum	EL 813.3 M
Normal	EL 817.0 M
Maximum	EL 817.0 M

iii) Heads

Maximum net head	49.6 M
Minimum net head	40.80 M
Rated head	42.73 M

The maximum gross head available is 49.6 m and the design head is 42.73 m. For this head Francis turbine has been proposed. For 42.73 m design head and 66.67 MW generator output, the rotational speed of the turbine and generator has been selected as 125 rpm, which is two speed higher than the calculated speed (as per IS-12837 part-I) for optimizing the length of the Power House. For the above speed the specific speed will be 363.78. The rated discharge of turbine would be 171.67 cumecs.

Turbine is also capable of delivering 110% load at generator terminal. The centreline of turbine runner has been set at EL 809.0m, 4.3 m below the minimum TWL which is at EL 813.3m.

The Governor would be electro-hydraulic digital PID type suitable for fully automatic control. The closing time of wicket gates would be so adjusted so as not to increase the speed rise and pressure rise more than 45% and 30%respectively under full load throw off condition.

It is proposed to provide a Main Inlet Valve of Butterfly type for each turbine. The opening of the valve would be achieved through pressurized oil servomotor and closing through counter weight.

6.1.1.3 Generator

The generator will be of synchronous type with a rated output of 74.07 MVA, 11 kV, 0.9 p.f. 3 phase, 50 HZ, 125 rpm. The generator will be capable of delivering 110% load. The machine shall be air-cooled / water cooled type.

The generators would be provided with static excitation equipment and voltage regulator. Necessary power for excitation would be provided by tapping the generator terminals. Necessary fire/temp. Detectors and one banks of CO_2 cylinder would be provided for fire protection of the generator. Generator will be provided with its necessary auxiliaries such as HP oil pump, braking & Jacking, Brake dust collector etc.

6.1.1.4 Bus Duct, Unit Step up Transformer

The 11 kV isolated bus ducts has been envisaged for connection between the 11 kV generator terminals with 11 kV bushings of step up transformers. Bus duct has been proposed with tapping for Unit Auxiliary Transformer, Excitation Transformer and LAVT.

Three phase 81.5 MVA, 11/400 kV transformers would be provided for each generating unit. The transformers would be located upstream of power house building at service

bay level EL 830.5m. The 11 kV bushings of the transformers would be connected with 11 kV terminals of generator through 11 kV bus ducts.

6.1.1.5 Switchyard

As the space to accommodate 400kV Air Insulated Switchyard (AIS) is not available in the vicinity of Powerhouse, the 400 kV switch yard is proposed to be of Gas Insulated Switchgear (GIS) & Pothead yard with a total bench area of approximately 150m X 56m assuming tentatively eight bays viz three generators bays, four feeder bays and one spare bay as the power evacuation arrangement for the above Project is yet to be taken up with Power Grid/CTU. The generator step up transformers are proposed to be connected to the 400 kV GIS in the Switchyard area through 400 kV XLPE cable.

However, the actual dimensions of flat piece of land for housing the Switchyard will be finalized after the finalization of Power Evacuation arrangement by PowerGrid/CTU.

6.1.1.6 Auxiliary Equipments and System for Power House

Following equipments for the auxiliary systems of the powerhouse would be provided:

- SCADA system for Power House
- Protection system for unit, 400 kV Lines & Bus Bar.
- Cooling water system for turbines, generators, unit step up transformers etc.
- Drainage & Dewatering System
- Low Pressure Compressed Air System
- 415V LTAC supply system comprising of station service transformers, Station service board, Unit auxiliary board etc.
- D.C. supply system comprising 220 V DC battery, chargers, DC distribution board
- DG sets for emergency backup supply.
- Elevators for power house
- Ventilation & Air conditioning system for the power house
- Illumination system
- Earthing system
- Oil handling system
- Power and control cables
- Fire protection system
- Security & Surveillance system
- Electrical & Mechanical system

6.1.1.7 EOT Crane

The generator rotor weight is less than 250 tonnes. It is therefore proposed to install two EOT cranes of 125 tonnes capacity along with one 10 tonnes auxiliary hook for facilitating erection of generators and for subsequent repairs and maintenance.

It is proposed to install one EOT crane of 150 tonnes capacity along with one 20 tonnes auxiliary hook for facilitating erection of Main Inlet Valve & Turbines and for subsequent repairs and maintenance.

6.1.2 Power Evacuation Arrangement

Grid Connectivity Regulation 2010 envisages Power evacuation planning of hydro project capacity greater than 50MW by Power grid. No discussion has been held with Powergrid regarding power evacuation arrangement for the above project. The same will be finalized during DPR stage and after discussion with Power Grid/CTU. As such, the cost of power evacuation arrangement has not been considered in the project cost.

6.1.3 Construction Power & Telecommunication arrangement

6.1.3.1 Construction Power Arrangement

Power supply will be required at work sites of Dam and power house and at head quarter complex. The peak power demand for the construction activities of the project for Dam, power house etc is estimated to be about 4MW taking capacity of electric driven equipment and lighting which are to work within the target time for consideration.

The availability of the construction power from nearby Sub-station needs to be explored / taken up with the local authorities. Apart from this arrangement, adequate capacity of DG set back up shall be kept by project authority at various construction sites for timely completion of project in case of power failures & emergency.

6.1.3.2 Telecommunication

The project site is well connected with mobile connectivity and P&T communication as on date. However, to ensure efficient execution at various sites, adequate and reliable telecommunication network is necessary. An electronic private Automatic Exchange with a capacity of about 50 lines is proposed. Suitable numbers of walky talkies are also proposed.

6.2 Left Bank Power House (19 MW)

6.2.1 Electro-Mechanical Equipments

6.2.1.1 Installed Capacity

As per the EAC (Expert Appraisal Committee) recommendation, the environmental discharge that will be released from the dam 30% of the monsoon flow, 25% of the non-monsoon & non-lean flow and 25% of the lean flow.

A Dam Toe Power House on the left bank has been envisaged to utilize the above mandatory environment release from the Dam to generate 19 MW Power by using 02 Nos. Francis Turbines driven Generating Units, each rated 9.5 MW at rated net head of 42.73 m. The turbine generators shall be of vertical, semi- umbrella type. The tentative Layout (cross section and plan) of power house is indicated in Plates. Following are main floors for accommodating various Electro-Mechanical Equipments:-

Sr.No	Floor	Elevation
1	Service Bay Floor	El.830.50 m
2	Machine Hall	El.822.00 m
3	Generator Floor	El.817.00 m
4	Turbine Floor	El.812.50 m
5	Centre Line of Distributer	El. 809.50 m
6	MIV / Runner Removal Floor	El. 806.50 m
7	DT Bottom including concreting	El. 802.00 m
8	Transformer Deck, Pothead Yard and GIS	El. 830.50 m

6.2.1.2 Turbine, Governor and Main Inlet Valve

The upstream levels, tailrace level and head available for power generation are indicated below:

i) Upstream Level

FRL	EL 862.9M
MDDL	EL 860.0 M

ii) Tailrace Levels

Minimum	EL 813.3 M
Normal	EL 817.0 M
Maximum	EL 817.0 M

iii) Heads

Maximum net head	49.60 M
Minimum net head	40.80 M
Rated head	42.73 M

The maximum gross head available is 49.6 m and the design head is 42.73 m. For this head Francis turbine has been proposed. For 42.73 m design head and 9.5 MW generator output, the rotational speed of the turbine and generator will be 300 rpm. For the above speed the specific speed will be 330.41. The rated discharge of turbine would be 24.86 cumecs.

Turbine is also capable of delivering 110% load at generator terminal. The centreline of turbine runner has been set at EL 809.5m, 3.8 m below the minimum TWL which is at EL 813.3m.

The Governor would be electro-hydraulic digital PID type suitable for fully automatic control. The closing time of wicket gates would be so adjusted so as not to increase the speed rise and pressure rise more than 45% and 30%respectively under full load throw off condition.

It is proposed to provide a Main Inlet Valve of Butterfly type for each turbine. The opening of the valve would be achieved through pressurized oil servomotor and closing through counter weight.

6.2.1.3 Generator

The generator will be of synchronous type with a rated output of 11.18 MVA, 11 kV, 0.85 p.f. 3 phase, 50 HZ, 300 rpm. The generator will be capable of delivering 110% load. The machine shall be air-cooled / water cooled type.

The generators would be provided with static excitation equipment and voltage regulator. Necessary power for excitation would be provided by tapping the generator terminals. Necessary fire / temp. Detectors and one banks of CO2 cylinder would be provided for fire protection of the generator. Generator will be provided with its necessary auxiliaries such as HP oil pump, braking & Jacking, Brake dust collector etc.

6.2.1.4 Bus Duct, Unit Step up Transformer

The 11 kV isolated bus ducts has been envisaged for connection between the 11 kV generator terminals with 11 kV bushings of step up transformers. Bus duct has been proposed with tapping for Unit Auxiliary Transformer, Excitation Transformer and LAVT.

Three phase 12.3 MVA, 11/66 kV transformers would be provided for each generating unit. The transformers would be located upstream of power house building at service bay level EL 830.5m. The 11 kV bushings of the transformers would be connected with 11 kV terminals of generator through 11 kV bus ducts.

6.2.1.5 Switchyard

To ensure availability and reliability of the Switchgear 66 kV GIS with double bus bar scheme having two generator incoming feeders, two line feeder, one bus coupler and bus bar equipments (Bus PT and Bus Earth Switch) has been envisaged. GIS has been opted because of limited availability of flat piece of land on left bank of the Power House.

Termination from GIS to Line termination equipment of Pot head yard and Generator transformer has been envisaged through 66 kV XLPE Aluminium cable. GIS building will be at an elevation EL 830.50 m at upstream of Power House.

66 kV GIS and 66 kV XLPE cables are manufactured and supplied indigenously.

6.2.1.6 Auxiliary Equipments and System for Power House

Following equipments for the auxiliary systems of the powerhouse would be provided:

- SCADA system for Power House
- Protection system for unit, Lines & Bus Bar.
- Cooling water system for turbines, generators, unit step up transformers etc.
- Drainage & Dewatering System
- Low Pressure Compressed Air System
- 415V LTAC supply system comprising of station service transformers, Station service board, Unit auxiliary board etc.
- D.C. supply system comprising 220 V DC battery, chargers, DC distribution board
- DG sets for emergency backup supply.
- Elevators for power house
- Ventilation & Air conditioning system for the power house
- Illumination system
- Earthing system
- Oil handling system

- Power and control cables
- Fire protection system
- Security & Surveillance system
- Electrical & Mechanical system

6.2.1.7 EOT Crane

One no. EOT crane of size 60/10 T with main and auxiliary hooks are proposed to be provided in the Power House for handling all E&M equipments.

EOT crane will be used to lift the assembled Rotor from service bay to respective Generator barrel. The EOT crane will be operated through operator cabin directly mounted on the main girder and shall also be capable for radio remote control for fine control.

CONSTRUCTION MATERIAL

STAGE-I

7. CONSTRUCTION MATERIAL

7.1. Construction Materials

7.1.1. Introduction

The specification of construction materials of adequate quality is essential to ensure that the long term integrity of the project is achieved. Construction materials also make up a significant proportion of the overall project cost.

Noting that SJVN Ltd. is keen to adopt policies which ensure the use of the best quality of materials in the proposed Luhri hydroelectric project stage-I, then consideration should be given to the following when preparing the technical specifications:

- The introduction of higher specifications (where appropriate) to incorporate the use of recent technological developments to improve quality and reduce cost.
- Means of ensuring effective monitoring and regulation of the production of materials, especially by smaller producers.
- Provide incentives for the contractors to adopt improved methods and materials.
- Review procurement mechanisms to reduce the cost of construction.

The materials required for the construction of the project include:

- cement,
- sand, aggregates
- steel,
- bricks, tiles,
- timber, aluminium, glass and plastics
- paints and chemicals, mineral products
- Fixtures and fittings.

Requirements for the principal construction materials and their sources are discussed further below.

7.1.2. Quantities of Cement and Aggregate

The Luhri Hydroelectric Project Stage-I envisages construction of the following major project components:

- Concrete dam at Nirath
- Toe power house at right bank (200MW) & at left bank (19MW)

For the above proposed project components, the approximate quantity of cement, fine and coarse aggregates required for the project is as shown in Table 7.1 below.

Table 7.1 Estimated Quantities of Cement and Aggregates

	Particulars	Quantity (m^3)	Quantity (t)	Notes
1	**Concrete**			Unit weight of concrete is assumed as 25 kN/m^3.
	Dam and toe power houses	7,50,000	18,75,000	
	Total	**7,50,000**	**18,75,000**	
2	**Cement**			The mix proportion for M20 concrete has been assumed as 1:1.5:3
	Dam and toe power houses		3,40,910	
	Total		**3,40,910**	
3	**Fine Aggregates**			The mix proportion for M20 concrete has been assumed as 1:1.5:3
	Dam and toe power houses		5,11,364	
	Total		**5,11,364**	
4	**Coarse Aggregate**			The mix proportion for M20 concrete has been assumed as 1:1.5:3
	Dam and toe power houses		10,22,728	
	Total		**10,22,728**	
5	**Total Fine and Coarse Aggregates**		**15,34,092**	

7.1.3. Availability of Materials

The optimum availability of construction materials at site is essential to curtail and avoid time overrun during the construction of the project. Construction materials such as cement, structural steel, reinforcement steel, rock bolts, bricks, paints, timber will be procured directly by the contractor from sources approved by SJVN Ltd. However, fine and coarse aggregate to be used in the preparation of concrete is planned to be made available from suitable quarry sites in the vicinity of the project components and muck from tunnel excavation to optimise the applicable cost of construction materials.

7.1.3.1. Location of Quarries, Crushing Plants and Batching Plants

The reconnaissance survey for locating suitable quarry sites for fine and coarse aggregates was undertaken by SJVN Ltd. so that the quantity of aggregate required is available close to project components. Accordingly quarry sites were identified at Moin and Bithal**.** Moin quarry site is about 500m from project site and Bithal is about six km. from the project site.

7.1.3.2. Estimated Quantity of Aggregate Available from Quarry Sites

The total estimated quantity of aggregate available from the identified quarry sites Moin and Bithal is as shown in Table 7-2 below.

It is assumed that only 40% to 50% of the total volume is available for use since 10% will not be usable and 50% will remain unutilised due to bench development as required by the mining department. The Specific Gravity of aggregates has been assumed as 1.7 to 2.2.

Table 7-2 Quantities of Aggregate Available from Quarry Sites

Sr. No.	Location and Type	Area	Average height	Available Volume	Total Available Quantity (m3)	Total Available Quantity (t)
1	Moin Terrace River bed material:	4.8 ha	40 m	40%	7,68,000	13,05,600
2	Bithal Sand Quarry	3.0 ha	30m	40%	3,60,000	6,12,000
	Total				11,28,000	19,17,600

7.1.3.3. Estimated Quantity of Aggregate Available from Excavated Muck

During the excavation there is every possibility that it will encounter quartzitic geological strata. It is therefore possible that the muck excavated may be suitable for use as an additional source of aggregates. As a preliminary estimate, 15% of total quantity of DT & dam muck may be considered as available and suitable as shown in Table 7-3.

Table 7-3 Quantities of Aggregate Available from Excavated Muck

	Type	Estimated Quantity of Muck (m^3)	Available Volume	Total Available Quantity (m^3)	Total Available Quantity (t)
1	Excavated Muck:	19,00,000	15%	2,85,000	7,12,500

7.1.3.4. Net Aggregate Available

The total estimated quantity of aggregate available is as shown in Table-7-4 below.

Table 7-4 Net Aggregate Availability from Quarry Site and Excavated Muck

Total aggregate from quarry	19,17,600 t
Total aggregate from muck	7,12,500 t
Total aggregate available	26,30,100 t

The comparison between the total quantity of aggregate required and the total quantity of aggregate available is as shown in Table 7-5. It is clear that there is very good availability of aggregates for preparation of concrete for the Luhri Hydroelectric Project Stage-I.

Table 7-5 Quantity of Aggregate Required compared to Available Quantity

Aggregate Quantity Required (t)	Aggregate Quantity Available (t)
15,34,092	26,30,100

7.1.3.5. Laboratory Investigations

The laboratory investigations have been carried out by Central Soil and Materials Research Station (CSMRS), New Delhi to check the suitability of the aggregates available from the above identified quarries. Laboratory tests have been completed and results of physical and chemical tests are available and appended.

Suitability of Moin quarry and Khaira quarry for Course Aggregate in Concerete Based on Physical Test Results and Petrographic Examination are as under.

Quarry	Sample No.	Suitability based on Physical Test Results			Petrographic Examination		Remarks
		Suitablity in r/o both wearing and non waring surfaces	Suitablity for non wearing surfaces only.	Not Suitable	Inncuous	Delterious	
Terrace deposits of riverbed materials in Moin Quarry	Moin-I	No	Yes	-	-	Susceptible to Alkali aggregate reaction	Suitable for use in non-wearing surfaces only
Khaira rock quarry	Khaira-I	Yes	-	-	-	Susceptible to Alkali aggregate reaction	Suitable for use in both wearing and non-wearing surfaces

COST ESTIMATE & ECONOMIC EVALUATION

STAGE-I

8. COST ESTIMATE & ECONOMIC EVALUATION

8.1. Basis of Estimates

The estimate of LHEP Stage-I (219 MW) has been made to arrive at the capital cost of the project and the level of accuracy of estimate is of Inception Report. Rates of major items of Civil Works and Electrical Works for preparation of cost estimates have been adopted from "CEA Guidelines for preparation of Cost Estimates of Pre-Feasibility Report of Hydro Electric Projects". The rates at Jan 2013 price level has been considered. However detailed analysis of rates need to be done at DPR stage to work out rates of various items of work pertaining to the project and cost estimate of the project shall be revised accordingly.

8.2. Description of Item

8.2.1. Unit-I Civil Works

Under '**Civil Works'** provisions have been made for the various components of the project as detailed hereunder:

8.2.1.1. A-Preliminary

Under this sub head, provision of Rs. 2089.6 lacs has been made for surveys/investigations required to be conducted for the DPR preparation and to arrive at the optimum designs of project components. Consultancy fee of 10% has been considered. Thus the amount against A-Preliminary works out to Rs. 2299.60 lacs.

8.2.1.2. B-Land

A provision of Rs. 18842.69 lakh has been made under this sub head. This covers the total requirement for project components, colonies, offices, project roads, dumping areas, land for afforestation and land for rehabilitation purposes. The land required has been broadly identified as non-cultivated land (forest & barren land) and cultivated land (forest & private land). The rates for different types of land viz. forest land (excluding cost of forest growth), barren land and cultivable land have been obtained from the concerned revenue department of project area.

8.2.1.3. Civil Works

This covers the cost of civil engineering structures comprising river diversion arrangement, coffer dams, concrete dam (including spillway and plunge pool),

pressure shafts/penstocks, power house complex, tailrace tunnel and hydro mechanical works. The total cost works out to Rs.76951.19 lacs.

8.2.1.4. K-Buildings

The requirement of residential and non-residential buildings, both permanent and temporary, have been assessed based on the expected organization strength (excluding that of contractor's) at the site for actual execution of the project and considering the requirements for construction facilities to be developed. The cost of buildings has been estimated as Rs. 8614.32 lacs.

8.2.1.5. M-Plantation

A provision of Rs.177.50 lacs has been kept for plantation of trees, their maintenance and protection for three years along the project roads, colonies and important project components viz. Dam Area, Power House etc.

8.2.1.6. O-Miscellaneous

As per the guidelines of CEA, the amount against O-Miscellaneous works out to Rs. 4260.11 lacs.

8.2.1.7. P-Maintenance

As per the guidelines of CEA, the amount against P-Maintenance works out to Rs. 1468.89 lacs.

8.2.1.8. Q- Special Tools And Plants

As the major civil works have been proposed to be executed on contract basis, machinery required for departmental activities like infrastructural works, their subsequent repair/maintenance and supervision works has mainly been included under this sub-head. The cost works out to Rs. 50 lacs.

8.2.1.9. R-Communication

The assessment about the total length of new roads, major bridges, requirement of improvement of existing roads, strengthening of existing bridges, provision of helipad etc., has been made based on the site visits to the project areas. Under this provision of Rs. 3619.23 lacs has been kept.

8.2.1.10. X-Environment And Ecology

A provision under this sub head for maintaining/improving the environmental status of the project area as per the guidelines of CEA. Thus the amount against this sub-head works out to Rs. 7440.41 lacs.

8.2.1.11. Y-Losses On Stocks

As per guidelines of CEA, the provision under this sub head has been considered.The amount under this sub head works out to Rs. 259.54 lacs.

8.2.1.12. II- Establishment

The amount against this sub head works out to Rs. 21155.23 lacs.

8.2.1.13. III- Tools And Plants

The amount against this sub head works out to Rs. 100 lacs. This provision is meant to cover survey instruments, office equipments and other small tools and plants.

8.2.1.14. V-Receipt And Recoveries On Capital Account

This head is meant to account for estimated recoveries by way of resale or transfer of temporary buildings and Q-Special T&P. As per the guidelines of CEA/CWC the detail of cost has been worked out to Rs 86.43 lacs .

8.2.1.15. Indirect Charges- Audit And Accounts

The provision for audit and accounts charges has been considered as per CEA guidelines. The amount under this sub head works out to Rs.355.59 lacs.

8.2.2. UNIT-II E&M Cost

Under this head a provision of Rs. 39771 lacs has been made

ABSTRACT OF COST ESTIMATES

	Amount in Crores
Unit- I Civil Works	1580.40
Unit-II Production	397.11
Total cost of the project	1978.11

8.3. Economic Evaluation

8.3.1. Project Benefits

The scheme would afford an annual energy generation of 868 Gwh in a 90% dependable year. For assessing the tariff, design energy generation of 868 GWh calculated with 95% capacity in a 90% dependable year has been adopted.

8.3.2. Capital Cost

The project cost has been estimated at Rs. 1978.11 crore without IDC and is as given below:

i) Cost of Civil Works = Rs. 1580.40 crore

ii) Cost of Electrical/Mechanical Works = Rs. 397.71 crore

Total Cost = **Rs.1978.11 crore**

8.3.3. Interest During Construction (IDC)

For IDC calculation, equity to debt ratio has been assumed at 30:70. IDC at Bus bar works out to Rs. 296.00 crore.

8.3.4. Rate Of Depreciation

Rate of depreciation works out to 4.991% for first 12 years and 1.309 % for next 23 years .

8.3.5. Cost Of Energy Generation

Levellised tariff has been worked out based on tariff calculations for 35 years and interest on working capital has been assumed 13.20 % per annum. The sale rate per unit at bus bar for first year and levellised tariff are given below:

Sr. No.	Description	Traiff (Rs./Kwh)
1.	First year tariff	**6.54**
2.	Levellised tariff	**5.78**

Annexure-I (1/4)

10-Daily flow series at Nirat Dam site on river Satluj Catchment area 51600 sq km cumec

Month	10-daily	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82
Jun	I	481	786	343	708	844	392	820	267	618	410
	II	616	1610	521	1040	652	260	649	708	828	394
	III	820	1542	433	1186	463	716	1179	1722	1131	890
Jul	I	932	1242	503	779	846	1362	1419	1256	1105	774
	II	851	1292	992	1372	1228	1458	1171	1497	1286	1045
	III	951	1045	976	1134	1439	1119	1162	1201	1180	1277
Aug	I	865	924	960	1258	875	1484	1492	1097	1259	1330
	II	845	909	928	1366	732	878	1278	1053	781	1135
	III	651	921	639	1019	587	656	820	801	612	733
Sep	I	665	874	486	653	535	641	923	632	528	502
	II	467	610	329	490	348	508	637	388	401	355
	III	282	457	261	344	280	341	403	236	283	289
Oct	I	221	272	182	268	228	244	305	209	232	214
	II	192	211	176	228	188	196	237	179	191	174
	III	153	197	143	212	177	173	195	159	167	157
Nov	I	140	174	130	192	155	164	180	151	141	151
	II	127	152	113	178	141	151	167	133	125	122
	III	114	127	94	152	128	138	157	128	110	105
Dec	I	105	114	101	131	107	128	146	108	99	95
	II	105	101	95	124	99	118	133	96	92	90
	III	102	102	85	117	100	109	121	96	90	85
Jan	I	97	99	83	110	98	92	109	94	85	84
	II	96	95	88	105	94	91	106	94	80	82
	III	96	96	97	100	96	92	104	93	81	80
Feb	I	93	91	112	99	92	92	101	92	80	82
	II	94	86	118	103	84	91	96	93	79	84
	III	98	85	116	112	93	90	94	88	77	83
Mar	I	98	95	130	115	99	93	102	90	85	88
	II	104	96	143	113	98	109	125	69	88	86
	III	149	124	150	134	88	117	138	95	101	102
Apr	I	188	141	200	140	106	120	196	121	110	180
	II	232	165	203	179	105	212	253	151	210	193
	III	576	215	283	346	118	217	264	217	266	256
May	I	1113	288	342	316	124	401	370	306	437	385
	II	578	288	596	412	148	573	331	328	446	336
	III	694	221	515	520	240	618	276	359	557	397

Annexure-I (2/4)

10-Daily flow series at Nirat Dam site on river Satluj in cumec,
Catchment area 51600 sq km

Month	10-daily	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92
Jun	I	611	788	950	573	319	807	599	906	772	983
	II	1215	665	800	640	812	718	601	701	655	1267
	III	893	922	731	734	1381	800	1013	651	1320	1083
Jul	I	1269	1041	827	734	979	1123	1003	742	1134	1369
	II	1262	686	573	823	1138	1012	1040	1059	966	1167
	III	1335	1217	801	862	1406	1182	1159	1220	864	1132
Aug	I	1179	1300	756	748	1158	941	1087	771	961	894
	II	1159	1081	829	858	1023	845	896	713	889	646
	III	736	1123	772	768	783	799	672	783	781	706
Sep	I	511	867	639	618	627	674	535	566	662	623
	II	431	645	415	421	366	456	408	381	528	483
	III	298	428	246	325	288	354	500	322	397	297
Oct	I	207	291	185	241	216	219	286	232	265	229
	II	185	236	161	276	189	174	216	196	220	192
	III	163	199	144	191	162	155	173	180	187	167
Nov	I	148	174	125	158	152	143	158	168	160	152
	II	135	147	106	137	144	131	148	151	156	140
	III	117	119	98	121	136	128	142	141	150	130
Dec	I	103	118	93	104	133	121	135	133	142	124
	II	98	105	91	95	131	117	131	123	137	121
	III	93	99	86	90	127	114	132	122	121	121
Jan	I	89	96	83	83	120	112	131	108	95	113
	II	93	90	78	79	117	111	125	105	92	112
	III	91	86	77	77	114	106	114	105	90	112
Feb	I	92	84	75	82	112	88	112	108	92	117
	II	92	84	73	83	112	74	110	108	94	115
	III	92	90	75	85	114	76	108	105	96	108
Mar	I	92	95	84	95	114	78	114	109	101	113
	II	98	115	90	109	117	87	120	116	110	118
	III	106	142	94	111	127	94	130	142	144	136
Apr	I	140	145	94	124	145	101	131	142	214	137
	II	157	166	117	190	143	266	144	178	194	150
	III	210	256	153	251	199	329	142	247	233	221
May	I	354	311	205	294	241	491	169	346	369	259
	II	597	482	237	506	222	573	304	901	503	427
	III	608	649	586	280	340	580	530	794	610	391

Annexure-I (3/4)

10-Daily flow series at Nirat Dam site on river Satluj in cumec,

Catchment area 51600 sq km

Month	10-daily	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
Jun	I	476	515	744	710	601	327	701	274	360	322
	II	727	707	660	944	1078	463	626	545	471	449
	III	969	600	1253	557	1543	673	1146	654	565	417
Jul	I	620	700	1322	788	821	647	1531	767	482	566
	II	876	945	1103	867	985	791	1370	754	667	651
	III	1111	658	1362	906	996	801	992	762	984	714
Aug	I	910	689	1303	856	992	772	973	1017	972	653
	II	819	596	985	773	1126	831	1017	729	622	768
	III	724	553	934	699	687	625	696	628	569	592
Sep	I	656	493	802	648	587	428	463	453	542	452
	II	456	442	479	412	474	371	434	380	346	288
	III	268	281	268	286	324	219	494	315	251	201
Oct	I	222	208	239	234	259	138	313	232	178	159
	II	189	175	207	201	203	96	289	196	166	147
	III	158	152	170	168	171	76	262	184	154	138
Nov	I	138	138	155	146	156	72	213	174	148	138
	II	130	135	146	141	143	84	196	163	141	128
	III	125	129	137	135	136	135	185	150	131	110
Dec	I	122	125	131	130	132	123	171	142	124	98
	II	110	111	127	123	124	116	162	136	108	92
	III	107	105	123	122	117	107	156	126	107	89
Jan	I	106	106	119	119	113	99	151	123	103	88
	II	107	107	114	114	111	95	147	122	101	83
	III	106	103	110	111	108	92	142	121	99	82
Feb	I	102	100	107	108	108	89	140	118	89	81
	II	104	101	110	107	108	86	128	120	88	85
	III	106	104	114	109	107	87	129	118	90	83
Mar	I	106	103	111	113	107	93	129	118	89	98
	II	118	118	105	130	116	105	134	122	87	108
	III	129	129	128	139	112	109	133	128	99	122
Apr	I	121	139	125	146	118	131	154	147	108	132
	II	149	131	139	231	138	138	203	163	116	156
	III	253	141	168	367	176	260	323	180	128	224
May	I	455	241	224	381	235	344	354	214	179	316
	II	292	283	650	362	167	348	417	421	266	825
	III	467	592	371	532	256	743	531	437	229	616

Annexure-I (4/4)

10-Daily flow series at Nirat Dam site on river Satluj in cumec,

Catchment area 51600 sq km

Month	10-daily	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Jun	I	736	1057	267	279	581	262
	II	913	933	419	471	387	598
	III	791	801	409	1015	430	518
Jul	I	834	831	535	1076	806	650
	II	748	747	502	1106	740	488
	III	682	790	494	945	1033	614
Aug	I	721	805	547	889	1334	608
	II	846	662	552	679	903	665
	III	710	581	431	529	729	571
Sep	I	536	523	295	470	343	446
	II	445	386	305	350	335	256
	III	275	302	197	266	223	215
Oct	I	201	179	167	170	178	147
	II	177	155	151	141	153	114
	III	164	149	134	122	126	116
Nov	I	150	143	127	111	119	94
	II	142	135	103	106	117	89
	III	136	112	88	105	111	84
Dec	I	131	103	80	99	104	76
	II	123	97	75	89	93	77
	III	102	94	74	89	79	70
Jan	I	71	92	72	86	78	72
	II	62	92	72	83	81	72
	III	63	69	66	87	83	73
Feb	I	73	70	70	84	85	72
	II	74	81	76	86	83	71
	III	76	83	76	86	83	71
Mar	I	84	84	88	90	90	70
	II	80	87	99	89	106	77
	III	107	97	111	89	81	76
Apr	I	116	103	106	96	122	80
	II	191	107	117	108	136	103
	III	243	123	177	191	176	102
May	I	276	117	278	436	229	126
	II	578	206	262	623	282	187
	III	758	291	195	803	263	344

Extended Discharge for Nirath (cumecs)

		2008-09					2009-10				
		Rampir Discharge	Khab Discharge		Areal Transfer	Nirath Discharge	Rampir Discharge	Khab Discharge		Areal Transfer	Nirath Discharge
		A	B	A-B	D	D+B	A	B	A-B	D	D+B
JUN	I	445	101	344	380	481	476	145	330	365	510
	II	954	197	756	835	1033	404	130	274	302	432
	III	700	130	569	629	759	775	300	476	525	825
JUL	I	715	130	586	647	777	635	289	346	382	671
	II	677	123	554	611	735	837	285	552	610	895
	III	616	122	493	545	667	791	290	500	553	843
AUG	I	596	123	473	523	645	764	260	504	557	817
	II	624	128	496	548	676	735	241	493	545	786
	III	499	99	400	441	541	510	131	379	419	550
SEP	I	291	63	228	252	315	449	81	368	406	487
	II	223	38	185	204	242	497	76	421	466	541
	III	318	26	292	323	348	338	73	265	293	366
OCT	I	171	22	150	165	187	238	68	169	187	255
	II	137	18	119	131	149	201	58	143	158	216
	III	107	18	89	98	116	171	51	120	133	184
NOV	I	103	21	82	91	112	177	47	130	144	191
	II	97	21	76	84	105	171	45	125	138	184
	III	89	19	70	77	96	169	38	131	144	182
DEC	I	84	16	68	75	91	184	33	151	167	200
	II	87	15	72	80	95	171	32	139	154	186
	III	89	15	74	81	96	179	32	147	163	195
JAN	I	131	51	81	89	140	140	32	108	120	152
	II	138	44	94	104	148	126	32	94	103	135
	III	137	31	106	117	148	126	35	91	100	135
FEB	I	123	30	93	103	133	123	35	88	97	132
	II	120	30	90	99	129	127	35	92	101	136
	III	114	30	84	93	122	125	35	90	100	134
MAR	I	115	34	82	90	124	126	32	94	104	136
	II	117	43	73	81	124	128	32	96	106	138
	III	115	45	71	78	122	152	53	98	109	162
APR	I	109	44	65	72	116	113	62	50	56	118
	II	99	47	52	58	105	161	62	99	109	172
	III	126	53	73	81	134	191	71	120	133	204
MAY	I	170	67	103	114	181	357	125	232	256	381
	II	254	80	173	192	272	270	103	167	184	287
	III	398	129	269	297	426	383	330	53	59	388

		2010-11					2011-12				
		Rampir Discharge	Khab Discharge		Areal Transfer	Nirath Discharge	Rampir Discharge	Khab Discharge		Areal Transfer	Nirath Discharge
		A	B	A-B	D	D+B	A	B	A-B	D	D+B
JUN	I	445	168	277	306	474	426	151	275	304	455
	II	397	151	246	272	423	638	334	304	336	670
	III	830	384	447	493	877	968	331	636	703	1035
JUL	I	841	355	486	537	892	823	279	545	602	880
	II	891	380	512	565	945	734	253	481	531	784
	III	1261	598	663	732	1331	1033	363	670	740	1104
AUG	I	1567	696	871	962	1658	867	242	625	691	933
	II	1382	386	995	1100	1486	952	227	725	801	1028
	III	992	195	796	880	1075	748	205	543	600	805
SEP	I	789	113	676	747	860	666	171	495	547	718
	II	593	74	518	572	647	538	144	393	435	579
	III	414	63	351	388	451	315	101	214	237	338
OCT	I	311	63	248	274	337	247	75	172	190	265
	II	210	63	147	162	225	193	75	118	130	205
	III	234	63	171	188	251	156	75	81	89	164
NOV	I	189	32	157	173	205	157	32	125	138	170
	II	199	63	136	150	213	160	75	85	94	169
	III	174	63	111	122	185	173	57	116	128	185
DEC	I	184	63	121	134	197	132	37	95	105	142
	II	171	62	109	120	183	119	30	89	98	129
	III	179	55	125	138	193	132	37	95	105	142
JAN	I	169	42	127	140	182	169	34	135	149	183
	II	156	60	96	106	166	156	14	142	157	171
	III	149	60	89	99	159	149	28	121	134	162
FEB	I	128	60	68	75	135	128	28	100	110	138
	II	140	60	80	88	148	140	27	112	124	151
	III	131	60	71	78	138	131	27	104	114	142
MAR	I	143	60	83	92	152	143	32	111	123	155
	II	153	60	93	103	163	153	29	124	137	166
	III	159	60	99	110	170	159	47	112	124	171
APR	I	146	60	86	95	155	146	60	85	94	155
	II	155	48	107	118	166	155	34	121	134	168
	III	214	77	137	151	228	214	52	161	178	231
MAY	I	307	123	184	203	326	307	45	262	289	334
	II	458	202	256	283	485	458	123	335	370	493
	III	558	241	316	349	591	558	184	373	412	597

		2012-13					2013-14				
		Rampir Discharge	Khab Discharge		Areal Transfer	Nirath Discharge	Rampir Discharge	Khab Discharge		Areal Transfer	Nirath Discharge
		A	B	A-B	D	D+B	A	B	A-B	D	D+B
JUN	I	429	198	232	256	454	1126	471	655	723	1194
	II	476	226	250	277	502	982	568	414	457	1025
	III	764	344	420	464	808	1251	590	661	730	1320
JUL	I	833	413	420	464	877	1380	544	836	924	1468
	II	703	338	366	404	741	1080	363	717	792	1155
	III	836	458	378	418	875	997	330	667	737	1066
AUG	I	1032	462	571	630	1092	980	300	679	751	1051
	II	930	431	499	551	982	1069	351	718	793	1144
	III	912	422	490	542	964	875	361	514	568	928
SEP	I	758	346	412	455	801	553	186	367	405	591
	II	631	283	348	384	667	426	182	244	270	452
	III	354	147	208	230	376	349	144	205	226	370
OCT	I	254	97	157	174	271	253	97	157	173	269
	II	185	63	122	135	198	216	78	138	152	231
	III	195	68	127	140	208	168	54	113	125	180
NOV	I	189	65	124	137	202	148	45	104	114	159
	II	158	50	108	120	169	176	58	118	130	188
	III	149	45	104	115	160	200	70	130	143	214
DEC	I	123	32	91	100	133	124	33	91	101	134
	II	115	28	87	96	124	106	24	82	91	115
	III	103	22	80	89	111	93	17	75	83	101
JAN	I	98	20	78	86	106	79	11	68	76	86
	II	97	20	78	86	105	73	11	62	68	79
	III	85	14	72	79	93	76	11	65	72	83
FEB	I	99	20	79	87	107	66	11	55	61	72
	II	102	22	80	89	111	58	11	47	52	63
	III	110	26	84	93	119	53	11	42	46	57
MAR	I	118	30	88	98	128	57	11	46	51	62
	II	121	31	90	99	131	62	11	51	56	67
	III	141	41	100	110	152	101	21	80	88	109
APR	I	158	50	109	120	170	130	36	94	104	140
	II	191	66	125	138	204	128	35	93	103	137
	III	276	108	168	186	293	142	41	100	111	152
MAY	I	282	104	178	197	301	287	113	174	192	305
	II	453	150	303	335	485	226	83	143	158	241
	III	753	300	453	500	800	273	106	167	184	291

केन्द्रीय जल आयोग
CENTRAL WATER COMMISSION

Fax to: 0177-2670310

Attn: Sri Rajiv Aggarwal

भारत सरकार
केन्द्रीय जल आयोग
जल विज्ञान (उ) निदेशालय

कमरा न० 507(द०),सेवा भवन
रा० कृ० पुरम, नई दिल्ली –66.

विषय :- Luhri H.E. Project (775 MW) - Himachal Pradesh

संदर्भ :- CWC U.O No 29/68/2009-PA(N)/351 dt. 21/03/2012.

उपर्युक्त संदर्भित पत्र का कृपया अवलोकन करें जिसमें इस निदेशालय से उपरोक्त परियोजना सम्बंधी रिपोर्ट की टिप्पणी भेजने का अनुरोध किया है। इस सम्बन्ध में इस निदेशालय से टिप्पणी प्रेषित की जा रही है।

संलग्न : यथावत

जी० एल० बंसल
(जी०एल० बंसल) 8/6/12
निदेशक

निदेशक, परियोजना मूल्यांकन (उत्तर) निदेशालय, के०ज०आ०
फाइल संख्या 1/HP/17/2003/ज.वि.(उ.)/283 दिनांक 8.6.2012

June, 2012

No./1/HP/17//2003/Hyd(N)/
Central Water Commission
Hydrology (North) Dte

Subject: Design flood studies of Luhri H.E.P (775 MW) – Himachal Pradesh

Project Proposal

The Project is located in district Mandi of Himachal Pradesh on river Satluj d/s of Rampur Hydroelectric Project and u/s of Kol dam Project. The project envisages the construction of a concrete dam 86m high above deepest foundation level at Nirath and under ground power house near Chaba with an installed capacity of 775 MW. The catchment area of river Satluj up to the dam site is 51600 sq.km.

Water availability and Diversion flood studies were already cleared during March, 2010. The revised design flood study received through Director, PA(N), CWC vide letter No.29/68/2009-PA(N)/351 dated 21/03/2012 has been examined and following observations are made.

Design Flood:

As the height of the dam is more than 86m, the dam is classified as large dam and design flood shall be PMF. Permanent snow line has been considered at 4200m as adopted by IMD in the storm studies.

As the catchment area is quite large and about 70 to 80% of the area is under permanent snow, therefore, to compute the design flood for Luhri HE Project, the catchment is divided into two parts.

1. **Catchment up to Karcham Wangtoo dam:** (Catchment area is 48755 sq.km) CWC has already approved the PMF value of 6744 cumec and the flood hydrograph has been routed up to Luhri dam site.

2. **Catchment from Wangtoo to Nirath dam:** Intervening catchment area is 2845 sqkm, out of this 1895sq.km. is rain fed area. The flood has been estimated by hydro-meteorological approach using Flood Estimation report for Western Himalayas – zone 7 in absence of site specific short interval data.

The design storm study is based on DAD analysis of 28-29 September 1924 storm at Kilba. 1-day PMP value adopted based on DAD analysis and after applying altitude correction factor of 0.63 is 217.6 mm. Further clock hour corrections of 15% are also applied. Design loss rate of 0.3 cm/hr has been adopted. The PMF obtained by this approach for this segment is 12146 cumec.

Finally, after adding the flood hydrographs of the above two catchments, the peak flood works out as **13462** cumec and same is recommended for further planning and design purposes.

However, project authorities are suggested to install a good network of hydro-meteorological observations including SRRG and start taking short interval rainfall and discharge data, so that studies may be firmed up at later stage when sufficient project specific data shall be available.

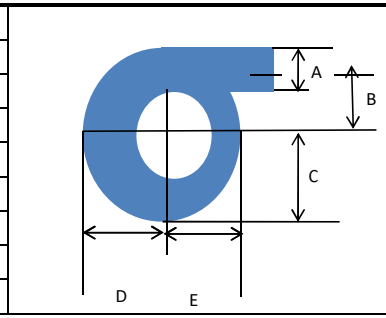
PLANT PARAMETERS

Sno	DESCRIPTION	SYMBOL	FORMULA	VALUE	UNIT
1	Full reservior level	FRL		862.9	m
2	Minimum draw down level	MDDL		860	m
3	Weighted average reservoir level	WARL	MDDL+2/3*(FRL-MDDL)	861.933	m
4	Flood TWL	TWL_{flood}		830	m
5	Maximum TWL	TWL_{max}		817	m
6	Normal TWL	TWL_{nor}		817	m
7	Minimum TWL	TWL_{min}		813.3	m
8	Installed capacity	P		19000	KW
9	Number of units	n_u		2	
10	Design discharge (for all units)	Q		49.73	m^3/s
11	Head losses	H_L		2.2	m
12	Generator efficiency	η_g		0.98	
13	Turbine efficiency	η_t		0.93	
14	Design discharge per unit	q	Q/n_u	24.86	m^3/s
15	Installed capacity per unit	P_g	P/n_u	9500	kW/unit
16	Gross head	Hg	$FRL-TWL_{min}$	49.6	m
17	Minimum net head	Hn_{min}	$MDDL-TWL_{max}-HL$	40.80	m
18	Maximum net head	Hn_{max}	Hg-HL	49.6	m
19	Net Design head/Rated head	Hr/Hd	$WARL-TWL_{nor}-HL$	42.73	m
20	Turbine output power per unit	P_t	P_g/η_g	9693.88	kW
21	Turbine output considering 10% overload	P_t	$P_t+(P_t*0.10)$	10663.27	kW

TURBINE CALCULATIONS

Sno	DESCRIPTION	SYMBOL	FORMULA	VALUE		UNIT	REMARKS
1	Trial specific speed	n_s'		342.14		rpm	from fig1 of IS-12800
2	Trial synchronous speed	n'	$n_s'*Hn^{*1.25}/(P_t*1.358)^{(1/2)}$	310.65		rpm	
3	No. of poles (from trial synchronous speed)		6000/n'	19.31			
	Percentage head variations						
4	From maximum net head		$((Hn_{max}-Hn)/Hn)*100$	16.07		%	
5	From minimum net head		$((Hn-Hn_{min})/Hn)*100$	4.52		%	
6	**Maximum head variation**		$((Hn_{max}-Hn_{min})/Hn)*100$	20.59		%	
7	Other options for pole pairs	P_{opted}	P		P		From clause 4.2.2.3 and 4.2.3 of page 2 of IS-12800
8	Pairs				10		
9	Machine rated speed	n	60f/P		300	rpm	
10	Machine rated speed (round off)	n			300	rpm	
11	**Final rated synchronous speed (for calculations)**	n			**300**	rpm	
12	**Final specific speed**	n_s	$(n(Pt*1.358)^{1/2})/(Hn)^{1.25}$		**330.41**	rpm	
	TURBINE SETTING						
13	Installed capacity	P			19000	kW	
14	Design net head	H_n			42.73	m	
15	Synchronous speed	n			**300**	rpm	
16	Specific speed	n_s			**330.41**	rpm	
17	Thoma's coefficient	σ			0.24		

18	Average water temperature				20	^{o}c	
19	Altitude	TWL_{min}			813.3	m	
20	Height of water column		Hb-Hv		9.03037	m	From fig 2 page 2 of IS-12800
21	Suction head	H_s	(Hb-Hv)-σ(Hmax)		**-2.87363**	m	
22	Margin				0.92637	m	
23	**Since Hs is negative, centre line should be kept below minimum TWL at**	H_s			**3.8**	m	
24	**Turbine distributor centre line should be set at:**	E_L	$TWL_{min}+H_s$		809.50	m	
	RUNNER DIMENSIONS						
25	**For specific speed**	n_s			**330.41**	**rpm**	
26	**Velocity coefficient**	K_u			1		Manual
27	Runner discharge diameter	D3	60*sqrt(2*g*H_{nmax})*K_u/∏n		**1.99**	m	
28	Runner inlet diameter	D1			1.32	m	From fig 7 page 5 of IS-12800
29	Runner throat diameter	D2			1.76	m	
30	Runner height above distributor center line	H1			0.31	m	
31	Runner depth below distributor center line	H2			0.70	m	

	SPIRAL CASING DIMENSIONS						
							
32		A			2.28	m	From fig 9a
33		B			2.48	m	
34		C			2.91	m	
35		D			3.36	m	From fig 9b
36		E			2.36	m	
		L			2.07	m	From fig 9c
		M			1.20	m	
		I			0.64	m	
	DRAFT TUBE DIMENSIONS(REFERENCE IS:5496-1993						
37	Depth of draft tube	H	(2.5 to 3.3)*D3		**6.50**	m	
38	Width of draft tube(clear width)	B	(2.6 to 3.3)*D3		**5.50**	m	
39	Length of draft tube from turbine axis	L	(4 to 5)*D3		**10.00**	m	
40	Height of draft tube at exit	h	(0.94 to 1.32)*D3		**2.30**	m	
41	Combined turbine and generator efficiency	η	$(\eta_g*\eta_t)$	**0.9114**	0.9114		
42	Rated discharge per unit	q	Power/(9.810*Hn*η)		24.8644	m^3/s	
43	Velocity at the exit of turbine	Ve	q/(B*h)		1.9657326	m/s	
44	**Minimum submergence**		$Ve^2/(2*g)$		0.1970145	m	
45	Say				0.3	m	
46	**The exit end of the draft tube will be**				**1.00**	m	
47	**Top end of exit of DT wil be**				**3.30**	m	
48	The height of draft tube below CL of guide apparatus	H1			6.50	m	
49	CL of guide apparatus below min TWL is				3.30	m	
50	Hence top end of exit of DT				7.00	m	below minimum tail water level
51	Minimum TWL	TWL_{min}			813.3	m	
52	EL of the top exit end of draft tube is				806.30	m	

Electrical Design Department

GENERATOR PARAMETERS

S.no	DESCRIPTION	SYMBOL	FORMULA		UNIT	REMARKS
	MAIN PARAMETERS OF HYDRO GENERATOR					
1	Generator rated output	P_g		9500	kW	
2	Power factor	p_f		0.85		
3	Rated MVA of Generator	W	$Pg/(p_f*1000)$	11.18	MVA	
4	Rated MVA after 10% overloading	W	(W+(0.1*W))	12.29	MVA	
5	No. of pairs of poles	P		10	nos	
6	Maximum rotor peripherical velocity	V_r		80.06666667	m/s	from fig15 of IS-12800
7	Output coefficient	K_o		6.17117284		from fig16 of IS-12800
8	Air gap diameter	D_g	(60*Vr/3.14*n)	2.90	m	Nigam Fig 6.5, page 98
9	Outer core diameter	D_o	Dg(1+(∏/P))	3.356	m	IS -12837
10	Stator frame diameter	D_f	(Do+1.2)	4.56	m	IS-12837
11	Inner diameter of generator barrel	D_b	(Df+(1.6 to 2.0))	6.16	m	
	(For semi-umbrella type contruction)					
12	Core length of stator	L_c	$W/(K_0*Dg^2*n)$	0.790	m	
13	Lc/Dg ratio		Lc/Dg	0.272279163		Semi-Umbrella Type Arrangement
14	Length of stator frame	L_f	Lc+(1.5 to 1.6 m)	2.390	m	
15	Axial hydraullic thrust coefficient	K		0.3476372		From fig 17a page 10 of IS-12800
16	Axial hydraullic thrust	P_H	$K*D3^2*Hn_{max}$	67.97	Tonnes	
17	Air gap diameter	D_g		2.90	m	
18	Weight of generator rotor	W_R	Lc*(value from graph)	53.48	Tonnes	From fig 18 page 6 of IS-12800
19	Runner inlet diameter	D1		1.32	m	

20	Weight of turbine runner	W_{tr}		4.55	Tonnes	From fig 19a page 11 of IS-12800 W.R.T D3
21	Weight of m/c rotating parts including hydraullic thrust		Wr+Wtr+P_H	125.99	Tonnes	
22	No. of arms of bearing bracket			4	nos	
23	Load per arm of bracket	L_t	(Wr+Wtr+P_H)/(no. of arms of bearing bracket)	31.50		
24		k		0.65		In accordance with table1
25	Height of load bearing bracket	h_j	k*sqrt(D_g)	1.11	m	

DIMENSIONS OF POWER HOUSE

Sno	DESCRIPTION	SYMBOL	FORMULA	VALUE	UNIT	REMARKS
	LENGTH OF POWER HOUSE					
1	Spiral casing width (for length of power house)		C+B+(A/2)	6.53	m	
2	Transverse length of spiral casing (for width of power house)		D+E	5.72	m	
3	Inner dia of generator barrel	D_b		6.16	m	
4	Spiral casing width with 2m concreting (for length of power house)			8.53	m	
5	Transverse length of spiral casing with 2m concreting (for width of power house)			7.72		
6	No. of pears			0	nos	
7	Width of one pier	W_{pier}	0.58*D3	0.00	m	
8	Total width of pier(s)	W_{piert}	No. of piers*W_{pier}	0.00	m	
9	Width of DT with pier width	B1	B+W_{piert}	5.50	m	
10	Outer dia of generator barrel	Do	Db+Concreting (1.5 m)	7.66	m	
11	Maximum dimensions out of above (for length of power house)	MaxDim		8.5339	m	
12	Unit spacing	Us	MaxDim+(clearances i.e. 1 m)*2)	10.53	m	
13	Additional unit space clearances			0.47	m	
14	Hence Unit spacing	Us	earlier unit spacing+additional clearances	11.00	m	
15	Erection bay/ Service bay length	L_s	(1 to 1.5)*Us	16.01	m	
16	Length of power house for Units	L_T	(No. of units*Us)	22.0	m	
			(+Ls)	16.0	m	
			Drainage Dewatering Space	0.00		
			(+Length of EOT crane to handle last unit)	2.00	m	
	Total length of power house	**L_T**		**40.0**	**m**	

	WIDTH OF POWER HOUSE (Wall to wall)						
15	**ON UPSTREAM SIDE**	W1	Max Dim/2		3.8278	m	
			(+moving space)		1.0	m	
			(+MIV spacing)		3.5	m	
			(+column width)		1	m	
		W1			9.33	m	
16	**ON DOWN STREAM SIDE**	W2	Max Dim/2		4.35580	m	
			(+moving space)		1.31	m	
			Service Block Area		0.00		
			(+column width)		1	m	
		W2			6.67	m	
17	**TOTAL WIDTH OF POWER HOUSE**	**W_T**	**W1+W2**		**16.00**	**m**	
18	**HEIGHT OF M/C HALL UPTO SERVICE BAY LEVEL**		Depth of DT(H1)		6.50	m	
			(+Depth of concrete)		1	m	
			(+Length of stator frame(Lf))		2.39	m	
			(+Height of load bearing bracket(h_j))		1.11	m	
			(+Height of bearing bracket above runner CL(K))		9	m	
					20.00	m	
	HEIGHT OF POWER HOUSE ABOVE SERVICE BAY LEVEL						
19	Machine hall elevation		(CL of distributor(E_L)+Lf+hj+K)		822.00	m	**Service bay has to be at El. 830.5 as HFL is El. 830m**
20	Crane clearance				16.50	m	
21	Elevation of EOT crane beam				838.50	m	
22	Roof truss bottom elevation		(Elevation of crane beam+2.5m)		841.00	m	
23	Height of roof truss		(Roof truss bottom elevation+1.5m)		842.50	m	
24	**Height of Power House**				**40.50**	**m**	

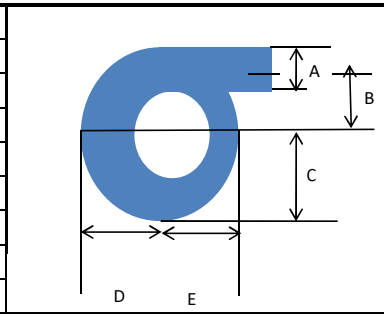
Electrical Design Department

PLANT PARAMETERS					
Sno	**DESCRIPTION**	**SYMBOL**	**FORMULA**	**VALUE**	**UNIT**
1	Full reservior level	FRL		862.9	m
2	Minimum draw down level	MDDL		860	m
3	Weighted average reservoir level	WARL	MDDL+2/3*(FRL-MDDL)	861.933	m
4	Flood TWL	TWL_{flood}		830	m
5	Maximum TWL	TWL_{max}		817	m
6	Normal TWL	TWL_{nor}		817	m
7	Minimum TWL	TWL_{min}		813.3	m
8	Installed capacity	P		200000	KW
9	Number of units	n_u		3	
10	Design discharge (for all units)	Q		515	m^3/s
11	Head losses	H_L		2.2	m
12	Generator efficiency	η_g		0.985	
13	Turbine efficiency	η_t		0.94	
14	Design discharge per unit	q	Q/n_u	171.67	m^3/s
15	Installed capacity per unit	P_g	P/n_u	66666.67	kW/unit
16	Gross head	Hg	$FRL-TWL_{min}$	49.6	m
17	Minimum net head	Hn_{min}	$MDDL-TWL_{max}-HL$	40.80	m
18	Maximum net head	Hn_{max}	Hg-HL	49.6	m
19	Net Design head/Rated head	Hr/Hd	$WARL-TWL_{nor}-HL$	42.73	m
20	Turbine output power per unit	P_t	P_g/η_g	67681.90	kW
21	Turbine output considering 10% overload	P_t	$P_t+(P_t*0.10)$	74450.08	kW

TURBINE CALCULATIONS

Sno	DESCRIPTION	SYMBOL	FORMULA	VALUE		UNIT	REMARKS
1	Trial specific speed	n_s'		342.14		rpm	from fig1 of IS-12800
2	Trial synchronous speed	n'	$n_s'*Hn^{1.25}/(P_t*1.358)^{(1/2)}$	117.57		rpm	
3	No. of poles (from trial synchronous speed)		6000/n'	51.04			
	Percentage head variations						
4	From maximum net head		$((Hn_{max}-Hn)/Hn)*100$	16.07		%	
5	From minimum net head		$((Hn-Hn_{min})/Hn)*100$	4.52		%	
6	**Maximum head variation**		$((Hn_{max}-Hn_{min})/Hn)*100$	20.59		%	
7	Other options for pole pairs	P_{opted}	P	P	P-2		From clause 4.2.2.3 and 4.2.3 of page 2 of IS-12800
8	Pairs			26	24		
9	Machine rated speed	n	60f/P	115.38462	125	rpm	
10	Machine rated speed (round off)	n		115.4	125	rpm	
11	**Final rated synchronous speed (for calculations)**	n		**115.4**	**125**	rpm	
12	**Final specific speed**	n_s	$(n(Pt*1.358)^{1/2})/(Hn)^{1.25}$	**335.84**	**363.78**	rpm	
	TURBINE SETTING						
13	Installed capacity	P		200000	200000	kW	
14	Design net head	H_n		42.73	42.73	m	
15	Synchronous speed	n		**115.4**	**125**	rpm	
16	Specific speed	n_s		**335.84**	**363.78**	rpm	
17	Thoma's coefficient	σ		0.2353	0.2557		

18	Average water temperature			20	20	°c	
19	Altitude	TWL_{min}		813.3	813.3	m	
20	Height of water column		Hb-Hv	9.03037	9.03037	m	From fig 2 page 2 of IS-12800
21	Suction head	H_s	(Hb-Hv)-σ(Hmax)	-2.64051	-3.65235	m	
22	Margin			1.15949	0.64765	m	Margin considered high because of ambiguity in ambient temp
23	**Since Hs is negative, centre line should be kept below minimum TWL at**	H_s		**3.8**	**4.3**	m	
24	**Turbine distributor centre line should be set at:**	E_L	$TWL_{min}+H_s$	809.50	809	m	
	RUNNER DIMENSIONS						
25	**For specific speed**	n_s		**335.84**	**363.78**	**rpm**	
26	**Velocity coefficient**	K_u		1.0286	1.1		
27	Runner discharge diameter	D3	$60*sqrt(2*g*H_{nmax})*K_u/\prod n$	**5.31**	**5.24**	m	
28	Runner inlet diameter	D1		3.50	3.36	m	From fig 7 page 5 of IS-12800
29	Runner throat diameter	D2		4.71	4.61	m	
30	Runner height above distributor center line	H1		0.83	0.84	m	
31	Runner depth below distributor center line	H2		1.86	1.84	m	

	SPIRAL CASING DIMENSIONS						
							
32		A		6.09	6.03	m	From fig 9a
33		B		6.64	6.55	m	
34		C		7.79	7.68	m	
35		D		8.9698	8.85	m	From fig 9b
36		E		6.32	6.23	m	
		L		5.55	5.52	m	From fig 9c
		M		3.21	3.17	m	
		I		1.72	1.75	m	
	DRAFT TUBE DIMENSIONS(REFERENCE IS:5496-1993						
37	Depth of draft tube	H	(2.5 to 3.3)*D3	**15.93**	**16.00**	m	
38	Width of draft tube(clear width)	B	(2.6 to 3.3)*D3	**15.40**	**15.20**	m	
39	Length of draft tube from turbine axis	L	(4 to 5)*D3	**23.89**	**24.00**	m	
40	Height of draft tube at exit	h	(0.94 to 1.32)*D3	**6.37**	**6.00**	m	
41	Combined turbine and generator efficiency	η	$(\eta_g*\eta_t)$	0.9259	0.9259		
42	Rated discharge per unit	q	Power/(9.810*Hn*η)	188.93	188.9303	m^3/s	
43	Velocity at the exit of turbine	Ve	q/(B*h)	1.93	2.07	m/s	
44	**Minimum submergence**		$Ve^2/(2*g)$	0.19	0.218809	m	
45	Say			0.19	0.22	m	
46	**The exit end of the draft tube will be**			**2.39**	**2.40**	m	
47	**Top end of exit of DT wil be**			**8.76**	**8.40**	m	
48	The height of draft tube below CL of guide apparatus	H1		15.93	16.00	m	
49	CL of guide apparatus below min TWL is			8.76	8.40	m	
50	Hence top end of exit of DT			10.97	11.90	m	below minimum tail water level
51	Minimum TWL	TWL_{min}		813.3	813.3	m	
52	EL of the top exit end of draft tube is			802.33	801.40	m	

GENERATOR PARAMETERS

S.no	DESCRIPTION	SYMBOL	FORMULA	VALUE		UNIT	REMARKS
	MAIN PARAMETERS OF HYDRO GENERATOR						
1	Generator rated output	P_g		66666.66667	66666.667	kW	
2	Power factor	p_f		0.9	0.9		
3	Rated MVA of Generator	W	Pg/(p_f*1000)	74.07	74.07	MVA	
4	Rated MVA after 10% overloading	W	(W+(0.1*W))	81.48	81.48	MVA	
5	No. of pairs of poles	P		26	24	nos	
6	Maximum rotor peripherical velocity	V_r		68.9893617	69.360465	m/s	from fig15 of IS-12800
7	Output coefficient	K_o		6.95252791	6.8714934		from fig16 of IS-12800
8	Air gap diameter	D_g	((60/∏)*(Vr/n))	11.42	10.60	m	
9	Outer core diameter	D_o	Dg(1+(∏/2P))	12.11	11.29	m	
10	Stator frame diameter	D_f	(Do+1.2)	13.31	12.49	m	
11	Inner diameter of generator barrel	D_b	(Df+(1.6 to 2.0))	15.31	14.49	m	
	(For semi-umbrella type contruction)						
12	Core length of stator	L_c	((W*1000)/(K_o*D^2g*n))	0.779	0.845	m	
13	Lc/Dg ratio		Lc/Dg	0.068256844	0.0797364		Semi-Umbrella Type Arrangement
14	Length of stator frame	L_f	Lc+(1.5 to 1.6 m)	2.379	2.445	m	
15	Axial hydraullic thrust coefficient	K		0.3538094	0.37004		From fig 17a page 10 of IS-12800
16	Axial hydraullic thrust	P_H	K*$D3^2$*Hn_{max}	494.60	504.22	Tonnes	
17	Air gap diameter	D_g		11.42	10.60	m	

18	Weight of generator rotor	W_R	Lc*(value from graph)	247.04	245.56	Tonnes	From fig 18 page 6 of IS-12800
19	Runner inlet diameter	D1		3.50	3.36	m	
20	Weight of turbine runner	W_{tr}		17.96	16.74	Tonnes	From fig 19a page 11 of IS-12800
21	Weight of m/c rotating parts including hydraullic thrust		$Wr+Wtr+P_H$	759.60	766.51	Tonnes	
22	No. of arms of bearing bracket			8	8	nos	
23	Load per arm of bracket	L_t	$(Wr+Wtr+P_H)/$(no. of arms of bearing bracket)	94.95	95.81		
24		k		0.75	0.75		In accordance with table1
25	Height of load bearing bracket	h_j	$k*sqrt(D_g)$	2.53	2.44	m	

DIMENSIONS OF POWER HOUSE

Sno	DESCRIPTION	SYMBOL	FORMULA	VALUE		UNIT	REMARKS
	LENGTH OF POWER HOUSE			**26 poles**	**24 ploes**		
1	Spiral casing width (for length of power house)		C+B+(A/2)	17.47	17.25	m	
2	Transverse length of spiral casing (for width of power house)		D+E	15.29	15.07	m	
3	Inner dia of generator barrel	D_b		15.31	14.49	m	
4	Spiral casing width with 3m concreting (for length of power house)			20.47	20.25	m	
5	Transverse length of spiral casing with 3m concreting (for width of power house)			18.29	18.07		
6	No. of pears			1	1	nos	
7	Width of one pier	W_{pier}	0.58*D3	3.1	3.0	m	
8	Total width of pier(s)	W_{piert}	No. of piers*W_{pier}	3.08	3.04	m	
9	Width of DT with pier width	B1	B+W_{piert}	18.47	18.24	m	
10	Outer dia of generator barrel	Do	Db+concrete thickness(1.5 m)	16.806	15.99	m	
11	Maximum dimensions out of above (for length of power house)	MaxDim		20.47	20.25	m	
12	Unit spacing	Us	MaxDim+clearances i.e. 2 m	22.47	22.25	m	
13	Additional unit space clearances			**0.03**	**0.25**	m	
14	Hence Unit spacing	Us	earlier unit spacing+additional clearances	22.50	22.50	m	
15	Erection bay/ Service bay length	L_s		39.41	37.78	m	
16	Total length of power house	L_T	(No. of units*Us)	67.5	67.5	m	
17			(+Ls)	39.50	38.00	m	
19			(+Length of EOT crane to handle last unit)	2	2	m	
	Total length of power house	**L_T**		**109.0**	**107.5**	**m**	

	WIDTH OF POWER HOUSE (Wall to wall)						
15	**ON UPSTREAM SIDE**	W1	Max Dim	8.403	7.99	m	
			(+moving space)	1.627	1.659	m	
			(+MIV Block)	13.5	13.5	m	
			(+column width)	2	2	m	
		W1		25.530	25.15	m	
16	**ON DOWN STREAM SIDE**	W2	Max Dim	10.4698	10.35	m	
			(+Service Block)	8	8	m	
			(+column width)	2	2	m	
		W2		20.47	20.35	m	
17	**TOTAL WIDTH OF POWER HOUSE**	**W_T**	**W1+W2**	**46.0**	**45.50**	**m**	
18	**HEIGHT OF M/C HALL UPTO MACHINE HALL LEVEL**		Depth of DT(H1)	15.93	16.00	m	
			(+Depth of concrete)	1.2	1.2	m	
			(+Length of stator frame(Lf))	2.38	2.44	m	
			(+Height of load bearing bracket(h_j))	2.53	2.44	m	
			(+Height of bearing bracket above runner CL(K))	9.09	9.11	m	
				31.13	31.20	m	
	HEIGHT OF POWER HOUSE ABOVE MACHINE HALL LEVEL						
19	Machine hall elevation		(CL of distributor(E_L)+Lf+hj+K)	823.50	823.00	Y	**Service bay has to be at El. 830.5 as HFL is El. 830m**
20	Crane clearance			18.5	18.5	m	
21	Elevation of EOT crane beam			842.00	841.50	m	
22	Roof truss bottom elevation		(Elevation of crane beam+5m)	847.00	846.50	m	
23	Height of roof truss		(Roof truss bottom elevation+5m)	852.00	851.50	m	
24	**Height of Power House**		**Height of Roof. - CL+H1+Depth of Concrete**	**59.63**	**59.70**	**m**	