Chapter- 5
Reservoir and Power

5.0 General

Reservoirs play significant role in conservation, management and development of water resources in our country. The precipitation in the country is uneven both in space and time and confined to monsoon season i.e. June to September only. Some parts of the country receive much more than the normal rainfall leading to heavy floods and at the same time some other parts receive less than the normal rainfall leading to droughts. The water availability even for drinking purposes becomes critical, particularly in the summer months as the rivers dry up and the ground water recedes.

The demand of water for various purposes like irrigation, drinking & industrial, power generation etc. would be throughout the year in a set pattern. To bridge the gap between seasonal water availability and water demand, creation of the storage reservoirs to store the water is essential. The reservoirs also facilitate the hydro power generation and supply of water to the needy areas by gravity flow. Considering the natural inflow pattern, water demands for various purposes at a particular time and keeping in view the techno-economic aspects, attempt has been made to fix the size of the reservoirs.

The objective of Damanganga-Pinjal Link Project is to transfer surplus waters available in Damanganga and Pinjal river basins to Mumbai city for augmentation of its domestic water supply. For this purpose a dam at Bhugad across river Damanganga; a dam at Khargihill across river Vagh along with a saddle dam have been proposed by NWDA. In addition, a dam across river Pinjal has been proposed by Government of Maharashtra. Two tunnels: (i) Connecting Bhugad reservoir with Khargihill reservoir; and (ii) Connecting Khargihill reservoir with Pinjal reservoir are also proposed. The Power houses at the toe of both Bhugad and Khargihill dams are also planned to generate the hydro-power by utilising waters proposed to be released to meet the water requirements downstream of the respective dam sites.

The surplus water of Damanganga basin at proposed Bhugad and Khargihill Dams will be first transferred to Pinjal dam (proposed by Government of Maharashtra) from where the combined waters of Damanganga and Pinjal rivers will be taken to Mumbai city as per the plans of Municipal Corporation of Greater Mumbai (MCGM) and Mumbai Metropolitan Region Development Authority (MMRDA).

Bhugad dam is proposed across river Damanganga near Bhugad village in Trimbak taluka of Nasik district of Maharashtra. Khargihill dam is proposed across river Vagh (a tributary of river Damanganga) near village Behadpada in Jawhar taluka of Thane district in Maharashtra State. A saddle dam is also proposed in Khargihill reservoir on the left side of Khargihill main dam near Vavar village. Pinjal dam is proposed across river Pinjal (Vaitarna basin) near village Khidse in Jawhar taluka of Thane district of Maharashtra state. The area under submergence of Bhugad and Khargihill reservoirs at FRL is assessed to be 1903 ha and 1558 ha respectively. The area of submergence under Pinjal reservoir is estimated to be 2000 ha.

The Bhugad and Khargihill reservoirs are planned to be utilized for diversion of surplus Damanganga water at these two dam sites to Pinjal reservoir for augmentation of domestic water supply to Mumbai city. The water needs of the people in the vicinity of these reservoirs for various purposes i.e. domestic and other requirements will be fulfilled before affecting any diversion of water to Pinjal. The Bhugad dam will intercept an area of 141 km^2 of Gujarat state. The water generated from this 141 km^2 area would have been available at existing Madhuban dam of Gujarat State if this area is not intercepted by Proposed Bhugad dam, as such the Gujarat state is to be compensated by release of 91 Mm^3 of water from proposed Bhugad reservoir to utilize at the existing Madhuban dam. Also the water to protect the ecology of river downstream of both the proposed dam sites needs to be released from the respective dams.

The power generation at each reservoir is planned utilizing environmental releases, committed d/s releases, spills etc.

A dam across river Pinjal near Village Khidse in Jawhar taluka of Thane district of Maharashtra was proposed by Water Resources Department

(WRD), Government of Maharashtra. The DPR of Pinjal dam was prepared by Water Resources Department, Government of Maharashtra during the year 1981. Presently the Pinjal Project is being developed by MCGM as drinking water supply project and the DPR is accordingly being revised/ prepared by MCGM. The details of Pinjal dam are taken from these reports.

The details of proposed Bhugad and Khargihill reservoirs are presented in following paragraphs:

5.1. Bhugad Reservoir

5.1.1. Fixation of Storage and Reservoir Levels - Approach–Criteria

The water availability studies at Bhugad, Khargihill and Pinjal dam sites have been carried out by the Hydrological Studies Organisation, CWC, New Delhi as a part of "Hydrological Studies of Damanganga-Pinjal Link Project". The Gross and Net Annual Yields at Bhugad dam site as per these studies are as given in Table: 5.1 below:

Table: 5.1
Gross & Net Annual Yields at Bhugad Dam Site

S.No.	Details	Annual Yield (Mm^3)	
		Gross	Net
1	100% Dependable yield	372	284
2	75% Dependable yield	517	395
3	50% Dependable yield	733	610
4	Average yield	785	668

The net water availability at Bhugad dam site has been worked out after subtracting all the consumptive upstream utilizations planned by States. Regeneration from irrigation projects has been neglected as all schemes upstream are minor irrigation projects. The regeneration from domestic & industrial uses has been considered as 80 percent of water diverted for the purpose. The net yield series generated at Bhugad dam site for the period from 1975-76 to 2008-09 is at Annexure: 3.6 in Volume - II.

The reservoir simulation study has been carried out for estimating the live storage capacity of the reservoir that would provide the required yield at specified reliability. The discharge data is available for a period of 25 years from 1984 to 2008 at Nani Palsan G & D site maintained by CWC, which is located at about 2 km d/s of Bhugad dam site. Rainfall – Runoff model has been developed using discharge data available at Nanipalsan G & D site and rainfall for the concurrent period. Using this Rainfall – Runoff model the yield series for the period from 1975-76 to 1983 - 84 at Bhugad dam site has been developed. The yield series at Bhugad dam site for the period from 1984-85 to 2008-09 has been developed on catchment area proportionate basis using observed discharge data of Nanipalsan G & D site after duly checking the consistency. The yield series so developed for the period from 1975 to 2008 has been used for simulation analysis.

The simulation analysis has been done using Simulation Program developed using c^{++}. This programme also takes into account the different releases from Bhugad reservoir: i) for local domestic & industrial water demand, ii) committed downstream demand for Madhuban reservoir, iii) local irrigation demand, iv) environmental and ecological requirements downstream of proposed dam site, and v) diversion to Khargihill reservoir for augmentation of domestic water supply of Mumbai. The result of this analysis is at Appendix 3.3 in Volume - IV which gives detailed output for the gross capacity of 390 Mm^3.

5.1.1.1 Dead Storage Level (DSL)

One of the most important issues in the planning of storage reservoirs is the loss in the storage capacity due to silting. Hence, it is necessary at the planning stage that a portion of the capacity of the reservoir is reserved for occupation by silt deposition. By providing extra storage volume in the reservoir for sediment accumulation, in addition to the live storage, it is ensured that the live storage will function at full efficiency for an assigned number of years. This volume of storage (in addition of live storage) is referred to as the dead storage and is equivalent to the volume of sediment expected to be deposited in the reservoir during the designed life of the structure.

The sediment entering into a storage reservoir gets deposited progressively with the passage of time and thereby reduces the dead as well as live storage capacity of the reservoir. This causes the bed level near the dam to rise and the raised bed level is termed as "New Zero Elevation". It is therefore necessary to assess the revised areas and capacities at various reservoir elevations that would be available in future and could be used in simulation studies to test the reservoir performance and also the New Zero Elevation. As per IS: 12182 (1987) – "Guidelines for Determination of Effects of Sedimentation in Planning and Performance of Reservoirs". The live storage is to be so planned that the benefits do not reduce for a period of 50 years (full service time) for irrigation or 25 years for hydropower projects connected to a grid on account of sedimentation. Also the sedimentation in the reservoir should not cause operational problems (sedimentation beyond the outlet) for 100 years for irrigation projects and 70 years for hydropower projects in a grid. Though Bhugad and Khargihill reservoirs are being planned mainly to meet the domestic and industrial water requirements of Greater Mumbai, their live storages are so planned that full benefits are available for 50 years and reservoirs will function normally for about 100 years. Accordingly, sedimentation studies have been carried out for 50 years (for reservoir simulation) and 100 years (for planning outlet).

The dead storage capacity of the Bhugad reservoir has been fixed on the basis of the guidelines given in "Fixing the capacities of reservoirs – Methods, Part 2 Dead storage, IS 5477 (Part 2): 1994".

The new zero elevation of the Bhugad reservoir has been worked out as 107.80 m and 112.50 m after 50 years and 100 years respectively on the basis of sedimentation studies. The corresponding capacities at these levels as per the original area - capacity table come to 91.40 ha m and 527.54 ha m respectively. However, Dead Storage Level of the reservoir has been proposed as 112.50 m (corresponding original capacity of 527.54 ha m) and sluices are proposed to be provided at this level. The details of sedimentation studies are furnished in Appendix 2.15 in Volume – III(B).

5.1.1.2 Low Water Level /Minimum Draw-Down Level (MDDL)

The minimum draw down level (MDDL) of Bhugad reservoir can be fixed anywhere above 112.50 m which is the new zero elevation after 100 years of operation of the reservoir, based on sedimentation studies carried out by Hydrological Studies Organisation, CWC, New Delhi. The water diverted from Damanganga basin alongwith the water available at Pinjal dam is to be taken up to Mumbai as per the plans of Municipal Corporation of Greater Mumbai (MCGM) and Mumbai Metropolitan Region Development Authority (MMRDA). The MCGM vide their letter No. ChE/WSP/4710 dated 1st November 2010 (Annexure - 5.1 in Volume - II) had informed that the water from Damanganga basin shall be made available at Pinjal dam at 92.50 m. To meet the demands of water for various uses by people in the vicinity of the reservoir and also to ensure delivery of Damanganga waters at Pinjal at elevation of 92.50 m, the MDDL of the Bhugad reservoir is kept at 124.83 m.

5.1.1.3 Full Reservoir Level (FRL)

Simulation studies carried out for Bhugad, Khargihill, Pinjal and existing Madhuban reservoirs indicates that the proposed Bhugad reservoir with Full Reservoir Level at 163.870 m will meet various planned demands at 100% success rate, ignoring 10% deficit on annual basis. Therefore, the Full Reservoir Level of Bhugad dam has been kept at 163.87 m.

5.1.1.4 Maximum Water Level (MWL)

Maximum water level of Bhugad reservoir has been kept as 164.249 m and the gates of spillway have been designed to pass design flood of 8992 Cumecs.

The flood routing study of Bhugad reservoir was carried out by CWC. The spillway of proposed Bhugad dam will have 10 gates. Computations were performed with the condition that 9 out of total 10 gates are in operation. The result of reservoir routing study indicates that the maximum water level attained was 163.89 m and the maximum outflow discharge was 8873 Cumec.

The maximum water level at Bhugad dam has been fixed as 164.249 m. The Flood Routing study for proposed Bhugad dam is at Annexure: 5.2 in Volume - II. Various levels fixed at Bhugad Reservoir are given in Table - 5.2:

Table -5.2
Levels Fixed as per Simulation Study

Bhugad Reservoir	**Elevation(m)**
MWL	164.249 m
FRL	163.870 m
MDDL	124.830 m
Bhugad – Khargihill Tunnel	
Invert level at entry	116.20 m
Crown level at entry	119.40 m
Invert level at exit	103.40 m
Crown level at exit	106.60 m
Powerhouse (at toe of dam)	
Invert Level of pen stock at inlet	106.41 m
TWL for Powerhouse	107.50 m

5.1.1.5 Maximum Backwater Level at Full Reservoir Level and Maximum Water Level and its Effect, Points to Which Backwater Effect is Felt, Maximum Distance of Such Points from the Axis of the Structure

The Full Reservoir Level (FRL) and Maximum Water Level (MWL) of the Bhugad dam have been fixed at 163.870 m and 164.249 m respectively. The maximum back water level at MWL is 164.249 m and the effect extends upto a distance of about 15 km from the axis of the dam (at the periphery of the reservoir) within which no structure of significant importance has been identified.

5.1.1.6 Saddles along the Reservoir Rim

The entire rim of proposed Bhugad reservoir is covered with the contours of value higher than the MWL as such no saddle is proposed along the rim of Bhugad reservoir

5.1.1.7 Fetch

The fetch of the reservoir was determined to fix the free board and the top of the dam. The fetch computations were done as per the Indian Standards IS: 10635-1993, "Guidelines for Free board requirements in Embankment Dams". The effective fetch length of 1.749 km & 1.750 km respectively at FRL and MWL has been worked out.

5.1.1.8 Direction of Wind - Velocity of Wind - Wave Height - Free Board-Top of Dam

The direction of wind in Bhugad reservoir area is mostly from east to west. The Nasik IMD station is located near to the Bhugad dam site. The maximum wind velocity of 13.2 km/hr is experienced in the month of June and the minimum wind velocity of 4.5 km/hr is experienced in the month of December. The average velocity of wind is 8.4 km/hr. However, a normal wind velocity of 44 m/sec has been considered. Wave height is estimated as 2.76 m. The following factors are taken into consideration while computing the free board requirement:

(a) Wave characteristics i.e. wave height and wave length;
(b) Upstream slope of the river and roughness of the pitching;
(c) Height of wind setup above the still water level.

The detailed computations for free board required for FRL and MWL conditions have been done and the details are furnished in Chapter – 4 on Design Aspects. The free board requirement has been worked out as 4.07 m. The top of the rock-fill portion of the Bhugad dam has been fixed at 168.270 m.

5.1.2 Sedimentation Data and Studies

The catchment area of Damanganga river upto proposed Bhugad dam site is 708 Km^2. Presently silt observations are not taken in the catchment area of Bhugad dam. The Government of Gujarat had carried out sedimentation study at existing Madhuban reservoir across Damanganga river in the downstream of proposed Bhugad dam. Using this data the sedimentation rate at Bhugad dam site has been assessed.

5.1.2.1 Rate of Sedimentation with Basis

As the silt in the catchment area of proposed Bhugad dam site is presently not observed at any location, the sedimentation data of existing Madhuban reservoir located across Damanganga river in the downstream of Bhugad dam site has been used for assessment of sedimentation rate. Considering the reservoir sedimentation rate of 8.94 ham/100 km^2/year at Madhuban reservoir, reservoir capacity and average inflows into reservoir, the inflow sedimentation rate at Madhuban dam has been back calculated as under:

Average Inflow at Madhuban dam (I)= 3116.06 Mm^3
Gross capacity of Madhuban dam at FRL (C) = 567.00 Mm^3
Capacity-Inflow ratio (C/I) = 567.0/3116.06 = 0.18196
As per Brune's curve Trap Efficiency (η) = 90.11 %
Observed sediment rate at Madhuban dam= 8.94 ham/100 km^2/year

So, sediment inflow at Madhuban dam = 8.94*100/90.11= 9.921 ham/100 km^2/year.

The Madhuban and Bhugad reservoirs lie in Damanganga basin and broadly have similar catchment characteristics and may be assumed to have similar sediment yields. Further, smaller catchments tend to be more susceptible to higher sedimentation yields than larger catchments (Clause 2.2 of ICOLD Bulletin 115- Dealing with Reservoir Sedimentation). As catchment area of Madhuban dam is about three times than the catchments of Bhugad Reservoir, the inflow sedimentation rate for Bhugad reservoir has been assumed to be 10 percent more than inflow sedimentation rate assessed at Madhuban dam. Accordingly, the inflow sedimentation rate of 10.912 ham/100 km^2/year has been taken for Bhugad reservoir.

5.1.2.2 Quantity of Sediment

Considering the inflow sedimentation rate of 10.912 ham/100 km^2/year the sediment volume at Bhugad reservoir will be as under:

i) 50 years sediment volume 36.795 Mm^3
ii) 100 years sediment volume 73.464 Mm^3

5.1.2.3 Type and Shape of Reservoir

The Bhugad reservoir is considered as flood plain-foot hill type and the standard classification is taken as Type II.

5.1.2.4 Sediment Studies – Bhugad Reservoir

As per IS 5477 (Part – 2): 1994 (Fixing the capacities of reservoirs), either the “Empirical Area Reduction” method or the “Area Incremental” method is recommended to be used for sedimentation study. In this report, the sedimentation study has been carried out using “Empirical Area Reduction” method.

5.1.2.5 Sediment Distribution

The sediment distribution is worked out for two periods, viz. 50 years and 100 years by Empirical Area Reduction method. For this purpose, the FRL 163.87 m is adopted and bed level of the reservoir is considered as 99.64 m. The original Elevation-Area-Capacity table for Bhugad reservoir is given in Table-5.3:

Table-5.3
Original Elevation-Area-Capacity Table for Bhugad Reservoir

Elevation (m)	Area (ha)	Capacity (Mm^3)
163.87	1903.01	427.07
163.00	1862.40	410.69
160.00	1700.57	357.26
157.00	1568.80	308.24
154.00	1423.02	263.38
151.00	1262.88	223.11

148.00	1102.40	187.66
145.00	996.73	156.19
142.00	887.38	127.94
139.00	767.57	103.14
136.00	686.54	81.34
133.00	570.00	62.52
130.00	457.36	47.14
127.00	339.74	35.23
124.00	281.40	25.92
121.00	210.08	18.58
118.00	170.00	12.89
115.50	150.00	8.89
112.50	111.00	5.28
112.00	94.15	4.65
111.70	90.00	3.83
111.00	80.10	3.65
110.00	74.78	2.97
109.00	64.61	1.75
108.00	48.20	1.00
107.80	43.40	0.91
107.50	36.00	0.79
107.20	30.00	0.70
107.00	28.00	0.64
106.00	25.56	0.37
103.00	2.00	0.02
100.00	0.02	0.00
99.64	0.00	0.00

The total sediment during 50 and 100 years will get distributed up to and above various elevations as given in the Table-5.4 below:

Table-5.4
Distribution of Total Sediment at Various Elevations of Bhugad Dam

Reservoir level	**Sediment deposition in Mm^3**	
	After 50 years	**After 100 years**
Upto 108 m	1.00	1.00
Above 108 m	35.89	73.14
Upto 112.5 m	3.22	5.28
Above 112.5 m	33.66	68.86
Upto 125 m	10.60	21.60
Above 125 m	26.29	52.54

The new zero elevation will be as follows:

After 50 years	= 107.80 m
After 100 years	= 112.50 m

The minimum draw down level (MDDL) can be fixed anywhere above 112.50 m which is the new zero elevation after 100 years of operation of the reservoir.

The plots of revised elevation-area-capacity curve for 50-Year sedimentation and 100 year sedimentation are given in Figure – 5.1 & 5.2 respectively:

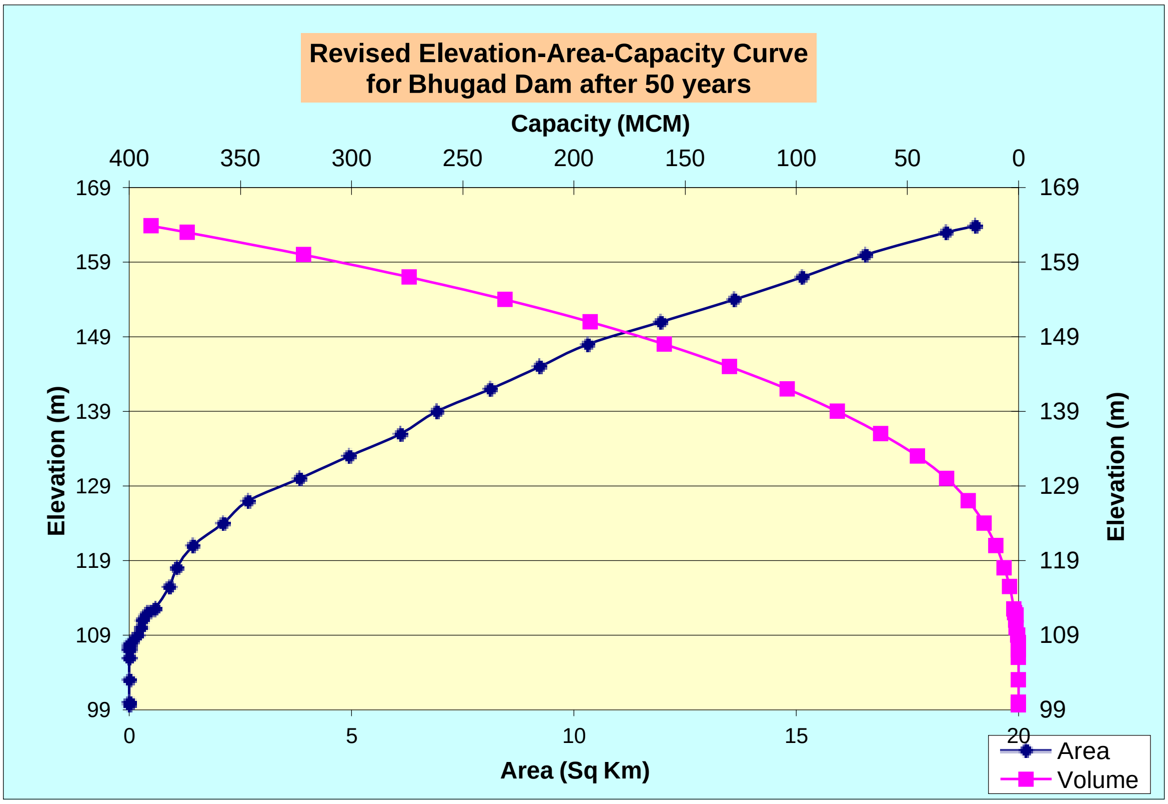

Figure – 5.1: Revised Elevation-Area-Capacity Curve of Bhugad Dam for 50 Year Sedimentation

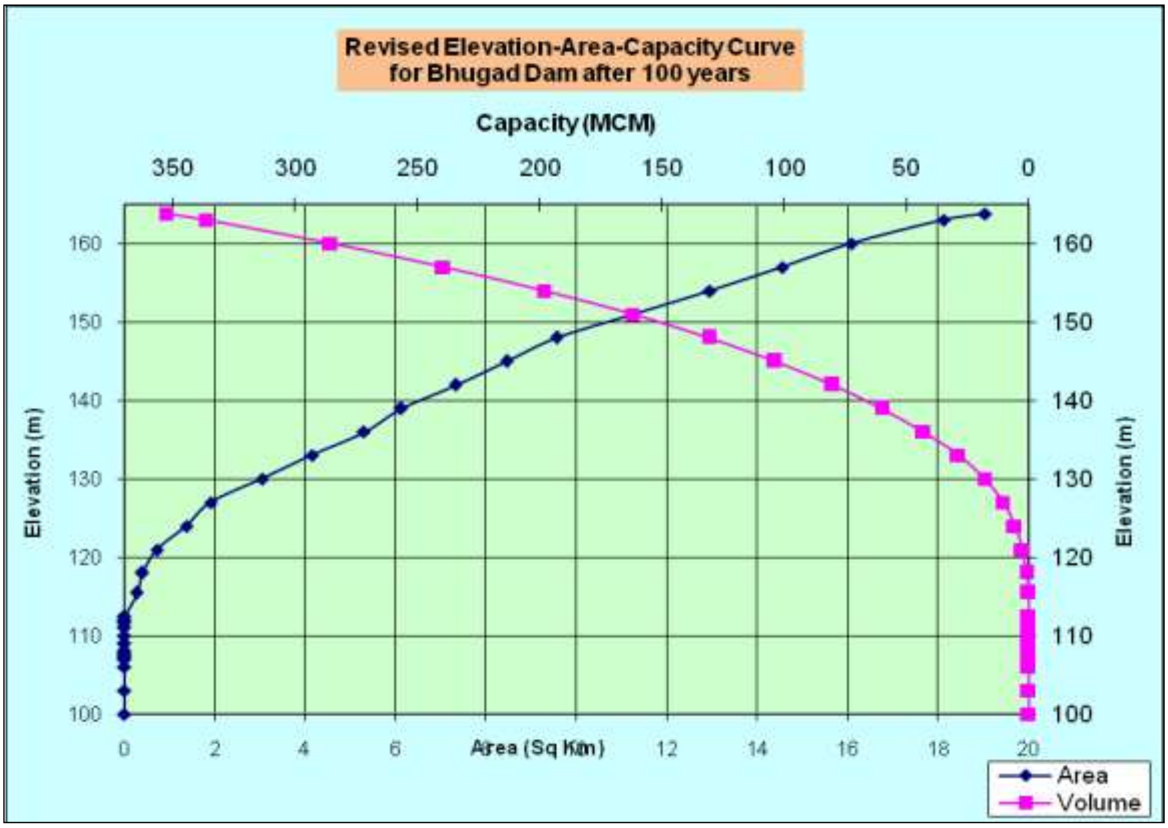

Figure – 5.2: Revised Elevation-Area-Capacity Curve of Bhugad Dam for 100 Year Sedimentation

Original and revised (after 50 and 100 years) Elevation-Area-Capacity table for Bhugad reservoir is given in Table-5.5 below:

Table-5.5

Original and Revised (after 50 and 100 years) Elevation – Area - Capacity Table for Bhugad Reservoir

Elevation	Original Area	Original Capacity	Revised Area after 50 yr	Revised Capacity after 50 yr	Revised Area after 100 yr	Revised Capacity after 100 yr
(m)	(ha)	(Mm^3)	(ha)	(Mm^3)	(ha)	(Mm^3)
163.87	1903.01	427.07	1903.01	390.18	1903.01	352.93
163.00	1862.40	410.69	1837.10	373.92	1810.65	336.78
160.00	1700.57	357.26	1655.19	321.55	1607.75	285.52
157.00	1568.80	308.24	1513.03	274.04	1454.72	239.60
154.00	1423.02	263.38	1360.27	230.96	1294.66	198.37
151.00	1262.88	223.11	1195.14	192.65	1124.32	162.11

148.00	1102.40	187.66	1031.08	159.28	956.50	130.93
145.00	996.73	156.19	922.90	129.99	845.71	103.91
142.00	887.38	127.94	811.95	103.98	733.08	80.24
139.00	767.57	103.14	691.32	81.45	611.59	60.10
136.00	686.54	81.34	610.17	61.94	530.32	42.98
133.00	570.00	62.52	494.18	45.40	414.90	28.83
130.00	457.36	47.14	382.72	32.28	304.67	18.06
127.00	339.74	35.23	266.91	22.58	190.75	10.68
124.00	281.40	25.92	211.01	15.43	137.41	5.77
121.00	210.08	18.58	142.80	10.15	72.45	2.65
118.00	170.00	12.89	106.54	6.42	40.19	0.97
115.50	150.00	8.89	90.34	3.96	27.96	0.12
112.50	111.00	5.28	56.74	2.05	0.00	0.00
112.00	94.15	4.65	40.89	1.70	0.00	0.00
111.70	90.00	3.83	37.35	1.03	0.00	0.00
111.00	80.10	3.65	28.94	1.22	0.00	0.00
110.00	74.78	2.97	25.87	1.04	0.00	0.00
109.00	64.61	1.75	18.09	0.29	0.00	0.00
108.00	48.20	1.00	4.26	0.00	0.00	0.00
107.80	43.40	0.91	0.00	0.00	0.00	0.00
107.50	36.00	0.79	0.00	0.00	0.00	0.00
107.20	30.00	0.70	0.00	0.00	0.00	0.00
107.00	28.00	0.64	0.00	0.00	0.00	0.00
106.00	25.56	0.37	0.00	0.00	0.00	0.00
103.00	2.00	0.02	0.00	0.00	0.00	0.00
100.00	0.02	0.00	0.00	0.00	0.00	0.00
99.64	0.00	0.00	0.00	0.00	0.00	0.00

The sedimentation study report of the reservoirs of Damanganga – Pinjal link project is at Appendix – 2.15 in Volume – III(B).

5.1.3 Life of Reservoir in Years with Basis

All the outlets from the reservoir are fixed at an elevation above the New Zero Elevation estimated after considering 100 years of sedimentation. Therefore, the life of the Bhugad reservoir has been considered as 100 years.

5.1.4 Capacity

5.1.4.1 Capacities of Bhugad Reservoir

S No.		Capacity (Mm^3)		
		Initial	**After 50 years**	**After 100 years**
1	Gross storage capacity	427.070	390.18	352.93
2	Live storage capacity	398.574	372.772	345.802
3	Storage capacity at MDDL	28.496	17.408	7.128
4	Dead storage capacity (DSL)	5.280	2.050	0.000

5.1.4.2 Storage

Simulation analysis considering the inflow and various water demands to be met from Bhugad reservoir has been carried out. Based on the simulation analysis the live storage has been provided so that the demand of water for various requirement could be met. The dead storage has been provided so that the functioning of the project would not affect even after accumulation of silt over a period of 100 years. Various storage details of the proposed Bhugad reservoir have been mentioned in the Para 5.1.4.1 above.

5.1.4.3 Water Tightness of the Reservoir

The Bhugad reservoir area is thickly forested and restricted to the valley with 200 to 300 m high steep (45^0 to 70^0) hills on both sides. Non-porphyritic, amygdular basalts with minor bands of dense basalts belonging to flow -1 of Salher formation are encountered in the area. No major fault or shear zone was noted in the area. The reservoir appears to be water tight. The report of GSI is at Appendix – 2.4 in Volume – III(A). Also the periphery of the proposed Bhugad reservoir is covered with the contours of value higher than the MWL.

5.1.4.4 Annual Losses

The simulation study carried out for Bhugad reservoir for the period from 1975 to 2004 indicates that the annual average evaporation loss from

Bhugad reservoir is 19.8 Mm^3 with highest evaporation loss as 21.9 Mm^3 during the year 1976 and the lowest evaporation loss as 10.2 Mm^3 during the year 1987. Maximum Monthly evaporation loss is in October month and least Monthly evaporation loss is in July.

5.1.4.5 Flood Absorption

No flood storage is earmarked for this project. However, from reservoir routing it is seen that the maximum water level attained was 163.89 m (maximum storage 427.00 Mm^3) and the maximum outflow discharge was at 8873 Cumec.

5.1.5 Effects on Sub Soil Water Table in the Adjoining Areas Particularly Downstream of the Dam

The sub-soil water table will improve due to the impoundment of water in the Bhugad reservoir. In addition, the regulated flows from the Bhugad dam into Damanganga River to meet committed downstream requirements under Madhuban dam and environmental purposes will increase the sub soil water level in the adjoining areas even during lean season.

5.1.6 Reservoir Rim Stability

To analyze the problems of reservoir stability and reservoir competency with respect to seepage/leakage the Bhugad reservoir area was geologically mapped on 1 : 20000 scale upto RL 173 m by Engineering Geology Division – I, GSI, Pune during Field season 1997-98. The entire Reservoir area lies in the Deccan volcanies. The rock assemblage exposed has been classified as Salher Formation which comprises of Group of Pahoehoe flows succession. The rock type encountered is moderately to highly amygdular basalt, which is generally non-porphyritic in nature with occasional thin bands of massive basalt occurring in it. Occasional dykes of dolerite composition have been observed.

Three prominent joint sets observed in these rocks are given below.

i) J1 = N-S swinging to N15^o-25^{o}W to N15^o-25^{o}with dips 80^o - 85^o either way to vertical. Rarely the dip amount upto 65^o is also observed.

ii) J2 = N80^{o}E-S80^{o}W to N80^{o}E dip vertical.

iii) J3 = N40^o-65^{o}W-S40^o-65^{o}E dipping 60^0-85^o southerly to vertical.

iv) J4= besides the above joints basal or horizontal joints were also observed.

The spacing of joints is upto 1 m. Continuity varies from a few centimeters to more than 10 m. Filling in the joints is scarcely seen and wherever observed it comprises mostly of zeolite. The reservoir area appears to be tight with no perceptible shear or fault zone criss-crossing the area. The report of GSI is at Appendix – 2.4 in Volume – III(A).

5.1.7 Area of Submergence

5.1.7.1 At Maximum Water Level

Area of submergence of Bhugad reservoir at MWL is 1921 ha.

5.1.7.2 At Full Reservoir Level

Area of submergence of Bhugad reservoir at FRL is 1903 ha.

5.1.7.3 Submergence Ratio - Submerged (Cultivated) Area/CCA

The Bhugad reservoir has been proposed as part of Damanganga-Pinjal link project which is mainly a drinking water supply project to augment the domestic water supply of Mumbai city.

5.1.8 Land Acquisition-Property Submerged-Rehabilitation

5.1.8.1 Land Acquisition

The land to be acquired is about 1903 ha (forest land: 290 ha, cultivable land: 810 and other lands including river portion: 803 ha) that is coming under submergence of Bhugad reservoir.

5.1.8.2 Details of Property Submerged

Due to creation of Bhugad reservoir 14 villages will be partially affected. All these villages come under Peint and Trimbak talukas of Nasik district of Maharashtra and Kaparada taluka of Valsad district of Gujarat. Total 1098 households of these villages are likely to be affected.

(i) Details of Dislocation of Communication (Railway(S), Road(S), Right of Way, Telegraph Lines Etc.) as a Result of the Project

No railway line is coming under the submergence area of Bhugad reservoir. No road communication of significance is existing in the submergence area of Bhugad reservoir for which right of way needs to be provided. No telegraph/ telephone line needs to be dislocated as a result of the project.

(ii) Details of Valuable Mineral Deposits / Mines

The Engineering Geological Division of GSI, Nagpur vide Letter No. 329/EG/GSI/2010 dated 26th July, 2010 (Annexure – 2.3 in Volume - II) informed that Bhugad reservoir is devoid of any mineral of economic importance.

(iii) Historic/Archaeological Monuments

The Archaeological Survey of the project area has been carried out by Archaeological Survey of India (ASI), Aurangabad Circle during May, 2009 and December, 2010. The Superintending Archaeologist, ASI, Aurangabad Circle vide their F. No.12/2009 -10/Tech-3036 dated 17-2-2011 have submitted the brief report on the archaeological survey and informed that no monuments or any remains of archaeological importance were noticed at dam sites and in the submergence area of Bhugad and Khargihill reservoirs proposed under Damanganga - Pinjal Link Project. A copy of the report on archaeological survey is at Appendix 2.1 in Volume – III(A).

5.1.8.3 Rehabilitation of Project Affected People

The objective of development is poverty alleviation, social justice and a better quality of life for people. Some development situations however entail displacement of populations and adverse impacts including disruption of social and kinship networks and livelihoods and other economic or cultural loss.

Lack of development, however, can also impact on the environment and lead to distress migration. Involuntary displacement by dams or other water resource projects must therefore be sought to be converted into a development opportunity that leaves those affected better off through enlightened processes of resettlement and rehabilitation. The Social and Occupational profile of the people of the project area is described in the Chapter -9 "Socio- economic Studies and R&R Plan".

Due to creation of Bhugad reservoir 1098 households/ families are likely to be affected. These Project Affected People (PAPs) are to be compensated for their loss of land, home etc, for which a R&R package has been evolved. The process of R&R has three distinct components: relocation of PAPs to a new location where necessary; resettlement in that location and the restoration of livelihood; and rehabilitation so that every individual could regain and/or improve his/her life and socio-economic status within a reasonable time after displacement.

The R&R package for PAPs has been devised considering the provisions of "National Policy on Rehabilitation & Resettlement -2007" formulated by Ministry of Rural Development, Government of India, as basic minimum criteria. Due weightage has also been given to various provisions of the Resettlement & Rehabilitation (R&R) Plan adopted for Sardar Sarovar Project by the states of Gujarat and Maharashtra.

Resettlement and Rehabilitation (R&R) Plan adopted for Sardar Sarovar Project by the states of Gujarat and Maharashtra has been reviewed and compared with NPRR, 2007 and the best norms of each policy have been adopted. People's perception on the resettlement aspects and facilities they expect in the area where they are supposed to be resettled after displacement and preferences of affected population regarding compensation package, whether it should be in cash or kind have also been considered while formulating the Resettlement & Rehabilitation package for the people likely to be affected due to the submergence of Bhugad and Khargihill reservoirs. The details of R & R package are described in the Chapter – 9 (Socio- economic studies and R&R plan).

5.1.9 Recreation Facilities

Following are the recreational facilities which are proposed to be developed.

- Development of parks/gardens in d/s of dam.
- Development of Children parks in the township.
- Development of Tourist spot with boating facilities
- Development of Guest house, inspection bungalow and dormitory accommodation.

These facilities will ensure tourism development in the area.

5.1.10 Pisciculture

The submergence area of Bhugad reservoir is 1903 ha and there is lot of scope for developing fisheries. Based on literature review, the present average fish production rate in Indian reservoirs is given in Table – 5. 6 below:

Table – 5.6

Average Fish Production Rates in Reservoirs

Reservoir Type	Yield (kg/ ha)
Small	49.90
Medium	12.30
Large	11.43

Fish Seed Committee of the Government of India (1966) termed all water bodies of more than 200 ha in area as reservoirs. David *et al.* (1974) while classifying the water bodies of Karnataka State, considered impoundments above 500 ha as reservoirs and named the smaller ones as irrigation tanks.

Reservoirs are classified generally as small (<1 000 ha), medium (1 000 to 5 000 ha) and large (> 5 000 ha), especially in the records of the Government of India (Sarma, 1990, Srivastava *et al*., 1985), which has been followed in the present study.

Considering the water spread area of Bhugad reservoir and the fish production rate indicated above, expected fish production in Bhugad reservoir will be about 95 tonnes per year which will increase the revenue from the project.

5.1.11 Need and Recommendation for Soil Conservation Measure in the Catchment

The chances of soil erosion, if any can be prevented/minimized by adopting following measures:

- Step drain
- Angle iron barbed wire fencing
- Stone masonry,
- Check dams
- Contour bunding
- Development of nurseries
- Plantation/ afforestation
- Pasture development
- Social forestry

Appropriate financial provisions have been provided for soil conservation measures in the catchment area.

5.2 Khargihill Reservoir

5.2.1 Fixation of Storage and Reservoir Levels-Approach–Criteria

The water availability studies at Bhugad, Khargihill and Pinjal dam sites have been carried out by the Hydrological Studies Organisation, CWC, New Delhi as a part of "Hydrological Studies of Damanganga-Pinjal Link Project". The Gross and Net Annual Yields at Khargihill dam site (original dam site proposed near village Behadpada) as per these studies are as given in Table – 5.7 below:

Table – 5.7
Gross & Net Annual Yields at Khargihill Dam Site

S.No.	Details	Annual Yield (Mm^3)	
		Gross	Net
1	100% Dependable yield	477	401
2	75% Dependable yield	748	629
3	50% Dependable yield	939	820
4	Average yield	986	871

The net water availability at Khargihill dam site has been worked out after subtracting all the consumptive upstream utilizations planned by States. Regeneration from irrigation projects has been neglected as all schemes upstream are minor irrigation projects. The regeneration from domestic & industrial uses has been considered as 80 percent of water diverted for the purpose. The net yield series generated at Khargihill dam site for the period from 1975-76 to 2008-09 is furnished in Annexure: 3.7 in Volume - II.

The reservoir simulation study has been carried out for estimating the live storage capacity of the reservoir that would provide the required yield at specified reliability. The discharge data is available for a period of 25 years from 1984 to 2008 at Ozarkhed G&D site maintained by CWC, which is located at about 2 km d/s of Khargihill dam site. Rainfall – Runoff model has been developed using discharge data available at Ozarkhed G&D site and rainfall for the concurrent period. Using this Rainfall – Runoff model the yield series for the period from 1975-76 to 1983-84 at Khargihill dam site has been developed. The yield series at Khargihill dam site for the period from 1984-85 to 2008-09 has been developed on catchment area proportionate basis using observed discharge data of Ozarkhed G&D site after duly checking the consistency. The yield series so developed for the period from 1975 to 2008 has been used for simulation analysis.

The simulation analysis has been done using Simulation Program developed using c^{++} and considering diversions of water from Bhugad reservoir to Khargihill reservoir and net contribution of Vagh river up to the dam site as inflows, taking into account the different releases: i) for local domestic & industrial water demand, ii) environmental and ecological requirements downstream of proposed dam site, iii) local irrigation demand, iv) and diversion to Pinjal reservoir for augmentation of domestic water supply of Mumbai. The simulation study indicates that Gross storage (revised reservoir capacity with 50 years sedimentation) of 426.67 Mm^3 fixed for the reservoir is sufficient to meet all the withdrawals proposed from the reservoir. The detailed simulation analysis report is at Appendix 3.3 in Volume –IV.

5.2.1.1 Dead Storage Level (DSL)

The dead storage capacity of the Khargihill reservoir has been fixed on the basis of the guidelines given in “Fixing the capacities of reservoirs – Methods, Part 2 Dead storage, IS 5477 (Part 2): 1994”.

The new zero elevation of the Khargihill reservoir has been worked out as 89.60 m and 93.00 m after 50 years and 100 years respectively on the basis of sedimentation studies. The corresponding capacities at these levels as per the original area - capacity table come to 80.40 ha-m and 254.20 ha-m respectively. However, Dead Storage Level of the reservoir has been proposed as 93.00 m (corresponding original capacity of 254.20 ha-m) and sluices are proposed to be provided at this level. The sedimentation study report is furnished at Appendix 2.15 in Volume – III(B).

5.2.1.2 Low Water Level /Minimum Draw-Down Level (MDDL)

The minimum draw down level (MDDL) of Khargihill reservoir can be fixed anywhere above 93.00 m which is the new zero elevation after 100 years of operation of the reservoir, based on sedimentation studies carried out by Hydrological Studies Organisation, CWC, New Delhi. The water diverted from Damanganga basin alongwith the water available at Pinjal dam is to be taken up to Mumbai as per the plans of Municipal Corporation of Greater Mumbai (MCGM) and Mumbai Metropolitan Region Development Authority (MMRDA). The MCGM vide their letter No. ChE/WSP/4710 dated 1st November 2010 had informed that the water from Damanganga basin shall be made available at Pinjal dam at 92.50 m. to meet the demands of water for various uses by people in the vicinity of the reservoir and also to ensure delivery of Damanganga waters at Pinjal at elevation of 92.50 m, the MDDL of the Khargihill reservoir is kept at 109.75 m.

5.2.1.3 Full Reservoir Level (FRL)

Simulation studies carried for Bhugad, Khargihill, Pinjal and Existing Madhuban reservoirs indicates that the proposed Khargihill reservoir with Full Reservoir Level at 154.52 m will meet various planned demands at 100% success rate, ignoring 10% deficit on annual basis. Therefore, the Full Reservoir Level of Khargihill dam has been kept at 154.52 m.

5.2.1.4 Maximum Water Level (MWL)

Maximum water level of Khargihill reservoir has been kept as 155.00 m and the gates of spillway have been designed to pass design flood of 10222 Cumec.

The flood routing study of Khargihill reservoir was carried out By CWC. The spillway of proposed Khargihill dam will have 6 gates. Computations were performed with the condition that 5 out of total 6 gates are in operation. The result of reservoir routing study indicates that the maximum water level attained was 155.124 m and the maximum outflow discharge was 9238 Cumec.

The maximum water level at Khargihill dam has been fixed as 155.00 m. The Flood Routing study for proposed Khargihill dam is at Annexure: 5.3 in Volume - II. Various levels fixed at Khargihill Reservoir are given in Table - 5.8.

Table -5.8
Levels Fixed As Per Simulation Study

Khargihill Reservoir	**Elevation(m)**
MWL	155.00 m
FRL	154.52 m
MDDL	109.75 m
Khargihill-Pinjal Tunnel	
Invert level at entry	100.00 m
Crown level at entry	104.00 m
Invert level at exit	85.50 m
Crown level at exit	89.50 m
Power house (at toe of dam)	
Invert Level of pen stock at inlet	86.05 m
TWL for Powerhouse	89.00 m

5.2.1.5 Maximum Backwater Level at Full Reservoir Level and Maximum Water Level and its Effect, Points to Which Backwater Effect is Felt, Maximum Distance of Such Points From the Axis of the Structure

The Full Reservoir Level (FRL) and Maximum Water Level (MWL) of the Khargihill dam have been fixed at 154.52 m and 155.00 m respectively. The maximum back water level at MWL is 155.00 m and the effect extends upto a distance of about 16 km from the axis of the dam (at the periphery of the reservoir) within which no structure of significant importance has been identified.

5.2.1.6 Saddles along the Reservoir Rim

A saddle is present on the left flank of the Khargihill reservoir, as such to plug this, a saddle dam is proposed on the left side of the Khargihill main dam near Vavar village.

5.2.1.7 Fetch

The fetch of the reservoir was determined to fix the free board and the top of the dam. The fetch computations were done as per the Indian Standards IS: 10635-1993, “Guidelines for Free board requirements in Embankment Dams”.

The effective fetch length of 1.092 km & 1.102 km respectively at FRL and MWL has been worked out for Khargihill main dam and saddle dam.

5.2.1.8 Direction of Wind - Velocity of Wind - Wave Height - Free Board-Top of Dam

The direction of wind in Khargihill reservoir area is mostly from SE - NW to. The Nasik IMD station is located near to the Khargihill dam site. The maximum wind velocity of 13.2 km/hr is experienced in the month of June and the minimum wind velocity of 4.5 km/hr is experienced in the month of December. The average velocity of wind is 8.4 km/hr. However, maximum wind velocity of 44 m/s has been considered. Wave height is estimated as 2.13 m. The following factors are taken into consideration while computing the free board requirement:

(a) Wave characteristics i.e. wave height and wave length;
(b) Upstream slope of the river and roughness of the pitching;
(c) Height of wind setup above the still water level.

The detailed computations for free board required for FRL and MWL conditions have been done and the details are furnished in Chapter – 4 on Design Aspects. The free board requirement has been worked out as 5.04 m for Khargihill main dam and saddle dam. The top of the rock-fill portion of the Khargihill dam has been fixed at 158.92 m.

5.2.2 Sedimentation Data and Studies

The catchment area of Vagh river (a tributary of Damanganga river) upto proposed Khargihill dam site is 646 Km^2. Presently silt observations are not taken in the catchment area of Khargihill dam. The Government of Gujarat had carried out sedimentation study at existing Madhuban reservoir across Damanganga river located in the downstream of proposed Bhugad and Khargihill dam sites. Using this data the sedimentation rate at Khargihill dam site has been assessed.

5.2.2.1 Rate of Sedimentation with Basis

As the silt in the catchment area of proposed Khargihill dam site is presently not observed at any location, the sedimentation data of existing Madhuban reservoir located across Damanganga river in the downstream of Bhugad and Khargihill dam sites has been used for assessment of sedimentation rate. Considering the reservoir sedimentation rate of 8.94 ham/100 km^2/year at Madhuban reservoir, reservoir capacity and average inflows into reservoir, the inflow sedimentation rate at Madhuban dam has been back calculated as under:

Average Inflow at Madhuban dam (I)= 3116.06 Mm^3
Gross capacity of Madhuban dam at FRL (C) = 567.00 Mm^3
Capacity-Inflow ratio (C/I) = 567.0/3116.06 = 0.18196
As per Brune's curve Trap Efficiency (η) = 90.11 %
Observed sediment rate at Madhuban dam= 8.94 ham/100 km^2/year

So, sediment inflow at Madhuban dam = 8.94*100/90.11= 9.921 ham/100 km^2/year.

The Madhuban and Khargihill reservoirs lie in Damanganga basin and broadly have similar catchment characteristics and may be assumed to have similar sediment yields. Further, smaller catchments tend to be more susceptible to higher sedimentation yields than larger catchments (Clause 2.2 of ICOLD Bulletin 115- Dealing with Reservoir Sedimentation). As catchment area of Madhuban dam is about three times than the catchments of Khargihill Reservoir, the inflow sedimentation rate for Khargihill reservoir has been assumed to be 10 percent more than inflow sedimentation rate assessed at Madhuban dam. Accordingly, the inflow sedimentation rate of 10.912 ham/100 km^2/year has been taken for Khargihill reservoir.

5.2.2.2 Quantity of Sediment

Considering the inflow sedimentation rate of 10.912 ham/100 km^2/year the sediment volume at Khargihill reservoir will be as follow:

i.	50 years sediment volume	33.92 Mm^3
ii.	100 years sediment volume	67.73 Mm^3

5.2.2.3 Type and Shape of Reservoir

The Khargihill reservoir is considered as flood plain-foot hill type and the standard classification is taken as Type II.

5.2.2.4 Sediment Studies – Khargihill Reservoir

As per IS 5477 (Part – 2): 1994 (Fixing the capacities of reservoirs), either the “Empirical Area Reduction” method or the “Area Incremental” method is recommended to be used for sedimentation study. In this report, the sedimentation study has been carried out using “Empirical Area Reduction” method.

5.2.2.5 Sediment Distribution

The sediment distribution is worked out for two periods, viz. 50 years and 100 years by Empirical Area Reduction method. For this purpose, the FRL 154.52 m is adopted and bed level of the reservoir is considered as 83.30 m. The original Elevation-Area-Capacity table for Khargihill reservoir is given in Table 5.9:

Table – 5.9

Elevation- Area- Capacity Table for Khargihill Reservoir

Elevation (m)	Area(ha)	Capacity (Mm^3)
154.520	1558.053	460.896
154.000	1540.736	452.839
151.000	1446.512	408.031
148.000	1355.261	366.004
145.000	1266.983	326.670
142.000	1181.677	289.941
139.000	1098.730	255.734
136.000	1017.620	223.989
133.000	939.619	194.631
130.000	864.728	167.565
127.000	792.947	142.700
124.000	724.275	119.942
121.000	658.713	99.197
118.000	584.146	80.554
115.000	508.418	64.166
112.000	437.945	49.970
109.000	372.728	37.810
106.000	312.766	27.528
103.000	258.059	18.965
100.000	208.607	11.965
97.000	140.390	6.730
94.000	85.637	3.340
93.000	74.000	2.542
91.000	44.348	1.358
90.000	35.000	0.962
89.600	29.300	0.804
89.500	28.000	0.641
89.000	25.000	0.509
88.627	22.338	0.420
88.000	16.523	0.299
85.000	2.162	0.018
83.300	0.000	0.000

The total sediment during 50 and 100 years will get distributed up to and above various elevations as given in the Table – 5.10 below:

Table 5.10
Distribution of Total Sediment at Various Elevations of Khargihill Dam

Reservoir level	Sediment Deposition in Mm^3	
	After 50 years	After 100 years
Upto 90.00 m	0.92	0.96
Above 90.00 m	33.31	66.79
Upto 93.00 m	1.93	2.54
Above 93.00 m	32.30	65.21
Upto 110 m	10.20	19.20
Above 110 m	24.03	48.55

The new zero elevation will be as follows:

After 50 years = 89.60 m
After 100 years = 93.00 m

The minimum draw down level (MDDL) can be fixed anywhere above 93.00 m which is the new zero elevation after 100 years of operation of the reservoir.

The plots of revised elevation-area-capacity curve for 50-Year sedimentation and 100 year sedimentation are given in Figure – 5.3 & - 5.4 respectively:

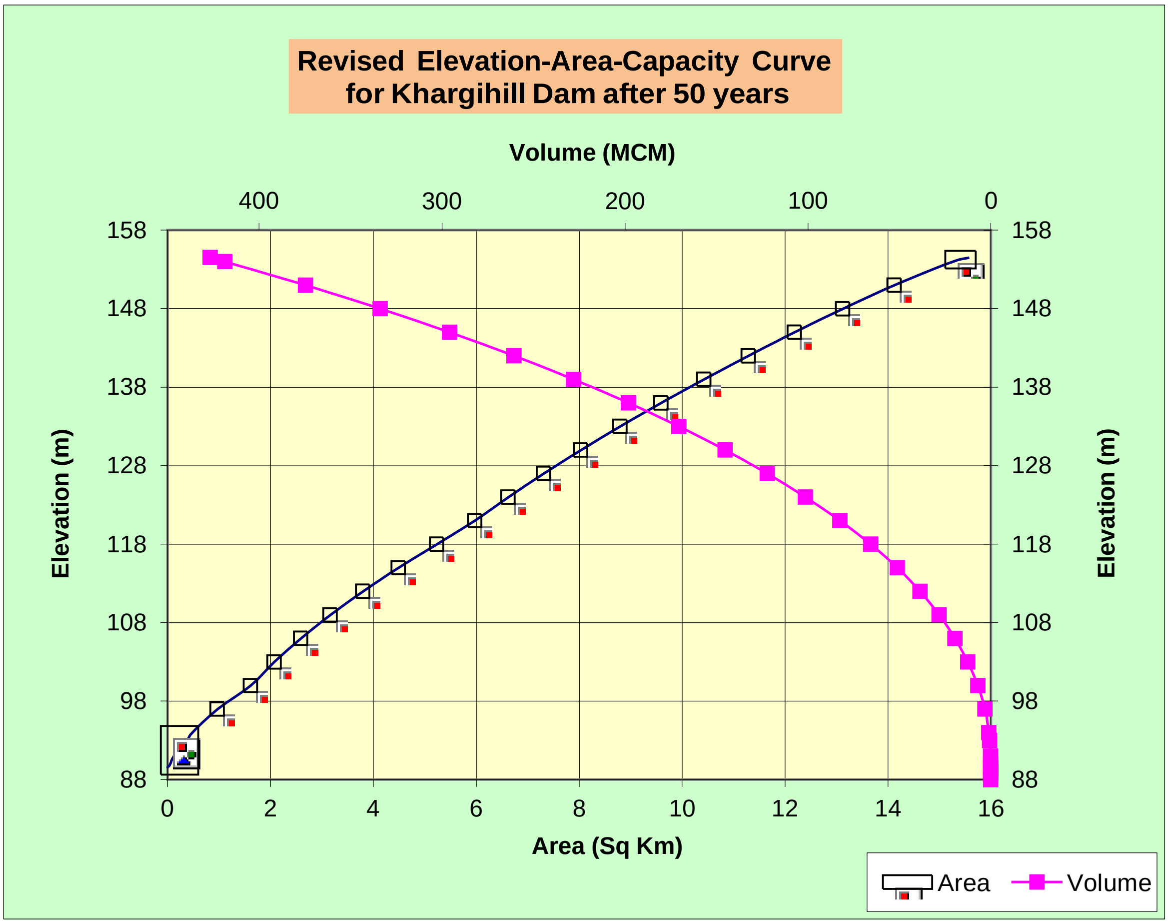

Figure – 5.3: Revised Elevation-Area-Capacity Curve of Khargihill Reservoir for 50-Year Sedimentation

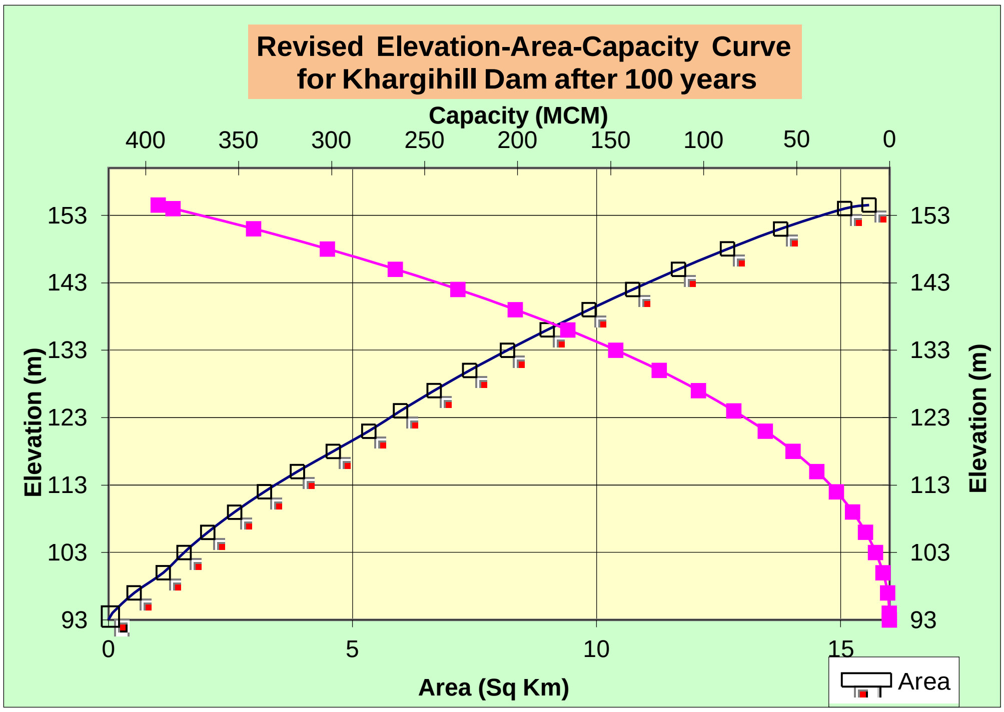

Figure – 5.4: Revised Elevation-Area-Capacity Curve of Khargihill Reservoir for 100 Year Sedimentation

Original and revised (after 50 and 100 years) Elevation-Area-Capacity table for Khargihill reservoir is given in Table-5.11 below:

Table-5.11
Original and Revised (after 50 and 100 years) Elevation – Area - Capacity Table for Khargihill Reservoir

Elevation	Original Area	Original Capacity	Revised Area after 50 yr	Revised Capacity after 50 yr	Revised Area after 100 yr	Revised Capacity after 100 yr
(m)	(ha)	(Mm^3)	(ha)	(Mm^3)	(ha)	(Mm^3)
154.520	1558.053	460.896	1558.05	426.67	1558.05	393.15
154.000	1540.736	452.839	1524.67	418.65	1508.30	385.17
151.000	1446.512	408.031	1412.18	374.60	1377.20	341.89
148.000	1355.261	366.004	1312.19	333.73	1268.30	302.21
145.000	1266.983	326.670	1218.02	295.78	1168.13	265.66
142.000	1181.677	289.941	1128.43	260.58	1074.17	232.03
139.000	1098.730	255.734	1042.29	228.02	984.79	201.14
136.000	1017.620	223.989	958.83	198.01	898.92	172.89
133.000	939.619	194.631	879.15	170.44	817.53	147.14
130.000	864.728	167.565	803.16	145.20	740.42	123.77
127.000	792.947	142.700	730.79	122.19	667.46	102.65
124.000	724.275	119.942	662.00	101.30	598.55	83.66
121.000	658.713	99.197	596.76	82.42	533.64	66.68
118.000	584.146	80.554	522.94	65.62	460.58	51.77
115.000	508.418	64.166	448.37	51.05	387.20	39.05
112.000	437.945	49.970	379.48	38.64	319.92	28.44
109.000	372.728	37.810	316.27	28.20	258.76	19.76
106.000	312.766	27.528	258.77	19.58	203.76	12.83
103.000	258.059	18.965	207.02	12.59	155.01	7.44
100.000	208.607	11.965	161.06	7.07	112.62	3.43
97.000	140.390	6.730	96.98	3.20	52.74	0.95
94.000	85.637	3.340	47.13	1.03	7.90	0.04
93.000	74.000	2.542	37.35	0.61	0.00	0.00
91.000	44.348	1.358	11.79	0.12	0.00	0.00
90.000	35.000	0.962	4.73	0.04	0.00	0.00

89.600	29.300	0.804	0.00	0.00	0.00	0.00
89.500	28.000	0.641	0.00	0.00	0.00	0.00
89.000	25.000	0.509	0.00	0.00	0.00	0.00
88.627	22.338	0.420	0.00	0.00	0.00	0.00
88.000	16.523	0.299	0.00	0.00	0.00	0.00
85.000	2.162	0.018	0.00	0.00	0.00	0.00
83.300	0.000	0.000	0.00	0.00	0.00	0.00

The sedimentation study report of the reservoirs of Damanganga – Pinjal link project is at Appendix – 2.15 in Volume – III(B).

5.2.3 Life of Reservoir in Years with Basis

All the outlets from the reservoir are fixed at an elevation above the New Zero Elevation estimated after considering 100 years of sedimentation. Therefore, the life of the Khargihill reservoir has been considered as 100 years.

5.2.4 Capacity

5.2.4.1 Capacities of Khargihill Reservoir

S No.		Capacity (Mm^3)		
		Initial	**After 50 years**	**After 100 years**
1	Gross storage capacity	460.896	426.67	393.15
2	Live storage capacity	420.046	395.858	371.22
3	Storage capacity at MDDL	40.850	30.809	21.930
4	Dead storage capacity (DSL)	2.542	0.612	0.000

5.2.4.2 Storage

Simulation analysis considering the inflow and various water demands to be met from Khargihill reservoir has been carried out. Based on the simulation analysis the live storage has been provided so that the demand of water for various requirement could be met. The dead storage has been provided so that the functioning of the project would not affect even after accumulation of silt over a period of 100 years. Various storage details of the proposed Khargihill reservoir have been mentioned in the Para 5.2.4.1 above.

5.2.4.3 Water Tightness of the Reservoir

The Khargihill reservoir area is made of pahoehoe and aa flows of Deccan volcanoes belonging to lower part of Salher Formation. The reservoir is contained in a valley bounded by steep hills. The rocks are hard, massive and devoid of any major fault or shear zones. On the basis of Geotechnical studies carried out, it is observed that the reservoir area is competent and likely to hold water. The report of GSI is at Appendix – 2.4 in Volume – III(A). A saddle is present on the left flank of the Khargihill reservoir, as such to plug this, a saddle dam is proposed on the left side of the Khargihill main dam near Vavar village.

5.2.4.4 Annual Losses

The simulation study carried out for Khargihill reservoir for the period from 1975 to 2004 indicates that the annual average evaporation loss from Khargihill reservoir is 17.4 Mm^3 with highest evaporation loss of 21.9 Mm^3 during the year 1976 and the lowest evaporation loss of 13.3 Mm^3 during the year 1987. Maximum Monthly evaporation loss is in October month and least Monthly evaporation loss is in July.

5.2.4.5 Flood Absorption

No flood storage is earmarked for this project. However, from reservoir routing it is seen that the maximum water level attained was 155.124 m (maximum storage 470 Mm^3) and the maximum outflow was at 9238 Cumec.

5.2.5 Effects on Sub Soil Water Table in the Adjoining Areas Particularly Downstream of the Dam

The sub-soil water table will improve due to the impoundment of water in the Khargihill reservoir. In addition, the regulated releases from the

Khargihill dam to meet environmental needs will increase the sub soil water level in the adjoining areas.

5.2.6 Reservoir Rim Stability

To analyze the problems of reservoir stability and reservoir competency with respect to seepage/leakage the Khargihill reservoir area was geologically mapped on 1: 15000 scale by Engineering Geology Division I, GSI, Pune during field season 1997-98. The FRL of the reservoir is 154.52 m and the reservoir area is confined in the river valleys of Vagh and its main tributary Val. The hill slopes are generally steep on both sides of the river and are thickly to moderately forested. The reservoir area comprise of Deccan volcanoes of pahoehoe and aa flow of rocks belonging to lower part of Salher Formation. In the reservoir area drained by Vagh River three units of groups of flows have been delineated upto RL 180 m, which comprise in order of decreasing antiquity, group of predominantly non-porphyritic pahoehoe flows group-1, directly overlained by group-3, Porphyritic pahoehoe flows, which are successively overlain by group - 4, as flow dense basalt. In the part of reservoir drained by Val tributary the section observed upto RL 165 m expose only rock unit placed under group-I of non-porphyritic pahoehoe flows.

The group-I flows lithologically comprise of Amygdular basalts with minor bands of dense basalts. This unit is non-porphyritic in nature and distinctly different in texture from the overlying unit of group 3 flows which are porphyritic in nature. The plane of contact between two lies at about RL 150 and 155 m and is marked by glomeroporphyritic textured Amygdular Basalt at the basal part of upper unit flow - 3 which has thickness upto 2 m. The group 2 unit, (Refer to the General Stratigraphic succession of Salher Formation) has not been observed in the reservoir area studied. The overlying group 4 flows comprising of aa flows of dense basalt occur at about RL 170 m in the Vagh river part of the reservoir.

The three sets of joints present in these rocks are as fallows.

1. J_1 – N15^o –25^{o}W – S15^o -25^o-E dipping vertical to near vertical
2. J_2 – N75^o –85^{o}W – S73^o -85^o-E dipping vertical to near vertical

3. J_3 –Basal horizontal joint

The joint spacing and continuity vary from place to place. No fault or major shear zone was observed in the area and there is no problem of stability of hill slope. The report of GSI is at Appendix – 2.4 in Volume – III(B).

5.2.7 Area of Submergence

5.2.7.1 At Maximum Water Level

Area of submergence of Khargihill reservoir at MWL is 1565 ha.

5.2.7.2 At Full Reservoir Level

Area of submergence of Khargihill reservoir at FRL is 1558 ha.

5.2.7.3 Submergence Ratio - Submerged (Cultivated) Area/ CCA

The Khargihill reservoir has been proposed as part of Damanganga-Pinjal link project which is a drinking water supply project to augment the domestic water supply of Mumbai city.

5.2.8 Land Acquisition-Property Submerged-Rehabilitation

5.2.8.1 Land Acquisition

The land to be acquired is about 1558 ha (forest land: 676 ha, cultivable land: 612 and other lands including river portion: 270 ha) that is coming under submergence of Khargihill reservoir.

5.2.8.2 Details of Property Submerged

Due to creation of Khargihill reservoir 16 villages will be partially affected. All these villages come under Mokhada and Jawhar talukas of Thane district and Trimbak taluka of Nasik district of Maharashtra. Total 1204 households of these villages are likely to be affected.

(i) Details of Dislocation of Communication (Railway(S), Road(S), Right of Way, Telegraph Lines Etc.) as a Result of the Project

No railway line is coming under the submergence area of Khargihill reservoir. No road communication of significance is existing in the submergence area of Khargihill reservoir for which right of way needs to be provided. No telegraph/telephone lines needs to be dislocated as a result of the project.

(ii) Details of Valuable Mineral Deposits / Mines

The Engineering Geological Division of GSI, Nagpur vide Letter No. 329/EG/GSI/2010 dated 26th July, 2010 (Annexure – 2.3 in Volume - II) informed that Khargihill reservoir is devoid of any mineral of economic importance.

(iii) Historic/Archaeological Monuments

The Archaeological Survey of the project area has been carried out by Archaeological Survey of India (ASI), Aurangabad Circle during May, 2009 and December, 2010. The Superintending Archaeologist, ASI, Aurangabad Circle vide their F.No.12/2009 -10/Tech-3036 dated 17-2-2011 have submitted the brief report on the archaeological survey and informed that no monuments or any remains of archaeological importance were noticed at dam sites and in the submergence area of Bhugad and Khargihill reservoirs proposed under Damanganga - Pinjal Link Project. A copy of the report on archaeological survey is at Appendix 2.1 in Volume – III(A).

5.2.8.3 Rehabilitation of Project Affected People

Due to creation of Khargihill reservoir 1204 households/ families are likely to be affected. These Project Affected People (PAPs) are to be compensated for their loss of land, home etc, for which a R&R package has been evolved. The process of R&R has three distinct components: relocation of PAPs to a new location where necessary; resettlement in that location and the restoration of livelihood; and rehabilitation so that every individual could regain and/or improve his/her life and socio-economic status within a reasonable time after displacement.

The R&R package for PAPs has been devised considering the provisions of "National Policy on Rehabilitation & Resettlement -2007" formulated by Ministry of Rural Development, Government of India, as basic minimum criteria. Due weightage has also been given to various provisions of the Resettlement & Rehabilitation (R&R) Plan adopted for Sardar Sarovar Project by the states of Gujarat and Maharashtra.

Resettlement & Rehabilitation (R&R) Plan adopted for Sardar Sarovar Project by the States of Gujarat and Maharashtra has been reviewed and compared with NPRR, 2007 and the best norms of each policy have been adopted. People's perception on the resettlement aspects and facilities they expect in the area where they are supposed to be resettled after displacement and preferences of affected population regarding compensation package, whether it should be in cash or kind have also been considered while formulating the Resettlement & Rehabilitation package for the people likely to be affected due to the submergence of Bhugad and Khargihill reservoirs. The social and occupational profile of the people of the project area and details of R & R package are described in the Chapter – 9 (Socio- economic studies and R&R plan).

5.2.9 Recreation Facilities

Following recreational facilities are proposed to be developed:

- Development of parks/gardens in d/s of dam.
- Development of Children parks in the township.
- Development of Tourist spot with boating facilities
- Development of Guest house, inspection bungalow and dormitory accommodation.

These facilities will develop tourism in the area.

5.2.10 Pisciculture

The submergence area of Khargihill reservoir is 1558 ha and there is lot of scope for developing fisheries.

Considering the water spread area of Khargihill reservoir and the fish production rate indicated in Para 5.1.10, expected fish production in Khargihill reservoir will be about 75 tonnes per year which will increase the revenue from the project.

5.2.11 Need and Recommendation for Soil Conservation Measures in the Catchment

The chances of soil erosion, if any can be prevented/minimized by adopting following measures.

- Step drain
- Angle iron barbed wire fencing
- Stone masonry,
- Check dams
- Contour bunding
- Development of nurseries
- Plantation/ afforestation
- Pasture development
- Social forestry

Appropriate financial provisions have been provided for soil conservation measures in the catchment area.

5.3 Pinjal Reservoir

A dam across river Pinjal (a tributary of Vaitarna river) near Village Khidse in Jawhar taluka of Thane district of Maharashtra was proposed by Water Resources Department (WRD), Government of Maharashtra. The DPR of Pinjal dam was prepared by Water Resources Department, Government of Maharashtra during the year 1981. Presently the Pinjal Project is being developed by Municipal Corporation of Greater Mumbai

(MCGM) as drinking water supply project and the DPR is accordingly being revised/ prepared by MCGM. As per the draft Detailed Project Report (DPR) of Pinjal dam being prepared by MCGM, the MWL/FRL of Pinjal dam has been fixed at 145.00 m with gross storage capacity of 483.00 Mm^3 and Live storage capacity of 473.10 Mm^3. The dam is proposed to be Roller Compacted Concrete dam and the height of the dam from deepest foundation level up to FRL is about 75.0 m.

The Hydrology (South) Directorate of Central Water Commission has carried out the water availability study of Damanganga – Pinjal link. As per this study the 75% dependable gross yield at Pinjal dam site is 514.50 Mm^3.

5.4 Power

Power is one of the basic inputs necessary for the industries and socio economic development. Growing energy demand in the country and concern for carbon emission from thermal and gas based power plants is making hydropower development more favorable for India. Development of hydropower wherever feasible in the present scenario taking in to account its renewability and non-polluting nature and relative low cost, is becoming a main source of renewable energy. The possibilities of hydropower generation from the dams envisaged in the Damanganga-Pinjal link project have been highlighted in the tripartite Memorandum of Understanding (MoU) signed by Hon'ble Chief Ministers of Gujarat and Maharashtra states with Hon'ble Union Minister for Water Resources on 3rd May 2010 for preparation of DPRs of Par – Tapi – Narmada and Damanganga – Pinjal link projects. As such, the power potential studies were carried out through THDC, Rishikesh at proposed Bhugad and Khargihill reservoirs and assessed the quantum of hydropower generation at both Bhugad and Khargihill reservoirs.

5.4.1 Present Status of Power Development in Maharashtra & Gujarat States

5.4.1.1 Available Generating Capacity

(a) Power Scenario in Maharashtra

Maharashtra is the largest power generating state in India with installed electricity generation capacity of 26,538 MW (10,237 MW by MSPG Co. Ltd). Maharashtra constitutes 13% of the total installed electricity generation capacity in India which is mainly from fossil fuels such as coal and natural gas. However since 2005, Maharashtra's power sector has been unable to meet electricity demand of the State. The State utilities have been re-sorting to load shedding to bridge the gap between supply and demand. Several parts of the state have 8 to 10 hours of load shed. Despite the additional installed capacity, the peak demand deficit in the state has increased from 17% in 2005-06 to 22% in 2011-12. Between 2005-06 and 2011-12, peak electricity demand grew at a compound annual growth rate (CAGR) of 5%, while peak demand met at the CAGR of 4% over the period of 8 years. The capacity has been increased to 26,538 MW in the year 2012 (August 12, CEA). To meet the expanding energy requirement in the state, additions to generating capacity were made both in the private as well as the state sector, expected to lead in reducing deficits. The state of Maharashtra is also forms a major constituent of the western grid of India which now comes under North, East, West and North Eastern (NEWNE) grid of India.

The peak energy demand in Maharashtra is 21,069 MW as against the same only 16,471 MW is met with. Thus presently, Maharashtra is facing energy shortage of 4600 MW. As per 16th Electric Power Survey, the CEA has projected an average growth rate of 5.9 % for the period ending 2017 for Maharashtra and the peak load requirement would be in tune of 29,738 MW. The shortfall is so significant that the state cannot ignore the power supply position from the perspective of development. In order to match the demand, new capacity additions to the tune of about 12,500 MW are slated to come up over the next two Five Year Plans. Overall, the electricity scenario is not good in the state and needs further investment to increase power generation. The State owned Maharashtra State Power Generation Co. Ltd (Mahagenco) has capacity addition programme of 4230 MW capacity of Thermal Power stations and various projects under non-conventional energy sector such as Solar and Wind energy are being considered to mitigate the energy deficit.

Maharashtra State Power Generation Co. Ltd (Mahagenco) has an installed capacity of 10237 MW, of which nearly 75% comprises of Thermal and gas based generation capacity (thermal 6980 MW, and gas based generating capacity 672 MW). The Hydro Electric Projects in the State of Maharashtra were designed, erected and commissioned through the Water Resource Department (WRD) of GoM. After commissioning, the hydro projects were handed over on long term lease to Mahagenco for purpose of Operation and Maintenance. Presently there are 26 hydel projects having a capacity of 2585 MW. Details are in Table 5.12:

Table 5.12
Installed Capacity of MAHAGENCO

Sr. No.	Power Station	Units & Size (MW)	Installed Capacity (MW)
A	**Thermal Power Stations**		
1	Koradi 5 To 7	1x200 + 2x210	620
2	Nasik 3 To 5	3x210	630
3	Bhusawal 2 & 3	2x210	420
4	Paras 3 & 4	2x250	500
5	Parli 3 To 7	3x210+ 2x250	1130
6	K'kheda 1 To 5	4x210 + 1x500 Mw	1340
7	Chandrapur 1 To 7	4x210 + 3x500	2340
	Total		**6980**
B	**Gas Turbine Power Station**		
1	Uran G.T.	4x108	432
2	W.H.R. 1&2	2x120	240
	Total		**672**
C	**Hydro Power Stations**		
1	Koyna Hydro	St I&II- 4x70 + 4x80, St III- 4x80, St. IV- 4x250 & Koyna Dam Foot- 2x18	1956
2	Small Hydro		379
3	Ghatghar Pump Storage	2x125	250
	Total		**2585**
	Grand Total (A+B+C)		**10237**

Mahagenco is also implementing capacity additions programmes of about 17040 MW. Project execution works of 4230 MW projects are in full swing and 8850 MW project are in advanced stages of planning. Further Mahagenco identified land for 3960 MW projects in various location of Maharashtra. Mahagenco is also planned to setup about 650 MW solar power projects in various locations of Maharashtra.

(b) Power Scenario in Gujarat

When Indian power sector is facing challenges despite the significant growth in generation capacity over the past few decades, over the last few years, Gujarat has successfully crossed all these barriers and has become successful in securing its overall energy requirements with installed power generation capacity of 21,062. Gujarat is rich in solar energy, biomass and wind energy. It is also the leading state in terms of overall solar energy installation in India. The details are in Table – 5.13:

Table – 5.13
Gujarat State Installed Capacity as on 31.12.2012

	Units	Type of Fuel	Installed capacity	Derated Total
I	**Gujarat State Electricity Corporation Ltd (GSECL)**			
	Dhuvaran	Gas	219	219
	Ukai (Thermal)	Coal	850	850
	Gandhinagar	Coal	870	870
	Wanakbori	Coal	1470	1470
	Sikka	Coal	240	240
	Kutch Lignite Tanandhrao	Lignite	290	290
	Utran-I	Gas	135	135
	Utran-II	Gas	375	375
	Ukai	Hydro	305	305
	Kadana	Hydro	242	242
	Sub Total		4996	4996
II	**Private Sector**			
	Torrent Power – AE CO	Coal/Gas	500	500
	GIPCL-I	Gas/Naptha	145	145
	GIPCL-II	Gas/Naptha	165	165

	SLPP (GIPCL)	Lignite	500	500
	Gujarat State Energy Generation Ltd (GSEG)/ GSPC	Gas	156	156
	GPEC	Gas	655	655
	ESSAR Power	Coal	515	300
	ESSAR Power	Coal	1200	1000
	Akrimota Thermal Station	Coal	250	250
	SUGEN	Gas	1148	1148
	Adani Power Ltd.	Coal	2640	2000
	ACB Ltd	Coal	270	200
	Sub Total		8144	7019
III	**Central Sector**			
	NPC-Kakrapar	Nuclear	440	125
	NPC-Tarapur-I	Nuclear	320	160
	NPC-Tarapur-II	Nuclear	1080	274
	NTPC-Korba	Coal	2100	360
	NTPC-Korba-VII	Coal	500	96
	NTPC-Vindhyachal STPS Stage-I	Coal	1260	230
	NTPC-Vindhyachal STPS Stage-II	Coal	1000	239
	NTPC-Vindhyachal STPS Stage-III	Coal	1000	266
	NTPC-Vindhyachal STPS Stage-IV	Coal	500	120
	NTPC-Jhanor	Gas	657.4	237
	NTPC-Kawas	Gas	656.2	187
	SIPAT Stage-I	Coal	1980	540
	SIPAT Stage-II	Coal	1000	273
	Sardar Sarovar Project CHPH	Hydro	250	40
	Sardar Sarovar Project-RBPH	Hydro	1200	192
	Kahelgoan	Coal	1500	141
	CGPL, (TATA Power) Mundra	Coal	3320	1577
	MSTPS-I		500	120
	Sub Total		19264	5177
IV	**Other**			**17192**
	Wind Installed capacity		3008.6	3008.6

	Solar Installed capacity		823.9	823.9
	Biomass Installed capacity		31.2	31.2
	Madhuban Dam	Hydro	3	3
	Karjan Dam	Hydro	3	3
	Grand Total		**36274**	**21062**

source: http://www.sldcguj.com

5.4.1.2 Present Status of Utilisation of Power Produced

Status of power generation and consumption in Maharashtra State during the year 2009-10 is shown in Table: 5.14:

Table: 5.14
Electricity Generation and Consumption in Maharashtra State in 2009-10

Sl. No.	Item	2009-10
A	**Generation (MkWh)**	
	1) Thermal	54,978
	2) Oil	-
	3) Hydro	5,654
	4) Natural Gas	15,322
	5) Captive Power	365
	6) Renewable Energy	5,026
	Total	**81,345**
B	**Consumption (MkWh)**	
	1) Domestic	18,171
	2) Commercial	10,546
	3) Industrial	30,866
	4) Public lighting	807
	5) Railways	2,119
	6) Agriculture	13,925
	7) Public Water Works	1,851
	8) Miscellaneous	854
	Total	**79,139**
C	**Per capita consumption (kWh)**	
	1) Commercial	95.5
	2) Industrial	279.4

Source: Economic Survey of Maharashtra 2010-11, published by Directorate of Economics & Statistics, Govt. of Maharashtra.

Status of power generation and consumption in Gujarat State during the years 2009-10 to 2011-12 is shown in Table: 5.15 & 5.16:

Table: 5.15

Sector wise Energy Generation (in MUs) in Gujarat

Year	GSECL	Private Sector	Central Sector	Wind Energy	Solar	Biomass	Total MUs
2009-10	28507	25314	13334	2729	0	0	69884
2010-11	27762	32965	7708	2815	3	3	71256
2011-12	28638	37116	8723	3960	167	47	78651

Source: http://www.sldcguj.com

Table: 5.16

Category wise Energy Consumption (in MUs) in Gujarat

Sr. No	Type	2009-10	2010-11	2011-12
1	For Jyothi Gram Yojana (JGY)	8064	8791	9508
2	Urban/Town	9844	10831	11236
3	Agriculture	18981	15931	18114
4	Industries	17491	18686	21114
	Total	54380	54239	59972

Source: http://www.sldcguj.com

5.4.1.3 Shortages/Surpluses and Import/Export of Power from the Neighboring States/Regions

In Maharashtra State during 2009-10, the peak demand of 16, 582 MW was met on 20th March, 2010 and the shortfall of 4,168 MW was bridged by resorting to load shedding. MAHADISCOM has purchased 85,474 MkWh electricity during 2009-10 costing Rs. 23,842 crore.

In Gujarat State the electricity generated during 2011-12 was 78,651 MU and whereas, consumption of electric power was 59,972 MU. The installed capacity from conventional sources in the State has increased from 13134 MW to 15306 MW at the end of 11th Five Year Plan (as on 31.3.2012) against the peak level demand of 11500 MW. The Capacity to the tune of 10770 MW is planned to be added in 12th Five Year plan (out of which 1141 MW has already operationalised) and installed capacity is proposed to be doubled by the end of 12th Five Year Plan.

Owing to the substantial capacity addition, GUVNL has become power surplus. GUVNL has disposed of surplus power to other states to avoid the situation of keeping machine idle, to optimize power generation and to reduce overall power purchase cost. GUVNL has sold the surplus power through bilateral agreements as well as through Power Exchanges. The power sold outside the state through bilateral arrangement and power exchanges during the year 2011-12 was 5815 MUs amounting to Rs. 2182 crores at an average rate of Rs.3.75/unit. *(Source: Annual Report GUNL 2011-12)*

5.4.1.4 Transmission Network and Operation Voltages

The operation voltage details of Maharashtra state and availability of transmission infrastructure as on 31st March, 2012 are furnished in Table:5.17 below:

Table: 5.17
Operation Voltage Details of Maharashtra State and Availability of Transmission Infrastructure as on 31st March, 2012

Voltage level	EHV Substation	Transformation Capacity (MVA)	EHV Lines (CKT KM.)
500kV HVDC	2	3582	1504
400kV	22	18180	7405
220kV	171	39383	13209
132kV	260	21633	12073
110kV	34	2674	1724
100kV	36	2587	686
66kV	34	1139	3270
TOTAL	**559**	**89178**	**39871**

The operation voltage details of Gujarat state and availability of transmission infrastructure as on 31st March, 2012 are furnished in Table: 5.18 below:

Table: 5.18
Operation Voltage Details of Gujarat State and Availability of Transmission Infrastructure as on 31st March, 2012

Voltage Class	Transmission Network	
	No. of Substations	**Transmission Lines in Ckt. Km**
400 kV	11	3188.67
220 kV	79	14852.38
132 kV	49	4807.53
66/33 kV	1131	22107.91
TOTAL	**1270**	**44,956.49**

5.4.1.5 Future Plans of Power Development

Maharashtra state: Details on the proposed power plants in Maharashtra State are as furnished below:

1. Uran Gas Based Combined Cycle Power Plant (1220 MW): (Block-I : 406 MW, Block-II: 814 MW)
2. Bhusawal TPS Unit 6 (1 x 660 MW)
3. Nasik TPS Unit 6 (1 x 660 MW)
4. Paras Thermal Power Project Unit 5 (1 x 250 MW)
5. Latur Coal Based Unit 1&2 (2 x 660 MW) or Gas based CCPP Block-I & II (2 x 750 MW)
6. Dhopawe TPS Project Unit – 1 to 3 (3 x 660 MW)
7. Dondaicha TPS Unit – 1, 2, 3, 4 & 5 (5 x 660 MW)
8. Coal based Thermal Power Project near Kanpa (Taluka Nagbhid, District Chandrapur) (2x660 MW)
9. Coal based Thermal Power Project in Mendki (Taluk Brahmapuri, District Chandrapur) (2x660 MW):
10. Coal based Thermal Power Project near Manora (Taluk Tiroda, District Gondia (2 x 660 MW)

Ongoing Thermal Power Projects – 4230 MW:

1. Bhusawal TPS Unit 4 & 5 (2 x 500 MW): The latest major milestones achieved on the project are: Trial operation of Unit 4 completed on 18.07.2012 and Unit-5 operated on full load on 30.03.2012. Further works on the project are in progress.

2. Chandrapur TPS Unit 8 & 9 (2 x 500 MW): The latest major milestones achieved on the project are: Hydraulic test (Drainable) of Unit 8 is achieved on 05.06.2012 and 'Boiler Drum lifting' of Unit-9 is achieved on 25.09.11. Further works on the project are in progress. The commissioning (COD) of Unit 8 is expected by November 2013 followed by Unit 9 by February 2014.

3. Parli TPS Unit 8 (1 x 250 MW): The latest major milestone achieved on the project is 'Commencement of Condenser erection' on 24.04.2012. Further works on the project are in progress.

4. Koradi TPS Unit 8, 9 & 10 (3 x 660 MW): The latest major milestones achieved on the project are: Commencement of Condenser Erection' of Unit 8 on 10.05.2012 and 'Commencement of Boiler Erection' of Unit 9 & 10 on 28.10.11 & 15.02.2012 respectively. Further works on the project are in progress.

Projects Nearing Completion

1. New Parli Thermal Project Unit 1 (250 MW)
2. Paras TPS Expansion Unit 1 (250 MW)

Gujarat State

Details regarding capacity addition planned during 2012-17 in Gujarat State are given in Table: 5.19

Table: 5.19

S No.	Name of Project	Fuel	Capacity (MW)	Year wise Addition during 12th Plan				
				2012-13	2013-14	2014-15	2015-16	2016-17
1	GSECL, Ukai -VI	Coal	500	500	-	-	-	-
2	GSECL Sikka 3 & 4	Imp Coal	500	-	500	-	-	-
3	GSECL Dhuvaran CCPP	Gas	396	-	396	-	-	-
4	GSECL Wanakbori	Coal	800	-	-	-	800	-
5	GPPC Pipavav CCPP	Gas	700	700	-	-	-	-
6	BECl Bhavnagar	Lignite	500	-	500	-	-	-
7	GIPCL Ext III	Lignite	500	-	-	500	-	-
8	ACB Ltd.	Coal	100	100	-	-	-	-
9	Essar Power	Imp Coal	1300	500	-	-	800	-
10	Shapoorji Pallonji Energy	Imp Coal	800	-	-	-	800	-
11	TATA Power UMPP	Coal	1444	722	722	-	-	-
12	JIPL UMPP Tilaiya	Coal	300	-	-	180	120	-
13	NTPC Muvada	Coal	480	240	-	-	240	-
14	NTPS Sipat Stag I	Coal	180	180	-	-	-	-
15	NTPC Vidhyachal IV	Coal	240	240	-	-	-	-
16	NTPC Lara	Coal	280	-	-	-	140	140
17	NTPC	Atomic	476	-	-	-	476	-

	Kakrapar Ext								
18	NTPC Barh	Coal	174	-	-	-	-	174
19	NTPC Dhuvaran	Coal	660	-	-	-	-	660
20	NTPC Khargone	Coal	220	-	-	-	-	220
21	NTPC Gadarwara	Coal	220	-	-	-	-	220
	Total		**10770**	**3182**	**2118**	**680**	**3376**	**1414**

Source: Website, Gujarat State Electricity Corporation Limited

Projects under implementation through private/joint sector participation in Gujarat are as under:

1. 480 MW Pit head Lignite based Power Project at Ghogha in Bhavnagar district by Bhavanagar Energy Company Limited.
2. 700 MW Gas based Power Project at Kovaya in Amreli district in joint venture with GSPC Pipavav Power Company Limited.
3. 1000+ MW Coal based Power Project at Pipavav in joint venture with Torrent Power Limited.

5.5 Assessment of the Power Benefits from Damanganga – Pinjal Link Project

The objective of Damanganga-Pinjal Link Project is to transfer the surplus water (after meeting requirement of water for all the purposes of the people in the vicinity of the project) of Damanganga basin available at proposed Bhugad and Khargihill dams to the Pinjal dam (proposed by Government of Maharashtra across river Pinjal, a tributary of Vaitarna River) from where the combined waters of Damanganga and Pinjal rivers will be taken to Mumbai city to augment its domestic water supply.

Damanganga-Pinjal Link Project envisages construction of a dam across river Damanganga near Bhugad village in Trimbak taluka of Nasik district of Maharashtra; a dam at Khargihill across river Vagh (a tributary of Damanganga) near village Behadpada in Mokhada taluka of Thane district of Maharashtra state; a dam across river Pinjal near village Khidse in Wada taluka of Thane district (proposed by Government of Maharashtra); and 2 tunnels connecting Bhugad reservoir with Khargihill reservoir and Khargihill reservoir with Pinjal reservoir.

The Government of Gujarat has constructed Madhuban dam across river Damanganga in the downstream of proposed Bhugad and Khargihill reservoirs to utilize the waters being generated from the catchment area of Damanganga river lying in Gujarat state. Proposed Bhugad dam will intercept an area of about 141 Km^2 of Gujarat catchment. As such the Gujarat state is need to be compensated by way of release of water from proposed Bhugad reservoir equal to the quantity of water likely to be generated from 141 Km^2 area intercepted by proposed Bhugad dam. Also, for meeting the requirement of water for various purposes of the people in the vicinity of the reservoirs and also in the downstream, environment and ecological purpose etc, water is to be released. It is proposed to generate the hydropower by release of water through power houses proposed at both Bhugad and Khargihill dams.

As such, the power potential studies were carried out through THDC, Rishikesh at the proposed Bhugad and Khargihill reservoirs and assessed the potential of hydropower generation at these reservoirs. The Power Potential study reports of Bhugad and Khargihill Powerhouses are at Appendix – 5.1 and 5.2 respectively in Volume – IV and the E&M report of these Powerhouses are at Appendix 5.3 and 5.4 respectively in Volume - IV. The details of the studies are furnished in the following paragraphs:

5.5.1 Bhugad Dam Power House

5.5.1.1 Power Potential Study

5.5.1.1.1 Type of Project

The proposed Bhugad reservoir is being developed as storage type domestic water supply project. The Storage Capacity of the reservoir is proposed for diversion of water to Mumbai city for augmentation of its domestic water supply, and committed downstream release for Madhuban reservoir including fulfilling the Domestic, Industrial and other requirements of local people and environmental releases. The committed downstream releases are proposed to be released at the toe of the Bhugad Dam into Damanganga River through power house.

5.5.1.1.2 Hydrology, Sedimentation Studies and Criteria for Fixing up Reservoir Levels

Water Availability

The water Availability Study of Damanganga basin and at proposed Bhugad and Khargihill dam sites has been carried out. Net yield Series at Bhugad dam site is available for the period from 1975 to 2004 and the same has been utilized for power potential studies.

The downstream commitment, irrigation releases and other water requirements have also been considered in the studies. The planned utilizations of Bhugad Reservoir are as given in Table – 5.20 below:

Table – 5.20
Planned Utilizations of Bhugad Reservoir

S.No.	Type of Demand	Total Utilization	Remarks
1	Annual Environmental Demand	4.80 Mm^3	From Oct to May
2	Annual Committed D/S demand for Madhuban Dam	91.00 Mm^3	With Success Rate @ 100%
3	Domestic & Industrial	5.00 Mm^3	
4	Irrigation	11.00 Mm^3	
5	Annual Diversion Demand to MWSS	210.00 Mm^3	Through link tunnel to Khargihill dam.

Parameter Used in Power Potential Study

Full Reservoir Level: FRL of the Reservoir has been kept at 163.87 m.

Minimum Draw Down Level: The MDDL has been kept at 124.83 m. The MDDL shall be kept as to satisfy the submergence requirement of the proposed power intake of generating plant and Link tunnel to Khargihill dam.

Tail Water Level – As per topographical map of the D/s of Bhugad dam and site visit, Tail water outlet has been proposed to be kept approximately 200 meter away from the toe of the Dam. Accordingly, average Tail Water Level has been considered at an elevation of 109.00 m for power potential studies.

5.5.1.1.3 Reservoir Operation

Operation of the reservoir has been kept in such a way that maximum level shall be achieved during monsoon period and during non- monsoon season reservoir shall be depleted up to minimum reservoir level to the extent possible. After releasing the water for MWSS through the link tunnel, balance releases except domestic and industrial demand and irrigation demand, shall be taken through power house including some parts of spillage during monsoon.

5.5.1.1.4 Simulation Studies

Simulation Studies have been done using net yield series at Bhugad Dam site for 30 years i.e. from the year 1975 to 2004. The parameters involved in the simulation studies includes monthly inflows into the reservoir, various demands, evaporation losses, elevation-area- capacity relationship of the reservoir after 50 years of the sedimentation. The details of simulation study carried out for the assessment of power potential are at Appendix 5.1 (Power Potential study of Bhugad dam power house) in volume – IV.

5.5.1.1.5 Firm Power

The Bhugad Power Plant will be able to operate continuously on 24 hours basis during non-monsoon period from Nov to May. No power shall be generated during the period from June to October due to non-release of water in the downstream for commited uses. However, during wet Season, additional Power shall be generated as per available discharge. The firm annual energy generation in 90% and 50% dependable years with Installed

Capacity of 2.0 MW and annual Plant load factor of 51.89% will be 9.09 MU and 13.43 MU respectively at 95% plant availability.

5.5.1.1.6 Installed Capacity

One of the most commonly used criterion for optimization of the installed capacity is based on the analysis of incremental energy that is generated with a unit increase in the installed capacity.

In the present optimization studies, energy generation has been analyzed with different installed capacities, ranging from 1.00 MW to 2.50 MW. The energy computations are done for the 90% dependable year and for all the 30 years for which flow data is available. The installed capacity is increased in steps of 0.10 MW. In each case, unrestricted energy and the firm energy have been computed. The results for 90% dependable year are summarized in Table 5.21:

Table 5.21
Incremental Energy Benefits in a 90% Dependable Year (1985)

S. No.	Installed Capacity	Annual Energy Gen.	95% Energy (MU)	ANNUAL PLF	KWh/kW	d(kWh)/ d(kW)
	MW	MU	MU	%		
1	1.000	5.166	4.91	56.02	4907.7	-
2	1.100	5.675	5.39	55.95	4901.0	4833.6
3	1.200	6.184	5.87	55.88	4895.4	4833.6
4	1.300	6.692	6.36	55.83	4890.6	4833.6
5	1.400	7.201	6.84	55.78	4886.5	4833.6
6	1.500	7.708	7.32	55.73	4881.6	4812.2
7	1.600	8.142	7.74	55.19	4834.4	4126.8
8	1.700	8.577	8.15	54.71	4792.8	4126.8
9	1.800	8.965	8.52	54.02	4731.7	3693.7
10	1.900	9.282	8.82	52.98	4641.0	3007.4
11	2.000	9.570	9.09	51.89	4545.7	2736.0
12	2.100	9.851	9.36	50.87	4456.4	2669.4
13	2.200	10.054	9.55	49.56	4341.4	1926.5
14	2.300	10.127	9.62	47.75	4182.8	694.3
15	2.400	10.185	9.68	46.02	4031.4	549.4
16	2.500	10.185	9.68	44.18	3870.2	0.0

The ratio of incremental energy to incremental installed capacity (d(kWh)/ d(kW) for 90% dependable year is plotted against the installed capacity in Figure 5.5:

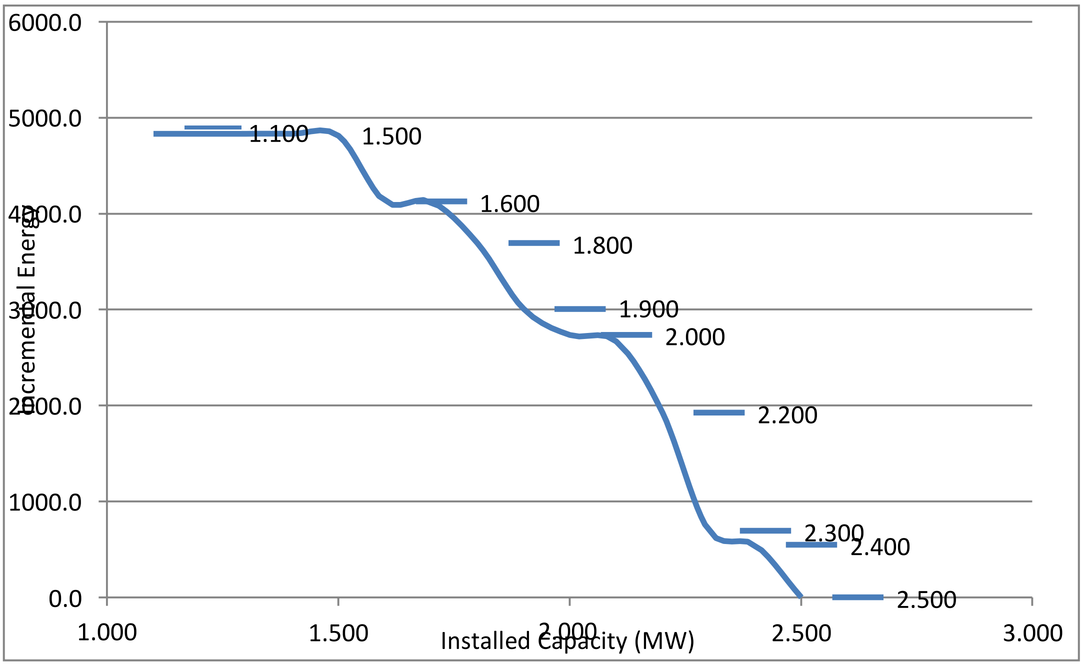

Fig 5.5: Installed Capacity vs. Incremental Energy (90% Dependable year)

Based on incremental consideration, the optimum installed capacity at Bhugad Dam is of the order of 1.80 MW for 90% dependable year. Keeping in view the power potential analysis for 90% dependable year, it has been observed that installed capacity is varying from 1.60 MW to 2.20 MW, hence, in order to maximum utilization of releases, a plant of 2.00 MW installed capacity with 2 units of 1.00 MW each has been proposed.

Annual Plant load factor for 1.80 MW installed capacity is 54.02% with annual generation of 8.52 MU. From the calculation, it has also been observed that PLF for 2.00 MW installed capacity is 51.89% with annual energy generation of 9.09 MU is just near to PLF of 1.80 MW which is also quite good for 90% dependable year.

5.5.1.1.7 Scope for Seasonal/Secondary Power Generation

The design energy in 90% dependable year has been calculated as 9.09 MU. Reviewing the energy calculated for the year 1975 to year 2004, it is seen that additional energy i.e. secondary energy can be generated in many years. The following table summaries the distribution of no. of years in which secondary energy is available. The details are furnished in Table – 5.22:

Table – 5.22

Assessment of Secondary Energy

No. of months with secondary energy	No. of years in the hydrological series	%age of time	Cumulative %age	Secondary energy (MU)	95% Secondary energy (MU)
0	7	23.333	100.000	0.000	0.000
1	1	3.333	76.667	1.440	1.368
2	4	13.333	73.333	2.880	2.736
3	13	43.333	60.000	4.320	4.104
4	5	16.667	16.667	5.760	5.472
Total	**30**	**100**		**14.400**	**13.680**

It is seen that for 23 years out of 30 years for which hydrological data is available i.e. for 76.67% of time, secondary energy available is 1.44 MU. For 60% of time, i.e. 18 years out of 30 years, 4.32 MU of secondary energy is available. In 5 out of 30 years i.e. 16.67% of time, additional 5.76 MU secondary energy shall be available.

For economic viability of the project, only design energy has been considered. Sale of secondary energy will increase the revenue and improve the viability of the project.

5.5.1.1.8 Size and Type of Generating Units

The proposed 2000 kW Bhugad Hydro-Electric Project would have a surface power station located on the left bank of Damanganga river at toe of the Bhugad Dam. The installed capacity of 2.0 MW would be provided by 2 number Francis turbine driven generating units of 1.00 MW each. The units would operate under a net head range of 54.64 m to 15.63 m. The rated net head has been worked out as 41.66 m.

5.5.1.1.9 Number of Generating Units

Keeping in view the power potential analysis for 90% dependable year, it has been observed that installed capacity is varying from 1.60 MW to 2.20 MW, hence, in order to maximum utilization of releases, a plant with 2 units of 1.00 MW each has been proposed.

5.5.1.1.10 Stand by Unit

The project is being developed as a storage type water supply scheme. As per Hydrological analysis water is available for generation from Nov to May for non-monsoon period. Hence, keeping in view the limited water availability, stand by unit is not recommendable.

5.5.1.2 Electrical & Mechanical Works

The proposed 2000 kW Bhugad Hydro-Electric Project would have a surface power station located on the left bank of the Damanganga river at toe of the Bhugad Dam, proposed across river Damanganga near village Bhugad in Trimbak taluka of Nasik district in Maharashtra state. The installed capacity (2.0 MW) would be provided by 2 number Francis turbine driven generating units of 1.00 MW each. The units would operate under a net head range of 54.67 m to 15.63 m. The rated net head has been worked out as 41.66 m. The step-up 3.3kV/33 kV three phase Transformers would be at the unloading bay level on the downstream side, the power house service bay also being at EL 106.50 m. From the transformers, power would be taken to the switchyard by short overhead lines. Power would be transmitted from switchyard by 33 kV outgoing transmission lines.

This project is being developed as storage type water supply scheme with a dam toe type power station. The gross head range would be about 54.87 m to 15.83 m. The average tail water level has been taken as 109.00 m. The selection criteria for electro-mechanical works including turbine, generator, transformer, controls and protections and all other associated works for the power plant including Power evacuation and its transmission to sub-station for Bhugad HEP are discussed below:

5.5.1.2.1 Turbine

i) Selection of Type of Turbine: As per the power potential studies described under Para 5.5.1.1, two turbines - each of 1000 kW capacity have been proposed. The selection of type of turbine for a Hydro Power Project is a function of its specific speed. As per IS: 12800 (Part 3):1991, head variation has been considered from 125% to 65% and accordingly trial speed has been calculated. Based on the calculation, rotational speed has been taken as 750 rpm with Horizontal Francis Turbine.

Following are the design parameters for Bhugad Hydro Electric Project:

FRL at intake	=	EL 163.87 m
M D D L	=	EL 124.83 m
Average Tail Water Level	=	EL 109.00 m
Maximum Gross Head	=	163.87 – 109.00 = 54.87 m
Minimum Gross Head	=	124.83 – 109.00 = 15.83 m
Rated gross head	=	$15.83 + {}^{2}/_{3}\,(54.87 – 15.83)$
	=	41.856 m
Total Head Loss	=	0.200 m (Assumed)
Hence, Design (net) head	=	41.856-0.200
		= 41.656 m Say 41.66 m

The specific speed of turbine can be calculated from the following formula:
Specified Speed

$$n_s = \frac{N(Pr)^{0.5}}{Hr^{5/4}}$$

N = Rotational speed of turbine in rpm = 750 (chosen)

Hr = Rated head = 41.66 m

Pr = Rated turbine output in metric Horse Power

= 0.9863 x Horse Power

Now required output of Generator = 1000 kW plus 10% continuous overload =

1150 kW

Assume efficiency of generator = 95%

∴ Turbine output = 1150 ÷ 0.95

= 1157.89 kW

Now, 1 Horse Power = 745.7 Watts

= 0.7457 kW

∴ 1 kW = 1 ÷ 0.7457 HP

= 1.34 HP

Hence, P_r = 1157.89 kW

= 1157.89 x 1.34

= 1551.58 HP

= 0.9863 x 1551.58 Metric HP

= 1530.32 Metric HP

$$n_s = \frac{750 \times (1530.32)^{0.5}}{(41.66)^{5/4}}$$

$$= 277.20$$

The ranges of specific speeds for various types of turbines are given below:

	Type of runner		**n_s**
(i)	Impulse Pelton/ Turgo	=	12 - 70
(ii)	Crossflow	=	20 - 80
(iii)	Reaction - Francis	=	80 - 400
(iv)	Propeller and Kaplan	=	340 - 1000

This indicates a choice of Francis turbine.

For the given head condition also, Francis turbines are recommended. Each turbine shall be capable of running at 110 % of rated capacity. Each turbine shall be horizontal shaft type suitable for coupling directly to horizontal shaft synchronous generator of 1000 kW plus 10% overload i.e., 1150 kW rating.

ii) Turbine Setting: Setting of Francis runner has been calculated to eliminate any chance of development of cavitations as per Thoma's criteria (ref: IS: 12800 (Part 3):1991).

As per the criteria, Maximum permissible setting of Francis runner bottom above the minimum tail water level is computed as:

$$z = H_a - H_v - \sigma H$$

Where

H_a = Atmospheric Pressure Head, in meter, at plant location

H_v = Vapour Pressure for altitude with highest expected temperature

For 109.00 m altitude and 42^0 C at sea level

H_a = 9.40 m (Considered)

H_v = 0.096 m

Thus, for Bhugad HEP,

$H_a - H_v = 9.40 - 0.096 = 9.304$

$\sigma = (n_s)^{1.64} /50327$

$= (277.20)^{1.64} /50327 \quad = 0.201$

Hence, $z = 9.304 - 0.201 \times 41.66$

$= 0.930$ m (Say)

Positive value of z indicates that the runner shall be set above the minimum tail water level (TWL). Turbine setting with respect to Min TWL has been considered as (+) 0.50m.

Now, Minimum TWL = EL 107.50 m (Assumed)

∴ Elevation of runner = 107.50 + 0.50 = EL 108.00 m.

All other levels of powerhouse, centre line of the runner, centre line of penstock branch pipe feeding the machine and tailrace levels have been shown using the data provided by the equipment supplier.

iii) Runner Diameter: As per IS: 12800 (Part 3):1991), runner dia D_3 is computed as:

Discharge Diameter, D3

D3 $= 84.6\ \varphi\ (H)^{1/2}/n$ for Francis turbines;

Velocity ratio (φ)

$\varphi = 0.0211\ (Ns)^{2/3}$

Therefore, $\varphi = 0.0211\ (277.2)^{2/3}$

$= 0.897$

D3 $= 84.6 \times 0.897 \times (41.66)^{1/2}/750$

Therefore,

$D_3 = 0.653$ m

Computed runner dia = 653 mm

The manufacturer has provided runner dia. as 730 mm. All other turbine and casing dimensions have been computed with respect to above value of D_3 as adopted by the manufacturer viz. 730 mm.

5.5.1.2.2 Francis Turbine and Associated Equipments

i) Type: The Turbine shall be of the Horizontal Shaft Francis suitable for coupling directly to horizontal shaft synchronous generator. The direction of rotation shall be anti-clock wise when viewed from coupling end. The turbine shall be capable of giving outputs higher than rated outputs to match the over load capability of generator.

ii) Spiral Casing: The Turbine shall be of spiral casing type so constructed as to allow all the removable parts to be dismantled conveniently. The design shall also permit removal of rotating parts without disturbing the guide apparatus. The design shall also permit horizontal/vertical movement of runner shaft by an amount sufficient for adjustment of bearing and for clearing the joint at the coupling between the turbine and the generator.

iii) Runner: The Runner shall be of 13/4 chromium-nickel steel. The runner shall be cast integrally of stainless steel. The runner will have adequate number of blades which shall be polished and ground smooth and shall be free from roughness, cracks, high spots etc. The finished machine and ground runner shall be dynamically balanced.

iv) Shaft and Coupling: The turbine shaft is not applicable, as Turbine Runner is proposed to be mounted on the extended shaft of Generator.

v) Turbine Guide and Thrust Bearings: The turbine will be provided with an oil-lubricated guide bearing with suitable Babbitt lining for the shaft. The bearing to be designed for the turbine radial and axial loads. The bearing will be split to facilitate dismantling. Bearing to be provided with suitable instrumentation for monitoring the temperature and oil level.

vi) Draft Tube: Each turbine shall be provided with a draft tube liner/suction bend of welded construction of structural steel. The design of the draft tube shall be such as to ensure the best overall efficiency for the turbine and stable and pulsation –free operation of the machines.

vii) Wicket–Gate Mechanism with Gate Operating Mechanism:

(a) The generator side and draft tube side head cover shall be of suitable construction of steel, to accommodate guide bearings, casings, labyrinth rings, shaft sealing, guide vane bearings etc. The head covers will be suitably designed to resist the superimposed hydraulic load, such that any consequential deflections / slopes of the head cover would not hamper the functioning of the wicket-gate operating mechanism.

(b) **Guide Vanes:** Each guide vane and its stem will be an integral casting in Stainless steel. The contacting surface of gates and the gate stems will be smooth and machine finished. All guide vane bearings (Axial/radial) shall be maintenance free, with appropriate sealing against water flow channel by ‘O’ rings. The angular movement of the gates will be so limited and the mechanism so designed that the bedding faces of the guide vanes close, with no gap, with the servomotor at its closed position.

(c) **Levers/Links:** The guide vane links/levers to be clamped to the guide vane stem and locked in position during assembly. A suitably designed frictional clutch mechanism to prevent possible damage to the wicket gates in case of trapped foreign bodies between the gates will be provided.

(d) **Gate Operating Ring:** A suitably designed gate operating ring will be operated by a servo-motor. The operating ring will be provided with maintenance free bushes.

(e) **Servomotor:** Double Acting servomotors operated by governor oil pressure shall be mounted on the generator side head-cover. The servo-motor shall be supplied with a feedback transmitter. Servo-motor will be of sufficient capacity to operate the gates, when supplied with oil at minimum pressure.

5.5.1.2.3 Inlet Valves

Two Nos. butterfly valves, each of 950 mm dia and operated by hydraulic pressure are proposed to be provided upstream of each turbine inlet to isolate any one of the machines in case of emergency and to afford flexibility of operation of the power plant. The valve will be opened by using an oil servomotor and closed by counter weight under all operating conditions. The counter weight shall be provided as a fail-safe feature, so that it will have a closing bias in case of fault condition.

The body shall be welded construction, with its operating feet to take all Horizontal loads at foundations. The body to house door trunions complete with self lubricated PTFE/chevron type bushes for bearings. The disc shall be fabricated from steel plates. The valve disc will have a peripheral sealing ring of rubber.

The disk shall be optimally designed to provide minimum resistance to flow. Oil operated servomotors shall be mounted on a mounting frame for opening under balanced conditions, so that separate foundations for oil servomotor are avoided.

The oil pressure system for operating the valve shall be common with the governor oil, pressure system. The bypass valve with hydraulically operated main valve shall be provided for opening the valve under balanced conditions.

An inlet pipe of suitable bore shall be flanged u/s of the valve, about 500 mm long for welding to the penstock at site. A dismantling joint of telescopic type shall be located d/s of the valve.

5.5.1.2.4 Governing Equipment

The turbine shall be equipped with suitable electronic governor conforming to IEC No. 308/Hydro-Mechanical governor complete with all accessories. Standard protections like over speed device, brake control, emergency shut down and alarm etc., shall be provided in the governing system.

5.5.1.2.5 Pressure Oil System

Each unit will be provided Oil pressure unit systems which comprise a sump tank and a pressure tank separate for each generating unit. Two numbers of electrically operated governor oil pumps will be provided, one for normal running and the other acting as standby for each unit. Provision of emergency shutdown of the unit without any oil pump shall be made.

5.5.1.2.6 Generator

i) General: There are two types of generators namely:

1. Synchronous, and
2. Induction.

Induction generators are generally about 20% cheaper than the synchronous generators of same output. Whereas synchronous generators are self contained in developing its own excitation power, induction generators require an external source for providing it with the magnetization power. The induction generator uses excitation power supplied from an external source, which is normally the grid. However, in case of grid failure, black start of machines will be difficult. Since Bhugad HEP is not a very small project, dependency on grid could result in loss of power due to standstill generator. Hence it has been proposed to use synchronous generators.

The generator shall conform to the following broad specifications:

S. No.	**Description**	**Specifications**
1	Type of Generator	A.C. Synchronous
2	Rated output (kW)	1000 +10% overload capacity
3	Quantity	2 Nos.
4	Rated P. F.	0.85
5	Rated RPM.	750
6	Run away Speed in RPM	1357
7	Duration of Runaway speed	15 min.
8	Voltage & Variation	3.3 kV ± 10%
9	Frequency & Variation	50 Hz ± 5%
10	Type of Enclosure	IP 23
11	Shaft Orientation	Horizontal
12	Type of Coupling	Not Applicable as Turbine Runner is mounted on extended Generator shaft
13	Insulation class	Class 'F'
14	Ambient Temperature	+ 40 ^{0}C to 0 ^{0}C
15	Rise in temperature over cool air at rated output/maximum output	Class "B" at Rated load Class "F" at Overload
16	Bearing	The generator bearings will be Sleeve type
17	Thrust on Bearing	Yes
18	Short Circuit Ratio	0.8 (Min.)
20	Excitation system features	Brush-less excitation system with Thyrister with AVR, APFC, Under and Over excitation limited, Diode failure relays.
21	Standard	As per IS 4722/equivalent (IEC).
22	Application	Water turbine
23	Direction of rotation	Clockwise when viewed from turbine.

ii) Speed Rise and Runaway Speed: Each generator shall be designed and constructed so as to be capable of running for a period of 15 minutes at a maximum runaway speed. The runaway speed test shall be considered successful if after undergoing the test, 'no injury' is apparent. The runaway speed test may be carried out at a site and at works.

iii) Cooling System: Generator shall be of open type construction with IP: 23 /IC: 01 enclosure

iv) Stator: The stator frame shall be manufactured of cast iron/fabricated steel construction. The frame shall be designed to withstand the bending stresses and deflections due to its self weight and the weight of the core supported by it.

The stator core shall be built up by segmental punching made of low loss silicon sheet steel non-oriented type and end plates. Each punching shall be properly debarred and applied with insulating varnish on both the sides.

The stator winding shall be star connected. The terminal leads of each phase are brought out to a separate terminal box. Six Nos. (Two resistance element per phase) embedded temperature detectors for each generator of resistance type shall be provided for stator winding located symmetrically. The connections on the resistor elements shall be well insulated and extended to a box on the outside of stator frame. The generator stator windings will be provided with epoxy insulation of class "F" type.

v) Rotor: The design and construction of the rotor shall as per latest practice and also in accordance with the best modern practice. The factor of safety at minimum runaway speed based on yield point of material shall not be less than 1.5.

Necessary flywheel effect shall be determined, in case required moment of inertia is not available from rotor, separate flywheel shall be provided to furnish additional flywheel effect. A mechanical over speed device with electrical contacts (two sets) one for alarm and other for trip shall be mounted on non-driving end of the generator and in case of shorting of diodes there shall be trip command.

vi) Shaft: The generator shaft shall be made of the best quality carbon steel properly heat-treated. The shaft shall be of adequate size to operate at all speeds including maximum runaway speed and shall be able to withstand short circuit stresses without excessive vibrations or distortion.

The shaft shall be accurately machined all over and polished where it passes through the bearings and accessible points for alignment check.

vii) Bearings: The generator bearings shall be Antifriction ball / roller type / Tilting Pad. One No. of bearing shall be mounted on DE & NDE. These bearings shall be guaranteed for minimum continuous working for 100,000 (one hundred thousand) hours and shall be of proven design and performance and have minimum maintenance.

Bearings shall be adequately insulated to prevent any harmful circulating currents. The bearings shall be designed to withstand operation of runaway speed for a period of 15 minutes.

Dial type thermometer with two No. contacts shall be provided one Number on each DE & NDE bearings. At each bearing one no. duplex RTD shall be provided for indication/recording and alarm as well as for tripping the unit in case of high temperature.

The guaranteed operating temperature of the bearing at rated output & overload condition shall be indicated. However the bearing temperature for "alarm" & "unit trip" shall not be higher than 75^0 C & 80^0 C respectively.

viii) Heaters: The heater suitable for 240 volts, single-phase AC supply shall be provided.

ix) Brakes: For stopping the generating units quickly, each generator shall be provided with pneumatically operated brakes, which will be operated automatically or manually. The generator brake would consist of a suitable number of brake shoes, which will operate against a polished segmental steel brake track bolted to rotor or to any other component such as fly wheel, if any.

x) Terminal Box: Separate terminal boxes shall be provided for the following:

- Phase terminals of the generator.
- Neutral terminals of the generator.
- Space heater.
- Temperature detectors.

The phase & neutral terminal boxes shall be of phase segregated type.

Terminal boxes shall be of weatherproof construction to eliminate entry of dust, vermin and water with a degree of protection IP: 54.

xi) The generator shall be designed to have a noise level not exceeding 90 db at a distance of one meter from the equipment.

xii) For the rated and 110% overload generator output within the permissible operating conditions, the temperature rise limits of the stator windings would be restricted and the limit would be as per latest Bureau of Indian Standards over the ambient air temperature prevailing at site.

The generator manufacturer shall coordinate with the turbine manufacturer to match the speed, runaway speed, moment of inertia, overload capacity and coupling arrangements etc.

5.5.1.2.7 Electrical Control and Protection Equipments

i) General: Digital Electronic governor with Oil Pressure Unit (OPU) is proposed to be housed in one of the corners of the power house. This system will serve the following four purposes:

- Indication
- Metering
- Protection

- Control

ii) Indications: All the indications such as butterfly valve on/off status, breaker on / off status etc. will be indicated on the unit control board incorporated in the Electronic Governor. 110 Volt D.C. lamps of different colour codes will be used for this purpose.

iii) Metering: All the necessary parameters like voltage, frequency, power factor, current, power, energy, unit hour running etc. will be measured through suitably scaled meters mounted on the unit control board of the Governor.

iv) Controls: All Controls like control for closing the butterfly valves and motor operated circuit breakers for load switching will be incorporated in the Digital Electronic Governor. Thus, the electronic unit control shall have a complete and coordinated set of instruments, controls and safety devices for indication, metering and protection related to all conditions of running of the plant including activating / de-activating various protection devices during emergency operating conditions for the plant.

v) D.C. Equipment: 110 Volt, 150 AH SMF VRLA Battery with battery charger will be provided for feeding power to indication lamps, protection relay coils, initial impulse to the self excitation system by means of field flashing and to operate few emergency lights.

Central Board of Irrigation and Power (CBIP) Technical report no. 79 (Manual on Sub-Station, Chapter 1 on substation battery charging equipment and D.C. switch gear) will be followed for detailed designing.

vi) Fire Protection: Latest techniques available for control of fire using fire-fighting equipments, smoke detectors etc. will be used. Automatic system with manual override is recommended.

vii) Material Handling in the Power House: It is proposed to provide a girder type electric operated crane with a capacity of 10 tons. The hoisting operation shall be done by electric motor operated hoist, which can be operated from the generator floor level. The EOT crane would facilitate a small group of erection and maintenance personnel to handle both erection and maintenance activities.

viii) Auxiliary Power Supply: 3 Phase, 33 kV / 415 V Star / Delta 150 kVA capacity step-down transformer will be used for feeding the station lighting and heating load for power house, illumination for approach road and switch yard.

Emergency lights on important places will be operated by D.C. battery provided in the power house. 150 kVA diesel generator set will also be provided for illumination in power house, staff colony, streetlights & switchyard during shut down of machines.

ix) Cables and Boxes: Heat shrink type cable and boxes shall be provided for HT cable connecting generator to control panel, neutral grounding and relays.

x) Station Drainage System: Adequate provision will be made for collection of any leakage water around the turbine and its delivery to a lowest point of the station drain. A drain connector at lowest point of scroll case for drawing into the draft tube will be provided.

xi) Ventilation System: It is proposed to install six (06) nos. of exhaust fans of 300 mm size, 1000 rpm mounted at a suitable elevation facing towards the tail race.

xii) Draft Tube Gate: Two numbers stop log type gates are proposed as the draft tube gate for each unit for facilitating maintenance of the turbine.

The gates shall be operated from a gantry girder provided for the purpose on the draft tube deck. The lifting and lowering operations shall be possible with a chain pulley block of requisite capacity.

The gate shall be provided with a suitable lifting beam with grab-clamps.

xiii) Tailrace Channel: The tail race channel will connect the draft tubes of the power house with the Damanganga River.

5.5.1.2.8 Switchyard

A comparatively flat terrace exists near powerhouse at EL + 109.00 m where the switchyard has been proposed with 33 kV Outdoor Switchyard Equipments comprising of Vacuum Circuit Breakers, CT's, PT's, LA's, Isolators, Jumpers, and Structure etc. In this location one number three phase power transformer will be kept on plinth. Earth mat will be laid underground. Proper fuse sets, switches etc. will be mounted on M.S. poles. The total area will be strongly fenced as per Indian electrical safety rules. High voltage cable will be laid underground in cable trenches. The power cable will connect low voltage side of the step-up transformer.

5.5.1.2.9 Grounding Systems

i) General: The following equipments / systems are required to be earthed:

- Neutral points of different voltages
- Equipment frame work and other metallic parts
- Boundary fence, steel structures etc.
- Lightning arrestor

ii) Design: The grounding system shall conform to IS 3043-1987 or latest edition and Indian Electricity Rules 1956 along with latest amendments. Power house and switch yard areas shall be protected against electric shocks by providing electrodes and earthing mat for the power house and switchyard areas as per computed/measured electrical resistivity values. Earthing electrodes shall be uniformly distributed and located adjacent to fencing of switchyard and powerhouse.

5.5.1.2.10 Transmission and Distribution Works

i) General: During the meeting at the level of Chief Engineers of states of Gujarat and Maharashtra held on 23rd September, 2011 at Ukai dam the issue of Sharing of Hydro power likely to be generated by the project was also discussed. It was indicated in the meeting that there is a possibility of generating Hydro Power in the downstream of both Bhugad and Khargihill dam sites through committed release of water to meet the downstream requirement and the Power Potential studies at both the dam sites are being carried out by NWDA. It was suggested that the Government of Gujarat shall enjoy sole benefit of Hydro-Power likely to be generated by Power house downstream of Bhugad dam and the cost of construction of this Power house shall be borne by Govt. of Gujarat. Similarly the Govt. of Maharashtra shall enjoy the sole benefit of Hydro-Power likely to be generated from Power house downstream of Khargihill dam and the cost of this Power house shall be borne by Government of Maharashtra. The representatives of both the states have agreed with the suggestion.

As such it is proposed that the power likely to be generated at Bhugad shall be evacuated at the nearest sub – station located in the Gujarat area. The nearest Substation (proposed) with a capacity of 66 kV is situated at Valveri village (Sahuda) of Kaparada Taluka of Valsad District of Gujarat State. Total length of the transmission line from Bhugad switchyard to GETCO's 66kV substation is assessed to be approximately 6.50 km.

As an alternative the option of evacuating the Power to be generated at Bhugad Hydro Power Project to the nearest Sub- station in Maharashtra has also been included in the study. The existing 33 kV sub-station of Maharashtra SEB located in Harsul town is the nearest sub-station in Maharashtra area. The distance of sub-station from Bhugad switchyard is approximately 12.5 km.

ii) Power Evacuation: It is proposed that the electricity shall be generated at 3.3 kV level and evacuated at 33 kV level.

Option – I: One number Step-up transformer, of 2850 kVA rating and 3.3 kV / 33 kV voltage level for these machines shall be provided at switchyard near the powerhouse. The electricity at 33 kV voltage level will be transmitted to the 66 kV SEB sub-station located at Valveri (Sahuda). Appropriate arrangements for protection of the transmission line shall be made.

Step-up Transformers for the Switchyard: As mentioned earlier, Single transformer is proposed to be provided in the switchyard adjacent to the powerhouse. This transformer shall be of 2850 kVA rating, outdoor type, oil filled, 50 Hz, 3 Phase, vector group Y n d 11, natural air cooled. The windings shall be of copper. The connections at HV winding side shall be star and LV winding side shall be delta. Off-load taps on HV side shall be (+) 2.5% to (-) 7.5% in steps of 2.5%. The LV side shall be suitable for cable box whereas HV side shall be suitable for the selected conductor.

The temperature rise on any part of the transformer shall not exceed 40^0 C by oil thermometer and 60^0 C in winding by resistance (RTDs) under full load conditions. The cover of the tank of the transformer shall be bolted to the tank for easy maintenance. C.B.I.P. manual and IS code 2026 – 1977 will be followed for detailed design of transformers.

Transmission Lines: The 33 kV transmission line from Powerhouse to SEB sub-station located at Valveri (Sahuda) shall be supported on steel poles- SP-55 with ACSR Dog conductor and insulators etc. as per the prevailing practice. Total length of the transmission line from switchyard to SEB substation is assessed to be app. 6.50 km. Necessary arrangement with 33/66kV step up transformer, LA, PT's, CT's and Breaker with control panels and metering panels shall be made at Sub-Station end for 33 kV incomer line.

Option –II: Bhugad Hydro-Electric Project would have a surface power station located on the left bank of the Damanganga River near village Bhugad in the Peint Taluka of Nasik District of Maharashtra State. There is also a possibility of evacuation of power to the existing 33 kV sub-station of Maharashtra State Electricity Board (MSEB) located in Harsul town in the Peint Taluka of Nasik District of Maharashtra State. In this proposal also the electricity shall be generated at 3.3 kV level and evacuated at 33 kV level.

One number Step-up transformer, of 2850 kVA rating and 3.3 kV / 33 kV voltage level for these machines shall be provided at switchyard near the powerhouse. The electricity at 33 kV voltage level will be transmitted to the 33 kV SEB sub-station. Appropriate arrangements for protection of the transmission line shall be made.

The 33 kV transmission line from Powerhouse to MSEB sub-station located at Harsul shall also be supported on steel poles- SP-55 with ACSR

Dog conductor and insulators etc. as per the prevailing practice. Total length of the transmission line from switchyard to SEB substation is assessed to be app. 12.50 km. Necessary arrangements with control panels and metering panels shall be made at Sub-Station end for 33 kV incomer line at 33 kV SEB sub-station.

5.5.1.2.11 Drawings

Detailed working drawings of all electrical - mechanical systems shall be furnished at the time of detailed design stage by the E&M equipment supplier. The general arrangement drawing with Plan view and Sectional views of the Powerhouse has been prepared and annexed with the E & M report as Appendix 5. 3 in Volume - IV.

5.5.1.2.12 Cost Estimate (S-Power Plant)

The cost of Electro-Mechanical Works has been computed by utilizing the quotations obtained from leading E & M equipment manufacturers. Of the various Quotations obtained from the reputed equipment manufacturers, the price quoted by one of the reputed manufacturer was found to be most realistic and hence the same has been adopted in formulating the cost estimate for E&M works.

The cost of the Transmission line from Powerhouse to SEB Sub-station has been computed based on the prevailing rates of the state's power transmission organizations.

i) Option-I: Total cost of S-Power Plant which includes prices for Manufacture, Supply, and Transportation up to Project Site of E&M Equipments, Erection & Commissioning of E&M Equipments and Transmission cost up to 66 kV SEB situated at Valveri village (Sahuda) of Kaparada Taluka in Valsad District of Gujarat State are Rs 959.33 Lakh. The cost is based on the price level in the year 2012-13.

ii) Option-II: Total cost of S-Power Plant which includes prices for Manufacture, Supply, and Transportation up to Project Site of E&M Equipments, Erection & Commissioning of E&M Equipments and

Transmission cost up to 33 kV SEB situated at Harsul in the Peint Taluka of Nasik District of Maharashtra State are Rs 940.82 Lakh. The cost is based on the price level in the year 2012-13.

Schedule of requirement of Electro-mechanical equipments has been annexed as Annexures 5.4 in Volume - II.

Details of Cost estimates for option I and option II have been annexed respectively as Annexure-5.5 and 5.6 in Volume - II.

5.5.2 Khargihill Dam Power House

5.5.2.1 Power Potential Study

5.5.2.1.1 Type of Project

The proposed Khargihill reservoir is being developed as storage type domestic water supply project. The Storage Capacity of the reservoir is proposed for diversion of water to Mumbai city for augmentation of its domestic water supply, and committed downstream release for fulfilling the Domestic, Industrial and other requirements of local people and environmental releases. The committed downstream releases are proposed to be released at the toe of the Khargihill Dam into Vagh river (a tributary of Damanganga River) through power house.

5.5.2.1.2 Hydrology, Sedimentation Studies and Criteria for Fixing up Reservoir Levels

Water Availability

The water Availability Study of Damanganga basin and at proposed Bhugad and Khargihill dam sites has been carried out. Net yield Series at Khargihill dam site is available for the period from 1975 to 2004 and the same has been utilized for power potential studies.

The downstream commitment, irrigation releases and other water requirements have also been considered in the studies. The planned utilizations of Khargihill Reservoir are furnished in Table 5.23:

Table 5.23: Planned Utilizations of Khargihill Reservoir

S. No.	Type of Demand	Total Utilization	Remarks
1	Annual Environmental Demand	4.0 Mm^3	From Oct to May
2	Domestic & Industrial	5.00 Mm^3	
3	Irrigation	9.00 Mm^3	
4	Annual Diversion Demand to Mumbai Water Supply System (MWSS)	369.00 Mm^3	Through link tunnel to Pinjal

Parameter Used in Power Potential Study

Full Reservoir Level: FRL of the Reservoir has been kept at 154.52 m.

Minimum Draw Down Level: The MDDL has been kept at 109.75 m. The MDDL shall be kept as to satisfy the submergence requirement of the proposed power intake of generating plant and Link tunnel to Pinjal dam.

Tail Water Level – Tail Water Level has been considered at an elevation of 90.00m for power potential studies.

5.5.2.1.3 Reservoir Operation

Operation of the reservoir has been kept in such a way that maximum level shall be achieved during monsoon period and during non- monsoon season reservoir shall be depleted up to minimum reservoir level to the extent possible. After releasing the water for Mumbai Water Supply System (MWSS) through the link tunnel, balance releases except domestic and industrial demand and irrigation demand, shall be taken through power house including some parts of spillage during monsoon.

5.5.2.1.4 Simulation Studies

Simulation Studies have been done using net yield series at Khargihill Dam site for 30 years (from year 1975 to 2004). The parameters involved in the present Simulation Studies include monthly inflows into the reservoir, diversion from Bhugad reservoir, various demands, evaporation losses, elevations- area - capacity relationship of the reservoir after 50 years of sedimentation. The details of simulation study carried out for assessment of power potential are at Appendix 5.2 (Power Potential study of Khargihill dam power house) in Volume - IV.

5.5.2.1.5 Firm power

The Khargihill Power Plant will be able to operate continuously on 24 hours basis during non-monsoon period from Nov to May. No power shall be generated during the period from June to October due to non-release of water in the downstream for commited uses. However, during wet Season, additional Power shall be generated as per available discharge. The firm annual energy generation in 90% dependable year with Installed Capacity of 3.0 MW and annual Plant load factor of 61.64% will be 16.20 MU at 95% plant availability.

5.5.2.1.6 Installed Capacity

One of the most commonly used criterion for optimization of the installed capacity is based on the analysis of incremental energy that is generated with a unit increase in the installed capacity.

In the present optimization studies, energy generation has been analyzed with different installed capacities, ranging from 0.10 MW to 2.00 MW. The energy computations are done for the 90% dependable year and for all the 30 years for which flow data is available. The installed capacity is increased in steps of 0.20 MW. In each case, unrestricted energy and the firm energy have been computed. The details of computation are presented in Table 5.24:

Table 5.24

Incremental Energy Benefits in a 90% Dependable Year (Year 2001)

S. No.	Installed Capacity	Annual Energy Gen.	95% Energy (MU)	Annual PLF	kWh/kW	d(kWh)/ d(kW)
1	0.100	0.578	0.55	62.71	5493.1	-
2	0.200	1.087	1.03	58.94	5163.4	4833.6
3	0.400	2.105	2.00	57.06	4998.5	4833.6
4	0.600	3.027	2.88	54.71	4792.5	4380.5
5	0.800	3.736	3.55	50.65	4437.0	3370.4
6	1.000	4.179	3.97	45.32	3970.0	2102.2
7	1.200	4.238	4.03	38.30	3355.4	282.3
8	1.400	4.238	4.03	32.83	2876.0	0.0
9	1.600	4.238	4.03	28.73	2516.5	0.0
10	1.800	4.238	4.03	25.54	2236.9	0.0
11	2.000	4.238	4.03	22.98	2013.2	0.0

The ratio of incremental energy to incremental installed capacity (d(kWh)/ d(kW) for 90% dependable year is plotted against the installed capacity in Figure- 5.6

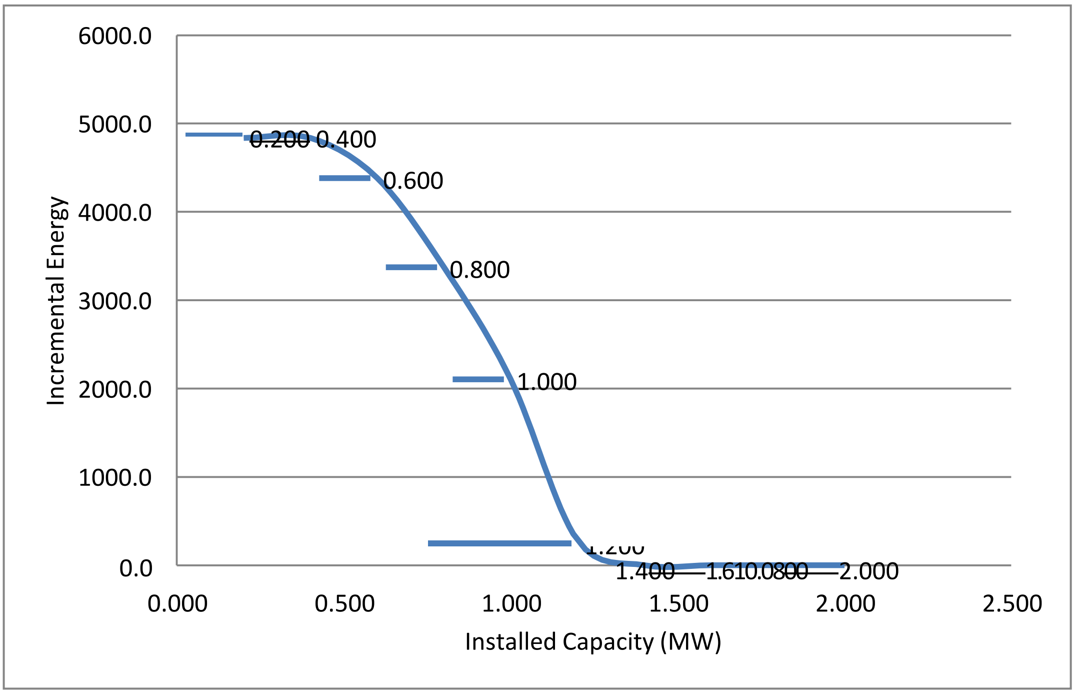

Fig- 5.6: Installed Capacity vs. Incremental Energy (Year 2001)

Perusal of the above results indicates that, based on incremental consideration, the optimal installed capacity at Khargihill Dam is of the order of 0.600 MW for 90% dependable year. Annual Plant load factor for 0.600 MW installed capacity is 54.80 % with annual genration of 2.88 MU.

During studies, it has been observed that unrestricted annual energy generation is abruptly decreasing during year 2001, 2000 and 1987. Further the energy figures for year 1978, which is rated as 88.5 % dependable year is near to 90% dependable year. If, year 1978 being considered as equivalent to 90% dependable year, the optimal installed capacity comes to 3.00 MW with annual Plant load factor of 61.64% and annual generation of 16.20 MU at 95% plant availability, which is also quite good for 90% dependable year. Keeping in view this aspect, the installed capacity of Khargihill hydroelectric Project has been kept as 3.00 MW with two units of 1.50 MW each. The annual energy generation for the year 1978 and other details are summarized in Table 5.25:

Table 5.25

Incremental Energy Benefits for Year 1978

S. No.	**Installed Capacity**	**Annual Energy Gen.**	**95% Energy (MU)**	**AnnuaL PLF**	**kWh/kW**	**d(kWh)/ d(kW)**
	MW	MU	MU	**%**		
1	0.200	1.310	1.24	71.05	6224.4	-
2	0.400	2.621	2.49	71.05	6224.4	6224.4
3	0.600	3.931	3.73	71.05	6224.4	6224.4
4	0.800	5.242	4.98	71.05	6224.4	6224.4
5	1.000	6.552	6.22	71.05	6224.4	6224.4
6	1.200	7.862	7.47	71.05	6224.4	6224.4
7	1.400	9.173	8.71	71.05	6224.4	6224.4
8	1.600	10.483	9.96	71.05	6224.4	6224.4
9	1.800	11.658	11.07	70.24	6152.7	5579.1
10	2.000	12.819	12.18	69.51	6089.2	5517.6
11	2.400	14.803	14.06	66.89	5859.6	4711.8
12	2.600	15.672	14.89	65.37	5726.3	4126.8
13	2.800	16.502	15.68	63.91	5598.7	3940.1
14	3.000	17.050	16.20	61.64	5399.2	2606.1
15	3.200	17.487	16.61	59.26	5191.5	2074.8

The ratio of incremental energy to incremental installed capacity (d (kWh)/ d (kW) for the year 1978 is plotted against the installed capacity in Figure-5.7:

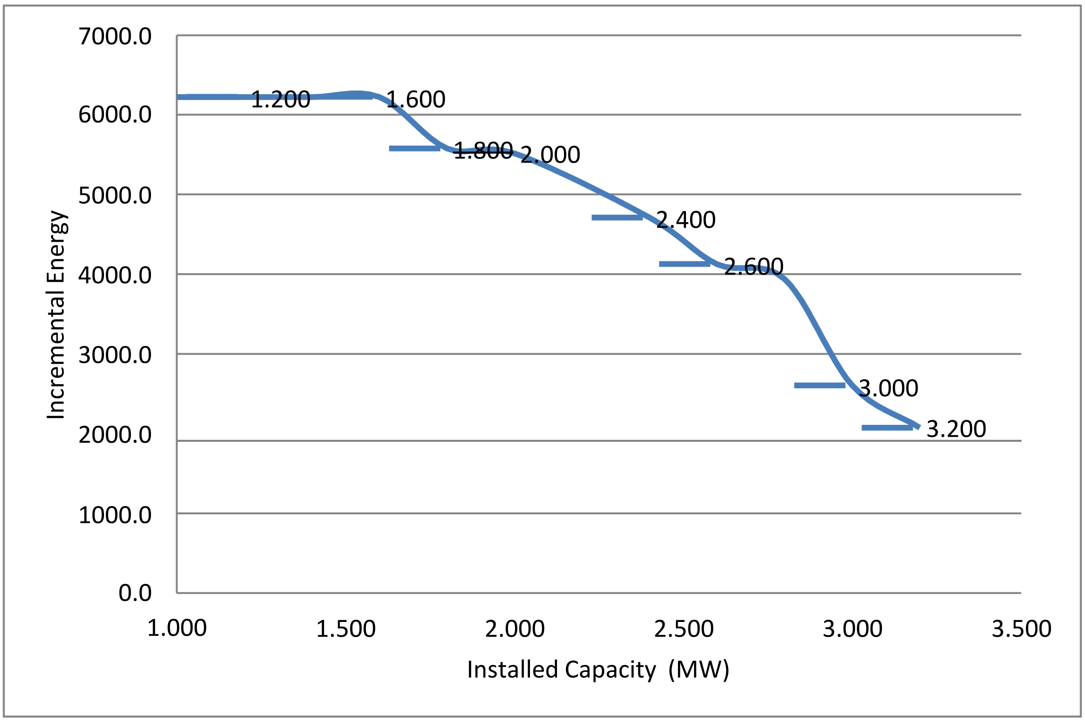

Fig -5.7: Installed Capacity vs. Incremental Energy(Year 1978)

5.5.2.1.7 Scope for Seasonal/Secondary Power Generation

The design energy in 90% dependable year has been calculated as 16.20 MU. Reviewing the energy calculated for the year 1975 to year 2004, it is seen that additional energy i.e. secondary energy can be generated in many years. The following table summaries the distribution of no. of years in which secondary energy is available. The details are furnished in Table 5.26:

Table – 5 .26

Assessment of Secondary Energy

No. of months with secondary energy	No. of years in the hydrologic al series	%age of time	Cumulativ e %age	Secondar y energy (MU)	95% Secondar y energy (MU)
0	3	10.00	100.00	0.00	0.000
1	6	20.00	90.00	2.16	2.052
2	4	13.33	70.00	4.32	4.104

3	14	46.67	56.67	6.48	6.156
4	3	10.00	10.00	8.64	8.208
Total	30	100			20.520

It is seen that for 27 years out of 30 years for which hydrological data is available i.e. for 90% of time, secondary energy available is 2.16 MU. For 56.67% of time, i.e. 17 years out of 30 years, 6.48 MU of secondary energy is available. In 3 out of 30 years i.e. 10% of time, additional 8.64 MU secondary energy shall be available.

For economic viability of the project, only design energy has been considered. Sale of secondary energy will increase the revenue and improve the viability of the project.

5.5.2.1.8 Size and Type of Generating Units

The proposed 3000 kW Khargihill Hydro-Electric Project would have a surface power station located on the left bank of the Vagh river at toe of the Khargihill Dam. The installed capacity of 3.0 MW would be provided by 2 number Francis turbine driven generating units of 1.50 MW each. The units would operate under a net head range of 64.32 m to 19.55 m. The rated net head has been worked out as 49.40 m.

5.5.2.1.9 Number of Generating Units

Keeping in view the power potential analysis a plant with 2 units of 1.50 MW each has been proposed.

5.5.2.1.10 Stand by Unit

The project is being developed as a storage type water supply scheme. As per hydrological analysis, water is available for generation from Nov to May for non-monsoon period. Hence, keeping in view the limited water availability, stand by unit is not recommendable.

5.5.2.2 Electrical & Mechanical Works

The proposed 3000 kW Khargihill Hydro-Electric Project would have a surface power station located on the left bank of the Vagh river at toe of the Khargihill Dam, proposed across Vagh river near village Behadpada in Mokhada taluka of Thane district of Maharashtra. The installed capacity (3.0 MW) would be provided by 2 number Francis turbine driven generating units of 1.50 MW each. The units would operate under a net head range of 64.32 m to 19.55 m. The rated net head has been worked out as 49.40 m. The step-up 3.3kV/33 kV three phase Transformers would be at the unloading bay level on the downstream side, the power house service bay also being at El 90.65 m. From the transformers, power would be taken to the switchyard by short overhead lines. Power would be transmitted from switchyard by 33 kV outgoing transmission lines.

This project is being developed as storage type water supply scheme with a dam toe type power station. The gross head range would be about 64.52 m to 19.75 m. The average tail water level has been taken as 90.00m. In this Chapter selection criteria for electro-mechanical works including turbine, generator, transformer, controls and protections and all other associated works including Power evacuation and its transmission to sub-station for the power plant for Khargihill HEP are discussed below:

5.5.2.2.1 Turbine

i) Selection of Type of Turbine: As per the power potential studies, two turbines of 1500 kW Installed Capacity each have been proposed. The selection of type of turbine for a Hydro Power Project is a function of its specific speed. As per IS: 12800 (Part 3):1991, head variation has been considered from 125% to 65% and accordingly trial speed has been calculated. Based on the calculation, rotational speed has been taken as 750 rpm with Horizontal Francis Turbine.

Following are the design parameters for Khargihill Hydro Electric Project:

FRL at intake	=	EL 154.52 m
M D D L	=	EL 109.75 m

Average Tail Water Level = EL 90.00 m
Maximum Gross Head = 154.52 – 90.00 = 64.52 m
Minimum Gross Head = 109.75 – 90.00 = 19.75 m
Rated gross head = 19.75 + $^{2}/_{3}$ (64.52 – 19.75) = 49.596 m
Total Head Loss = 0.200 m (Assumed)
Hence, Design (net) head = 49.596-0.200
= 49.396 m say 49.40 m

The specific speed of turbine can be calculated from the following formula:

Specified Speed

$$n_s = \frac{N(Pr)^{0.5}}{Hr^{5/4}}$$

N = Rotational speed of turbine in rpm = 750 (chosen)

Hr = Rated head = 49.40 m

Pr = Rated turbine output in metric Horse Power

= 0.9863 x Horse Power

Now required output of Generator = 1500 kW plus 10% continuous overload = 1650 kW

Assume efficiency of generator = 95%

∴ Turbine output = 1650 ÷ 0.95
= 1736.84 kW

Now, 1 Horse Power = 745.7 Watts
= 0.7457 kW

∴ 1 kW = 1 ÷ 0.7457 Horse Power
= 1.34 HP

Hence, P_r = 1736.84 kW
= 1736.84 x 1.34
= 2327.37 HP
= 0.9863 x 2327.37 Metric HP
= 2295.48 Metric HP

$$n_s = \frac{750 \times (2295.48)^{0.5}}{(49.4)^{5/4}}$$

= 274.37

The ranges of specific speeds for various types of turbines are given below:

	Type of runner		**n_s**
(i)	Impulse Pelton/ Turgo	=	12 - 70
(ii)	Crossflow	=	20 - 80
(iii)	Reaction - Francis	=	80 - 400
(iv)	Propeller and Kaplan	=	340 - 1000

This indicates a choice of Francis turbine. For the given head condition also, Francis turbines are recommended. Each turbine shall be capable of running at 110 % of rated capacity. Each turbine shall be horizontal shaft type suitable for coupling directly to horizontal shaft synchronous generator of 1500 kW plus 10% overload i.e., 1650 kW rating.

ii) Turbine Setting: Setting of Francis runner has been calculated to eliminate any chance of development of cavitations as per Thoma's criteria (ref: IS: 12800 (Part 3):1991).

As per the criteria, Maximum permissible setting of Francis runner bottom above the minimum tail water level is computed as:

$z = H_a - H_v - \sigma H$

Where

H_a = Atmospheric Pressure Head, in meter, at plant location

H_v = Vapour Pressure for altitude with highest expected temperature

For 90.00 m altitude and 42^0 C at sea level

H_a = 9.40 m (Considered)

H_v = 0.096 m

Thus, for Khargihill HEP,

$H_a - H_v$ = 9.304 m

$\sigma = (n_s)^{1.64} / 50327$

$= (274.37)^{1.64} / 50327$

$= 0.198$

Hence, $z = 9.304 - 0.198 \times 49.4 = -0.477$ m

$= -0.480$ m (Say)

Negative value of z indicates that in order to avoid cavitations, the runner shall be set below the minimum tail water level (TWL). Turbine setting with respect to Min TWL has been considered as (-) 1.25m.

Now, Minimum TWL = EL 89.00 m (Assumed)

$\therefore$ Elevation of runner = 89.00 – 1.25 = EL 87.75 m.

All other levels of powerhouse, centre line of the runner, centre line of penstock branch pipe feeding the machine and tailrace levels have been shown using the data provided by the equipment supplier.

iii) Runner Diameter: As per IS: 12800 (Part 3):1991), runner dia D_3 is computed as :

Discharge Diameter, D3

D3 $=84.6\ \varphi\ (H)^{1/2}/n$ for Francis turbines;

Velocity ratio (φ)

$\varphi = 0.0211\ (Ns)^{2/3}$

Therefore, $\varphi = 0.0211\ (274.37)^{2/3}$

$=0.890$

D3 $=84.6 \times 0.890 \times (49.4)^{1/2}/750$

Therefore, $D_3 = 0.705$ m

Computed runner dia = 700 mm

The manufacturer has provided runner dia. as 790 mm. All other turbine and casing dimensions have been computed with respect to above value of D_3 as adopted by the manufacturer viz. 790 mm.

5.5.2.2.2 Francis Turbine and Associated Equipments

i) Type: The Turbine shall be of the Horizontal Shaft Francis suitable for coupling directly to horizontal shaft synchronous generator. The direction of rotation shall be anti-clock wise when viewed from coupling end. The turbine shall be capable of giving outputs higher than rated outputs to match the over load capability of generator.

ii) Spiral Casing: The Turbine shall be of spiral casing type so constructed as to allow all the removable parts to be dismantled conveniently. The design shall also permit removal of rotating parts without disturbing the guide apparatus. The design shall also permit horizontal/vertical movement of runner shaft by an amount sufficient for adjustment of bearing and for clearing the joint at the coupling between the turbine and the generator.

iii) Runner: The Runner shall be of 13/4 chromium-nickel steel. The runner shall be cast integrally of stainless steel. The runner will have adequate number of blades which shall be polished and ground smooth and shall be free from roughness, cracks, high spots etc. The finished machine and ground runner shall be dynamically balanced.

iv) Shaft and Coupling (If required): The turbine shaft, if required, shall be forged carbon steel or alloy steel confirming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should be conform to American standard ANSI-49.1, 1967. The turbine shaft shall be connected to the runner at one side and to the gear box / flywheel generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion. However, the turbine shaft is not applicable, as Turbine Runner will be mounted on the extended shaft of Generator.

v) Turbine Guide and Thrust Bearings: The turbine will be provided with an oil-lubricated guide bearing with suitable Babbitt lining for the shaft. The bearing to be designed for the turbine radial and axial loads. The bearing will be split to facilitate dismantling. Bearing to be provided with suitable instrumentation for monitoring the temperature and oil level.

vi) Draft Tube: Each turbine shall be provided with a draft tube liner/suction bend of welded construction of structural steel. The design of the draft tube shall be such as to ensure the best overall efficiency for the turbine and stable and pulsation –free operation of the machines.

vii) Wicket–Gate Mechanism with Gate Operating Mechanism:

(a) The generator side and draft tube side head cover shall be of suitable construction of steel, to accommodate guide bearings, casings, labyrinth rings, shaft sealing, guide vane bearings etc. The head covers will be suitably designed to resist the superimposed hydraulic load, such that any consequential deflections / slopes of the head cover would not hamper the -functioning of the wicket-gate operating mechanism.

(b) **Guide Vanes:** Each guide vane and its stem will be an integral casting in Stainless steel. The contacting surface of gates and the gate stems will be smooth and machine finished. All guide vane bearings (Axial/radial) shall be maintenance free, with appropriate sealing against water flow channel by 'O' rings. The angular movement of the gates will be so limited and the mechanism so designed that the bedding faces of the guide vanes close, with no gap, with the servomotor at its closed position.

(c) **Levers/Links:** The guide vane links/levers to be clamped to the guide vane stem and locked in position during assembly. A suitably designed frictional clutch mechanism to prevent possible damage to the wicket gates in case of trapped foreign bodies between the gates will be provided.

(d) **Gate Operating Ring:** A suitably designed gate operating ring will be operated by a servo-motor. The operating ring will be provided with maintenance free bushes.

(e) **Servomotor:** Double Acting servomotors operated by governor oil pressure shall be mounted on the generator side head-cover. The servo-motor shall be supplied with a feedback transmitter. Servo-motor will be of sufficient capacity to operate the gates, when supplied with oil at minimum pressure.

5.5.2.2.3 Inlet Valves

Two Nos. butterfly valves, each of 1100 mm dia and operated by hydraulic pressure are proposed to be provided upstream of each turbine inlet to isolate any one of the machines in case of emergency and to afford flexibility of operation of the power plant. The valve will be opened by using an oil servomotor and closed by counter weight under all operating conditions. The counter weight shall be provided as a fail-safe feature, so that it will have a closing bias in case of fault condition. The body shall be welded construction, with its operating feet to take all Horizontal loads at foundations. The body to house door trunions complete with self lubricated PTFE/chevron type bushes for bearings.

The disc shall be fabricated from steel plates. The valve disc will have a peripheral sealing ring of rubber. The disk shall be optimally designed to provide minimum resistance to flow. Oil operated servomotors shall be mounted on a mounting frame for opening under balanced conditions, so that separate foundations for oil servomotor are avoided.

The oil pressure system for operating the valve shall be common with the governor oil, pressure system. The bypass valve with hydraulically operated main valve shall be provided for opening the valve under balanced conditions.

An inlet pipe of suitable bore shall be flanged u/s of the valve, about 500 mm long for welding to the penstock at site. A dismantling joint of telescopic type shall be located d/s of the valve.

5.5.2.2.4 Governing Equipment

The turbine shall be equipped with suitable electronic governor conforming to IEC No. 308/Hydro-Mechanical governor complete with all accessories. Standard protections like over speed device, brake control, emergency shut down and alarm etc., shall be provided in the governing system.

5.5.2.2.5 Pressure Oil System

Each unit will be provided Oil pressure unit systems which comprise a sump tank and a pressure tank separate for each generating unit. Two numbers of electrically operated governor oil pumps will be provided, one for normal running and the other acting as standby for each unit. Provision of emergency shutdown of the unit without any oil pump shall be made.

5.5.2.2.6 Generator

i) General: There are two types of generators namely:

1. Synchronous, and
2. Induction

Induction generators are generally about 20% cheaper than the synchronous generators of same output. Whereas synchronous generators are self contained in developing its own excitation power, induction generators require an external source for providing it with the magnetization power. The induction generator uses excitation power supplied from an external source, which is normally the grid. However, in case of grid failure, black start of machines will be difficult. Since Khargihill HEP is not a very small project, dependency on grid could result in loss of power due to standstill generator. Hence it has been proposed to use synchronous generators.

The generator shall conform to the following broad specifications:

S. No.	Description	Specifications
1	Type of Generator	A.C. Synchronous
2	Rated output (kW)	1500
3	Quantity	2 Nos.
4	Rated P. F.	0.85
5	Rated RPM.	750
6	Run away Speed in RPM	1357
7	Duration of Runaway speed	15 min.
8	Voltage & Variation	3.3 kV ± 10%
9	Frequency & Variation	50 Hz ± 5%

10	Type of Enclosure	IP 23
11	Shaft Orientation	Horizontal
12	Type of Coupling	Not Applicable as Turbine Runner is mounted on extended Generator shaft
13	Insulation class	Class 'F'
14	Ambient Temperature	+ 40^0 C to 0^0 C
15	Rise in temperature over cool air at rated output/maximum output	Class ‘B’ at Rated load Class ‘F’ at Overload
16	Bearing	The generator bearings will be Sleeve type
17	Thrust on Bearing	Yes
18	Short Circuit Ratio	0.8 (Min.)
19	Overload	10%
20	Excitation system features	Brush-less excitation system with Thyrister with AVR, APFC, Under and Over excitation limited, Diode failure relays.
21	Standard	As per IS 4722/equivalent (IEC).
22	Application	Water Turbine
23	Direction of rotation	Clockwise when viewed from turbine.

ii) Speed Rise and Runaway Speed: Each generator shall be designed and constructed so as to be capable of running for a period of 15 minutes at a maximum runaway speed. The runaway speed test shall be considered successful if after undergoing the test, ‘no injury’ is apparent. The runaway speed test may be carried out at a site and at works.

iii) Cooling System: Generator shall be of open type construction with IP: 23 /IC: 01 enclosure

iv) Stator: The stator frame shall be manufactured of cast iron/fabricated steel construction. The frame shall be designed to withstand the bending stresses and deflections due to its self weight and the weight of the core supported by it.

The stator core shall be built up by segmental punching made of low loss silicon sheet steel non-oriented type and end plates. Each punching shall be properly debarred and applied with insulating varnish on both the sides.

The stator winding shall be star connected. The terminal leads of each phase are brought out to a separate terminal box. Six Nos. (Two resistance element per phase) embedded temperature detectors for each generator of resistance type shall be provided for stator winding located symmetrically. The connections on the resistor elements shall be well insulated and extended to a box on the outside of stator frame. The generator stator windings will be provided with epoxy insulation of class “F” type.

v) Rotor: The design and construction of the rotor shall as per latest practice and also in accordance with the best modern practice. The factor of safety at minimum runaway speed based on yield point of material shall not be less than 1.5.

Necessary flywheel effect shall be determined, in case required moment of inertia is not available from rotor, separate flywheel shall be provided to furnish additional flywheel effect. A mechanical over speed device with electrical contacts (two sets) one for alarm and other for trip shall be mounted on non-driving end of the generator and in case of shorting of diodes there shall be trip command.

vi) Shaft: The generator shaft shall be made of the best quality carbon steel properly heat-treated. The shaft shall be of adequate size to operate at all speeds including maximum runaway speed and shall be able to withstand short circuit stresses without excessive vibrations or distortion.

The shaft shall be accurately machined all over and polished where it passes through the bearings and accessible points for alignment check.

vii) Bearings: The generator bearings shall be Antifriction ball / roller type / Tilting Pad. One No. of bearing shall be mounted on DE & NDE. These bearings shall be guaranteed for minimum continuous working for 100,000 (one hundred thousand) hours and shall be of proven design and performance and have minimum maintenance.

Bearings shall be adequately insulated to prevent any harmful circulating currents. The bearings shall be designed to withstand operation of runaway speed for a period of 15 minutes.

Dial type thermometer with two No. contacts shall be provided one Number on each DE & NDE bearings. At each bearing one no. duplex RTD shall be provided for indication/recording and alarm as well as for tripping the unit in case of high temperature.

The guaranteed operating temperature of the bearing at rated output & overload condition shall be indicated. However the bearing temperature for "alarm" & "unit trip" shall not be higher than 75^0 C & 80^0 C respectively.

viii) Heaters: The heater suitable for 240 volts, single-phase AC supply shall be provided.

ix) Brakes: For stopping the generating units quickly, each generator shall be provided with pneumatically operated brakes, which will be operated automatically or manually. The generator brake would consist of a suitable number of brake shoes, which will operate against a polished segmental steel brake track bolted to rotor or to any other component such as fly wheel, if any.

x) Terminal Box: Separate terminal boxes shall be provided for the following:

- Phase terminals of the generator.
- Neutral terminals of the generator.
- Space heater.
- Temperature detectors.

The phase & neutral terminal boxes shall be of phase segregated type. Terminal boxes shall be of weatherproof construction to eliminate entry of dust, vermin and water with a degree of protection IP: 54.

xi) The generator shall be designed to have a noise level not exceeding 90 db at a distance of one meter from the equipment.

xii) For the rated and 110% overload generator output within the permissible operating conditions, the temperature rise limits of the stator windings would be restricted and the limit would be as per latest Bureau of Indian Standards over the ambient air temperature prevailing at site.

The generator manufacturer shall coordinate with the turbine manufacturer to match the speed, runaway speed, moment of inertia, overload capacity and coupling arrangements etc.

5.5.2.2.7 Electrical Control and Protection Equipments

i) General: Digital Electronic governor with Oil Pressure Unit (OPU) is proposed to be housed in one of the corners of the powerhouse. This system will serve the following four purposes:

- Indication
- Metering
- Protection
- Control

ii) Indication: All the indications such as butterfly valve on/off status, breaker on / off status etc. will be indicated on the unit control board incorporated in the Electronic Governor. 110 Volt D.C. lamps of different colour codes will be used for this purpose.

iii) Metering: All the necessary parameters like voltage, frequency, power factor, current, power, energy, unit hour running etc. will be measured through suitably scaled meters mounted on the unit control board of the Governor.

iv) Controls: All Controls like control for closing the butterfly valves and motor operated circuit breakers for load switching will be incorporated in the Digital Electronic Governor. Thus, the electronic unit control shall have a complete and coordinated set of instruments, controls and safety devices for indication, metering and protection related to all conditions of running of the plant including activating / de-activating various protection devices during emergency operating conditions for the plant.

v) D.C. System: Float cum boost charger 110 Volt, 200 AH capacity and tubular batteries will be provided for feeding power to indication lamps, protection relay coils, and initial impulse to the self excitation system by means of field flashing and to operate few emergency lights.

Central Board of Irrigation and Power (CBIP) Technical report no. 79 (Manual on Sub-Station, Chapter 1 on substation battery charging equipment and D.C. switch gear) will be followed for detailed designing.

vi) Fire Protection: Latest techniques available for control of fire using fire-fighting equipments, smoke detectors etc. will be used. Automatic system with manual override is recommended.

vii) Material Handling in the Power House: It is proposed to provide a girder type electric operated crane with a capacity of 12 tons. The hoisting operation shall be done by electric motor operated hoist, which can be operated from the generator floor level. The EOT crane would facilitate a small group of erection and maintenance personnel to handle both erection and maintenance activities.

viii) Auxiliary Power Supply: 3 Phase, 33 kV / 415 V Star / Delta 200 kVA capacity step-down transformer will be used for feeding the station lighting and heating load for power house, illumination for approach road and switch yard.

Emergency lights on important places will be operated by D.C. battery provided in the powerhouse. 200 kVA diesel generator set will also be provided for illumination in powerhouse, staff colony, streetlights & switchyard during shut down of machines.

ix) Cables and Boxes: Heat shrink type cable and boxes shall be provided for HT cable connecting generator to control panel, neutral grounding and relays.

x) Station Drainage System: Since the level of the bottom most floors is below the tail water level, there is likelihood of seepage water entering into the power station. Besides there is likelihood of leakage water from shaft seals etc.

It is proposed to provide a drain of 250 mm x 250 mm around the outer walls of the power station entering into a drainage sump whose floor level is fixed at 83.25 m. It is proposed to install two (02) nos. of sump pumps discharging into the tail race above the maximum tail water level.

xi) Dewatering System: It is proposed to dewater the draft tube by one number portable centrifugal pump of submersible type. For the purpose of dewatering of the draft tube, a 750 mm dia opening has been provided on the draft tube deck. The dewatering opening shall be closed by suitable mild steel cover with bolting facility and shall be flush with the floor level.

xii) Ventilation System: It is proposed to install six (06) nos. of exhaust fans of 300 mm size, 1000 RPM mounted at a suitable elevation facing towards the tail race.

xiii) Draft Tube Gate: Two numbers stop log type gates are proposed as the draft tube gate for each unit for facilitating maintenance of the turbine.

The gates shall be operated from a gantry girder provided for the purpose on the draft tube deck. The lifting and lowering operations shall be possible with a chain pulley block of requisite capacity. The gate shall be provided with a suitable lifting beam with grab-clamps.

xiv) Tailrace Channel: The tail race channel will connect the draft tubes of the power house with the Vagh River.

5.5.2.2.8 Switchyard

A comparatively flat terrace exists near powerhouse at EL + 90.00 m where the switchyard has been proposed with 33 kV Outdoor Switchyard Equipments comprising of Vacuum Circuit Breakers, CT's, PT's, LA's, Isolators, Jumpers, and Structure etc. In this location one no. three phase power transformer will be kept on plinth. Earth mat will be laid underground. Proper fuse sets, switches etc. will be mounted on M.S. poles. The total area will be strongly fenced as per Indian electrical safety rules. High voltage cable will be laid underground in cable trenches. The power cable will connect low voltage side of the step-up transformer.

5.5.2.2.9 Grounding Systems

i) General: The following equipments / systems are required to be earthed:

- Neutral points of different voltages
- Equipment frame work and other metallic parts
- Boundary fence, steel structures etc.
- Lightning arrestor

ii) Design: The grounding system shall conform to IS 3043-1987 or latest edition and Indian Electricity Rules 1956 along with latest amendments. Power house and switch yard areas shall be protected against electric shocks by providing electrodes and earthing mat for the power house and switchyard areas as per computed/measured electrical resistivity values. Earthing electrodes shall be uniformly distributed and located adjacent to fencing of switchyard and powerhouse.

5.5.2.2.10 Transmission and Distribution Works

i) General: Khargihill Hydro Power Project is proposed to be a grid-connected scheme. However, it is proposed to evacuate the power to the existing 33 kV sub-station of SEB located in Mokhada town. The distance of sub-station from Khargihill switchyard is approximately 23.5 km.

ii) Power Evacuation: It is proposed that the electricity shall be generated at 3.3 kV level and evacuated at 33 kV level.

One number Step-up transformer, of 4000 kVA rating and 3.3 kV / 33 kV voltage level for these machines shall be provided at switchyard near the powerhouse. The electricity at 33 kV voltage level will be transmitted to the 33 kV SEB sub-station. Appropriate arrangements for protection of the transmission line shall be made.

iii) Step-up Transformers for the Switchyard: As mentioned earlier, Single transformer is proposed to be provided in the switchyard adjacent to the powerhouse. This transformer shall be of 4000 kVA rating, outdoor type, oil filled, 50 Hz, 3 Phase, vector group Y n d 11, natural air cooled. The windings shall be of copper. The connections at HV winding side shall be star and LV winding side shall be delta. Off-load taps on HV side shall be (+) 2.5% to (-) 7.5% in steps of 2.5%. The LV side shall be suitable for cable box whereas HV side shall be suitable for the selected conductor.

The temperature rise on any part of the transformer shall not exceed 40^0 C by oil thermometer and 60^0 C in winding by resistance methods (RTDs) under full load conditions. The cover of the tank of the transformer shall be bolted to the tank for easy maintenance. C.B.I.P. manual and IS code 2026 – 1977 will be followed for detailed design of transformers.

iv) Transmission Lines: It is proposed to provide single circuit 33 kV transmission line supported on tubular steel poles for evacuation of the same. The 33 kV transmission line from Powerhouse to SEB sub-station located at Mokhada shall be supported on steel poles- SP-55 with ACSR Dog conductor and insulators etc. as per the prevailing practice. Total length of the transmission line from switchyard to SEB substation is assessed to be 23.5 km. Necessary arrangements with control panels and metering panels shall be made at Sub-Station end for 33 kV incomer line.

5.5.2.2.11 Drawings

Detailed working drawings of all electrical - mechanical systems shall be furnished at the time of detailed design stage by the E&M equipment supplier. The general arrangement drawing with Plan view and Sectional views of the Powerhouse has been prepared and annexed with the E & M report as Appendix 5.4 in Volume - IV.

5.5.2.2.12 Cost Estimate (S-Power Plant)

The cost of Electro-Mechanical Works has been computed by utilizing the quotations obtained from leading E & M equipment manufacturers. Of the various Quotations obtained from the reputed equipment manufacturers, the price quoted by one of the reputed manufacturer was found to be most realistic and hence the same has been adopted in formulating the cost estimate for E&M works.

The cost of the Transmission line from Powerhouse to MSEB has been computed based on the prevailing rates of the state’s power transmission organizations.

Total cost of S-Power Plant which includes prices for Manufacture, Supply, and Transportation up to Project Site of E&M Equipments, Erection & Commissioning of E&M Equipments and Transmission cost up to Mokhada SEB are Rs 1134.05 Lakh. The cost is based on the price level in the year 2012-13.

Schedule of requirement of Electro-mechanical equipments has been annexed as Annexures 5.7 in Volume - II.

Details of Cost estimate have been annexed as Annexure-5.8 in Volume - II.

Map showing the location of head works, powerhouses, switch yard, transmission lines etc. is at Fig - 5.8:

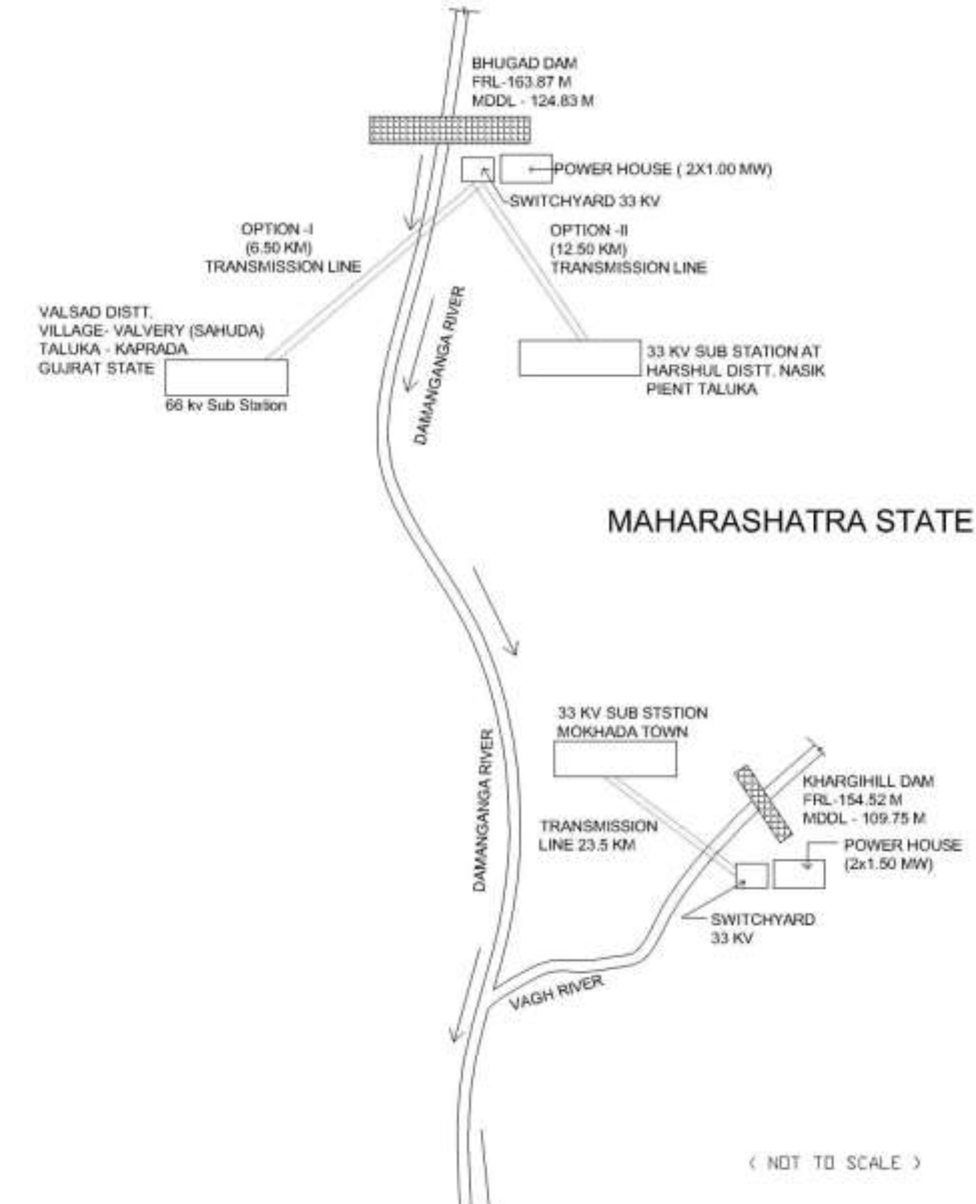

FIGURE 5.8 :LOCATION PLAN SHOWING DETAILS OF TRANSMISSION LINE AND SUB STATION FOR POWER EVACUATION ARRANGEMENTS FOR DAMANGANGA- PINJAL LINK PROJECT