

Chapter – 7 Reservoirs

As mentioned in earlier chapters, there are three reservoirs namely Bhugad, Kharihill and Pinjal in this link project. Studies of Bhugad and Kharihill reservoirs have been carried out by NWDA whereas study of Pinjal has been done by Govt. of Maharashtra.

7.1 Fixation of storage and reservoirs levels

Reservoir capacity and related levels depend on many interrelated parameters. The major factors are quantities and distribution of inflows, demand pattern, reliability of fulfillment of demands, sediment distribution, operational criteria and design flood. Inflow into the reservoirs and design flood have already been discussed in Chapter – 5 "Hydrology and Water Resources". Other factors have been described in the following paragraphs

7.2 Sedimentation studies

Reservoir sedimentation study for the two reservoirs has been carried out using Empirical area reduction method as per IS: 5477(part-ii)1969, 'Method for fixing the capacities of reservoirs'. In this method, rate of sedimentation and type of reservoir, are the main inputs. These are therefore discussed below.

7.2.1 Rate of sedimentation

The catchment area upto the dam site for both of the dams is as follows

Bhugad	729 sq km
Khargihill	710 sq km

The rate of sedimentation for the two reservoirs has been assumed to be of order of 715 M³/sq km / year. Further, it is also assumed that the bed load of sediment is 15% of suspended load.

7.2.2 Type of reservoirs

The type of the reservoir has been classified according to the classifications of types of reservoirs provided by Borland and Miller. The capacity inflow ratio has been calculated for each of the reservoirs and the trap efficiency corresponding to this ratio has been computed from the Brune's curve. The value of trap efficiency and parameters 'n' and 'm' are obtained from the plot of reservoir depth and reservoir capacity. The details are furnished in Table 7.1.

Table 7.1 Trap efficiency and type of reservoir using IS code

Reservoir	Trap efficiency	Value of "n"	Value of "m"	Type of reservoir
Bhugad	0.98	0.351	2.85	II
Khargihill	0.98	0.392	2.55	II

7.2.3 Sedimentation in the reservoir after 50 years and 100 years

The total quantity of sediment that would deposit in the reservoir and new zero elevations for 50 years and 100 years have been worked out and furnished in Table 7.2. The table also contains the dead storage levels or the MDDL adopted. Dead storage is provided for 100 years of sedimentation and revised area-capacity curve after 50 years of sedimentation has been considered for simulation study for estimating the regulated yield from the reservoirs.

Table 7.2
Sediment volume in 50 years and 100 years period

Reservoir	In 50 years		In 100 years		Dead storage level/ M.D.D.L. adopted (m)
	Sediment volume (Mm ³)	New zero elevation (m)	Sediment volume (Mm ³)	New zero elevation (m)	
Bhugad	26.064	106.359	52.123	110.033	124.83
Khargihill	25.355	88.627	50.710	91.884	109.75

7.2.4 Life of the reservoirs

The life of both the reservoirs of Damanganga-Pinjal link project is considered as 100 years for the purpose of sediment distribution and working out B.C. ratio.

7.3 Capacities

The capacity of both the reservoirs have been worked out by simulation studies. The factors affecting the reservoir capacities have been described in para 7.2. Some of these factors have already been discussed earlier in this chapter and in chapter-5. The other factors like demands and reliability of their fulfillment and their utilisation in simulation are discussed in simulation studies.

7.4 Simulation studies

Simulation studies have been done for estimating the reservoir capacity for Bhugad and Khargihill reservoirs using inflow data of Madhuban reservoir for a period of 14 years, from 1988 to 2001 for which inflow data is available. The parameters involved in the present simulation studies include monthly inflows into the reservoirs, various demands, evaporation, elevations, area-capacity relationship of the reservoir after 50 years of the sedimentation. The trap efficiency and type of reservoir are discussed in para 7.2.2. Sedimentation volume in 50 years and 100 years period are discussed in para 7.2.3.

For simulation of Bhugad and Khargihill reservoirs the demands considered and their success rate/targeted reliabilities to be achieved are as follows.

1. Upstream demands
 - i) Domestic and industrial water needs
 - ii) Irrigation needs
 - iii) Hydropower needs
2. Downstream demands
 - i) Committed downstream irrigation requirements at Madhuban dam.
 - ii) Release for Pinjal reservoir for Greater Mumbai water supply.

As informed by Pinjal river project authorities, water releases from Pinjal dam are only to be made in non-monsoon period, the net yield of Bhugad and Khargihill reservoirs has been computed for an extreme critical demand pattern when entire downstream water supply has to be made during non-monsoon period of 240 days. The regulated annual yield from Bhugad and Khargihill reservoirs at 100% and 100% success rate are obtained.

From simulation study and as per the release pattern trial 1, 2 and 3 given in Table 7.3, it is possible to divert 287 Mm³ and 290 Mm³ at 100% success rate from Bhugad and Khargihill reservoir respectively. The upstream abstractions has already been considered as per actual.

Table 7.3
Release pattern for water supply to Mumbai city

Pattern Trial	Release pattern for water supply (Feb.28 days)	
	Total days of Release	Monthwise Breakup
1.	240	7 th October to 3 rd June
2.	240	11 th October to 7 th June
3.	240	13 th October to 9 th June
4.	240	15 th October to 11 th June
5.	240	17 th October to 13 th June
6.	240	24 th October to 20 th June

Biseasonal working table

The simulation studies for proposed Bhugad and Khargihill reservoirs have been done for a period from 1988 to 2001. The results obtained are attempted by the biseasonal working table for monsoon and non-monsoon period for Bhugad and Khargihill reservoirs for 1901 to 1994 prepared for checking all the upstream and downstream demands. In these tables an attempt has been made to provide water for different uses at different success rates. In simulation studies success rate for all demands were identical for upstream municipal and industrial utilization which forms very small part of the total utilization, 100% success rate has been assigned. The target success rate for upstream hydro-electric power plants, upstream irrigation and water supply to Mumbai city have been kept as 90%, 75%, 95% and 100% respectively. The actual success rate obtained are higher than these. A provision of 91 Mm³ of water from Bhugad reservoir has also been kept for release to the Madhuban reservoir as downstream commitment.

Water conductor system

On examination of the topography and considering the flexibility of operation it has been found that it is possible to connect Bhugad and Khargihill reservoirs and again Khargihill and Pinjal reservoirs by pressure tunnels. These tunnels will connect the reservoirs below their MDDL. The purpose is to make the combined water from Bhugad and Khargihill reservoirs available at Pinjal reservoir, from where further arrangements for carrying the water to Mumbai can be made by Municipal Corporation of Greater Mumbai (MCGM) and Mumbai Metropolitan Regional Development Authority (MMRDA).
Discharge from the tunnel

$$Q = A * V$$

$$V = ((2gD H)/fL)^{0.5}$$

$$A = 3.14/4 * D^2$$

Where $g = 9.81$

$f = 0.01$

$H =$ Head between two reservoir

$L =$ Length between two reservoir

$D =$ Diameter of tunnel

A daily working table for demand pattern of release of water supply as finalized by simulation studies and biseasonal working table for 250 non-monsoon days for second alternative of operation plan has been attempted. As already fixed by simulation studies 287 Mm³ and 290 Mm³ of water from Bhugad and Khargihill reservoirs respectively at 100% dependability will be contributed annually while contribution from Pinjal as per revised studies done by Pinjal River Project Authorities to the tune of 332 Mm³ at 75% dependability considered annually. Hence, for a combined release from pinjal reservoir are to be made only for the non monsoon period of 240 days at the rate of 43.84 cumec per day. The diameter of tunnel in normal situation has been designed to be 5.0 m for Bhugad – Khargihill tunnel and 5.25 m for Khargihill-Pinjal tunnel. The non-monsoon flow in the Bhugad and Khargihill reservoirs has been taken as mean of annual non-monsoon flow plus hydro electric release contribution computed by biseasonal working table.

7.5 Annual losses

a) Evaporation losses in reservoir area

The average monthly evaporation losses in terms of depth observed at Madhuban reservoir have been used for simulation studies of the reservoirs.

b) Seepage in the reservoirs

The Bhugad and Khargihill reservoirs are contained in a valley bounded by steep hills. The rocks are hard, massive and devoid of any major fault or shear zones. The joints are mostly tight and as such poses no problems towards reservoir leakage as per Geological Survey of India, Pune.

7.6 Effect on sub-soil water table

Detailed studies for the above have not been carried out. However, as the reservoirs are situated in hilly terrain, the effect on the sub-soil water table may not be significant.

7.7 Submergence area

The total quantity of 577 Mm³ at 100% dependability would be available annually at these reservoirs for diversion. The total submergence area of these reservoirs is 3461 ha. Submergence area at FRL, consequent on the construction of reservoirs is as furnished in Table-7.4.

Table 7.4
Submergence area at F.R.L.

Unit : ha

Reservoir	Maharashtra			Gujarat	Total
	Peint Taluka	Mokhada Taluka	Jawhar Taluka	Kaprada taluka	
Bhugad	916	--	--	987	1903
Khargihill	351	1031	176	-	1558
Total	1267	1031	176	987	3461

7.8 Land acquisition, property submerged and rehabilitation

a) Extent of land

The submergence particulars of the reservoirs upto their F.R.L. are furnished in the Para 7.7 for acquisition of lands and properties coming under submergence. The acquisition of land has been considered upto M.W.L. of the reservoir.

a) Classification of lands

The details of classification of lands coming under submergence of the reservoirs upto their F.R.L. are furnished in Table 7.5.

Table 7.5
Classification of lands

Unit : ha

Sl. No.	Reservoir	Forest land	Cultivable land	River portion	Total
1.	Bhugad	890	796	217	1903
2.	Khargihill	734	552	272	1558
	Total	1624	1348	489	3461

7.9 Details of property submerged

a) Details of villages, houses and population

The number of villages, houses and population to be affected due to submergence of reservoirs are given in Table 7.6.

Table 7.6
Submergence details of properties

Sl. No.	Reservoir	No. of villages			No. of houses	Population	
		Full	Part	Total		Human	Live stock
1.	Bhuhad	1	13	14	503	3046	2179
2.	Khargihill	0	10	10	220	1484	1270
	Total	1	23	24	723	4530	3449

It can be seen from the above table that a total of 24 villages either fully or partly will get affected. Out of these, the habitation and land will be affected in 11 villages and only land will be affected in the remaining 13 villages. The total number of houses to be affected as a result of submergence in these reservoirs will be 723. A human population of 4530 and live stock of 3449 would also be affected.

b) Roads and cart tracks

Under Bhugad reservoir no metalled road will be affected. Only cart tracks will be affected as described below:

- (i) Cart track from Bhugad to Bharadi via Mohpada, about 7.8 km will be affected.
- (ii) Cart track from Savda to Kharset, about 6.4 km will be affected. No power line, telegraph and telephone lines are located in reservoir area.

Under Khargihill reservoir no major road will be affected. Two kachcha roads will be affected as describe below :

- (i) Behadpada – Brahmanpada road about 3.0 km will be affected.
- (ii) Bejpada – Hatheri road about 4.0 km will be affected. No power line, telegraph or telephone line will come under submergence.

b) Details of valuable mineral deposits/mines

It is indicated that no valuable mineral deposits would be submerged under any of the above reservoirs.

c) Details of historical archaeological monuments

It is also indicated that the submergence area of any of the above reservoirs is not having any historical or archaeological monument.

7.10 Rehabilitation of project displaced persons

In the rehabilitation package worked out for the displaced persons rehabilitation grant and maintenance allowances have been provided as per the norms. More details are furnished in the chapter "Environmental and Ecological aspects of the project."