Chapter – 6
Design Aspects

6.0 Engineering Assessment

As already discussed in the foregoing chapters, the main objective of Wainganga (Gosikhurd) – Nalganga (Purna Tapi) intra state link project is to divert the surplus waters of Wainganga, tributary of Godavari river basin to the water short western Vidarbha for augmentation of irrigation, domestic and industrial needs in Nagpur, Wardha, Yeotmal, Amravati, Akola and Buldhana districts. The project was proposed by the Govt. of Maharashtra as one of the Intra State link projects which was later reviewed considering single link catering the needs of all regions envisaged in the proposal of Govt. of Maharashtra through multiple links. The preparation of Detailed project report was taken up by the NWDA at the request of Govt. of Maharashtra.

6.1 General

Wainganga (Gosikhurd) – Nalganga (Purna Tapi) Intra State Link Project comprises the following components:

i) Head works at existing Gosikhurd reservoir (FRL 245.5 m) across Wainganga river for a peak discharge of 347.2 cumec.

ii) Link canal of length 426.54 km from Gosikhurd reservoir to Nalganga reservoir, comprising of open canal, pipe lines & tunnels

iii) Lifting arrangements through 6 stages of lifting 23.25 m (RD 2.4 to 2.9 km), 23.5 m (RD 20 to 20.9 km), 29.25 m (RD 39.9 to 42.7 km), 28 m (RD 169.6 to 170.4 km), 30 m (RD 176.9 to 178.1 km) and 21.25 m (RD 292.85 to 293.7 km) totaling to 155 m of static lift

iv) Canal falls at two locations at RDs 302.93 km (7 m) and 426.43 km (6 m) to dissipate the available excess head and reduce quantum of filling

v) Pipelines for 25.98 km length in 11reaches viz., RD 27.40 km (1210 m), RD 44 km (553 m), RD 49.65 km (1937 m), RD 60.05 km (9783 m), RD 83.6 km (3485 m), RD 87.7 km (1819 m), RD 93.4 km (3551 m), RD 112.45 (1111 m), RD 257.1 km (500 m), RD 363.88 km (1698 m) and RD 370.48 km (331 m)

vi) Seven tunnels for a cumulative length of 13.826 km located at RD 73.50 km (3317 m), RD 141.45 km (776 m), RD 150.25 km (6489 m), RD 298.98 km (667 m), RD 371.53 km (781 m), RD 406.08 km (948 m) and RD 411.78 km (848 m)

vii) Out fall structures and Head regulators for integration of existing reservoirs of Lower Wardha and Katepurna

viii) Raising of six existing storages to accommodate link waters

ix) Construction of 31 new storages along the link alignment to receive diverted waters

x) 22 nos. of Feeder canals/Direct sluices for integration of 38 existing/ proposed intermittent storages along the alignment

xi) Subsidiary lift arrangements from main link canal to feeder canals at RD 115.45 km (7 m), RD 147.55 km (5 m), RD 150.00 km (10 m), RD 246.30 km (10 m) and RD 377.13 km (8 m)

xii) Cross drainage/cross masonry and regulating works across the link canal (582 Nos.)

xiii) Command area development of about 371277 ha in Nagpur, Wardha, Yeotmal, Amravati, Akola and Buldhana districts

xiv) Canal top solar power generation arrangement at appropriate reaches along the link canal alignment.

xv) Outfall structure at existing Nalganga reservoir on Nalganga river, a tributary of Purna Tapi with FRL 294.44 m

6.2.1 Geology

Geological Investigations are being carried out by Geological Survey of India along the canal and the final report is awaited. The details of the investigation are covered in Chapter - Survey and Investigations.

6.2.2 Seismicity

The link canal takes off from Gosikhurd reservoir and out falls into Nalganga project, utilising existing Lower Wardha and Katepurna reservoirs as balancing reservoirs. Since all the four reservoirs are existing reservoirs and no new dams/reservoirs are proposed for diversion of water through the link canal, no site specific seismic studies are conducted at present. From the general seismology of Vidarbha region, the eastern districts of Bhandara and Nagpur fall in earthquake zone-I, which is considered the safest in India, while the other districts fall in zone-II. Gosikhurd project is located in Bhandara district, Nalganga in Buldhana district, Lower Wardha in Wardha district and Katepurna in Akola district. The enroute storages/tanks are proposed in Nagpur, Wardha, Amravati, Yeotmal, Akola and Buldhana districts. Therefore, the existing as well as proposed storages, which will be part of the link project are in Seismic Zones –I & II which are considered to be not earthquake prone. As such, for the present DPR, no site specific seismic study of the project area has been carried out.

6.2.3 Foundation Treatment:

As per the report on the geological features and sub strata of the major structures and the soil profiles along the canal alignment received from the GSI & CSMRS, it is seen that the hard rock formation is visible at many places and is available in shallow depth. The foundation treatment as would be required shall be assessed during the pre construction stage.

6.3 Head Regulators:

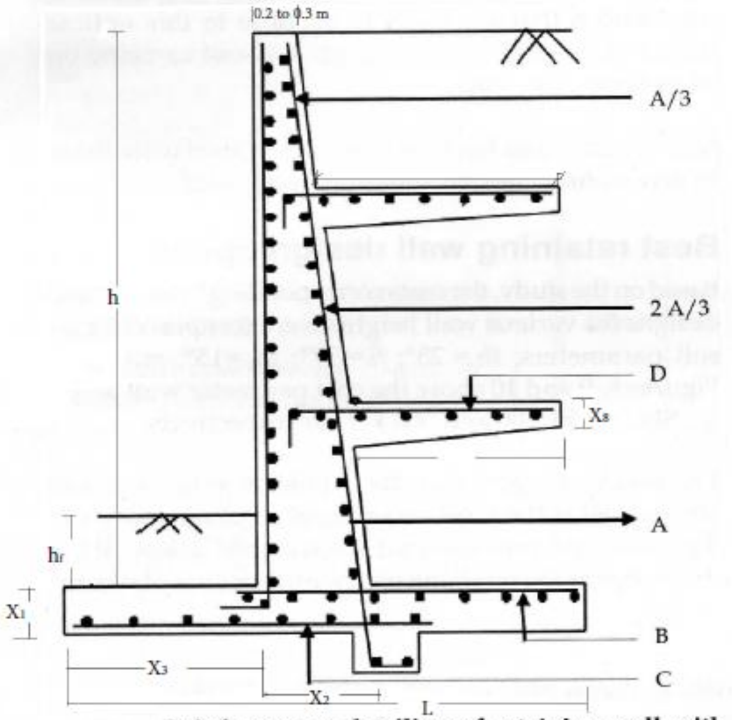
To divert the waters into the link canal from the existing reservoirs suitable head regulators for the control of flow in the canals are proposed. The details of head regulators and flared out walls proposed at existing Gosikhurd, Lower Wardha, and Katepurna reservoirs are described in the following paragraphs.

6.3.1 Head Regulator at Gosikhurd Dam

The proposed head regulator is located on the foreshore of reservoir near village Rajoli. The FRL and MDDL of Gosikhurd reservoir are 245.5 m and 241.29 respectively. The canal FSL is considered in such a way that even it can draw water just above MDDL of reservoir. The offtake FSL of canal is assumed to be 241.0 m so as to draw water just above MDDL. The drawl of water to the link project entirely depends on the reservoir operation policy. The canal from the head regulator to pumping station at RD 2.4 km is in cutting and hence the increase in FSL upto 243.0 m in future can be effected at later stage which may reduce the static delivery head to that extent at pumping station at RD 2.4 km.

The Head regulator with 6 bays, 5.5 m wide each is proposed. The piers will be in RCC of 1.5 m thick. The abutment foundation lies over the hard rock strata. In case, the hard strata are available above the crest level of the regulators, the base of abutment is proposed above the crest level. A RCC wall of 0.3 m thick is proposed below the abutment base upto crest to provide smooth surface which will be anchored with the hard rock.

The return/wing walls of the regulators are proposed with RCC cantilever type. If the height of the soil to be supported is more than 6.0 m, the RCC stem is provided with 2 relieving platforms. In case of excessive depth of soil, the soil pressure can be reduced using relieving platform, so as to provide an economical light weight design. The relieving platform make the pressure diagram discontinuous at the level of platform. Also, relieving platform carries the weight of soil above it and any surcharge loading, transferring them as relieving moment to the vertical stem. The relieving platforms are designed such that they intersect the plane of rupture from the soil above and behind the platforms preventing any load from the soil to act on the wall. **The optimal design of reinforced concrete retaining walls published in the Indian Concrete Journal, April 2012 authored by Dr. Devdas Menon, Professor, IIT, Madras and co-authored by Miss. Shravya Donkada, IIT Madras,** has been made use for dimensioning of return/ wing walls. The typical section of RCC retaining wall with relieving platforms is shown below:



Reinforcement detailing of retaining wall with relieving platforms. (A, B, C and D are area of reinforcement in mm²/m)

Identical vertical lift type fixed wheel service gate in each bay for opening size of 5.5 m wide x 9.0 m high, are proposed to control the discharge into canal. Sill level / Crest level of gate is EL 236.5 m. The gate shall be designed for water head corresponding to FRL of 245.50 m. These gates will be operated by means of rope drum hoist of 24 t capacity (tentative) mounted on steel bridge supported on trestles above top of pier EL 248.21 m. The general installation of Head Regulator Service Gate is at **Plate No: 6.1.** The Hydraulic design details of Head Regulator and Service Gate are at **Annexure: 6.1**

One set of wheel type stop logs of size 5.5 m x 9.2 m (over all height) (consisting of 5 units of 1.84 m high each) is proposed. The units of stop logs shall be interchangeable. These units shall be designed for maximum water head corresponding to MWL of EL 245.70 m (sill EL 236.50 m). Stop log units are provided with u/s skin plate and u/s sealing arrangement with music note type Teflon cladded side seal and wedge type rubber seal at the bottom. The stop log units shall be lowered and lifted by means of a monorail crane of 24 t capacity (tentative), with automatic engaging/disengaging device. The total weight of stop log gate is 15.2 t.

6.3.2 Head Regulator at Lower Wardha Dam:

The proposed head regulator is located on the foreshore of reservoir near village Piplakhunta. The FRL and MDDL of Lower Wardha reservoir is 283.80 m and 277.20 m respectively. The canal FSL is considered in such a way even that it can draw at 281.50 m of reservoir. The Head regulator with 4 bays, 5.0 m wide each is proposed. The piers will be RCC of 1.5 m thick. The abutment foundation lies over the hard rock strata. In case, the hard strata are available above the crest level of the regulators, the base of abutment is proposed above the crest level. A RCC wall of 0.3 m thick is proposed below the abutment base upto crest to provide smooth surface which will be anchored with the hard rock. The return/wing walls of the regulators are proposed with RCC cantilever type. If the height of the soil to be supported is more than 6.0 m, the RCC stem is provided with 2 relieving platforms.

Identical vertical lift type fixed wheel service gate in each bay for opening size of 5 m wide x 5.3 m high, are proposed to control the discharge in canals. Sill level / Crest level of gate is EL 278.5 m. The gate shall be designed for water head corresponding to FRL of 283.80 m. These gates will be operated by means of rope drum hoist of 11 t capacity (tentative) mounted on steel bridge supported on trestles above top of pier EL 286.75 m.

One set of wheel type stop logs of size 5.0 m x 6.0 m (over all height) (consisting of 4 units of 1.50 m high each) is proposed. The units of stop logs shall be interchangeable. These units shall be designed for maximum water head corresponding to MWL of EL 284.50 m (sill EL 278.50 m). Stop log units are provided with u/s skin plate and u/s sealing arrangement with music note type Teflon cladded side seal and wedge type rubber seal at the bottom. The stop log units shall be lowered and lifted by means of a monorail crane of 11 t capacity (tentative), with automatic engaging/disengaging device. The total weight of stop log gate is 6.8 t. The design of head regulator at Lower Wardha reservoir is furnished at **Appendix Volume of Design and Cost estimate.**

6.3.3 Head Regulator at Katepurna Dam:

The proposed head regulator is located on the foreshore of reservoir close to left end of dam axis. The FRL and MDDL of Katepurna reservoir is 347.77 m and 337.41 m respectively. The canal FSL is considered in such a way that even it can draw at 343.30 m of reservoir. The Head regulator with 2 bays, 4.25 m wide each is proposed. The piers will be RCC of 2.0 m thick. The abutment foundation lies over the hard rock strata. In case, the hard strata are available above the crest level of the regulators, the base of abutment is proposed above the crest level. A RCC wall of 0.3 m thick is proposed below the abutment base upto crest to provide smooth surface which will be anchored with the hard rock. The return/wing walls of the regulators are proposed with RCC cantilever type. If the height of the soil to be supported is more than 6.0 m, the RCC stem is provided with 2 relieving platforms.

Identical vertical lift type fixed wheel service gate in each bay for opening size of 4.25 m wide x 7.8 m high, are proposed to control the discharge in canals. Sill level / Crest level of gate is EL 340.00 m. The gate shall be designed for water head corresponding to FRL of 347.77 m. These gates will be operated by means of rope drum hoist of 14 t capacity (tentative) mounted on steel bridge supported on trestles above top of pier EL 350.63 m.

One set of wheel type stop logs of size 4.25 m x 8.69 m (over all height) (consisting of 5 units of 1.74 m high each) is proposed. The units of stop logs shall be interchangeable. These units shall be designed for maximum water head corresponding to MWL of EL 348.69 m (sill EL 340.0 m). Each stop log unit is provided with u/s skin plate and u/s sealing arrangement with music note type Teflon cladded side seal and wedge type rubber seal at the bottom. The stop log units shall be lowered and lifted by means of a monorail crane of 14 t capacity (tentative), with automatic engaging/disengaging device. The total weight of stop log gate is 9.2 t. The design of head regulator at Katepurna reservoir is furnished at **Appendix Volume of Design and Cost estimate.** The salient features of all the three head regulators are given are shown in **Table 6.1:**

Table 6.1
Salient features of head regulators

Sl. No	Details	HR at Gosikhurd	HR at Lower Wardha	HR at Katepurna
1	FRL (m)	245.50	283.80	347.77
2	Water drawn level (m)	241.30	281.50	343.30
3	Crest level(m)	236.50	278.50	340.00
4	No. of bays	6	4	2
5	Width of bays(m)	5.5	5.0	4.25

6	Length of regulator(m)	40.5	24.5	10.5
7	U/S floor level (m)	236.0	278.0	339.50
8	D/S floor level (m)	233.50	274.00	336.00
9	Crest width (m)	3.0	3.0	3.0
10	U/S floor			
(i)	length (m)	10.0	10.0	10.0
(ii)	Glacis (m)	1.0	1.0	1.0
(iii)	Cutoff pile level	233.0	274.00	336.50
11	D/S floor			
(i)	D/S horizontal	23.0	16.0	19.0
(ii)	Glacis	9.0	13.50	12.0
(iii)	Ramp	1.5	1.50	2.8
(iv)	D/S cutoff pile level	228.00	268.80	331.0
12	Top of operating platform	248.21	286.75	350.63
13	Top of road level	245.02	284.52	347.97
14	Abutment foundation level	242.62	282.75	344.97
15	Top of abutment width	1.0	1.0	1.0
16	Bottom width of abutment	3.15	2.58	3.18
17	Pier width at top	1.50	1.5	2.0
18	Pier foundation level	233.50	274.0	336.0
19	U/S wingwall			
(i)	Length	10.25	10.0	10.68
(ii)	Top width	0.3	0.3	0.3
(iii)	Bottom width (Base slab)	2.37	1.93	1.81
(iv)	Foundation level	243.12	283.25	345.47
20	D/S wingwall			
(i)	Length	26.0	19.0	22.0
(ii)	Top width	0.3	0.3	0.3
(iii)	Bottom width (Base slab)	1.50	1.20	1.81
(iv)	Foundation level	243.12	283.25	345.47

6.4 Pump Houses:

As stated earlier the link canal starts from Gosikhurd reservoir on Wainganga river at FSL 241.0 m and out fall into Nalganga reservoir at an FSL of about 310.0 m. Water is to be lifted from elevation of 241.0 m to 348 m (Katepurna reservoir) besides accounting the head losses for transiting the water through the canal. 6 pump houses have been identified along the canal alignment to pump the water where the topographical conditions are suitable for the location of pump houses. In addition, 5 more pump houses have been identified along the canal to pump the water to the feeder canals as the offtake level of feeder canal are above the canal FSL. The static head of the pump houses ranges from 21.25 m to 30.0 m for main canal whereas the it is in the range of 5.0 to 10.0 m for feeder canal. The canal capacity at the offtake is 347.2 cumec and as such the high-volume pumps are considered.

Surface pump House has been provided to house number of Vertical turbine pumps. The structure comprises of RCC columns and beams designed to carry the loads coming from various electro-mechanical equipment. A steel roof truss has been provided at top of the pump house. The location of surface pump house has been selected by studying the contour details available. However, the location of pump house, type of pumps, electrical and mechanical equipment's will be studied in detail during the pre-construction stage. The preliminary details of pumping components are given below:

6.4.1 Sump/Intake Well:

The basic arrangement of sump depends upon the type of intake. The bellmouth intakes are preferred for smooth flow. The bellmouth diameter is in the ratio between 1.5 to 1.8 of pump inlet dia. The minimum distance between bellmouth and wall should be 0.25 D, where D is dia. of bellmouth. For a horizontal intake, the corner fillets are omitted. The bell mouth may be omitted over part of its circumference thus allowing the intake to be set with its center line ½ d above the sump floor. The mean velocity to be maintained at pump inlet, bell mouth should be 4.0 m/sec and 1.3 m/sec respectively. The minimum water level to avoid cavitation should be 1.0 D above the top of the bellmouth. For a given depth of water, above highest point of intake bell mouth, a horizontal intake in the end wall gives slightly better flow conditions than the vertical intake. However, a vertical intake gives a lower minimum operating depth than the horizontal intake. As the quantum of water to be lifted is huge, it is proposed to adopt the concrete volute pumps and the horizontal intake is preferred over vertical intake.

The multiple pumps are to be used to lift water. Thus, the multiple sump which include the approach to the sump is considered. The problem of providing steady and uniform flow to a multiple sump is more difficult. In majority of applications, the intakes must function satisfactorily with all possible combination of pumps in operation. The multiple sumps are categorized into two. They are (i) unitized sump and (ii) open sump. In unitized sumps, each intake is separated by the divide walls thus making independent and uniform flow to the intake. As in case of open sump, it may require the baffles or splitters or a grid to distribute the flow evenly to all the sumps. The choice of minimum submergence of a sump is a critical one from design perspective as it defines the lowest point of the pumping station.

The sump is provided with RCC retaining walls of suitable size to retain the earth pressure. In case the sump is in hard rock strata, the RCC wall of 0.5 m uniform thickness is anchored with the sides. The retaining walls are proposed with RCC cantilever type. If the height of the soil to be supported is more than 6.0 m, the RCC stem is provided with 2 relieving platforms. The width of the sump is taken at 1 to 2.0 times of the dia. of the bellmouth. Plain cement concrete of mix M10 1:4:8 of about 0.2 m thick is proposed for the floor of the bed.

6.4.2 Pumps

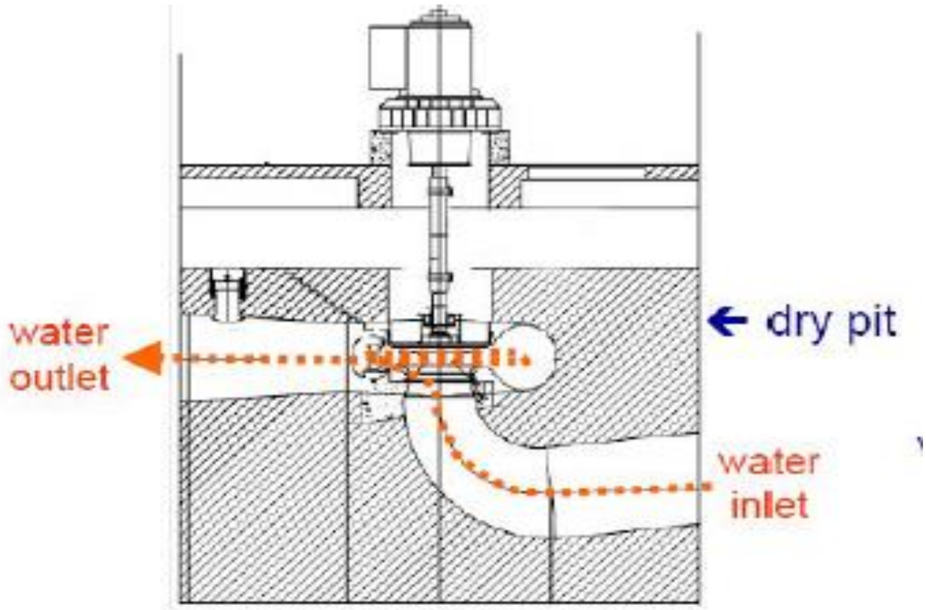
(a) Concrete Volute pumps:

It is proposed to install Concrete Volute pumps with a capacity of 10 to 20 cumec discharge for the pump houses. The concrete volute pumps are considered for the following reasons:

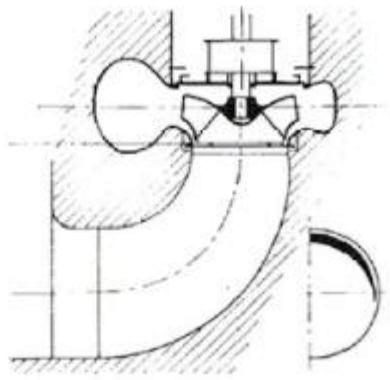
(i) Casing and Suction Draft Tube is cast in-situ Concrete.
(ii) The rotating parts are metallic.
(iii) Simple mechanical design.
(iv) Pumps are expected to run continuously for prolonged times.
(v) Concrete Volute Pump guarantees strength and rigidity and virtually eliminates the problems of corrosion and erosion.
(vi) Higher & consistent pump efficiencies over a sustained period of operation.
(vii) As the size of the pump increases, the dimension and weights of the heaviest parts have a large influence on the choice of construction material used. Concrete is therefore, the natural choice for the pump body.
(viii) Mass casing in concrete provides excellent inertia anti seismic construction, simple preventive maintenance on yearly schedule.

(ix) Main pump parts can be checked is-situ and without pump dewatering.
(x) Few moving and metallic parts in contact with water.
(xi) Perfect Hydraulic design of Draft Tube and Volute eliminates Vortices and risks of concrete deterioration and low submergence required.
(xii) Lower crane height & lifting capacity requirement.
(xiii) Easy internal inspection without dismantling. Impeller can be examined from suction elbow and Rotor from manhole.
(xiv) Overall expenditures for the complete pumping system are substantially lower.
(xv) No pump casing, therefore total weight of removable components is a small fraction of that of conventional units.
(xvi) No anchoring necessary.
(xvii) Low Maintenance equipment and less manpower required. Fewer spare parts to be kept handy
(xviii) Simple to construct Volute and Draft tube, can be carried out by Civil Construction Company at site.

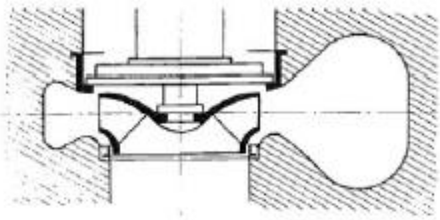
Concrete Volute Pump Construction can be grouped into three major sections viz. (i) Concrete Volute Casing and Draft Tube, (ii) Grouted Embedded Components and (iii) Rotating Assembly.



The typical section of pumping arrangement



The typical section of suction pipe (Draft tube)



The typical shape of volute

Concrete volute pump under construction

6.4.3 Electro Mechanical Equipments:

The electro mechanical components consist of Pump Turbine, Motor, cooling system, transformer connections, Inlet Valve, Surge Protection & Neutral Earthing System, Supervisory Control and Data Acquisition System, Pipe Valves, Main Step-up Transformer, Switchyard Equipment, Control & Protection Equipment, Auxiliary Mechanical Services, EOT Crane for Pump house, Electrical lifts and elevators, Workshop equipment, Test Laboratory, Telemetry, Ventilation & air conditioning, Fire protection, Auxiliary Electrical services etc.

6.4.4 Delivery Main

The mild steel rising mains of 3.0 m dia. has been provided. The delivery pipes of 2 pumps are joined together outside the pump house and connected with rising main which outfalls into delivery cistern. Hazen Williams equation $V = K\ C\ (D/4)^{0.63}\ S^{0.54}$ has been considered to work out the frictional loss of the pipe, where K, unit conversion factor as 0.85, C Hazen William co efficient as 145 was adopted. D is dia. of pipe and S is head loss/ length of pipe. The thickness of pipe to withstand the pressure is computed considering 50 % above the working pressure. Extra thickness of 1 to 3 mm for corrosion is also considered. As epoxy painting is considered inside and outside the pipe, the provision for corrosion is limited to 1 mm.

The velocity in the pipes are almost limited to less than 3.0 m/sec. The pipelines are partly buried and partly exposed. The PCC for bedding and RCC of about 1 m height surrounding the pipe is also provided for anchoring and supporting the pipeline. The provision for expansion joint, pressure relief valves, air relief valves and water draining arrangement also provided. The pipelines shall pass over beams supported by piers wherever it crosses nalas / rivers.

6.4.5 Delivery Cistern

The rising main from the pump house is let into outfall in the delivery cistern. The rising main is kept such a way that it is above the delivery cistern pond level so that the water from the cistern is not entered into the pipeline. The delivery cistern is of rectangular size with transition to connect with the canal. The delivery cistern is provided with RCC retaining walls of suitable size to retain the earth pressure. In case the cistern is in hard rock strata, the RCC wall of 0.3 m uniform thickness is anchored with the sides. If the height of the soil to be supported is more than 6.0 m, the RCC retaining wall stem is provided with 2 relieving platforms. The width of the pond is taken at 2.0 times of the dia. of the pipe. The top of cistern is taken 1 m above center line of pipe. The floor of the cistern is kept 0.5 m below the canal bed. Plain cement concrete of mix M10 1:4:8 of about 0.2 m thick is proposed.

The typical design of pump, pipelines, sump and delivery chambers designed at RD 2.4 km is shown at **Annexure: 6.2** and depicted at **Plate No: 6.2.** The design of pump, pipelines, sump and delivery chambers located at other places are furnished at **Appendix volume of Design and Cost estimate**. The salient features of all pumping schemes are shown in **Table 6.2 & 6.3.**

Table 6.2
Salient features of pumping schemes for the main canal

Sl. No	Description	Location of pump house RD in Km					
		2.4	20.0	39.9	169.6	176.9	292.85
1	NSL (m)	259.62	274.71	308.24	296.80	316.38	341.39
2	FSL (m)	240.87	262.70	283.47	280.89	308.33	327.38
3	Canal disc (Cumec)	347.2	347.2	323.7	192.50	192.50	114.30
4	Canal FSD (m)	6.5	6.0	6.5	6.0	6.0	5.25
5	Canal bed width (m)	38.0	38.0	35.25	23.5	23.5	17.0
6	Static delivery head (m)	23.12	27.19	31.72	30.89	33.33	23.63
7	Installed capacity (MW)	148.2	152.0	187.2	92.0	100.0	43.2
8	No. of pumps	38	38	36	20	20	12
9	Type of pump	Concrete Volute pumps with vertical turbine					
10	Dia. of inlet (m)	1.8					
11	Dia. of delivery pipe (m)	2.25					
12	Bellmouth size (m)	2.85 height x 2.7 width					
13	Rising main dia. (m)	3.0					
14	Rising main length (m)	216	616	2516	610	1010	705

15	No. of rising mains	19	19	18	10	10	6
16	Thickness of main (mm)	10	10	12	10	12	10
17	**Intake well**						
(i)	Width (m)	281	281	266	147	147	88
(ii)	Length rect. sump (m)						45
(iii)	Transition length (m)	121	121	115	62	62	35
(iv)	Floor level (m)	230.3	252.1	272.9	270.3	297.8	316.8
(v)	Type	Unitized					
18	**Pump house**						
(i)	Length (m)	289	289	274	155	155	96
(ii)	Width (m)	16					
19	**Delivery cistern**						
(i)	Width (m)	114	114	108	60	60	36
(ii)	Length rect. sump (m)	30					
(iii)	Transition length	76	76	73	37	37	19
(iv)	Floor level	256.6	279.19	305.1	301.89	331.23	341.28

Table 6.3
Salient features of pumping schemes for the feeder canal

Sl. No	Description	Location of pump house RD in Km				
		115.45	147.55	150.0	246.30	377.13
1	NSL (m)	291.44	285.23	299.57	344.53	331.0
2	FSL (m)	290.66	287.51	286.91	332.39	324.26
3	Canal disc (Cumec)	7.5	8.5	26.9	13.5	21.3
4	Canal FSD (m)	1.75	1.75	2.75	2.25	2.5
5	Canal bed width (m)	3.75	4.0	6.0	4.0	5.75
6	Static delivery head (m)	7.0	5.0	10.0	10.0	8.0
7	Installed capacity (MW)	1.2	0.8	4.4	2.4	3.2
8	No. of pumps	4	4	4	4	4
9	Type of pump	Pumps with vertical turbine				
10	Dia. of inlet (m)	1.0	1.0	1.6	1.30	1.45
11	Dia. of delivery pipe (m)	1.5	1.5	2.5	2.0	2.25

12	Bellmouth size (m)	1.5 x 1.27	1.5 x 1.27	2.50 x 2.16	1.95 x 1.59	2.18 x 1.75
13	Rising main dia. (m)	1.5	1.5	2.5	2.0	2.25
14	Rising main length (m)	100	50	100	100	100
15	No. of rising mains	2	2	2	2	2
16	Thickness of main (mm)	6.0	6.0	6.0	6.0	6.0
17	**Intake well**					
(i)	Width (m)	18.0	18.0	26.0	22.0	24.0
(ii)	Length rect. sump (m)	25.0	25.0	26.0	32.0	24.0
(iii)	Transition length (m)	7.0	7.0	10.0	9.0	9.0
(iv)	Floor level (m)	285.30	282.2	279.1	326.6	317.5
(v)	Type	Unitized				
18	**Pump house**					
(i)	Length (m)	23.0	23.0	39.0	28.0	31.0
(ii)	Width (m)	9.0	9.0	14.0	11.0	13.0
19	**Delivery cistern**					
(i)	Width (m)	6.0	6.0	25.0	8.0	9.0.
(ii)	Length rect. sump (m)	15.0	15.0	25.0	20.0	22.5
(iii)	Transition length	2.25	2.0	4.0	4.0	3.25
(iv)	Floor level	293.0	288.0	291.5	337.25	326.88

6.5 Design Aspects of Link Canal

In planning and design of canal system of link project, the open canal, tunnels and pipe line systems are studied to minimise the land acquisition, deep cutting and high embankment for canal construction. The pipe line system though costly, is considered due to the topographical constraints and developmental activities enroute. The pipelines and other alternatives to minimize the high embankment reaches shall be duly studied during the pre-construction stage. The proposed link canal project consists of three main reaches. They are:

i) Canal off-taking from Gosikhurd reservoir and terminating in Lower Wardha reservoir (0 -167.90 km)

ii) Canal off-taking from Lower Wardha reservoir and terminating in Katepurna reservoir (167.90 - 298.63 km)
iii) Canal off-taking from Katepurna reservoir and terminating in Nalganga reservoir (298.63 - 426.54 km)

6.5.1 Canal Alignment

The alignment of the proposed link canal finalized based on field surveys has been marked on toposheets. Canal was aligned as contour canal. The canal off takes with FSL of 241.0 m from Head Regulator at Gosikhurd reservoir and outfalls into Nalganga reservoir at FSL 310.53 m. Enroute, the link canal also outfalls and offtakes from the existing reservoirs namely Lower Wardha and Katepurna. The natural surface level (NSL) of the canal alignment between Gosikhurd reservoir to Katepurna reservoir is obtained from the field topographical surveys whereas the same between Katepurna to Nalganga was obtained from the DEM of NRSA which needs to be verified on ground. The details of topographical surveys conducted are briefed in the Chapter 4 : ‘Surveys & Investigations’.

The bed slope of the canal from Gosikhurd reservoir to Katepurna reservoir (0 to RD 298.63 km) will be 1 in 20,000 where as from Katepurna reservoir to tail end reservoir (Nalganga) it is kept as 1 in 20000 and 1 in 10000. The bed slope of 1 in 10,000 considered in tail end reach at PFR stage, involved deep cutting for almost entire length and thus, a flatter slope of 1 in 20000 is considered upto RD 377.13 to minimize the cutting volume.

The link canal crosses the ridges between various basins and sub-basins enroute, where deep cuts are involved as well as many rivers / streams requiring construction of cross drainage works. Seven tunnels are proposed to avoid circuitous route and deep cutting. Eleven pipelines are proposed to avoid circuitous route and high embankment.

In the present alignment, the reduced distance has been measured from turning point to turning point for design and cost estimation purposes. However, during construction, the alignment will be provided with straight lines and circular curves as per Clause 6.4 of IS code 5968: ‘Guidelines for planning and layout of canal system’. The range of radius shall be as given in **Table:6.4.**

Table 6.4.
Radii of curves for canal

Discharge (m^3/s)	Radius, Min(m)
280 and above	900
Between 280 to 200	750
Between 200 to 140	600
Between 140 to 70	450
Between 70 to 40	300
Between 40 to 10	200
Between 10 to 3	150
Between 3 to 0.3	100
Less than 0.3	50

The alignment has been marked on the strip survey contour sheet for every 2.5 km along with the corresponding longitudinal section. Total 173 Nos. of sheets for canal alignment have been prepared. The sheets containing the L.S. and strip contour maps of link canal have been depicted at **Plates 4.5.1 to 4.5.173.** The canal alignment is measured at 50 m interval. The NSL at 50 m interval and at structures with corresponding Full Supply Depth (FSD) of the canal in the three reaches are furnished as head loss statement and shown at **Annexure: 6.3.1 to 6.3.3.**

6.5.2 Canal Capacity

The 426.54 km long link canal, off takes from Gosikhurd reservoir with the FSL of 241.0 m. In the initial reaches starting from Gosikhurd reservoir, the canal has a carrying capacity of 347.2 cumec. As the canal moves west and south west wards, it releases water at various locations to feed the various existing/proposed reservoirs. Thus, the capacity of canal decreases at the respective RDs where the feeder canals/direct sluices are proposed. 18 feeder canals and 4 direct sluices have been proposed along the canal. The cutoff statement of the canal considering the water requirement of feeder canal and direct sluices and transmission losses enroute is prepared and is shown in Annexure: 6.4. The canal carrying capacity at different reaches are given in **Table: 6.5**

Table 6.5
Canal carrying capacity

Sl.no	Reservoirs	Details	Canal FSL (m)	Reach	Canal capacity (cumec)
1	Gosikhurd	offtake	241.00	Initial reach	347.20
2	Lower Wardha	outfall	284.38		211.30
3	Lower Wardha	offtake	281.00	Middle reach	192.50
4	Katepurna	outfall	348.30		96.70
5	Katepurna	offtake	342.80	Tail end reach	76.70
6	Nalganga	outfall	310.53		10.70

6.5.3 Hydraulic Designs

As the length of the canal proceeds from the off taking point at Gosikhurd reservoir, it releases water at various locations to feed enroute proposed/ existing reservoirs and hence the section of the canal needs to be changed. However, it is not practical to change the section of the canal at each and every off-take point. Thus the canal is divided into suitable reaches and canal sections are designed to carry the required discharges in the particular reaches.

6.5.3.1 Link Canal / Open canal:

The shape of the canal has been selected as trapezoidal with rounded corners as per provisions of IS code: 10430. The fluming of canal is also considered by increasing the canal FSD by 0.5 m wherever the deep cut reaches are encountered on hard /weathered rock strata. The FSD of 6.0 m has been kept constant with gradually reduced bed width for the reach between Gosikhurd and Lower Wardha reservoirs. However, in other reaches both bed width and FSD decrease from head to tail so that intended flow velocity is generated. To prevent losses and to reduce the required section of canal, plain cement concrete lining is proposed throughout the canal reaches of link project.

The canal section is designed using Manning's formula. As the available head for the main canal was inadequate, effort was made to make the canal section as hydraulically efficient as possible. Therefore, trapezoidal lined canal with rounded corners was provided to improve hydraulic radius of section. The side slope of 1.5:1 (H: V) on soil portion, 1:1 on weathered rock portion and 0.5: 1 on hard rock portion have been assumed for design of canal section. Outer side slope in embankment is considered as 2: 1(H: V). Berms of 2.0 m wide on each side wherever, the height of embankment exceeds 6.0 m is provided. In hard rock and weathered rock portions, the berms are provided at the top of rock level on inner side of cutting. Longitudinal slopes for canal were provided between 1 in 20,000 to 1 in 10000, duly considering the deciding factors like topography, available head between various reaches and expected head losses due to canal and various cross drainage structures along the length of canal in finalizing the slopes.

Velocity to be adopted depends upon the type of lining and maximum / minimum permissible velocities for the section. Due to restraint of available head, steeper slopes to provide higher velocities near to permissible velocity in cement concrete lining and thereby availing the benefit of cement concrete lining could not be made. The hydraulic particulars of link are given in the **Table 6.6.**

Hydraulic parameters:

Area of Cross section (A)	$= bd+d^2 (\theta + \cot\theta)$
Manning's formula (V)	$= (1 / n)\ R^{2/3}\ S^{1/2}$
Rugosity Coefficient (n)	= 0.018
Bed slope (s)	= 1 :20000 (0.00 km to 377.13 km)
	= 1 :10000 (RD 377.13 km to 426.54 km)
Side slope of canal:	
Soil section	= 1.5 :1
Weathered Rock	= 1: 1
Hard rock	= 0.5: 1
Wetted perimeter P	$= b+2d (\theta + \cot\theta)$
Radians for curve: θ	
Soil section	= 0.588
Weathered rock	= 0.7854
Hard rock	= 1.107

Table 6.6
Hydraulic particulars of canal at various reaches

Reach (km)		Design discharge (cumec)	Bed width (m)	FSD (m)	Area (sq.m)	Wetted perimeter (m)	Velocity (m/sec)	Actual discharge (cumec)
From	To							
On soil section								
0.00	25.00	347.20	39.25	6.00	310.70	64.30	1.12	348.00
25.00	42.70	323.70	36.15	6.00	292.10	61.20	1.11	324.20
42.70	112.50	289.40	31.35	6.00	263.30	56.40	1.10	289.60
112.50	147.55	259.80	27.60	6.00	240.80	52.70	1.08	260.10
147.55	150.00	238.10	24.60	6.00	222.80	49.70	1.07	238.40
150.00	167.90	211.30	21.00	6.00	201.20	46.10	1.05	211.30
167.90	195.45	192.50	20.85	5.75	188.90	44.90	1.02	192.70
195.45	214.30	169.30	19.60	5.50	171.00	42.60	0.99	169.30
214.30	237.55	140.80	17.30	5.25	148.40	39.20	0.95	141.00
237.55	293.32	114.30	14.75	5.00	126.00	35.60	0.91	114.70
293.32	298.63	96.70	13.30	4.75	110.30	33.10	0.88	97.10
298.63	303.32	76.70	11.25	4.50	92.90	30.00	0.83	77.10
303.32	321.32	48.10	7.75	4.00	64.40	24.50	0.75	48.30
321.32	377.13	38.20	7.50	3.60	54.10	22.50	0.71	38.40
377.13	426.54	10.70	3.75	2.00	15.90	12.10	0.67	10.70
On weathered Rock section								
0.00	25.00	347.20	34.00	6.50	296.40	57.20	1.18	349.80
25.00	42.70	323.70	31.10	6.50	277.60	54.30	1.17	324.80
42.70	112.50	289.40	27.15	6.50	251.90	50.40	1.15	289.70
112.50	147.55	259.80	23.80	6.50	230.10	47.00	1.13	260.00
147.55	150.00	238.10	21.10	6.50	212.60	44.30	1.12	238.10
150.00	167.90	211.30	18.00	6.50	192.40	41.20	1.10	211.60
167.90	195.45	192.50	19.60	6.00	181.90	41.00	1.06	192.80
195.45	214.30	169.30	16.50	6.00	163.30	37.90	1.04	169.80
214.30	237.55	140.80	16.10	5.50	142.60	35.70	0.99	141.20
237.55	293.32	114.30	13.60	5.25	120.60	32.30	0.95	114.60
293.32	298.63	96.70	12.35	5.00	106.40	30.20	0.91	96.80
298.63	303.32	76.70	10.25	4.75	89.00	27.20	0.87	77.40
303.32	321.32	48.10	7.00	4.25	62.00	22.20	0.78	48.40
321.32	377.13	38.20	6.00	4.00	52.60	20.30	0.74	38.90
377.13	426.54	10.70	4.30	2.00	15.70	11.40	0.69	10.80
On hard rock section								
0.00	25.00	347.20	38.00	6.50	292.90	55.70	1.19	348.60
25.00	42.70	323.70	35.25	6.50	275.00	53.00	1.18	324.50

42.70	112.50	289.40	31.35	6.50	249.60	49.10	1.16	289.50
112.50	147.55	259.80	27.80	6.50	226.60	45.50	1.15	260.60
147.55	150.00	238.10	25.40	6.50	211.00	43.10	1.13	238.40
150.00	167.90	211.30	22.25	6.50	190.50	40.00	1.11	211.50
167.90	195.45	192.50	23.50	6.00	180.10	39.90	1.07	192.70
195.45	214.30	169.30	20.40	6.00	161.50	36.80	1.05	169.60
214.30	237.55	140.80	19.65	5.50	140.90	34.60	1.00	140.90
237.55	293.32	114.30	17.00	5.25	119.20	31.30	0.96	114.40
293.32	298.63	96.70	15.60	5.00	105.10	29.20	0.92	96.70
298.63	303.32	76.70	13.25	4.75	87.40	26.20	0.88	76.90
303.32	321.32	48.10	9.80	4.25	61.30	21.40	0.79	48.40
321.32	377.13	38.20	8.50	4.00	51.40	19.40	0.75	38.60
377.13	426.54	10.70	5.60	2.00	15.50	11.10	0.69	10.70

Typical Canal sections at different reaches of Main Canal are shown at **Plate Nos. 6.3.1 & 6.3.2.** The typical canal sections in deep cutting and high embankment are shown at **Plate No. 6.3.3 & 6.3.4.**

6.5.3.2 Tunnels:

The tunnels are designed as modified Horse type, free flow in nature and concrete lined. The alignment of the link tunnels and construction adits have been finalized on the basis of strip contour maps and depth of cutting.

The hydraulic designs of the link tunnels have been carried out for conveying actual discharge available at that location. The slope of the link tunnel is considered between 1 in 5000 to 1 in 2700 depending upon the canal discharge. Flatter slope is adopted for higher discharge. The value of Manning's coefficient adopted is 0.014 for the concrete lined tunnel. The tunnels generally are short in nature as such adits are not provided. However, the tunnel at RD 150.25 km is about 6.5 km long for which 1 adit is proposed.

The link tunnels are provided with plain cement concrete lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The lining shall be of RCC at junctions with shafts, very poor rock strata and any other specified reaches identified during construction. The lining has been designed to resist the external and internal water pressure. The entire rock load is assumed to be carried by the rock support system consisting of rock bolts, steel fibre reinforced shotcrete (SFRS) and steel ribs. The link tunnels are proposed to be excavated by conventional drill and blast method (DBM).

The rock support system may need appropriate modifications depending upon the actual rock mass encountered. Also, the design of rock support system is not meant for shear zones, weak zones, cavities and very low cover zones at junctions with adits /vertical shafts, etc. of the tunnel and the design in these zones requires special consideration. Further, the design of the tunnel is valid for full face excavation of tunneling with conventional drill and blast method (DBM).

A typical scheme of contact and consolidation grouting has been proposed. The contact grouting in the tunnels is proposed to fully pack up the space between the concrete lining and the rock surface caused by shrinkage of concrete lining. The consolidation grouting is proposed to fill up the joints and discontinuity in the rock upto a desired depth.

The following assumptions have been considered for the hydraulic designs of link tunnels:

a. The minor losses occurring in the tunnel e.g. entrance losses, trash rack loss, transition loss, exit loss; bend losses etc. are of negligible amount in comparison to the friction losses occurring in the tunnels and therefore not taken into consideration.

b. The flow through the tunnel is free flow and is driven by the head difference between the upper and lower FSL.

c. The tunnels are designed for free flow conditions and waters are regulated at Head regulators. As such, gates are not considered.

d. The maximum velocity in circular tunnels occurs when the depth of flow is 0.94 times of diameter. In this tunnel designs also, the depth of flow for maximum velocity is considered at 0.94 times of the dia. of tunnel.

e. The tunnel lining (PCC M25) is considered as 6 cm per m dia. of tunnel subject to minimum of 30 cm for good rocks.

(i) Tunnel at RD 73.5 km:

The designed discharge of the canal is 289.40 cumec, however, the tunnel is designed for 286.6 cumec capacity considering the upstream release of water. The tunnel diameter is 12.34 m. The tunnel length is 3317 m including the transitions. The slope of the tunnel is 1 in 5000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The hydraulic design of tunnel and support system are furnished at **Annexure: 6.5**. The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII). The typical excavation and rock support system, concrete lining and grouting details are shown at **Plate No. 6.4.** The details of inlet and outlet portals are given in **Table 6.7**

Table 6.7
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal
1	RD (km)	73.53	76.79
2	NSL (m)	313.70	320.22
3	HR level (m)	313.44	306.02
4	Soffit level (m)	302.83	302.06
5	Bed level (m)	290.22	289.57

(ii) Tunnel at RD 141.45 km:

The designed discharge of the canal is 259.80 cumec, however, the tunnel is designed for 247.7 cumec capacity considering the upstream release of water. The tunnel diameter is 11.7 m. The tunnel length is 776 m including the transitions. The slope of the tunnel is 1 in 5000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The designs of Tunnel at RD 141.45 km is furnished at **Appendix Volume of Design and Cost estimate.** The details of inlet and outlet portals are given **Table 6.8.**

Table 6.8
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal
1	RD (km)	141.47	142.20
2	NSL (m)	298.02	311.98
3	HR level (m)	296.70	293.30
4	Soffit level (m)	288.88	288.63
5	Bed level (m)	276.94	276.79

(iii) Tunnel at RD 150.25 km:

The designed discharge of the canal is 211.3 cumec, the tunnel diameter is 11.0 m. The tunnel length is 6489 m including the transitions. The slope of the tunnel is 1 in 5000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The canal alignment in this reach has 2 turning points. Besides, it traverses along the periphery of the submergence of tank near Amlapur village. The alignment in this reach needs to be straightened and shifted on westwards.

One construction adit (6mx6m D- shape, 500 m long) has been provided near village Saldara with appropriate rock support system to facilitate construction of link tunnel by providing additional faces for excavation. The adit will be provided with access gate in the tunnel plug for carrying out any future maintenance. The portal location for adit has been selected based on limited data and shall be firmed up at pre-construction stage based on the actual site conditions in consultation with geologist. The design of tunnel at RD 150.25 km is furnished at **Appendix Volume of Design and Cost estimate.** The details of portals are furnished in **Table 6.9.**

Table 6.9
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal	Adit
1	RD (km)	150.27	156.72	153.40
2	NSL (m)	300.22	301.09	336.40
3	HR level (m)	299.90	294.45	330.20
4	Soffit level (m)	287.54	286.15	281.64
5	Bed level	276.32	275.03	275.64

(iv) Tunnel at RD 298.98 km

The designed discharge of the canal is 76.70 cumec capacity of water. The tunnel diameter is 6.80 m. The tunnel length is 668 m including the transitions. The slope of the tunnel is 1 in 2700. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The designs of Tunnel at RD 298.98 km is furnished at **Appendix Volume of Design and Cost estimate.** The details of portals are furnished in **Table 6.10.**

Table 6.10
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal
1	RD (km)	298.99	299.63
2	NSL (m)	359.96	364.71
3	HR level (m)	359.96	364.71
4	Soffit level (m)	343.58	343.22
5	Bed level	336.52	336.28

(v) Tunnel at RD 371.53 km

The designed discharge of the canal is 38.2 cumec capacity of water. The tunnel diameter is 5.4 m. The tunnel length is 781 m including the transitions. The slope of the tunnel is 1 in 3000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The designs of tunnel at RD 371.53 km is furnished at **Appendix Volume of Design and Cost estimate.** The details of portals are furnished in **Table 6.11.**

Table 6.11
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal
1	RD (km)	371.54	372.30
2	NSL (m)	341.74	342.35
3	HR level (m)	341.74	340.02
4	Soffit level (m)	325.54	325.21
5	Bed level	320.14	319.88

(vi) Tunnel at RD 406.08 km

The designed discharge of the canal is 10.7 cumec. The tunnel diameter is 3.44 m. The tunnel length is 948 m including the transitions. The slope of the tunnel is 1 in 3000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The design of Tunnel at RD 406.08 km is furnished at **Appendix Volume of Design and Cost estimate.** The details of portals are furnished in **Table 6.12.**

Table 6.12
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal
1	RD (km)	406.10	407.02
2	NSL (m)	336.47	336.39
3	HR level (m)	336.47	333.26
4	Soffit level (m)	320.75	320.40
5	Bed level	317.23	316.91

(vii) Tunnel at RD 411.78 km

The designed discharge of the canal is 10.7 cumec, the tunnel diameter is 3.44 m. The tunnel length is 848 m including the transitions. The slope of the tunnel is 1 in 3000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The design of tunnel at RD 411.78 km is furnished at **Appendix Volume of Design and Cost estimate.** The details of portals are furnished in **Table 6.13.**

Table 6.13
Inlet outlet portal details

Sl.No	Details	Inlet portal	Outlet portal
1	RD (km)	411.78	412.62
2	NSL (m)	334.49	335.36
3	HR level (m)	334.05	334.38
4	Soffit level (m)	319.67	319.36
5	Bed level	316.15	315.87

6.5.3.3 Pipelines:

To avoid lengthy traverse of canal and high embankment, pipelines are proposed. Eleven reaches have been identified for pipeline where the height of embankment is more than 15.0 m and are of considerably long length. Mild steel pipes of 3.0 m dia. with epoxy painting are preferred for pipelines. These pipelines are under pressure in nature.

The number of the pipes and dia. of pipes required for conveying actual discharge under pressure have been computed. The discharge through pipes is reduced to that extent of upstream withdrawal of the canal discharge to minimize the cost of pipelines while designing. Hazen Williams equation $V = K C (D/4)^{0.63} S^{0.54}$ has been considered to work out the frictional loss of the pipe, where K unit conversion factor as 0.85, C Hazen William co efficient as 145 are adopted. D is dia. of pipe and S is head loss/ length of pipe. The minor losses e.g. entrance losses, trash rack loss, transition loss, exit loss; bend losses, gate groove losses, etc. are of negligible amount in comparison to the friction losses occurring in the pipes and therefore are not taken into consideration.

The thickness of pipe to withstand the pressure is computed considering 50 % above the working pressure. Extra thickness of 1 to 3 mm for corrosion is also considered. As epoxy painting is considered inside and outside the pipeline, the provision for corrosion is limited to 1 mm.

The inlet and outlet bays on either side of pipelines openings are provided. The PCC walls are considered for the chambers and are designed to withstand the water pressure. The floor of the chambers rest on hard strata. The pipes are embedded on the walls. The embedded portion is provided with RCC M15. Gate erection grooves are provided for the gates. One set of gates similar to stop log gates are proposed to be provided in case of repairs and maintenance purpose. The bellmouth openings are provided at both ends of the pipe for uniform flow and to minimize the entry/exit loss. The outlet structures to feed the feeder/sluices are also accommodated wherever such points are identified in the chambers.

The dia. of the pipe is considered as 3.0 m to 2.0 m as per the discharge conditions. The velocity in the pipes are almost limited less than 3.0 m/sec since the water is lifted at 6 places. The pipelines are partly buried and partly exposed. The PCC for bedding and about 1 m height surrounding the pipe is also provided for anchoring and supporting the pipeline. The provision for expansion joint, pressure relief valves, air relief valves and water draining arrangement is also provided. The pipelines shall pass over beams supported by piers wherever it crosses nallas / rivers. The typical design of pipelines and inlet and outlet bays designed at RD 27.40 km is shown at **Annexure: 6.6.** and depicted at **Plate No.6.5.** The typical design of pipelines and inlet and outlet bays designed for other sections are shown at **Appendix Volume of Design and Cost estimate.**

The salient features of pipelines at various reduced distances are given in **Table 6.14.**

Table 6.14
Salient Features of pipelines

Sl.No	Details	27.40 km	44.0 km	49.65 km	60.05 km	83.60 km
1	Canal Discharge (cumec)	323.7	289.4	289.4	289.4	289.4
2	Discharge through pipe (cumec)	20.43	18.8	21.35	14.49	17.39
3	Dia. of pipe (m)	3	3	3	3	3
4	Length of pipe (m)	1044	390	1786	9560	3310
5	No. of pipes	16	15	14	20	16
6	Velocity in pipe m/sec	2.89	2.66	3.02	2.05	2.46
7	Head loss in pipe (m)	1.40	0.45	2.6	6.8	3.3
8	Height of bell mouth (m)	4.5	4.5	4.5	4.5	4.5
9	Width of bell mouth	4.0	3.6	4.1	2.8	3.4
10	Inlet chamber					
(i)	FSL (m)	285.66	312.66	311.99	309.02	300.80
(ii)	NSL (m)	269.99	295.03	296.21	295.18	283.89
(iii)	Length (m)	104.85	81.65	76.65	112	87.65
(iv)	Width (m)	96	90	84	120	96
(v)	Bottom width of wall	7.3	8	7.6	5.8	9.9
(vi)	Top width of wall	1.5	1.5	1.5	1.5	1.5

	(m)					
11	Outlet chamber					
(i)	FSL (m)	284.26	312.21	309.39	302.22	297.50
(ii)	NSL (m)	269.37	294.83	294.33	290.75	282.64
12	Total length of pipeline system	1210	553	1937	9783	3485
13	Gates					
(i)	Size (m)	4.62 x 4.12	4.62 x 3.72	4.62 x 4.22	4.62 x 2.92	4.62x3.52
(ii)	No. of units	8	8	8	5	8
(iii)	Weight of gate (t)	8.3	7.8	8.9	4.2	8.8

Sl.No	Details	87.70 km	93.40 km	112.45 km	257.10 km	363.88 km	370.48 km
1	Canal Discharge (Cumec)	289.4	289.4	289.4	114.3	38.2	38.2
2	Discharge through pipe (Cumec)	17.81	15.48	17.8	19.9	9.72	13.47
3	Dia. of pipe (m)	3	3	3	3	2.35	2.15
4	Length of pipe (m)	1630	3364	916	392	1612	270
5	No. of pipes	16	17	15	6	4	3
6	Velocity in pipe m/sec	2.52	2.19	2.52	2.82	2.24	3.71
7	head loss in pipe (m)	1.70	2.7	0.95	0.5	1.8	0.85
8	Height of bell mouth (m)	4.5	4.5	4.5	4.5	3.3	3.76
9	Width of bell mouth	3.4	3	3.4	3.3	2.6	3
10	Inlet chamber						
(i)	FSL (m)	297.47	295.60	291.69	331.35	326.14	325.80
(ii)	NSL (m)	280.49	277.67	274.95	332.44	314.42	320.05
(iii)	Length (m)	94.65	93.65	97.4	54	41	31
(iv)	Width (m)	109	102	102	46	21	19
(v)	Bottom width of wall	8.2	9.4	9.2	3	6.7	4.5
(vi)	Top width of wall (m)	1.5	1.5	1.5	1.5	1.5	1.5

11	Outlet chamber						
(i)	FSL (m)	295.77	292.90	290.74	330.94	326.14	324.95
(ii)	NSL (m)	282.52	277.32	274.64	329.84	313.05	321.32
12	Total length of pipeline system	1819	3551	1111	500	1694	331
13	Gates						
(i)	Size (m)	4.62 x 3.52	4.62 x 3.22	4.62x 3.52	4.62 x 3.92	3.42 x 2.72	3.88 x 3.22
(ii)	No. of units	8	8	8	4	4	4
(iii)	Weight of gate(t)	7.4	7.1	8.2	2.5	3.2	3.2

6.5.4. Details of Lining Provided

Lining is provided for the entire length of main canal to minimize seepage. Lining with plain cement concrete 1:4:8 is proposed in canal bed as well as in side slopes. The thickness of lining varies from 100 mm to 75 mm according to canal capacity as per IS code 3873-1978: Laying cement concrete/stone slab lining on canals. However, lining of 100 mm thickness is assumed for most of the reaches. Typical cross section of lining of canal is indicated in the drawings. At places where ground water table or otherwise water table is higher, suitable drainage arrangement has been suggested, including provision of non-return valves, in staggered pattern, at the rate of 1 pressure release valve (PRV) for every 40 m^2 of lining along the side slopes and at every 100 m^2 of lining in canal bed. Typical details of canal lining and drainage arrangement under the lining are shown at **Plate No. 6.6.**

6.5.5 Description of Soil Profile along the Canal Alignment

Soil samples are collected along the link canal alignment by digging pits or drilling auger holes. The report and results of the soil profiles are furnished by the outsourcing agency.

6.5.6 Evaluation of Design Parameters based on the Samples collected along the Canal Alignment, Borrow Area and suggested Treatment for Problematic Reaches

CSMRS recommended that based on geotechnical investigations (soil) carried out, the link canal can be taken up along the proposed route. However, in reaches where very weak soil such as soil of MH and CH group are present, it was suggested to deviate route slightly based on the soil availability or else the designers may design the canal based on investigated data.

6.5.7 Transmission Losses

The transmission losses in the canal occurs in the form of seepage through the lining and evaporation from the surface of water. 0.6 cumec per million square meter of wetted area is considered as transmission loss along the canal.

6.6 Canal Structures across Link Canal

6.6.1 Cross Drainage Works / Regulators

As per the available data, various canal structures, bridges and cross drainage structures have been proposed. Details of structures is given in the **Table:6.15**

Table: 6.15
Details of Structures

S N	Type of Structure	Gosikhurd to Lower Wardha	Lower Wardha to Katepurna	Katepurna to Nalganga	Total
1	Aqueduct	8	9	15	32
2	Super Passage	2	2	9	13
3	Syphon Aqueduct	1	2	4	7
4	Canal Syphon	8	5	4	17
5	Canal Falls	0	0	2	2
6	Under Tunnels	107	25	48	180
7	Over Pass	41	30	79	150
8	SLRB	44	40	28	112
9	DLRB	5	7	11	23
10	FLRB	1	1	1	3
11	RLY B	2	2	1	5
12	Canal Escapes	2	2	2	6
13	Cross Regulator	3	3	4	10
14	Feeder Canal	8	6	4	18

	Regulator				
15	Sluice	3	1		4
	Total	**235**	**135**	**212**	**582**

The pipe lines proposed against the higher embankment portion crosses many streams/rivers. The pipelines taken over the beam supported by piers are proposed for crossing the pipe lines over river/nalla. Detailed designs of the above structures will be done at the time of construction.

6.6.2 Layout and Foundation

Detailed laboratory tests for finding the suitability of soils for foundations of all cross-drainage works have not been carried out except for few major rivers. However, based on the soil samples collected, it is inferred that hard rock can be met with at reasonable depths below the stream bed levels. This is required to be confirmed at pre-construction stage.

6.6.3 Cross Drainages Works

The type of cross drainage structure to be provided depends on the physical features of the stream crossed such as position of bed level of stream in relation to canal bed level. Loss of head at each structure is computed based on the 100 years design flood and the drain/canal details. Though head loss in the structure mainly depend upon the length and fluming adopted, more the length and fluming more is the head loss. Fluming of canal at the structures is considered to an extent of 60 to 70% wherever possible to achieve economy in cost of structure. The 50 and 100 years period design flood estimation were computed based on the method enumerated in flood estimation reports of Lower Godavari sub basin and Upper Narmada and Tapi basin by the Central Water Commission. The 50/100 years period design flood estimation for 24 Nos. of streams and rivers of major to minor in nature which come across canal alignment have been estimated. The 100 years design flood estimation carried out for Amb river at RD 13.631 km and and Nirguna river at RD 332.40 km are shown as **Annexures:6.7.1 and 6.7.2** respectively. Based on estimated values of 100 years design flood of number of streams with varying catchment area, 100 years design flood estimation curves were developed for Wainganga river and Tapi river independently to find the design flood estimation for the other streams realistically. The 100 years design flood curves for Wainganga river and Tapi river are shown in **Annexure 6.8.1 and 6.8.2** respectively. The design flood estimation of other streams/rivers are shown at **Appendix Volume of Design and Cost estimate.**

The piers of the structures will be RCC of 1.25 m thick. The abutment foundation lies over the hard rock strata. In case, the hard strata are available above the river bed level, the base of abutment is proposed above the river bed level. A RCC wall of 0.3 m thick is proposed below of abutment base upto floor level to provide smooth surface which will be anchored with the hard rock. The return/wing walls are proposed with RCC cantilever type. If the height of the soil to be supported is more than 6.0 m, the RCC stem is provided with 2 relieving platforms. **The optimal design of reinforced concrete retaining walls published in the Indian Concrete Journal, April 2012 authored by Dr. Devdas Menon, Professor, IIT, Madras and co-authored by Miss. Shravya Donkada, IIT Madras,** has been made use for dimensioning of return/ wing walls. The head loss likely to occur at the cross-drainage structures computed is shown at **Annexure: 6.9.**

(A) Aqueducts:

Aqueducts have been proposed along the link canal at the crossings of major streams where the bed level of the link canal is above the highest flood level of the drain with sufficient free board. In all, 32 aqueducts are proposed.

Heights of piers vary from few meters to about 25.0 m depending upon the depth of drainage bed from bottom of aqueduct. However, considering average conditions, RCC Piers of 1.25 m width with spread footing were assumed in analysis. Since aqueduct portion were not flumed, length of piers with assumed width were sufficient enough to keep foundation pressures quite low. General layout of Aqueduct at RD 37.65 km is shown at **Plate No. 6.7**. and typical design details of Aqueduct at RD 37.65 km are shown at **Annexure 6.10.** Also, the hydraulic and structural designs of major components were carried out for structures at RD 109.3 km, 175.4 km, 202.0 km, 315.00 km and 362.0 km for preparation the cost curve for aqueducts which are shown at **Appendix Volume of Design and Cost estimate.**

(B) Super Passages

Super Passages have been proposed along the link canal at the crossings of major streams where the bed level of the drain is above the FSL level of the drain with sufficient free board. In all, 13 Super passages are proposed. RCC barrels were proposed for super structure. The top of the barrel is kept about 1 m below the river bed to avoid damages from the rolling stone. General layout of super passages at RD 161.24 km is shown at **Plate No. 6.8**. and typical design details of super passage at RD 161.24 km are shown at **Annexure 6.11.** In addition, the hydraulic and structural design of major component were carried out for structures at RD 134.96 km, 266.70 km, 291.70 km, 300.60 km and 410.70 km for preparation the cost curve for super passages which are shown at **Appendix Volume of Design and Cost estimate.**

(C) Syphon Aqueducts

Syphon Aqueducts have been proposed along the link canal at the crossings of major streams where the bed level of the link canal is just at the highest flood level of the drain. The bed of the drain is depressed to an extent of about 1.0 m below the actual drain bed level. In all, 7 syphon aqueducts are proposed. The structural design for aqueduct and syphon aqueduct is almost same. As such, no specific design for syphon aqueduct is furnished.

(D) Canal Syphons

Canal syphons have been proposed along the link canal at the crossings of major streams where the full supply level of the link canal lie between the drain bed and the highest flood level of the drain. However, the choice of canal syphon depends upon the discharge capacity of canal vis a vis the design flood and physical characteristics of drain. It is advantageous to consider canal syphons than the syphon aqueducts, since the canal flow is free from silt and floating debris. The head loss in canal syphon is more than the syphon aqueduct. As such, due consideration for economical design should be kept in mind. The top of the canal syphon barrel is kept about 1 m below the river bed to avoid damages from the rolling stone. A total of 17 canal syphons are proposed. Slopes of inlet and outlet portion of syphon are proposed as 1 in 3 (V:H). General layout of canal syphon at RD 13.65 km is shown at **Plate No. 6.9**. and typical design details of canal syphon at RD 13.65 km are shown at **Annexure 6.12.** Also, the hydraulic and structural designs of major components were carried out for structures at RD 103.55 km, 160.5 km, 215.0 km, 279.0 km and 418.60 km for preparation the cost curve for canal syphons which are shown at **Appendix Volume of Design and Cost estimate.**

(E) Cross Regulators / Canal Regulators

Cross regulators are provided at regular intervals in order to ensure effective water regulation as well as change in canal sections. 10 cross regulators are proposed along the link canal. The loss of head of 150 mm is considered at each cross regulator. Typical cross regulator cum head regulator proposed at RD 195.45 km is indicated at **Annexure 6.13.** The general layout and typical details of cross regulators at RD 195.45 km is shown at **Plate No. 6.10**.

(F) Regulators

Regulators can be categorized into, (i) Head regulators from where the canal offtakes from the head works such as reservoir or barrages, (ii) canal regulators from where the branch canal/ distributaries draw water from main canal and (iii) outfall regulators to prevent the back flow of water from head works such as barrages/reservoirs.

(i) Head regulators

The link canal offtakes from the submergence area of three reservoirs. Three head regulators one each at Gosikhurd, Lower Wardha and Katepurna reservoirs are provided. These regulators forms part of Head Works.

(ii) Canal Regulators

The feeder canals and direct sluices were identified by the Government of Maharashtra based on the toposheets study to cater the need of the existing/proposed reservoirs in Godavari and Tapi basins. In absence of the alignment of the feeder canal and direct sluices, the location of regulators were fixed as furnished by Govt. of Maharashtra or any canal structures identified now to optimize the cost of canal. Twenty-two regulators identified and considered in the study are shown in **Table:6.16.**

Table: 6.16
Feeder canal/direct sluice details

Sl No	RD in Km		Name	Type	Located on	Discharge (cumec)
	Original	Proposed now				
1	25.0	25.0	Satara	Feeder canal 1	Right side	22.5
2	42.0	42.70	Saiki	Feeder canal 2	Left side (Delivery cistern)	30.7
3	42.0	42.70	Khalsana	DS 1	Right side (Delivery cistern)	2.9
4	68.0	66.85	Vadagaon	DS 2	Left side (on pipeline)	2.8
5	86.0	85.1	Bhansuli	Feeder canal 3	Left side (on pipeline)	10.4
6	90.2	89.52	Seldoh	Feeder canal 4	Left side (Pipeline outlet bay)	6.4
7	114.5	112.5	Juwadi Khairi	Feeder canal 5	Left side (pipeline inlet bay)	7.6
8	117.2	117.2	Borkhedi kalan	Feeder canal 6	Left side	7.5
9	122.5	123.77	Tamaswada	DS 3	Left side	4.6
10	145.0	147.55	Sukali Raising	Feeder canal 7	Left side	8.5
11	150.0	150	Vai	Feeder canal 8	Left side	26.9
12	184.3	184.3	Wadgaon	Feeder canal 9	Left side	12.2
13	195.3	195.45	Bembla	Feeder canal 10	Left side	10.3
14	208.3	208.3	Yerandgaon	DS 4	Left side	3.9
15	214.3	214.3	Nandgaon Khandeswar	Feeder canal 11	Left side	24.1
16	237.3	237.3	Shelgund	Feeder canal 12	Left side	12.5
17	246.3	246.3	Papal-I	Feeder canal 13	Left side	13.5
18	293.3	293.32	Lower	Feeder	Right side	16.3

			Katepurna	canal 14		
19	303.3	303.32	Yelwan	Feeder canal 15	Right side	28.5
20	321.3	321.32	Chikhalgaon	Feeder canal 16	Right side	9.6
21	371.3	371.38	Kolori	Feeder canal 17	Right side	5.4
22	378.3	377.13	Shelodi	Feeder canal 18	Right side	21.3

(iii) Outfall regulators

These regulators are similar to cross regulators which are provided to avoid the back flow of water from reservoirs when the water level in head works is above the FSL of the canal or to keep the canal dry during the maintenance. Three outfall regulators are provided each one at Lower Wardha, Katepurna and Nalganga reservoirs.

(G) Canal Escapes

The canal escapes are provided to release the water from the canal to streams to safe guard the canal during emergency conditions like breaching of canal, excess water flow in the canal. The canal escapes are designed to drain 50 % of canal discharge. The escapes are usually to be provided at the U/S of aqueducts or at the U/S of HR/CR junction. The canal escape regulators are similar to branch canal regulators. There are 6 nos. of canal escapes provided in the link canal.

(H) Bridges

Overall 143 Nos. of bridges comprising of 112 Nos. of SLRB, 23 Nos. of DLRB, 3 Nos. of FLRB and 5 Nos. of Railway Bridges are proposed along the length of the canal. In case, canal FSL is just above railway track level, the canal syphons are provided for railway crossing. Loss of head of 0.012 to 0.006 m is considered at each bridge, due to piers located in canal bed. The canal is not flumed at bridge sites to preserve head available. Typical designs and drawings published by IRC for T-beam RCC bridges having spans larger than 10.5 m have been adopted. Foundations of pier shall be at depths equal to greater than scour depth as per strata available. General layout of road bridge

(Double lane) at RD 25.77 km is shown at **Plate Nos. 6.11**. Typical design details of the road bridge is shown at **Annexure: 6.14.** Also, the structural designs of major components were carried out for bridges at RD 109.12 km, 195.37 km, 260.15 km, 327.00 km and 386.59 km for preparation the cost curve for road bridges which are shown at **Appendix Volume of Design and Cost estimate.**

(I) Falls

Canal falls are provided wherever, the ground profile is steeper than the bed slope of canal and to avoid canal passing in high embankment. Canal falls are identified at 2 locations in the Katepurna to Nalganga reach of canal at RD 302.93 km and RD 426.43 km. For low head structures, the design of weir type may be prohibitive and uneconomical where as drop is economical and is preferred. The main features of drop are, the free over fall, the nappe impact and the hydraulic jump. At the nappe impact, a recirculating pool of water forms behind the overfalling jet. This mass of water is important as it provides a pressure force parallel to the floor which is required to change the jet momentum direction from an angle to the bottom, to parallel to horizontal bottom.

At RD 302.93 km, the pooled stepped cascades are proposed as the discharge and FSD of water is considerably high. If the steps are designed as small stilling basins to dissipate the energy, they are called pooled step cascades. Two steps are proposed to accommodate the canal fall of 7.0 m high. Each step is 26.37 m long. As the bed of the floor is rest on the hard rock profile, RCC of M20 mix is proposed to take the impact of the nappe. If the quality of hard rock is sound enough to take the jet, the floor bed concrete can be avoided to minimize the cost of the canal. A body wall of 1.0 m high at the end of the step is proposed to pond the pool. The wing/ return walls are of RCC retaining wall with cantilever type. The detailed design of fall is shown at **Annexure: 6.15** and the drawings are depicted at **Plate No.6.12**

At RD 426.43 km, a drop of 6.0 m is proposed. The canal discharge is 10.70 cumec. The basin length of the drop is 19.32 m. As the bed of the floor is rest on the hard rock, RCC of M20 mix is proposed to take the impact of the drop. If the quality of hard rock is sound enough to take the jet, the floor bed concrete can be avoided to minimize the cost of the canal. As the outfall into reservoir is just 1.0 km d/s and structures in between fall to outfall are not identified, the option of pipe conduit with head loss of 6.0 m can be explored during construction stage. The detailed design of fall is shown at **Annexure :6.16** and the drawings are depicted at **Plate No. 6.13**

These falls are with low height and duration of flow is very much limited. Therefore, the option of power generation from the falls not considered.

(j) Under Tunnels/Over Pass

The link canal on its enroute crosses 330 nos. of streams/existing canals of smaller in nature. Suitable structures are to be provided at these crossings to avoid water logging in the area. Under tunnels are provided if the bank level of stream /canal lie between canal bed level and free board of the main canal. Box type culverts are proposed for under tunnels for which head loss is not considered. The detailed design of under tunnel is shown at **Annexure: 6.17** and the drawings are depicted at **Plate No.6.14.** The detailed design of under tunnels at RDS 100.83 km, 114.61 km, 123.77 km, 281.54 km, 334.41 km and 338.39 km were also carried out for preparation of the cost curve for under tunnel which are shown at **Appendix Volume of Design and Cost estimate.**

Overpasses are provided when the stream/existing canal bed level lie well above the free board of canal. The water conduit of the stream/ existing canal is either through pipe or trough depending upon the discharge of stream/ canal. The trough or pipe is supported by piers. Thus, there will be reduction in the area of canal flow that leads to loss of head in canal. The loss of head for overpass is considered equivalent to road bridges.

6.7 Study of Integrated Network of Canal System and its Operation

The canal system will be operated as an integrated network with the existing/proposed reservoirs enroute for optimum utilization of available waters.

6.8 Broad Outline of Canal Automation and Branch Canals upto 8 cumec

The canal automation technology adopted for Sardar Sarovar Project canal system shall be adopted for the link canal system also.

6.9 Instrumentation

The requirement of special instruments for the construction of dams, (enroute storages) tunnels and pump houses shall be assessed during pre-construction stage.

6.10 Other Studies

The studies required at DPR stage have been carried out and included in the report. The other studies which are not covered in the DPR like designs of enroute storage reservoirs/tanks etc. will be carried out at preconstruction stage.