Chapter - 6
Design Aspects

6.0 General

The main objective of the Godavari (Janampet) - Cauvery (Grand Anicut) link project is to divert the unused waters of river Indravati in Chhattisgarh along with part of surplus water assessed at proposed Janampet barrage across river Godavari to stabilize existing irrigation systems and provide irrigation to available new areas in the states of Telangana, Andhra Pradesh and Tamilnadu to meet the irrigation, domestic and industrial demands.

Godavari (Janampet) - Cauvery (Grand Anicut) link project comprises the following components

: Head works at proposed Janampet barrage across river Godavari in Pinapaka mandal of Bhadradri Kottagudem dist with full pond level (FPL) 67m.

i) Link canal of length 1251.59 km from Janampet barrage to Grand Anicut comprising of open canal, lifting arrangements and tunnels
ii) Lifting arrangements through 3 stages of lifting of 36 m (RD 10 km), 52m (RD 334 km) and 52m (RD 337 km) totaling to 140 m of static lift and lean season pumping at Somasila reservoir into the link canal.
iii) Powerhouse at canal head ay Nagarjunasagr reservoir with a head of about 20m.
iv) Five tunnels of total length 21.87 km located 12.50 km from RD 107.60 to 120.10.km; 1.27 km from RD 343.58 to 344.85; 4 km long tunnel at the offtake of link canal near headworks of Somasila; one km from RD 741.72 to 742.72 km; and 3.10 km from 867.52 to 870.62.
v) Existing Nagarjunasagar on river Krishna, Somasila on river Pennar as balancing reservoirs enroute.

vi) In all, 38 number of branch canals and 7 direct sluices / feeders to facilitate irrigation enroute and in the existing irrigation systems through piped distribution.

vii) Cross drainage/ cross masonry and regulating works across the link canal.

viii) New command of about 4.31 lakh ha at 100 % intensity in Bhadradri Kottagudem, Khammam, Prakasam, Nellore, Chittor, Thiruvallur, Vellore, Kancheepuram, Thiruvanmalai, Villupuram and Cuddalore districts and stabilization of 3.64 lakh at 138 to 140% of irrigation intensity together fetching 9.38 lakh ha of irrigation annually.

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

x) The existing Grand Anicut as outfall structure on river Cauvery with FPL 59.22 m

6.2 Geology, seismicity and foundation

6.2.1 Geology

Geological Investigations are carried out by Geological Survey of India along the link canal. The details of the investigation are covered in **Chapter 4: Surveys and Investigations.**

6.2.2 Seismicity

The link canal takes off from the proposed Janampet barrage and falls into existing Grand Anicut utilizing existing Nagarjunasagar and Somasila as balancing reservoirs. Thus, there is only one proposed barrage with full pond level limited to river portion and hence no site specific seismic studies are proposed. From the general seismology of the Chhattisgarh / Telangana region the Bhadradri Kothagudem district falls in earthquake zone-III as per I S Code: IS1897 – 1984, which is considered as moderately vulnerable for seismic activity and damage. Seismic studies, if required shall be carried out at pre-construction stage.

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 Barrage at Janampet

The Janampet barrage is proposed across Godavari river at latitude of 18º 06' 23" N and longitude of 80º 44' 38" E (right bank) near Bhupathirao pet village in Pinapaka mandal of Bhadradri Kothagudem district. The catchment area of the Godavari basin upto Janampet barrage site is 273126 km^2 and the catchment area between the Medigadda barrage and the Janampet is 47274 km^2. The river width is about 1.7 km at the proposed site. The design of barrage is furnished in the following paragraphs.

6.3.1 Design flood at Janampet

The design flood for the barrage at Janampet has been determined keeping in view the criteria laid done in **IS 6966 Part-I 1989 – "Hydraulic Design of Barrage and Weirs"**. According to this code, the design flood for barrages and weirs should be 50 year flood. However, in this particular case 100 year flood is proposed to be considered as design flood for barrage. For, fixing the free board normally 500 year return period flood or Standard Project Flood (SPF) as the case may be can be considered. Since the catchment area intercepted by the barrage is quite large, estimation of standard project flood can be time consuming particularly with regard to collection of requisite hydro - meteorological data, it is decided to estimate the design flood by frequency approach utilizing the annual peak discharge data of Perur G&D site furnished in **Annexure 6.1.**

Most of the frequency distribution functions applicable in hydrologic studies are expressed by the general equation

$Xt = Xmean + Kt \times SD$

Where Xt = Value of the variate X of a random hydrologic series with a return period T

Xmean = Mean of the variate

SD = Standard deviation of the variate

Kt = Frequency factor which depends upon the return period T and the frequency distribution being fitted

The frequency factor Kt is obtained for Gumbel's extreme value distribution by, **Kt = -sqrt (6)/π {+Ln [Ln(T/t-1)]}** where T is the return period.

The estimated 50, 100 and 500 year return floods, thus obtained are corrected for the catchment factor as the actual barrage site is at Janampet (instead of Perur). The results are furnished in **Table 6.1.**

Table 6.1 Flood frequency analysis for different return periods using Gumbel's extreme value distribution

Return period (Years)	**Estimated flood (cumec)**	
	Perur CA: 268200 sqkm	**Janampet CA:273126**
50	64977	66173
100	**72300**	**73630**
500	89221	90863

The details of flood frequency analysis at Janampet barrage site are furnished in **Annexure 6.2.** The layout of proposed barrage at Janampet is shown a**t Plate 6.1**

6.3.2 Hydraulic design of barrage

The barrage at Janampet is designed for a flood of 74702 cumec for which the Lacey's waterway is obtained as 1299m. The number of bays proposed in under sluice portion are 8 (4 each on left and right sides) considering about 18.20% of discharge to pass through, and the number of bays proposed in river sluice portion are 41. After due provision of 3.0m wide piers for under sluices and 2.50 m wide piers for river sluices and 2nos of 3.0m thick divide walls, the overall waterway obtained is about 867.50m. The barrage will pass safely the designed discharge considering an afflux of

1.0m. The details are furnished in **Table 6.2.** The plan of Janampet barrage is shown at **Plate 6.2**

Table 6.2 Salient features of headworks

Sl.No	Details	Barrage at Janampet
1	FPL (m)	67.0
2	Crest level (m) (i) Under sluice (ii) River sluice	 57.0 59.0
3	Afflux (m)	1.0 m
4	No. of bays	
	Under sluice (4 bays each on left and right side)	8
	River sluice	41
5	Gate size	
	Under sluice	15 x 10 m
	River sluice	15 x 8 m
6	Overall length of barrage (m)	867.5
7	Discharge allowed (**cumec)**	74702

The computation of rugosity coefficient of .042 for the barrage is given in **Annexure 6.3.1** while the hydraulic design of the barrage is furnished in **Annexures 6.3.2 to 6.3.7.** The layout of headworks showing barrage, head regulator and other appurtenant works along with colonies etc is shown in **Plate 6.1.** The cross section and other particulars of the barrage are shown at **Plate 6.3 to 6.5.**

6.4 Head Regulators:

Head regulators are proposed at three locations viz at the proposed right flank of the proposed Janampet barrage, existing Nagarjunasagar and Somasila reservoirs to regulate waters into the link canal at various locations. The details of head regulators are furnished below.

6.4.1 Head regulator at Janampet barrage

The proposed head regulator is located on the right flank of river Godavari at the proposed barrage near village Bhupathirao pet. The canal is proposed to take off with FSL of 66.0m. The head regulator is proposed with 5 bays of 6.4 m wide each. The piers will be in RCC of 2.0 m thick. The abutment foundation lies over the hard rock strata. An 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.

Identical vertical lift type fixed wheel service gate in each bay for opening size of 6.4m wide x 8 m high, are proposed to regulate the discharge into canal. Sill level / crest level of gate is 59 m. The Hydraulic design details of head regulator and service gate are at **Annexures 6.4 & 6.4.1.** The design features of head regulator are shown in **Plate 6.6.** The salient features of head regulator are furnished in **Table 6.3.**

Table 6.3 Salient features of head regulator

Sl. No	Parameter	Value
1	FPL (m)	67.0
2	Water drawn level (m)	61.0
3	Crest level(m)	59.0
4	No. of bays	5
5	Width of bays(m)	6.4
6	Length of regulator(m)	40.0
7	U/S floor level (m)	58.8
8	D/S floor level (m)	55.0

6.5 Design of conveyance system

The design of conveyance system comprises design of open canal, tunnels, lifting arrangements and CD/CM works.

The proposed link canal project consists of three main reaches. They are:

i) Canal taking off from Godavari (Janampet) and terminating at Krishna (Nagarjunasagar) (0 - 340.00 km)

ii) Canal taking off from Krishna (Nagarjunasagar) and terminating at Pennar (Somasila) (340.0 – 733.02 km)
iii) Canal taking off from Pennar (Somasila) and terminating at Cauvery (Grand Anicut) (733.02 – 1251.59 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 a contour canal. The canal takes with FSL of 66.0m from Janampet barrage and falls into Grand Anicut with an FSL of 60.86m. The link canal utilizes existing Nagarjunasagar and Somasila as balancing reservoirs. The natural surface level (NSL) of the canal alignment is obtained from the field topographical surveys. The details of topographical surveys conducted are discussed in the **Chapter 4: Surveys & investigations.**

The bed slope of the canal is considered as 1 in 20,000 where as the same for the major tunnel (12.5 km) is considered as 1 in 6000. 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. Two tunnels are considered one for crossing Godavari - Krishna ridge and the other at the deep cut near offtake point of the canal from Nagarjunasagar.

The NSL at 50 m interval and at structures with corresponding Full Supply Level (FSL) of the canal in the three reaches are furnished as head loss statement in **Annexures 6.5.1 to 6.5.3.** The alignment has been generated as strip contour plan plotting about 25km in a sheet with the corresponding longitudinal profile.

6.5.2 Canal capacity

The 1251.59 km long link canal, takes off from the Janampet barrage with FSL of 66m. The monthly demands of command area in various reaches are worked out and furnished in **Chapter 8: Irrigation planning and command area development.** Further, the divertible quantity in each 10 daily period / month is worked out from the simulation at Janampet using net surplus flows. These details are furnished in **Chapter 5: Hydrology and**

water resources. The discharge in initial reach is worked out as 721cumec. As the canal moves southwards, it releases water into various branch canals identified along the alignment of the canal. In all, 35 outlets are proposed all along the link 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 6.6**. The canal carrying capacity at different reaches are given in **Table: 6.4**

Table 6.4
Canal carrying capacity at offtake of the three reaches

Sl. No	Reservoirs	RD (km)	Canal FSL (m)	Canal capacity (cumec)
1	Janampet	0.00	66.0	721
2	Nagarjunasagar	340.00	151.67	488
3	Somsaila	733.02	97.30	603
4	Grand Anicut	1251.59	-	-

6.5.3 Design of canal

The canal releases water at various locations to feed enroute proposed/ existing reservoirs and accordingly the section of the canal needs to be reduced. However, it is not practical to change the section of the canal at each and every off-take point of branch canal. Therefore, the canal is divided into suitable reaches and canal sections are designed to carry the required discharges in the particular reaches. In general, a new canal section is designed wherever the discharge reduces by 10% from that of the previous reach.

The canal has been designed as a trapezoidal section with rounded corners as per provisions of IS Code: 10430 - 2000. Normally, the FSD has been kept constant in a particular reach with gradually reduced bed width. The fluming of canal is also considered by increasing the canal FSD by about 0.5 m wherever the deep cut reaches are encountered on hard /weathered rock strata. In order to prevent losses and reduce the required section of canal, plain cement concrete (M 15) lining is proposed throughout the length of link project.

The canal section is designed using Manning's formula. The side slope of 1.5:1 (H : V) in normal cutting and 0.5: 1 on hard rock portion (deep cut) 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.

The hydraulic particulars of link are given in the **Table 6.5.**

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 = 0.018

Bed slope = 1 : 20000

Side slope = 1.5:1 (Normal cut)

= 0.5 :1(Deep cut)

Wetted perimeter (P) = $b+ 2d (\theta + \cot \theta)$

Table 6.5 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							
Janampet								
0.00	107.00	721	66	7	564.31	95.23	1.29	726
107.00	242.00	657	59	7	515.31	88.23	1.27	657
242.00	340.00	619	55.3	7	489.41	84.53	1.27	620
Nagarjunasagar								
340.00	542.75	488	21.3	7	226.32	43.36	2.16	488
Merger of link canal with existing NSRBC								
542.75	599.00	565	67.5	6	480.17	92.56	1.18	565
599.00	643.55	539	64.1	6	459.77	89.16	1.17	539
643.55	733.02	498	58.9	6	428.57	83.96	1.16	499
733.02	881.77	603	73	6	512.87	98.01	1.18	607
881.77	992.88	524	62.5	6	449.87	87.51	1.17	526
992.88	1080.18	408	47	6	357.17	72.06	1.14	408
1080.18	1251.12	379	43.5	6	335.87	68.51	1.13	381
1251.12	1251.59	351	70	4.5	357.28	88.79	0.99	355

The design of canal in various reaches and reach wise hydraulic particulars are presented in **Annexure 6.7.** Typical canal sections at different normal reaches of main canal and the same in in deep cutting and high embankment, tunnel are shown at **Plate 6.7.**

6.5.4 Tunnels

The tunnels are designed as modified horse shoe 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 design of the tunnels has been carried out for conveying actual discharge available at that location. The slope of the link tunnel is considered as 1 in 6000 in case of first tunnel at Godavari - Krishna ridge and 1 in 486 in second tunnel. The value of Manning's coefficient adopted is 0.014 for the concrete lined tunnel.

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 as would be 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 are 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 107.60 km to 120.10 km

The designed discharge of the canal is 657 cumec and twin tunnels of dia 14 m each are proposed to carry the required discharge. The length of tunnel is 12500 m excluding transitions. The slope of the tunnel is 1 in 6000. 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: 6.8.1.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(ii) Tunnel at RD 343.58 km to 344.85 km

The designed discharge of the canal is 488 cumec and a tunnel of dia 10m is proposed to carry the required discharge. The length of tunnel is 1.27 km excluding transitions. The slope of the tunnel is 1 in 486. 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: 6.8.2.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(iii) Tunnel at offtake of link canal from Somasila dam (733.02km)

Two tunnels with dia 10.30m each are proposed as part of headworks at Somasila reservoir to carry designed discharge of 601 cumec. The length of tunnel is 4.0 km excluding transitions. The slope of the tunnel is 1 in 5000. The tunnels are 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: 6.8.3.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(iv) Tunnel at RD 741.72 km to 742.72 km

The designed discharge is 601 cumec and two tunnels of dia 12.62 m are proposed to carry the required discharge. The length of tunnel is 1.0 km excluding 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: 6.8.3.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(v) Tunnel at RD 867.52 km to 870.62 km

The designed discharge is 580 cumec and two tunnels of dia 12.46 m are proposed to carry the required discharge. The length of tunnel is 3.1 km excluding 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: 6.8.4.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

6.5.5 Lifting arrangements

The link canal takes off from Janampet barrage with an FSL of 66m and falls into Nagarjunasagar in its first reach with an FSL of about 181.401m. The lifting arrangements are provided in three stages at locations viz RD 10km, 334km, and 337km based on the topographical conditions, keeping in view the elevation of command area and the tail end reservoir. In all, 20 pumps have been provided including two standby in first stage and 18 pumps including two standby are provided in each of the second and third stages. In addition, one lift on NSLBC Feeder branch canal of 30 m is proposed at RD 105 km before the tunnel inlet to minimize the discharge capacity and size of the tunnel. The static head of the pump houses at the three stages are 36m, 52m and 52m on main canal. The canal capacity at the offtake is 721 cumec.

Surface pumphouses have been proposed 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 ground profile from toposheets/field surveys. However, the location of pump house, type of pumps, electrical and mechanical equipments will be studied in detail during the pre-construction stage. The preliminary details of pumping components are given below:

Sump/ intake well:

The sump is provided with RCC retaining walls of suitable size to retain the earth pressure. The retaining walls are proposed with RCC cantilever type. 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.

Pumps

(a) Concrete volute pumps:

It is proposed to install concrete volute pumps with a capacity of 40 cumec discharging capacity 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 in-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 expenditure for the complete pumping system is 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 and can be carried out by civil construction company at site.

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.

Delivery main

The mild steel rising mains of suitable dia are provided. 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 is unit conversion factor (0.85), C is Hazen William co efficient (145). 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 PCC for bedding and RCC of about 1 m thick 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.

Delivery cistern

The rising main from the pump house is let into fall in the delivery cistern. The rising main is kept in such a way that it is at least one metre 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. Plain cement concrete of mix M10 1:4:8 of about 0.2 m thick is proposed.

The design of lifting arrangements is **shown** in **Annexure 6.9.1 to Annexure 6.9.3.** The design particulars of lifting arrangements on NSLBC feeder branch is shown in **Annexure 6.9.4**. The typical design features of lifting arrangements at RD 10.00km are shown in **Plate 6.8 (a) and Plate 6.8 (b).** The salient features of the lifting arrangements are furnished in **Table 6.6.**

Table 6.6

Salient features of lifting arrangements on the main canal and feeder branch

Sl. No	**Description**	**Location of pump house RD (km)**				
		Main canal			**Branch canal**	
	RD (km)	**10.0**	**334.0**	**337.0**	**105.0**	
1	NSL (m)	96	85	179.60	123.96	
2	FSL (m)	65.45	77.75	129.60	94.14	
3	Discharge (cumec)	721	619	619	64	
4	Canal FSD (m)	7	7	7	3	
5	Canal bed width (m)	66	55.3	55.3	24	
6	Static head (m)	35	52.7	52.55	26	
7	Pump capacity (cumec)	40	40	40	40	
8	No. of pumps	20	18	18	3	
9	Suction pipe dia (m)	4.5	4.5	4.5	4.5	
10	Delivery pipe dia	3.25	3.25	3.25	3.25	

	(m)					
11	Delivery main dia (m)	3.75	3.75	3.75	3.75	
12	Installed capacity (MW)	20.2x 20	29.2x 18	28.7x 18	17.2x3	
13	Power required (MU)	904	1125	1104	69	**Total: 3202**
14	**Intake well**					
(i)	Length (m)	285.47	261.64	264.84	67.75	
(ii)	Width (m)	343.5	309	309	50.25	
(iii)	Depth (m)	62	39	78	60.96	
15	**Pump house**					
(i)	Length (m)	408	372	372	102	
(ii)	Width (m)	31.05	31.05	31.05	31.05	
(iii)	Depth (m)	43.7	19.7	59.7	39.66	
16	**Delivery cistern**					
(i)	Length (m)	277.97	254.14	257.34	60.25	
(ii)	Width (m)	150	135	135	22.5	
(iii)	Depth (m)	6.3	6.3	6.3	6.3	

6.5.6 Powerhouse at the offtake of link canal from Nagarjunasagar

The link canal takes off from the Nagarjunasagar at the same off-take level as that of the existing NSRBC and hence, it is proposed to construct a power house on the link canal similar to the existing one on NSRBC. The water to be drawn into link canal would be guided through the powerhouse. It is proposed to install 4 units of 30 MW each including one standby unit. The effective installed capacity of the powerhouse would be 90 MW. The head regulator of the link canal is proposed to be similar to that of the existing one on the NSRBC but with 8 vents of same size of 3.05 m x 4.575 m with a sill level of 149.05 m. A power block of length 70 m with 4 Nos. of penstocks and dam toe power house of size 67m x 39 m is proposed on the right side of the existing similar structures of NSRBC. The water after power generation using the available head would be guided to the link canal through 130 m long tailrace channel. Suitable modifications to the right embankment of Nagarjunasagar dam are proposed to be carried out for accommodating the

proposed head regulator, power block with penstocks etc., leading to the proposed power house on the link canal.

The following civil and electrical works would be required to be undertaken for the proposed powerhouse.

Civil works

(i) 4 Nos. of trash rack structures
i) Powerhouse civil works
ii) 4 Nos. of penstocks of 6 m dia. and 133 m length.
iii) Intake gate shafts
iv) Powerhouse pit to accommodate 4 Nos. of turbines and generating units
v) Draft tube gate shaft to connect the runner to the tail race
vi) Switch yard
vii) Tail race pool

Electrical works

i) Power station, generation & control equipment
ii) Power station auxiliaries
iii) Power station transformer and outdoor equipment

The design particulars of the powerhouse are furnished in A**nnexure 6.10.** The lay out, plan and sectional elevations of the powerhouse are shown in **Plates 6.15 to Plate 6.17**

6.5.7 Description of soil profile along the link canal

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 agencies.

6.5.8 Evaluation of design parameters

Various expert agencies viz. JNTU,APERL,CSMRS etc., suggested that the link canal can be taken up along the proposed alignment, based on geophysical and geotechnical investigations (soil) carried out. 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.

6.5.9 Transmission Losses

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

6.6 Canal structures

6.6.1 Cross drainage/Cross masonry works / regulators

Various canal structures, bridges and cross drainage structures have been proposed. In all, there are 988 structures proposed all along the link project. There are 171 structures in all in Reach I, 328 structures in Reach II and 318 structures in Reach III.

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. The head loss in the structure mainly depends 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.

a) Flood estimation of various streams

In its entire course of 1251.59 km, the link canal has been provided with 505 cross drainage works, of which 52. are aqueducts, 4 are syphon acqueducts, 8 are the inlets, 108 are superpassages and 333 are undertunnels. The design flood value of each drain has been worked out using the empirical formulae given in **Table 6.3**, which are adopted by the Irrigation Department of the Government of Andhra Pradesh.

Table 6.3: Formulae for computing design flood

S.No.	Catchment area (km^2)	Design flood value (Cumec)
1.	< 2.6	$19.50A^{3/4}$
2.	2.6 to 78	$16.70A^{3/4}$
3.	78 to 1300	$14.75A^{3/4}$
4.	>1300	$123.20A^{1/2}$

Where A is the catchment area of the drain

a) Aqueducts

Aqueducts have been proposed along the link canal at the major stream crossings where the bed level of the link canal is above the highest flood level of the drain with sufficient free board. In all, 52 aqueducts are proposed. The hydraulic design of aqueduct across Musi river at Rd 568.23 km is furnished in **Annexure 6.11**. Typical plan and section of aqueduct is shown at **Plate 6.9.**

b) Super passages

Super Passages have been proposed along the link canal at the major stream crossings where the bed level of the drain is above the FSL of the canal with sufficient free board. In all, 108 super passages are proposed. The hydraulic design of super passage across Peddavagu at RD 264.29 km is

presented at **Annexure 6.12**. Typical plan and section of superpassage is shown at **Plate 6.10.**

c) Syphon aqueducts

Syphon Aqueducts have been proposed along the link canal at the major stream crossings 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, 4 syphon aqueducts are proposed.

d) Canal syphon

Canal syphons have been proposed along the link canal at the major stream crossings 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. The top of the canal syphon barrel is kept about 1 m below the river/drain bed to avoid damages from the rolling stone. A total of 25 canal syphons are proposed. The hydraulic design of canal siphon across Paleru nadi at RD 617.52 km is given as **Annexure 6.13**. Typical plan and section of canal syphon is shown at **Plate 6.11.**

e) Cross regulators / canal regulators

Cross regulators are provided at regular intervals in order to ensure effective water regulation to the command area as well as change in canal sections. In all, 38 cross regulators are proposed along the link canal. The hydraulic design of cross regulator at RD 570.15 km is furnished at **Annexure 6.14**. Typical plan and section of cross regulator is shown at **Plate 6.14.**

f) Head regulators

The link canal is provided with three head regulators at Janampet, Nagarjunasagar and Somasila. These head regulators are normally considered as part of headworks.

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 etc. 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 4 nos. of canal escapes provided in the link canal.

h) Under tunnels/ Over pass

The link canal crosses about 340 nos. of small streams/ existing canal distributaries all along its path. Under tunnels/over passes are provided at these crossings. Box type culverts are proposed for under tunnels/over passes for which head loss is not considered. Piped under tunnels/over passes are also provided where the streams carry insignificant discharge and the elevations are not permitting for box culverts. The hydraulic design of under tunnel at RD 333.17 km is furnished at **Annexure 6.15**. Typical plan and section of undertunnel is shown at **Plate 6.12.**

(j) Bridges

The project area is well developed as far as communications are concerned. There are several roadways and railways encountered by the link canal alignment. Hence, to maintain the existing communications intact and to provide additional communications in anticipation of the developmental activities due to the link canal, several road bridges and railway bridges are proposed. In all, 349 nos. of bridges comprising of 280 of SLRB, 59 of DLRB and 10 of railway bridges are proposed along the length of the canal. The hydraulic designs of road bridges are presented in **Annexure 6.16.** Typical plan and section of double lane road bridge is shown at **Plate 6.13.**

6.7 Cost curves for cross drainage and cross masonry works

The cost curves developed for preparing feasibility studies of various components of Godavari (Janampet) - Cauvery (Grand Anicut) link project are considered in the study. The cost curves adopted while estimating cost of

structures in feasibility studies are updated to 2018-19 price level and made use for estimation of cost of structures of the link project.

6.8 Integration of link canal with the existing reservoirs and canals

The link canal system will be operated as an integral part of existing / proposed reservoirs and existing canal net work for optimum utilization of the created infrastructure and storage capacity.

6.9 Canal automation and branch canals

The canal automation technology being adopted for the contemporary projects considering technological updation, will be adopted for the link project as well.

6.10 Instrumentation

The requirement of special instruments for the construction of barrage, tunnels and pump houses shall be assessed during the pre-construction stage.

6.11 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, if any, will be carried out at preconstruction stage.