Chapter 6
Designs and Layout

6.1 The Head Works

6.1.1 Location of the Head Works

The link canal off-takes from the proposed Inchampalli reservoir on the river Godavari and out-falls in the existing Nagarjunasagar reservoir on the river Krishna. As such, the Inchampalli reservoir is at its head and the Nagarjunasagar reservoir is at its tail end.

6.1.1.1 Inchampalli Project and the Link Canal Off-take

The Inchampalli project is a proposed multipurpose project on the river Godavari. The project comprises of a dam across the Godavari at about 12 km downstream of the confluence of the Indravati with the Godavari River. It is a joint venture project of the states of Maharashtra, Chhattisgarh and Andhra Pradesh.The River Godavari forms the boundary between the states of Chhattisgarh and Andhra Pradesh at the dam site. The project has one hydropower block and two main canals of lengths 293 and 94 kms respectively taking-off from the right and left flanks of the dam. The right flank is located in Mahadevpur taluk of the Karimnagar district of Andhra Pradesh and the left flank is located in Madhya Pradesh.

The Inchampalli project provides irrigation to about 63580 ha of CCA by these canals and generates 975 MW of hydroelectric power to meet peak demand for 10 hours besides providing for pisciculture, recreation and mitigation of flood hazards.

Since the surplus waters available at Inchampalli are proposed to be diverted to Nagarjunasagar and Pulichintala reservoirs through the NWDA link proposals, there will be reduction in power generation in the originally contemplated power scheme of the Inchampalli joint project. Hence, it is now proposed to have a pumped - storage scheme by installing reversible turbine units instead of conventional ones and creation of suitable storage in the downstream of the dam for operation of turbines as pumps in this link project.

The catchment area of the dam is 269000 $km^{2.}$ The total length of the gravity dam is 1701 m (excluding left flank saddle dyke) comprising of masonry dam with overflow and non-over flow sections, power-block and saddle dykes on the right flank. The length of the spillway is 1075.50 m and that of the non-over flow portion is 49 m on the left side of the spillway. A power-block of length 371 m is located on the right side of the spillway followed by an earthen dam with saddle dyke of length 205.50 m.

The maximum height of the masonry dam is 49 m above the deepest foundation level. The MWL / FRL of the reservoir is 112.77 m and TBL is 119m. The gross storage capacity of the reservoir is 10374 Mm^3 (366.38 TMC). The live storage capacity is 4285 Mm^3 (151.35 TMC) above the MDDL of 106.98 m.

The link canal off-takes from the foreshore of the Inchampalli reservoir utilising the Gandamchakla vagu which is on right flank, as an approach channel of length 1.300 km. The designed discharging capacity of the link canal has been assessed as 1090 cumec.

6.1.1.2 Nagarjunasagar project

The Nagarjunasagar project is an existing multi-purpose project on the river Krishna. The project comprises of a dam constructed across Krishna at 1.5 km downstream of Nandikonda village in Nalgonda district of Andhra Pradesh and two main canals, Nagarjunasagar Right Bank Canal (NSRBC) called Jawahar Canal and Nagarjunasagar Left Bank Canal (NSLBC) called Lalbahadur Canal. NSRBC takes - off from the right flank of the dam and NSLBC takes-off from the foreshore of the reservoir on its left flank (irrigating a total area of 6.30 lakh ha). The project has three hydel plants, the main being at the toe of the dam on the left bank and the other two at the canal heads. The project has a total installed capacity of 966 MW of hydroelectric power.

The total length of the Nagarjunasagar dam is 4863 m, comprising of a masonry dam with overflow and non-overflow sections and earth dams on both the flanks. The length of the spillway is 470.92 m and that of the non-overflow masonry dam is 978.71 m. The lengths of the earth dams on the left and on the right are 2560.32 m and 853.44 m respectively.

The maximum height of the masonry dam is 124.66m. The FRL of the reservoir is 179.83m and the MWL 181.05m. The gross storage capacity of the reservoir is 11560 Mm^3 and live storage capacity is 5733 Mm^3 above the MDDL of 155.45m.

6.2 Design Features of Godavari (Inchampalli) – Krishna (Nagarjunasagar) Link Canal

6.2.1 Description of the Canal System

6.2.1.1 The Main Canal

The proposed link canal off-takes from the foreshore of the Inchampalli reservoir utilising the existing Gandamchekla vagu as an approach channel of 1.300 km long. An initial 35.000 m static lift (stage – I) is proposed to maintain a full supply level of 141.000m from where the actual link canal commences at RD 0.000 km to divert 16426 Mm^3 of water.

The link canal runs for most of its length in southwest direction from the Inchampalli reservoir to the Nagarjunasagar reservoir. In the initial head-reach of about 65.000 km, the canal runs in dense forests and the remaining in patta lands. The total length of the canal from the Inchampalli to its outfall at the Nagarjunasagar reservoir is about 299.256 km. The FSL of the canal at the off-take and out-fall points are 106.000 and 180.254 m respectively. The link canal runs in moderate lifts and by gravity in its initial stages upto RD 60.500 km. The total lift involved is about 107 m in four stages. The lifts involved in four stages at RDs 0.000, 18.000, 26.500 and 60.500 kms are 35, 38, 23 and 11 m respectively. It crosses the ridge between the Godavari and the Krishna basins through a tunnel of about 9.150 km length from RD 86.350 to 95.500 km. The link canal runs in deep cut reaches covering a total length of 161.706 km and the remaining 128.400 km in normal cut / partial cut / full embankments. Maximum depth of the cutting of the canal is 40 m and maximum height of filling is 14 m.

A uniform bed slope of 1 in 20000 has been adopted for the entire link canal whereas in case of tunnel, it is 1 in 5000. The canal is designed as a trapezoidal section with rounded bottom corners and is proposed to be lined for its entire length. Eight typical sections of the canal in four reaches have been designed based on depth of cutting / embankment etc. The velocities at the head and tail ends of the link canal are 1.306 and 1.302 m / sec respectively. The full supply depth is 7.40m in deep cut reaches and is 6.75 m in normal cut reaches. Sections of the

canal at head and tail are 109.60 m x 6.75 m and 104.40 m x 6.75 m respectively. The canal has been designed for 1.1 times the peak discharge. A free board of 1.0m is provided throughout the length of the link canal. The canal designed discharges are 1090, 1074, 1061 and 1041 cumecs for the four reaches 0.000 to 97.500, 97.500 to 162.700, 162.700 to 192.700 and 192.700 to 299.256 kms respectively.

6.2.1.2 The Lead Canal

A Lead Canal is proposed to divert 218 Mm^3 of water from the link canal to the ongoing Kakatiya Canal Stage – II (SRSP stage – II) in order to provide irrigation to the part command area under the Kakatiya Canal. The length of the Lead Canal from its off-take to the outfall point into Kakatiya canal is 21.850 km. It off-takes from RD 97.500 km where the FSL of the link canal is 204.900 m. The FSL of Lead Canal which outfall into the Kakatiya canal is 256.527 m. This difference in levels is proposed to be negotiated through a two stage lifting i.e. at RD 0.000 and 21.000 km with lifts of 40 and 15 m respectively. A uniform bed slope of 1 in 7500 has been adopted for the entire length of the Lead Canal. The Lead Canal is designed as a trapezoidal section with rounded bottom corners and is proposed to be lined. The reach between 9.500 km and 12.500 km involves deep cutting and the remaining length is of normal cutting. The maximum depth of cutting in the Lead Canal is 17 m and the maximum height of embankment is 13 m. Velocities in the deep cut and normal cut portions are 0.825 and 0.761 m / sec respectively. Full supply depth in the deep cut reach is 1.90 m and it is 1.65 m in other reaches. Cross section of the canal both at the head and tail end is 9.0 m x 1.65 m. The designed discharge is 16 cumec.

6.2.2 Utilisation of Water Potential from the Streams Crossed by the Link Canal

Various streams and rivulets crossed by the Godavari (Inchamapalli) – Krishna (Nagarjunasagar) link canal are not perennial. The yields are undependable and flowing in drought-prone areas. Moreover, all the streams flowing in this area are inter connected by a series of tanks, which play vital role for drinking and irrigation purposes. In view of the above, utilization of water from these enroute streams may not be feasible.

6.2.3 Description of Soil Profile along the Canal Alignment

Geo-physical investigations along the Inchampalli – Nagarjunasagar link canal from RD 78.350 km to 299.256 km has been entrusted to the National Geo-physical Research Institute (NGRI), Govt. of India, and Hyderabad for assessing the soil profile. A report on Geological investigations submitted by Geological Survey of India (GSI), Hyderabad contains particulars of soil profile along the link canal alignment from RD 59.750 to 78.350 km. Based on this data, NWDA has extra-polated the soil profile data from RD 0.000 to 59.750 km.

6.2.4 Evaluation of the Design Parameters Based on Samples Collected En route

54% of the canal alignment generally runs in deep cutting and 43% runs in normal cutting / partial cutting & filling / full embankments. The soils as available from cutting and adjoining identified borrow areas are considered to be generally suitable for embankment purposes.

6.2.5 Lining

The IS 3873–1978, recommends minimum thickness of CC lining related with the canal capacity and full supply depth. For a canal capacity of 300 to 700 cumecs and FSD 6.5 to 9.0 m, a minimum thickness of 12 to 15 cm is recommended. However, considering other R&D works done on this aspect and the thickness of lining provided on other major projects, a 100 mm thick CC 1: 2: 4 lining is proposed for both bed and sides throughout the length of the canal.

6.2.6 Transmission Losses

The transmission losses are assumed as 0.60 cumec per million sq.m of wetted area as per the Bureau of Indian Standard Code IS: 10430 – 1982.

6.2.7 Design Calculations for Adequacy of Canal Section Formulae Used

a) Formulae used

The canal sections for various reaches are designed using Manning's formula,

$V = (1/N) R^{2/3} S^{1/2}$

Where,

V = Velocity

N = Rugosity Co-efficient

= Bed slope

= Hydraulic mean depth (A/P)

A = Area of cross section —

$= bd + \frac{d^2}{2}(\phi/2 + \cot\phi + \text{Cosec}\phi)$ for deep cut portions (considering r = d/2)

$= bd + d^2 (\phi + \cot \phi)$ (Normal cut portions) (Considering r=d)

P = Wetted perimeter

$= b + d (\phi + \cot \phi + \text{cosec } \phi)$ (Deep cut portions)

$= b + 2d (\phi + \cot \phi)$ (normal cut portions)

b = bed width

d = depth of water

ϕ = Angle of side slope

The formula adopted for critical velocity is $V_o = 0.55\ d^{0.64}$

The Rugosity co-efficient for the lined canal is taken as 0.018. Side slope of 1.5 H : 1 V is adopted except for deep cutting in hard rock where the slope adopted is 0.5 H : 1V. A uniform bed slope of 1 in 20000 is adopted for the entire length of the canal.

(b) Design of Canal Sections in Various Reaches

The Inchampalli – Nagarjunasagar link is planned to divert annually a total quantity of 16426 Mm^3. As per the simulation studies carried out for the Inchampalli reservoir integrating the proposed Bhopalapatnam reservoir, peak discharge works out to 990.52 cumec based on the maximum diversion of 2653 Mm^3 proposed through the link during August.

The canal sections are designed for the above peak discharge increased by a capacity factor of 1.1 to take care of any future eventualities. As such the designed discharge at the head is taken as 1090 cumec. The canal is designed for this discharge as a trapezoidal section with rounded corners and to be lined for its entire length. The hydraulic design is done as per Manning's formula with values of co-efficient of rugosity as 0.018 and 0.014 for the open channel and the tunnel portion respectively. The

typical sections of the canal as given in IS 10430 – 1982 “Criteria for design of lined canals and guidelines for selection of type of lining” are adopted.

As the canal advances from the reservoir, the discharge in the canal gets reduced due to drawl of water into the branch canals to meet the requirement of enroute commands, resulting in scope for reduction in the canal section. Hence, the canal is broadly divided into suitable hydraulic reaches depending on the reduction in the discharge and the sections have been designed accordingly into 4 reaches.

Salient features of the link canal at its head and the tunnel are given in Table 6.1.

Table 6.1
Salient Features of the Link Canal and Tunnel

A	**Link canal at Head**	
	Type of canal	Lined(Trapezoidal with bottom rounded corners)
	Design discharge	1090 cumec
	Bed width	109.60 m
	Full supply depth	6.75 m
	Velocity	1.306 m / sec
	Bed slope	1 in 20,000
	Side slope	1.5 H to 1 V
	Manning’s ‘N’	O0.018
B	**Tunnel**	
	Shape	Modified Horse-Shoe
	No.of tunnels	2
	Design Discharge	545 cumecs each
	Diameter of tunnel	16 m
	Velocity	2.8 m / sec
	Bed Slope	1 in 5000
	Manning’s ‘N’	0.014

The head loss calculations for various major structures along the link canal have been worked out and taken into account as given in Table 6.2.

Table 6.2
Head Loss Calculations for Major Structures

S.No	Name of the Structure	RD (km)	Head Loss (m)
A	**Aqueducts**		
1.	Akeru river	153.590	0.156
2.	Palleru river	167.065	0.122
3.	Gudipalli vagu	289.000	0.111
B.	**Syphon Aqueducts**		
1.	Palleru river	223.425	0.106
2.	Pedda vagu	239.030	0.106
3.	Hallia river	260.700	0.156
4.	AMRLIS canal	292.040	0.101
5.	AMRLIS canal	294.530	0.101

The head losses for the remaining structures are considered as given in Table 6.3.

Table 6.3
Head Losses Provided for the Remaining Structures

Sl.No	Name of the Structure	Head Loss (m)
1.	Super passage	0.030
2.	Road / Railway bridge	0.010
3.	Regulator	0.200
4.	Under Tunnel	Nil

The typical hydraulic designs of the above structures have also been carried out and it is found that the head losses obtained are within the above values only.

The total head loss due to structures worked out to be 5.479 m. in the entire 299.256 km length of the canal and that due to bed fall is 16.502m.

6.3 Canal Structures

6.3.1 General

Based on field survey, the locations of the cross drainage works and cross masonry works have been identified. In general, aqueducts have

been proposed across major rivers / streams and under tunnels across small drains. Super passages have been provided where the drains are to be taken over the canal. Cross regulators have been proposed at the off-take points of the branch canals and at the points of change in the section of the canal to facilitate negotiation of variation in the bed width and levels.

6.3.2 Cross Drainage Works

In its entire run of 299.25 km, the link canal has been provided with 105 cross drainage works which comprises 3 aqueducts, 8 syphon aqueducts, 36 super passages and the rest 58 are under tunnels. The design flood value of each drain has been worked out using the empirical formulae as given in Table 6.4 which were adopted by the Irrigation Department of the Government of Andhra Pradesh.

Table 6.4
Formulae for Computing Design Flood

Sl.No	Catchment Area (Sq. km)	Design Flood Value (cumec)
1	< 2.6	$19.5\ A^{3/4}$
2	2.6 to 78	$16.70\ A^{3/4}$
3	78 to 1300	$14.75\ A^{¾}$
4	>1300	$123.20\ A^{½}$
'A' represents catchment area of the drain		

Source: Inchampalli project Report, Govt. of A.P

6.3.2.1 Aqueducts / Syphon Aqueducts

Three aqueducts have been proposed at the crossings of the major streams where the bed level of the canal is above the high flood level of the drain. A total head loss of 0.389 m has been assessed at these three aqueducts based on the hydraulic designs of these structures. Wherever the flood level of the drain is higher than the canal bed but much below the FSL, a syphon aqueduct has been provided. In all, there are 8 syphon aqueducts and a total head loss of 0.570 m has been assessed for these structures based on actual hydraulic designs.

6.3.2.2 Super Passages

Super passages have been proposed at the crossings, wherever the bed level of the intersecting drain is well above the FSL of the link canal. There are 37 such crossings where super passages are proposed. A sample hydraulic design of super passage has been done and head loss worked out to 0.026 m. Hence, a higher value of 0.03 m has been considered.

6.3.2.3 Under Tunnels

Under tunnels have been proposed along the link canal at crossings of small drains. No head loss has been provided at under tunnels. A total number of 57 under tunnels have been identified. Provision has also been made in the cost estimate for small hillside drains and diversion of nalas.

6.3.3 Cross Masonry Works

6.3.3.1 Bridges

A total of 119 road bridges have been proposed across the link canal, of which 16 are double lane and 103 are single lane bridges. Computations of Head loss at the bridges have been carried out using Yarnell's formula. As can be seen, the head loss worked out to be less than 0.01m at the bridges and hence a uniform loss of 0.01 m has been provided for each of these bridges.

The link canal crosses the South Central Railway line at two places. It crosses the railway line connecting Warangal and Khammam at RD 132.965 km near Kesamudram and at RD 240.555 km near Mallepalligudem, it crosses the Nalgonda – Mirialaguda line. Double track railway bridges are proposed at these crossings.

6.3.3.2 Cross / Escape Regulators

In all, 9 cross regulators inclusive of those required at Peddavagu, Tummalgutta and Musi balancing reservoirs at RD 13.500 km, 26.500 km and 199.150 km (both in-fall & off-take regulators at Musi) respectively and a tail end regulator at RD 299.256 km are proposed along the link canal. Two numbers of single lane road bridges – cum – cross regulators are proposed at Chinna Nemulla and Viblapuram branch canals of

Kakatiya Canal in order to connect the existing villages on either side of the canal.

Similarly, 2 escape regulators cum cross regulators are also proposed along the canal at suitable places i.e. at RD 151.800 km and 260.400 km where natural streams are available to accommodate the surplus discharges of the link canal. The discharging capacity of the escape regulator has been considered as half of the designed discharge of the ssscanal at that point. A head loss of 0.20 m has been considered for each of the regulators.