Chapter 6
Structure and Layout

6.1 General

The Krishna (Almatti) – Pennar link canal is proposed to off-take from the right flank of the Almatti dam in Karnataka State. As the Almatti dam is proposed to be used without any modification to the structure, a brief description of the design features of the head works of the Almatti project, as given in the project report, is presented here. However, detailed surveys of the proposed link canal were carried out by NWDA and based on the surveys, the designs of the canal and other CD/CM works have been carried out and are presented in this Chapter.

6.2 Structure, Layout and Design Features of the Head Works

6.2.1 Location of the Head Works

The Almatti dam is an ongoing project on Krishna River just downstream of its confluence with Ghataprabha River near Almatti village in Bagewadi taluk of Bagalkot district in Karnataka State. The construction of Almatti dam has been taken up by the Government of Karnataka in two stages. The link canal is proposed to off-take from Almatti reservoir. The FSL of the canal at off-take is proposed to be 510.00 m. A new reservoir is proposed at RD 386.400 km on river Pennar to serve as a balancing reservoir. The existing Bukkapatnam tank at RD 536.200 km across Chitravati River is also proposed to be utilised as a balancing reservoir.

6.2.2 Components of the Head Works

a) Almatti Dam

The Almatti dam comprises of a concrete spillway in the centre and masonry non-overflow section as well as earthen dams on either flank. The FRL of reservoir is 519.6 m. The total length of the dam is 1564.83 m and its height is 52.24 m. The gross storage capacity of the reservoir is 3439.7 Mm^3 and the live storage 3104.70 Mm^3.

Length of the spillway of Almatti dam is 486.50 m. The non-overflow dam is of length 676.33 m and the earthen dam is of 402.00 m including dykes. There will be regulated release of water from Almatti dam to be picked up downstream at Narayanpur dam for diversion into the left bank canal.

b) Link Canal Off-take

The link canal is proposed to off-take from the right bank of Almatti Dam. The required discharging capacity of the link canal has been worked out to be 230 cumec. A powerhouse is proposed at the head of the link canal. The installed capacity of the powerhouse has been estimated to be 13.5 MW and it is proposed to install 3 generating units of 4.5 MW each. The link canal off-takes from 200m upstream of right flank of the dam. The length of approach channel is about 700m followed by 1125 m long tunnel. A head regulator is proposed at the off-take point.

The link canal is proposed to be operated for 6 months i.e., from June to November. The withdrawal pattern of link canal varies from peak demand of 230 cumec during August to lean demand of 30 cumec during June. The reservoir simulation study conducted reveals that the reservoir level fluctuates from 519.60 m to 514.49 m during June to November.

c) Kalvapalli Balancing Reservoir

The Kalvapalli balancing reservoir is proposed across Pennar River in Anantapur district. The FRL of the reservoir will be 475 m with gross storage capacity of 83 Mm^3 and live storage capacity of 73 Mm^3. NWDA has carried out a detailed topographical survey of the reservoir. The proposed link canal falls into Kalvapalli reservoir at RD 386.400 km with its FSL at 475.606 m and again off-takes from right bank of the reservoir with FSL 463.000 m. The inflow into the reservoir from its own catchment is fully earmarked for uses downstream of the reservoir and will not be diverted into the link canal. The dam is a composite dam with 2825 m earthen portion and 400 m masonry. The non-spillway section is for 300 m and spillway for 100 m in masonry portion. A head regulator for releasing water to the link canal has been provided with two openings of 2 m x 3 m each. The sill level of the regulator is kept at the DSL of 466.00 m. Since the bed level of the canal at the off-take from Kalvapalli dam is 459.4 m, there will be a fall of 6.6 m. Hence, a stilling basin is provided at the outlet for dissipation of energy before water is let into the canal.

d) Bukkapatnam Tank

The Bukkapatnam tank is an existing tank across Chitravati River to store 15.30 Mm^3 of water near Kothacheruvu village, Bukkapatnam Mandal in Anantapur district. The tank is formed by an earthen bund 5.60 km long.

A free over fall masonry weir is located on the left flank and 3 weirs at right flank to discharge a maximum flood of 566 cumec. There are four sluices located in earthen dam to feed eight canals. The FTL of the tank is 448.07m.

The proposed Krishna (Almatti) – Pennar Link canal outfalls into Bukkapatnam tank on its left bank at RD 536.200 km with FSL 449.766 m and again off-takes from the right bank of the tank with FSL 440.00 m. Thereafter the link canal traverses in north direction through the Kottakota reserved forest.

6.3 Design Features of Link Canal

6.3.1 Description of the Canal System

The Krishna (Almatti) – Pennar link canal off-takes from right bank of the Almatti dam on river Krishna with FSL 510.00 m. The general topography of the area through which the link canal passes through is mostly plain. Five tunnels with a total length 35.66 km are proposed along the alignment to cross the ridges. The canal for most of its length runs in south east direction.

6.3.2 Utilisation of Water Potential from the Streams Crossed by the Canal

Various streams and rivulets crossed by the Krishna (Almatti) – Pennar link canal are not perennial. The yields are undependable and the streams are prone to flash floods. One balancing reservoir is proposed across the river Pennar near Kalvapalli. The inflow from its catchment is earmarked for downstream uses. Therefore, augmentation of the flows in the link canal from the waters available in the streams crossed by the canal is planned.

6.3.3 Description of Soil Profile along the Canal Alignment

The details of sub-surface strata have been collected by the CSMRS by excavating open trial pits along the canal alignment. A total of 44 samples have been collected. The trial pits were made where the bed level of the canal is up to 3 m from the NSL. The reaches where the depth is more than 3 m geophysical investigation was carried out.

6.3.4 Evaluation of the Design Parameters based on Samples Collected Enroute

The canal alignment generally runs in partial cutting and embankment. The soils available from cutting and adjoining borrow areas are found to be suitable for embankment purposes. When the canal runs in embankment higher than 8 m, the soils available in the adjoining fields are proposed to be used for formation of the embankment.

6.3.5 Lining

100 mm thick concrete (CC 1:3:6) lining is proposed for both bed and sides throughout the length of the canal.

6.3.6 Design Calculations for Adequacy of Canal Section

(a) Formulae used

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

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

V = Velocity

n = Rugosity co-efficient

S = Bed slope

R = Hydraulic mean depth (A/P)

A = Area of cross section = $bd + d^2 (\theta + \cot \theta)$

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

b = bed width

d = depth of water

θ = Angle of the side slope

The critical velocity for the canal is given by $Vo = 0.55\ d^{0.64}$

A rugosity co-efficient of 0.018, side slope of 1.5 horizontal to 1 vertical and bed slope of 1 in 20000 up to Kalvapalli dam, 1 in 12000 from Kalvapalli to Bukkapatnam and 1 in 15000 from Bukkapatnam to tail end have been adopted. Different bed slopes for three different reaches have been adopted considering the natural soil level to avoid high embankments and deep cutting.

(b) Design of Canal Section in Various Reaches

The peak discharge required at the head of the canal is worked out based on crop water requirement. The design discharge is considered to be greater of the following:

i) 1.1 times the peak discharge and
ii) 1.25 times the average discharge

The design discharge at the head thus calculated is 230.00 cumec, against the actual peak discharge.

As the canal advances from the Almatti dam, the discharge in the canal gets reduced at different reaches due to drawl of water to meet the irrigation requirement of enroute command. This necessitates reduction in canal section in order to affect economy. Hence, the canal is broadly divided into suitable hydraulic reaches and sections are designed to carry the required discharge in that particular reach.

The entire canal is divided into six reaches based on the following consideration.
i) Downstream of major off-take points
ii) Considerable reduction in the discharge

The velocity at different reaches is in the range of 1.02 to 0.740 m/sec. The full supply depth provided is 5.25 m in the head reach and 3.00 m in the tail reach. A free board of 0.75 m above FSL is provided throughout the length of the canal.

6.4 Canal Structures

6.4.1 Cross Drainage Works

As the link is aligned as a contour canal, it crosses several streams, rivers, roads and hills. The type of cross drainage work depends upon the HFL and bed level of the stream with reference to full supply level and bed level of the canal at the crossing. In its entire length of 587.175 km of the link canal, 99 cross drainage works are provided, which comprise of 21 aqueducts, 30 super passages and 39 canal syphons and 9 syphons aqueducts. In addition, 31 under tunnels are provided.

6.4.2 Cross Masonry Works

The link canal crosses a number of roads and railway lines enroute. The location of road / rail bridges has been ascertained from topographical surveys. A total of 97 road bridges, 5 nos. of cross regulators and 2 nos. escape regulators have been provided.

6.4.3 Tunnels

The link canal along its entire length of 587.175 km, pass through 5 tunnels for a total length of 35.66 km. Shortest tunnel is of 1.125 km and longest is of 20 km length. Altogether there are 220 structures. Details are given in Table 6.1

Table 6.1
Number of structures

Type of structure	Numbers
Head works	3
CD works	99
CM works	113
Tunnels	5
Total	220

6.4.4 Power House

It is proposed to generate power from the discharge of link canal at the exit of tunnel no.1 at the off-take point from Almatti reservoir. An approach channel of 700 m long and 32.00 m wide off-takes from the foreshore of Almatti dam, followed by a tunnel of 1.125 km and 9.0 m dia. A fore bay of 12 m long and 63.6 m wide is provided at the exit of tunnel. A reinforced concrete intake structure consisting of 6 nos. of vents of 2.0 m x 5.0 m is provided at the end of the intake fore bay to feed turbines at 2 vents for each turbine. Three nos. of turbines of 4.50 MW each has been proposed. The details are given under Chapter on 'Power'.

6.4.5 Head Loss at Different Structures

Head losses due to various CD/CM works have been worked out using the formulae given in I.S. Codes and text books.

The head loss due to various structures works out to 20.366 m, including the bed slope within the structures.

6.5 Alternative Proposal to be considered for Detailed Investigation at the time of Preparation of DPR

6.5.1 Canal instead of Tunnel between RD 77.9 to 97.9 km

The alignment of the canal from RD 77.90 km to RD 97.90 km passes through the tunnel with less core overburden. Hence, instead of tunnel the canal can be detoured. The length of detoured canal works out to approximately 100 km. The comparative costs of the alternatives are to be worked out.

6.5.2 Crossing Point of Road connecting Arod to Gaddi Village at RD 154 km.

The proposed canal at RD 150 km runs along the foothills and after traversing for a distance of approximately 6 km, it takes a 'U' turn and at RD 154.057 km it takes a 60^{o} turn and moves away from the hills. Between RD 150 and 166 km, the link canal passes through high embankment in the order of 30 m for about 3 km around the periphery of the hillock. The alignment along the foothills was proposed to cover the command area around the periphery of the hillock. Alternatively a tunnel can be provided from RD 154 km to avoid the provision of high embankment and this will also help in reducing length of the canal from 18 km to approximately 5 km. Since the Tungabhadra Left Bank Canal passes in close proximity with the proposed link canal, the command area around the foothills is very marginal. Small distributaries from the off-take and exit of tunnel may be able to cater to the irrigation needs of the command area around the foothills. The provision of tunnel appears to be a better proposition and detailed investigation may be carried out at the time of preparation of DPR.

6.5.3 Provision of Tunnel between R.D. 211 to 214 km

As per pre-feasibility report the canal alignment at this reach passes through the foot hill very near to the Tungabhadra High Level Canal. The link canal at this reach will run in deep cutting. Virtually there is no space for canal excavation between the hill and the High Level Canal. The canal has, therefore, been diverted through the hillock. Since, the overburden is more than 50 m, a tunnel can be provided at this reach.

6.5.4 Possible Reduction in Cost of Project

In the pre-feasibility report, the off-take level at Almatti was taken as 510 m considering the FRL of 512.256 m. Subsequently, the FRL has been raised to 519.60 m and there is a proposal to further increase the FRL to 524.256 m. The off-take level of the link canal can, therefore, be raised to 516.00 m which will enable raising of bed level of the canal in the initial reach, where it is running in deep cutting, besides helping to increase the gradient of four tunnels to 1:3,500 from 1:10,000 enabling considerable reduction in the diameter of tunnel which will also cause smooth transition from open channel to tunnel and from tunnel to open channel at the intake and exit of tunnels, respectively. Since the CCA available in all the en route sub-basins are much more than as envisaged in the PFR, the canal can be terminated at Bukkapatnam tank and the CCA in the en route sub-basins increased proportionately so that the total CCA of the link canal remains unchanged. The savings from the excavation and lining of the canal and tunnels by increasing the off-take level from 510.0 to 516.0 m is estimated to be Rs. 53,000 lakhs and from curtailment of canal beyond Bukkapatnam is Rs. 66,600 lakhs approximately. The total cost of the project works out to Rs. 540,380 lakhs against Rs. 659,980 lakhs and the corresponding B.C. Ratio will be 1.35.