

Chapter 4

Surveys and Investigations

4.1 Topographical surveys

4.1.1 Canal and canal structures

The centre line of the link canal marked on the 1:50000 scale toposheets of Survey of India has been transferred to the ground by first measuring the bearings of the alignment on the toposheets and then setting them on ground with the help of compass/theodolite. In the initial reach upto RD 202.75 km where the link canal runs by the side of the existing NSRBC to its right, the centre line of the link canal is aligned 35 to 60 m away from the top inner edge of the existing right bund of the NSRBC.

Along the centre line of the link canal, levels are taken at 50 m interval upto RD 202.75 km and at 200 m interval from RD 202.75 km to the tail end, by double levelling. The double levelling carried out was checked for its accuracy by connecting to many GTS bench marks located along the alignment.

Cross sections are taken by single levelling at 200 m interval along the alignment in the reach upto RD 202.75 km, with levels at 50 m interval extending upto the inner edge of the right bank of NSRBC on the left of centre line of the link canal and upto 200 m on its right. From RD 202.75 km to the tail end, the cross sections are taken at 400 m interval along the alignment with levels at 100 m interval extending upto 200 m on either side of the alignment. Wherever appreciable change in topography is noticed along the cross sectional lines, levels are taken at closer intervals.

Block levelling has been carried out at places where cross drainage works are proposed by forming 50 m or less interval grid lines to cover an area upto 300 m on either side of the centre line of the link canal along the stream and laterally upto the firm bank plus 100 m on either bank of the stream. Similarly, block levelling by forming 50 m interval grids was done at road/railway crossings along the alignment, covering an area upto 300 m on either side of the centre line of the link canal and 100 m either side from the centre line of the road/railway. However, block levelling was extended only upto the existing structures on NSRBC, to the left of alignment, upto RD 202.75 km.

4.1.2 Powerhouse, switch yards, surge-shaft, tailrace, etc.

Block levelling by forming 10 m interval grid lines has been carried out near the off-take point of the link canal covering an area of 260m x 160m at the proposed site for locating link canal head regulator, power house, switch-yards, tail race channel etc. The length of the grid along the link alignment is 260 m and the width of the grid is 160 m extending to 60 m on the left of centre line upto the existing NSRBC and to 100 m to the right side of the centre line of the proposed link canal.

4.1.3 Tunnel

A tunnel of length 1.265 km has been proposed across Pasuvemula ridge between RD 3.580 km and 4.845 km, parallel to the existing Pasuvemula tunnel of NSRBC. A centre to centre distance of 100 m is kept between the two tunnels. Block levelling has been carried out by forming 50 m grid lines extending upto 100 m on upstream and 100 m on downstream of in-let and exit of tunnel, extending upto 500 m on the right side of the centre line of the link tunnel and on the left side, upto the centre line of the existing Pasuvemula tunnel of NSRBC. Levels at 50 m interval were taken for the complete length along centre line of tunnel and cross sections were taken at 200 m interval along the centre line taking levels at 50 m interval, extending upto 200 m on the right side and upto the centre line of the existing Pasuvemula tunnel of NSRBC on the left.

4.1.4 Command area

Major part of the command area proposed enroute the link lies in the Prakasam district and the rest in the Nellore district of Andhra Pradesh. The proposed gross command area is about 3.76 lakh ha excluding the land covered under water bodies and the culturable command area is about 168017 ha. The topographical mapping of the command area was entrusted to Survey of India (SOI), Hyderabad. The Survey of India has supplied 41 maps in all, which were prepared to a scale of 1:25000 with contours at 5 m vertical interval covering the entire command area. These maps with closer ground elevation information were utilised for drawing the layout of branch canals and distributory network for the command area.

4.2 Soil conservation, archaeological and mineral surveys

As the link proposal is not envisaged to construct any new reservoirs, archaeological and mineral surveys and surveys for soil conservation as required in case of reservoirs were not undertaken.

4.3 Geology and geo-technical features

The Geological Survey of India (GSI) was entrusted with the work of preparation of preliminary geological report of the proposed powerhouse site and tunnel. The report was prepared by the GSI after field visits by their Geologist to the respective sites. Geological mapping of the proposed tunnel alignment and examination of powerhouse site were carried out during the investigations.

The geo-technical evaluation of the above sites, as enunciated by the GSI in their report is enumerated in the following paras:

a) Powerhouse site

The area around the existing power house at the toe of the Nagarjunasagar dam and at the commencement of the right bank canal does not exhibit any rock outcrops, since it is all either covered by soil or by recreation items like parks. The present proposal of the project is to have powerhouse at the toe of the dam and at the head of the Krishna (Nagarjunasagar) - Pennar (Somasila) link canal. At this site also, no rock outcrops are noticed.

The ground level at the proposed powerhouse site would be around 162 m while the deepest foundation level for the powerhouse would be around 127 m. Thus a maximum depth of 35 m of excavation would be involved to reach the bottom most level in the powerhouse. From the sub-surface exploratory data available from the Nagarjunasagar dam site, it is expected that the excavation for the proposed power house might pass through 2 to 3 m thick soil at the top, below which predominant quartzites with sub-units such as thin bedded quartzites and shaly quartzites might occur between RL 162 m and 144 m, and massive quartzites in between RL 144 m and 128 m.

These rock types belong to Srisailam formation of the Cuddapah Super Group. They are predominantly horizontally bedded. These quartzites overlie the basement granites (Archaean) as recorded in the foundations of the Nagarjunasagar dam, at about EL 109 m.

Excepting open vertical joints likely to be present in the quartzites in the top horizons below the soil cover, the excavation, if done with proper slopes, can be expected to pose no major problems regarding slope stability. Detailed assessment of the geological conditions at the proposed powerhouse site can be made at the pre-construction stage by undertaking subsurface exploration.

b) Tunnel

Massive quartzites are exposed as small patchy outcrops and also as blocks/boulders mixed with reddish brown soil over most of the area along the proposed alignment of the tunnel. The quartzites are pale brown and buff coloured, and are medium to fine grained. They are horizontally bedded except for minor undulations. Two prominent sets of vertical joints trending in N 75° W – S 75° E and N.E. – S.W., directions are present in the quartzites besides bedding joints. However, the following joint sets, which are less prominent, are also present:

S.No.	Strike	Dip
i)	N10° to 30°W – S10° to 30°E	Vertical
ii)	N – S	Vertical
iii)	E – W	Vertical
iv)	N 20° E – S 20°W	80° towards N 70°W

The proposed tunnel is considered feasible in the context of improved present day techniques in the support system which are available today. However, in view of non-uniform thickness and distribution of various sub-units present within the quartzites, a detailed sub-surface exploration by means of bore holes would be necessary in order to prepare a dependable geological section based on which the tunnel level itself can be decided and tunnelling conditions can be prognosticated. Such a programme of drilling can be mounted and taken up during the pre-construction stage.

4.4 Foundation investigations along the canal alignment

The characteristics of various soils at river crossings/proposed CD works along the length of the canal beyond RD 202.75 km up to the tail end have been studied by collecting soil samples at 22 locations. These samples were tested at Andhra Pradesh Engineering Research Laboratory (APERL), Hyderabad.

To derive the surface profile of the formations along the link alignment beyond the RD 202.75 km, 72 open wells along and in the vicinity of the alignment were measured for the thickness and depth of each formation below the ground level. With the help of these measurements the sub-surface profile was drawn for the entire reach beyond RD 202.75 km.

For the initial reach of the link canal, i.e upto RD 202.75 km, the detailed classification of soils done by the Govt. of Andhra Pradesh by excavating open trial pits/auger holes for the existing NSRBC are adopted for the link canal as the link canal is proposed to be aligned adjacent to the NSRBC.

4.5 Construction material investigation

Necessary borrow/quarry area surveys have been carried out for construction materials such as soils for embankments, stone, sand etc. after identifying the locations of quarries and borrow areas in the vicinity.

4.5.1 Soils

Thirty five borrow areas have been identified along the entire length of the alignment from which soil samples have been collected and tested in Andhra Pradesh Engineering Research Laboratory (APERL). The test results indicate that soils from most of the identified borrow areas are generally suitable for embankment. It is estimated that about $35.75 \times 10^6 \text{ m}^3$ of earth is available from these quarries. The average lead is around 10 km.

4.5.2 Sand

Eleven sand quarry sites have been identified for the entire length of the link canal from Nagarjunasagar to Somasila. Three sand quarries have been identified in the rivers Halliar, Konkeru and Musi from which sand can be obtained and used for the initial reach upto 210 km. The average

leads from the above quarries are 70 km, 58 km and 77 km to the respective nearby reaches. Another 8 sand quarries have been identified for the remaining portion of the canal with an average lead varying from 6 to 40 km from various quarries to the respective reaches. Among the 11 quarries, three representative samples were tested at APERL. The total sand is about $2.95 \times 10^6 \text{ m}^3$.

4.5.3 Rock and aggregates

Fourteen stone quarries have been identified in the vicinity of link canal, which cumulatively yield $59.8 \times 10^6 \text{ m}^3$ of stone. Quarry No. 1 to 6 are in the vicinity of the existing NSRBC and stones from these quarries were used for the construction of NSRBC. Since the proposed link canal is close to the existing NSRBC, the same quarries can be utilised for the construction of the initial reach of proposed link canal alignment. Four representative samples from the remaining 8 quarries were tested at APERL and found generally suitable for the construction work. The average lead from different quarries varies from 9 to 36 km to the respective reaches.

4.5.4 Bricks

Soils of suitable quality for manufacture of bricks and tiles for use in building construction are available along the entire length of canal alignment. Gopalapuram village near Pamur is famous for good quality bricks in Prakasam district.

4.5.5 Cement and steel

Cement manufactured by reputed companies located in the vicinity at Macherla, Karampudi and Pidiguralla is proposed to be used. Cement and steel can be received at the railway stations located near the canal alignment i.e Macherla, Pidigurala, Vinukonda, Kurichedu, Donakonda, Ongole, Singarayakonda, Kavali, Kovur and Nellore and transported to the site of construction.

4.6 Soil surveys - mapping of existing land use/land cover and irrigability

Red earths, red sandy soils and black cotton soils are the predominant soils available in the command.

The work of preparation of thematic maps of i) existing land use/land cover, and ii) soil and land irrigability of the entire new command area of 394514 ha was entrusted to the National Remote Sensing Agency (NRSA), Hyderabad. The NRSA has utilised satellite remote sensing data for the thematic mapping of the command area. The LISS-II data obtained through Indian Remote Sensing Satellite (IRS-1B) was made use of for the work. In addition to the thematic mapping for the command as above, the NRSA has also done studies for the land evaluation for crop suitabilities and incorporated the same in the report prepared by them. The thematic maps of the land use/land cover and land irrigability prepared and supplied by the NRSA were utilised for planning of the command area and visual presentations of land use/land cover in coloured maps. Irrigable tracts of land were delineated and demarcated on 1:50000 land irrigability maps which facilitated reliable identification of the irrigable area under each of the branch canals.

Land use classification details

The land use/land cover classification details of the command area of the link canal generated by application of the satellite remote sensing data are given in Table 4.1.

Table 4.1
Land use/land cover statistics of the command area of Krishna
(Nagarjunasagar) - Pennar (Somasila) link Canal

Class	Sub-class	Land use / Land cover category	Area in ha	Percentage
I	1	Settlements	3724	0.94
II		Forest land		
	2	Degraded forest (D.F)	13131	3.33
	3	Open forest (O.F)	6759	1.71
		Sub total	19890	4.04
III		Agricultural land		
	4	Kharif crop land (single crop)	143151	36.28
	5	Rabi cropland (single crop)	7248	1.84
	6	Double crop land (kharaff & Rabi)	55298	14.02
	7	Fallow	25111	6.37
		Sub total	230808	58.51
IV		Waste lands		
	8	Land with or without Scrub	95168	24.12
	9	Barren Land	7424	1.88
	10	Sand (Coastal/River/Desertic)	19053	4.83
		Sub total	121645	30.83
V	11	Water (Tanks/Streams)	18447	4.68
		Total	394514	100.00

Total geographical area	= 394514 ha.
Total crop land (Kharif + Rabi + Double crop)	= 205697 ha (52.14%)
Total kharif cropped area	= 198449 ha.
Total rabi cropped area	= 62546 ha.

Soil classification

Soils in the proposed command area are mainly falling under four orders viz. Inceptisols, Alfisols, Vertisols, and Entisols. About 63% of the gross command area is covered by Inceptisols, 26% by Alfisols, 8% by Vertisols and the remaining 3% by Entisols. Table 4.2 shows physiography and soil classification in the proposed new command area enroute the link canal.

The available soils of the command area so grouped according to the physiographic units have been classified into soil irrigability classes considering various soil characteristics such as soil depth, texture, permeability, moisture holding capacity, sub-surface cover, salinity, sub-soil drainage, erosion status etc.

Table 4.2
Physiography and soils in the proposed command area enroute the Krishna (Nagarjunasagar) – Pennar (Somasila) link canal

Soil Mapping unit	Physiography	Soil Classification	Area (km ²)
C	LANDSCAPE OVER COASTAL ALLUVIUM		
C1	Coastal plane	Fine undertic Ustochrepts	27.425
C2	Back swamps	Fine Aquic ustochrepts	7.975
C3	Beach ridges	Typic Ustipsaments	5.775
G	LANDCAPE OVER GRANITE/GRANTIC-GENISSES/SCHITST/ PHYLLITES		
G1	Residual hills/Inselbergs	Loamy-skeletal lithic/typic Ustochrepts	107.325
G2	Pediment		
G21	With moderate erosion	Loamy-skeletal Typic Ustochrepts Loamy-skeletal Typic Rhodustalfs	287.025
G22	With severe erosion	Loamy-skeletal Typic Ustothents Loamy-skeletal Typic Ustochrepts	103.425
G3	Buried pediment		
G31	Nil to slight erosion	Fine Typic Haplusters	20.025

		Fine Vertic ustochrepts	
G32	Moderate erosion	Fine Loamy Typic Ustochrepts Fine Vertic ustochrepts	41.775
G4	Weathered pediplain		
G41	Nearly level	Fine typic RhodustalFs	230.440
G42	Gently sloping		
G421	With slight erosion	Fine loamy typic HaplustalFs Fine Typic RhodustalFs/HaplustalFs	636.150
G422	With moderate erosion	Loamy-skeletal Typic Ustochrepts Fine loamy Typic HaplustalFs	622.725
G423	With severe erosion	Loamy-skeletal Typic Ustochrepts	104.425
G5	Buried pediplain		
G51	Nearly level	Fine Typic HaplustalFs Fine Vertic ustochrepts Fine Typic/Vertic ustochrepts	280.900
G52	Gently sloping	Fine Loamy Typic ustochrepts	171.225
G6	Valley fill		
G61	Salt affected		
G611	Moderate affected	Fine typic (Saline-Sodic) Ustochrepts	221.025
G612	Severe affected	Fine (Saline-Sodic) typic Ustochrepts	186.500
G62	Non Salt-affected	Fine Typic/vertic Ustochrepts Fine loamy Fluventic ustochrepts	600.400
L	LATERIC LANDSCAPE		
L1	Weathered pediplain		
L11	Nearly level	Fine loamy typic RhodustalFs	57.200
L12	Gently sloping	Loamy skeletal typic Ustochrepts/ Ustrothents	54.950
		Total	3766.690

Land irrigability classification

Land irrigability classification is further grouping of the irrigable soils into land irrigability classes considering the slope, subsurface grading, drainage, depth of water table below ground level etc. Land suitable for irrigation is grouped under classes 1 to 4 according to their limitations. Lands not suitable for irrigation are grouped under classes 5 and 6.

The final irrigability classification details of the command area of the Nagarjunasagar - Somasila link canal obtained by the above methodology are given in Table 4.3.

Table 4.3
Irrigability classification of the command area of the Krishna
(Nagarjunasagar) - Pennar (Somasila) link canal

Land irrigability class	Characteristics	Limitations for sustained use under irrigation	Soil mapping units*	Area (in lakh ha.)
1	Nearly level, deep rooting zone, good permeability favourable texture and moisture holding capacity.	Few limitations	-	-
2	Very gentle slopes, less than ideal soil depth, texture permeability, moderate salinity/ alkalinity, unfavourable topography and drainage conditions.	Moderate limitations	C1, G31, G32, G41, G421, G422, G51, G52	2.03
3	Gentle slopes, unfavourable soil depth, texture and permeability, moderate to severe salinity/ alkalinity, unfavourable topography or drainage conditions	Severe limitations	G21, G423, G62, L11, L12	1.10
4	Moderately steep slopes, unfavourable soil depth, texture, permeability, severe salinity, very unfavourable topography and drainage conditions	Very severe limitations	C2, G22, G611	0.33
5	Temporarily not suitable for sustained use under irrigation	-	-	
6	Not suitable for sustained use under irrigation	-	C3, G1, G612	0.30
			Total	3.76

*The alphabets C,G and L indicate different physiographic units of Coastal alluvium, Granite/Gneiss and Laterites and the numbers 1,2,3 etc. indicate sub-classes within the same physiographic unit.

Land evaluation for crop suitabilities

The land evaluation for crop suitabilities is the process of evaluating the potential of the land for growing specific crops. The land under each mapping unit is independently evaluated for the principal crops grown in the area, viz. paddy, cotton, tobacco, sunflower, chillies, and soyabean

to assess their suitability or otherwise for sustained production. The Food and Agricultural Organisation (FAO) frame work which involves pragmatic classification was followed in the evaluation of the land in the command area of the Krishna (Nagarjunasagar) - Pennar (Somasila) link and recommendations on crop suitabilities for the classes of land found in the command area were also included in the report prepared by NRSA. The scheme of evaluation envisages two orders – one “suitable” (S) and the other “not suitable” (N). The suitability order is further divided into four classes viz, (1) highly suitable without any limitations, (2) suitable with slight limitations, (3) moderately suitable with moderate limitations, and (4) marginally suitable with severe limitations. The soil suitability rating for different principal crops grown in the area as assessed by NRSA and indicated in the report are presented in Table 4.4.

Table 4.4
Soil suitability ratings for principal crops grown in the command area

	Paddy	Cotton	Tobacco	Sunflower	Soyabean	Chillies
G1	N	N	N	N	N	N
G21	N	S4	N	S3	N	N
G22	N	N	N	S4	N	N
G31	S1	S1	S2	S2/S3	S1	S1
G32	S2	S2	S2	S2/S3	S1	S2
G41	S2	S3	S1	S2	S1	S3
G421	S2	S3	S1	S2	S1	S3
G422	S3	S4	S2	S3	S2	S4
G423	S3	S4	S3	S3	S3	S4
G51	S1	S1	S2	S2/S3	S1	S1
G52	S2	S2	S2	S2/S3	S1	S2
G611	S3	N	N	N	N	N
G612	N	N	N	N	N	N
G62	S1	N	N	N	N	N
L11	S2	S3	S2	S3	S3	S2
C1	S1	S3	N	S4	S3	S4
C2	S3	N	N	N	N	N
C3	N	N	N	N	N	N

S1= Highly suitable without any limitations; S2= Suitable with slight limitations; S3= Moderately suitable with moderate limitations; S4= Marginally suitable with severe limitations; N= Not suitable.

4.7 Drainage survey

The proposed enroute command area is well drained by rivers/streams like Musi, Palleru, Manneru and also by a number of major/minor drains. As such, the proposed command area is not likely to encounter any serious drainage problem. However, certain provision is made in the estimate for providing drainage facilities in the command, though no detailed surveys were undertaken for the purpose. The information available on natural drainage system in the command area in the form of rivers, streams, nallas etc. is utilised. Since the branch canals and major distributaries are planned as ridge canals, no major drainage problem is anticipated in the command area.

4.8 Communication surveys

All the important structures of the Nagarjunasagar - Somasila link project are approachable by pucca / kachcha roads. The National High way No. 5 and the South Central Railway line connecting Chennai and Vijayawada passes through the eastern part of the proposed command area. All the important villages/towns situated along the canal alignment and in the command area are well connected by telephone lines, power lines and wide network of roads. There can be further improvement in the communication system in the command area in the course of development in future. Inspection roads of major branch canals in the command area would lead to further improvement in the communication systems.

4.9 Hydrological and meteorological investigations

The data from hydrological and meteorological stations available in the command area were collected and used for computations and designs of the canal components. The details of these stations are given in the following paragraphs:

4.9.1 Hydrological data

There are four gauge and discharge sites in the basin of streams between Gundlakamma and Pennar, out of which one site at V.G. Palem on Musi River is maintained by CWC and the remaining three sites at Palleru-Bitragunta Anicut, Rallapadu reservoir and Lower Upputeru Anicut, are maintained by the Government of Andhra Pradesh. The required data of these stations have been collected.

4.9.2 Climate

The summer season is from March to May, the monsoon is from June to December and the winter is from January to February in the vicinity of the command area. There are three IMD observatories namely, Ongole, Nellore and Cuddapah in and around the command area and the nearest one to the proposed command area is at Ongole. The data on rainfall, temperature, relative humidity, wind speed, cloud cover, etc. are available at the observatories.

4.9.3 Rainfall

There are 25 raingauge stations in and around the command area. The rainfall data for these raingauge stations are available for varying periods.

4.9.4 Temperature

The monthly average maximum and minimum temperatures observed at Cuddapah observatory are 40.3° C in the month of May and 19.1° C in the month of December respectively.

4.9.5 Relative humidity

The maximum and minimum values of relative humidity observed at the three observatories are 84% and 36% respectively.

4.9.6 Wind speed

The command area is influenced by winds from the south-west during the monsoon season. The maximum wind velocity is 11.6 km/hr in June and the minimum is 4.30 km/hr in December.

4.9.7 Cloud cover

The sky is heavily clouded during the south-west monsoon. During remaining part of the year, clear or lightly clouded sky prevails. The maximum cloud amount is 6.7 oktas in the month of July and minimum is 1.5 oktas in the month of January.