PART - I

Chapter I

INTRODUCTION

INTRODUCTION

PRELUDE

Irrigation is being practiced in the country from the times immemorial as is evident from the ancient literature and historical records. The existence of a number of old irrigation structures in different parts of the country, which are still in use, further testifies it. The nature of these structures varies, depending on the physiographical features and other conditions of the area in which they are located. In the northern plains comprising Indus and Ganges basins, the perennial river waters were used for irrigation by diverting the river flows, while in the southern region where rain is scanty, the rainwater is collected in large tanks for using the same later for agricultural purposes. The groundwater through wells is also very common wherever the water table is high and feasible to tap.

The positive effect of an irrigation project would be the increase in agricultural production, power supply, water supply-domestic and industrial, employment opportunities and socio-economic inputs, etc. The negative effect could be waterlogging, salt efflorescence, health hazards due to stagnant water, deforestation, loss of land fertility due to trapping of sediments in the reservoirs, displacement of people and submergence of properties, changes in downstream river regimes, adverse effects on down stream water supplies, changes in the ecological balance of flora and fauna etc.

Many problems of land and water management of grave importance threaten the irrigated agriculture. Large quantities of water harvested from watersheds, diverted from streams or pumped from ground water sources are lost by seepage and evaporation form tanks, canals, watercourses and field channels. The loss from field watercourses alone is estimated to be about 20 percent of the water delivered at the canal outlet. Inadequately or improperly designed field irrigation systems and unscientific water application methods are leading to huge losses of water by seepage and deep percolation below the root zone. Seepage and deep percolation represent the loss of valuable resources developed at high cost and the loss of fertilizers by leaching. In many area, not only is the loss of water and fertilizer are of great concern but the damage they create by waterlogging and accumulation of harmful salts are considerable. In many cases the source of waterlogging and salt problems could be traced to the faulty planning of irrigation schemes that were executed without due consideration for drainage. Efficient water management should, therefore, be an essential feature of any irrigation planning. Integrated development of water resources, efficient methods of conveyance and distribution of water on the farm, judicious methods of water application, scientific timing of irrigation according to the developmental rhythm of the plant and the removal of excess water from irrigated lands are important aspects of a comprehensive irrigation development program.

With the advent of Green Revolution all over the country, the surface water development also gained momentum. During last three decades the Gujarat, a predominantly agrarian state, owing to its favourable geo-environmental conditions and ample natural resources has witnessed rapid growth and has become one of the most important industrial states of the country. Heavy industrialization and unprecedented expansion of the urban centers have resulted into a manifold increase in the demand of various terrain resources and agricultural produce. In order to keep pace with the demand, the land and water resources have been exploited to their optimum level, causing an irreparable damage to various environmental attributes.

The presented study represents one such case example of Chalthan Branch Canal Command Area, which is constituting a part of Kakrapar Left Bank Canal Command Area.

AIMS AND OBJECTIVES

Presented study aims at evaluating the consequences of canal irrigation and its impact on soil and water regimes; corroborating secular and the vector changes in water table, water chemistry and the salt balance in soil and sub-soil horizons. The information thus generated; to be utilized for conceptualising and suggesting appropriate management strategies, to mitigate the adverse effects.

The main thrust of the investigation pertains to a critical evaluation of the following parameters:

- Surface and subsurface geological conditions, sediment nature and extent,
- Basic terrain characteristics, landuse pattern and long term changes,
- Water table behaviour pattern – secular and vector changes and its causes,
- Canal water input and its contribution to groundwater regimes as return irrigation seepage,
- Soil-water chemistry vis-à-vis secular and vector changes,
- Surface and sub-surface outflow and the factors governing the outflow.
- Crop-water demand scenario and existing management practices.

Approach and Methodology

A multi-disciplinary approach was adopted to achieve the above-cited objectives. The methodology thus followed:

- Collection of existing geohydrological data pertaining to the study area, to be used for working out long term and spatial changes in the command area in general and Chalthan Branch specific.
- Detailed fieldwork - to delineate the effect of irrigation on soil and water regime, change in land use pattern using satellite data and the field checks.
- Inventory of groundwater table changes for different seasons on identified observation wells and groundwater sampling.
- Collection of soil samples from soil and sub-soil horizons.
- Determination of physical and chemical characteristics of the water and soil samples.

- Data evaluation – graphical and statistical treatments for understanding geohydrological regime, groundwater flow pattern and spatial distribution of dissolved chemical content in soil-water regimes and geoenvironmental hazards.
- Working out an appropriate management strategy to minimize the geo-environmental hazards.

LOCATION AND EXTENT

The Kakrapar Left Bank Canal Project covers an area of Surat and Valsad districts characterized by the eastern rocky terrain and the western alluvial plain of South Gujarat (Fig. 1.1). The study area is bounded between the 20^0 31′ to 21^0 18′ N latitudes and 72^0 40′ to 73^0 20′ E longitudes. Geographically the study area bounded on north by the Tapi river, in south by the Par river, in west by Arabian Sea and in east by the Trappean plateau of Deccan basalts.

COMMUNICATION NETWORK

The National Highway No. 8 passes through Surat, Billimora, and Valsad towns. The various cities and major villages are interlinked by state highways. While other minor villages are interlinked by mettled and unmettled roads. Several cart tracks in the area are motorable in dry season. The State Transport buses regularly ply on most of these roads. The main broad gauge railway line i.e. Delhi-Bombay (Western Railway) and Surat-Bhusawal (Central Railway) passes through the Kakrapar Left Bank Canal Command area. The town of Waghai is connected by narrow gauge railway line from Billimora.

PHYSIOGRAPHY

On the basis of the elevation variations, the South Gujarat terrain can be divided into 04 physiographic zones, viz. (i) Trappean Highlands (> 100 m AMSL), (ii) Trappean Pediments (50-100 m), (iii) Alluvium Plain (10-50 m) and (iv) Coastal Plain (< 10 m).

The Trappean Highlands constitute the northernmost extension of the Western Ghats Escarpments. The topography is highly irregular, marked by chains of hills and narrow intermountain valleys. The area display general slope towards west. Owing to intense residual and mechanical weathering, the plateau surfaces have been enriched with a good thickness of soils. The landscape is dominated by a thick canopy of a typical deciduous forest.

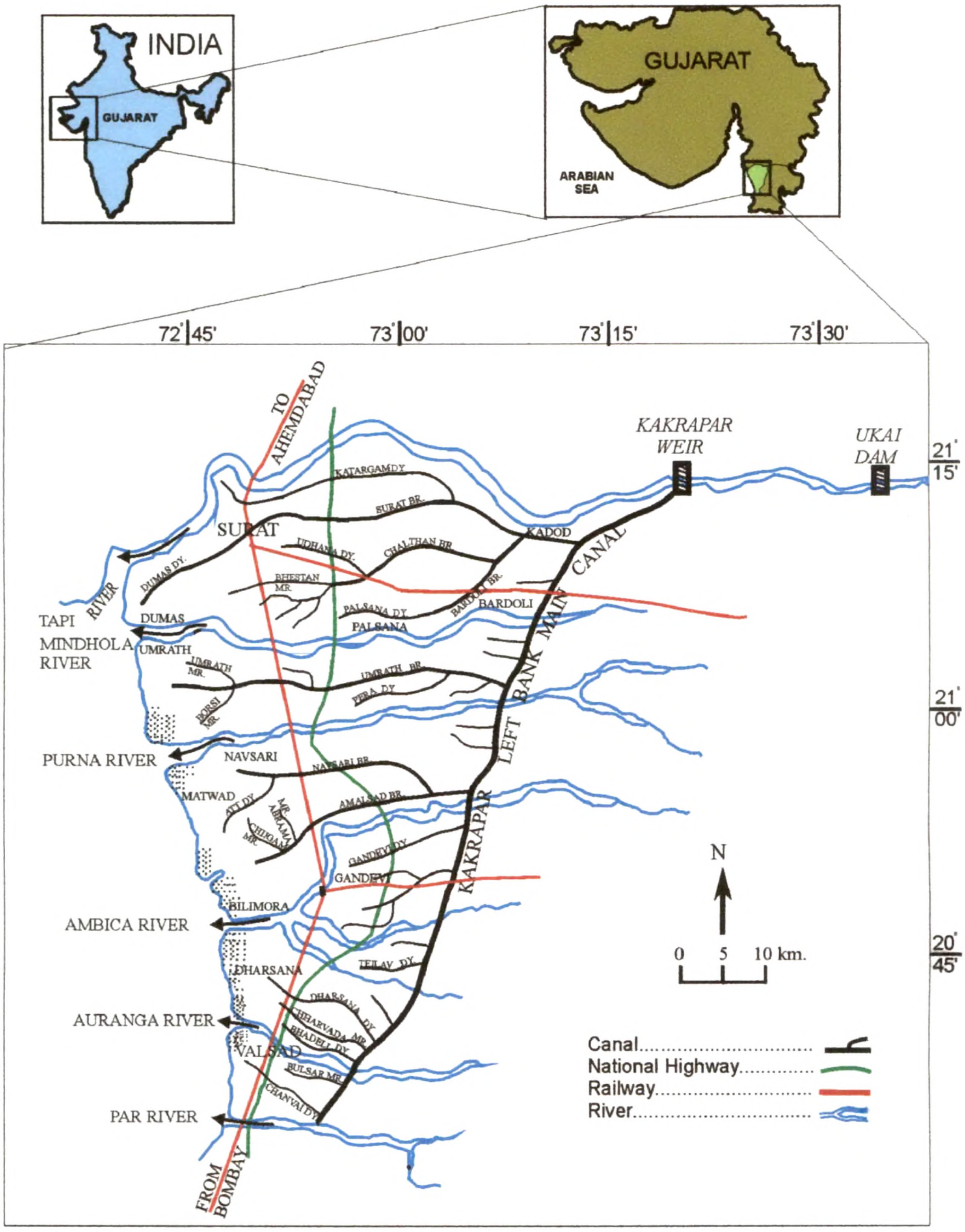

Fig. 1.1 Location Map of Kakrapar Left Bank Canal Project.

Trappean pediment is a transitional zone between Alluvial Plain and Trappean Highlands. This zone is characterized by low relief and rolling topography and partly covered by the rocky outcrops i.e. dyke ridges and a substantial thickness of colluvial materials. The pediment zone is widest in northern parts and tends to narrow down southerly.

An alluvium plain is characterized by a wide planation surface between moderate - steeply sloping pediment zone in the east and a narrow coastal plain strip in the west. Alluvium plain predominantly comprises an admixture of gravel, sand, silt and clays, deposited under riverine environment. From north to south the width of the alluvium plain tend to decrease southward. The alluvium plains are drained by a well-knitted westerly flowing drainage system.

Abutting with the alluvium plains in east, the coastal plain is distinguished by an extensive flat terrain, with the features like sandy beaches, bars, spits, barrier ridges, dune ridges, creeks and mud flats. Vegetation cover is scanty, often marked by prosopis sp., palms and poor mangrove vegetation.

Drainage

The South Gujarat drainage is characterized by a system of westerly flowing rivers. Most of the rivers are perennial in nature and originate from the eastern Trappean highlands and ultimately meet the Arabian Sea. In all seven major streams viz. Tapi, Mindhola, Purna, Ambica, Auranga and Par drain the area. Of these Tapi is a major river, which originates further east beyond the limit of Gujarat and cuts across the Trappean hills and flowing through a regional E-W trending fracture. The main drainage as well as those quite a few numbers of low order streams follows the fracture pattern. The various rivers basins are rather narrow and linear, roughly E-W and point to a strong influence of E-W fractures. Tapi is a perennial river, with lots of water flowing year round, where as others rivers tend to have decreased the quantities of the water in the months other then monsoon.

GENERAL GEOLOGY

Geologically the command area comprises the sediment record ranging from Cretaceo-Eocene to Recent time. The Deccan lava flows constitutes the base above which younger sediments lies. Tertiaries on the left bank command area are concealed beneath the Quaternary - Recent alluviums. The eastern part of the area is rocky and as one moves westerly the trappean rocks goes beneath the alluvium under the influences of N-S trending fault system. The top soil, which is silty-clay in nature in highly fertile and popularly known as the Black Cotton soil. The sub soil horizons are represented by alternate layers of fine sands and clays. Broad litho-stratigraphic succession as worked out on the basis of borehole data is given as under:

Period	Sediments	Thickness (m)
Recent to Holocene	Silty-clay with organic materials (Black Cotton Soil)	1.5 - 3.0
Quaternary	Intercalation of clay-sand-kankar (Riverine)	0.5 - 160.0
Tertiary	Variegated clays, silt stones, sandstones, laterites	Subsurface
Cretaceo-Eocene	Basalts (Deccan Traps)	Basement

CLIMATE

The climate of the study area is predominantly falling under humid conditions, characterized by a hot summer and general dryness except during the southwest monsoon. The year may be divided into four seasons. The mild cold season from December to February is followed by the hot season from March to May. The period from June to about the end of September is the southwest monsoon season. October and November constitute the post-monsoon or retreating monsoon season.

Rainfall

Information of rainfall in the area is available form various station for a fairly long period. The details of the rainfall at these stations and for the area given in table. The average annual rainfall in the area is 1282 mm. The area receives its rainfall entirely from the Arabian Sea branch of the monsoon current. The monsoon usually arrives in the second week of June and lasts till the end of September, July being the rainiest month. Rainfall is increases as one proceeds from the coastal plain towards the hilly tracks in the east. It also increases from north to south (Fig. 1.2). The heaviest rainfall in 24 hours recorded at any station in the district was 987.3 mm at Dharampur on 2nd July 1941.

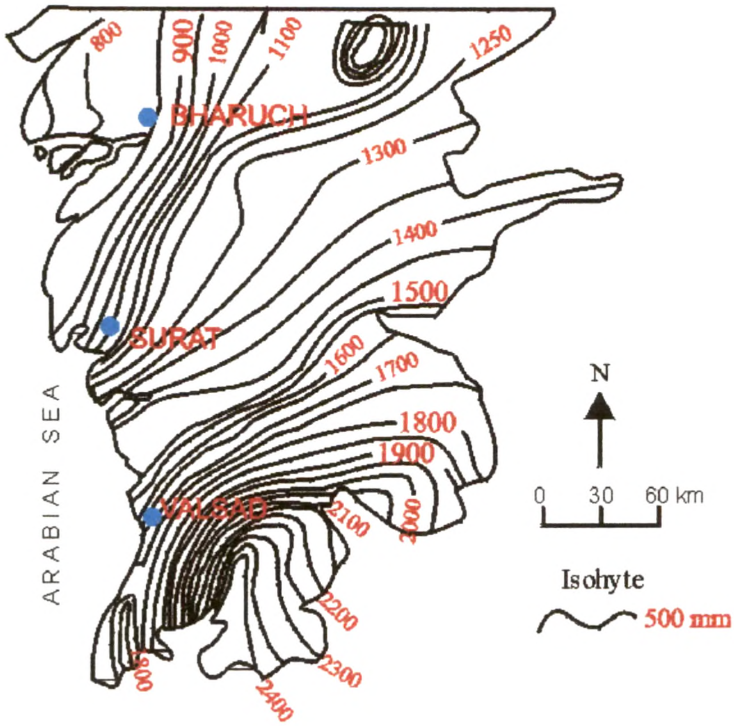

Fig. 1.2 Isohyet Map of South Gujarat.

Temperature

The area lies in an area of high temperatures. After February temperatures begin to increases steadily. April is generally the month with the highest day temperatures, the mean daily maximum temperatures sometimes-rising upto over 45 ^{0}C. With the advance of the monsoon i.e. about mid-June there is appreciable drop in the day temperature but the nights throughout the monsoon season are warm. After the withdrawal of the monsoon by about the end of September there is a slight rise in the day temperatures. However, nights become progressively cooler after the withdrawal of the monsoon. After November both the day and night temperature drop rapidly till January, which is the coldest month of the year. The mean daily maximum temperature during January is about 31 ^{0}C and means daily minimum is about 15 ^{0}C. During the cold season the area is sometimes affected by cold waves in association with the passage of western disturbances across north India and on such occasions the minimum temperature occasionally drops down to about 5^{0}c.

Humidity

The humidity in general maximum in the early morning and decreases with the advance of the day is attaining a minimum during the hottest period in the afternoon and again increases towards evening. The lowest humidities occur during the winter and summer months November to April. The humidity in general is higher in the coastal region than in the interior. During the monsoon season the relative humidity generally exceeds 70 percent. The average relative humidity in the morning is 80 to 85% and in the afternoon 70 to 75%.

Winds

Light winds mainly from the north to east directions blow throughout the day and night during November and December. Similar winds prevail during the mornings in January to March also but, in the afternoons, they blow from westerly directions (see-breeze). In April as well as in October the winds are variable. From May to September southwesterly winds from the Arabian Sea prevail. The mean daily wind speed is 7 mph (maximum) in the months May to August and 3 to 4 mph in other months. The cyclonic storms or depressions from the Arabian Sea in May and in the post-monsoon season reach the neighborhood of the area causing heavy rain and gusty winds.

THE KAKRAPAR PROJECT

Though no lands were present during 1876 that could be irrigated from the Tapi, several projects from time to time have been framed with a prime object of using river water for the irrigation purpose. About the year 1856 Captain Trevor of the Bombay Engineers, drew the attention of Government to the admirable, sites for irrigation works presented by some rocky barriers that, in the east of the Surat district, across the channel of river Tapi. Three years later, three sites had been pointed out by Captain Trevor as suitable places for irrigation works. These were the rocky barriers at Kakrapar, 100 km upstream the Tapi river mouth, at Puna about eight miles in down stream; and at Wagheecha, about six miles further down stream of Puna. In Captain Trevor's opinion Kakrapar, the highest of these three sites, as it is commanding a much greater area of culturable land, was the most promising place for building a weir.

The Ukai-Kakrapar project as on today is the biggest existing irrigation scheme in Gujarat. Development of the lower Tapi Basin in Gujarat has been planned in two stages. The Kakrapar weir and Canals Project forming the Stage-I was commissioned in 1954. Its canal system provides seasonal irrigation facilities to about

2,04,000 ha from the run of the river. The stage-II viz. Ukai Project consisting of a dam impounding about 8.5 km^3 of water across the river Tapi about 29 km upstream of Kakrapar, serves an additional canal system of 1,52,000 ha besides catering up the seasonal irrigation and providing some perennial irrigation under Kakrapar weir (Plate-1). With the installed capacity of 300 MW power project, the reservoir has been generating about 1000 million units on an average annually.

Plate 1. Close View of Kakrapar Weir Across Tapi River.

Kakrapar has two canal systems, one on each bank and together they serve about 2,04,000 ha. The details regarding nature of canal network and irrigated command area is given in Table 1.1 and 1.2.

Table 1.1 Details Regarding Lined and Unlined Canals in KLBC Area.

Sr. No.	Canals	Length in km.			Total
		Lined		Unlined	
		Before 1999	After 1999		
1	Main	0.00	35.00	29.00	64.00
2	Branch	0.00	11.00	233.32	244.32
3	Distributaries	0.00	0.00	218.80	218.80
4	Minor	50.38	0.00	360.80	411.18
5	Sub-minor	112.66	0.00	1294.73	1407.39
Total		163.04	66.00	2136.65	2345.69

(Source: SIC, Surat)

Table 1.2 Statement Showing the Detail Regarding Taluka Wise G.C.A., C.C.A. and Potential Created for Kakrapar Left Bank Command Area.

Taluka	G.C.A.	C.C.A.	Potential Created
	Area in ha.		
Chorasi	31604	15776	15187
Kamrej	35592	17767	17767
Palsana	25354	12656	11563
Bardoli	43287	21608	21023
Mahuwa	11675	5828	5535
Navsari	39713	34420	34420
Gandevi	13909	11810	11810
Chikhli	10536	10033	10033
Valsad	17883	15437	14754
Total	229553	145335	142092

(Source: SIC, Surat)

Salient Features of Kakrapar Irrigation Project

A. Location:

1. Location : Lat. N 21^{0}16'20"
   Long. E 73^{0}22'50"
   (Toposheet no. 46G/7).
2. State : Gujarat
3. District : Surat
4. Taluka : Mandvi
5. Village : Kakrapar
6. River : Tapi
7. Site of weir : The river Tapi about 80 km. upstream of Surat and 100 km. upstream from the mouth of sea near Kakrapar village.

B. Hydrology:

1. Drainage area of the river up to the weir site. : 59,940 km^2.
2. Nature of river. : Perennial.
3. Average annual rainfall. : 78.63cm. (for the whole catchment).
4. Maximum annual rainfall in the watershed. : 119.14cm. (year 1944).

5. Minimum annual rainfall in the water shed.	: 27.10 cm. (year 1899).
6. Highest observed flood level at weir.	: 55.32 mt. (year 1968).
7. Maximum observed flood discharge of river.	: 42480 cumsec (year 1968).
(i) By gauge & velocity Observation at hope bridge near Surat as computed by Surat Dn.	: 25488 cumsec.
(ii) As worked out by unit hydrograph methods by C.W. & P.C. under a combination of number of adverse circumstance.	: 37807.2 cumsec.
8. Design flood capacity.	: 38,232 cumsec.
9. Year of commencement.	: 1949-50.
10. Year of completion.	: 1957.

C. Pick-up Weir:

1.Height.	
(i) Length of pick up weir between flank walls overflow section.	: 613.38 m.
(ii) Right bank open sluice channel sill R.L. 43.3 m.	: 15.24 m.
(iii) Partial overflow divide wall crest R.L. 51.85 m.	: 2.44 m.
(iv) Non-overflow weir adjustment to right bank sluice channel.	: 2.44 m.
Total	: 633.50 m.
2. Type of Weir.	: Ogee shaped gravity section built from random rubble masonry.
3. Crest R.L. of weir.	: R.L. 48.77 m. (Raised by 1.5 m.) in 1981 S.O.R.L. 48.77m.
4. Height of weir.	: 15.50 m. At the deepest foundation level.

5. Calculated H.F.L. over pick up weir with afflux.	: R.L. 56.30 m. (after raising by 1.5 m.).
6. Number and size of scouring sluices.	
(i) Right bank.	: 1No. 15.35 m. wide open sluice channel with 15.24 m. * 3.96m. (50'*13') vertical lift gate sill level R.L. 43.31 m.
(ii) Left bank.	: 6No. 3.05 m. * 2.83 m. under slice with vertical lift gates with R.L. 37.00 m.
7. Head regulator.	
(i) Type of gate.	: Vertical lift gates.
(ii) Nos. and size of gates	
a) Right bank sill level R.L. 197'.	: 3 Nos. 6.1 m. * 2.44 m.
b) Left bank sill level R.L. 145'.	: 3 Nos. 6.1 m. * 3.05 m.

D. Flood Embankments:

1. Top level.	: R.L. 58.82 m.
2. Length.	
a) Right bank.	: 2743.00 m.
b) Left bank.	: 4572.00 m. 7313.00 m. (After raising of weir by 1.50 m. with extension.)
3. Free board of the embankment above HFL.	: 2.44 m.
4. Top width.	: 3.05 m.
5. Side slopes water side.	: 3:1
6. Non water side.	: Nil.

E. Canals:

			K.L.B.C.	K.R.B.C.
1.	Length of main canal	:	64.00 km	64.00 km.
2.	Length of Branch	:	306 km	37.6 km
3.	Length of Distributeries	:	877 km	76.62 km
4.	Capacity	:	85.58 m^3/s. 3020 cusecs	70.18m^3/s. 2480 cusecs (incl. U.R.B.C.)
5.	Type of Canal	:	Unlined	Unlined
6.	Desectiond @ Bed width	:	27.75 mt.	27.44 mt.

7. Full supply depth	:	3.05 mt.	2.80 mt.
8. Gradient	:	1 in 10,000	1 in 10,000
9. Canal slope	:	1 in 1	1 in 1
10. G.C.A.	:	179370 ha	68071 ha
11. Irrigable Command Area	:	136989 ha	55956 ha
12. C.C.A.	:	145335 ha.	58745 ha.
13. Year of commencement and completion	:	1952 & 1954	1952 & 1954

(Source: S.I.C., Surat)

THE THESIS

The thesis is divided in to two parts. Part-I includes the Chapters I to V, giving broad appraisal of the geological information, terrain characteristics, water resources and soil characteristics of the Kakrapar Left Bank Canal Command Area. Part-II includes Chapters from VI to X incorporate an in depth study on geoenvironmental aspects of the Chalthan Branch Canal Command Area. Chapter wise gist is given as under.

PART - I

Chapter I. Introduction; covers the background information, the Kakrapar project, aims & objectives, general description of the project area and adopted approach and methodology.

Chapter II. Geological Information; covers the regional litho-stratigraphic setup and tectonic framework of the project area and its environ.

Chapter III. Terrain characteristics; contains the physiography, landform features, drainage system and landuse pattern of the project area.

Chapter IV. Water resources evaluation, deals with the hydrogeological setup, groundwater investigations and surface water resources of the project area.

Chapter V. Soil and sub soil characteristic; deals with basic soil types and its characteristic properties (physical and chemical), land irrigability classification of the project area.

PART - II

Chapter VI. Chalthan Branch; gives the general information regarding the study area.

Chapter VII. Water regime; deals with the surface and groundwater resources of the study area and the groundwater chemistry.

Chapter VIII. Soil regime; deals with the study of surface and subsurface soil investigations and detailed physical and chemical characteristics.

Chapter IX. Impact of irrigation on soil and water regimes; discusses the degradation of soil, the problems of waterlogging and effect of irrigation on soil and water regimes and landuse pattern.

Chapter X. Soil and water management strategies; deals with the suggested remedial measures to eradicate the adverse effects of irrigation on soil and water regimes and the management of soil and water resources of the Chalthan Branch Command Area.