CHAPTER - II

PREVIOUS WORK

GENERAL

From the point of view of systematic studies on geoenvironment, the area has not received enough attention. However, detailed studies have been carried out for the various aspects of the geology and structure. Fairly good account about the water resources is available. Data on climate is generated by numerous agencies. In this chapter an attempt to summarize the available information that would provide an overview of the prevailing environmental conditions.

GEOLOGY

The district has an interesting history of geological evolution. The exposed geological formations mainly comprise of two extreme age groups with very big geochrononical hiatus; Precambrian crystallines and Quaternary sediments. The tectonism has played a major role in bringing the oldest and the youngest formations in juxtaposition. This peculiar geological framework characteristically is reflected in the geomorphic configuration and occurrence of water resources. The district has a unique location in the regional geological setup (Fig 2.1). The Proterozoic rocks of Rajasthan and Gujarat are exposed in the east and northeast. The Mesozoics and Deccan Trap occur in the neighboring areas of Kachchh, Saurashtra and Sabarkantha. The Quaternaries are the most important formation of the district, covering a major part of the area extending northward in Rajasthan, and to the south they merge into the Gujarat Alluvium. The Holocene, predominantly marine deposits of the Ranns of Kachchh, lie to the west of the district. The regional geological set up has been controlled by the NE-SW Precambrian (Delhi) orogenic trend, N-S trend of Cambia Tertiary Basin and E-W trend of Kachchh Mesozoic Basin (Fig 2.2).

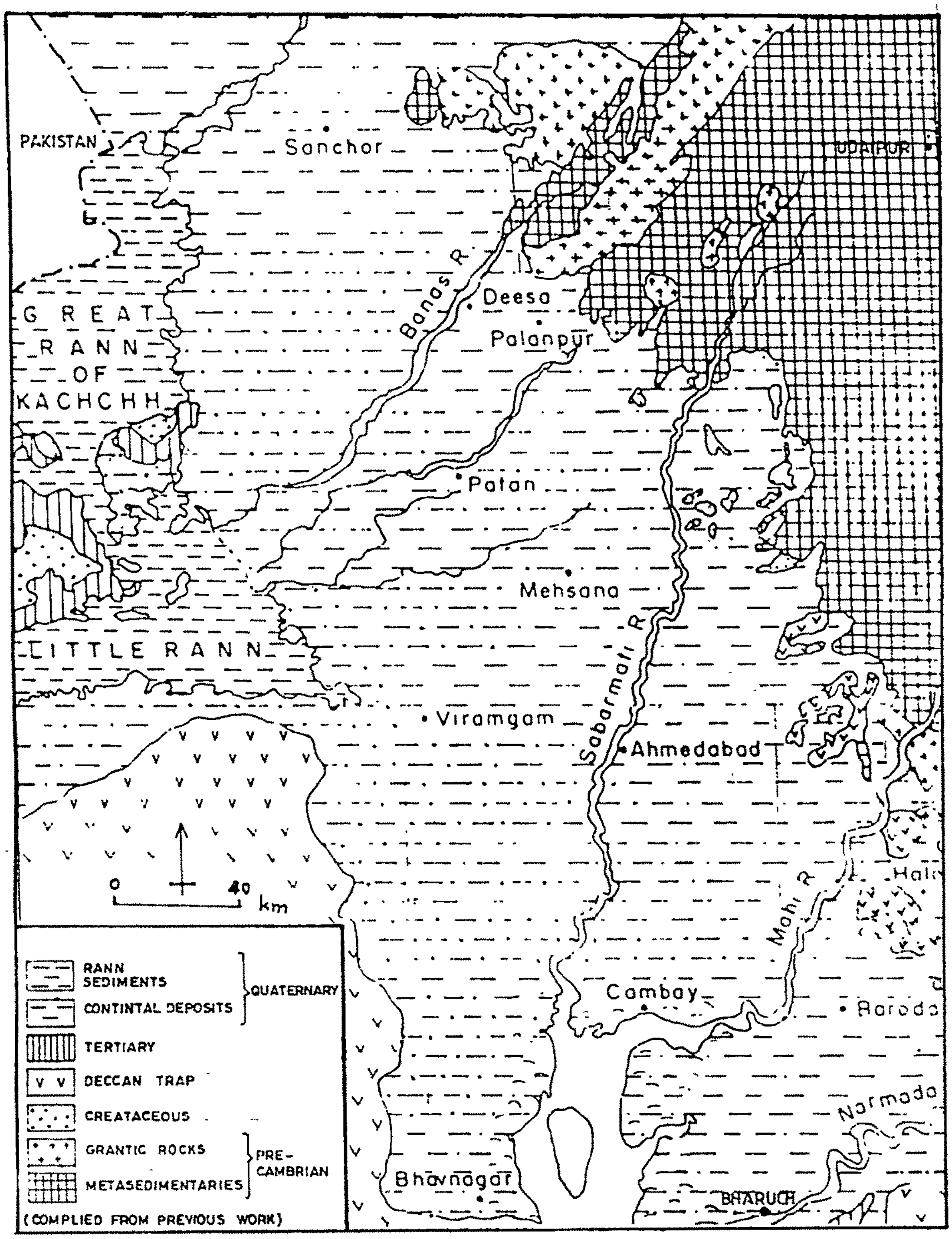

FIG-2·1 REGIONAL GEOLOGICAL SETUP OF STUDY AREA

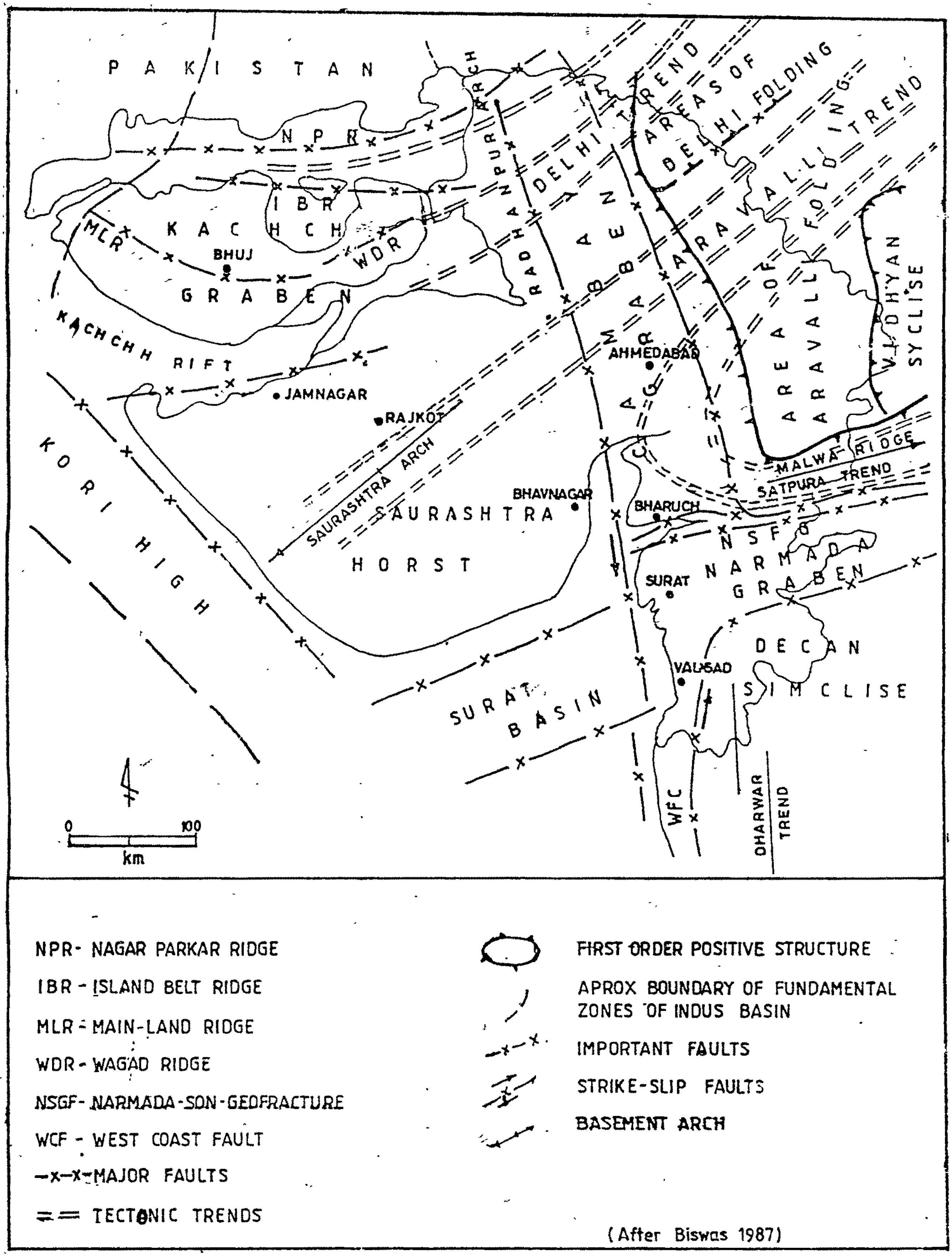

FIG-2·2 TECTONIC SETTING OF GUJARAT

REGIONAL GEOLOGY

The earlier geological studies include mapping by Geological Survey of India (GSI) followed by the exploratory programme of the Oil and Natural Gas Corporation (ONGC) and relatively recent literature available from the academic institutions and other research organizations. The works by the GSI mainly include those of Middlemiss (1921) in Idar area, Sharma (1931) in Danta area, Coulson (1933) in Sirohi area, and Heron and Ghosh (1938) in Palanpur, Danta and Idar areas. They have given excellent outcrop descriptions, petrological and mineralogical details and prepared lithological maps. The stratigraphic successions, locally built by them in their respective mapping areas have however, subsequently undergone considerable revision at the hands of subsequent workers.

The work of ONGC has provided details about subsurface geology and the structure. They are available in the publications by Mathur *et.al.*,(1968), Chandra and Choudhury (1969), Roy Choudhary *et.al.*, (1972), Mehrotra *et.al.*, (1981), Raju (1982), etc. But by far most comprehensive account of the stratigraphy for entire Cambay was first documented by Chandra and Choudhary (1969) which has recently been updated by Pande *et.al.*,(1993). Biswas (1981, 1982 & 1987) described the Kachchh, Saurashtra, Cambay and Narmada basin as peri-continental rift basins in western margin of Indian Craton. The Northern extension of the Cambay Basin separates the Precambrian rocks of Rajasthan and North Gujarat from the Mesozoics and Tertiaries of the Kachchh and Saurashtra. The major part of the study area lies in this zone of the basin (Pande *et.al.*, 1993) and falls in the Sanchor-Patan tectonic block of the basin (Fig 2.3). Extensive literature on the different aspects of the geology in the region is available, which mainly includes that of Merh (1967, 1978, 1987, 1992 and 1995), Allchin *et.al.*, (1978), Rao (1987), Gupta (1972, 1975), Patel and Desai (1988), Gupta *et.al.*, (1992) etc.

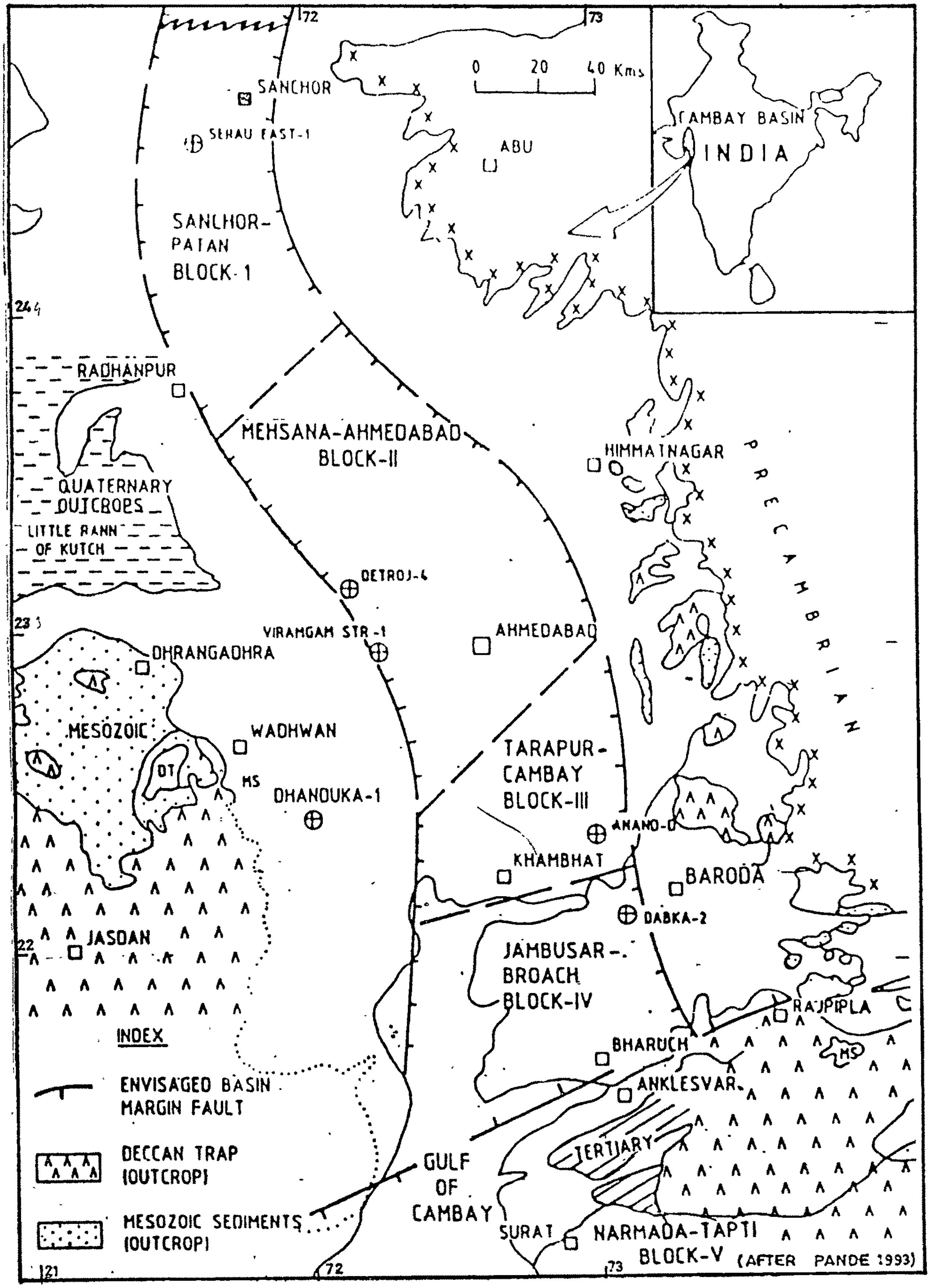

FIG-2·3 STRUCTURAL SETUP OF CAMBAY BASIN

GEOLOGY OF THE DISTRICT

The Precambrian rocks are prominently exposed in the eastern part of the area. The central and western parts are covered by the Quaternary deposits .The Jurassic and Tertiary formations of Kachchh have their extention into the district and a couple of patchy exposures is found near the border area (Fig 2.4). The earlier mapping of the Precambrian rocks is due to the GSI carried out by Coulson (1933) in Sirohi area and Heron and Ghosh (1938) in Palanpur, Danta and Idar areas. More recently several workers from universities, mainly the M.S. University of Baroda and Pune University has worked in the area; they include Merh (1950), Patel (1971), Desai *et.al.*, (1978), Peswa *et.al.*, (1977), Malpathak (1979), Patel *et.al.*, (1982), Power *et.al.*, (1984), Roy and Das (1985), Sychanthavong (1990), Limaye (1992), etc. Recent work of the GSI includes that of Bakliwal and Ramswamy (1987) on lineament fabric of Rajasthan and Gujarat, and Gupta *et.al.*, (1992) who reviewed the lithostratigraphy of Proterozoic rocks of the region.

The subsurface Tertiary rocks occupying the Sanchor-Patan block of the North Cambay Basin are described by Mehrotra and Ramkrishna (1980) and Sastri *et.al.*, (1984). The Quaternaries of the area have been studied by several workers Ahmed (1986), Sareen *et. al.*, (1988), De and Mathur (1988), Chamyal and Merh (1992), Merh (1993), Merh and Chamyal (1993), and Sridhar *et.al.*, (1994). Based on the previous work, following generalised geological succession has been worked out (Table 2.1).

GEOENVIRONMENTAL ASPECTS

The district of Banaskantha have not received the attention in the past, and only sporadic references to its landscape features including past and present drainage as well as sediment accumulations related to fluvial aeolian and marine processes are available in

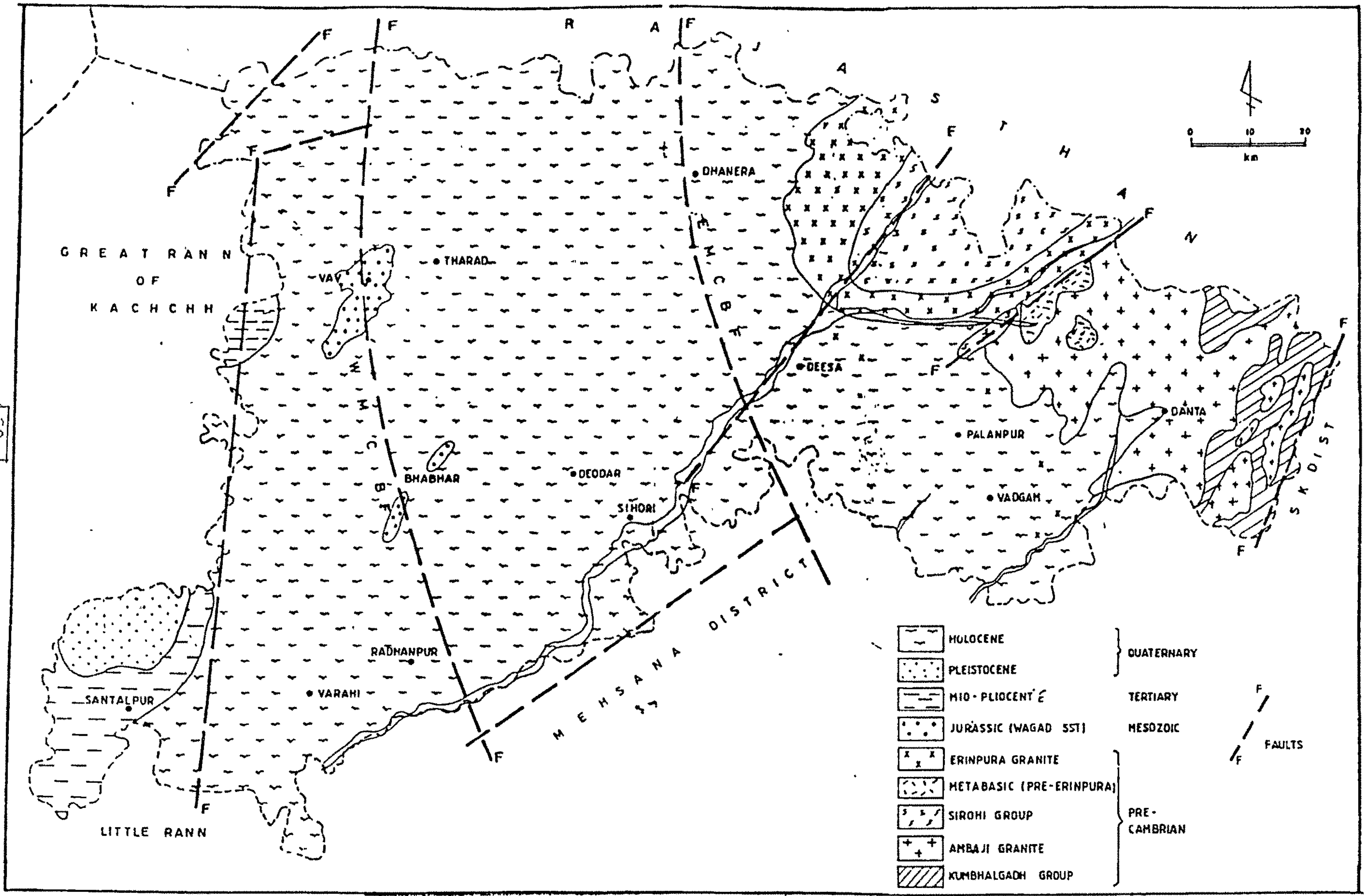

FIG-2.4 GEOLOGICAL MAP OF BANASKANTHA DISTRICT

Table 2.1 Geological succession of the Banaskantha district.

Period	Age	Group\Formation	Lithology	Location of the Occurrence
Quaternary	Holocene and Pleistocene	Gujarat Alluvium	Sands, silts, clays with gravel beds	Plains of central and eastern parts and valley fills in eastern parts
Tertiary	Pliocene and Miocene	Kankavati and Khari	Gypsiferous shale and clays	Chorar island in Santalpur taluka
	Cretaceo-Eocene	Deccan Trap	Dykes and sills	
Mesozoic	Upper Jurrasic	Wagad Sandstone (Katrol Group)	Brown and red felsapathic sandstone with shale beds	Chorar island in Santalpur taluka
Precambrian	Post-Delhi Magmatism	Malani Intrusive	Trachy andesite and albitised basalt	Hilly tract of district (parts of Danta, Vadgam, Palanpur and Dhanera talukas)
		Erinpura Granite	Potash-granite and microgranite	
		Pre-Erinpura Granite	Metagabbro, metadolierite, epidiorite and amphibolite	
	Delhi Supergroup	Sirohi Group	Phyllite, mica-schist and calc-schist	
		Sendra-Ambaji Granite	Granite, granodiorite and granite -gneiss	
		Kumbhalgarh Group	Calc-schist, calc-gneiss, mica-schist and marble	
	Aravalli Super Group and Basement	Basement	Granite and gneiss	Not exposed

various Quaternary studies on Rajasthan and North Gujarat in connection with works on climatic and tectonic changes. However, these studies provide a very good background to the present investigation. Because of the fact that the district comprises a transitional terrain, alluvial to rocky and semi-arid to arid, and it has landscape characteristics of both Rajasthan and Gujarat. In this sense, Quaternary studies by a number of workers on the drainage of Rajasthan and North Gujarat, sequence of climatic fluctutations ranging from humid to arid and strong imprints of neotectonic changes of western India, have direct bearing on the present day geoenvironmental conditions of the district. The author has briefly summarised the work of different investigators with a view to provide a suitable background.

Past studies have been mostly carried out by archeologists, geologists and geomorphologists, who have dealt with three aspects as under :

1. Past and present drainage,
2. Influence of Quaternary tectonism and
3. Role of climate in landscape evolution.

PAST AND PRESENT DRAINAGE

Oldham C.F. (1874, 1893) of the Geological Survey of India (GSI) for the first time, gave an account of the various rivers flowing across northwest India and discussed the past behaviour. Another officer of GSI Oldham R.D. (1886) also described some of the ancient rivers of northwest India and suggested that the river Yamuna originally flowed across Rajasthan and was a feeder channel for most of the rivers of Vedic period, which are now more or less lost in the desert sands.

The aspect of drainage disruption however, remained uninvestigated for almost a century, and it was only in 1980s that the Rajasthan drainage system received special attention. Of course, a few decades earlier Ghosh (1965, 1971) did attempt to describe the ancient drainage system of South Rajasthan. While working on Luni river basin, with help of aerial photographs he observed relicts of numerous older channel. After reconstructing the courses of dead stream channels he suggested that a few thousand years ago the region was marked by an extensive drainage system.

Bakliwal and Grover (1988) of GSI and Amal Kar and his associates (1987, 1988a, 1988b, 1990, 1993) of Central Arid Zone Research Institute (CAZRI), with the help of satellite imagery of the Thar desert, contributed significantly towards the proper understanding of the evolution of Rajasthan drainage system. The former recognized numerous signatures of paleo-channels, though they did not provide any integrated picture of the then flowing rivers. To Amal Kar goes the credit of providing a much more precise picture of the ancient fluvial system.

All these workers though highlighting the factor of climate also invoked role of tectonism in drainage disruption. Ghosh (1979, 1982) has envisaged the existence of a Paleo-river bed beneath the Rann sediments, and according to him, during a marine incursion around 7000 B.P. (Middle Holocene), the sea transgressed over an earlier alluvial channel network. He showed the existence of an ancient channel network existing of rivers of Banas, Saraswati and others, which flowed into Gulf of Kachchh and NW-SE fault limits Little Rann truncated these rivers in early Holocene. The wide buried channels along central axis of Little Rann of Kachchh continuing from the mainland in NE to head of Gulf of Kachchh in SW, indicates past water coarse of the rivers draining into gulf. Braided and branching nature of channels reflects deltaic conditions.

INFLUENCE OF QUATERNARY TECTONISM

Most earlier workers, especially geologists and geomorphologists have highlighted the role of tectonism in landscape evolution and drainage disruption. Heron (1917, 1936, Another landmark work is that of Wasson *et. al.*, (1983) who studied the Thar dune fields and described the geomorphology, late Quaternary stratigraphy and palaeoclimatology. A major part of sandy alluvium of the area has been described by them as poorly organized dunes. They further found that dunes overlap sandy alluvial deposits and the entire sequence below 6 m of dunes (at Langhnaj in N. Gujarat) is fluviatile. However, the central part around Dhanera, showed some geometry and was described as linear dunes. The random distribution and lack of directional pattern of the dunes suggest that they are the result of the aeolian reworking of spreads of alluvium deposited by the ancestors of modern rivers of North Gujarat plains. They considered the stabilization of the dunes during middle to late Holocene on the evidences of archeological, radiocarbon and Thermoluminence (TL) dating.

Rajaguru and his associates (1982) have emphasized on the problem of late Pleistocene aridity. Their studies around Didwana in Nagaur district of Rajasthan have established the existence of a well organized drainage system during the early Quaternary which was subsequently disorganized due to the paleohydrological and climatic factors. The flood plains developed by the early drainage system were exposed to strong aeolian activity. With the onset of aridity, dunes developed over the defunct flood playas in abandoned meander lakes. It was observed by them that the existence of calcrete layers interstratified within the fossil dunes indicated that the dune activity was not continuos but was marked by climatic fluctuations.

To Singhvi *et. al.*, (1982) goes the credit of Thermoluminence (TL) dating of the various evolutionary phases, and thereby suggesting a likely chronology of paleoclimatic changes.

plains were deposited in structural depressions within the Cambay and Narmada grabens. Sridhar *et. al.*, (1994) in their recent work on Sabarmati river have provided greater details of the total alluvial thickness of around 300 m in North Gujarat. On the basis of a critical evaluation of the exposed sequences of various North Gujarat rivers including Sabarmati, Rupen, Pushpavati, Khari, Banas, and Luni and subsurface drill hole data, it has been possible to enable them to obtain a clear picture of the lithology of various horizons and their depositional processes. According to them the entire alluvial sequence was a product of an ancient super-fluvial system which has since been partly destroyed. This earlier drainage system which originated in the Aravalli highland flowed southwestward and met the sea a few km landward from the present day boundaries of the two Ranns of Kachchh. It has been suggested by them that the earlier course of Sabarmati river coincided with the Rupen river flowing into the Gulf of Kachchh, and subsequent development of a major NNE-SSW trending fault that captured the course of the Sabarmati river causing it to swing away from its earlier course and to flow into the Gulf of Cambay. They have also suggested that the existing rivers of North Gujarat comprise relict fragments of the earlier disrupted rivers, some channels having been destroyed while others reactivated. They have invoked a combination of neotectonic activity in the Cambay basin, glacio-eustatic sea level changes and paleoclimatic fluctuations that played a major role in controlling the depositional history of the fluvial sequence and the disruption of the super-fluvial drainage system.

WATER REGIME

Previous studies on the water regime of Banaskantha district, in most cases, form parts of the regional studies either for whole of Gujarat or North Gujarat. Main thrust of the various investigations pertained to surface and subsurface water availability, its harnessing and exploitation. Obviously, most of the investigations comprised either those relating to surface water, mainly rivers and streams or were related to the exploration and exploitation of groundwater.

SURFACE WATER

The surface water regime has not been studied in an integrated manner either by a hydrulic engineers or a geomorphologist. An engineer having a mechanical approach towards a drainage basin in terms of surface flow quantifications. While a geomorphologist tries to give an evolutionary account of the basin and its physical characterisation. In the study of water resource potential, surface and underground; an integrated approach towards the drainage basin as a hydro-geomorphic unit is necessary. Unfortunately, in the post-independence period our river basins were simply taken as geographic areas bounded within watershed divides that convert rainfall into surface flows that is gauged and quantifications made. The figures were straightway used for river valley development projects. This developmental approached missed the important aspects of genetic evolution and future course of behaviour of the hydrologic units.

A large network of river flow gauging has been provided by the Central and State Government agencies and enormous amount of data generated. The data many a time lacked cross verification and used for design purposes. But unfortunately, no mechanism developed either at state or central government level to study the hydrogeomorphic charcterisation of our drainage basins. The river basins, are not simply the producers of surface water but groundwater resource is also regulated by them. The river basin thus, got lopsided treatment. In this respect our surface water studies are incomplete.

Little informations is available on rivers and streams in the works of the officers of Geological Survey of India (GSI). Heron and Ghosh (1938) however, for the first time gave some details of the river Banas which flows across the study area and the name Banaskantha connotes the banks of the Banas river. Its major tributaries are Sipu, Balaram, and smaller rivers like Khari and Chekharia. The other smaller rivers like Sukal, Rel and Saraswati by and large, contribute to the surface water regime of the district. Although a small portion of the right bank of Sabarmati river which makes the easternmost boundary of the district could also be included in the list of Banaskantha streams. A number of Government and Non-Government agencies and experts have in the course of last three to four decades studied and described the surface water availability. Whereas some investigations dealt with entire Gujarat state, others have paid more attention to Banaskantha especially to the Banas, Sipu and Saraswati rivers.

References to the Banaskantha rivers vis-a-vis availability of surface water was made for the first time almost two decades back by Rao (1979). His work however, dealt with the basinwise estimates for the whole country. He had classified the river basins of India into four groups based on catchment characteristics as major(>20,000 sq km), medium(20,000 to 2000 sq km), minor(<2000 sq km) and desert areas (Table 2.2).

Rao has included the river basins of Luni, Machai, Banas, Saraswati, and Rupen of Rajasthan and North Gujarat into the group IV (Desert areas). These rivers flow for small distances and disappear in the desert sands and thus do not contribute significantly to water availability. Their waters are used for irrigation but their flow is uncertain in magnitude and time due to the highly erratic nature of rainfall.

Table 2.2 Classification and details of river basins of India.

River Basin	Total Catchment		Total Runoff	
Group	Million Sq km	(%) of the Country	BCM	(%) of Total
I Major	2.58	(83)	1406	(85)
II Medium	0.24	(8)	112	(7)
III Minor	0.20	(6)	127	(8)
IV Desert	0.10	(3)	-	-
Total	3.12	(100)	1645	(!00)

In subsequent years, especially after the formation of the separate state of Gujarat, attention has been paid towards the surface water resources of various parts of Gujarat and special efforts have been aimed at optimum utilization of available surface water of arid to semi-arid areas like North Gujarat and Kachchh. In this context, the district of Banaskantha has received extra attention and has been studied by a number of Government and Non-Government organizations, each giving their own estimates and assessments of surface water resources.

The Central Water Commission (CWC) of the Government of India, since last 3 decades, has been continuously monitoring the surface water resources of various river basins of India through a network of river gauge stations and in this context in the district of Banaskantha 4 gauge stations of CWC have been set up for measuring the river discharge and sediment transport.

The Irrigation Department of the State Government has also its own network of river and raingauging stations, and within the limits of Banaskantha the department has setup 11 river gauging stations and 40 rain-gauging stations (Fig 2.5). Apart from this continuously

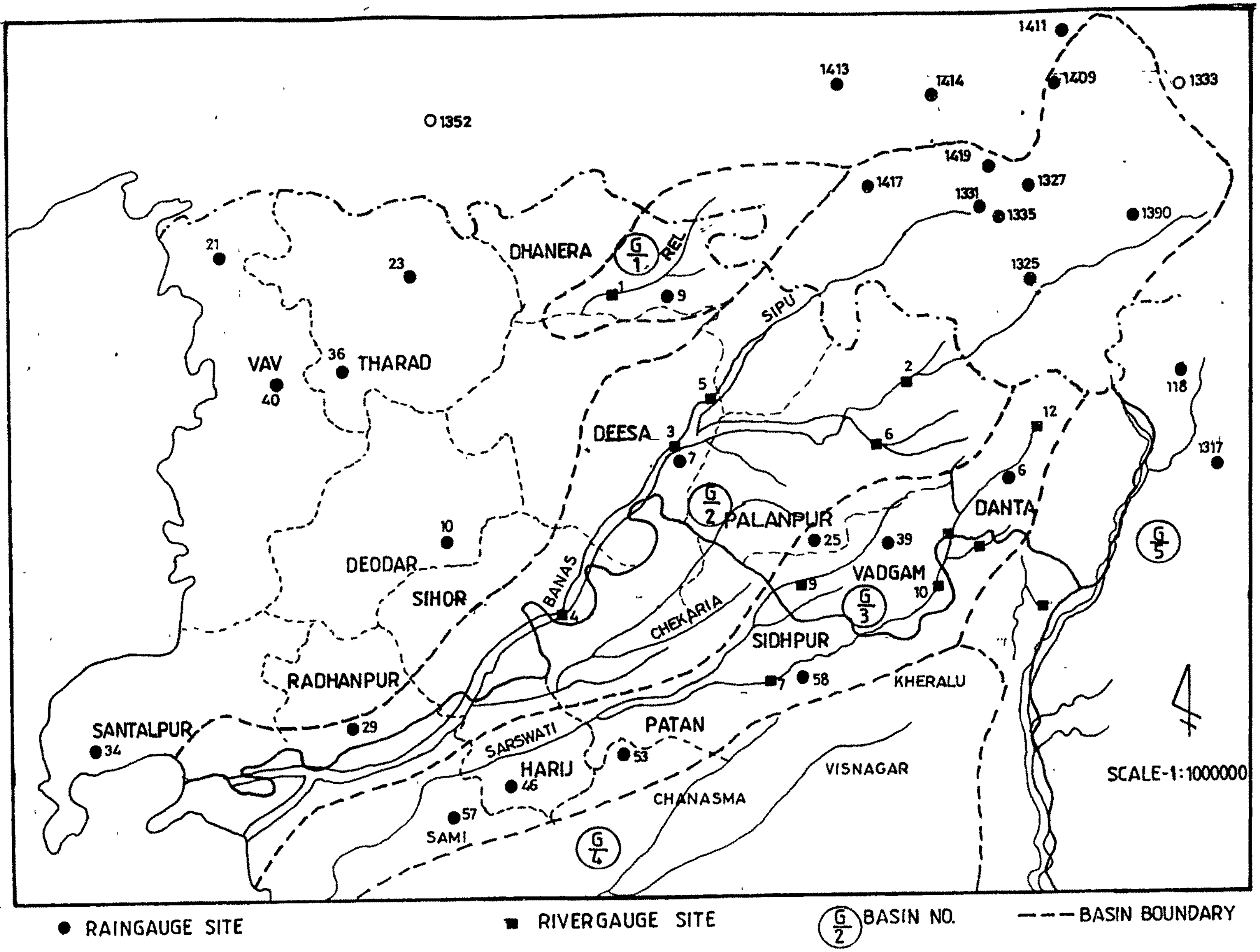

FIG- 2.5 RAINGAUGE AND RIVERGAUGE SITES IN BANASKANTHA DISTRICT monitoring, the State Irrigation Department has conducted exclusive surveys in connection with the river valley projects on Banas, Sipu and Saraswati. The emphasis has been on the surface water potential at different rainfall dependabilities. It has been concluded that the surface water potential tends to increase towards the eastern part while towards the west it decreases due to climatic and terrain factors.

The Ministry of Agriculture (Government of India) in 1988 for the first time made a systematic hierarchical classification of the river basins into five-fold division on the basis of factors of water resource region, basin, catchment, sub-catchment and watershed. In this scheme the district is shared by two water resource regions i.e. 5 (flowing into Arabian sea) and 6 (Ephemeral desert drainage). The study area falls into 3 basins, 5H (Gulf of Kachchh), 5F (Sabarmati) and 6A (Great Rann of Kachchh). These basins comprise 4 catchments, 5 subcatchments and 19 watersheds(Fig. 2.6). Details of the watersheds contributing to the surface water availability of the district are given in (Table 2.3).

The work of Pathan et. al.,(1988) on Balaram watershed which was carried out for the purpose of harnessing the small stream is important in the sense that the investigation comprised a methodology for watershed delineation using Landsat imagery and digital system for the purpose of systematic development of water resources. The most recent work on surface water resource of study area was carried out by Tahal Engineering Consultants (TEC,1995-96). As a part of their report containing a detailed synthesis of surface water resources of the entire state employing 'state-of-art' techniques and modern computation methods and arriving at more dependable estimates, information on the 4 rivers of the Banaskantha and adjoining districts namely Banas, Rel, Saraswati and Rupen as estimated is given in (Table 2.4).

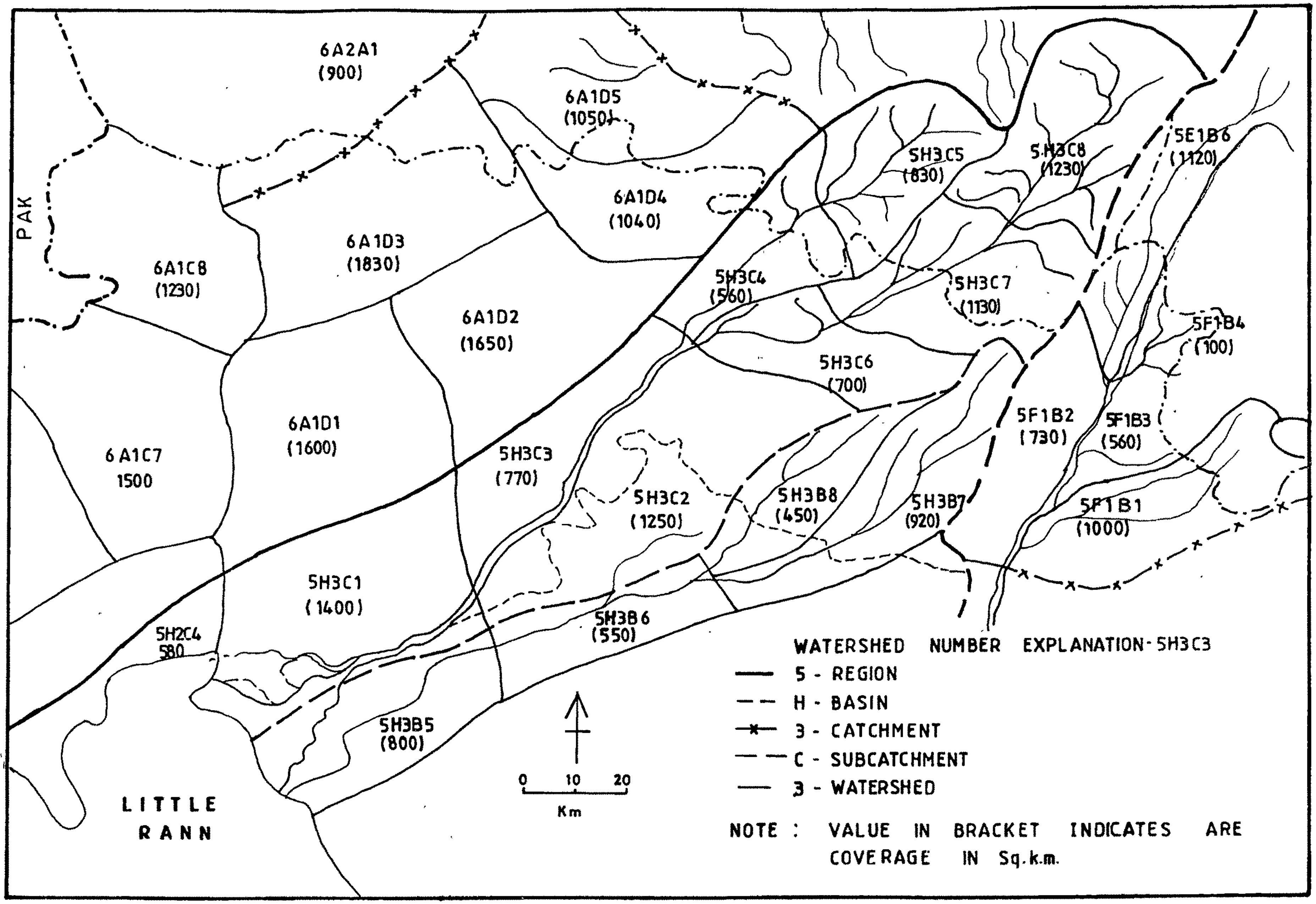

Fig 2·6 WATERSHED MAP OF BANASKANTHA DISTRICT

Table 2.3 Details of the Watershed pertaining to Banaskantha district.

Basin	Catchment	Sub-Catchment	Watershed	Stream /River	Area (sq km)	District covered
5H	5H3 (Rupen, Saraswati, Banas draining to Little Rann)	5H3B Rupen and Saraswati	5H3B7	Arjuni	920	B.K and Mehsana
			5H3B8	Amardashi	450	B.K and Mehsana
		5H3C Banas	5H3C1	L. Banas	1400	B.K and Mehsana
			5H3C2	Khara and Chekaria	1250	B.K and Mehsana
			5H3C3	RB Banas	770	B.K
			5H3C4	Sipu	560	B.K and Sirohi
			5H3C5	Sili and Sukli	830	Sirohi and B.K
			5H3C6	Balaram	700	B.K
			5H3C7	U. Banas	1130	Sirohi and B.K
5F	5F1 Upper part	5F1B	5F1B1	Harnav	1000	B.K, Sirohi ,Meh.
			5F1B2	RB Sabarmati	720	B.K and Mehsana
	Beyond Hathmati		5F1B3	LB Sabarmati	560	B.K and Udaipur
			5F1B4	Pamri	1000	Udaipur and B.K
6A	6A1	6A1D	6A1D1	Ephemeral Drainage of Sand dunes.	1600	B.K
			6A1D2		1650	B.K
			6A1D3		1830	B.K and Jalor
			6A1D4		1040	B.K, Sirohi and Jalor
	6A2	6A2A (Sukri Jawai)	6A1D5		1090	Jalor and B.K
			6A2A1	LB Luni	900	Jalor and B.K
Total	04	05	19	-	19400	-

Table 2.4 Surface water flow in the river basins of North Gujarat.

Sr.	River	Catchment	Yearly Average Flow	
		sq km	BCM	mm
1	Rel	238	17	70
2	Banas	4383	341	85
3	Saraswati	2282	140	61
4	Rupen	2662	163	61
	Total	9565	661	69

It has been stated in the report that through 2 major, 1 medium and 33 minor schemes, gross storage potential of 147 MCM and 34,624 ha land has been covered under irrigation upto 1993-94 (TEC, 1995).

GROUNDWATER

The groundwater resource of Gujarat state has received less attention in the past and the geological aspects of sub-surface water occurrence in Gujarat have remained practically uninvestigated. In the course of last six decades, different areas of Gujarat, either comprising erstwhile princely states or parts of the Bombay Presidency, were surveyed for the purposes of harnessing groundwater, mostly for agriculture and domestic and industrial water supply. Most of the studies unfortunately lie scattered in unpublished reports which are now either not available or difficult to procure. However, since the independence of the country and integration of princely states into Gujarat region, a concerted programme of groundwater investigation by various Central and State Government agencies were taken up.

The region of Gujarat is characterised by very diverse types and modes of groundwater occurrence, and since this has been the most dominant source of water supply, for purposes related to irrigation, water supply and industrial uses, a lot of data has been generated on the groundwater availability and its exploitation.

As already stated above, studies on groundwater in different areas have been carried out by a number of Central agencies or those of the State Government. North Gujarat in general and Banaskantha district in particular has also received some attention. These agencies have emphasized on the aspects of availability and exploitation of groundwater. In recent years however, considerable awareness has been generated in respect of the dangers of unplanned exploitation or over-exploitation of this resource, a factor which is very vital in causing environmental degradation. In this task of monitoring and highlighting this harmful aspect of groundwater development, apart from efforts made by Government agencies, important role has also been played by a number of voluntary agencies (NGO's) who have made very valuable contribution towards a proper understanding of the entire phenomenon of groundwater occurrence.

CENTRAL GOVERNMENT AGENCIES

Two agencies sponsored by the Central Government have carried out groundwater studies in Banaskantha district. They are the Central Groundwater Board (CGWB) and United Nations Development Programme (UNDP). The activities of CGWB have an all India base and as a part of which North Gujarat in general and Banaskantha in particular have received their due attention. Various officers of CGWB have from time to time referred to the Banaskantha area and provided some details. Baweja (1969) investigated the groundwater conditions of the adjoining Mehasana district and his statements are of considerable relevance to the study area. The hydrogeological map of India and accompanying brochure published by CGWB (1976) is a valuable document for the study area CGWB has established the existence of hydrograph stations for monitoring water level and quality.

Charlu and Dutt (1982) of Rural Electricity Corporation (REC) while describing all India groundwater occurrence, have paid special attention to the Banaskantha district. They have observed the area to comprise a terrain underlain by unconsolidated formations of Gujarat alluvial plains, dotted with a number of artesian wells. The thickness of alluvium in North Gujarat has been 40-500 m within which the groundwater occurs under semiconfined to confined conditions; "most of these aquifers appear to coalesce into one unconfined aquifer" in recharge aquifer close to the hilly terrain. The free flowing groundwater artesian wells give around 54 m^3/hr discharge but the quality shows deterioration from area of recharge to the areas of discharge. These workers have further stated that in the hilly areas, joints, fractures, fissures etc. contribute to the groundwater storage. And in such crystalline rocks the water occurs under phreatic conditions in open wells. The CGWB and UNDP have jointly carried out groundwater surveys exclusively for North Gujarat.

A project by UNDP in three phases (1971, 1976, 1988-85) carried out detailed surveys mainly through a programme of drilling, to study and monitor the extent of over-exploitation. A phreatic aquifer down to depths of 35-260 m and confined aquifer system extending to depth of 600 m were deciphered. A recharge zone where the two systems merge, designated as 'common recharge zone' was delineated towards NE. The effects of excessive exploitation were recorded in both the aquifer systems. As a remedial measure the UNDP report suggested a strategy of artificial recharge for the declining groundwater from available surplus surface water. Several deep exploratory tubewells were drilled for the first time to assess the aquifer parameters and also to work out depths of aquifers. UNDP and CGWB prepared a mathematical model and carried out artificial recharge experiments during 1980 to 1985, and it was observed that phreatic aquifers can be recharged by spreading channels and recharge wells in common recharge zone.

To Phadtare (1983, 1989) of CGWB goes the credit of providing a comprehensive account of hydrogeology of Gujarat. According to him the unconsolidated Quaternary deposits formed a multi aquifers system extending to depth of 500 m. The aquifers have their area of recharge in Piedmont zone and hilly area of the NE. He also studied the problem of over-exploitation and suggested artificial recharge methods. His observations are very much relevant to the study area.

STATE GOVERNMENT ORGANIZATIONS AND VOLUNTARY AGENCIES

The various agencies of State Government have investigated groundwater conditions of a number of areas in Gujarat, but mostly in isolation, with the specific areas and the purpose in mind. As such therefore, in-depth investigations on the groundwater of the entire state is not available in concise form. At present, the most important agency namely Gujarat Water Resource Development Corporation Limited (GWRDC) has generated information on groundwater of various districts of the state, and their investigations have been carried out by classifying the total area of the state into zones of groundwater occurrence.

It is in this context that groundwater information of the Banaskantha district has been provided. This state level body has carried out systematic studies on the groundwater resource development on the basis of field surveys, exploration and monitoring of wells of different categories. The studies based on the observation wells located in the district, as well as monitoring of data from other wells, periodic estimation of groundwater potential upto taluka level has been made on the basis of detailed field inventory. The area has been categorized into hard rock and alluvial from the point of view of suitability for exploitation through tubewell and openwells. Alluvial area is further categorized into yielding fresh and saline water. GWRDC (1991) computed groundwater potential and development for each taluka of the state giving the recharge, draft, balance and level of exploitation, and made a projection for next five year. The groundwater resource and irrigation potential of the district is given in Table 2.5.

Table 2.5 Groundwater resource & Irrigation potential of district.

Details	Quantity
Total recharge	1027.90 MCM/yr
Utilisable recharge	873.70 MCM/yr
Gross draft	1120.22 MCM/yr
Balance	89.56 MCM/yr
Level of development	89.74 %
Category	Dark
Irrigation Potential Created	206350 ha
Balance Irrigation Potential	23570 ha
Ultimate Irrigation Potential	229920 ha
Additional number of wells feasible for 100% level of development.	19925

The talukas have been classified into three different categories based an draft as percentage of recharge as white (<65% draft), grey (65-85% draft) and dark (>85% draft) Accordingly, on this basis, out of 11 taluka of the Banaskantha district, six fall in the dark category. Although, in a general way the whole district could also be considered to fall into dark category. GWRDC is also carrying on monitoring of water level and quality through 42 observation wells scattered all over district since 1984 (Fig 2.7).

Exclusively groundwater studies for North Gujarat including Banaskantha district, were carried out by Narmada Water Resource Development (NWRD) in 1991, and their thrust was towards a proper understanding of the problem of overexploitation. This agency suggested measures for augmenting groundwater availability through surface water recharge, and recommended induced recharge works through conservation of soil and water and afforestation.

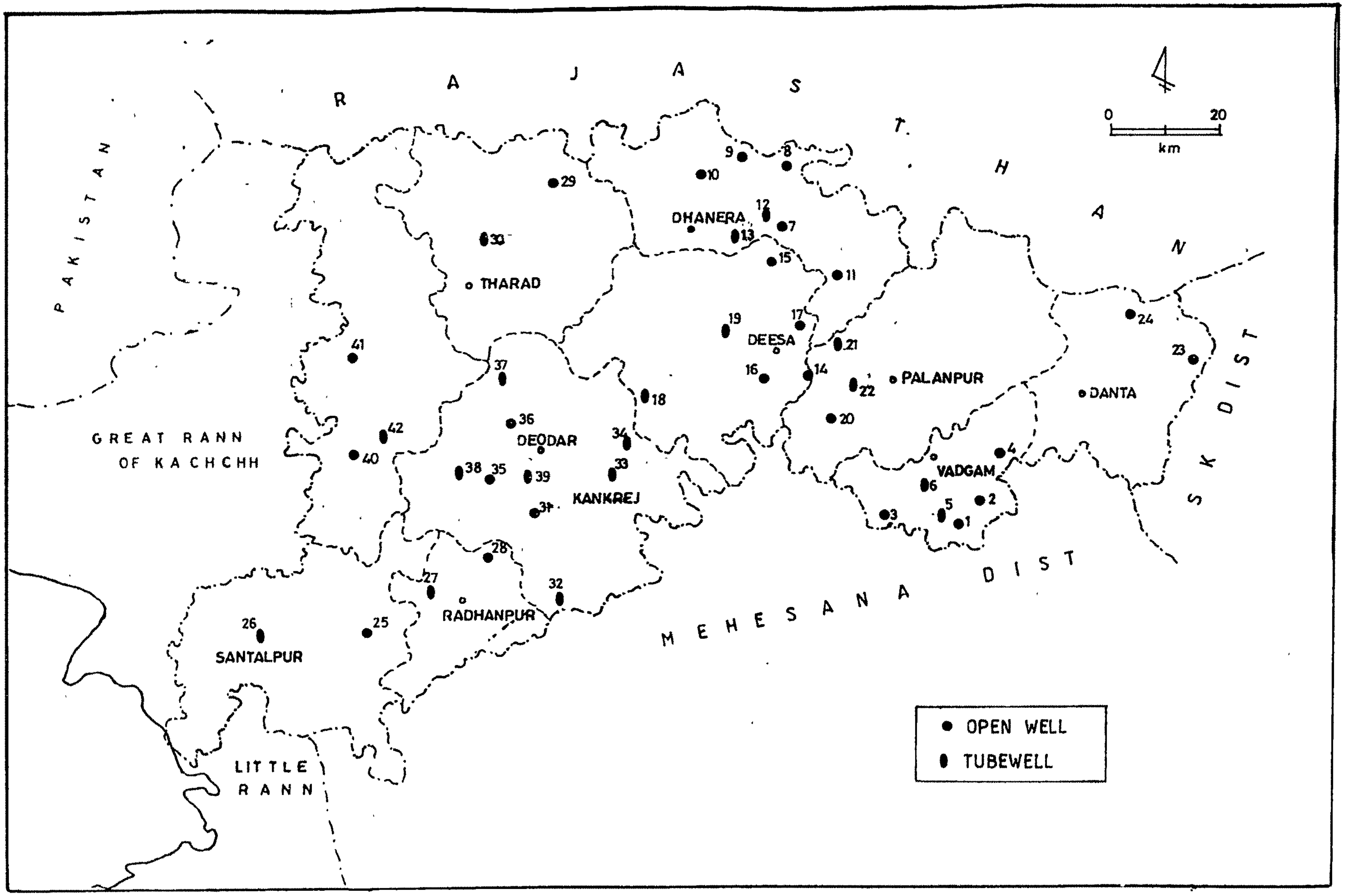

FIG-2·7 LOCATIONS OF GWRDC OBSERVATION WELLS

Operation Research Group (ORG) in 1993, carried out a groundwater modelling study for the area between Sarbarmati and Banas rivers (Sabarmati-Banas Doab). A small part of this area falls within Banaskantha district. As the entire area investigated is more or less identical, the findings of ORG could be applicable for Banaskantha as well. The model predicts areas suitable for developing groundwater where levels are shallower than 5 m.

Dalal Consultants (1992) made a groundwater model for the region between the river Banas and the Rajasthan border. The study conceptualized the aquifer system as an upper phreatic layer separated by an aquiclude from a lower confined layer. Hydraulic Research, Wallingford, UK, (HRW) in 1993 made an assessment of the impact of Sardar Sarover Project on environment of North Gujarat. In their report western part of Banaskantha district was also included. The study identified some key hydrogeologial environmental issues viz. rising groundwater levels, water-logging and salinization of soil and water. In a subsequent study by HRW carried out groundwater modelling of the Sardar Sarovar Project Command area to predict the groundwater behaviour vis-a-vis impact of the proposed project on hydrogeological system of North Gujarat.

Tahal Engineers Consultants (TEC,1995), made an analysis of the groundwater resource and development using latest computer techniques.

Specific theme-based studies on one or the other aspects of water resource management of the district with emphasis on subsurface water were conducted by a number of voluntary (NGO's) organizations. Shah (1992) of IRMA studied the problem of water marketing and related issues. Marcus (1992) of VIKSAT highlighted the implications of falling subsurface water levels and suggested appropriate remedial management options. Gujarat Loksamiti and Bhansali Trusts, the two voluntary agencies in North Gujarat have carried out artificial recharge through construction of underground checkdams in Radhanpur area. Vaidya, (Loksamiti) a Sarvodaya leader working since about a decade, has studied the overall water management related problems of Banaskantha district and has observed the imbalances and hazards and his main contribution pertains to the agitation for riparian rights of the people of the downstream of Dantiwada and Sipu. To him goes the credit of generating people's awareness towards the environmental degradation caused by the construction of dams in the upstream and compelled the Government to agree on releasing regular flow of water form dams for catering to the needs of downstream villages.

SOIL AND LAND USE

As per 1991 district Census, the pattern of landuse and land cover shows that district is dominanltly covered under agricultural use followed by forest, fallow land and permanent pastures, and the rest is under varieties of use (Table 2.6).

Table 2.6 Landuse Pattern of the district (1988-89) in Hectares

Landuse Pattern	Area	
	(ha)	(%)
Total Area Reported	1232724	-
Total Forest Area	148262	12
Total Barren Uncultural land	35401	12.8
Non-Agricultural land	68779	05
Permanent Pasture land	69610	06
Culturable Waste	23751	02
Net Area Sown	758936	61.6
Gross Cropped Area	983113	79.8

Gujarat Engineering Research Institute, GERI (1993) mapped the physical conditions of the wastelands of the Banaskantha district, and their study has revealed that 21.61% of land area of the district falls under wasteland category of different types. Major parts of the wasteland fall under the categories of (i) upland with or without scrub, (ii) salinity/alkalinity affected coastal land and (iii) unutilized degraded forest land (Table 2.7).

Table 2.7 Wasteland Statistics of Banaskantha district (1990-91).

Category	Area	
	ha	(%)
Gullied \ Ravenous Land	8040	0.63
Upland with or without scrub	123666	9.74
Water logged and Marshy Land	5362	0.42
Land affected by Salinity, alkalinity-coastal \ Inland	55186	4.35
Under utilized \ Degraded notified forest land	54697	4.31
Degraded pastures \ Grazing land	884	0.07
Degraded land under plantation crops	108	0.008
Sands Desertic\Coastal	4705	0.372
Mining \ Industrial	377	0.03
Barren Rocky \ Stony waste sheet rock areas	5278	0.42
Steep sloping area	15993	1.26
Total	274296	21.61

Sharma *et. al.*, (1994), based on the data and information generated by National Bureau of Soil Survey and Land Use Planning (NBSS and LUP) of Nagpur and the departments of Water Resource and Agriculture, Government of Gujarat, carried out soil resource mapping of the state using latest technology. They have classified the soils of Gujarat as per soil taxonomy, and according to their survey, the soils of Gujarat belong to 5 orders, 11 suborders, 20 greatgroups and 45 subgroups. As per their scheme of classification, the soils of Banaskantha mainly comprise 4 suborders viz. Ochrepts, Psamments , Orthids and Fluvents (Fig.2.8).

According to Dubey *et. al.*, (1995) of CSSRI, who studied the salt affected soils of Gujarat, the Banaskantha district has 243 sq km area in 5 talukas in western parts showing soil degradation due to salinity problem (Table 2.8)

Table 2.8 Salt affected soils in different talukas of district.

Name of Taluka	Salt Affected Area (sq km)
Vav	69.55
Tharad	47.50
Deodar	26.60
Santalpur	72.04
Radhanpur	27.00
Total	242.69

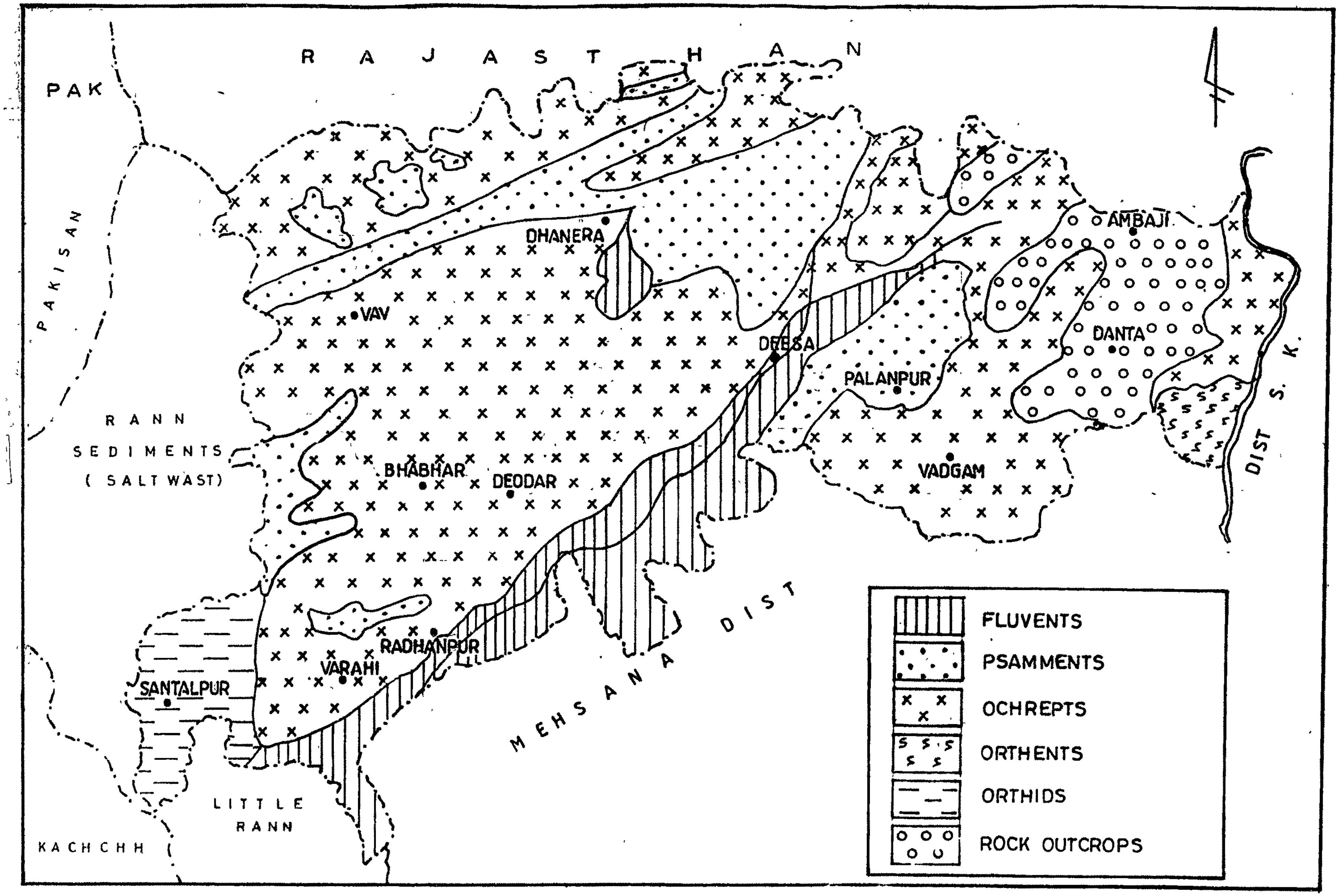

FIG- 2.8 SOIL MAP OF BANASKANTHA DISTRICT