PART II

HYDROGEOLOGICAL STUDIES

CHAPTER IX

HYDROGEOLOGICAL FRAMEWORK

HYDROGEOLOGICAL FRAMEWORK

INTRODUCTION

Water is an important natural resource that is essential for the sustenance of human civilization, of which groundwater plays an important role in meeting a substantial part of the domestic, agricultural and industrial needs. The occurrence, distribution and potential of water resources in any area is a function of numerous variables predominated by the geological parameters and hydroclimatological factors. The evaluation of water resource potential and utilization, especially the groundwater resource, needs an elaborate study of various factors governing the monsoon pattern, surface runoff, infiltration, various hydraulic characteristics of the aquifer systems, etc. Due to differential topographic conditions, the hydrogeological studies of any area vary widely.

Even though the Indian subcontinent is rich in groundwater resources, the quantitative and qualitative availabilty of groundwater is a real problem in the northwestern parts comprising the arid and semi-arid zones of Rajasthan, *viz.*, the Thar Desert. Having one of the most unfavourable climatic conditions characterised by scanty, capricious and erratic rainfall, high temperatures, high evaporation far exceeding the precipitation and consequent insufficiency of moisture to sustain vegetation, the Thar region faces acute shortage of surface water as well as

groundwater, a further setback to the region. Deep groundwater levels, highly saline water, limited recharge and uneconomical exploitation are characteristic of the groundwater scenario of the region. Fresh water zones do occur in the Thar, especially in the deeper aquifers and the eastern parts, but they are highly localised as compared to the saline water tracts.

The precarious conditions of water resources in the arid-semi arid regions of Rajasthan coupled with poor surface and subsurface drainage has led to a large scale survey of the available groundwater resources in the recent years. Extensive hydrogeological and hydrochemical studies have been undertaken by various organisations, *viz.*, the Central Groundwater Board (CGWB) and the Rajasthan State Groundwater Department. Periodic assessment and updating of the total groundwater resources of the region, which form the major source of drinking water, are being carried out by these organisations.

OBJECTIVES AND METHODS OF PRESENT STUDY

The Luni and Kantli watersheds, forming a part of the Thar desert, have unfavourable hydroclimatic regime. Large scale heterogeneity in lithology and thick pile of aeolian cover, pose a challenging task in evaluating the various hydrogeological aspects of the area. Paucity in recharge, inherent groundwater salinity and lack of continuity in the aquifer systems have further worsened the hopes of locating potable and potential groundwater aquifers and well sites therein.

The present hydrogeological studies do not aim at making a firm quantitative assessment of the groundwater resources of the area, but only to make a general appraisal of the hydrogeological conditions that control the mode of occurrence, distribution and quality of groundwater. The following objectives were taken up in the present study.

- Mode of occurrence and distribution of groundwater resources.
- Geohydrological appraisal of various aquifer units.
- Hydrogeological categorisation of the study area with respect to lithology, structure and geomorphological parameters.

- Hydrochemical studies of groundwater and distribution pattern.
- Groundwater utilisation and aspects of water resources management.

In order to achieve these objectives, the author has adopted the following methodology:

1. Collection of available literature from various agencies, *viz.*, CGWB, CAZRI, RSGWD, etc.
2. Critical appraisal of collected data.
3. Groundwater inventory and collection of water samples for evaluating groundwater chemistry at selected locations.
4. Preparation of hydrogeological and groundwater potential maps with the help of geological and remote sensing data.
5. Overall hydrogeological-geohydrological and hydrochemical appraisal of the study area.

GROUNDWATER : DISTRIBUTION AND MODE OF OCCURRENCE

It is an established fact that the Indian sub-continent is characterised by a well defined monsoon season and influenced by orographic factors. Rainwater being the only source of recharge to the groundwater regime, the monsoon rain is governed by a number of hydroclimatic parameters. In the study area due to unfavourable orographic conditions the monsoon is highly erratic and scarce. The area being a part of the arid-semi arid terrain, is always hit by the vagaries of monsoon, i.e. **Drought Prone**. High rate of evaporation and prolonged dry weather conditions have significantly deteriorated the quality and quantity of surface and subsurface waters.

The occurrence of groundwater in the study area is mainly controlled by the physiography and lithology. Groundwater in the study area occurs under phreatic and semi-confined to confined conditions. In the hard rock terrain the groundwater by and large occurs in the phreatic zone characterised by the weathered and disintegrated rock profile. The deeper aquifers which are of semi-confined nature are infact restricted to the fractured zones. The Quaternary sediments, comprising wind-blown sands, fluviatile deposits of sand, gravel and pebbles (alluvium), form the principal and potential aquifers in the study area. Owing to predominantly hard rock terrain

particularly in the central, southern and eastern parts, the occurrence and distribution of groundwater to a large extent is restricted to the phreatic aquifers. However, in the western, northwestern and northern parts of the area, thick cover of alluvium and aeolian material has given rise to deep semi-confined aquifers. Local confined aquifers also occur in the Luni and Kantli river basins. The Quaternary sediments generally constitute a single hydrogeological unit.

GEOHYDROLOGICAL CHARACTERISTICS

Studies on the geohydrological aspects of Luni and Kantli watersheds have been carried out to understand the behavioural pattern of the aquifers in terms of water table fluctuations and related hydraulic characteristics.

Owing to numerous constraints, the author was unable to carry out seasonal monitoring of groundwater and was able to collect very limited primary data from the field. Hence, major part of studies on this aspect is based on the data collected from the Central Groundwater Board (CGWB), an apex body carrying out regional groundwater monitoring through National Network Observation Stations. However, in order to maintain the authenticity of the available data, the author has selectively carried out the geohydrological studies and collected groundwater samples for determination of their chemistry. Based on the collected data and their critical scrutiny, an overall geohydrological appraisal of the study area is discussed as under:

GROUNDWATER LEVEL AND ITS FLUCTUATION

To study the disposition of the groundwater level and its fluctuations in the Upper Luni and Kantli river basins, water table data of 60 observation wells, for the period 1978 to 1988, have been utilised. Based on these data, the pre-monsoon (April) and post-monsoon (November) average reduced water level contour maps of the study area were drawn and also the seasonal water level fluctuations were calculated. The long term fluctuations in water levels have been studied by superimposing the post-monsoon reduced water level contour map of September 1992 on the post-monsoon reduced water level contour map for the 1978 period. Hydrographs for few

selected wells distributed within the study area, have been studied for analysing the long term water level fluctuation trends.

Depth to Water Table

In the study area the water table shows strong influence of topography and depth to water table varies from area to area. Study of the Reduced Water Table contour map (Fig. 9.1) has revealed that in the northeastern parts of the study area encompassing upper reaches of Kantli basin, the depth to water table ranges between 10-25 m. The water table depth tends to increase northward around Pilani, Chirawa, Chandgoti, Alsisar, Bissau, Fatehpur, Nawalgarh, etc; up to more than 40 m. This is possibly attributed to the lowering of bedrock profile and increase in thickness of alluvium.

In the central parts of the study area, water table conditions are by and large shallow, especially in the salt lake area around Sambhar, Kuchaman, Nawa, etc., and Danta Ramgarh, Khur, Dhod, etc., where the water table ranges between 1-10 m.

However in the Luni basin, the water table conditions are seen at variable depths. The area along the Luni flood plains and pediment plains are characterised by relatively shallow water table conditions, i.e., 10-25 m. The water table depth tends to increase northwestward to the order of 40-50 m. The areas around Banthri, Jayal, Tithri, Khudana, Sheshda etc., are characterised by deeper water table conditions. In the southwestern parts of the study area, i.e., around Bilara, Kekind, Jodhpur, Dangiyawas, Luni etc., the water table depth is generally in the range of 10-25 m.

Water Table Fluctuations

Observations on the water table fluctuations in the study area are in conformation to the rainfall. A perusal of the various hydrographs of the National Network Observation Stations distributed within the study area indicates that rise in water level is due to precipitation. Varying amplitudes of rise in different years correspond to the variation in the monsoon precipitation from year to

year. Generally, the water table declines in the premonsoon period and recovers partially or fully depending on the intensity and quantum of rainfall received.

Seasonal Water Level Fluctuation

Apart from the minor diurnal changes that affect the groundwater levels in the study area, the water level is subjected to the seasonal fluctuations which are conspicuous and directly correspond to the changes in the groundwater storage which is in turn related to the annual precipitation. The rise and fall of water level represent the increase and depletion of the groundwater storage respectively.

To study the behavioural pattern of the water table fluctuations, a Reduced Water Level (R.W.L.) contour map (Fig. 9.1) has been prepared for the premonsoon and postmonsoon seasons with the help of long term monitoring data from 1978-1988. A perusal of this map shows that,

(1) Large scale seasonal groundwater level fluctuations are not observed in the region.
(2) The seasonal fluctuations are generally reflected in the form of rise in water table during the postmonsoon periods of each year.
(3) The fluctuation in water table generally ranges between 0.1 and 5 meters.
(4) The water table fluctuation is more pronounced in the hard rock terrain than in the alluvium area.

Long Term Water Level Fluctuations

In order to study the long term groundwater level fluctuations in the study area, the available CGWB water level data of selected National Network Hydrograph Stations for a period from 1969 to 1985 were analysed. The long term water level fluctuation map (Fig. 9.2) comprising the average post monsoon water table contours for the 1978 period superimposed over the postmonsoon water table contours for the September, 1992 field season shows no significant change in the water level depths and thereby groundwater storage. In the northeastern parts of

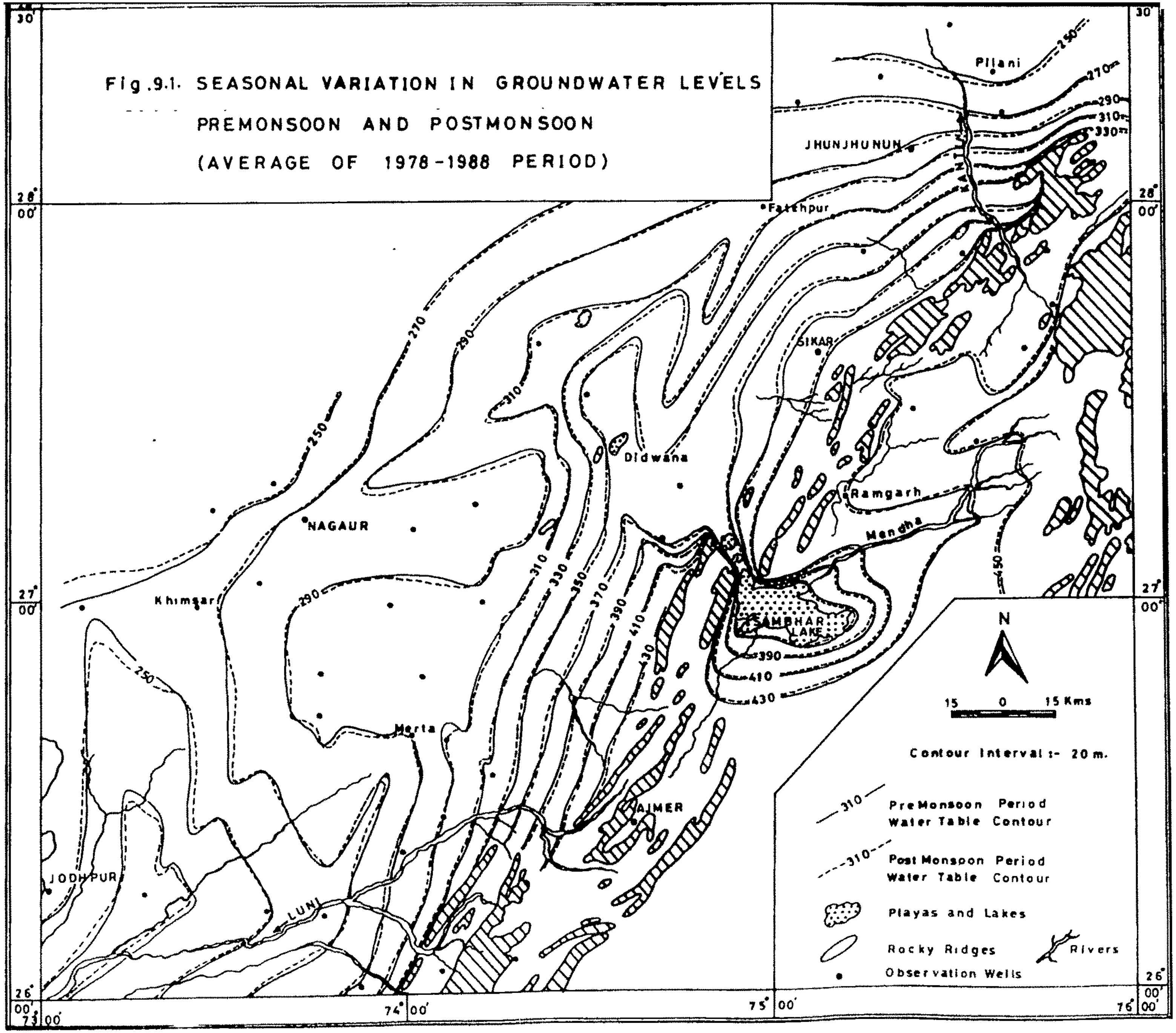


Fig.9.1. SEASONAL VARIATION IN GROUNDWATER LEVELS PREMONSOON AND POSTMONSOON (AVERAGE OF 1978-1988 PERIOD)

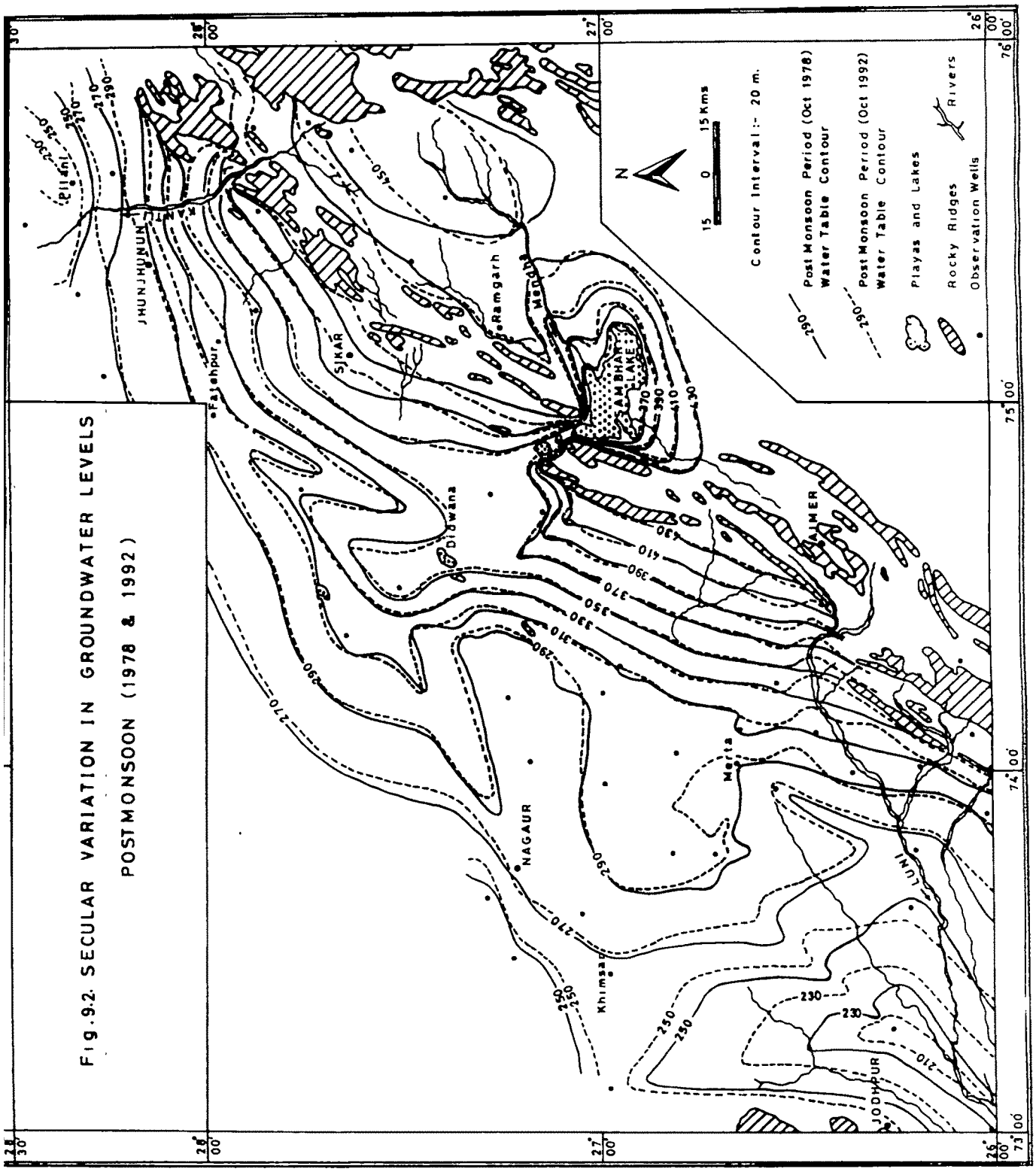


Fig.9.2. SECULAR VARIATION IN GROUNDWATER LEVELS POSTMONSOON (1978 & 1992)

the Kantli watershed, marked rise in water levels are observed in the areas around Alsisar, Chirawa, Bisanpura, Singhana, Khudana, Khetri, Baragaon, Mundwa, etc. This rise in water levels is attributed to the increase in rainfall, thereby the recharge to the groundwater regime.

Various hydrographs of National Network Observation wells within the study area were carefully scrutinized to study the long term water level fluctuations. A perusal of these hydro-graphs of Upper Luni basin (Figs. 9.3a-e) and Kantli basin (Fig. 9.4) indicates that the rise in water level is due to high precipitation. The study of the hydrographs indicates that in the Luni basin rise in water levels to the order of 5 to 20 m occurred at some localities during the period 1974 to 1980, which is attributed to the good amount of rainfall received in that region during the period, thereby increased groundwater recharge. In the Kantli basin the water level fluctuation seems to be erratic but more confined to the watershed. The variations in the monsoon precipitation from year to year are manifested in the hydrographs as different amplitudes of rise in different years. The locations showing long term water level fluctuations to the order of 5-15.m in the study area are given in the Table 9.1.

Groundwater Movement Direction and Gradient

It has been observed that the groundwater movement direction and gradient display strong influence of topography and landform configuration. The water level contour map (Fig. 9.1) suggests that in the Luni river basin, i.e., the southwestern parts of the study area, the upper reaches of Luni river abutting the Aravalli Mountain Range is characterised by the pediment zone and pediment plains comprising of colluvial materials. Here the groundwater movement direction is northwesterly and displays steep gradient (1:328). Further northwest, the hydraulic gradient becomes gentler (1:1825), however the groundwater movement direction tends to shift southwesterly i.e., along a regional topographic slope. The areas falling within the Luni flood plains are characterised by this gentle hydraulic gradient. The change in the groundwater movement direction from northwest to southwest is probably under the influence of the NE-SW trending Luni-Sukri lineament.

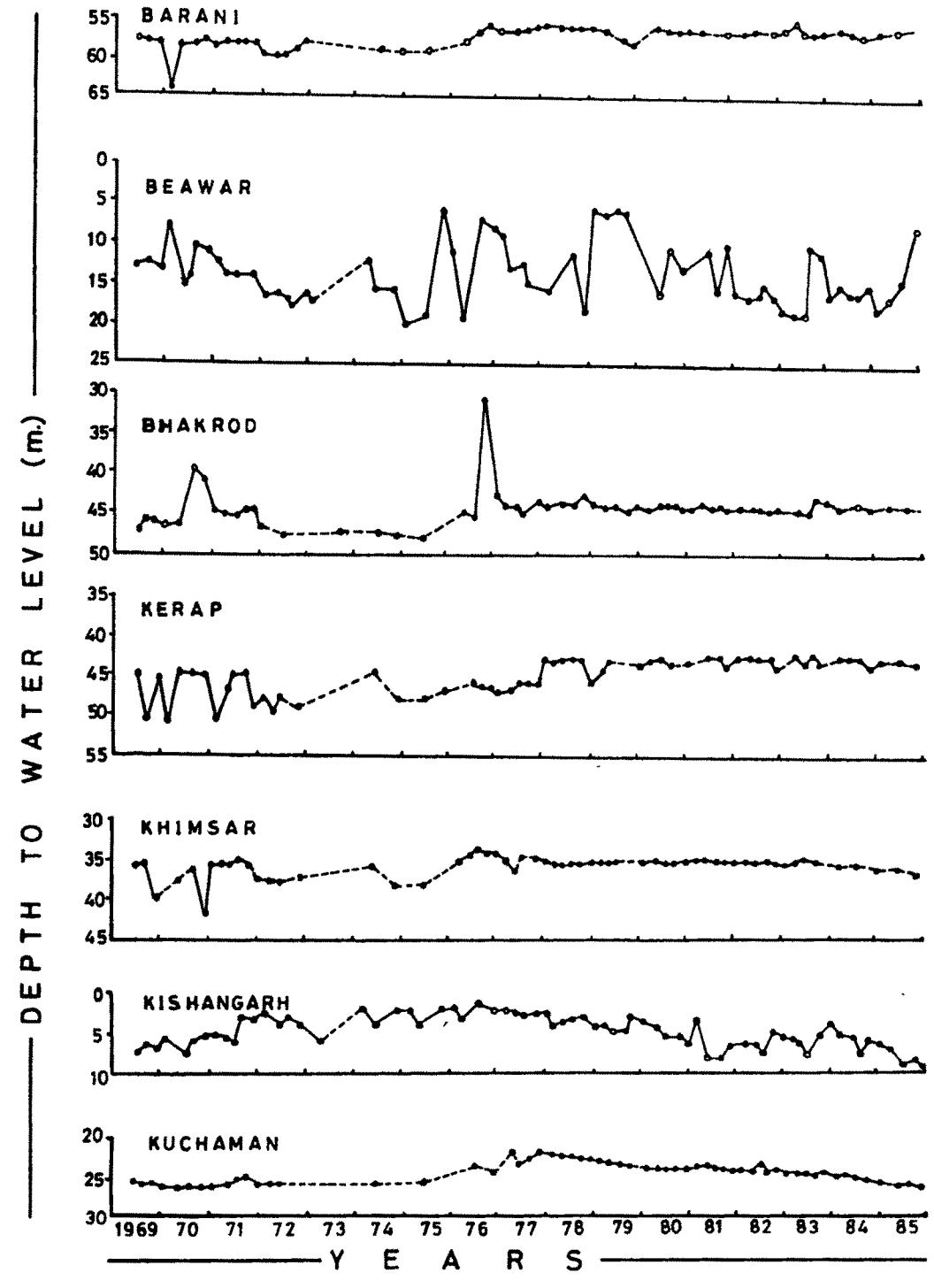


Fig. 9.3a Hydrographs of National Network Observation Wells in the Upper Luni River Basin

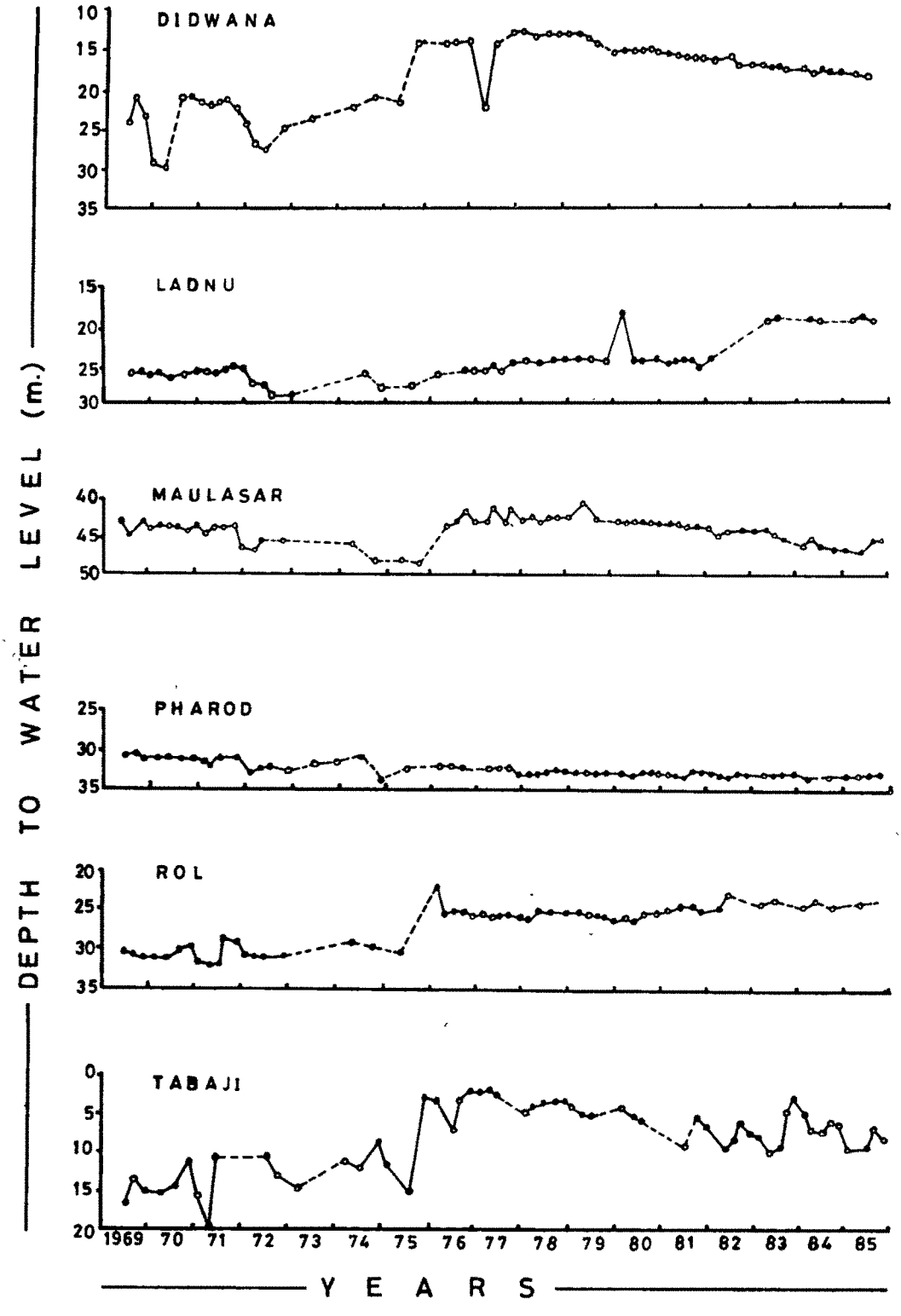


Fig. 9.3.b. Hydrographs of National Network Observation Wells in the Upper Luni Basin

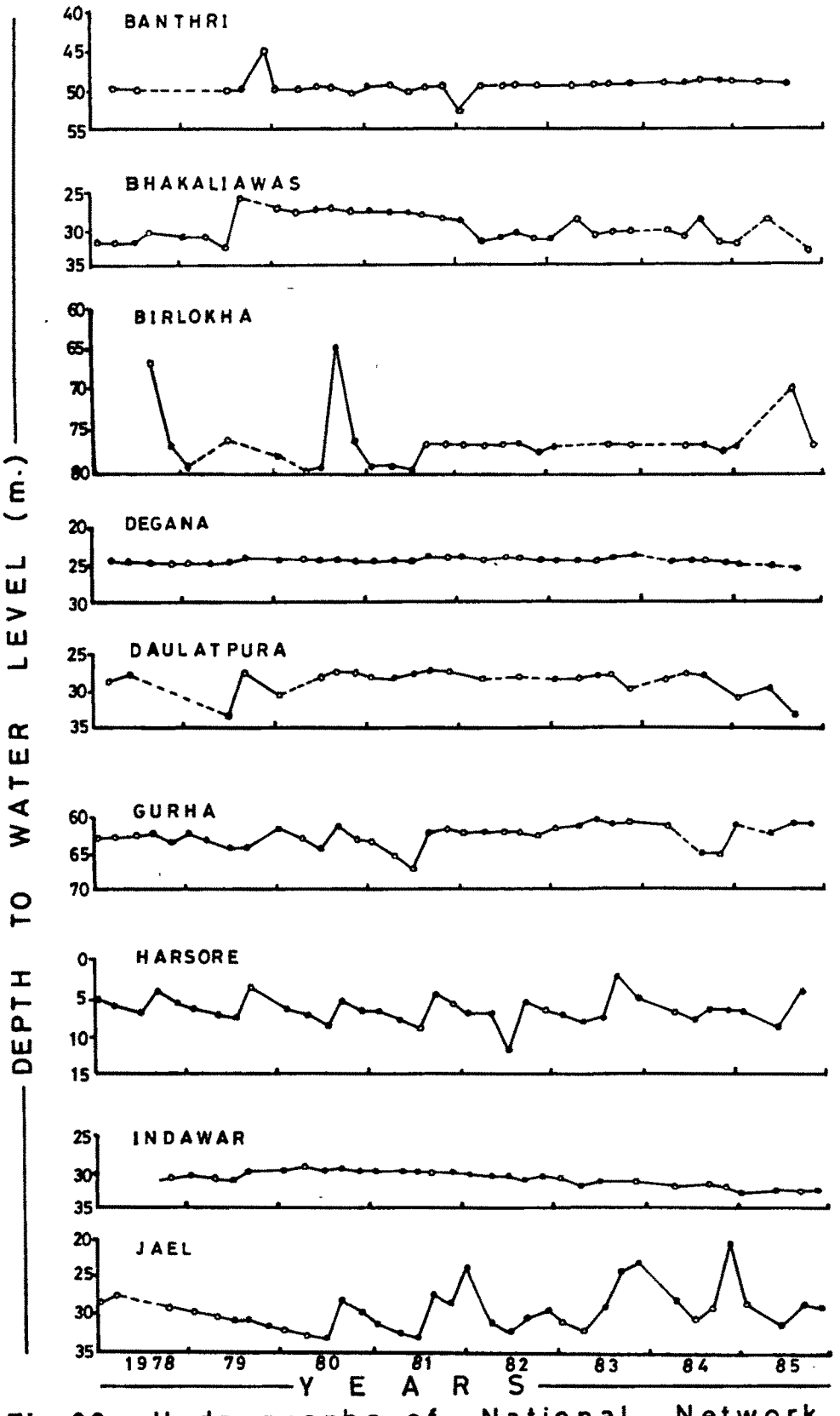


Fig.9.3c. Hydrographs of National Network Observation Wells in the Upper Luni Basin

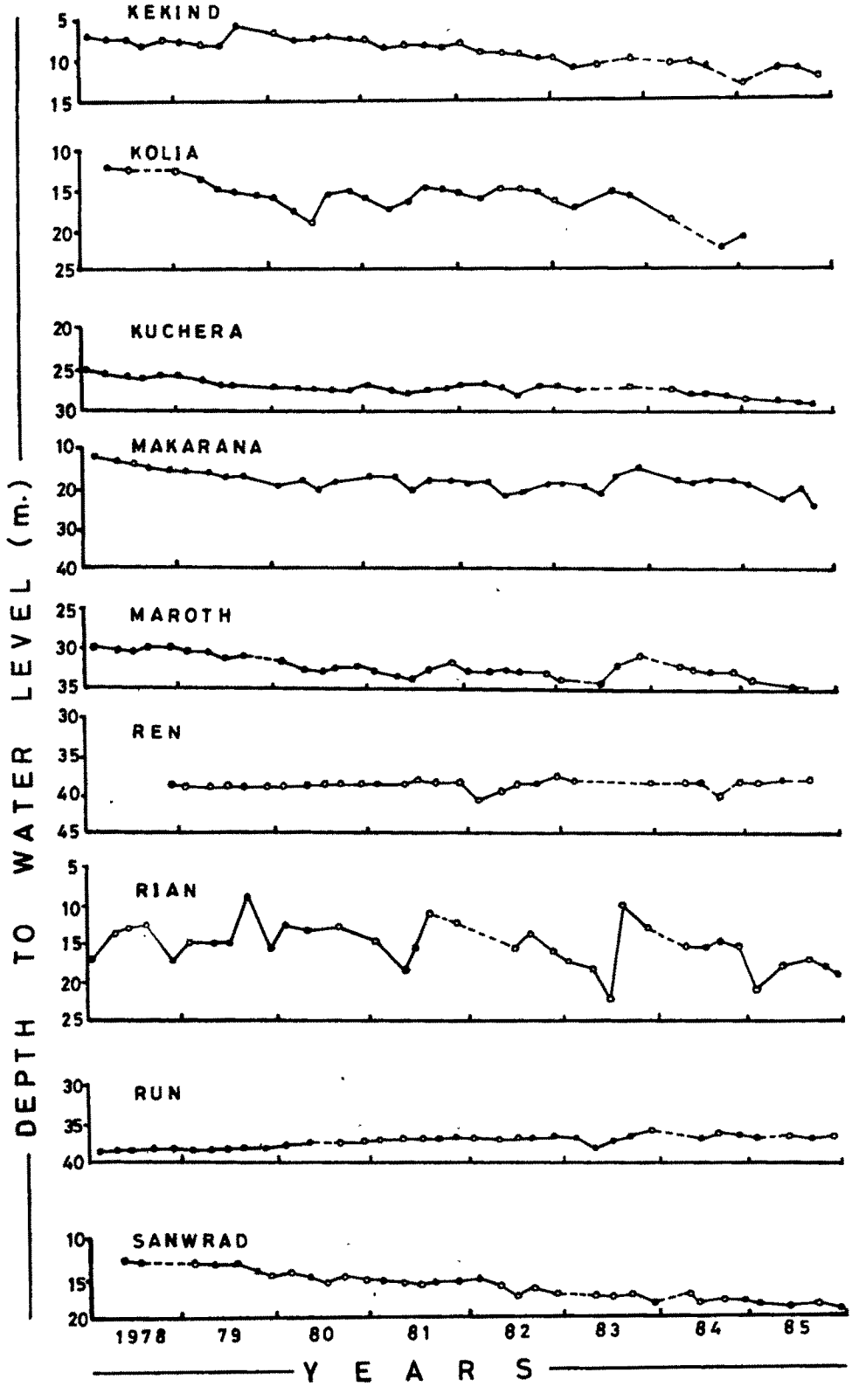


Fig.9.3.d Hydrographs of National Network Observation Wells in the Upper Luni Basin

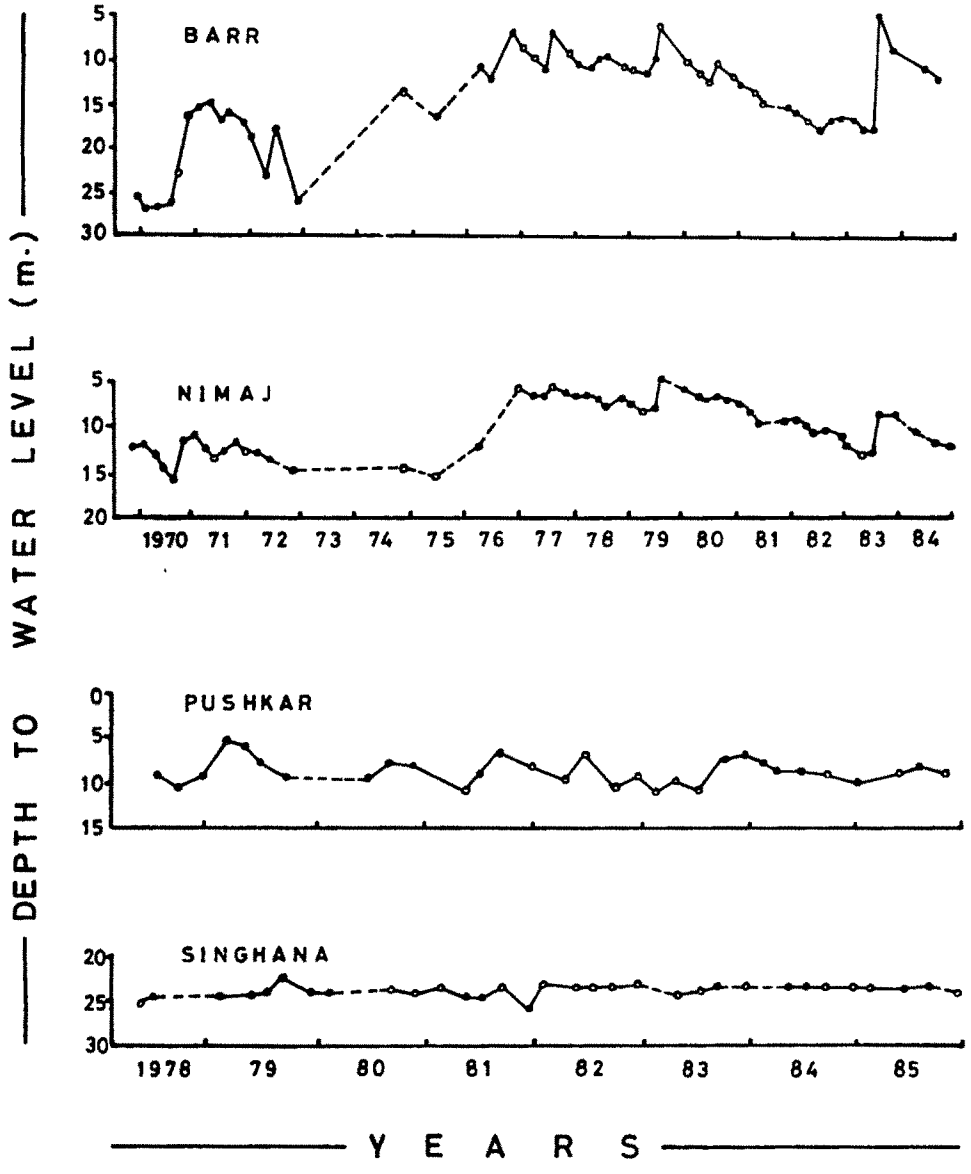


Fig. 9.3.e Hydrographs of National Network Observation Wells in the Upper Luni Basin

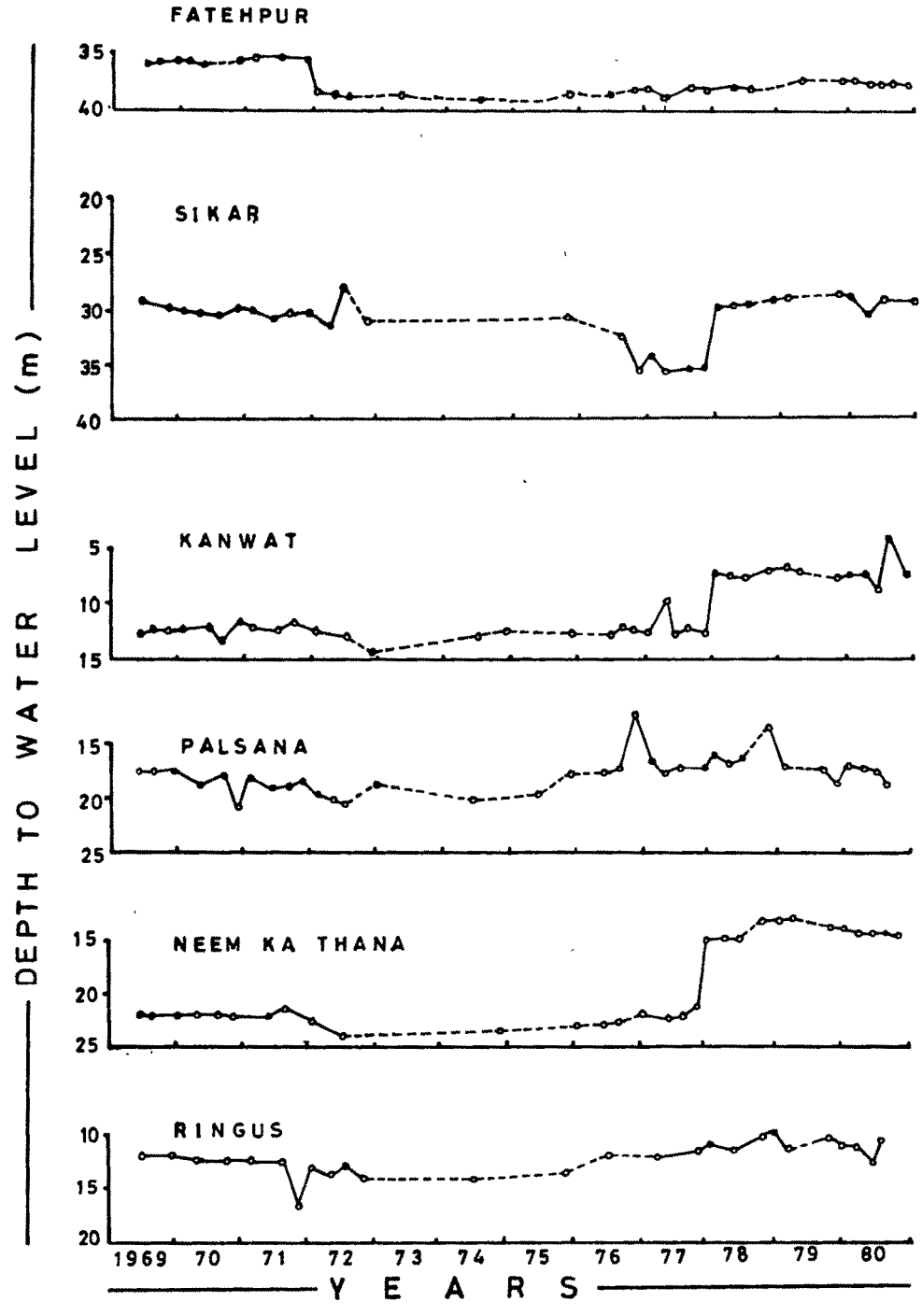


Fig.9.4. Hydrographs of National Network Observation Wells in the Kantli River Basin

Table 9.1 Locations in the study area showing long term water level fluctuations

Block	Rise in GWL	Decline in GWL	Near equilibrium GWL
Upper Luni	Kerap, Run, Barr, Ladnun, Rol, Tabaji	Kuchaman, Sanward, Maroth, Bhakliawas, Daulatpura, Kekind, Kolia, Nimaj, Rian, Didwana, Maulasar, Kishangarh, Indawar, Kuchera, Makrana	Bhakrod, Singhana, Banthri, Barani, Degana, Khimsar, Ren, Pharod, Beawar, Pushkar, Gurha, Harsore, Jayal, Birlokha
Kantli	Kanwat, Nim ka Thana,	Fatehpur	Sikar, Palsana, Ringus

In the central parts of the study area, i.e., around Sambhar, Didwana, Kuchaman and Danta Ramgarh, which are characterised by flat and broad valley depressions, the water table gradient is gentler (1:550). A linear belt between the Sambhar and Didwana lakes shows sub-horizontal gradient (1:2450). An apparent northeasterly shift in the groundwater movement direction with a change in gradient (1:910) is also observed in this part of the study area.

In the Kantli basin the groundwater movement direction is northerly. The hydraulic gradient is steeper in this part of the study area (1:299), which becomes gentler further northwards (1:438).

HYDRAULIC CHARACTERISTICS

Studies dealing with the hydraulic characteristics of various aquifer units form important criteria for the hydrogeological evaluation of any area. The study area forming a part of the Trans-Aravalli terrain of western Rajasthan comprises various lithologic units which form the aquifers. Therefore, an appraisal of the hydraulic characteristics of these diverse formations is a prerequisite for the hydrogeological evaluation and thereby the area categorisation.

Groundwater Conditions in Different Formations

As mentioned earlier, groundwater in the study area occurs under water table conditions in the shallow zone of Quaternary sediments as well as in the zone of weathering and fractures in the hard rocks. Quaternary alluvium and blown sand constitute the most important water table aquifers in major parts of the study area. The groundwater conditions in the three broad hydrogeological litho-units *viz.*, consolidated, semiconsolidated and unconsolidated formations (Davis and DeWiest, 1966) of the study area are briefly discussed as under:

Consolidated Formations

Hard rocks belonging to the Pre-Aravallis, Delhis and post-Delhi intrusives comprising granites, gneisses, amphibolites, quartzites, rhyolites, epidiorites etc., constitute sufficient parts of the

study area. Groundwater in these rocks occurs in the joints, fractures, other structurally weak zones and in the upper weathered portions.

These rocks form poor aquifers with average yield of 2,500 to 60,000 litres per day. Open wells tapping the schists yield 30,000 to 80,000 litres per day. Yields of 20 lpm to 210 lpm of water of non-potable quality have also been observed from the aquifers developed within schists, phyllites and gneisses in the areas around Dabri, Roru, Sanward and Kanwai in the Upper Luni basin. The yields of wells tapping phreatic zones of granitic and gneissic rocks around Ajmer area range from 20,000 to 95,000 litres per day. The tubewells tapping these rocks yield poor quantities of water averaging about 140 litres per day with an average drawdown of 6 m. Recuperation of water in the wells tapping the granitic and gneissose aquifers is slow, but faster than those in the schists which is due to high propotion of clayey minerals. The yield in open wells tapping quartzites vary from 40,000 to 1 lakh litres per day. Recuperation is faster than in the wells tapping schists and granites and the water quality is also fresh. The borewells in quartzites yield about 2000 litres per day, generally more than the granitic aquifers, which can be attributed to high order fracturing and jointing.

In the Kantli block, the yield of wells tapping the Delhi Supergroup of rocks and intrusives *viz.*, quartzites, schists, phyllites, amphibolites, etc., is generally less than 250,000 litres per day with an average drawdown of more than 4 m.

Hardrock aquifers constituting the consolidated formations are confined mostly to the southeastern and eastern parts of the study area. Generally these consolidated formations form poor aquifer systems and constitute the low groundwater potential zones of the area, where discharge of water predominates over recharge. The transmissivity values of these rocks vary from 156 m^2/day to 7766 m^2/day, but the general range is between 150 m^2/day and 350 m^2/day. The hydraulic conductivity values range between 1 m/day and 80 m/day.

Semi-Consolidated Formations

The rocks belonging to the Marwar Supergroup of rocks, *viz.*, Jodhpur sandstone, Bilara limestone and Nagaur sandstone and few rock types of the pre-Aravallis and Delhis *viz.*, slates, marble, phyllites, schists, etc., constitute the semiconsolidated category in the study area. These rocks have high to moderate porosity and permeability and form relatively good aquifer systems with the water table usually occurring at medium depths. Jodhpur sandstone, which is coarse grained and quite compact, constitutes a poor aquifer and the groundwater contained in it is usually saline. The wells tapping these sandstones have low yield of about 24 m^3/day.

The Bilara Group limestone is a potentially productive aquifer in the study area yielding good quality water. In Ajmer district limestone occurrences have been reported from the areas between Bassi and Nand of Saraswati and Sagarmati interstream area in the north and Bhakthawarpura village in the south. Groundwater yield as high as 1 lakh litres per day has been reported from wells tapping limestone aquifers. A well at Nokha Joda has yielded 90 m^3/hr of groundwater, but the quality was saline with E.C. exceeding 9000 μmhos/cm at 25° C. Limestone tapped at Gotan (Merta) in a tube well had yielded 544 m^3/day of good quality water. The transmissivity value was 79.81 m^2/day. The limestone aquifers of Upper Luni basin are by and large characterised by high yields ranging between 14 m^3/day and 1000 m^3/day.

The Nagaur sandstones are coarse to very coarse grained, loosely cemented and have a basal gravelly horizon. The aquifers developed within these sandstones are characterised by good to moderate quality of water (E.C. 900 - 2590 μmhos/cm at 25° C) with discharge varying between 100 lpm to 320 lpm for a drawdown of 3 m. The transmissivity values vary from 50.9 m^2/day to 344 m^2/day.

The semiconsolidated formations that constitute the aquifer systems of the study area are distributed in the central, western and northwestern parts.

Unconsolidated Formations

The Quaternary alluvium comprising of unconsolidated sand, gravel, silt and clay with occasional pebbles and cobbles occurring as younger alluvium along the channels of Luni, Raipur Luni, Sukri, Lilri, Mitri (Jojri), Mendha, Rupangarh, Kantli, Sahibi and Chandrawati rivers, and as older alluvium along the palaeochannels constitute the major aquifer system of the study area. These aquifers are by and large of water table (phreatic) type and are distributed within the depth range of 2-50 m. The permeability of these aquifers varies between 45 m/day and 250 m/day. The discharge of wells tapping vary from 300 lpm to about 1500 lpm for drawdown up to 15 m. The transmissivity values vary between 2.5 m^2/day to 900 m^2/day. The yield of groundwater from the dug wells range between 10 m^3/day and 220 m^3/day, whereas the yield from the tube wells range between 33 m^3/day and 1150 m^3/day.

The quality of groundwater in the unconsolidated sediments is generally good with E.C. within 5000 μmhos/cm. The alluvium filled valleys of the Saraswati, Sagarmati, Rupangarh, Mendha and Kantli rivers constitute the most potential aquifer systems of the study area. Yield of tubewells in the Saraswati valley is in the range of 36,320 to 68,100 lph with an average drawdown of 3.03 m. The tubewells in the Ganhera area yield over 8.5 lakh litres of water per day. In the vicinity of the Sambhar lake, the water in the alluvial formation is generally brackish. The area between Kuchaman and Didwana, area to the east of Degana and the area between Merta city and Jayal have been delineated as areas feasible for high capacity wells.

The overall aquifer characteristics of the study area are summarised in the Table 9.2. The disposition and distribution of these aquifer systems in the area as seen in the fence diagrams and profile sections is given in Figures 9.5, 9.6 and 9.7 corresponding to the Kantli, Sambhar and Upper Luni basins respectively.

Table 9.2 General Geohydrological characteristics of the study area

Aquifers (Formations)	Rock Types	Depth of Well (m bgl)	SWL (m bgl)	Yield (m^3/Day)	Drawdown (m)	Transmissivity (m^2/Day)	Hydraulic Conductivity (m/Day)	Groundwater Potential
Unconsolidated	Quaternay alluvium-sand, gravel, silt pediments	30-275	02-50	10-250	12-15	100-900	50-450	Potential groundwater aquifers, main water table, saturated zones-15 to 70 m
Semiconsolidated	Nagaur sandstone	50-150	25-40	20-100	01-14	50-350	08-100	Small quantity of fresh water, moderate aquifers
	Bilara limestone	80-400	25-45	20-1000	01-10	70-390		Potential aquifers
	Jodhpur sandstone	100-450	25-50	24-50	01-05	50-250		Poor aquifers
Consolidated	Granites, gneisses, schists, phyllites, slates, amphibolites, epidiorites, quartzites	50-100	05-10	25-100	05-16	150-350	01-80	Low groundwater potential, water yielding capacity restricted to fractures, joints, solution cavities and weathered zones. Poor to moderate aquifers with limited water yielding capacity

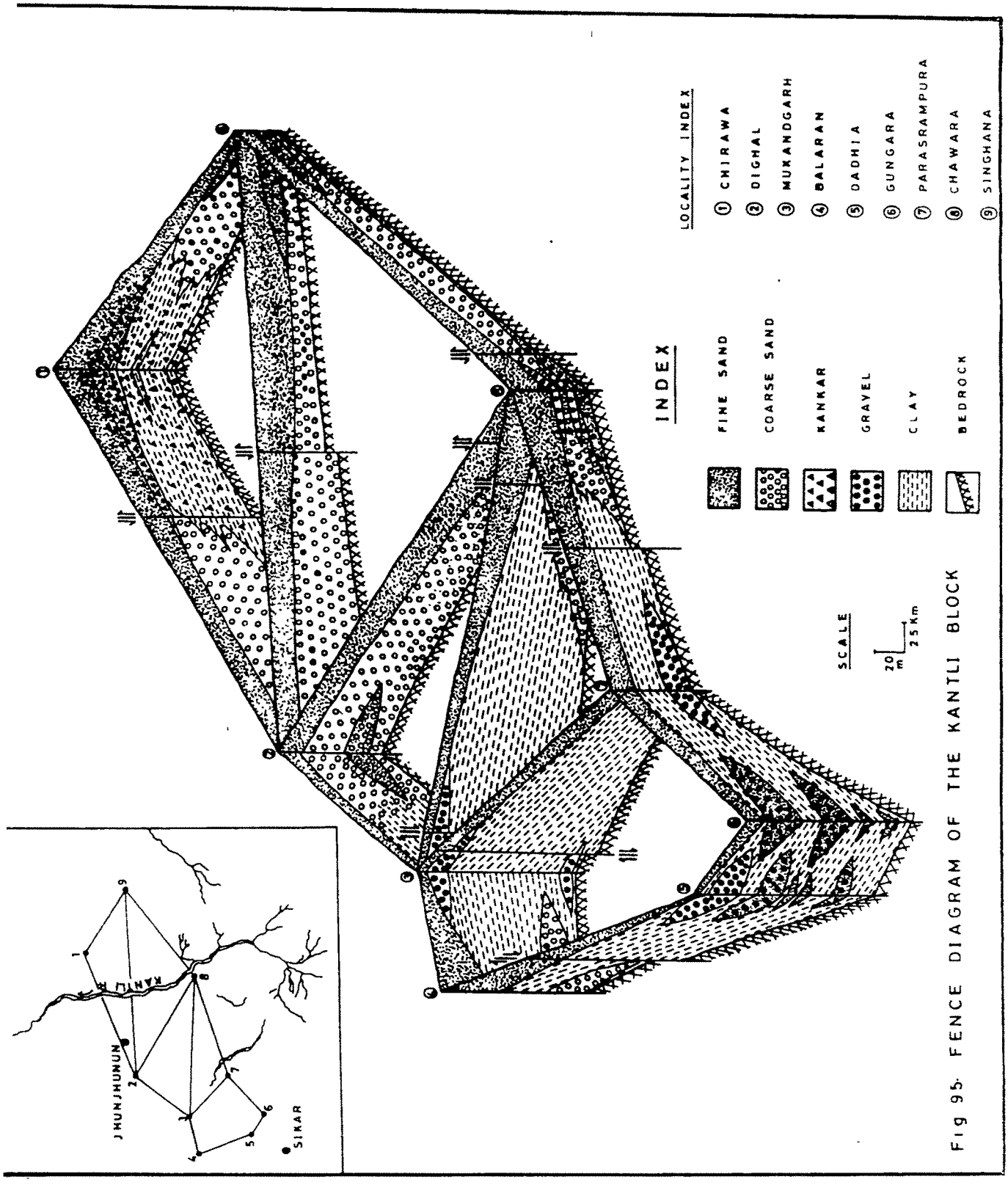


Fig 95. FENCE DIAGRAM OF THE KANTLI BLOCK

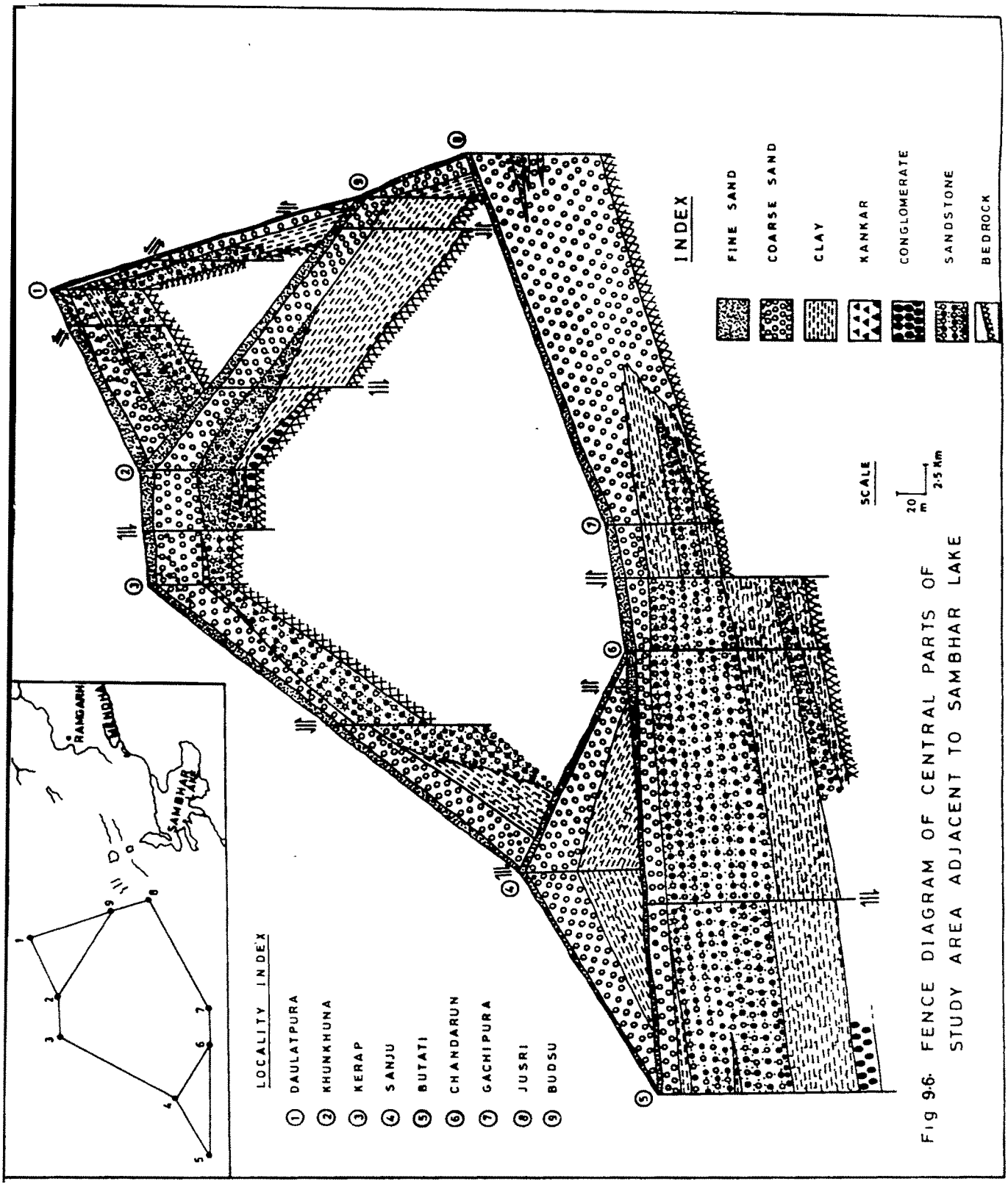


Fig 9.6 FENCE DIAGRAM OF CENTRAL PARTS OF STUDY AREA ADJACENT TO SAMBHAR LAKE

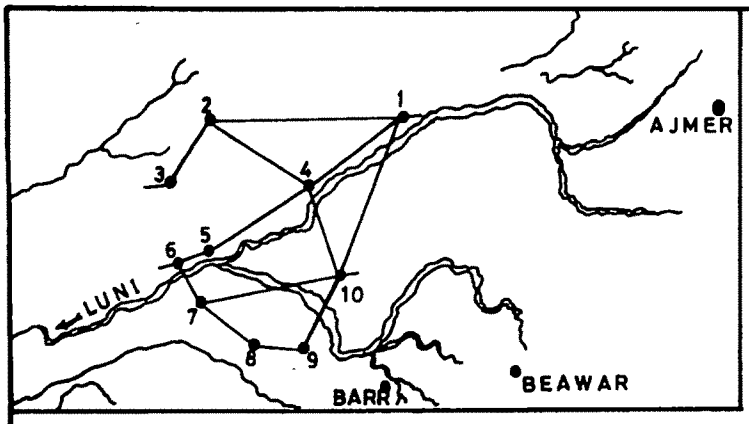
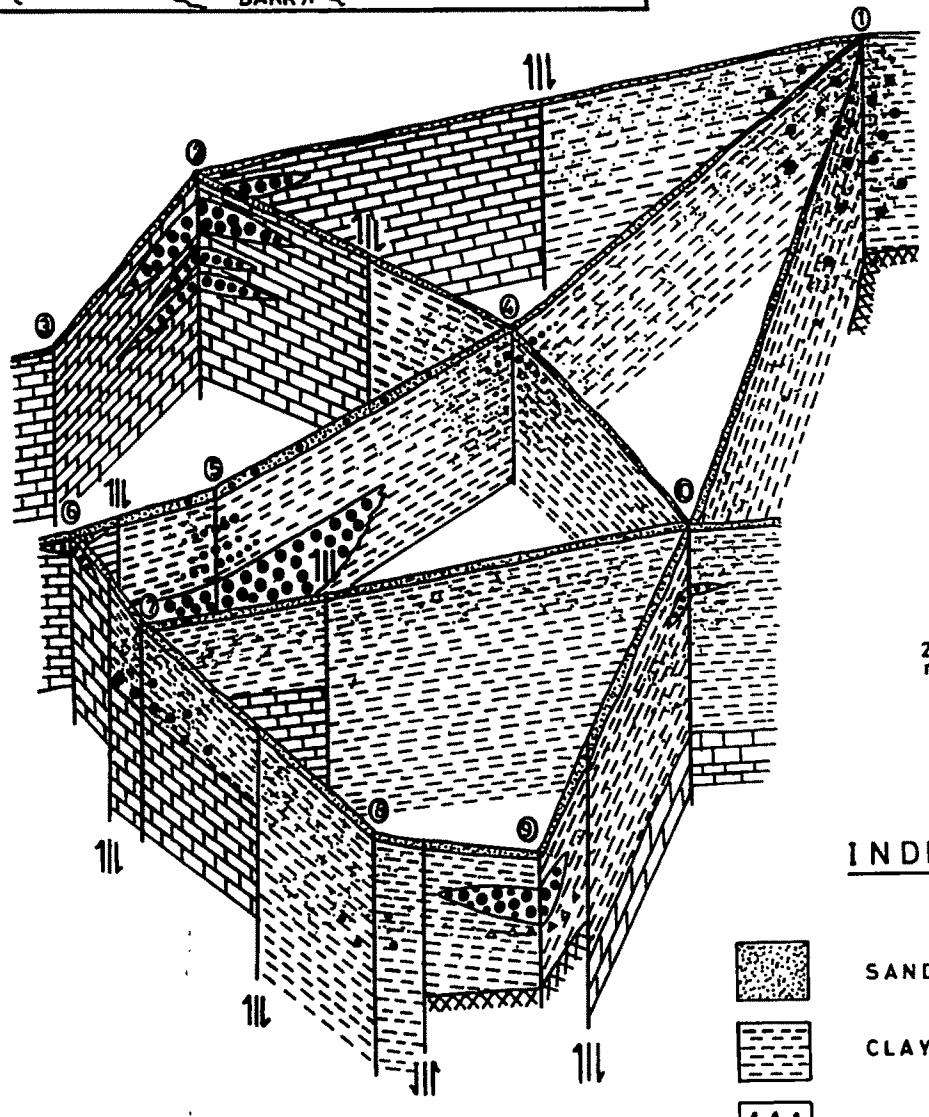


Fig.9.7. FENCE DIAGRAM OF THE UPPER LUNI BLOCK



SCALE

20 m

2·5 Km

INDEX

- SAND
- CLAY
- KANKAR
- GRAVEL
- LIMESTONE
- BEDROCK

LOCALITY INDEX

① BADAULI	⑥ JHAK
② PATELNAGAR	⑦ BHER
③ RANSIGAON	⑧ AGEWA
④ ANANDPUR KALU	⑨ NIMAJ
⑤ NIMBOL	⑩ BALARA