CHAPTER - VII

HYDROGEOLOGICAL EVALUATION

GENERAL

In a regional hydrogeological set-up the study area is strategically situated at the trijunction of crystalline platform areas of the Archaean folding and Deccan trap fore-deep margin of this platform, comprising Quaternary sediments. Location of the study area in the context is shown in the hydrogeological map of Gujarat and adjacent areas as shown in Fig 7.1. This type of situation obviously points to the heterogenity of the conditions of the groundwater occurrence in the study area.

This chapter deals with hydrological aspects of the various geological formations, which include occurrence of groundwater, conditions of groundwater accumulation and its movement in different types of lithologies. The influence of tectonic setup and structural controls on groundwater accumulation and movement, effects of terrain landforms and drainage pattern in relation to slope and weathering, are highlighted; supporting evidences of geoelectrical properties and bore hole logs have also been given.

As pointed out in earlier chapters (II, III and IV) the significance of lithology, the structural setup, discontinuity surfaces and various geomorphic processes, is of prime importance for groundwater infiltration, movement and accumulation. Their combined effects enhance the water-holding capacity and create adequate aquifer conditions. The above stated factors however, are so much interelated to one another that, it is difficult to separate them. Even then, their individual identity matters quite a lot.

The hydrogeological factors controlling the groundwater occurrence in the study area could be grouped into three:

(1) Lithological controls.
(2) Structural controls.
(3) Geomorphic controls.

LITHOLOGICAL CONTROLS

Taking into account the mode of occurrence of groundwater, hydraulic properties (porosity, permeability, yield and transmissivity) of water bearing formations and groundwater regime characteristics, the lithological framework of the Heran river basin has been divided into two major categories:

1. Consolidated Formations (Indurated).
2. Unconsolidated Formations (Non-indurated).

CONSOLIDATED FORMATIONS

Out of 1209 sq.km. of total basin area, 847 sq.km (70%) area is occupied by consolidated rock formations belongs to Precambrian, Cretaceous and Cretaceo-Eocene age of the geologic time scale. These formations are dominantly confined to the upper and middle parts of the basin.

Occurrence of groundwater in these hard rocks are characterised by the presence of secondary porosity, i.e. fissures, fractures, joints, zones of weathering etc. Since these features do not occur uniformally all over the area and also do not extend to great depths, they do not provide large and extensive groundwater aquifer systems. However, under favourable geologic, geomorphic and hydrometeorologic conditions, sizable groundwater accumulation have also been formed in different litho-units of this category.

According to their stratigraphic positions these consolidated formations have been grouped in three units.

(i) Precambrians - Granite gneissess, granites, Quartzites, schists and phyllites.

(ii) Cretaceous - Sandstones, limestones interbedded with shales.

(iii) Cretaceo-Eocene - Deccan Trap basalts, basaltic and other alkaline igneous derivatives, viz; syenites, nepheline syenites, phonolites, granophyres, dolerites, gabbros and carbonatites etc.

In the crystalline terrain, groundwater occurs in three different forms :-

- Weathered mantle where rain water percolates and is stored in pockets of irregular thickness.
- joints and fractures within fresh rocks and their interconnections provide conduits for the transfer of groundwater through hard rocks, forming linear narrow zones of accumulation.
- Alluvium associated with seasonal rivers, that crosses the crystalline terrain.

General Hydrogeological characters

(A) Porosity and Permeability

A solid piece of fresh consolidated formation have porosity less than 3% and most commonly less than 1 percent, the few pores that are present are small and generally are not interconnected. As a result, permeabilities are so small that they can be regarded as zero, Davis and Dewiest (1970).

The average permeability of consolidated formations decreases rapidly with depth. This decrease is a combined effect of the weight of overlying rock and the tendency of surface disturbances to penetrate only a short distance into bedrock. Surface disturbances that produce rock permeability include landslides, rock falls, erosional unloading of underlying rock etc.

(B) Well Yields

In general, yields of wells are low in almost all consolidated rocks. Average yields for groups of wells in various regions are most commonly between 50 and 125 lpm. Deeply weathered rocks with substantial local recharge may have mean yields as high as 150 lpm. Differences in well yields tend to reflect differences in degree of weathering or fracturing rather than inherent differences of mineralogy or fabric within the rocks. According to Meier and Peterson (1951), the smallest yields come from phyllite and other soft foliated metamorphic rocks in which the fault and joint openings close rapidly with depth.

UNCONSOLIDATED FORMATION

The unconsolidated formations or non-indurated sediments occupy about 360 sq.km, which form 30% of the total basin area. These unconsolidated formations could be sub-divided on the basis of their modes of origin viz; alluvium, fluvial sands and gravels, colluvial deposits, clays and residual soils.

These non-indurated sediments are the products of consolidated formations which due to the combined effects of climatic variations, mechanical and bio-chemical decomposition have given rise to this materials. These cover vast expanses of the lower part of the basin area. In the middle and upper portions, their occurrence is patchy and mainly confined to hill pediments, along river channels, and major stream confluences and in areas of surficial depressions.

The investigations for groundwater in areas of unconsolidated segments commonly begin with the search for the occurrences of unconsolidated sediments; the primary and logical factors for this preferences being as under:-

(i) Non-indurated sediments have generally higher specific yields than consolidated formations.

(ii) Permeability and porosity are much higher than other indurated and semi-indurated formations with exception of some vesicular basalts and cavernous limestones.

(iii) The sediments are commonly in a favourable location with respect to recharge from nearby streams and river channels.

(iv) The deposits are most likely to be found in valleys where ground water levels are close to the surface, as a consequence pumping lift is small.

(v) The deposits are easy to drill so that exploration is rapid and highly cost effective.

General Hydrological Characters

A) Porosity of non indurated sediments range from a minimum of about 20 percent in coarse, poorly sorted alluvium to about 90 percent in soft clays.

B) Specific yield values range from almost zero to about 50 percent. Values typical of fine silts clays are less than 10 percent. Gravel and corase sands have values greater than 20%.

C) Permeability of various non-indurated sediments is highly variable and the values show a wide range of fluctuation. Highest permeability may be 10^9 times larger than the lowest permeabilities of 10^{-7}.

D) Well yields of 50 lpm to 250 lpm can be obtained from almost all such river deposits, that originate from perennial streams. Much larger yields of 450 to 9000 lpm are also common where the permeable zone total at least 3 m and the saturated zone in the alluvium is at least 12 to 15 m thick.

STRUCTURAL CONTROLS

It is observed that the nature and scale of the structural elements show a vital control over the groundwater conditions.

It has already been pointed out in Chapter III, that the large scale structures having a large linear extension contribute significantly towards the development of aquifer system; while, small scale structures regulate the initial drainage lines, thereby augmenting infiltration and enhancing the weathering processes.

On the basis of above stated hydrogeological characteristics, the structures could be grouped under two categories.

(i) Major Structures: Fracture zones, fault and shear zones, lithologic contacts, inter flow surfaces, dykes and master joints.

(ii) Minor Structures: Bedding planes, foliations, conjugate joints, columnar joints, vesicular cavities, redbole layers and local fractures.

MAJOR STRUCTURES

The role of major structural discontinuities is very much significant in the areas of consolidated formations. Due to their regional extent and then being more porous and permeable, they develop the aquifers of high potential.

Rocks which have been deformed considerably tend to develop water bearing fracture near mechanical discontinuities such as long hard brittle dykes and veins which cuts soft formations.

Generally faults and joints in the study area are nearly vertical (Plate VII. 1) when these planes intersects the regional horizontal joints the master joint planes may yield good supply of water. The more recent joints which have been developed due to change in stress and surface disturbances could be classified in two groups; surface joints, (Plate VII. 2) and deep terrain joints. Both receive water from the weathered mantle, with which they are in hydraulic continuity and act more as transmission zones than storage media. Such minor fractures and joints which are interconnected are also connected to master joints, are capable of transferring water through unaltered rocks below.

Since the fractures and master joints tend to become less abundant as the depth increases it can be stated that the hydraulic conductivity decreases with depth. Horizontal joints which form possibly in response to rock expansion associated with erosional unloading are spaced wider. In general the fractures, fissures, and joints occur very irregularly and spacing also vary considerably rapidly decreasing with increase in depth. Chemical weathering along the planes of weakness alter the fresh rock into granular

Plate VII.1 Field photograph showing columnar joints in basalt, facilitating high rate of infiltration to recharge the phreatic aquifers.(Loc. Near Kadipani).

Plate VII.2 Field photograph showing joint pattern in Bagh Sandstone.(Loc. Songir hill quarry).

masses. The movement of the groundwater is effected along the fractures, fissures and joints and the lateral circulation is on account of the constriction of openings with depth. The interflow surfaces also tend, to develop aquifers of sizable potential. When deep fractures and joints gets connected with these narrow inter-trappean beds they gets charged and provides high yield.

Dykes also play a significant role for developing hydrogeologic conditions. As these act as major vertical barriers they create subsurface groundwater pools, that change the nearby aquifers.

MINOR STRUCTURES

The role of minor structures is different from that of major regional structures. All the minor structures are of secondary importance and act as supporting media to major structures. These act as micro conducts through which groundwater flows and recharges the nearby aquifers. Bedding planes are of vital importance as they form a potential surfaces of groundwater accumulation, but it is observed in the study area, the interbedded surfaces are filled with clayey layers, having a high porosity but poor permeability.

Vesicular cavities are very localised and are filled with secondary minerals.

GEOMORPHIC CONTROLS

The various geomorphic controls on groundwater movements and accumulations are grouped as under:-

(i) Landform Featyres

(ii) Slope

(iii) Drainage Pattern and

(iv) Weathering.

The terrain configuration, landform patterns and drainage have an important bearing on the development of groundwater regime. The activity of different geomorphic processes comprises erosion of various lithologies and depositing the detritus at various places. The slope and relief of the terrain en¢hances the weathering process which directly raise the rate of infiltration for recharging the aquifers. The interaction between drainage, slope, landform weathering and river bed characteristics is the solely responsible for creating potential zones of groundwater aquifer except in the areas of structurally controlled aquifer systems.

LANDFORM FEATURES

The terrain configuration imparts varied topographic shape which are closely related to the nature of lithologies. As the entire Heran basin dominantly comprise of crystalline rocks of Precambrian granites, metamorphics and Deccan Trap lava flows; their distribution has given rise to two quite distinct types of landscapes.

In the upper basin, southern and southeastern parts represent steep hilly terrain with a good cover of vegetation, while the northern, northeastern and central part is very gently undulatory with less vegetative cover (Plate VII.3).

The middle part of the basin shows mixed nature of terrain, horizontality of Bagh beds is typically reflected in a flat topography (Plate VII.4).

Whereas the Deccan traps have imparted in the form of scattered hills and ridges (Plate VII.5); the ruggedness enhances the erosional capacity of rivulets and other stream channels, and also higher run-off from the surface. The flow of water over a gently undulatory terrain would be slow, thereby increased the rate of infiltration. Thick soil cover also enables vertical migration of water.

The topography of the lower segment is flat and made up of the detritus brought by the rivers Heran and Orsang. Flatness of terrain together with high porosity and permeability of the sediments, have provided ideal conditions

Plate VII.3 Field photograph showing residual trappean topography characterising scanty vegetation and poor groundwater potential. (Loc. Near village Bhiratha).

Plate VII.4 Field photograph showing a view of typical wasteland terrain of Bagh sandstone with poor groundwater occurrence. (Loc.Near village Wanmala).

Plate VII.5 Field photograph showing wide open river bed with gently rising northern bank. Dry sandy cover seen in the middle part, over the sub-surface river flow. (Loc.Near Village Mugalwant) for the groundwater accumulation.

In the central part of the upper basin the undulatory trappean topography comprising low lying trappean mounds, contains numerous depressions all over. It has been observed that the nature of the individual landform pattern also, contributes significantly in improving the groundwater conditions. The metamorphic rocky terrain north and north east of Panvad has generated basinal depression and domal bodies of variable sizes, the basins being local depressions provide sites for groundwater accumulation and developing shallow phreatic aquifers (Plate VII.6). Similarly the large surfacial depressions surrounded by bold hills are the sites of thick accumulation of residual soils, and these being pervious sand permeable in nature, have generated potential sources of groundwater. This has been observed in the vicinity of Phenaimata group of hills (Plate I.1). The greater depth of weathering and presence of thick soil cover in such depressed areas enhance the rate of infiltration which ultimately provides high potential groundwater. Such conditions have been witnessed in the area around Dungargam, (Plate VII.7), Tokri, Pipaldi and Bhumaswada villages. Also, hill pediments in the basaltic terrain being pervious in nature yield good amount of water (Plate VII.8).

Plate VII.6 Field photograph showing local depression in the basaltic terrain with moderate groundwater potential; characterised by thick vegetation growth. (Loc. Near village Rumadia).

Plate VII.7. Field photograph showing a view of a typical lowlying trappean landscope with of phreatic aquifers with thick residual soil cover. (Loc. Area north of Dungargam).

The transitional zones and river valleys are the sites of depositions, the changing pattern of river course has given rise levees, the detritus being heterogenous in composition and size, accumulates sizable quantity of groundwater. The area around Mankodi, Bagaliya, Moradungri and Rundhi exhibits this typical situations (Plate VII.9).

In the lower part of the basin, the landforms of the areas of unconsolidated formations, are less varied. The land features are the river terraces and floodplains. These, being highly porous and permeable produce, ample supply of groundwater. As these are seen forming intercalations of lenticular bodies of sand, silt, gravels and clays, groundwater occurs in semi-confined conditions.

Sometimes the man-made structures also help in recharging the aquifers. Artificial, bunding across small streams, check the surface flow of water and water infiltrate into the ground. The author has come across several such structures in the study area that are very much helpful in improving groundwater conditions (Plate VII.10). The road embankments also creates surface water pooling and enhance the recharge rate to nearby aquifers. The Plate VII.11 and Plate VII.12 & 13 illustrates such conditions near the villages Dungargam and Nandpur which are situated in trappean and metamorphic rocks, yield medium potential.

Plate VII.8 Field photograph showing pediment of basaltic hill, a zone of high groundwater potential. Rich agriculture land is seen in the photograph (Loc.Village Rundhi).

Plate VII. 9 Field photograph showing river terrace; presence of heterogenous material has produce potential zone of groundwater occurrence (Loc.Near village Mora Dungri).

Plate VII.10 Field photograph showing an upstream view of a check dam, enhancing the groundwater yield of the nearby well.(Loc. Near Panvad).

Plate VII.11 Field photograph showing a check dam for augmenting local groundwater potential. (Loc. Near village Untvali).

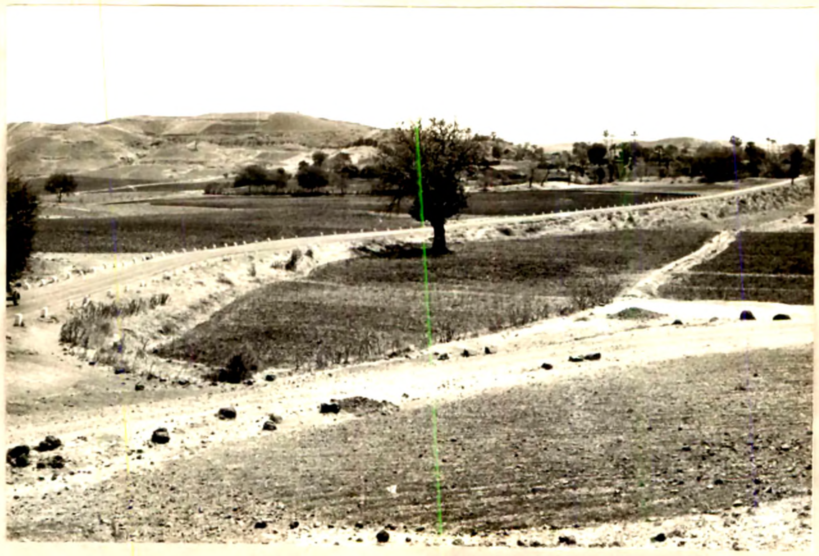


Plate VII.12 Field photograph showing embankment across a depression in trappean terrain. Groundwater recharge is locally enriched by the water pool. (Loc. village Dungargam).

Plate VII.13 Field photograph showing a road embankment creating surface water pool and indirectly enhancing the rate of infiltration for recharging the phreatic aquifer's of metamorphics. (Loc. Near Village Nandpur).

DRAINAGE PATTERN

Generally, uniform dendritic and radial patterns are unfavourable for recharging the aquifer system as their major contribution goes as runoff to main channels. But under certain drainage conditions, good groundwater potential is possible.

The drainage pattern especially in hard rock terrain also contributes towards developing potential zones of groundwater occurrence. The dendritic and radial drainage patterns, that develop in basalts and granites act primarily as discharging channels but, their modified characteristics have got a lot more bearing on groundwater recharge. For example, in the granitic terrain around village Serva, Vejaliya and Kelri, the combinations of several radial drainage patterns have given rise to centripetal drainage patterns, a characteristic feature of multi-depressional topography. The areas where such pattern exists provide ample potential of groundwater. About 3 km NE of Vejaliya such conditions provide perrennial source of groundwater in the form of springs (Fig.7.2).

The dentritic drainage pattern is indicative of a highly jointed rocky terrain. Whereas the influence of structural control modify the aquifer characteristics, generally resulting into linear aquifers of high potential. The fault controlled trellis drainage pattern exhibiting this characteristic property has been observed between Nani Pipaldi to Dungargaon and village Kadawal to Navalja in the central area of upper basin (Fig. 7.3).

SLOPE

As it has already been discussed in the preceeding chapter on geomorphology, the slope is one of the important governing factors in developing a hydrogeological regime. It has a direct bearing on groundwater infiltration, thereby augmenting recharge to the aquifers. On the basis of landforms and topographic configuration, the entire Heran river basin has been divided into three slope categories.

(i) Slopes less than 2%
(ii) Slopes between 2-4% and
(iii) Slopes more than 4%

These slope categories adequately, delineate the areas for groundwater exploration deemed suitable for selecting higher potential zones of groundwater occurrence, from those unsuitable. The slope of the terrain and landform features have direct relation to infiltration and runoff of precipitation. The area having a slope more than 4% are generally unfavourable for ground water accumulations because it has no contribution towards infiltration. Due to greater rate of erosion, rain water washes away the soil

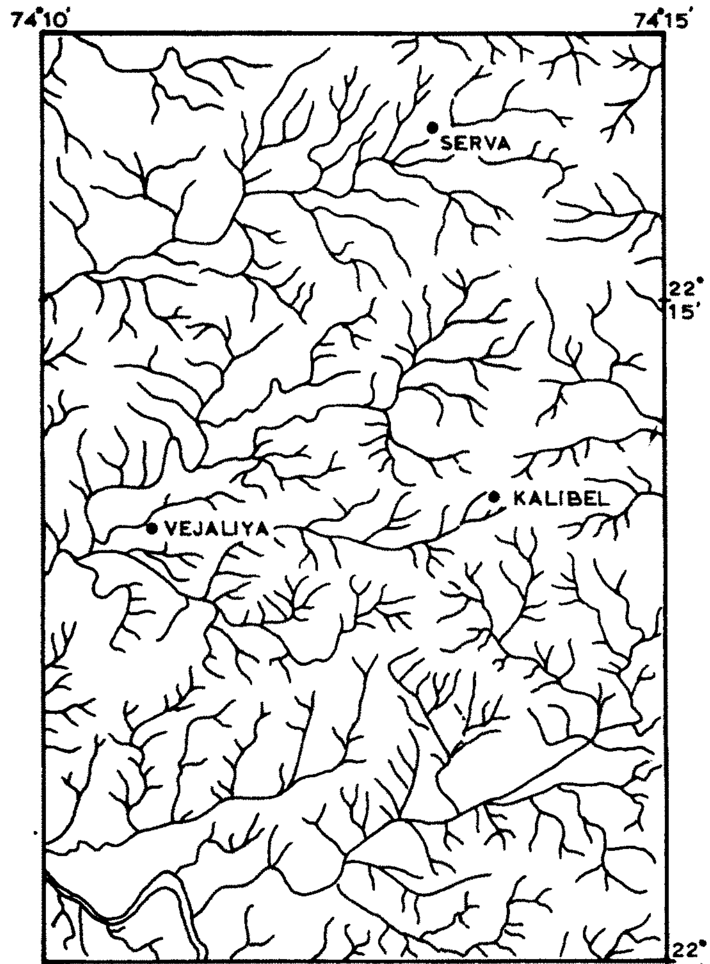


FIG. 7.2. RADIAL

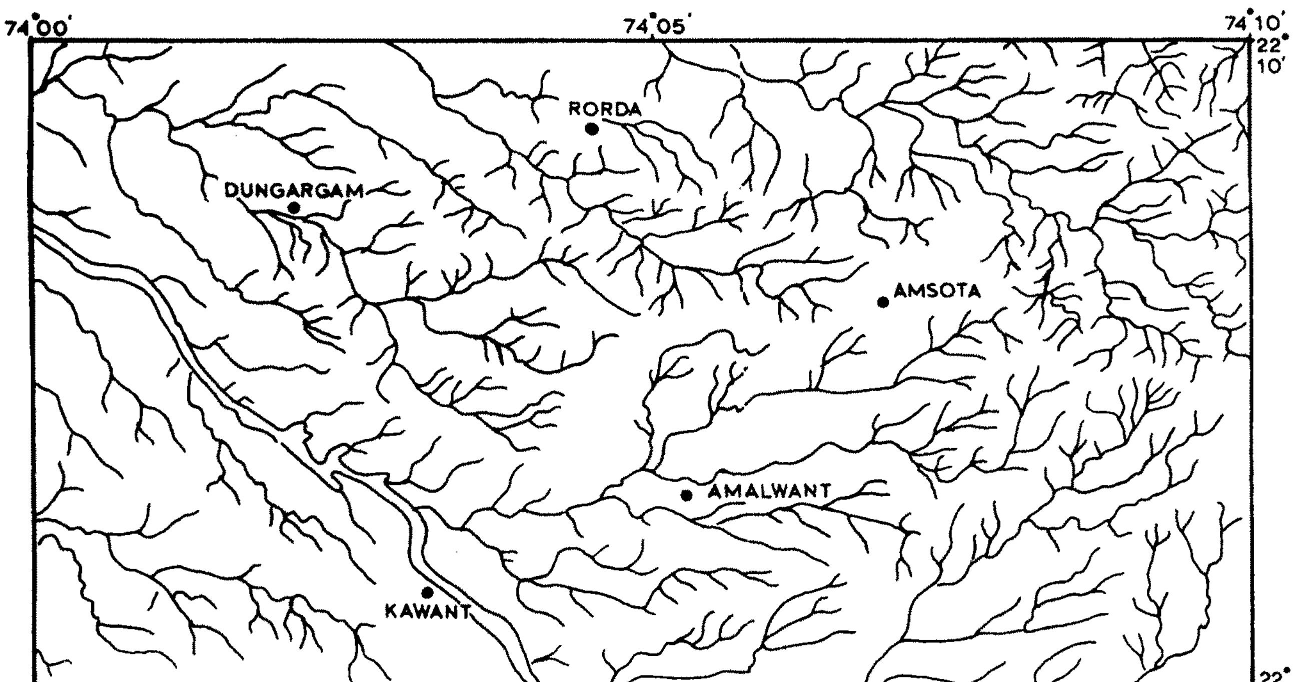


FIG. 7.3. FAULT TRELLIS

FIG. 7.2 & 7.3 : INFLUENCE OF DRAINAGE PATTERN CN GROUND WATER OCCURRENCE cover too. The area fall under the intermediate category of 2-4% slope relatively favourable but such areas are localised. The category less than 2% slope has been considered most favourable, as good vegetative and, thick soil covers as well as highly pervious and permeable nature of material provides better conditions for developing aquifers.

The areas of bold hills, dykes in the upper part of the basin have been grouped in the higher slope category. Dissected hill, pediments, gently undulatory ground of the central part of the upper basin have been taken into the intermediate category. The river valleys, flood plains, river terraces and flat alluvial tracts of middle and lower parts of the basin, comprising the first slope category have been considered the most favourable areas for locating potential aquifers.

WEATHERING

The study area comprises various litho-units of consolidated formations. All these crystalline rocks display varying susceptibility to weathering. As a result they have given rise to variable thicknesses of weathered residium. It has been observed that from massive rock to highly fractured and sheared rock, the depth of weathering mostly is in the range of 5 to 30 m, and these weathered zones are the sites of groundwater storage. Under favourable situations the weathered zones form very good receptacles for groundwater. The areas affected by faulting and shearing, particularly the south-eastern part of the central basin, apart from their behaving as a phreatic aquifers their weathered zone also help in circulating groundwater to deeper fracture system of the underlying hard rocks, thereby providing semi-confined aquifers.

Due to variation in topography rock type and degree of fracturing, the weathered zone exhibits considerable variation from place to place. Based on the several well section studies, bore hole logs these weathering profiles have been grouped into four zones as under.

Zone	Nature of Formation	Extent (depth)	Geohydrological characteristics
A	Sandy clays commonly alluminous and often concretionary.	From 2 to 3 m	High porosity but low permeability
B	Massive clays commonly kaolinite	From 5 to 20m.	Highly porous but very low permeability
C	Progressively ultered upward to granular aggregate and rock fragments.	From A few to as much as 30 m	low porosity and moderate to high permeability
A	Fractured and fissured rock.	From a few tens to a metre or so.	Low porosity and exhibits moderate permeability in fracture systems.

Groundwater stored in the weathered zone is intermittently replenished by direct infiltration from rainfall as well as by indirect infiltration from influent streams. As most weathered layers tend to be discontinuous both laterally and vertically, all recharge is of local origin and not supplied by any distant source. Most infiltrating water after passing through the soil is intermittently stored in zone (c) which has higher porosity and low permeability. This water drained slowly into zone (B) and then into the underlying fractures and fissures of zone (A). The amount of water available to recharge groundwater in weathered hard rock terrains of low relief (as is the case in the central part of the upper basin) depends on the annual total rainfall; the intensity; and the evapotranspiration.

GEO-ELECTRICAL CHARACTERISTICS

ELECTRICAL RESISTIVITY SURVEY

Electrical resistivity method has been widely accepted as the most effective of the various geophysical techniques in use for groundwater exploration due to its rapidity and low cost. This method has a unique advantage over the other methods in its ability to predict the water quality under favourable conditions.

The resistivity measurement of ground is done by passing low frequency AC current (I) into the ground through two electrodes and measuring the potential drop (V) between the two other electrodes. There are numerous electrode configurations in use of which the most popular are the Wenner and Schlumberger configurations. For the purposes of the present study, Schlumberger configuration has been selected, in which a collinear and symmetrical arrangement of electrodes is placed about the centre of the spread where the potential electrode separation is less than or equal to 1/5th of the current electrode separation. Thus the apparent resistivity is given by :

$$\rho_a = \frac{\pi(AB^2 - MN^2)}{4} \times \frac{V}{MN} \times \frac{1}{I}$$

Where, AB = current electrode separation

MN = potential electrode separation.

The apparent resistivity observations have been plotted on log-log graph sheet and then the field data curve, and then the field data curve is interpreted comparing them with theoritical master curves.

FIELD STUDIES

As this survey requires teamwork of 8-10 persons, only such areas were selected which were of hydrogeological interest. The objective was to locate tectonically disturbed zones such as faults and shear zones, determining maximum thicknesses of the valley fill material and paleo-river channel particularly in the area between villages Lalpur and Nava Timberva, in the middle part of the basin, and also to locate the deeper zones of weathering in the hard rock areas for determining the resistivity contrast between water bearing weathered zones and fresh or hard rock beneath it. Vertical Electrical Soundings (VES) were carried out by adopting Schlumberger configuration The locations of VES spots are shown in (Figure 7.4). A total of 13 VES were conducted.

Valley Fill Palaeo-channel Area

As discussed in the preceeding chapters, the area between Lalpur and Kosindra comprise sites of thick deposition of fluvial sediments, and air photo interpretation and field checks have revealed the presence of buried river course which presently exists in the form of a levee. To confirm its trend, bed rock profile and the thickness of fluvial sediments, a total of six numbers of soundings (VES No.1-6) were carried out along the N-S traverse between villages Nava-Timberva and Rundhi. Based on the resistivity survey results a geo-electrical cross section (I-I) Fig.7.4) has been prepared which itself is self explanatory.

Tectonically Disturbed Zone

The airphoto interpretation and subsequent field checks indicate, doubtful likelihood of a fault between Phenaimata hill and Lalpur village. A huge N-S trending surficial depression has been observed about half a km east of the present Heran course between Lalpur village and Phenai mata hill. For confirming the above cited observations in all three (7-9) VES observations were taken. The results of resistivity survey and well section studies have revealed the presence of a N-S shearzone, filled with fluvial debris brought by the river Heran. The observations and the present landform configuration is an indicative evidence that the old channel of the Heran river was wider than the present narrow channel between phenaimata hill and the small gabbroic hill. Heavy cutting on the southern bank and its subsequent deposition in this shear zone - controlled palaeo channel has caused the change in its course, to the present days restricted narrow channel. The geo-electrical cross section (II-II, Fig.7.4) shows the thickness of various sediments and bed rock profiles.

Hard Rock Area

For determining the resistivity values of the water bearing weathered rock portion, unweathered rocks and fractured rock, and also their relative gradation, the area around Rangpur Ashram and Wanta village was selected. A total of four soundings (VES 10-13) were taken (Fig. 7.4). The obtained resistivity curves helps to distinguish between single rock type areas and areas of different formations. It also gives a rough idea of the tectonically disturbed rocks i.e. fractured rock. In this predominantly basaltic terrain the less resistive surface soils covering hard fluvial sediments produces KH type curves. The curve type depends upon the thickness and resistivity of each formation unit and (ii) thickness and resistivity of the contact zones where the occurrence of groundwater resistivity value gradation is given in (Table 7.1) and the interpretation curves are shown (Annexure VII.1-3).

OBSERVATIONS

Based on the above sounding results it could be concluded that -

(i) Tectonically disturbed areas are characterised by multilayer cases.

(ii) Multilayer cases in valley fill area indicate that the electrical properties of valley fill material vary with depth; weathered and fractured crystallines rocks are also reflected in the curve.

(iii) The curve type is influenced by the highly resistive (dry gritty - sandy soils, out crops etc). or highly conductive (Black cotton soil and other clays) surface layers.

(iv) The contact between two different formations are reflected by multilayer curves of KH type.

BORE-HOLE DATA ANALYSIS

Bore hole records are of vital importance in the planning hydrogeological studies, because the primary interest in most groundwater studies is on (i) the information on the stratigraphy, structure, and hydraulic characteristics of the subsurface materials and (ii) on water table and piezometric surface levels and fluctuations,

In the study area GWRDC and PHED is carrying out tube well and bore well drilling under 'No Source Scheme' programme of the Government of Gujarat. But, with considerable effort author could collect only 25 tube well drilling records from GWRDC, out of which only thirteen fall in the basin area, and remaining are located in the surrounding areas. PHED has drilled hundreds of bores for the installation of hand pumps but, except discharge values and length of casing, no other details were made available. Out of 13 tubewell logs, only two tube wells have been drilled in the hard rock area i.e. Nava-Timberva and Wandha the rest are located in the alluvial plains of the lower basin.

Irrigation department has carried out exploratory drilling at the proposed Heran reservoir near Lalpur, and Rami dam project near Khandibaru village. Totally, 17 drilling records could be obtained. The author, has collected all the details of tubewells, bore wells and exploratory drilling records and critically evaluated them.

Cross Section No.1

The E-W trending cross section (Fig.7.5) is drawn across villages Bihora-Rampura-Diwalipura-Damoli and after crossing river Orsang upto Karnet. This section comprises intercalated sequence of clay, sand and Kankar. The clay lenses are dominant and extend upto the depth of 70 m. The most remarkable features in this profile is the presence of three lithologies of different stratigraphic horizons, as under:

Village	Rock type	Depth
(i) Bihora	Basalt	53.00 m
(ii) Diwalipura	Granite-gneiss	80.00 m
(iii) Damoli	Sandstone	43.00 m
(iv) Karnet	Sand & Clay	71.00 m

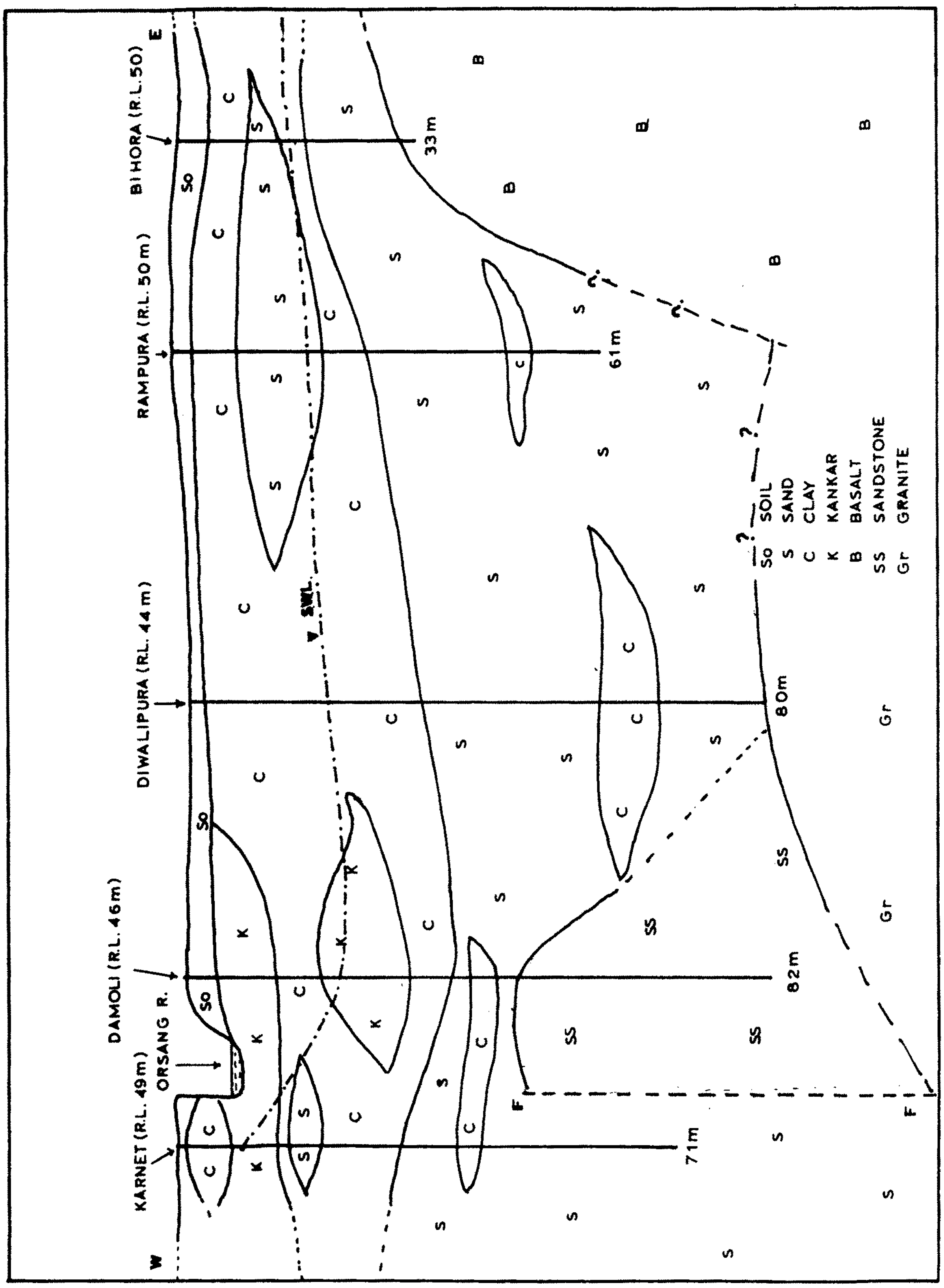
The bore hole log of villages Chanwada and Navi Nangrol further south of Karnet shows increasing thickness of sandy material which is indicative of a faulted contact between Baghs and alluvium.

Westerly gradient of groundwater level from Heran watershed divide to Orsang shows that the surficial groundwater divide does not correspond with subsurface divide and the aquifers of both the basins are interconnected.

Cross Section No.2

The characteristic feature of this NE-SW profile (Fig.7.6) is the dominance of sandy and gravelly lenses; clay

FIG. 7.5.



HYDROGEOLOGICAL CROSS-SECTION BETWEEN KARNET AND BIHORA

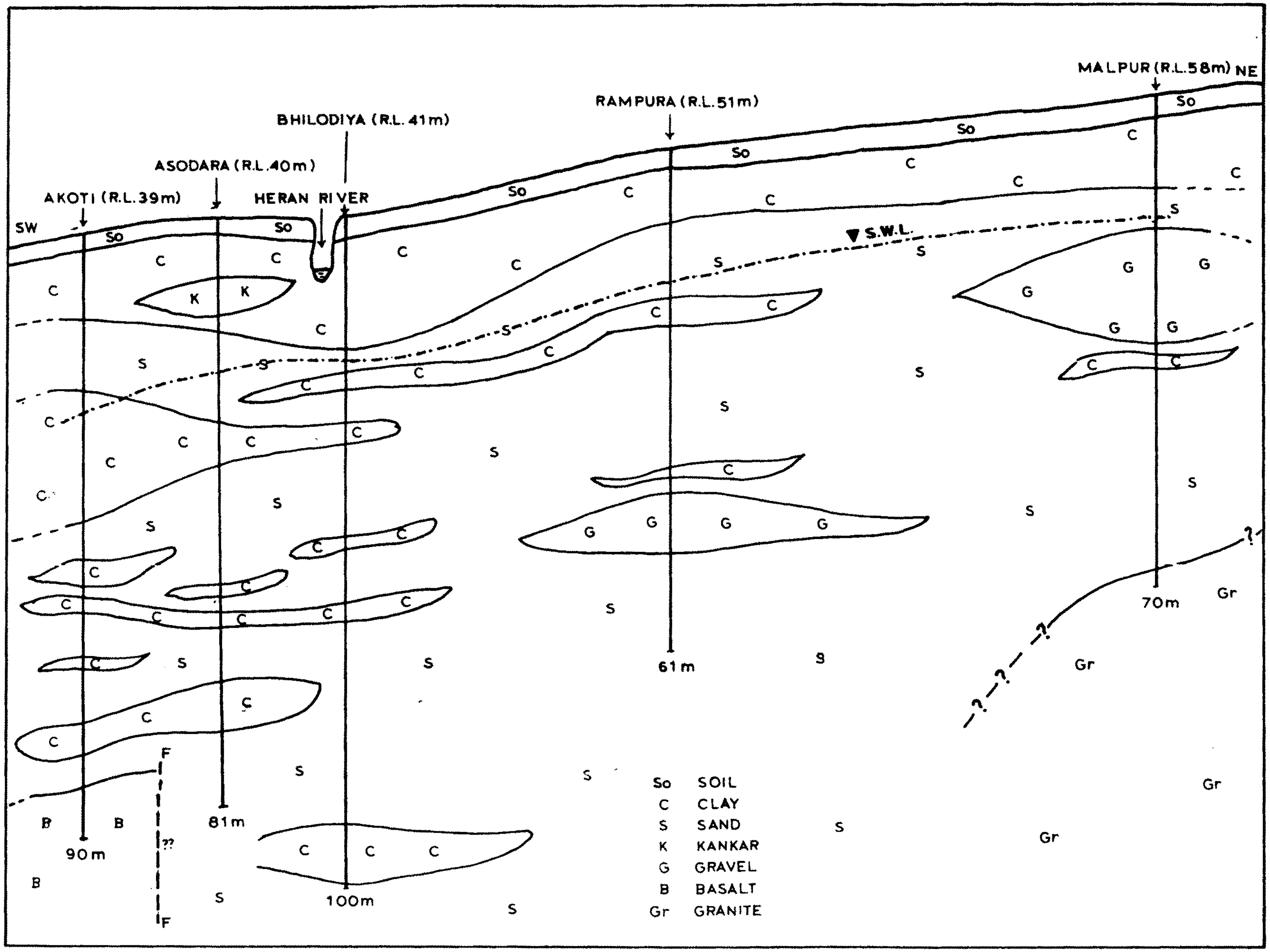


FIG. 7. 6.

HYDROGEOLOGAL CROSS-SECTION BETWEEN AKOTI AND MALPUR lenses are very narrow, except the upper one which continues from one end to other. The deepest section is represented at Bhilodiya i.e. 100.58 m, where the bore hole has been terminated over the clay lens. Except at Malpur i.e. NE end and Akoti i.e. SW end, no where rock has been encountered. At Malpur the basement granite occurs at the depth of 70 m, while at Akoti, basalt has been reported at the depth of 90 m.

The water table gradient is towards SW, and goes down from 19.0 m at Malpur to 28.0 m at Akoti.

Cross Section No.3 & 4

These cross sections have been drawn on the basis of exploratory drilling records of the irrigation department (Fig 7.7). The profile - 3 which has been drawn across Heran river near the village Lalpur shows intrusion of basalts in Precambrian granites. In the river bed, the overburden thickness is much less, while on the bank areas more than 10 m thickness of overburden is recorded.

On account of the landform and topographic configuration the river here is of affluent nature.

The profile-4 across Rami river shows homogeneous sandstone except a few basaltic sills that are seen within the sandstone. Overburden is very thin and the river bed is effluent in nature.

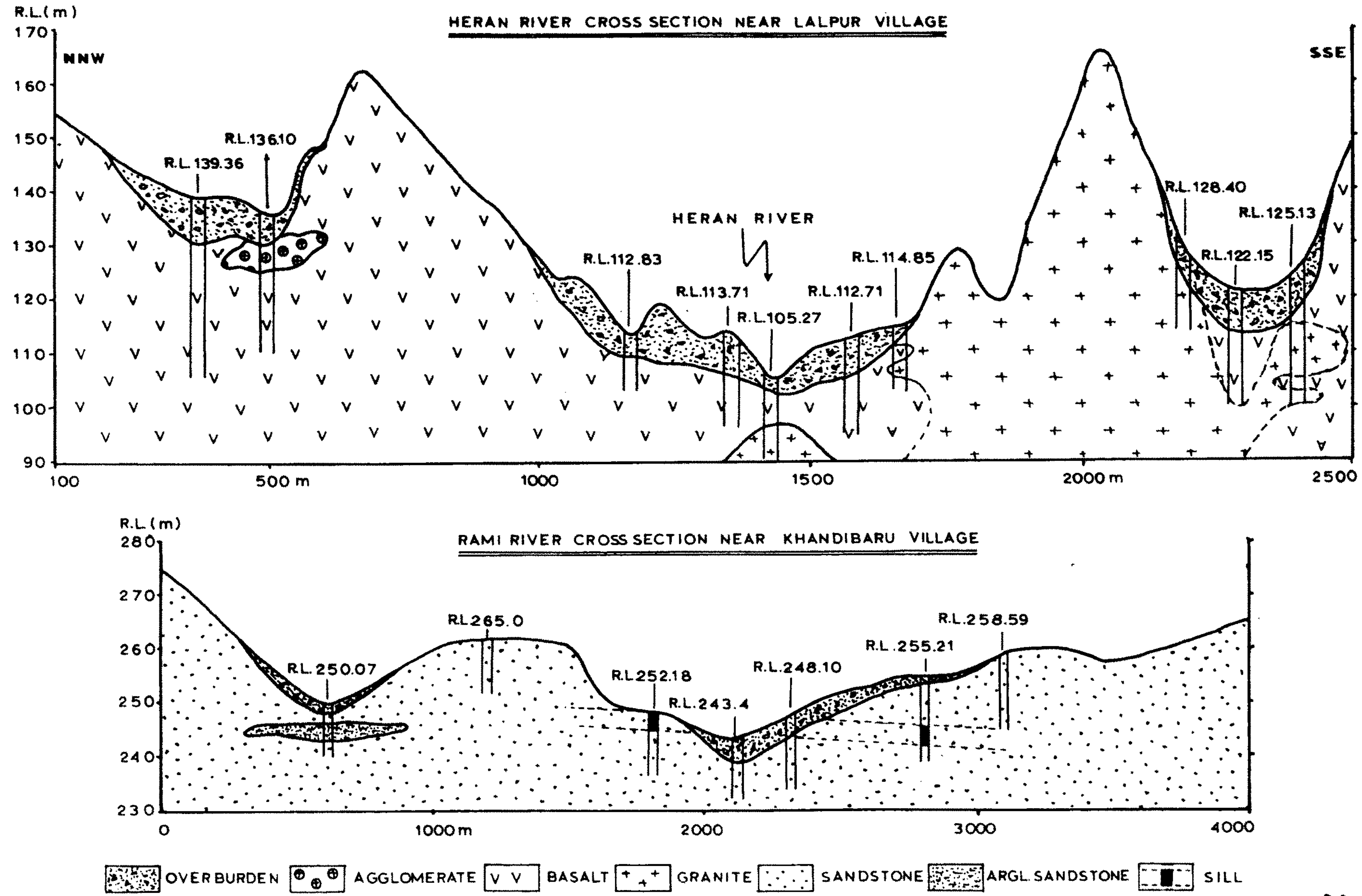

HERAN RIVER CROSS SECTION NEAR LALPUR VILLAGE
R.L.(m)
NNW
SSE
HERAN RIVER
R.L.139.36
R.L.136.10
R.L.112.83
R.L.113.71
R.L.105.27
R.L.112.71
R.L.114.85
R.L.128.40
R.L.125.13
R.L.122.15
100
500 m
1000
1500
2000 m
2500
RAMI RIVER CROSS SECTION NEAR KHANDIBARU VILLAGE
R.L.(m)
R.L.250.07
R.L.265.0
R.L.252.18
R.L.243.4
R.L.248.10
R.L.255.21
R.L.258.59
0
1000m
2000
3000
4000
OVERBURDEN
AGGLOMERATE
BASALT
GRANITE
SANDSTONE
ARGL. SANDSTONE
SILL

FIG. 7.7