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Study of groundwater conditions in the western part of grenter Rajshahi distric

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STUDY OF GROUNDWATER CONDITIONS IN THE WESTERN PART OF GREATER RAJSHAHI DISTRICT

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B. Sc. (Hons), M. Sc.

THESIS

SUBMITTED TO THE UNIVERSITY OF RAJSHAHI, RAJSHAHI FOR THE AWARD OF THE DEGREE OF MASTER OF PHILOSOPHY IN APPLIED PHYSICS AND ELECTRONICS

NOVEMBER, 1997.

DADICATED

TO

MY AFFECTIONATE DAUGHTER

NABILA ANZOOM

CERTIFICATE OF THE SUPERVISOR

I hereby certify that the thesis entitled "**Study of groundwater conditions in the western part of greater Rajshahi district**" submitted by Md. Nozibul Haque has been composed by him under my supervision.

It has not formed the basis for any degree or award elsewhere to the best of knowledge.

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ABSTRACT

With the phenomenal increase in the use of groundwater in recent years, need for better understanding of the functioning of groundwater reservoirs in response to natural and man-made conditions in the system has come to the fore. The objective of groundwater exploration is to locate aquifers capable of yielding water of suitable quality and economic quantities for different purposes. Groundwater resource, although replenishable, is not inexhaustible. But the uncontrolled exploration of this limited resource has caused many environmental degradation which calls for the need to adopt scientific use of this natural resource. The wide and uneven distribution of underground water thus necessitates detailed study in specific areas for the conservation of this vital resource.

The present study area- a part of Barind Tract- which is one of the major physiographic unit of Bangladesh- lies in the Western part of greater Rajshahi district. In recent years, the groundwater crisis of this area is highlighted. The present work attempts to study the feasibility of groundwater development in this region.

Lithological data are an important source of hydrogeological investigation. The borehole data of Bholahat, Shibganj, Gomastapur, Nachole, Nawabganj, Godagari, Tanore and Niamatpur of greater Rajshahi district are processed, analyzed and interpreted for the evaluation of groundwater condition. A Fence diagram has been prepared which clearly shows that the area mainly consists of three sub-surface geological formations: a top clayey layer, sandy layer of different grain size and at the bottom an impermeable clay zone. Computer aided groundwater maps have been prepared for qualitative and quantitative assessment of the aquifer system. The transmissivity and specific draw down maps prepared with their estimated values support the Eastern and Western sides

favorable for well development. Maps of composite sand thickness and yield index have been presented for qualitative study of groundwater potentiality in different regions of the area investigated. Interfacing planes between different geologic formations have been prepared and presented for the necessary assessment of the variation of individual sub-surface stratum in different parts of the study area. Some representative cross-sectional views have also been illustrated. The natural groundwater flow directions have been determined and the flow rate in different parts of the area has also been estimated. It is observed that the groundwater course is influenced by the topography and the upper surface of the impermeable zone. The fluctuation of groundwater level from 1986 to 1995 has been studied. The hydrographs show a gradual fall of water level since 1992. During this period the total amount of water discharged from and recharged to the aquifer system has been estimated and a negative balance is observed.

Finally, relating to the investigated area, a few potential zones have been identified for groundwater development.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	Area of cross-section
B. P. C	Black Plastic Clay
b	Thickness
cm/sec	Centimeter per second
i	Hydraulic head gradient
K	co-efficient of permeability
Km	Kilometer
L	Length
l/s	Liter per second
m	Meter
m/day	Meter per day
Q	Flow rate
S	Storativity
S. D. D	Specific Draw Down
S_y	Specific Yield
S_r	Specific Retention
T	Transmissivity
V	Volume
v	Velocity
W. H. P	Water Head Position
w	Width
φ	Porosity

LIST OF PUBLICATIONS IN THE SUPPORT OF THE THESIS

Haque, M.N., and Keramat, M., 1996, A study of groundwater level in Rajshahi City by electrical resistivity method, Accepted for publication in the Rajshahi University Studies.

Hossain, M.J., Haque, M.N., and Keramat, M., 1996, Groundwater resources evaluation of Nawabganj and Godagari thana of greater Rajshahi district, Journal of Bangladesh Academy of Sciences, Vol. 20, No. 2, p.191-196.

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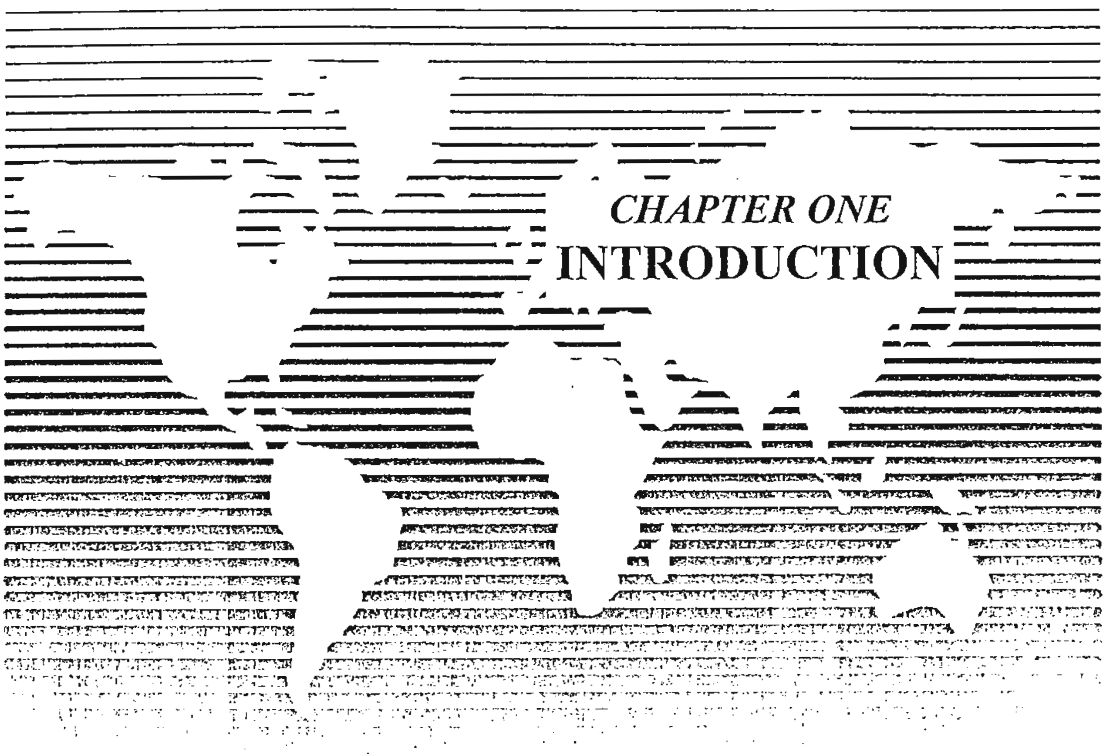

CHAPTER ONE

INTRODUCTION

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1.1 GENERAL INTRODUCTION

Water is absolutely essential to all life, both animal and plants. In order of importance with respect to life and geologic processes water took the position after Oxygen. But water also woes both in the home and on the firm, at the macro and micro level. Many of the world's people face a future without adequate water unless water is used more efficiently, and proper investments are made in providing and protecting this natural resource.

Some 80 countries with 40% of the world's population already experienced water shortages that threaten their agriculture, industry and health. Also, dirty water causes 80 percent of decease in developing countries and kills 10 million people a year.

Groundwater, a renewable resource, forms the major portion of earth's fresh water supply which is about 0.622 % of total volume of water in the earth. About 97% of the earth's fresh water supply is stored in the underground formations, so the conservation of soil is important to the conservation of water as it is for it's own sake. As generally speaking, groundwater is the purest form of water and as it stores in underground for long periods of time and at practically no cost, its value to man is readily understood. It is also flows over long distances through the aquifers and is available to a very large number of people at their home and their firms, but, unlike surface water, it is not lost to evaporation or seepage during storage and transmission and is not exposed to surface contamination .

Though groundwater have some advantages of use, there are certain limitations on the utilizable potential of groundwater regime. These arises due to predictable and unpredictable time domain variation of groundwater supply in relation to demands. Also a long part of groundwater is, however, not available to use as it occurs at depth, and could not be economically extracted with the present drilling technology.

Role of Groundwater in Bangladesh : In Bangladesh, one can not think or talk about the environment without reference to water. There is no exaggeration to say that water condition on our environment is more affecting factor than any other. The people living in this deltaic region as well as the flora and the fauna are all shaped by water. But, the fact is that the people of this country, except those in semi-arid regions, have never had to think much about water supply. The combination of a fairly high rainfall throughout most parts of the country, together with superb natural arteries of large inland rivers have deluded into believing that water is one resource about which it needs no concern.

Groundwater is a natural resource upon which a large part of population depends. Recently, requirements of water because of the growth of the population and the spread of modern facilities, have strained existing facilities for tapping natural water resources. This strain is especially evident in the case of groundwater. In many localities, rates of withdrawal exceeded those of natural replenishment and in some cases the result has been that soil water has invaded fresh water strata, in others, pumping cost have become very high. These difficulties, widely published, have led some to conclude that the country is drying up.

According to the Water Development Board (WDB) of Bangladesh, the overdeveloped area of the land is increasing year by year. It is observed that there was no overdeveloped zone in the year 1990, but in 1991, 1992, 1993, 1994 and 1995 it stands to 0.2%, 0.3%, 0.42%, 0.56% and 1.75% respectively, and still continuing. Scarcity of surface water bodies during the dry season is a major contributor to the overdraft process. Notable reasons for water shortfall are the direct effects of the reduced water flow in rivers, population exploration, indiscriminate use of shallow and deep tube wells and depletion of natural vegetation. The combined effect of all these phenomena has led to a marked lowering groundwater level. If all these processes are allowed to further deplete the underground water reserves, disastrous consequences are most likely to emerge in the form of accelerated desertification, displacement of soil plates resulting in damage to civil structure, and acute water shortage. So, to prevent the untoward effects of groundwater depletion, an effective management is essential.

Need for Groundwater Management : With the growing need to allow aquifers to continue to yield water at economical cost, in adequate quantity and suitable quality, the concept of groundwater management has evolved. Groundwater management consists of 'technical groundwater management' and 'overall integrated groundwater management' (Burdon, 1973). The former deals essentially with technical considerations and methods. The later treats the wider aspects of groundwater and its integration with other sources of water. However, scientific management of groundwater resource requires studies relating to Meteorology, Geology, Geophysics, Hydrology and Chemistry. In Bangladesh, the people are dependent on the sub-soil water during the dry months both for drinking and irrigation. In fact, the need for using this resource will go on increasing unless it is able to augment and preserve the surface water. Therefore, the maintenance of the purity of the groundwater ought to be given the highest priority. The program for the preservation of the underground water must receive the most urgent attention from the government, researchers as well as other concerned organizations of the country.

Now a days, the fresh water crisis in Bangladesh is considered as a national problem. The North and North-Western part of the country, especially the Barind Tract consists of older alluvial deposits of about 3150 sq.Km where life is written in water, is seriously affected area. In the dry season, the pumping systems face water deficiency due to layer failure. There has already been incessant growth of stress on groundwater regime due to increasing demand of water and has resulted in many environmental imbalances.

However, the major goal in the development of agriculture in Bangladesh is to achieve self sufficiency in food production through intensive irrigation with emphasis on quick yielding groundwater development. Bangladesh has abundant surface, groundwater resources, fertile soils and suitable climate for year round cropping. So, investment in water resources development, both surface and underground, would contribute substantially to achieve self sufficiency in food.

The quantitative response of the aquifer system under study to different output/input stresses enabling one to choose viable development plans and management.

1.2 DATA REQUIREMENTS

The success in finding groundwater potentiality greatly depends on the availability of adequate and accurate data base. The available data on the extent and hydrogeological characteristics of the aquifer are ascertained from the reconnaissance and previous records. Data on hydraulic heads occupy the most important position since these are the only directly observed parameters in groundwater flow problems. Once the nature of an aquifer is identified, water levels are measured from wells which tap only the aquifer zones under study. Lithological logs are a source of valuable data for hydrogeological studies. The hydraulic head, transmissivity and storativity values and their spatial distribution define the aquifer system properly and are normally estimated through long duration pumping test on fully penetrating well and using borehole lithological data.

The input to and output from the aquifer constitute the hydrological stresses. As compared to hydrogeological parameters, the estimation of stress usually more reliable because of the improved measurement techniques.

Recharging due to precipitation and infiltration from surface water bodies are the inputs to the aquifer. Total input may be estimated by conventional hydrological measurements of water level fluctuations and by using tracer.

Groundwater draft, evapotranspiration, lateral groundwater outflow, effluence of surface water bodies, etc. comprise the output from an aquifer.

However, the validity and applicability of interpreted results depend on the adequacy and reliability of the data.

1.3 SCOPE AND PURPOSE OF THE PRESENT WORK

The main object of this work is to study the groundwater potentiality of the Main Barind Tract. Groundwater problem of a region is rarely unique, for other region have encountered similar problem and in many instances has found satisfactory solutions. Borehole data is an important source of information for obtaining sub-surface formation distribution. In this regard, some 800 borehole information of the investigated area have been analyzed and interpreted both qualitatively and quantitatively. The lithological data are collected from the Barind Multiple Development Authority (BMDA).

It is highly desirable to have a clear picture about the variation of surface elevation, water-table and the thickness of the composite sand for the better understanding of the aquifer system of a particular area. In interpretation it is needed to present the above parameters in the form of contour map and two-dimensional surface view with respect to a datum plane for delineating groundwater potential zones. In addition, it will be absolutely nice to have vertical sectioning of the investigated area by varying different parameters of interest. All these functioning have to be done with the aid of available Computer Software.

The objectives of this thesis are:

(i) to study the hydrogeological parameters of the sub-surface water system,

(ii) to determine the groundwater flow direction and flow rate in different parts of the area,

(iii) to study the groundwater balance, and

(iv) to delineate the groundwater potential zones.

CHAPTER TWO

GENERAL FEATURES OF THE STUDY AREA

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Bangladesh consists primarily of the deltas of three great rivers: the Padma, the Jamuna and the Meghna which have laid down the alluvial plain. The dominating feature of the topography is the extreme flatness of the country in general, with only a few hills on the North-East and particularly, the South-East. There are some land zones and land systems of which the Barind Tract of the North-West form the level Barind of the Bagra, Dinajpur and Rangpur districts and the high Barind, North of Rajshahi (Anonymous,1991).

The North-Western region of Bangladesh is comparatively backward, less developed and more poverty-stricken as indicated by a number of recent reports and surveys. This region is non-industrialized and depend on agricultural system characterized by a number of agro-economic and socio-economic variables. The major factors are: slope and tenaced physiography, poor and nutrient deficient soil silted up and contracted rivers and surface water bodies, scant and fluctuating rainfall, extreme temperature, poverty, absent land owners and others. There are historical and political reasons too. Before 1947, the Northern region was more closely associated with the Calcutta in trade, commerce and economy and was well communicated by road, rail and river. After partition, due to lack of resources and political will, efficient communication network and trade and industrial ventures did not develop, thus leaving the region backward (Zuberi et. al, 1992).

Natural resource depletion and environmental degradation has been detected as major problem of the special land formations of the Barind and the adjacent regions. The ecosystems in this area are not stable, wide scale denudation of land and expansion of rice monoculture has contributed to soilerosion and land degradation. Rapid population growth and complete dependence on plant biomes for domestic and industrial energy requirement resulted in deforestation and nutrient and organic matter deficiency in soil and decline in agricultural production.

The World Bank Report on " The land and water resources sector study in Bangladesh" divided the whole country into four major regions to highlight the different potentialities and constraints on development in the country. According to the report the North-West zone is the most important zone which shows the maximum possibility of increased crop production. It is encouraging to note that the government has taken the serious step to implement the long neglected Barendra area. The Barendra scheme was undertaken in 1985 covering the area of 12,67,400 acres of land in 17 thanas of Chapai Nawabganj, Rajshahi and Naogaon district. The total project included sinking of about 6000 deep tube wells, re-excavation of 14000 ponds and canals measuring 305 miles, plantation of 55 lake saplings, modernization of 22 nurseries, eight hatcheries and construction of 145 kilometers of pakka roads.

The Barind Multiple Development Authority (BMDA) has principal objective to achieve multipurpose development of the Barind Tract. The Rajshahi Barind Tract offers a challenging area for undertaking such a program for two reasons. First, it has vast potential to support the continued government policy of achieving self sufficiency in food through irrigation development. Second, there is an urgent and imperative need for public sector intervention in order to arrest the process of desertification of a depressed and one of the least developed area of the country. To achieve the aforesaid objectives the following components have been undertaken:

(i) installation of deep tube wells for irrigation,

(ii) re-excavation of derelict ponds and khals,

(iii) large scale propagation of tree plantation, and

(iv) improvement of communication systems.

2.1 GEOGRAPHY

The study area is located in the Western part of the greater Rajshahi district comprising eight thanas: Bholahat, Shibganj, Gomastapur, Nawabganj, Nachole, Godagari, Niamatpur and Tanore [Fig.2.1]. The area represents the Nawabganj district along with two thanas of Rajshahi district and one thana of Naogaon district (Longitude 88°01' E to 88°40' E and Latitude 24°22' N to 25°01' N). The Western part of this area is almost a plain land of average elevation 21 meter whereas the North and North-Eastern part known as high Barind is greatly elevated with maximum of elevation 40 meter recorded at Rahanpur in Gomastapur thana (Chowdhury, 1996). The two major rivers, the Padma and the Mahananda sustaining the environmental balance and socio-economic development of the area. The Padma is flowing in the extreme South-East area and the Mahananda is from the North to South dividing this area into two parts. The floodplain of the river Padma and the Mahananda flank the South and Western side of the area respectively. There are numerous other small braided channels in the plain land and tightly meandered streams are observed in the high Barind area. The alluvium is composed of mostly clay, silt and fine sand and are well oxidized and typically radish brown or tan and

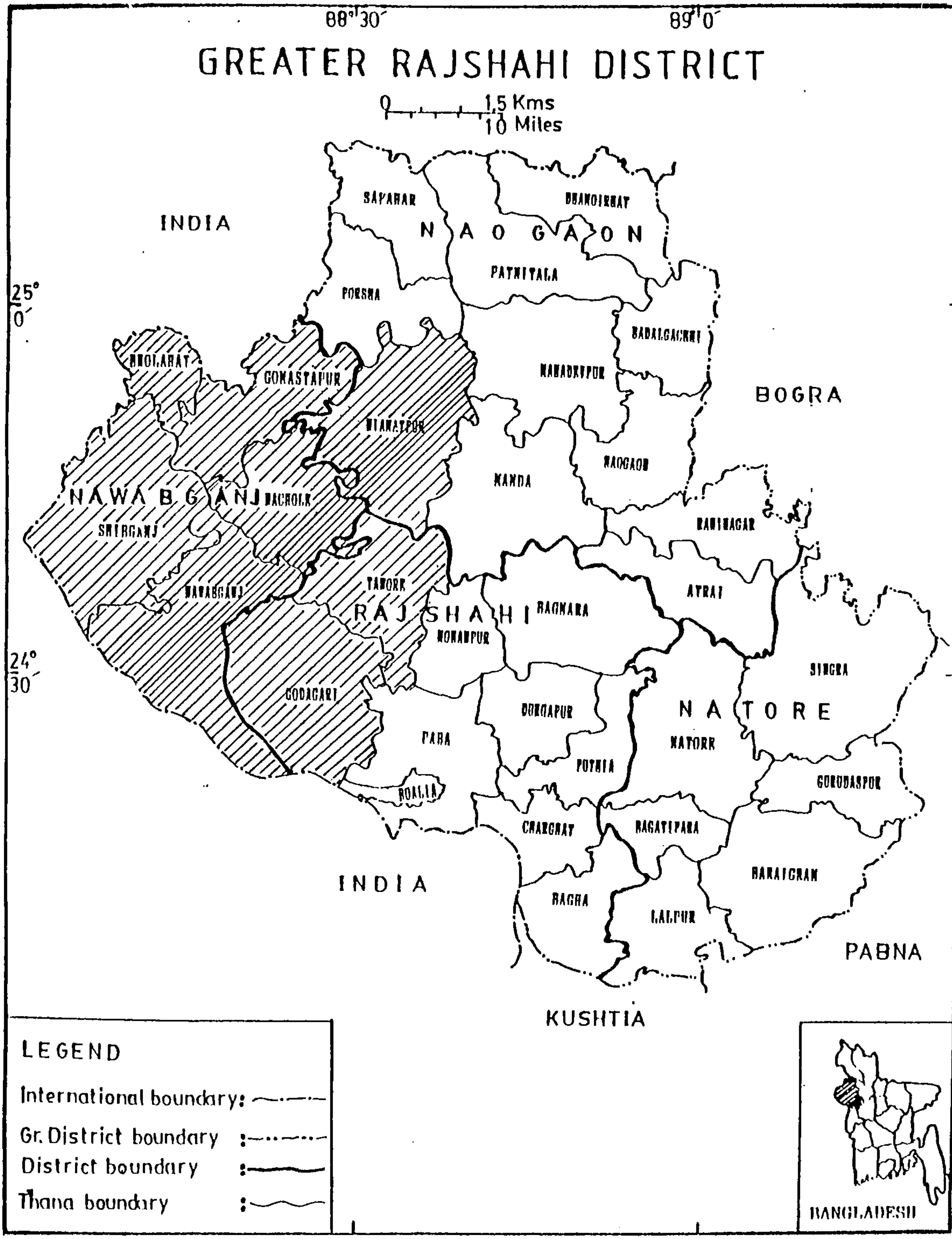


Fig.2.1 Key map of the study area.

are molted. The water contain is low due to firm and compact material (Morgan and McIntyre, 1959). Most of the study area is undulating with large level plains in Western and South-Western part. A gentle slope is registered towards the East, South and South-East corner of the area.

Old river-beds, ponds and marshes, and streams with sluggish current have a copious vegetation of vallisnenia and other plants. Lands subjected to inundation have usually a coverings of Tamarisk and reedy grass. There are no forests. Usually, the higher ground is covered with bamboos and grass. Imparata aroundinacea and Andopogon ociculutus are among them. The Banyan, Pipal and Simul may be seen. In the villages palms are grown. Besides these, numerous species of the Babul (acacia arabia) or gum trees are found throughout the study area (Siddiqui, 1976).

2.2 CLIMATIC CONDITION

Seasons: Barind has a typical monsoon climate. There are three main seasons: Winter- November through February, which is cool and almost rainless, Pre-monsoon- March through may, which is hot and has periodic thundershowers, and Monsoon or rainy season- June through October, which is warm and humid, and during which 80% or more of the total annual rainfall occurs.

Wind: Winds are ordinarily high throughout the year, but stronger winds blow for short periods in the Pre-monsoon season often in association with thunderstorms and occasionally with hail.

Rainfall: There are excess of rainfall varies over evaporation in the rainy season (June through October). The average is about 1.396m at Nawabganj weather station. In contrast, during the dry season , there is an excess of evaporation over rainfall of about 0.33m. Under these conditions, most of the soil are limited to the production of wet land crops, mainly without irrigation.

The average monthly and annual rainfall of ten years of the area were studied. The rainfall records reveal that it varies from 1.1m to 1.8m of which about 70% to 90% occurred from June through October. Normal rainfall ranges between 1.2m in the West and 1.5m in the East.

Temperature: Generally, the study area is a place of relatively warmer according to Bangladesh Meteorological Survey. Annual average maximum temperature varies from 31°C to 35.2°C, and average minimum temperature varies from 15° C to 20°C in the study area. The highest temperature occurs during the pre-monsoon season, at times exceeding 40°C and the lowest temperature occurs during the winter at times decreasing 9°C. The highest temperature generally occurs in April and the lowest temperature in January.

Mean monthly maximum temperature varies from 24.1°C to 35°C and mean monthly minimum temperature varies from 9°C to 26°C in the area.

Evaporation: Evaporation is the process whereby water is returned to the earth atmosphere through the medium of heat. It is very important in all water resources studies. It affects the yield of river basin, capacity of reservoirs, the size of pumping plant, the consumptive use of water by crops and the yield of underground supplies and so on.

The temperature is highly related to evaporation. Like temperature, the study area is also a highly evaporated. During the months from March to May, the temperature and humidity become high and low respectively and the evaporation is high in the same time. During the monsoon season, heavy rainfall accompanies with high humidity and low temperature respectively. So, the evaporation as well as evapotranspiration become low in this season. From March to May monthly evaporation varies from 41.9 mm to 62.4 mm and during the monsoon from June through September, the monthly evaporation varies from 44.7 to 17.6 mm. The minimum rate of evaporation during the month of November continuing till the end of February when monthly evaporation varies from 12 to 25 mm. The monthly maximum evaporation was 62.4 mm in the month of April and minimum evaporation was 12.9 mm in the month of January (Reja, 1995).

Evapotranspiration: Evapotraspiration is the combined term of the evaporation and transpiration, when water losses from water surface into the atmosphere then it's called evaporation and when it losses from different kinds of plants then it's called transpiration. In the field it is practically impossible to differentiate between evaporation and transpiration if the ground is covered with vegetation. The two processes are commonly linked together and refereed to as evapotranspiration. According to a study, the annual evapotranspiration for the study area in 1993 was 874 mm. The evapotranspiration was observed in the month of March, April and May when monthly variation varied from 106 to 140 mm. During the months from November to February, the rate of evapotranspiration varied from 40 mm to 80 mm (Reja, 1995).

Soil Moisture: The moisture content has been calculated to 7.89% in the study area during the year 1996.

Infiltration : Infiltration rate is defined as the maximum rate by which water can penetrate in to the soil. Infiltration rate depends on the number and size of pore spaces in the soil and the distribution of water within them. It has two components, one is transmission component which is constant and represents a steady flow through the soil; and diffusion component which is initially rapid and then an increasingly slow, filling-up of air filled pore spaces, from the surface downwards (Kirkby, 1969). These components can be expressed in the infiltration equation as :

$$f = A + B \cdot t^{-1}$$

where f is the instantaneous rate of infiltration, t is the time elapsed since the beginning of rainfall, A is the transmission constant and B is the diffusion constant of the soil.

The following table gives the minimum infiltration rate without vegetation cover:

Table 2.1 The minimum infiltration rate without vegetation cover :(after Kirkby, 1969).

Grain size class	Infiltration rates mm/hr
Clay	0 - 4
Silt	2 - 8
Sand	3 - 12

It is evident from above table that the infiltration rate may be traced for the study area which varies from majorly 0 - 8 mm/hr and rarely 3 - 12 mm/hr because of clayey and silty clayey dominated area.

The average infiltration rate of the Barind region has been determined as 12.5% (Khan, 1991) and 13% (Deppermann and Thiele, 1973).

Humidity: The relative humidity varies from 50 to a maximum of 100 per cent.

2.3 GEOLOGY

Bangladesh constitutes the major portion of the Bengal basin and more commonly known as the Himalayan Foredeep or Indo-Gangetic trough (Anonymous,1991). Surface and sub-surface stratigraphy of Bangladesh show the only geological information cropping out are of Cenozoic age. Sub-surface stratigraphy includes, in addition to the continuation of three surface geological information, the Pre-cambrian, the Permain Gondwana sediments, the upper Jurassic volcanic rock, and a thin mentle of Cretaceous sedimentary rocks originating mainly from the deposition of the denuded volcanic. The surface and sub-surface stratigraphy make it possible to divide Bangladesh into the Dinajpur shield and Platform, the Shillong Platform, and the basin provinces (Khan, 1991).

The study area is located in the Dinajpur shield which is situated under the Barind Tract of the Pleistocene area [Fig.2.2]. It was formed by the deposition of sediments carried by the river Padma and tributaries in the Pleistocene age (Morgan and McIntire, 1959). There are several boreholes in the area drilled by Bangladesh Water Development Board (BWDB) and Bangladesh Agricultural Development Corporation (BADC) for testing the aquifer, irrigation and water supply. A few long drilling upto the depth of 900m were performed by the Geological Survey of Bangladesh and Standard Vacuum Oil Company. The boring shows that the formation of the top soil is mostly clay though there is silt and fine sands encountered in some places. The formation of clay and silt underlain by fine, medium and coarse sand. The hole drilled by BWDB in some places near Nachole railway station did encounter medium and coarse sand up to a depth of 84m. Towards the South end of the Barind Tract there are clay at the top and sand mostly of coarser texture at depth between 60m to 84m. The study of the boreholes suggests that two terrace levels

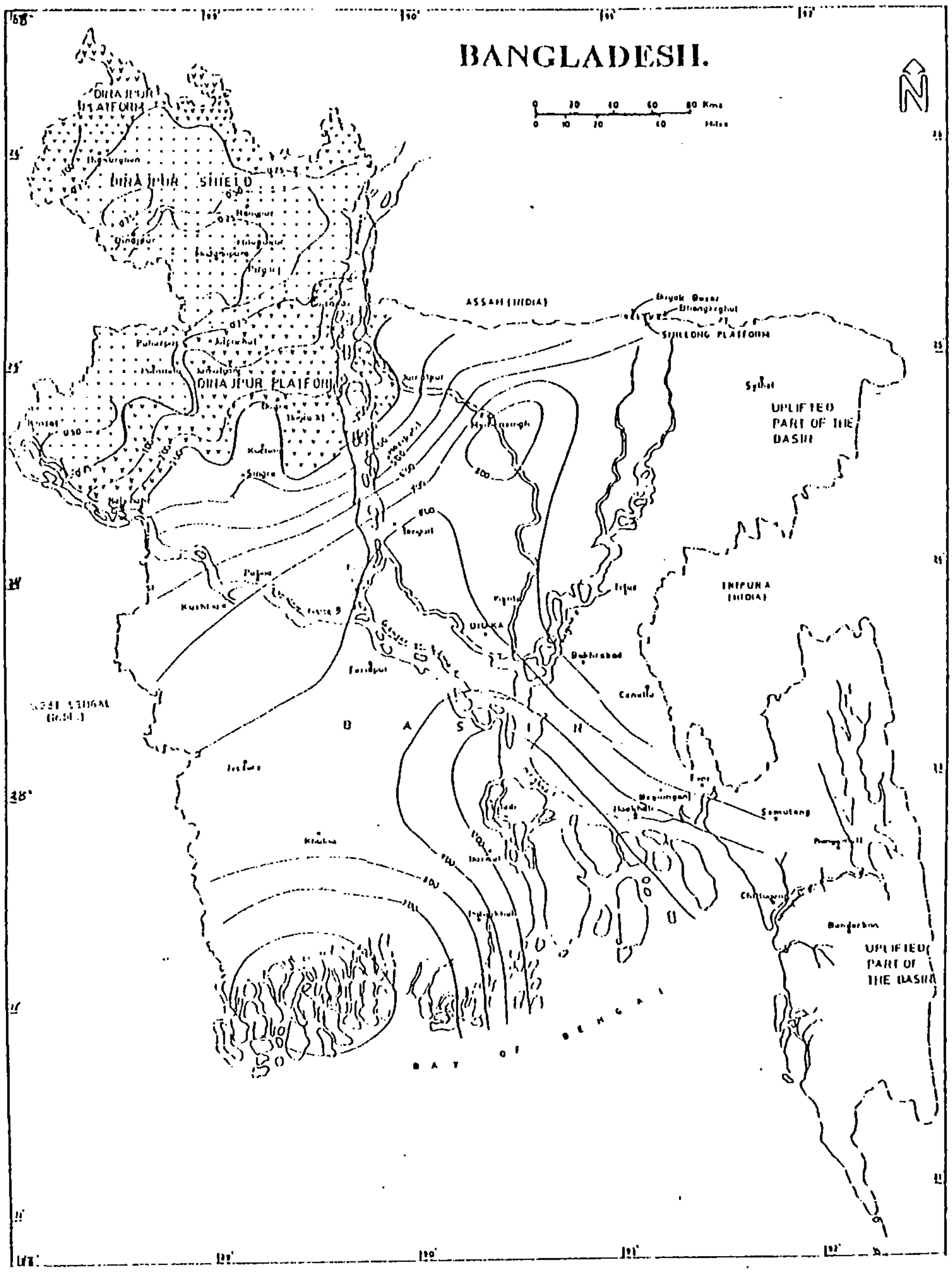


Fig.2.2 Depth Contours of the Pre-cambrian and Tectonic Division of Bangladesh.(After khan,1991).

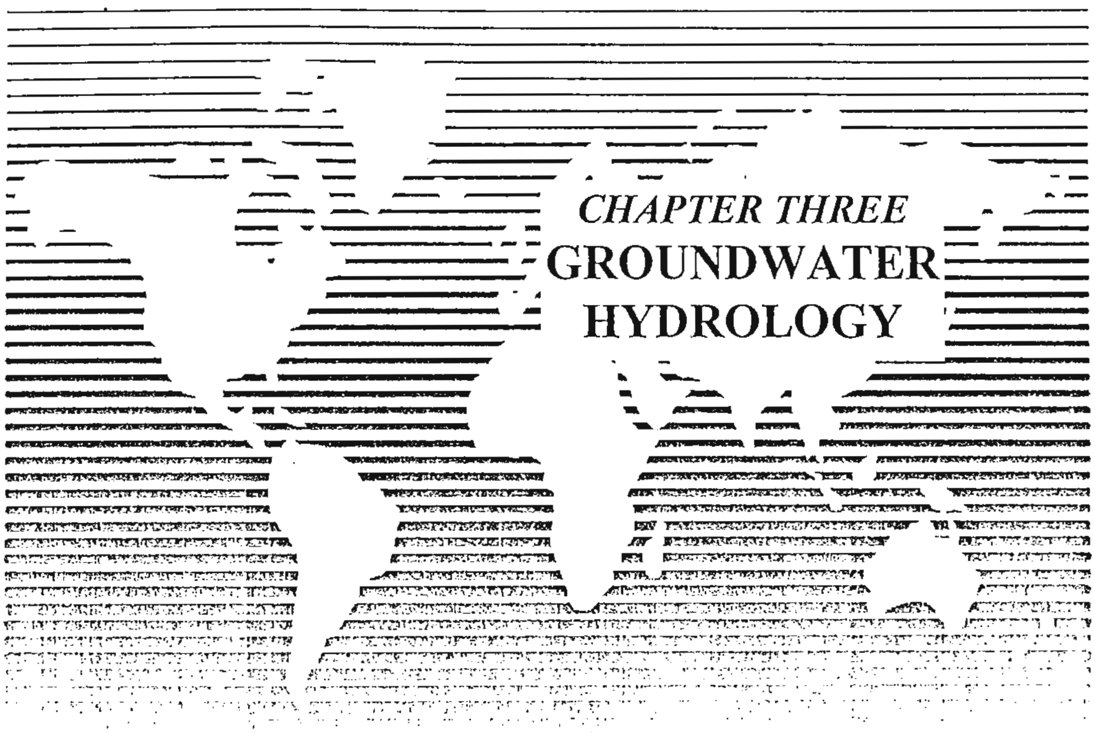
may be present in the Southern part. One level occurs at 13.9m above sea level, and the other less defined surface is at 19.5m to 22.5m above sea level. The borehole of the Eastern part of the river Atrai show that medium sand is found at the depth of 15m to 18m and medium to coarse sands at the depth of 36m to 51m (Ahmed, 1980).

The rock formation of Shibganj consists essentially of red ferrugineous shale, clay stone. A few fossiliferous limy beds appear to be more concentrated in upper part of the formation. Alternate dull ferrugineous brownish kaolineous red sand stone and shale seem to predominate rocks, although in the middle part with some globules of glauconit practice. The Pleistocene area called the Barind is the largest of Bengal basin unit has long been recognized old alluvium deferring from the surrounding recent flood plains. The Pleistocene sediments are flood plain deposits of the Padma and Jamuna rivers. The formation of the top soil is mostly clay though there is silt and fine sands encountered in some places. The formation of top clay and silt underlain by fine, medium and coarse sand (Khan,1991).

Hydrogeology: A Complete work on hydrogeology of the area had been made by the FAO (Food and Agricultural Organization) in conjunction with the then EPWAPDA (East Pakistan Water And Power Development Authority) during the year 1962 to 1966. The survey team investigated a vast area of Northern part of the then East Pakistan (Bangladesh) which includes Rajshahi and Bogra district and Northern part of Rangpur and Dinajpur district. The present study area (Barind Tract) falls in Rajshahi district. From the hydrogeological point of view they divided the Rajshahi Barind Tract into two great units (Eastern and Western) by a North-South line. According to their statement, hydrogeologically Eastern and South-Eastern part is more favorable than Western part. The report concluded for the result of measurements on shallow wells that the superficial clay layer is permeable and about 13% of the mean annual precipitation (1400 mm/year) of the area infiltrating into the ground (Deppermann and Thiele, 1969). But yet it remains questionable whether in view of the relatively thick clayey-silty top stratum, a share of 13% of the precipitation can be assumed to infiltrate the soil, especially, in the Southern and Western regions of Barind Tract of Rajshahi district.

A uniform continuous groundwater is to be expected with some reliability in the Eastern and Southern part of the Barind Tract. In the North-Eastern part of the region no continuous groundwater level is evident. The present study area is a part of the Western Unit. In this part the groundwater level is narrow and the sub-soil is likely to consist predominantly of silt/clay sediment.

The aquifer system in the Barind Tract may be schematized into an aquifer of variable thickness overlain by a semi-confining layer of variable thickness. The aquifers have been encountered just below the overlying clayey sediments which acts as the upper confining bed. However, the considerable thickness and low permeability of this layer is very significant in determining the recharge to the aquifer beneath this. Because of very great thickness of the upper confining bed and for the unfavorable grain size distribution, well-drilling is of high cost and is not always successful. According to a technical report of UNDP under the caption, "Groundwater survey- the hydrologic conditions of Bangladesh " in 1982 and from the drilling logs of many deep tube wells of the study area, it is clear that main aquifer does not occur in the upper 300 meter and the only exploitable aquifer which lies within the depth of 100 meter is a composite one. It is continuous but consists of composite sand (very fine to medium and to some extent coarse sand) formation. It has been tried to classify a part of this composite formation into main aquifer although it has no physical significance.



CHAPTER THREE

GROUNDWATER HYDROLOGY

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GROUNDWATER HYDROLOGY

Groundwater is a precious and the most widely distributed resource of the earth and unlike any other mineral resource, it gets it's annual replenishment from the meteoric precipitation. The amount of groundwater within 800m from the ground surface is over 30 times the amount of all fresh water of lakes and reservoirs, and about 3000 times the amount in stream channels, at any one time (Raghunath, 1987). The sub-surface water generally include chemical and physical properties, geological environment, natural movement, recovery and utilization. The groundwater becomes a usable resource when the formations in the zone of saturation are perennial.

3.1 GEOLOGIC FORM OF GROUNDWATER

If water bearing materials were uniformly pervious and homogeneous, groundwater problems could be solved by hydraulic data; studies of the effect of hydrologic variations and geologic structure of water bearing materials would be unnecessary. The materials underground, however, are heterogeneous and their hydraulic characteristics are valid. These variations control the quantity and distribution of groundwater.

Geologic formation or structures that transmit water in sufficient quantity to supply pumping wells or natural springs are called aquifers or water carriers.

Every geologic body has a geologic structure and a related hydrologic structure. In sedimentary rock, aquifers are usually formation of great extent, occurring as sheets separated by aquicludes also sheet like in form. About 25 percent of the sedimentary rock of the world is sand stone. In many countries sand stone strata form regional aquifers that have vast quantities of portable water. In superficial alluvial deposits; aquifers vary in shape, size and interconnection depending upon the source material and processes by which they are formed. In alluvial flood plain deposits and alluvial cones the aquifers are labeler in form; in flood plain deposits they are sinuous and interconnected, and in alluvial cones the tube are often divergent and not interconnected below the intake area.

The geologic structure and hydrologic characteristics of the stream bottom and underlain materials are specially important because they control influent seepage from stream which is important source of groundwater. Where underlying materials are uniformly pervious, seepage loss from the stream may be great, where a relatively impervious formation occurs between the stream bed and water-table, seepage loss may be nil. Soils have a vertical porosity due to not opening and animal burrows and flocculated colloids which give a certain degree of perviousness to material that otherwise might be practically impervious.

Earlier it was considered that there is no water in igneous and metamorphic rocks. Recent breaks though have occurred, both in methodology and technology for exploration and development in igneous and metamorphic rocks and especially in the rocks of the pre-cambrian shields. These have raised considerable hopes for the future of these developing regions.

Hard rock terrains comprise a great variety of igneous and metamorphic rocks. But from the hydrogeological point of view they are homogeneous in two respects:

(a) They have no primary porosity as do sand stones or other sedimentary rocks.

(b) They have secondary porosity due to fracturing and weathering, which permit the flow and storage of groundwater.

Unweathered hard rocks is quite impervious, the storage capacity is restricted to the interconnected system of fractures, joints and fissures in the rock. Weathering processes have a considerable influence on the storativity of hard rock.

3.2 SOURCE AND DISTRIBUTION OF GROUNDWATER

Though almost all groundwater can be thought of as a part of hydrologic cycle, but the groundwater may be classified as to source under the headings Meteoric water, Connate water and Juvenile water (Tolman, 1937).

Meteoric water : Meteoric water is derived from the atmosphere. It is precipitated on the surface of the earth and may enter the sub-surface reservoirs, sooner or later to return again to the atmosphere. It is the most important source of water used by Man.

Connate water : The openings and interstices of all sedimentary rocks deposited beneath the ocean were originally filled with salt water. After the rock has been lifted above the sea, fresh water slowly drives out and replaces the salt water. Connate water, therefore, exists as pockets of stagnant water, specially in structure which hold oil and gas. It is this source which supplies water in deep sedimentary strata of the crust.

Juvenile water : Juvenile water is new water. It constitutes addition to the water supply of the earth and is further classified according to origin as Magmatic, Volcanic and Cosmic water. Magma is molten rock occurring at a depth and consists of a mutual solution of molted rock forming minerals and of gases, the most important of which water vapor. That water driven out of Magma during its crystallization process is called Magmatic water. Volcanic water is a second type of Juvenile water and is furnished by surface lava flows. It contains no argon, which occurs in all atmospheric water, hence it is concluded that it is new water, not drive from atmospheric or groundwater. Cosmic water, that comes in from space with meteorites, is a third type of Juvenile water. Rejuvenile water is that water which is returned to the terrestrial water supply by geologic processes of compaction and metamorphism.

The rainfall that percolates below the ground surface passes through the voids of the rocks, and joins the water table. These voids are generally interconnected permitting the movement of groundwater. But in some rocks, they may be isolated, and thus, preventing the movement of water between the interstices. It is evident that the mode of occurrence of groundwater depends largely upon the type of formation and the geology of the area.

The sub-surface occurrence of groundwater can be divided into two main regions,

i) The zone of aeration, and

ii) The zone of saturation.

Zone of Aeration : The zone of aeration extents from the land surface to the level at which all of the pores in the earth material are not completely filled with water. It may be sub-divided into three belts, soil water zone, the capillary fringe zone and the intermediate zone [Fig.3.1].

Soil Water Zone : Water in the soil water zone lies immediately below the surface and in that region from which plants extract by their roots, the moisture necessary for growth. The thickness of this belt differs greatly with the type of soil and vegetation, ranging from a few meter in grass lands and field crop area as to several meter in forests and land supporting deep-rooted plants.

Capillary Fringe Zone : The capillary fringe occupies the bottom portion of the zone of aeration and lies immediately above the zone of saturation. Its name comes from the fact that the water in this belt is suspended by capillary forces similar to those which cause water to rise in a narrow or capillary tube above the level of the water in a larger vassal into which the tube has been placed up right. The narrower the tube or pores, the highest the water rises. Hence, the thickness of this belt depends upon the texture of the rock or soil and may be practically zero where the pores are large.

Intermediate Zone : This belt extends from the lower edge of the soil water zone to the upper limit of the capillary zone. This zone may vary in thickness from zero when the bounding zones merge with the water-table approaching the ground surface to several hundred meter under deep water-table conditions. The water stored in this zone is called pellicular water and is held in place by hydroscopic and capillary forces, and is equivalent to field capacity of the soil. The excess water over field capacity moves downward towards the water-table under the influence of gravity is referred to as gravitational water.

Zone of Saturation : In the zone of saturation all the openings are fully filled with water under hydrostatic pressure, hence the porosity is a direct measure of the water

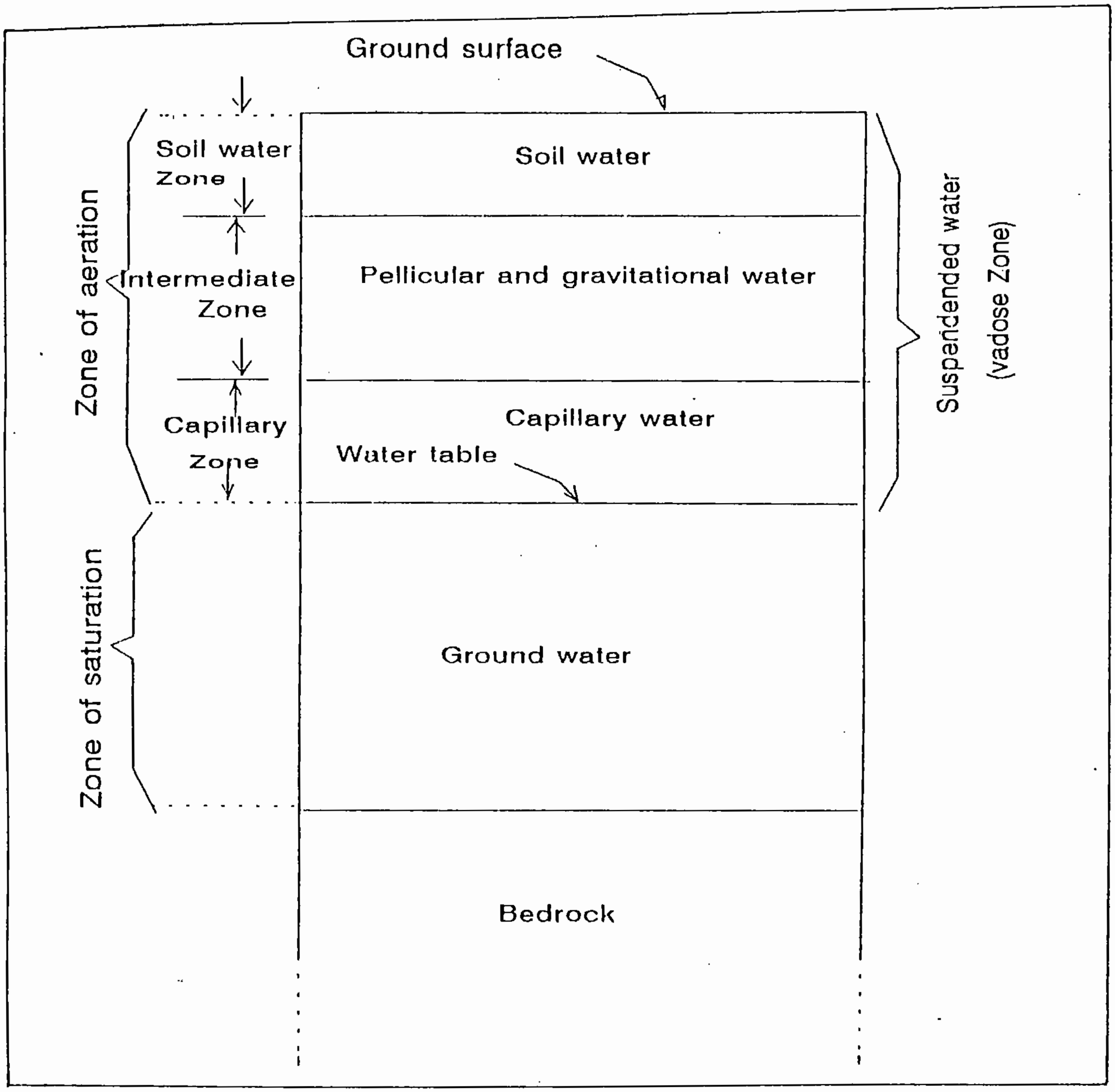

Fig.3.1 Distribution of sub-surface water

contain per unit volume. The water in the zone of saturation is generally known as groundwater. Not all of this water may be removed from the ground by pumping from a well, as molecular and surface tension forces will hold a portion of the water in place. The controlling factors in this zone are geologic structure, hydrologic characteristics of water bearing materials and hydraulic gradient. If water moves through an interconnected body of pervious material unhampered by impervious confining material, it may be termed free groundwater moving under the control of the slope of the water table. On the other hand, if water is held in small openings which resist water movement under the usual hydraulic gradient existing underground, is called fixed groundwater.

3.3 AQUIFER PROPERTIES AND GROUNDWATER FLOW

The word *"AQUIFER"* can be traced to its Latin origin. *Aqui-* is a combining form of *aqua*, meaning water and *fer-* comes from *fere*, to bear. Hence, an aquifer, literally, is a water bearer.

The amount of water to be soaked by the earth depends upon the nature of rock or sediments. On the basis of the relation that rocks or sediments bear to the percolation of water, these may be divided into two categories- pervious rocks that allow water to pass through them and impervious that do not. The pervious structure has no connection with porous nature of rock. Many rocks, that are massive and crystalline, have so many joints that they become pervious. On the other hand, many porous rocks have their pore spaces so small that water can not pass through them freely. For the purpose of groundwater, the rock or sediment that can hold, transmit and yield water are called Aquifer (Mahajan, 1989) and the accumulation of groundwater in a particular region will depend upon the presence of aquifers. The amount of water yielded by a well depend on many factors, some of which, such as the well diameter, are inherent in the well itself. But the permeability and the thickness of the aquifer are considered as the most important factors in design a water well.

There are mainly two types of aquifer based on the permeability of the covering layers.

(i) Unconfined aquifer, and

(ii) Confined aquifer

Unconfined Aquifer: An unconfined aquifer is one in which the water table serves as the upper surface of the saturation. It is also known the free phrestic or non-artesian aquifer. The groundwater level is free to rise or fall. The level of water table is the place where groundwater pressure is equal to the atmospheric pressure. Above the water table is the vadose zone, where water pressure is less than the atmospheric pressure. The lower boundary of unconfined aquifer is a layer of much less permeable material than the aquifer itself. Such confining stratum may consists of clay or other fine sand textured granular material or rocks [Fig.3.2].

Unconfined aquifers are commonly found in alluvium valleys, coastal plains, dunes and glacial deposits. They may range in thickness from few meter to hundreds of meter or more. The principal source of groundwater in unconfined aquifers is precipitation that has infiltered into the soil above aquifers, either directly as it feel on the ground or indirectly via surface runoff and seepage from stream and lakes. When groundwater flows from an unconfined aquifer into a pumped well, the water table drops and are moving through the vadose zone replaces water that has drained from the pores in the upper aquifer material.

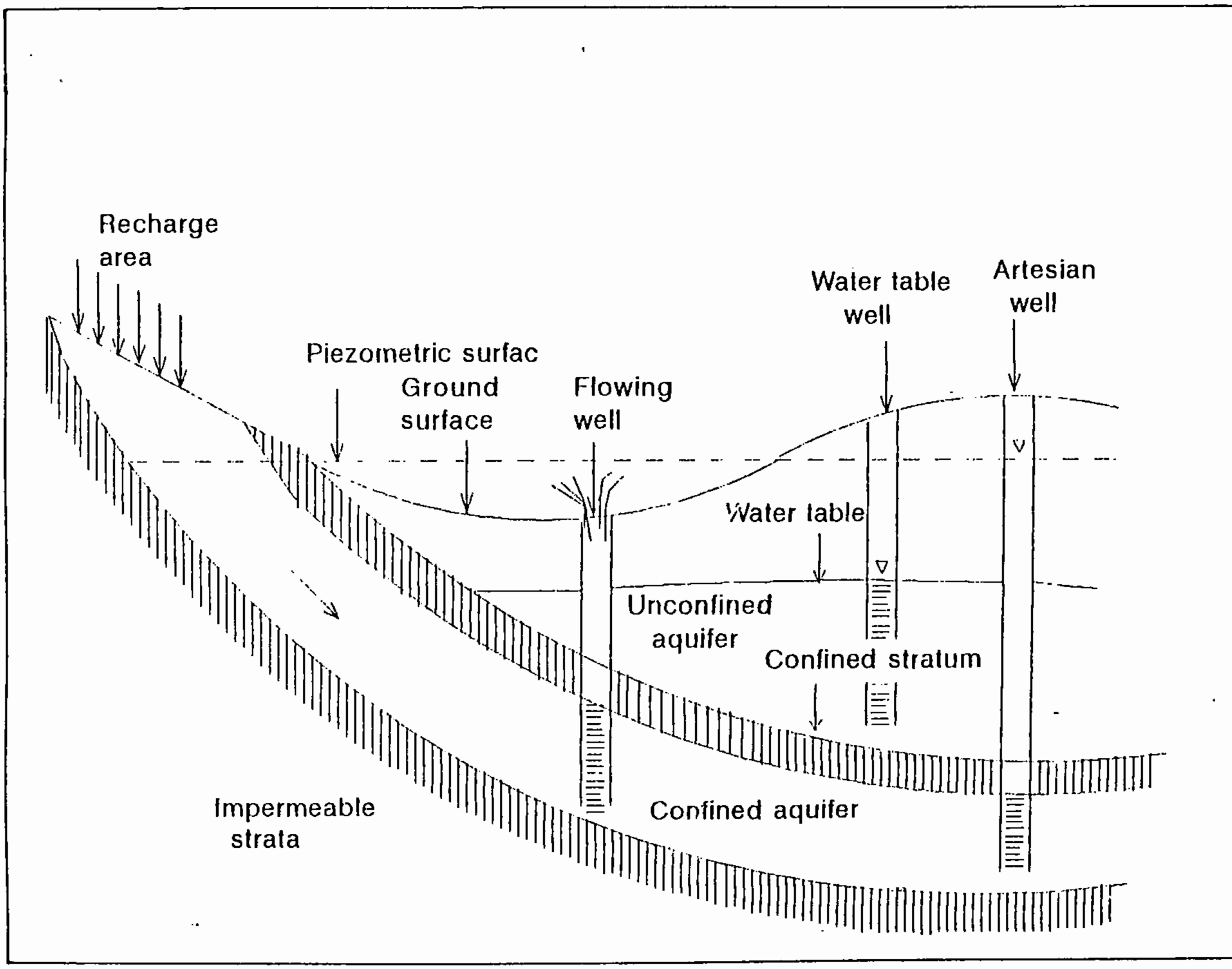

Fig. 3.2 Types of Aquifers
(after Todd,1959)

Confined Aquifer: Confined aquifer is a layer of water bearing material that is sandwiched between two layers of much less pervious, like a sandy layer between two clay layers or sand stone between layer of shale. The confined aquifer do not have free water table and are also known as artesian or pressure aquifers. The pressure conditions in a confined aquifer is characterized by the piezometric surface, which is the surface obtained by connecting equilibrium water levels in tubes or piezometers, penetrating the confined aquifer. If the piezimetric surface are above the upper confining layer, the static water level will be above the aquifer. If the piezometric surface is above the ground level, the confined aquifer will yield free flowing wells or flowing artesian well [Fig.3.2]. The term artesian is sometimes extended to include deep wells in which the water approaches the surface but does not actually reach it.

A particular aquifer at one place may be a confined aquifer while at another place it may behave as an unconfined aquifer where the water level falls below the base of the overlying confining layer. Similarly, at one particular place an aquifer may change from confined to unconfined character with time. A semi-confined aquifer is one which is completely saturated with water and is bounded above by semi-pervious layer. A semi-pervious is defined as layer which has measurable permeability.

The amount of groundwater which can be obtained in any area depends on the character of the underlying aquifer, its extent and the frequency of discharge. The yield of the water saturated formation is probably the most important single item of ultimate interest. Practically, in most cases the yield will determine whether or not the water saturation zone will be treated as a source of groundwater. One of the individual factors that affect the yield is the natural characteristics of the water bearing formation.

An aquifer performs two important functions (a) storage function and (b) Conduit function. It stores water serving as reservoir and transmit water like a pipeline. The openings in a water bearing formation serve both as storage spaces and as a network of conduits.

Storage Function : Storage function is the properties which control the entrance of water into water bearing formation, their capacity to hold, transmit and deliver of water, and confinement and concentration of percolation to the direction of maximum movement, soil materials contain void space. The space is described quantitatively by a property known as porosity, an index of how much water could be stored within the aquifer in the groundwater reservoir. It is defined as the ratio of the volume of the voids between the grains to the total volume of the material. The size, arrangement and shape of grains and the degree of assortment are some of the factors controlling the porosity of granular material.

While porosity is the measure of the water bearing capacity of the formation, all this water can not be drained by gravity or pumping, as a portion of the water is held in the void spaces. The volume of water, expressed as a percentage of the total volume of the saturated aquifer, that can be drained by gravity is called the specific yield (S_y) and the volume of water retained by molecular and surface tension forces, against the force of gravity, expressed as a percentage of the total volume of the saturated aquifer, is termed specific retention (S_r)and corresponds to field capacity as

$$\text{Porosity } (n) = \text{Specific Yield } (S_y) + \text{Specific retention } (S_r)$$

Specific yield is the water from unit volume of aquifer by pumping or drainage. It depends upon grain size, shape and distribution of pores and composition of the formation.

Storage co-efficient: Storage coefficient of an aquifer is the volume of water discharge from a vertical column of aquifer standing on a unit area ($1m^2$) as water level (piezometric level in confined aquifer) falls by a unit depth (lm). For unconfined aquifers (water table condition) the storage co- efficient is the same as specific yield. The storage co-efficient for confined aquifers ranges from 0.00005 to 0.005 and water table aquifers 0.05 to 0.03 to (Raghunath , 1987).

Under artesian conditions, when the piezometric surface is lowered by pumping water is released from storage by the compression of the water bearing material (aquifer) and by expansion of the water itself. Thus, the co-efficient of storage is function of the elasticity of water and the aquifer skeleton.

Permeability: The property of the water bearing formation which is related to its conduit function is called the permeability. Permeability (K) is a measure of the capacity of the porous media to transmit water under pressure. Movement of water from one point to another in the material takes place whenever a difference in pressure of head occurs between two points. The rate of movement of groundwater depends on the permeability of the rock through which it is flowing, and on the hydraulic gradient which provides the motion force. The co-efficient of permeability is defined as the rate of flow of water per unit cross-sectional area of the formation when subjected to a unit hydraulic head gradient per unit length of flow and has the dimension of velocity, i.e., L/T. Its value depends in general upon the degree of sorting, arrangement and size of the particles. It is usually low for fine textured or tightly cemented material and high for coarse.

Transmistivity : The co-efficient of transmisivity (T) is the discharge through unit width of aquifer for the fully saturated depth under a unit hydraulic gradient and is usually expressed as lpd/m or m^2/sec. It is the product of field permeability (K) and saturated thickness of the aquifer (b); T=Kb and has the dimension L^2/T.

In order to study the movement of groundwater effectively and accurately, an intimate knowledge of geologic factor is necessary. Thus, the lithology, structural sequence, thickness and lateral extents and hydrogeological parameters must be known. The lateral gradation of particles is of great significant with respect to the movement of groundwater. Depending upon the hydraulic gradient and permeability, water may move in various directions. Both the lateral and vertical extends of aquifer must be accurately known for determining the rate of movement of groundwater.

The position of water table with respect to m.s.l. is generally known as water head position. Groundwater moves from the level of higher energy to level of lower energy that means from the higher water head position to lower one. Its energy being essentially the result of elevation and pressure and the flow is generally laminar. Velocity of groundwater flow which is entirely laminar is given by Darcy's law. It states that 'the velocity of flow in a porous medium is proportional to the hydraulic gradient,'

that is,

$$v = Ki$$

where , K=Co-efficient of permeability, and

i = Hydraulic gradient (=Δh/L, if a head h is lost in a length L).

Groundwater flow, $Q = Av$

$$= AKi$$

Therefore, $Q=Tiw$

As $A=wb$, and $T=Kb$

where, A, w, b and T are cross-sectional area, width, saturated thickness and transmissivity of the aquifer.

3.4 GROUNDWATER MAPS

In an area the groundwater conditions can best be analyzed by plotting the groundwater data on maps. The following maps are most useful.

Water-Table Contour Maps: An water table map is a map of the phreafic surface, it can be prepared for specific period. The maps are prepared by the water levels of all the observation points on a topographical map and connecting points of equal water table elevation (Water-table contour lines or equipotential lines). Such maps enable to give the direction of groundwater flow. To draw contour lines, the water level between the observation points must be interpolated.

Depth to Water-Table Maps: A depth to water-table map is derived from the elevation between the contour lines of the ground surface and those of the water-table. A map showing the depth of the water-table below the ground surface is of special use in delimiting the extent of areas in need of drainage. For that reason depth to water-table maps are drawn from some chosen typical dates for example when the highest water-table occurs or when the lowest water occurs.

Groundwater Fluctuation Maps: Groundwater fluctuation maps are constructed by plotting a given span of time, the change of water level in the observation wells and drawing lines of equal change. These maps are prepared either by plotting the difference in water level in observation wells or by super-imposing two water-table contour maps and plotting the difference in water level at contour interactions. This type of map can be drawn both for fluctuations in the elevation of the water-table and fluctuations in the elevation of the potentiometric surface of a confined or semi-confined aquifers.

Hydraulic Head Difference Maps: For preparing hydraulic head difference maps double piezometers are required, one shallow piezometer in the upper unconfined aquifers and one deep piezometer in the lower aquifer may show different water levels. If the potentiometric head in the aquifer is higher than the groundwater level in the upper confined layer, the latter is recharged from the aquifer. If the potentiometric head is lower than the groundwater level in the upper layer, this layer losses water to the underlying aquifer. In such an areas it is useful to construct a hydraulic head difference map. This can be done by plotting for a given data, the difference in water level observed in double piezometer wells and drawing lines of equal head difference by superimposing for a given data. The contour maps of water-table and potentiometric surface and plotting the head difference at contour intersection lines of equal head difference can be drawn.

Groundwater Quality Maps : The main map to be drawn is an electrical conductivity (E.C) map of the shallow groundwater. It is preferable if the data from observation wells and piezometers area available, and electrical conductivity map of the deep groundwater should also be drawn. By plotting all the E.C values on a map, lines of equal electrical conductivity can be drawn.

3.5 GROUNDWATER DISTRIBUTION IN BANGLADESH

Groundwater is a vital source of water supply in Bangladesh. Bangladesh is almost entirely underlain by water bearing formations at depths varying from zero to 12 meter below the ground surface. Most of the area of Bangladesh possesses deltaic formation of alluvial deposits. The land elevation is about 61 meter in the Northern plains and 15 meter in the middle plains and a few meter above mean sea level at the coastal plains. Having all these topographical and hydrological conditions, the soil strata in Bangladesh contain water more or less everywhere below water-table. But all strata do not contain sufficient water that can be pumped or may not give water for a long time. Three main rivers- the Padma, the Jamuna and the Meghna with their network of tributaries pass through the deltaic region of Bangladesh filling the lands with alluvial deposits and other unconsolidated material such as sand and gravel which the river carry with them draining the Himalayan ranges. The thickness of these stratified alluvium in the entire area exceeds 30 meter. The continuous layers, although containing occasional lenses of clay occur at depth varying from 15m to 90m. Gravel is frequently marked with fine to medium sand. Coarse sand is found rarely and is thin layers. Within the stratified aquifer occurrence of medium sand is the maximum.

While some groundwater reservoirs are being replenished year after year by infiltration from precipitation, rivers, canals and so on, other are being replenished to much lesser degree or not at all. Extraction of water from this later reservoirs results in the continued depletion of groundwater level (Aziz, 1986). Many parts of Bangladesh are facing water supply problem due to the over exploration of groundwater. The planing of a water supply system requires a knowledge of the extents of storage, the rate of discharge from and recharge to the underground reservoirs.

In Bangladesh, Groundwater occurs particularly in the coarse grain, sandy gravely beds interbeded in the alluvial series filling the depression. The variation of the depth of groundwater level in different parts of Bangladesh is shown in Fig.3.3.

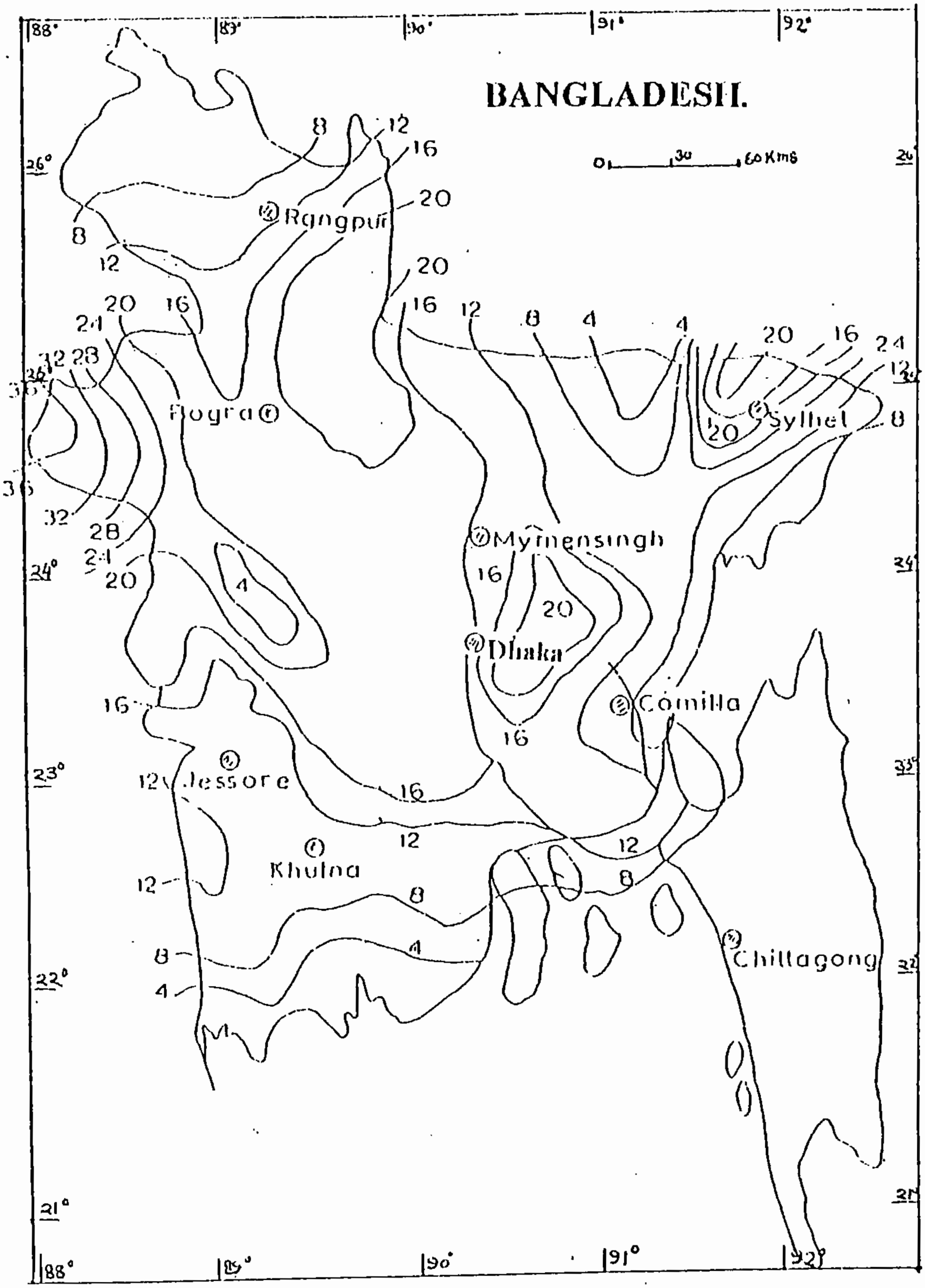

Fig.3.3 Variation of Static Water level in Bangladesh. (Contour interval=4 ft) (After Aziz,1986).

CHAPTER FOUR

HYDROGEOLOGICAL STUDY OF THE INVESTIGATED AREA

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HYDROGEOLOGICAL STUDY OF THE INVESTIGATED AREA

Hydrogeology means the science of water that deals with occurrence, circulation and distribution of water of the earth and earth's atmosphere. However, hydrogeology involves with the occurrence, distribution and movement of water below the surface of the earth. A complete inventory of water resources requires continuous checks at the land surface to determine the gross water supply from precipitation and the return to the atmosphere by evaporation and transpiration; in the groundwater reservoir to determine changes of storage, lateral movement and ultimate discharge. In the study of a particular groundwater source, surface collection areas and underground conduits and reservoirs must be identified and hydrologic behavior of the system must be discovered to evaluate the equation of hydrologic equilibrium.

4.1 DATA ACQUISITION

Bangladesh is rich in groundwater resources. The qualitative and quantitative availability of groundwater is generally influenced by varying geology, physiography and climatic conditions. As population increases more water will be required for agriculture, industry and domestic purposes. Groundwater in most of the parts of our country, particularly in the Barind Tract is believed to be over exploited. Falling water level, reduction in effluent seepage are manifestations which indicate that the management of this precious resource is not adequate. The groundwater resource management is vital for human survivor and is not feasible unless complete assessment of the system is made. Lithogical logs are a source of valuable data for hydrogeological studies.

About 800 borehole data collected from BMDA for the study area have been analyzed and interpreted for quantitative hydrogeological studies. The study area along with the data points is shown in Fig.4.1. The distribution of data points in the area investigated is clearly observed from the figure. In the adjoining areas of Gomastapur, Nachole and Niamatpur thana, no data is available due to the failure of drilling. Except the Northern part of Godagari thana and Southern part of Niamatpur thana the data density of the study area is almost uniform. An effective study area has been drawn [Fig.4.1] considering the sufficient data points within the area studied. The square constituted by the doted and continuous line is considered as analytical area and different maps of interpretation are to be presented in this square form.

4.2 FENCE DIAGRAM

Geologic formation is an important factor for identifying of groundwater potential zone. The stratigraphy describes the geometrical and age relations between the various lenses, beds and formations in geologic systems of sedimentary origin.

Borehole lithological data is an important source of information for obtaining the sub-surface formation distribution. The reliability of the information depends not only upon the accuracy of the data but also on the number of available data sources. It is customary to present borehole lithologs in a vertical section so that the formation distribution as they actually occur would be reconstructed but it is not feasible to present effectively all the vertical section in a single diagram. The sub-surface

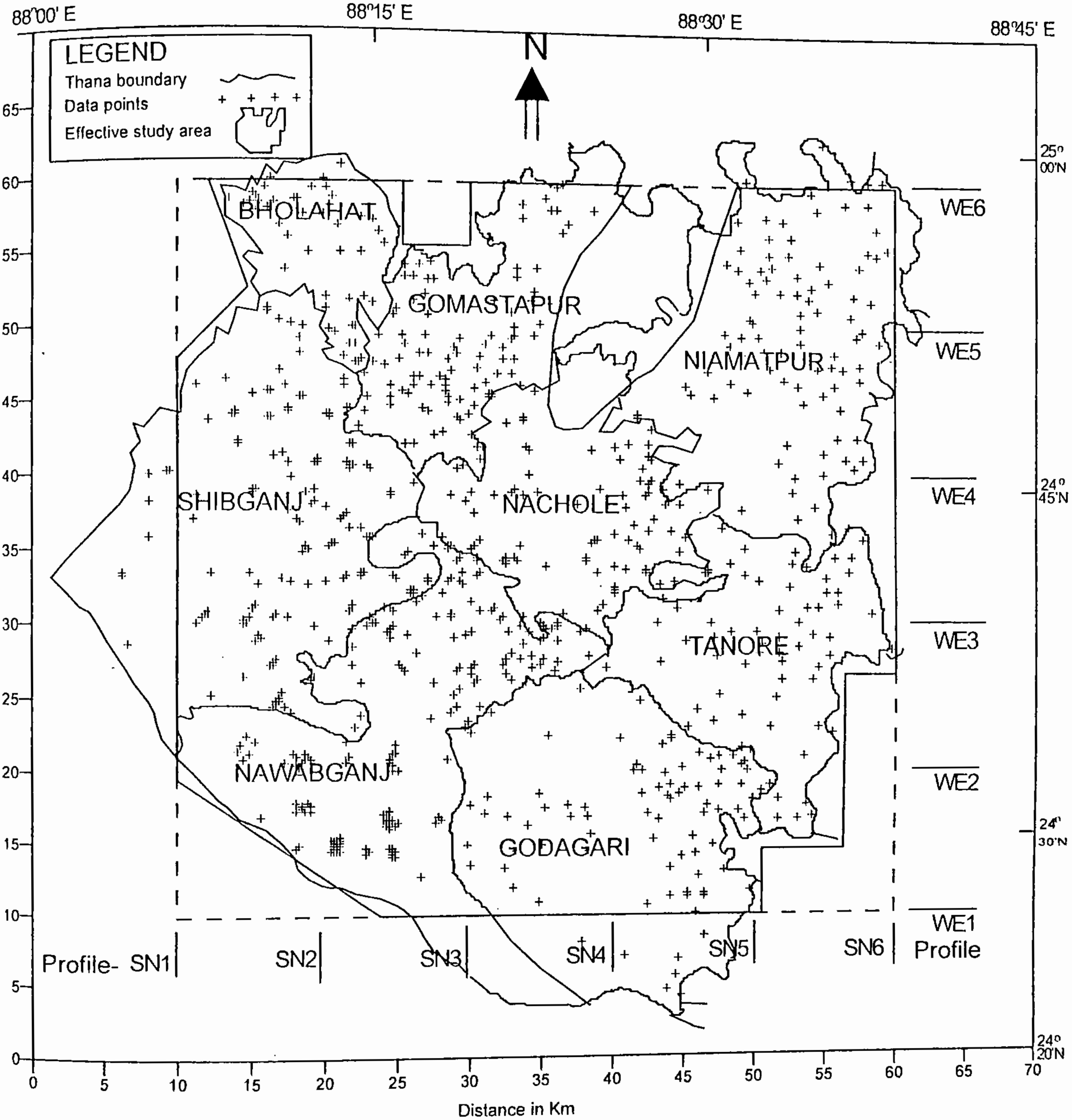

Fig.4.1 Effective study area showing data points.

geology of the area investigated has been studied upto 61m on the basis of lithological logs of 11 locations covering the whole area [Fig.4.2]. The stratigraphic Fence diagram is shown in Fig.4.3. The Fence diagram is extremely useful in predicting three dimensional distribution of the sub-surface formations. This diagram represents an over all view of the sub-surface geological formation delineating the major aquifer zones.

The area mainly consists of three sub-surface layers: a top clay layer, sandy layer of different grain size and at the bottom an impermeable clay zone. Studying the formations of sandy layer in the area this layer is clearly divided into two parts, one below the top clay which is fine in grains and another is consist of medium to coarse sand generally termed as 'Composite Sand'. The composite sandy formation is overlying on an impermeable clayey zone which is very common in the study area and usually known as 'Black Plastic Clay' (B.P.C.) due to high plasticity and black color. The thickness of the impermeable bed as recorded in the borehole lithologs is still undetermined.

In the Fence diagram a top clay layer of varying thickness is clearly observed. The maximum thickness of 18.3 m is recorded in Godagari thana. An average thickness of 8m to 12m clay bed is observed in the area investigated except the Northern zone where a thick bed is present. Below this top clayey layer a fine sand formation is found whose thickness is 5m in average except at location 6 (Shibganj) where it is recorded as 21m. The important water bearing formation is the composite sand bed which is presented as third layer in the Fence diagram. The maximum and minimum thickness of 33m and 12m are recorded in the Nawabganj and Bholahat (location-2) thana respectively. However, the favorable thickness of this bed is observed in the South-Eastern, South-Western, Central and North-Eastern part of the geology of the area investigated has been studied upto 61m on the basis of lithological logs of 11 locations covering the whole area [Fig.4.2]. The stratigraphic Fence diagram is shown in Fig.4.3. The Fence diagram is extremely useful in predicting three dimensional distribution of the sub-surface formations. This diagram represents an over all view of the sub-surface geological formation delineating the major aquifer zones.

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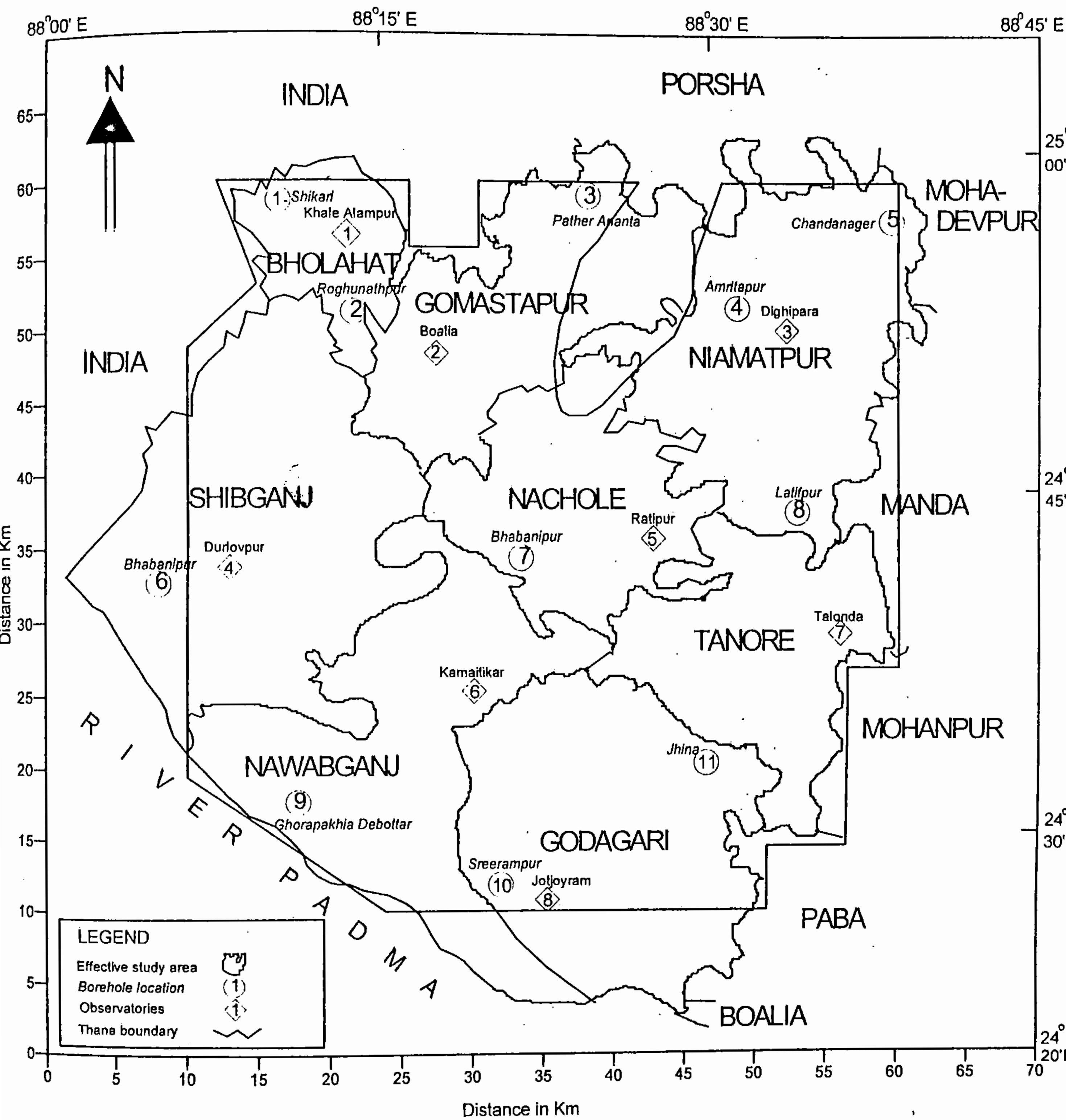


Fig.4.2 Effective study area showing borehole locations and observatories.

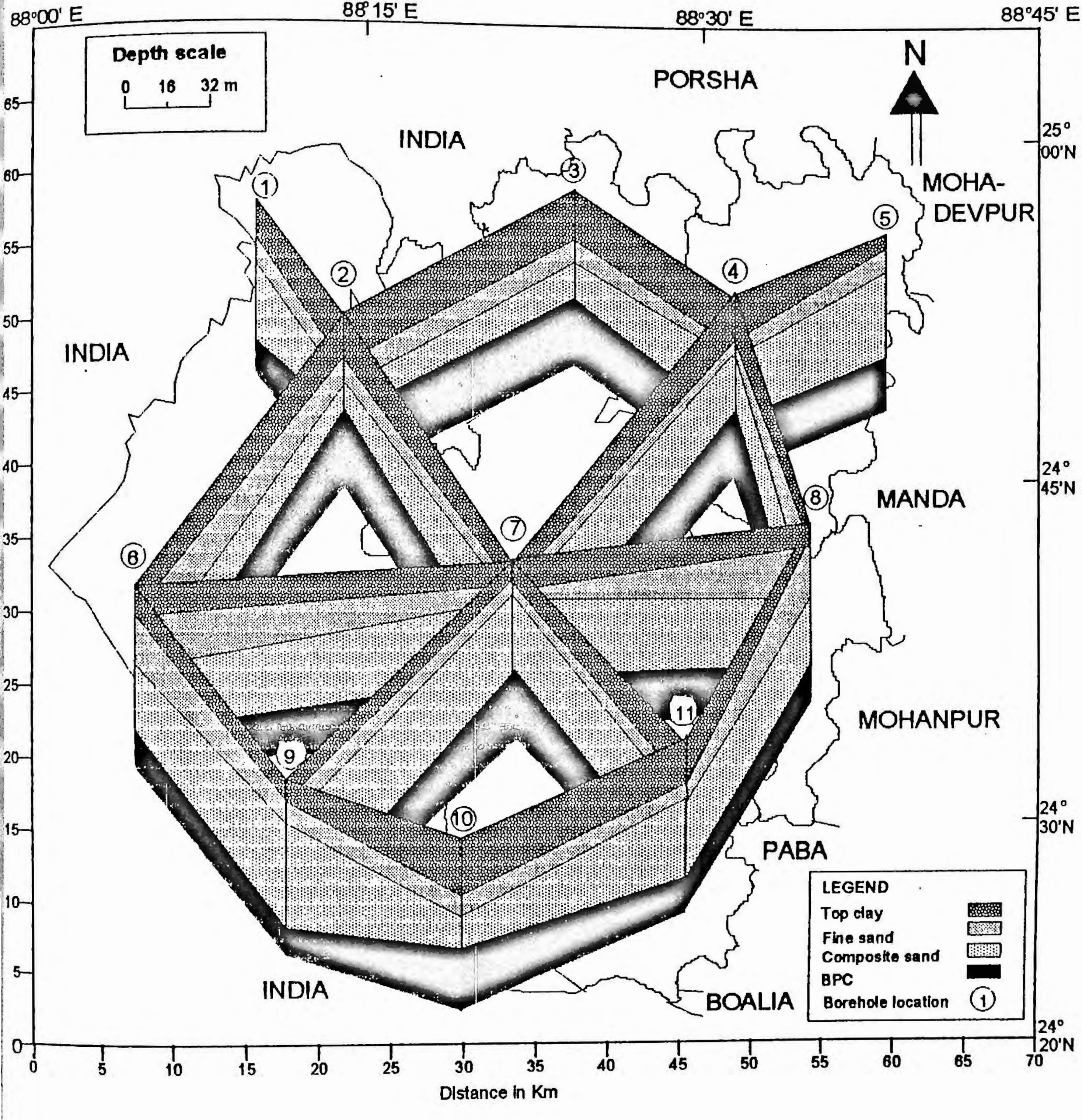


Fig.4.3 Fence diagram of the study area.

area. The minimum depth of impermeable bed is recorded at Nachole and Gomastapur thana whereas the maximum depth is found at Shibganj and Nawabganj.

From the overall discussion of the Fence diagram it could be concluded that the sub-surface geology is not unfavorable for groundwater exploration in small scale provided the other conditions are satisfied. It is also mentionable that the usable aquifer of the area investigated is unconfined in nature. So, the large scale abstraction of groundwater should be avoided otherwise ecological imbalance would affect the environmental system.

4.3 HYDROGEOLOGIC PROPERTIES OF SUB-SURFACE FORMATION

The important properties of an aquifer are its capacity to release the water held in its pores and its ability to transmit the flow easily. Two properties of an aquifer material related to its storage are its porosity and specific yield. The amount of groundwater which can be obtained in any area depends on the characters of the underlying aquifer, its extent and the frequency of discharge. The yield of the water saturated formation is probably the most important single item of ultimate interest. Practically, in most areas the yield will determine whether or not the water saturated zone will be treated as source of groundwater. One of the individual factors that affect the yield is the natural characteristics of the water bearing formation

Porosity : Those portion of a rock or soil not occupied by solid mineral matter are known as voids, interstices, pores, or pore space. Because interstices serve as water conduits, they are of fundamental importance to the study of groundwater.

A rock is said to be saturated when all its interstices are filled with water. In a saturated rock the porosity is practically the percentage of the total volume of the rock that is occupied by water.

Porosity of the aquifer materials (medium to fine sand) of the study area have been estimated in the laboratory (Khaleque,1994). The estimated values show that the porosity of the aquifer materials lies between 38% to 40%.

Permeability : Permeability is measured by the quantity of water passing through a unit cross section in a unit time under unit hydraulic gradient. It is supposed to vary approximately as the square of the diameter of grain of water-bearing material. It also varies with percentage of fine material and arrangement of grains of coarse and fine material.

Permeability of the study area is computed purely on the theoretical basis from the total amount of annual recharged groundwater and value is found as 4×10^{-4} m/day (Khaleque, 1994).

Specific Yield : Groundwater in the saturated zone can be divided into two parts: the portion which is free to drain out under the influence of gravity and the portion which will remain with the solid material, primarily because of capillary forces. The portion free to drain out is measured by specific yield (S_y). The storage capacity includes only the water (or space for water) that can be yielded by gravity, which is identical with the water that can be pumped out by wells.

Under simple water-table conditions only the storage coefficients obtained by standard aquifer tests is equal to specific yield, but under confined conditions does not equal to specific yield. It is observed from the borehole data that the existing aquifer in the study area is unconfined in nature. So, the value of specific yield is the same as storage co-efficient. The storage co-efficient of the study area has been calculated from the available pumping test results of Bangladesh Water Development Board (BWDB) during the year 1988-89. The analysis shows wide range of values from the hydraulic property of the aquifer. Most of the test were carried out for 4320 minutes. The pumping test results of seven thana in the study area are presented in Table-4.1.

Table-4.1 BWDB aquifer test analysis of seven thanas of Barind Tract including the present study area.

BWDB TEST NO. WITH LOCATION	TEST DURATION (minute)	DISCHARE (liter/sec.)	SWL FROM GROUND SURFACE (m)	PERME-ABILITY K (m/day)	TRANSM-ISSIVITY T (m^2/day)	STORAGE COEFFICIENT
TEST-18 TANORE	4320	30	9.35	40	700	0.05
TEST-22 GODAGARI	4320	34	6.88	15 - 18	600	0.10
TEST-21 NAWABGANJ	4320	31.15	4.67	57	1200	0.15
TEST- 9 GOMASTAPUR	4320	30	6.23	17	300	0.04
TEST-17 SHIBTGANJ	4320	40	7.24	25	700	0.115
TEST-14 NIAMATPUR	4320	36	9.40	14	400	0.05
TEST-13 NACHOLE	4320	34	11.60	12	224	0.06

It is observed from the Table-4.1 that the specific yield of the area investigated is varying between 4% to 15%. The specific yield values of Shibganj, Godagari and Nawabganj is more than 10% whereas in the rest of the area it is below 6%.

4.4 ESTIMATION OF HYDRAULIC CONDUCTIVITY

The groundwater can get store in the underground only if the unconsolidated formation is sufficiently porous. This porosity, however, in itself does not ensure the storage and flow of groundwater. One of the most important properties of sediments is its permeability which controls the flow of fluids through the formation. Permeability is influenced by particle shape, size and the state of packing. Permeability and porosity show no fixed relation although more highly porous rocks have a large permeability than less porous rocks. In groundwater well industry the term hydraulic conductivity (Transmissivity) is generally used. It depends both upon the properties of fluid as well as the properties of aquifer. The hydraulic conductivity of a water saturated zone represents its average water transmitting property which depends mainly on the number and diameter of the pores present.

Transmissivity : The value of transmissivity (T) all over the study area has been estimated from the borehole information. In the present study, transmissivity of water in the saturated formation i.e. below the water-table only has been taken into account. Considering the thickness of the layers of different grain size as obtained from the borehole data and the corresponding co-efficient of permeability, the transmissivity in different layers have been calculated. Then the individual values are added to get the transmissivity (T) value of that location. The value of transmissivity in the area has been estimated and presented in the form of shaded contour map with interval of 500 m^2/day as shown in Fig.4.4. It is observed from the figure that the transmissivity value lies between 500 m^2/day to 1500 m^2/day. In most of the areas this value covers 1000 m^2/day to 1500 m^2/day whereas in some parts of the Eastern and Western side it is recorded below 1000 m^2/day. In conclusion it could be said that the

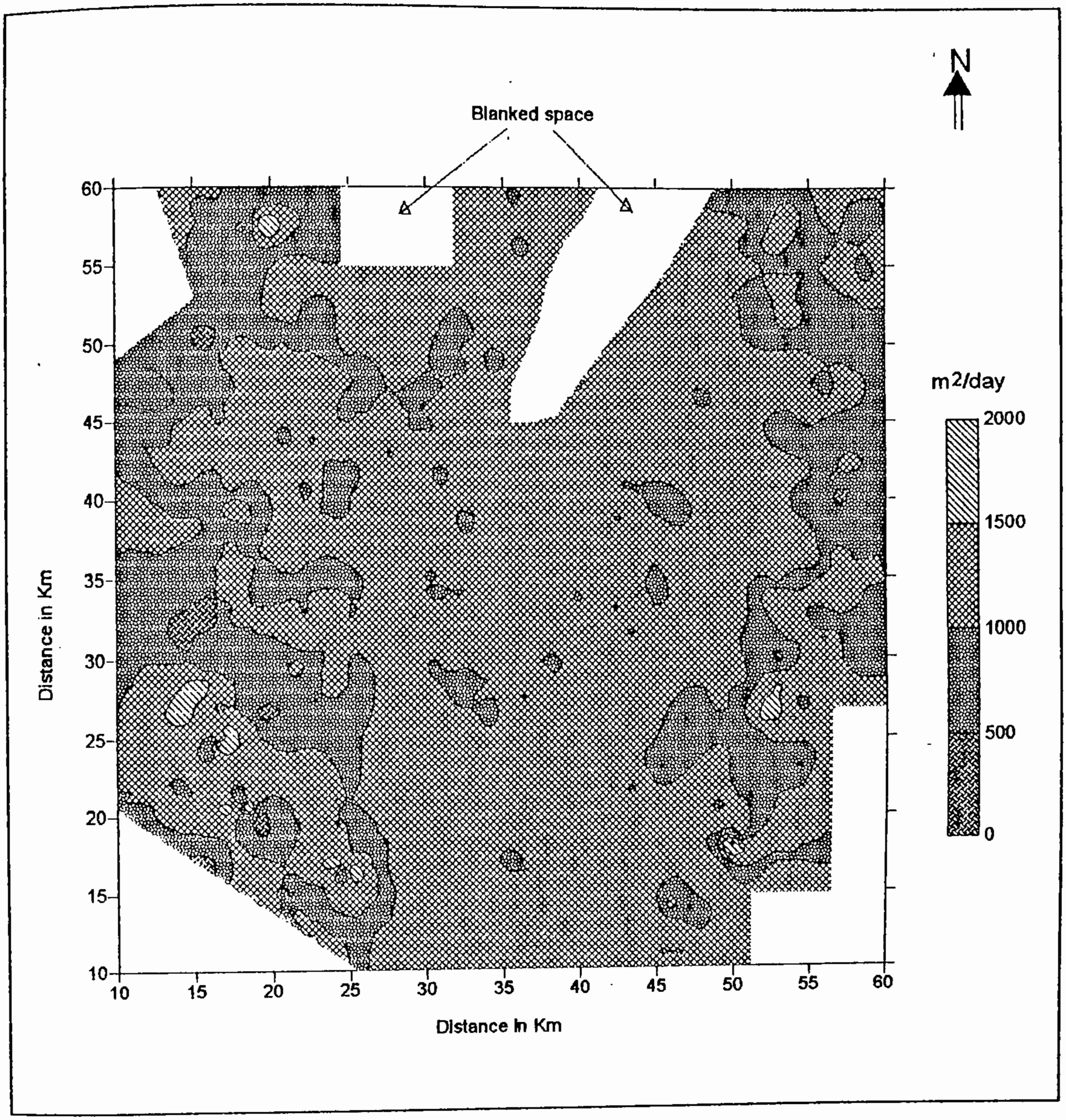


Fig.4.4 Transmissivity map of the effective study area with shade.

estimated value of transmissivity of the non-artesian aquifer of the area is favorable for groundwater exploration.

Specific Draw Down : When water is pumped from a well or discharges from an artesian boring, a cone of depression is created which spreads to the outer limit of the aquifer. It is extremely important to bear in mind that while the cone of depression is still spreading that is to say until the limits of the aquifer reached no new water cycle equilibrium becomes established for the groundwater out side the cone of depression. All that is actually happening is that withdrawals are being made from the aquifer water reserves. The new equilibrium only occurs when the cone of depression reaches the zones of recharge and natural discharge. The productivity of a well is usually indicated by the specific capacity which is given by the ratio of discharge to draw down, i.e., discharge per unit draw down. In well hydraulics the parameter specific draw down inverse of specific capacity is widely used for studying the aquifer properties e.g., transmissivity. The specific draw down map of the area studied is illustrated in Fig.4.5. In the Eastern and Western side of the low specific draw down is found whereas in the remaining part this value is above 223 m/cumec. The low draw down regions i.e., the Eastern and Western side of the area may be considered as favorable.

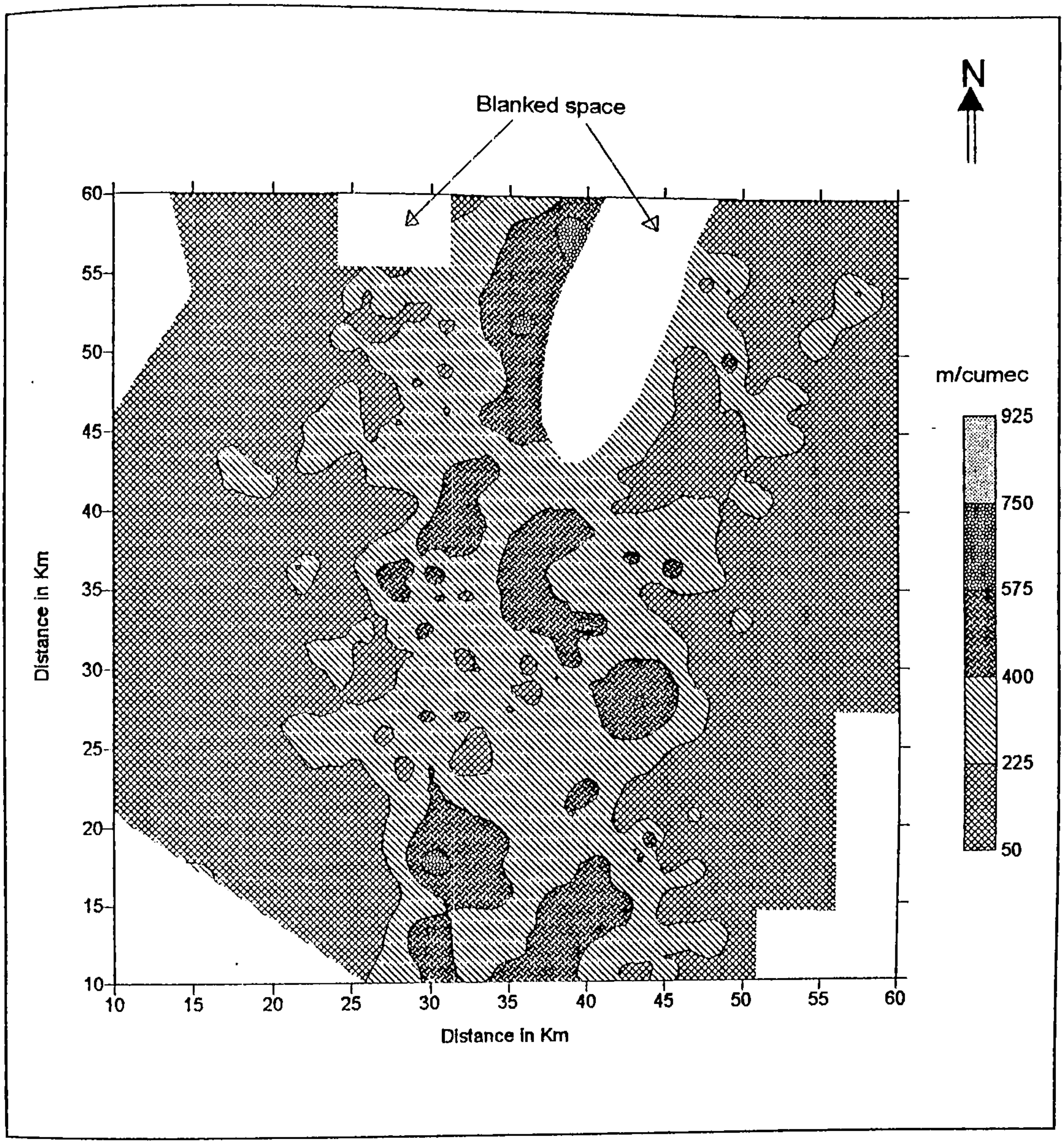
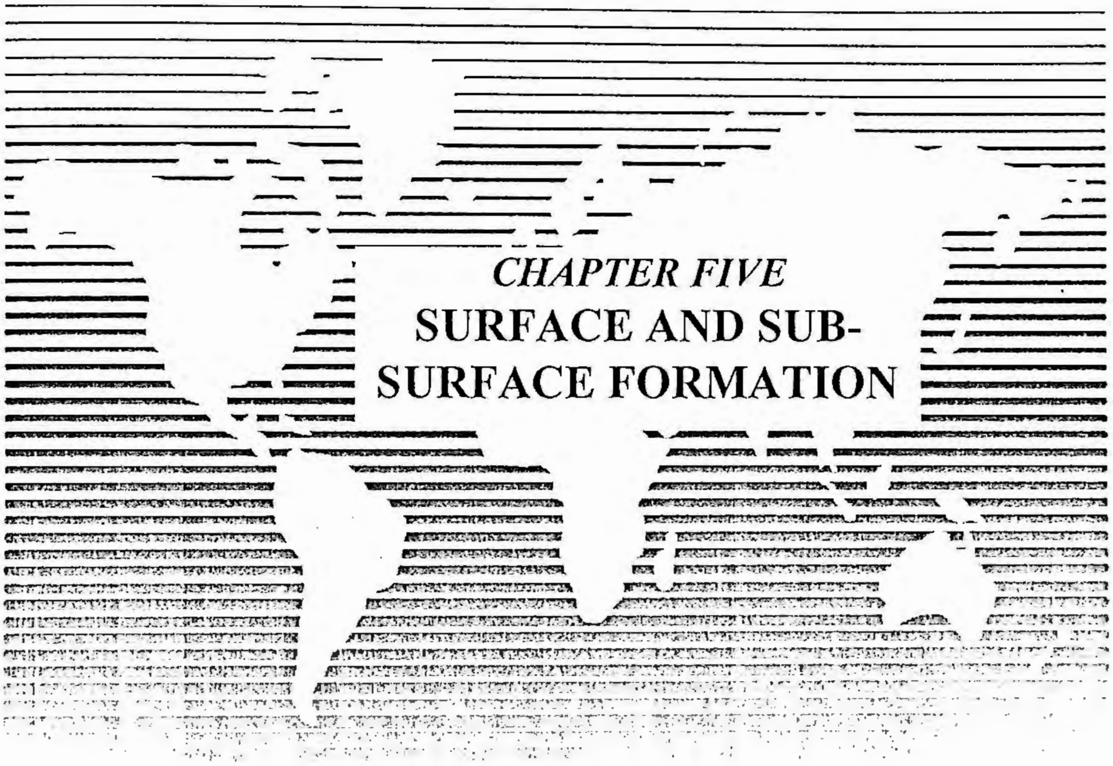


Fig.4.5 Specific draw down map of the effective study area.



CHAPTER FIVE
SURFACE AND SUB-SURFACE FORMATION

CHAPTER FIVE

SURFACE AND SUB-SURFACE FORMATION

The distribution of aquifers and aquitards in a geological system is controlled by lithology, stratigraphy and structure of the geologic formations. The lithology is the physical make up including the mineral composition, grain size and grain packing of the sediments or rocks that make up the geological systems. Cleavages, fractures, folds and faults are the geometrical properties of the geologic system produced by deformation after deposition or crystallization. In unconsolidated deposits, the lithology and stratigraphy constitute the most important controls. If water bearing materials were uniformly pervious and homogenous, groundwater problems could easily be solved by hydraulic data. The materials underground, however, heterogeneous and their hydrologic characteristics are varied. These variations control quantity and distribution of groundwater. In the present chapter the borehole date have been processed and presented in different forms. The minimum and maximum depth of borehole information were 28m and 76m respectively. In order to represent the interfaces between different sub-surface formations a datum is selected below 60.96m below m.s.l. covering the maximum depth of borehole information.

5.1 TOPOGRAPHY

The groundwater is a vital part of nature's great cycle. The formation and distribution of groundwater is greatly influenced by the topography of the area. Groundwater is renewable resource and its replenishment is done by infiltration. So, the easy of recharge is an important factor. The impermeable and highly undulating surfaces will produce rapid runoff and present adequate groundwater recharge. Topographic feature also play an important role in selecting the well sites. In general, the valley regions rather than sloppy and top of the hillock are considered more favorable for groundwater exploration. In order to study the surface feature of the area investigated a contour map with 4m interval accompanying physical shape with respect to the datum has been prepared as shown in Fig.5.1 with data location. From the map it is evident that the Western side is comparatively low and flat land, and the rest part is undulating in nature. The variation of elevation as recorded is 28m. It is also observed that the surface is sloping positively towards Western side, Eastern side and South-East corner from the central zone. The slope of the earth surface is maximum in the central part. The perceived valleys in the figure may be used for well sites.

5.2 SUB-SURFACE LAYERS AND FORMATION THICKNESS

Rock formations and the openings are the results of primary geologic processes and secondary processes acting on rocks may change or induce entirely new hydrologic structure which controls the motion and distribution of underground water. The hydrologic characteristics of sedimentary or alluvial deposits are inherited from the parent formation which under the classifying processes of nature may be re-deposited as aquifers. The development of underground water requires a knowledge of the characteristics of sub-surface water bearing zone, of which the composition and thickness are of importance. According to the borehole information, the sub-surface formations of the area is divided into main three layers:

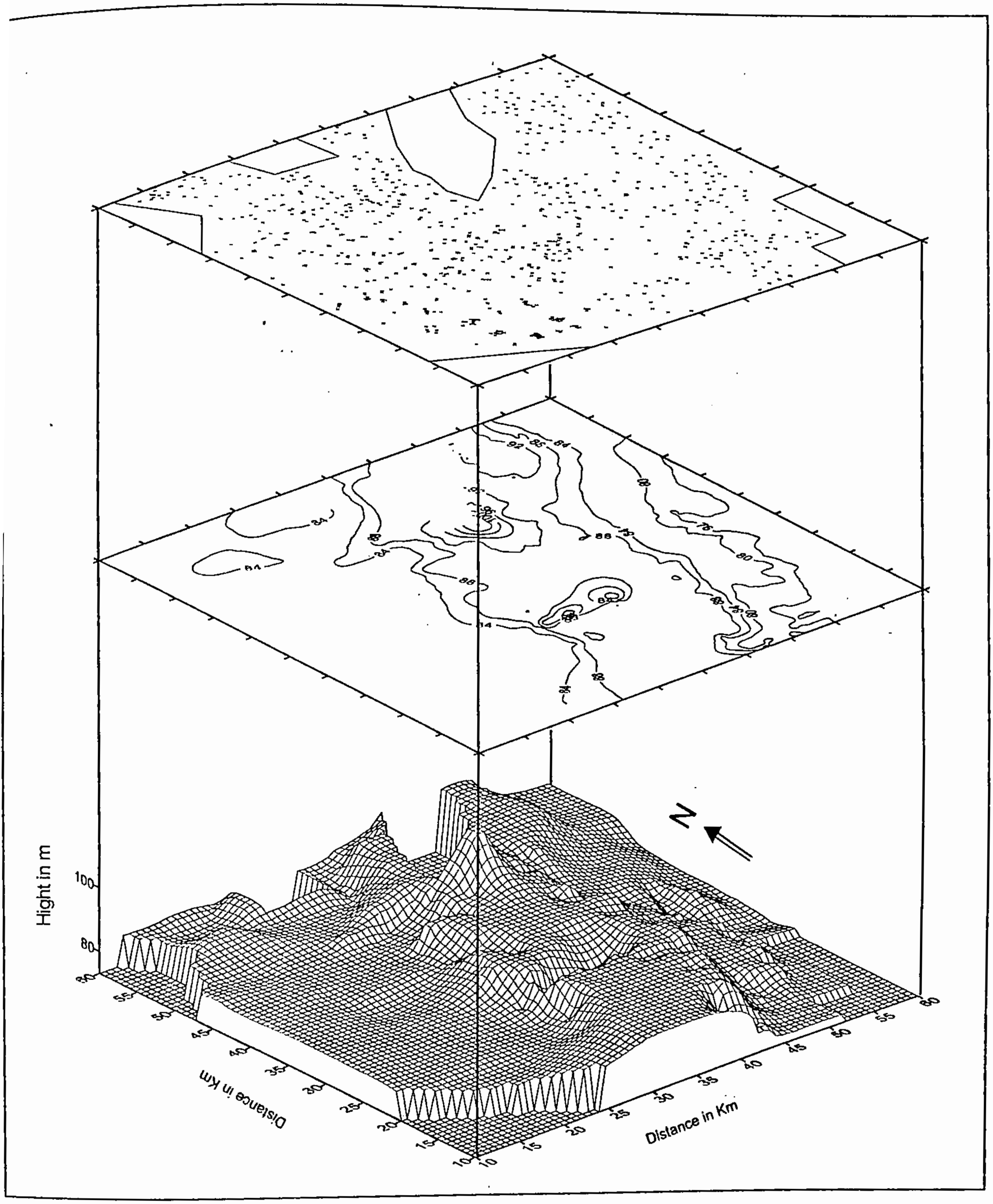


Fig.5.1 Data points over contouring and physical change of the earth surface.

Top Clayey Layer : Soils of the area investigated are predominantly clay loam with a few silt at places. In dry it becomes very hard and in wet season it is slippery rather than soft. This clayey formation is very common in the area. The contour map of the thickness of top clay has been prepared and illustrated in Fig.5.2. In most of the area the thickness is varying between 8m to 24m. In the South-Central and North-Central zone it is recorded above 24m. The variation of the thickness in different regions could be easily correlated with the physical change of the earth surface [Fig.5.1]. So, the extraction of groundwater from the Eastern and Western side of the area would be economical provided the aquifer system is favorable. This clayey layer is overlying the only sandy formation present in the area studied.

Sandy Layer : The occurrence and movement of groundwater are quite different in the types of openings present underground. In unconsolidated rocks generally, sands or gravels, the water bodies move with a continuous, nearly horizontal upper surface under gravity. Water bearing materials are rarely homogenous but usually occur in layers of varying permeability. In the investigated area a sandy formation of different particle size is found which serves as the only source of groundwater. The borehole information indicates the presence of a fine sandy layer almost everywhere just below the top clay formation. The interface between the top clay and find sand formation is shown in Fig.5.3. The undulating nature of this surface means that the top clay bad has been pierced into the find sandy stratum in most of the places of the area. The contour map in Fig.5.3 shows only the variation of lower position of the top clay or upper position of fine sand with respect to the datum. The thickness of this layer is comparatively low with respect to the clay thickness but its variation is very rough and tumble. The position of water level recorded in different observatories of the

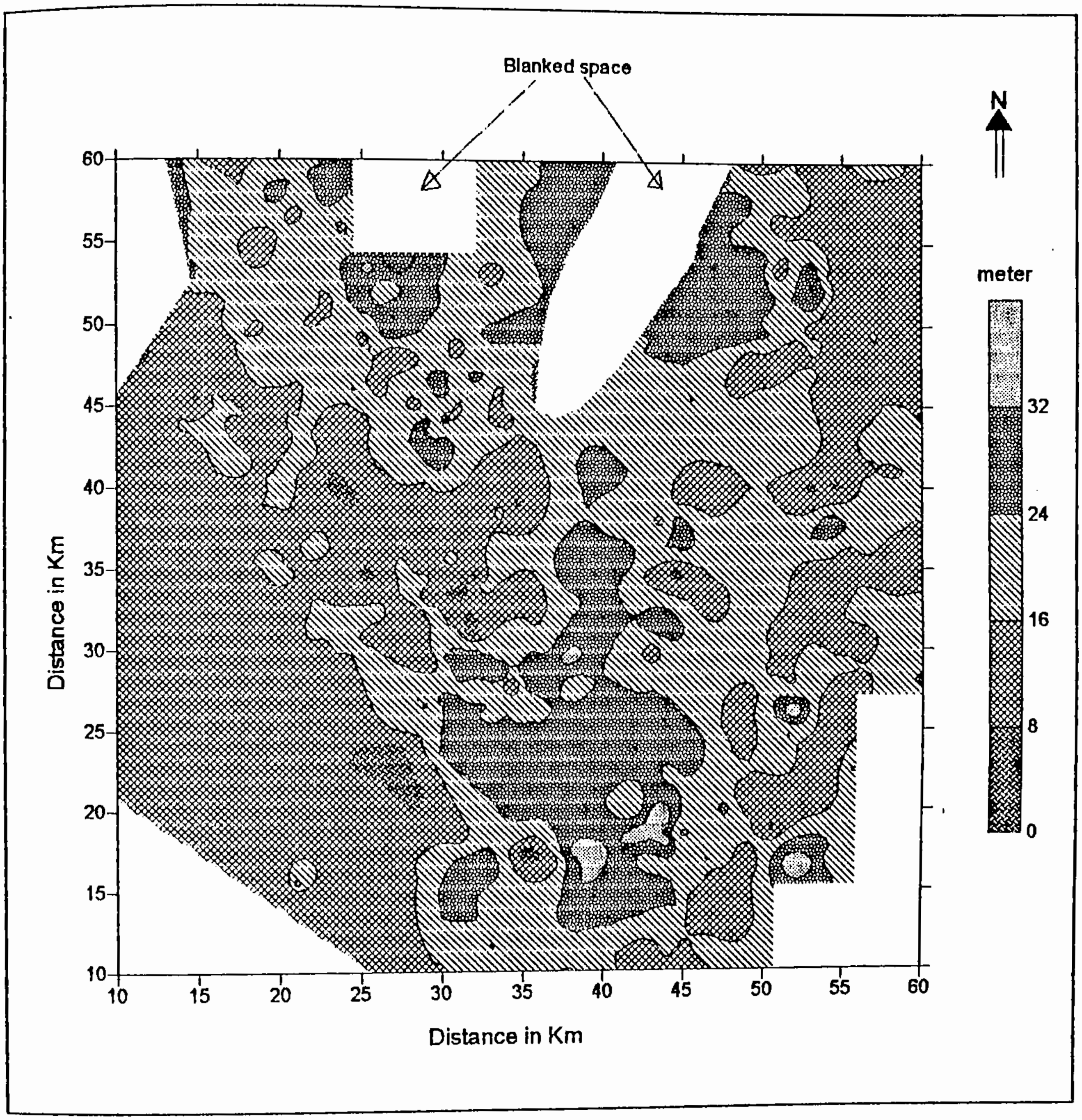


Fig.5.2 Contour map of top clay thichness with shade

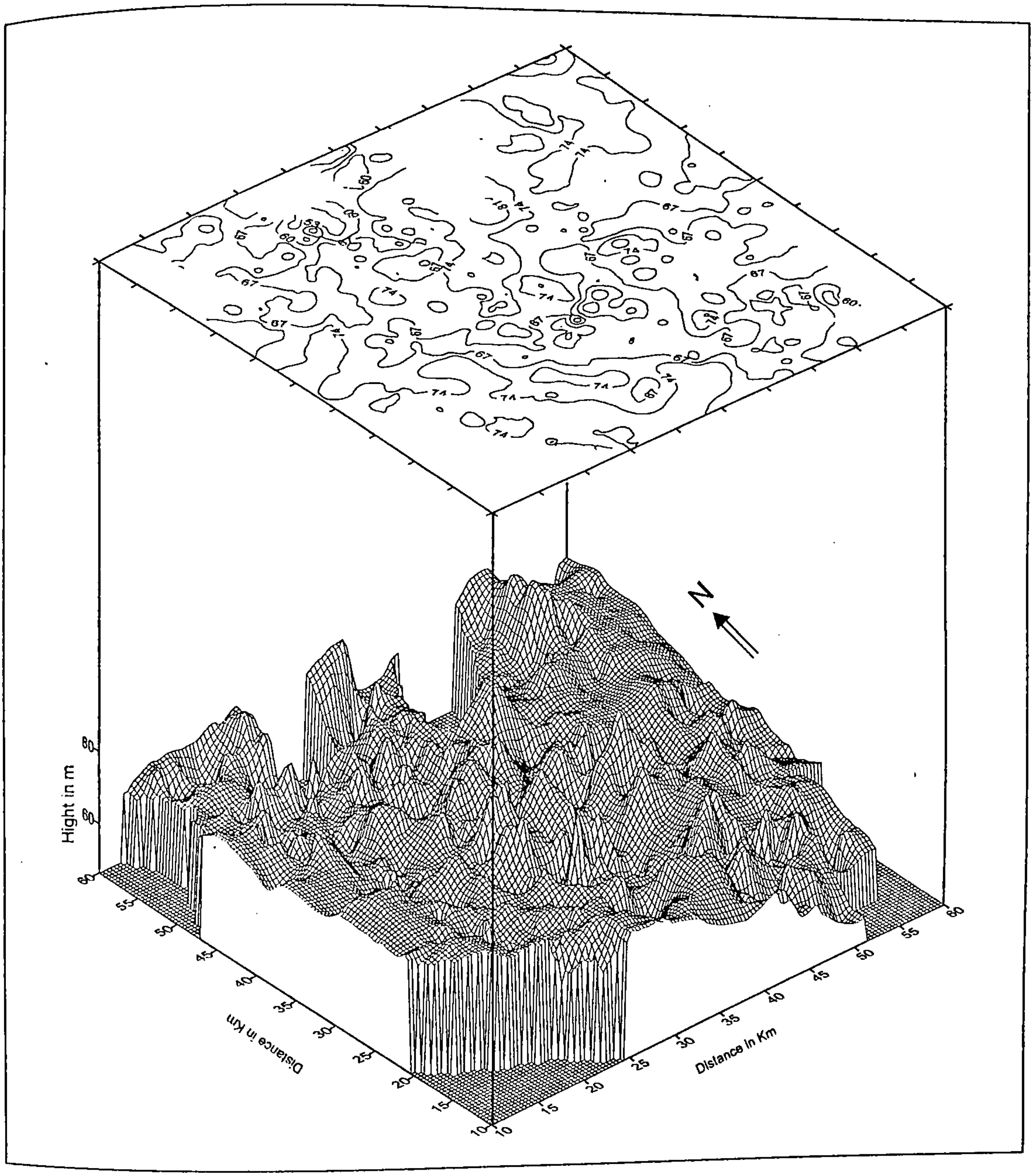


Fig.5.3 Contour map over physical shape of the lower surface of top clay.

study area confirms that the fluctuation of water-table in this region lies within the clay-fine sand layers. After rainy it stands totally within the top clay bed and in extreme dry, in many places, it falls into the fine sand bed.

The lithological data of this area have confirmed the presence of a sandy layer of different granular with the concentration of fine grained known as fine sand layer below the top clay followed by medium and course sized sand and mixed formations of various grains at different depths. In this present work this composition is termed as composite sandy layer. Fig.5.4 views the physical change of fine-composite sand interface with respect to datum. The figure indicates that the lower surface of the fine sand (i.e., upper surface of the composite sand) is uneven in nature like that of the upper surface.

The amount of water to be soaked, transmit and yield depends upon the nature of sediments. The most common aquifer materials are unconsolidated sands and gravels. Many factors affecting the production of groundwater in a particular area of which the natural characteristics of water bearing sand play the vital role. An aquifer performs two important functions, it stores water serving as reservoir and release it for extraction by pumping. So, grain size distribution plays an important role in the properties of the aquifer. In the investigated area the mixed grain sand formation is the only usable groundwater source. So, the assessment of the thickness of this composition is of great importance in groundwater exploration. The thickness of composite sandy layer of the study area has been estimated using the lithological information and presents in Fig.5.5. This figure gives a clear quantitative understanding of the presence of usable water saturated formation in different regions of the area studied. Except few pockets where the thickness is estimated very low, the existence of composite sandy formation in the area is good and recorded above 16m.

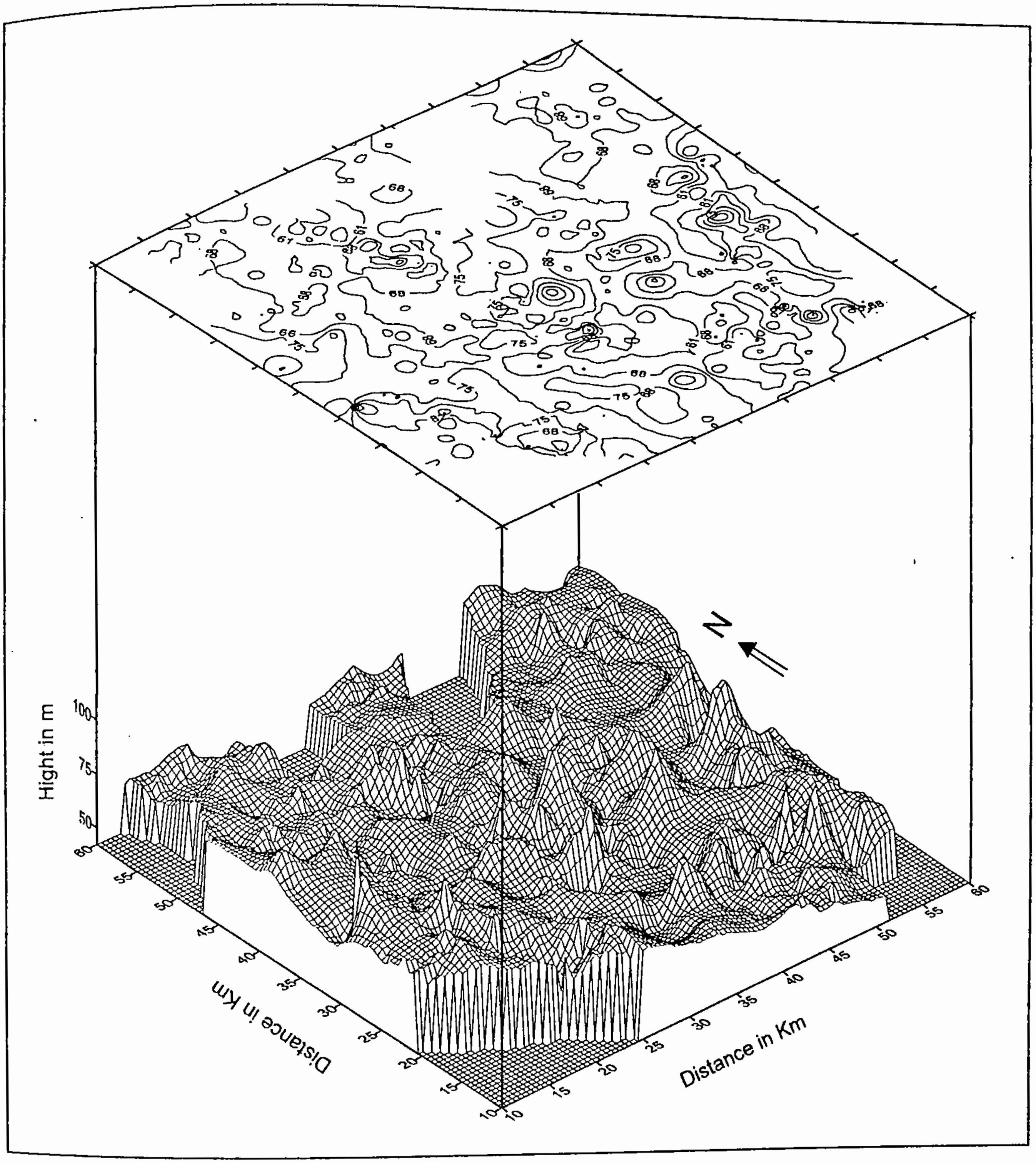


Fig.5.4 Contour map over surface plot of fine-composite sand interface.

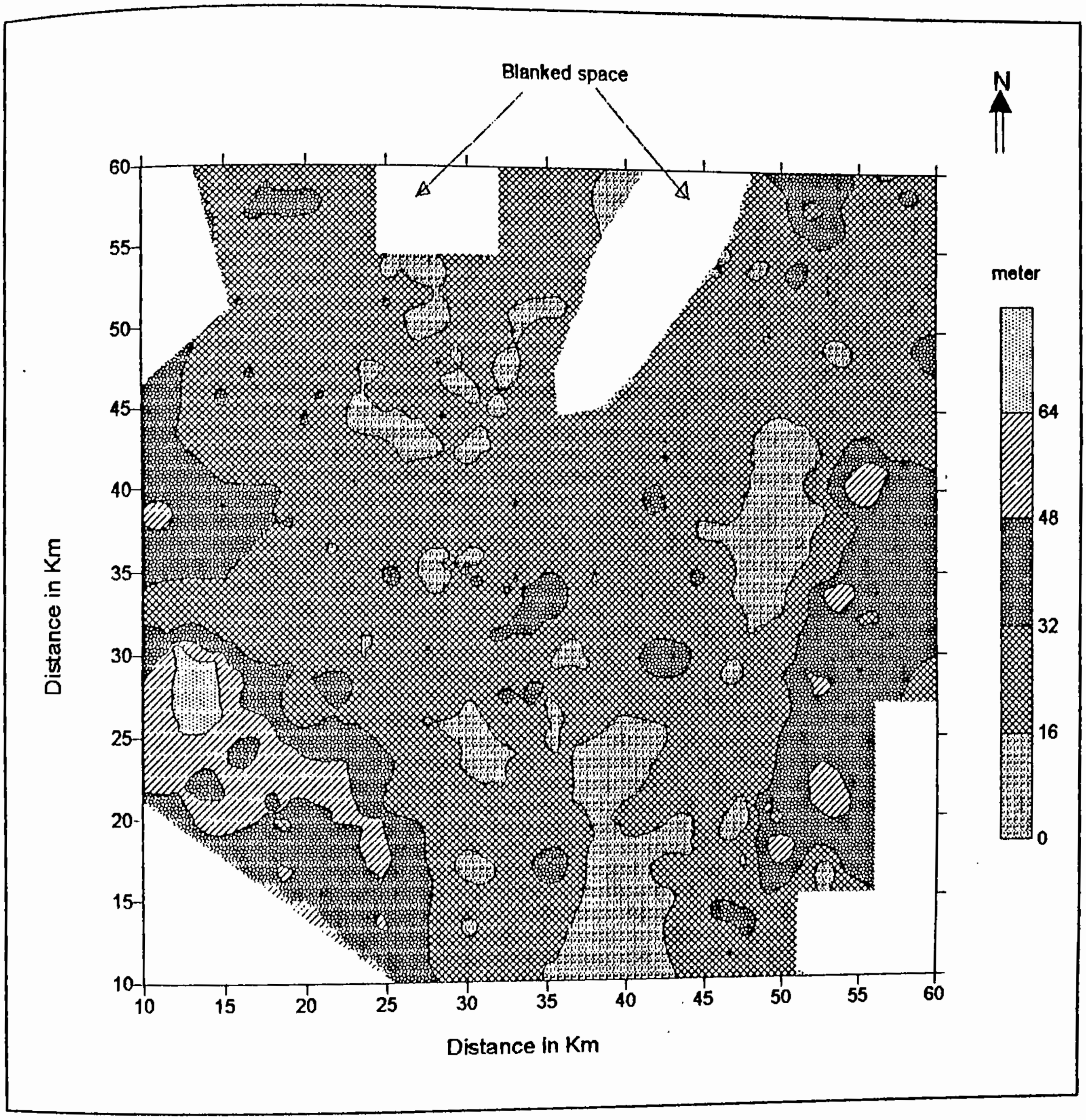


Fig.5.5 Contour map of composite sand thickness.

In the South-Western corner a thick formation is observed. In parts of Eastern and Western side the presence of this layer is identified whose thickness ranges from 32m to 48m. Excluding the above zones the thickness of composite sandy formation lies between 16m to 32m. Analyzing the Fig.5.5 it could be said that the areas occupied high thick bed of composite sand are more favorable for groundwater exploration and the rest would be used for small scale abstraction excepting the very less thicker pockets.

Yield potential of the water saturated zone may be quantitatively represented by means of some yield index. Yield capability of water saturated zone depends directly upon the size, shape, sorting and packing of the constituting grains. Quantitatively the groundwater yield is expressed in terms of formation tranmissivity. This parameter does not show much different in clay and fine sand. So, the index map of the area has been prepared by considering the combined thickness of top clay-fine sand and composite sand. In the index map the combined formation of top clay and fine sand is treated as clay. Therefore, the real distribution of total clay thickness to total composite sand ratio has been presented is Fig.5.6. It is observed from this map that the clay thickness is proportionately less in the Western and Eastern side of the area. This type of map is widely used for selecting the location of well sites.

Impermeable Zone (B.P.C) : The lower boundary of unconfined aquifer is a layer of much less permeable material than the aquifer itself. Such impermeable layer may consists of clay or other fine textured granular material or bed rocks. As far as the first aquifer is concerned, the passage of the water to and into it and its other characteristics are determined essentially by geographical condition. As the depth of the horizon increases the geographical influence becomes progressively slighter. In the area the only specified water bearing formation is unconfined in nature found

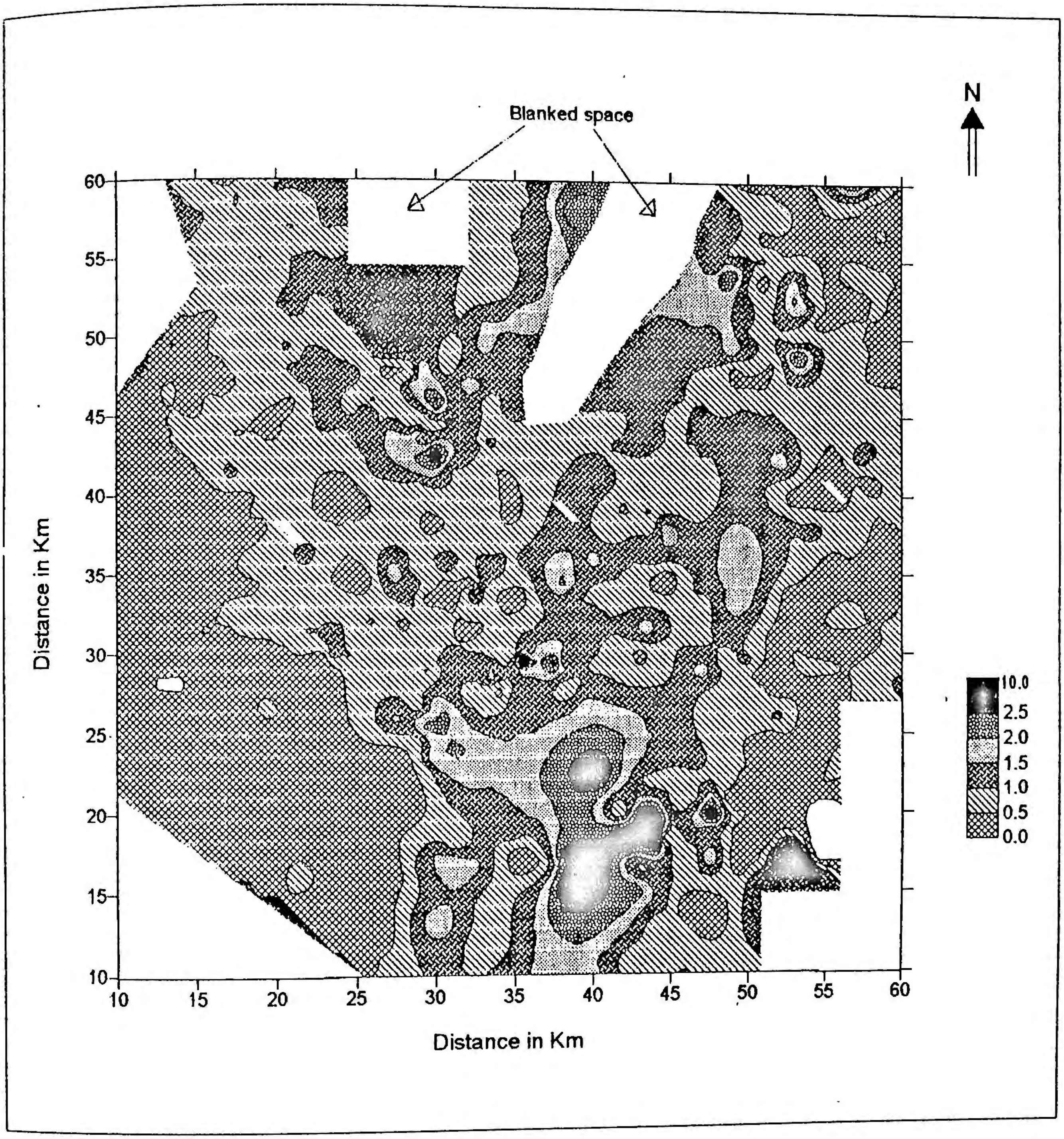


Fig.5.6 Contour map of clay-fine sand to composite sand ratio.

within the depth of 28m to 76m from the earth surface. So, the geographical pattern of the intersecting beds of different compositions play a major role in the occurrence, distribution and movements of underground water. This impermeable zone is underlying the composite sandy formation. The upper surface pattern of this confining bed with respect to datum is depicted in Fig.5.7. Like the other interfaces this surface is also wavy in nature and sloping towards different direction from the North-Eastern corner. So, it could be said that the natural flow of groundwater is originated from the North-Eastern corner. It is also clear from the Fig.5.7 that the composite sandy formation has been merged into the impermeable bed at different locations and these pockets may be used as groundwater source.

The sub-surface geologic formations of the area as obtained from the borehole data have been differentiated into four major formation distribution depending upon the grain size. The top two layers, clay and fine sand are generally not treated as groundwater source. The composite sandy formation represented as third layer in this area overlying the fourth layer of impermeable B.P.C. is being used as groundwater reservoir. The interbeded views along with the earth surface which have already been described in details have also been presented in the opposite directions in single view [Fig.5.8 and Fig.5.9] for a comparative study. These figures give clear and detail idea about the variation of the thickness of different formations at any specific location of the area investigated.

5.3 STRATIGRAPHIC VIEW OF THE STUDY AREA

An interplay of geomorphic and geologic features control, in a large measure, the amount of precipitation that contributes to groundwater recharge. The nature, distribution and structure of sub-surface geologic formations control the occurrence,

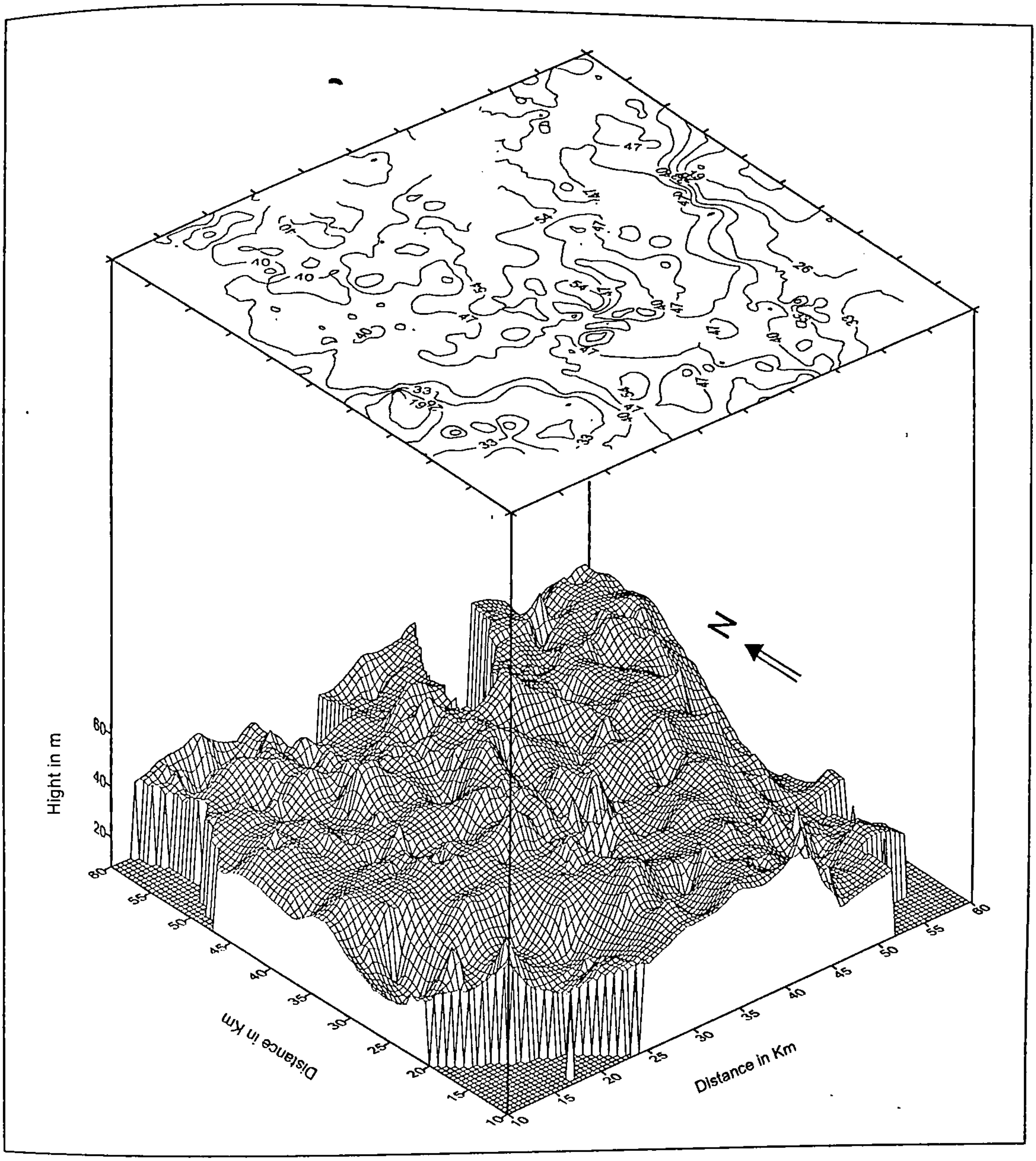


Fig.5.7 Upper surface pattern of B.P.C.

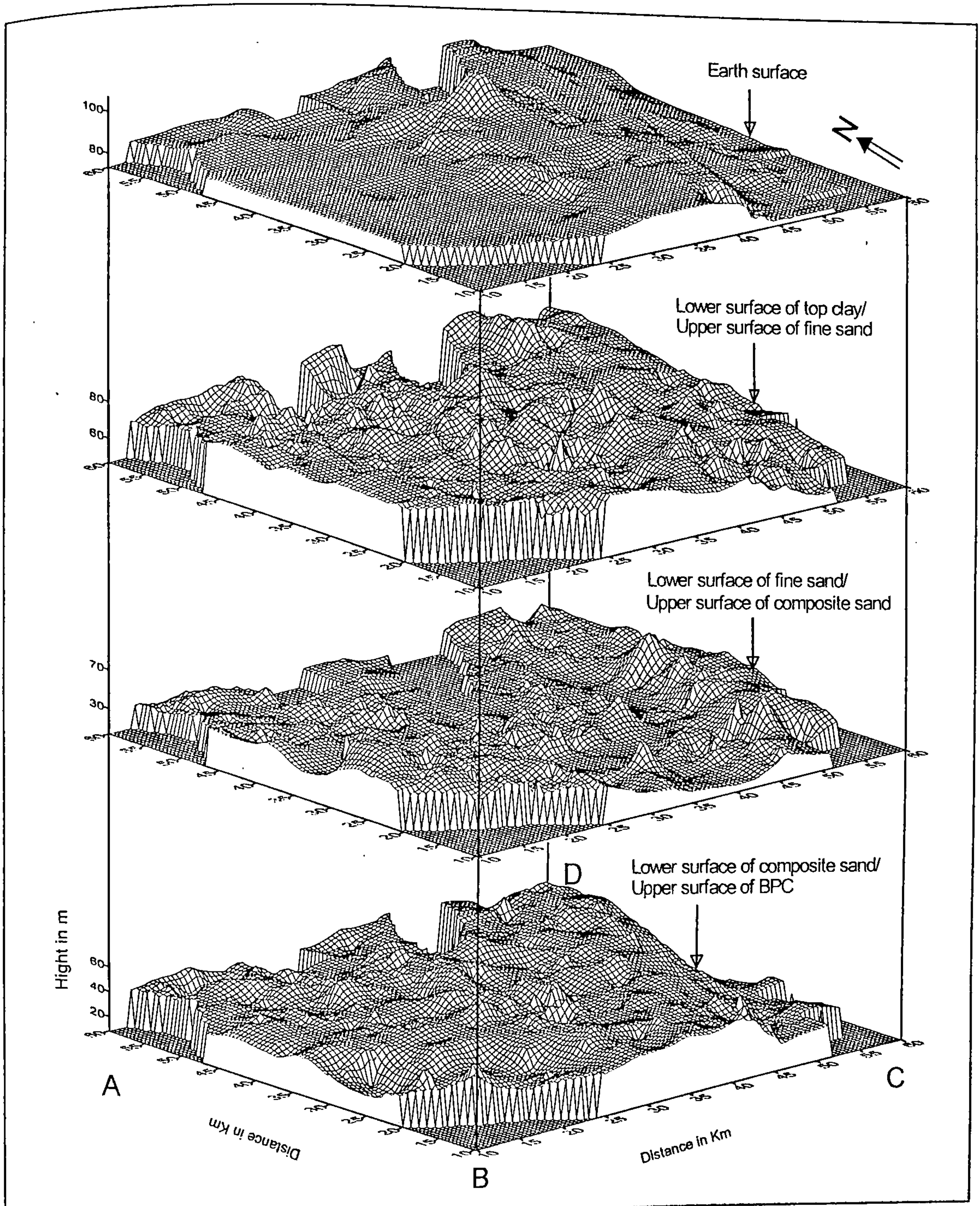


Fig.5.8 Surface views of different beds (view from South-West).

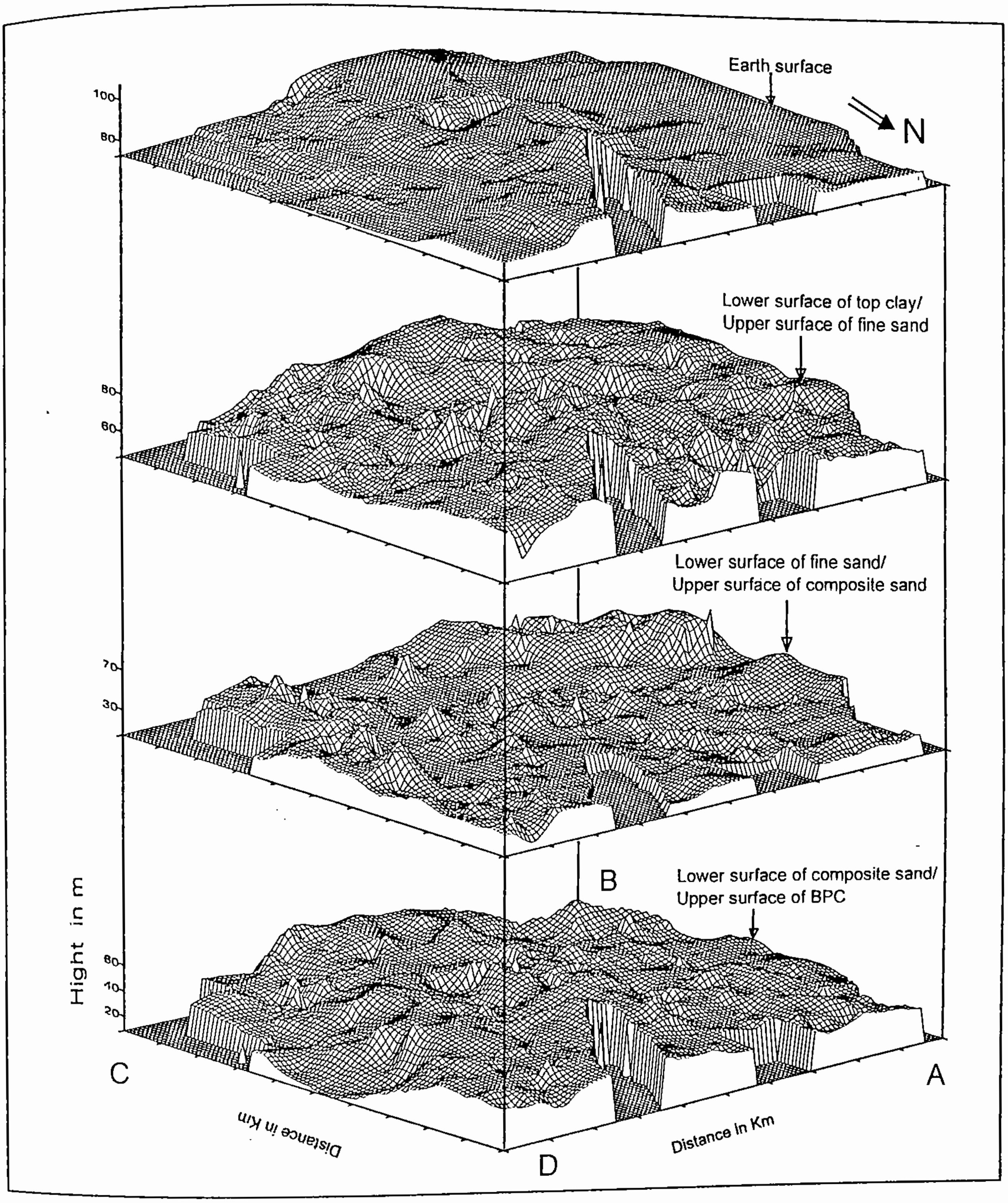


Fig.5.9 Surface views of different beds (view from North-East).

movement, quality and availability of groundwater. Of primary importance is the occurrence and distribution of aquifers and their relationship with associated relatively impermeable beds that act as confining layer and barriers to groundwater movement. The geologic structure has a marked influence on the lateral and vertical extent of aquifers. An integrated study of the evaluation of sub-surface geologic forms is useful to understand the occurrence of porous and permeable zones. The sub-surface runoff is governed, in part, by the geology on which depend the development of underground formations and their infiltration and transmission characteristics. So, the stratigraphy is an essential tool in the search for water in areas of wide spread sedimentary rock. Aquifers are commonly associated with unconfirmities, either in the weathered or fractured zone immediately below the surface of the buried landscape or in permeable zone in coarse grained sediments laid down on the top of this surface. The position and thickness of water bearing horizons and the continuity of confining beds are of particular importance in the development of groundwater exploration zones.

Groundwater in the investigated area occurs under water-table condition. This area is covered by a thick blanket of clay horizon. To observe the cross-sectional views in different parts of the effective investigated area twelve representative vertical sectioning along the profiles of both West-East and South-North directions have been prepared with the indication of water head position in dry, 1995. The orientations of the profiles e.g., WE1, SN2 etc., are shown in Fig.4.1. The figures have been drown considering the heights of different interfaces with respect to the datum plane. The sectional views clearly distinguish the earth surface elevation, thickness of top clayey layer, composite sand and the position of impermeable clay bed along the profiles. Fig.5.10 to Fig.5.15 represent the vertical divisions of sub-surface formations along the profiles oriented in the West-East direction. From the

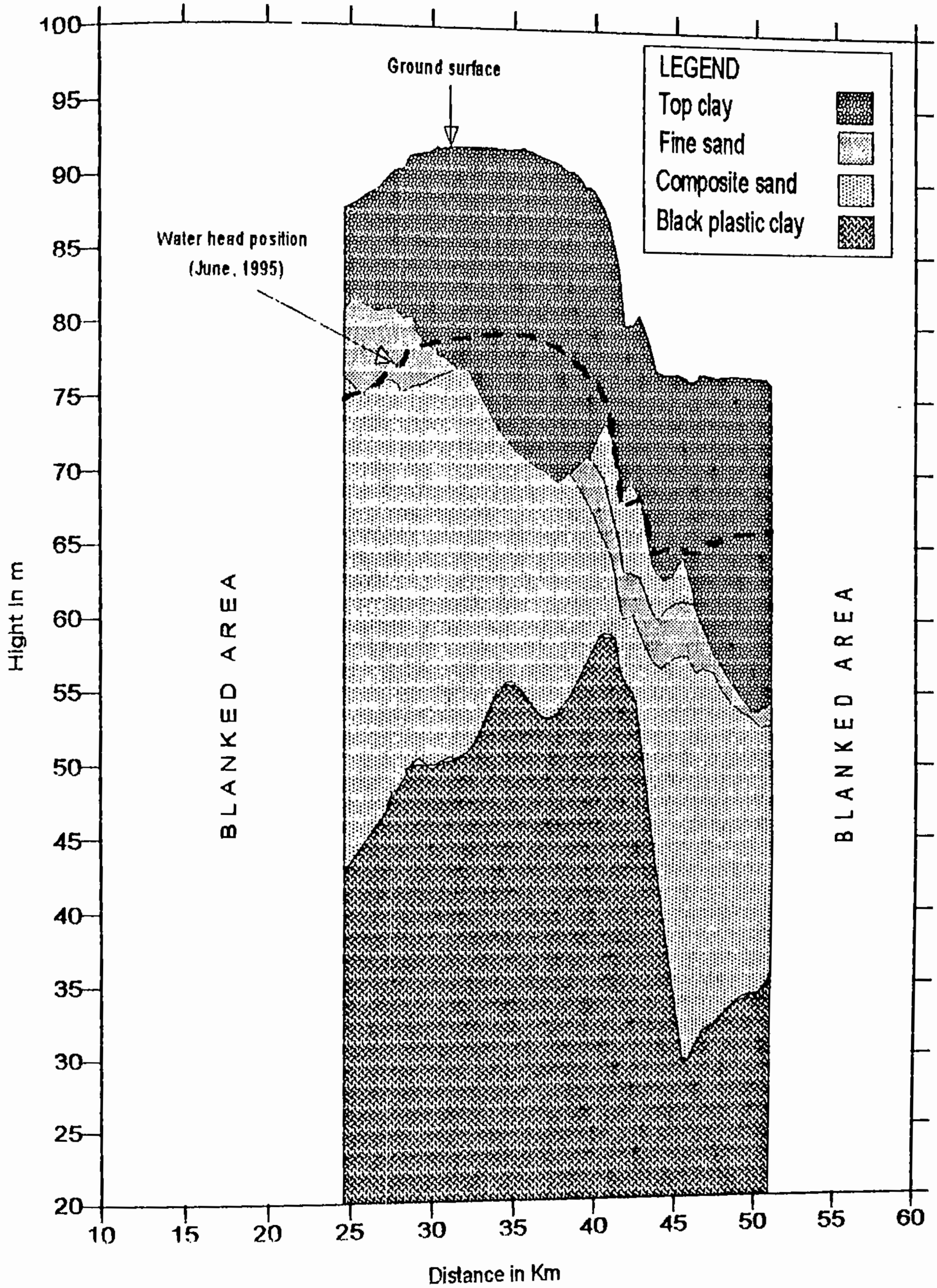


Fig.5.10 Sectional view along profile WE1.

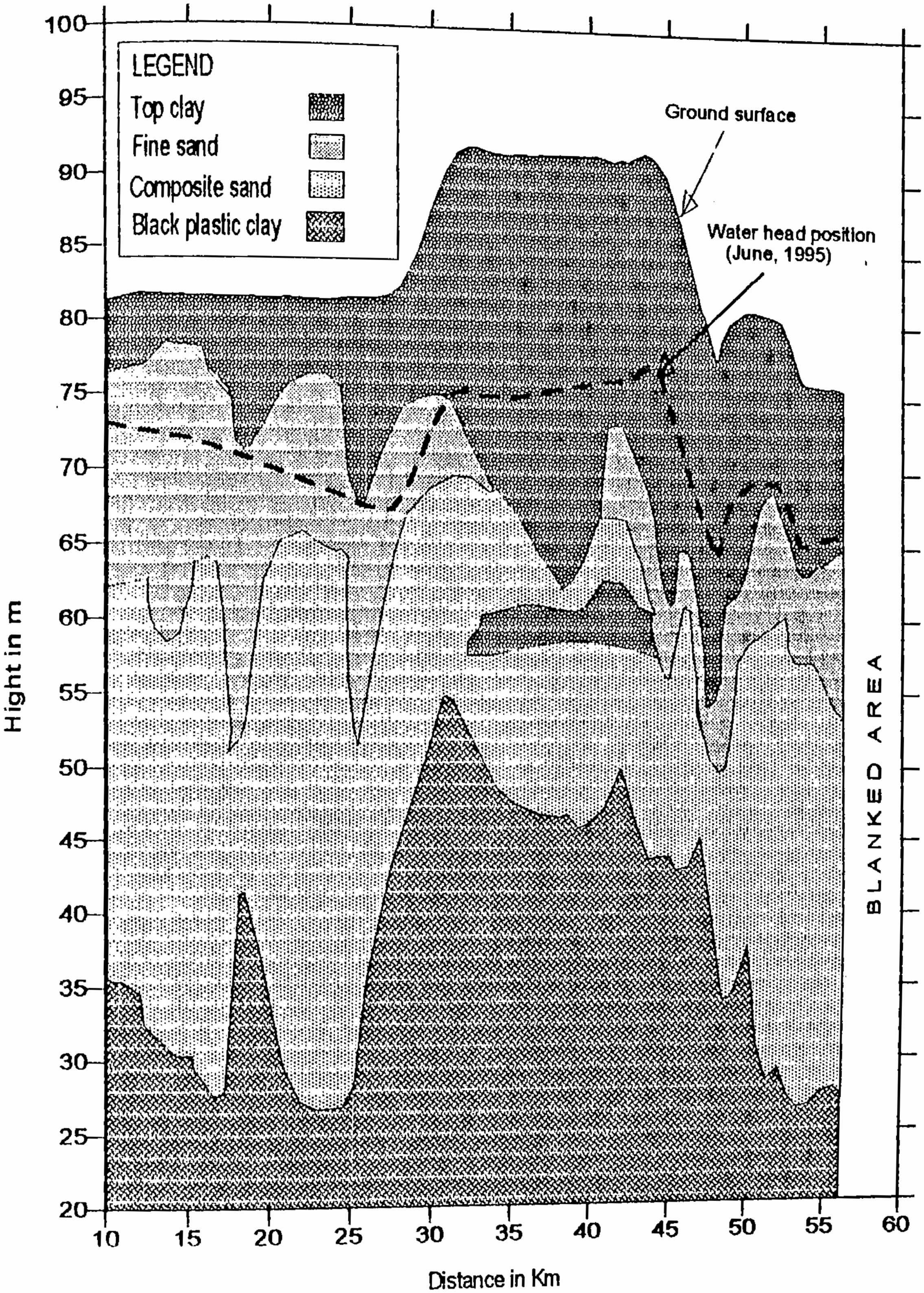


Fig.5.11 Sectional view along profile WE2.

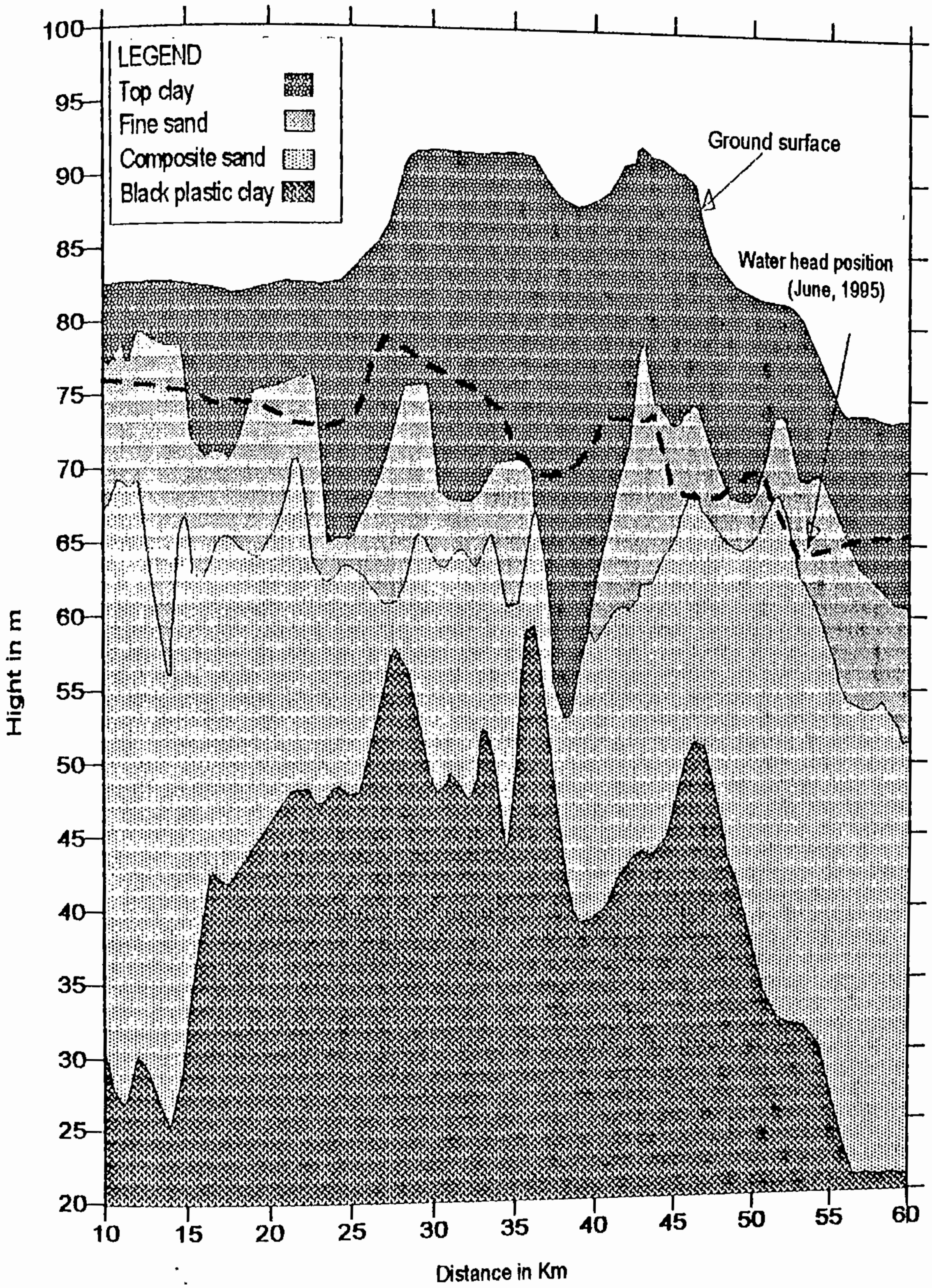


Fig.5.12 Sectional view along profile WE3

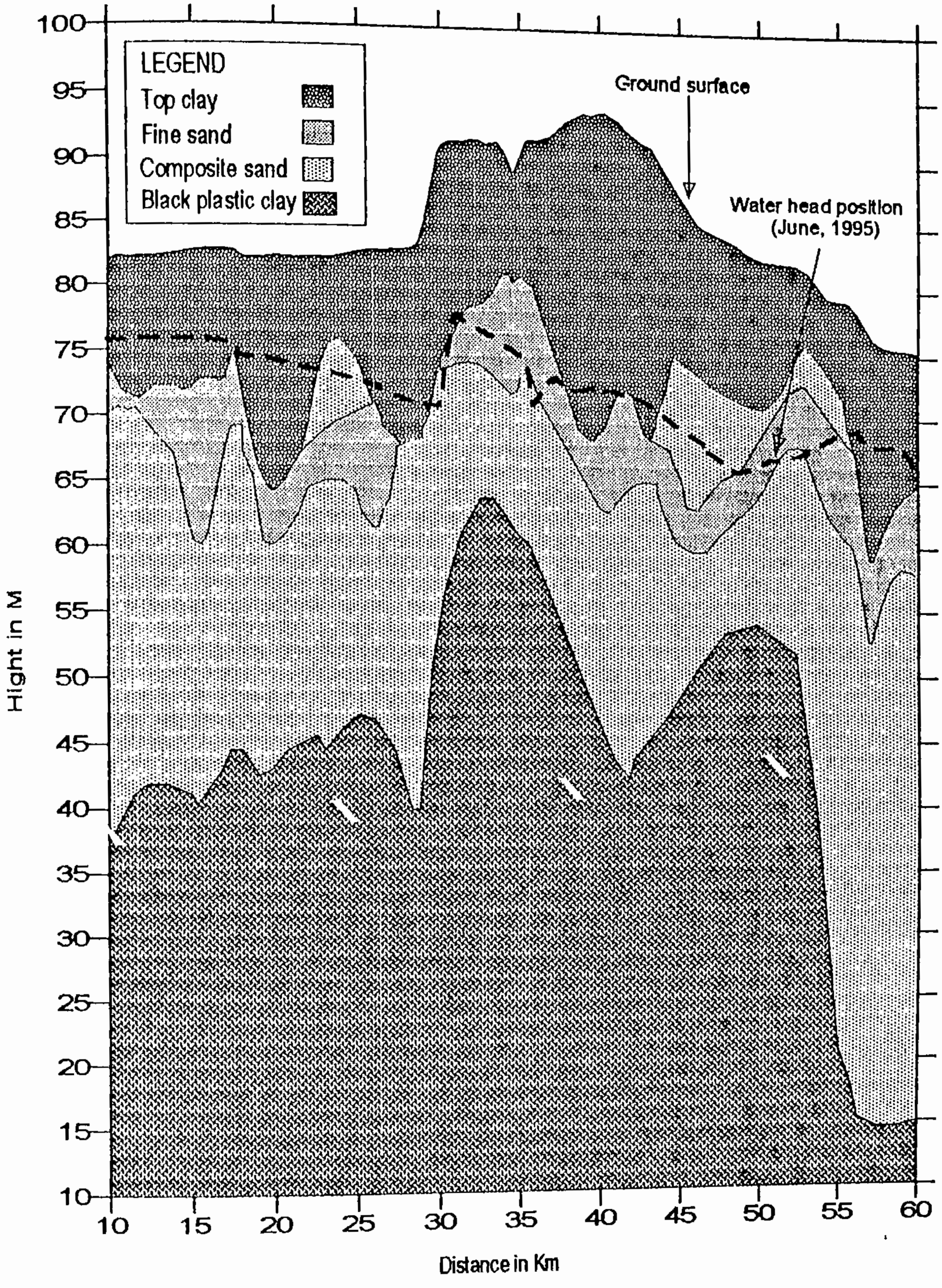


Fig.5.13 Sectional view along profile WE4.

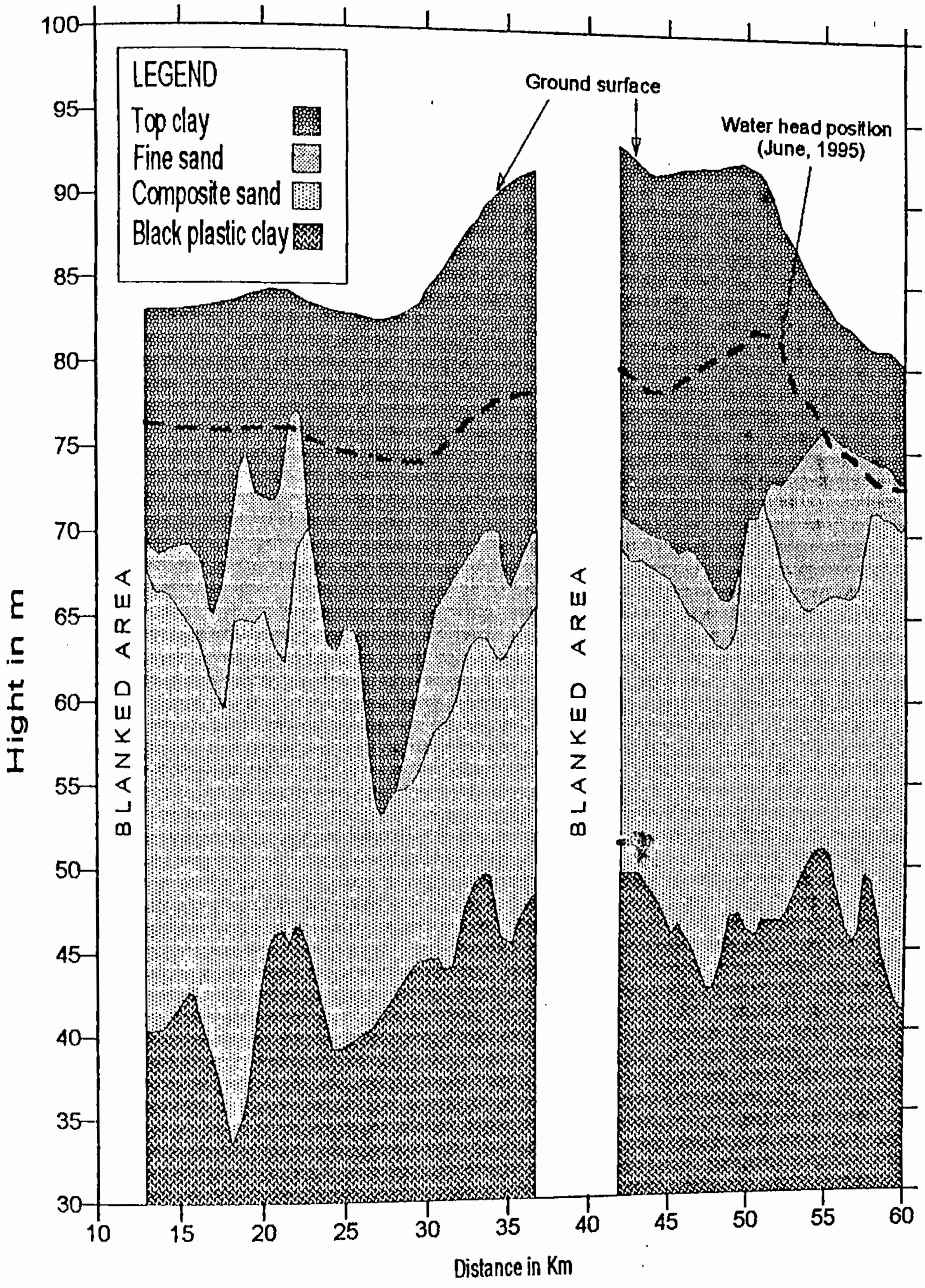


Fig.5.14 Sectional view along profile WE5.

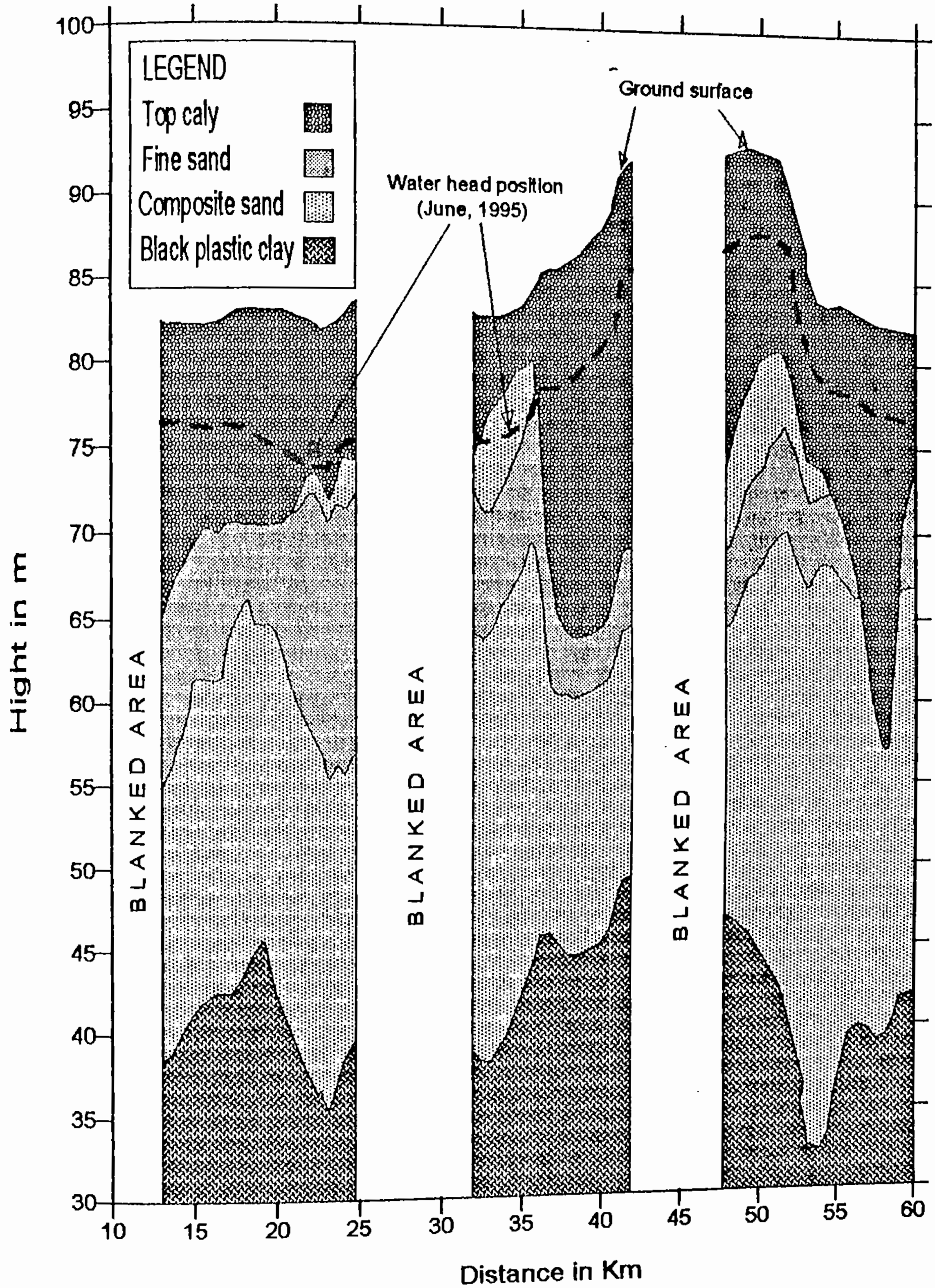


Fig.5.15 Sectional view along profile WE6.

above figures the elevation of the impermeable bed is clearly observed. The natural groundwater flow would definitely be controlled by the sharp gradient of this impermeable bed as observed in Fig.5.10, Fig.5.11, Fig.5.12 and Fig.5.13. The pockets may be used as groundwater source provided the thickness of the upper beds are favorable. Along the profile WE2 [Fig.5.11] the presence of perched clay is identified within the aquifer. An interesting feature is observed in Fig.5.12 where the top clay bed and impermeable zone are nearly to intersect each other. Depending on groundwater flow direction any one of the sides may be treated as groundwater potential zone.

The vertical sectionings along the South-North profiles are illustrated in Fig.5.16 to Fig.5.21. An abrupt change in the thickness of composite sand is marked in Fig.5.18. The sandy pockets along the profiles SN1, SN2, SN3, SN5 and SN6 indicate that the locations are favorable for groundwater extraction. Fig.5.19 shows the existence of perch clay and analyzing its position with respect to Fig.5.11 it is confirmed that this intermediate clay bed is located in the Northern part of Godagari thana. These sectional views would definitely play an important role for selecting suitable well sites and its designing.

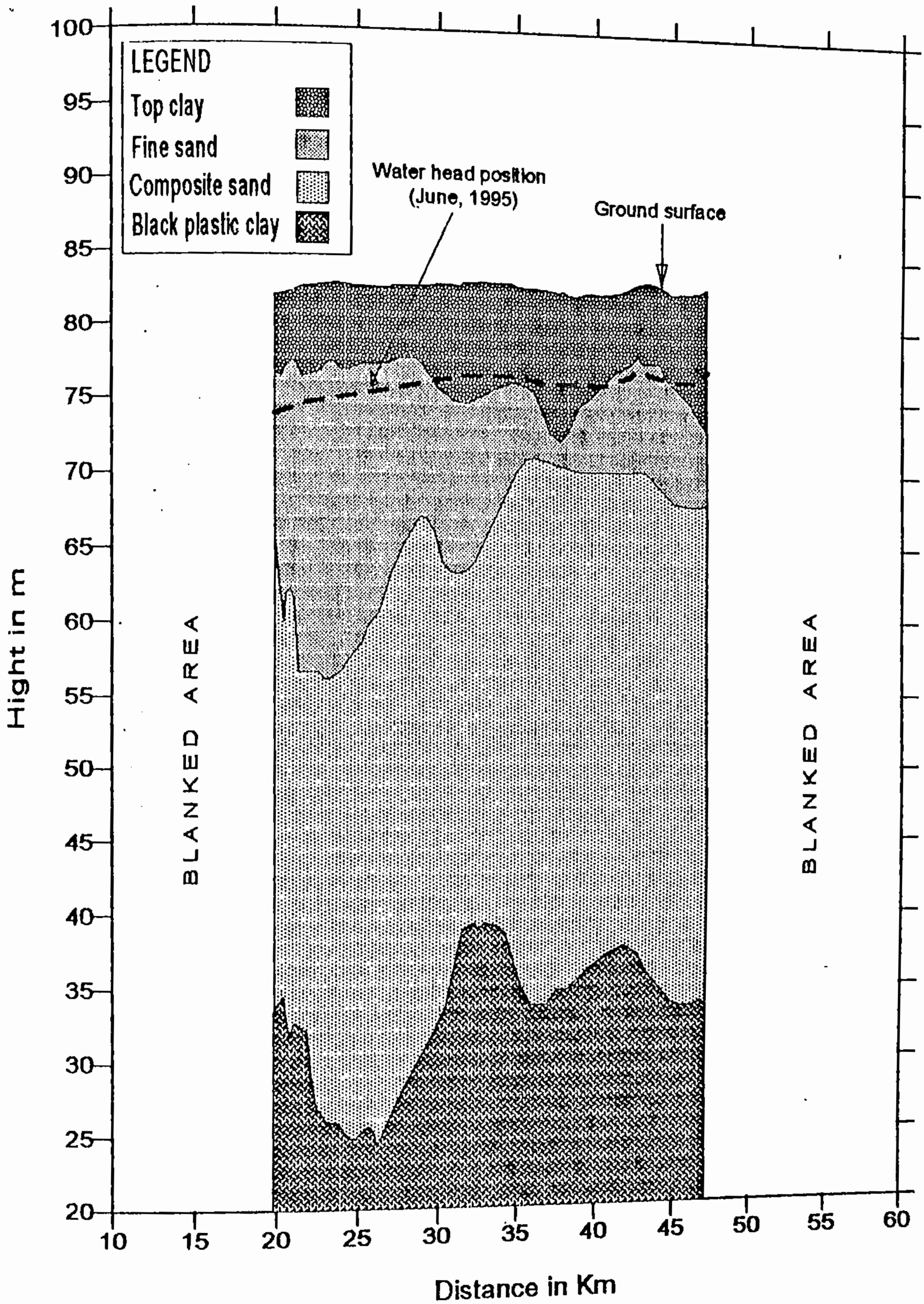


Fig.5.16 Sectional view along profile SN1.

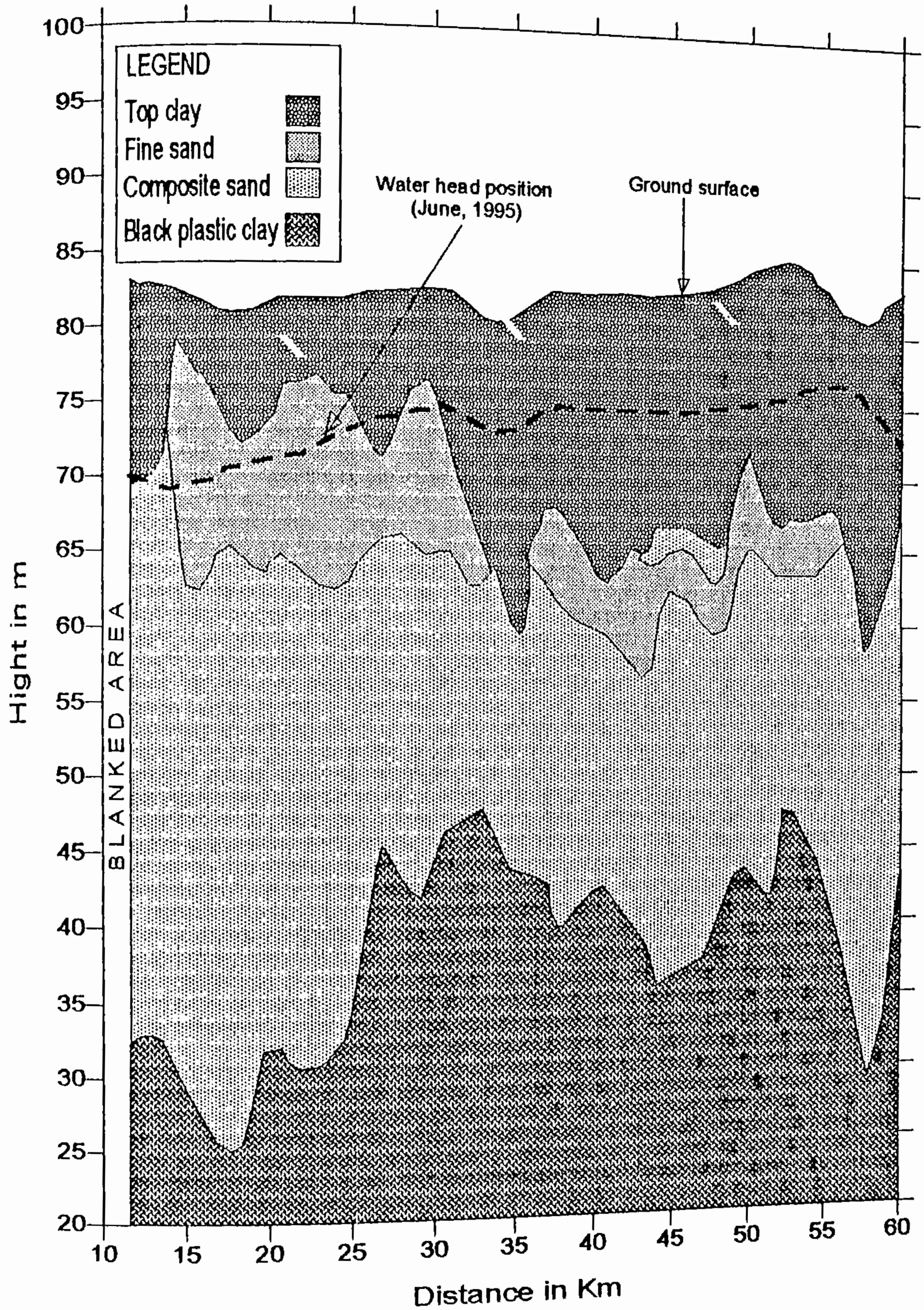


Fig.5.17 Sectional view along profile SN2.

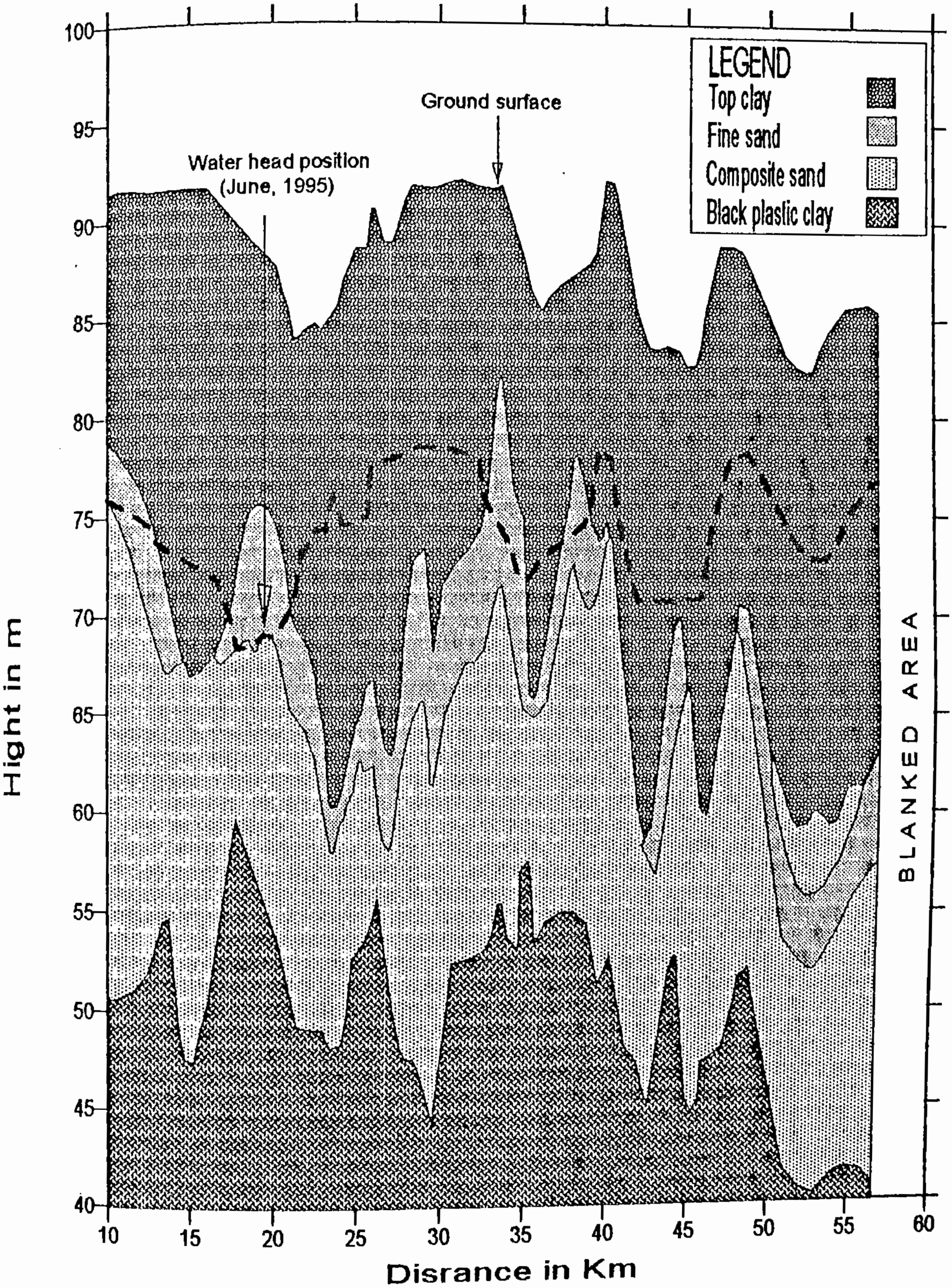


Fig.5.18 Sectional view along profile SN3.

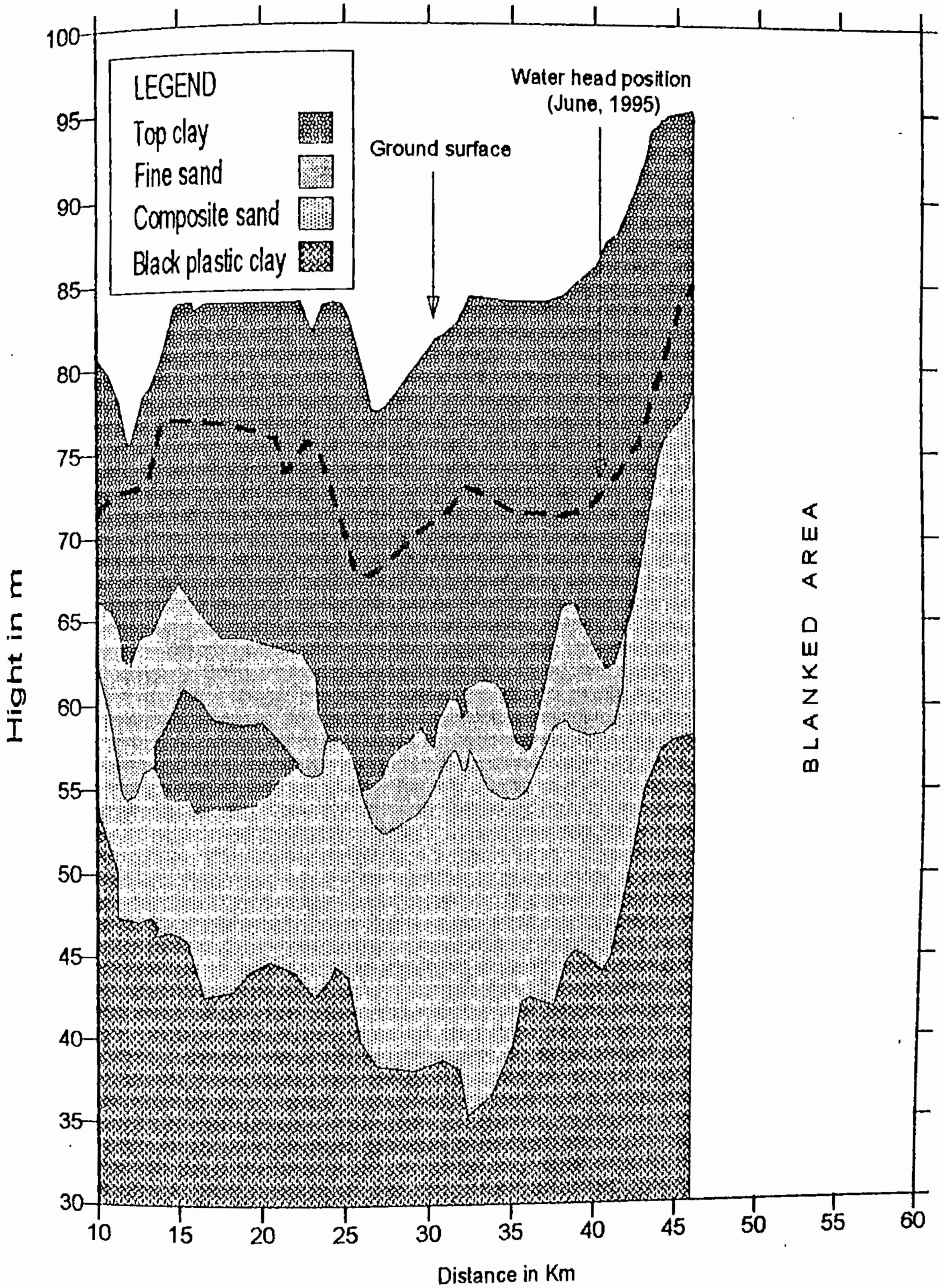


Fig.5.19 Sectional view along profile SN4.

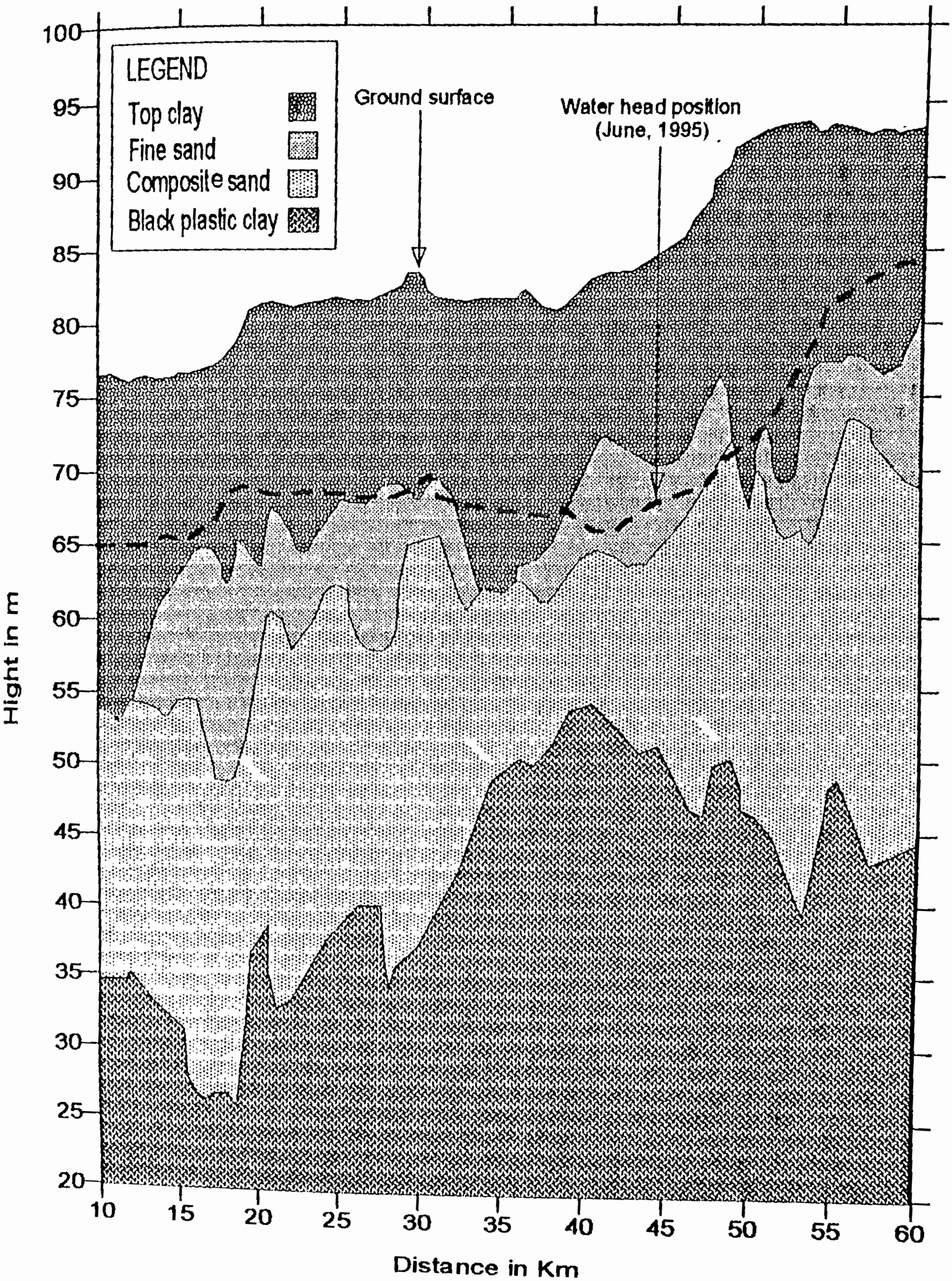


Fig.5.20 Sectional view along profile SN5.

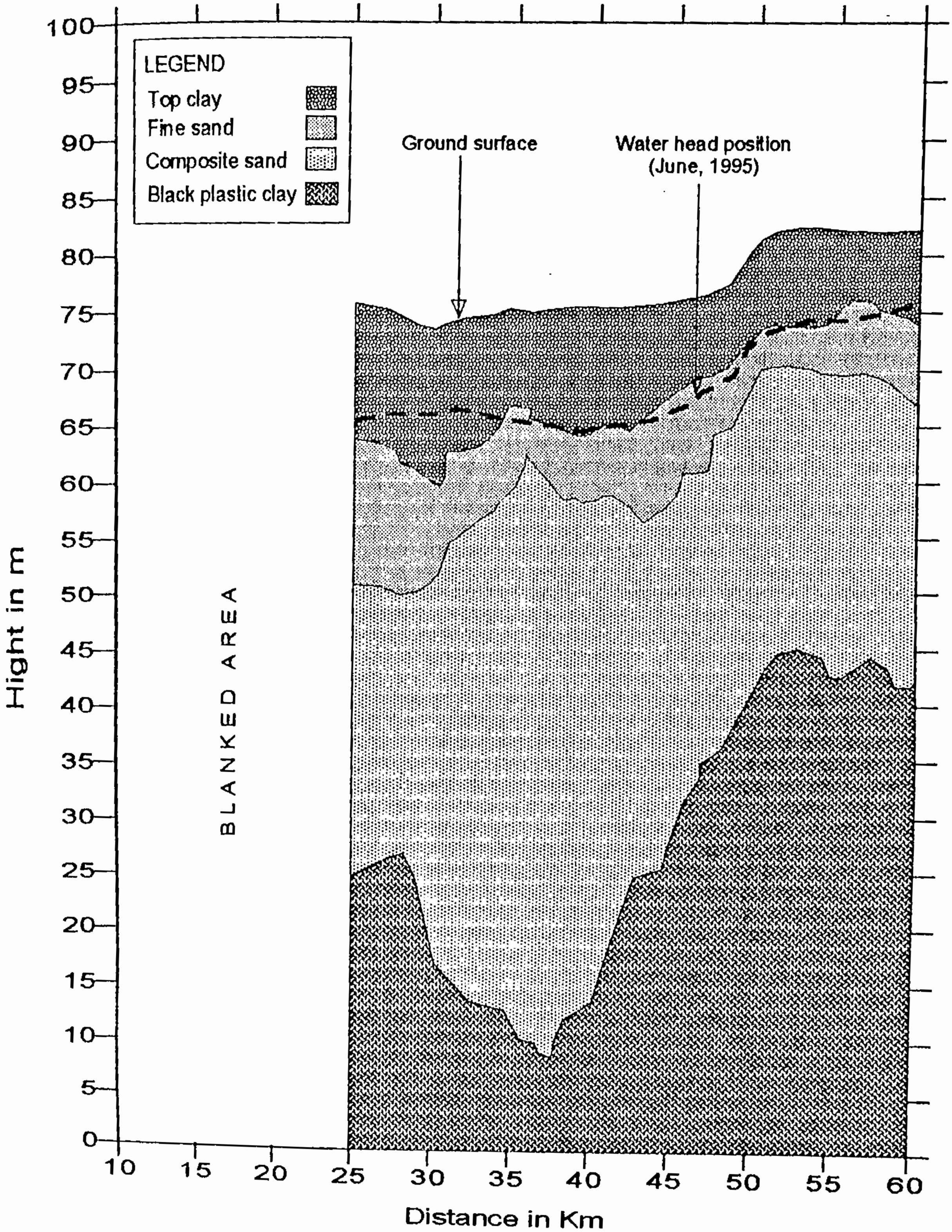


Fig.5.21 Sectional view along profile SN6.

CHAPTER SIX

GROUNDWATER MAPS AND THEIR INTERPRETATIONS

CHAPTER SIX

GROUNDWATER MAPS AND THEIR INTERPRETATIONS

Finding and using groundwater reservoir which discharge through springs represents no difficulty from the point of view of hydrodynamics i.e., it rarely gives rise to any dislocation of the general hydraulic system within the reservoir. The position is not the same when sub-surface water is extracted by wells. In that case consideration must be given to all the essential factors affecting the degree of disorganization of the reservoir regime and arising from water extraction at points which are not after all point of natural discharge. A knowledge of all these factors is of prime importance for interpreting hydraulic gradients for estimating future developments.

Only that groundwater which is in motion is of importance. An aquifer in which there is no movement could be dismissed from consideration since absence of movement means that there is no recharge and ultimate exploiting, this water would simple amount to use up a non replaceable reserve. Hence, the gradient of the water head surface is of considerable importance as much as the transmissivity of the aquifer. There are various ways of representing relief features on the map. The representation of various maps in two dimension can be made practically correct. In an area the groundwater conditions can best be analyzed by plotting the groundwater data on maps.

The variation of different parameters related to the evaluation of groundwater condition in the area investigated have been presented in the form of contour maps and its relative surface patterns.

6.1 WATER-TABLE MAP

The upper surface of the zone of saturation is called the water table or phreatic surface which separates the zone of saturation from the overlying zone of aeration. This concept of the water-table is valid only in formations with supercapillary interstices at and above the water-table. Where the interstices are of capillary dimensions, immediately above the water-table may be saturated although this water is not available freely to wells. So, the definition of the water-table as the upper surface of the zone of saturation has a restricted meaning. But definitely it is a graphic representation of the hydraulic slope of the free water body and is usually a "subdued replica" of the surface topography. In very permeable formations the water-table may tend to be flat, irrespective to the topographic inequalities.

The depth of the water-table or isobaths of the water-table depict the inequalities in the position of water-table with respect to the ground surface and are useful in delineating recharge and discharge areas, locating sites for wells and dealing with drainage, artificial recharge or other problems in which the depth of the water-table is critical.

The hydrologic character of the material is also indicated by the water-table map. If the material is fine, contours will be close together and the slope of the water-table will be steep because a steeper hydraulic gradient is required to force a given amount of water through fine material than through coarse material. The water-table slope is adjusted automatically to the velocity of moving water and to the permeability of the material. The direction of groundwater movement is always down the slope of the water-table. The construction and study of water-table maps are an important phase of groundwater investigation.

Fig. 6.1 Shows the water-table contour map of the area studied for rainy and dry season of the year 1995. In dry season the maximum and minimum depth to the water-table are recorded 22m and 8m respectively which forms an inverse conical shape towards the center of the study area. After monsoon the water-table rises from 4m to 10m in different areas, but no appreciable change in contour pattern is marked in the figures, dry and rainy. The water-table map is a map of the phreatic surface which enables to give the direction of groundwater flow.

6.2 WATER HEAD MAP

Groundwater moves in the direction of decreasing head or potential. The head at a point is taken as the elevation, above an arbitrary datum, of the top of a static column of water that can be supported above the point. The elevation of the point above the datum is called the elevation head. From the point of view of groundwater exploration it is desirable to know the true gradients of the water-table surface relative to a datum plane. The position of the water-table with respect to the m.s.l. is generally known as the Water Head Position (W.H.P.). The aerial variation of the head of water-table with respect to the m.s.l represents the potentiometric surface. A line joining points of equal head on the potentiometric surface is an equipotential line. At right angles to the tangent of the equipotential line is the flow line, define as line such that the microscopic velocity vector is everywhere tangent to it. Flow lines indicate the direction of movement of groundwater. The change in the head per unit distance is called hydraulic gradient and is maximum in the direction of the flow line. Converting the static water level [Fig.6.1] to water head position with respect to m.s.l. the contour maps with surface plot of dry and rainy season of the year

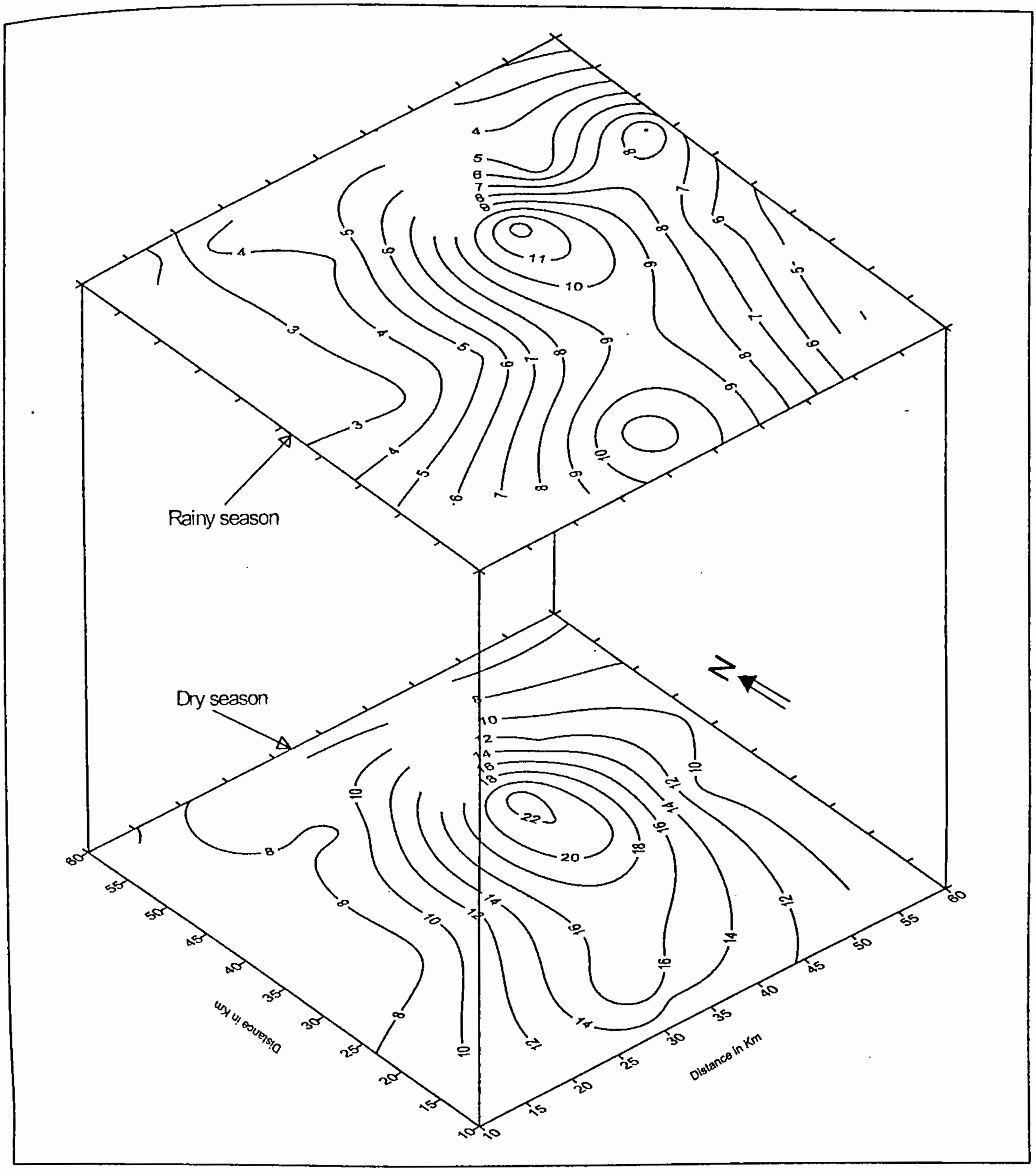


Fig.6.1 Contour map of water-table of rainy and dry season of the year, 1995.

1995 have been prepared and shown in Fig.6.2 and Fig.6.3 respectively. These two surfaces are so similar that except the variation of water head position no differentiation between them could be made. It is ascertained from above figures that irrespective of season the underground water flow of the area studied is originated from the North-Eastern corner. The water head position map of dry season of the year 1988 as illustrated in Fig.6.4 shows that the groundwater natural flow direction is also originated from the same corner.

6.3 GROUNDWATER FLOW DIRECTION

Groundwater is in constant motion from a point of recharge to a point of discharge, in accordance with laws governing flow of fluids in porous media. The law of linear resistance gives the rate at which groundwater in motion loses energy. Further, because of addition and withdrawal from storage, the volume of groundwater in motion changes with time and distance according to the principle of conservation of mass. Besides, the water transmitting properties of the media, physical properties of groundwater directly or indirectly affecting flow are the specific weight, density, viscosity, temperature and compressibility.

Approaching the equilibrium position by nature, water moves inside the ground from the higher head points to the point lower down. The contour lines of the water head position are in fact equipotental lines. Hence, the direction of groundwater flow, perpendicular to the equipotential lines, could be directly obtained from the water head contour map. Contour map of water heads together with the flow lines are useful for locating groundwater potential zones. However, the areas of best possible source of groundwater supply would be ascertained by favorable

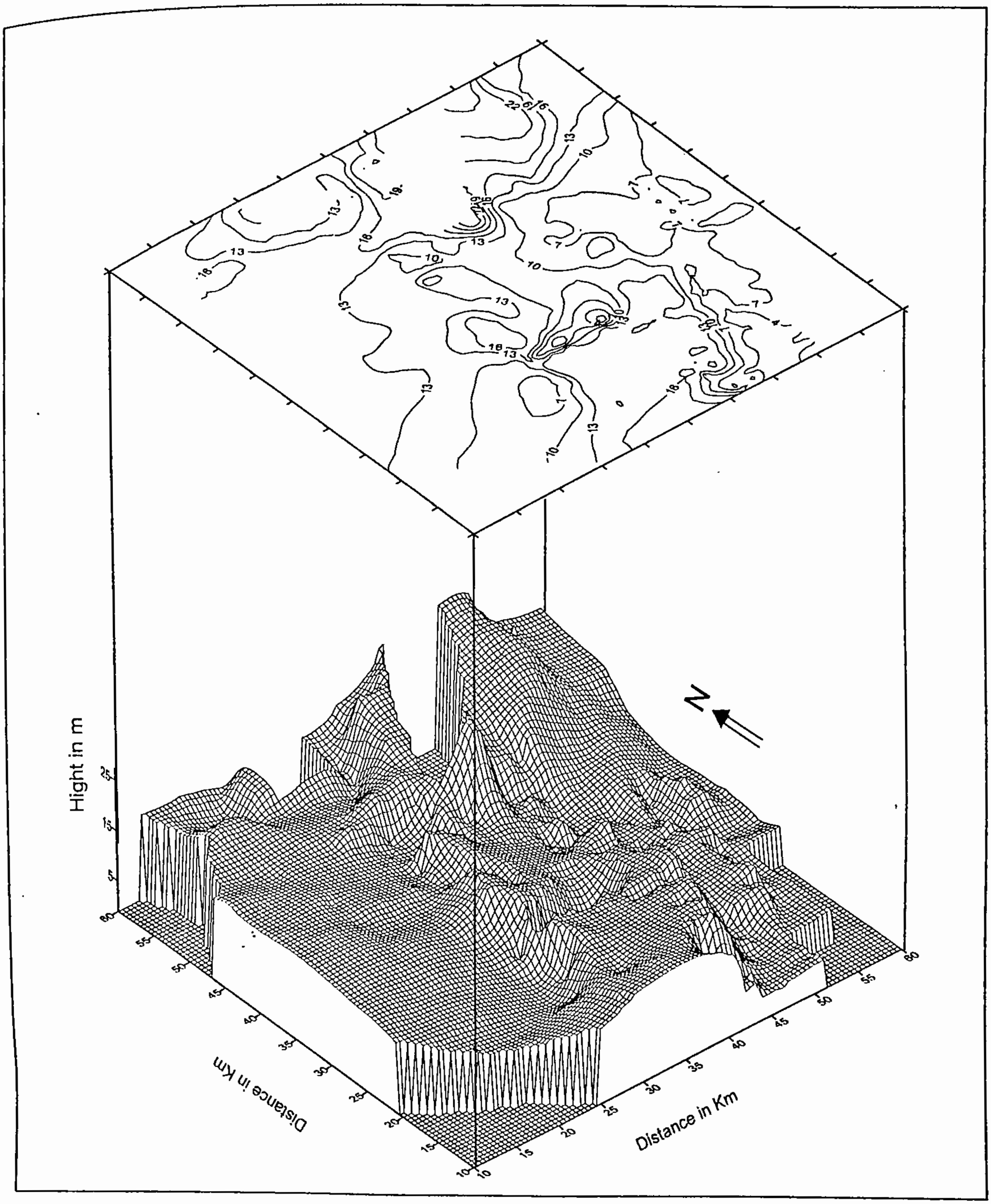


Fig.6.2 Contour map over surface plot of water head position (dry season, 1995).

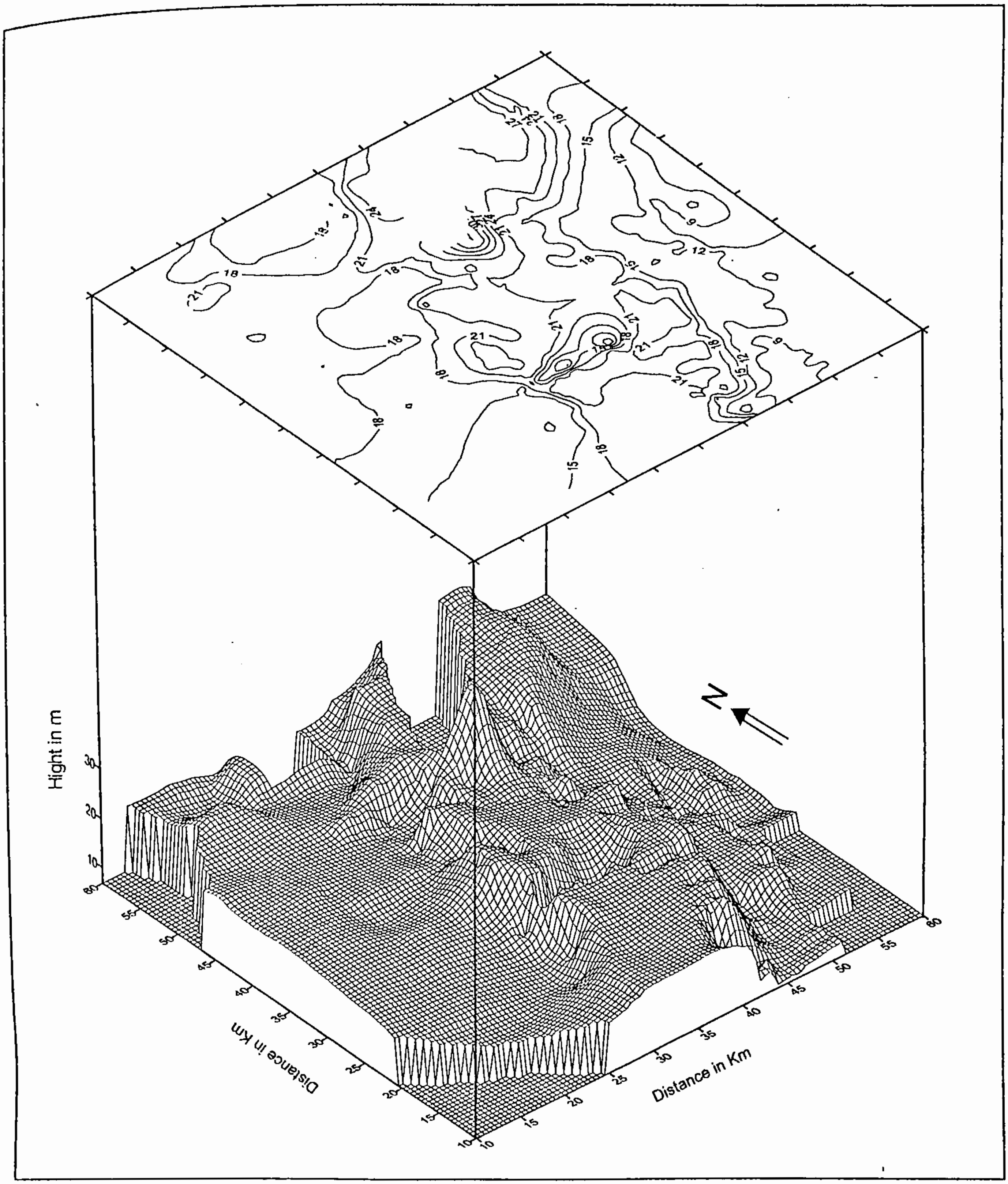


Fig.6.3 Contour map over surface plot.of water head position (rainy season, 1995).

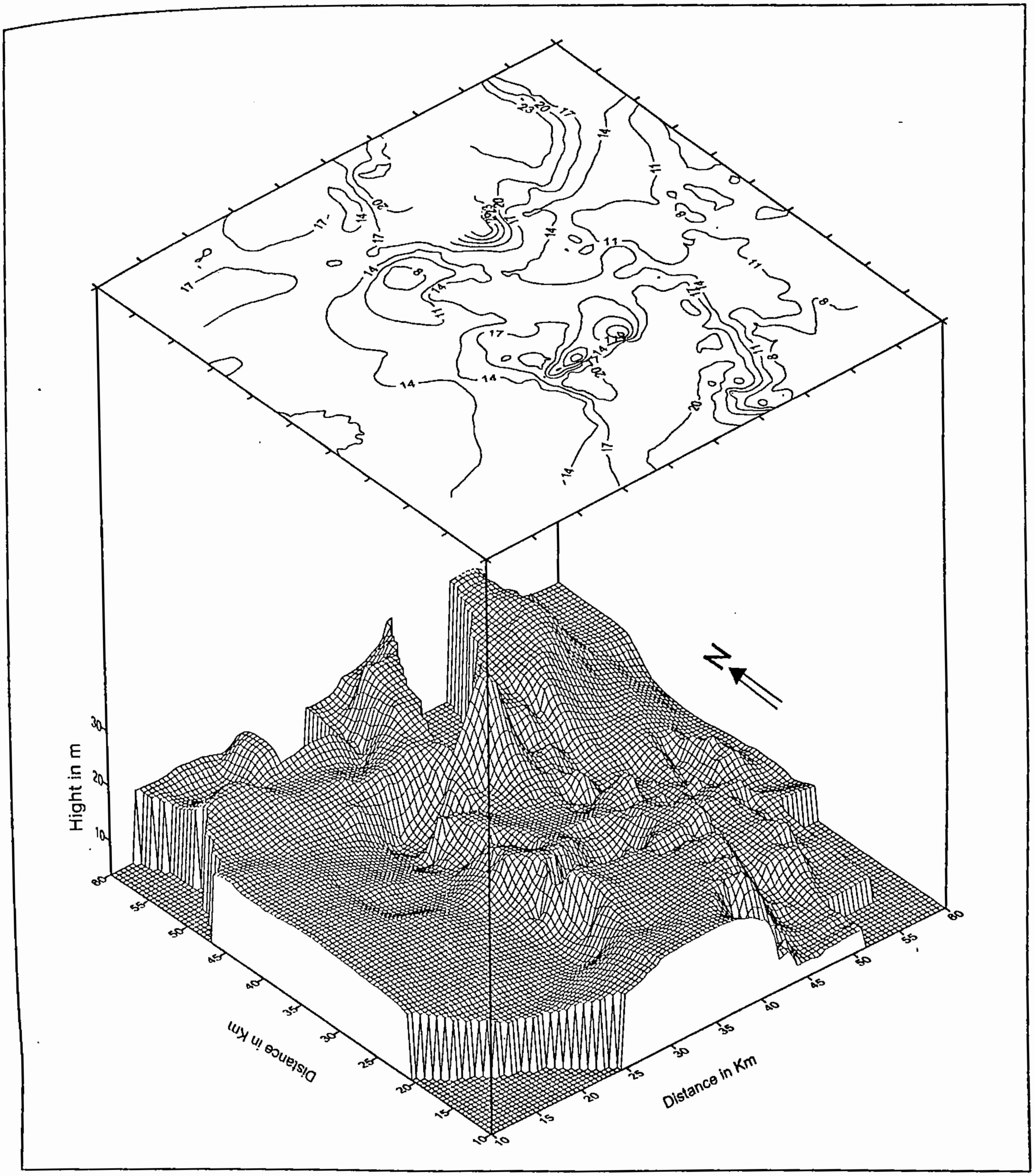


Fig.6.4 Contour map over surface plot of water head position (dry season,1988).

transmissivity value. If it is proposed to abstract water from an aquifer of a particular area, it is essential to determine weather and to what extent that aquifer is being recharged by itself and this can only be properly done if the direction of groundwater flow throughout the aquifer is known. In fact, groundwater movement is a three dimensional phenomena and although the dominants of the horizontal components has rightly given stressed, vertical component also play an important role. Thus, water moves not only along the horizontal gradient but also downward from the water-table and in places upward towards the water-table.

The contour map of water head position in dry, 1995 of the investigated area along with the supposed direction of groundwater motion is illustrated in Fig.6.5. The 13m equipotential surface of the area may be considered as equilibrium plane. The critical analysis of the groundwater movement confirms that it flows towards the different corners of the area studied originating from the North-Eastern side.

6.4 NATURAL FLOW RATE ESTIMATION

The importance of potentiometric surface in groundwater investigation has rightly been established. The relation between equality of flow, hydraulic gradient, hydraulic conductivity and other formation constants has illustrated in chapter three. In all the cases it is assume that the quantity of water in motion is constant and that the flow is horizontal in the aquifer system. In general the direction of groundwater flow relates groundwater movement to difference in head from which it is apparent that in normal circumstances groundwater moves from an area of greater to an area of lesser head.

A water head contour map of au aquifer is a graphical representation of the hydraulic head gradient. This gradient is the basis for calculating the rate of

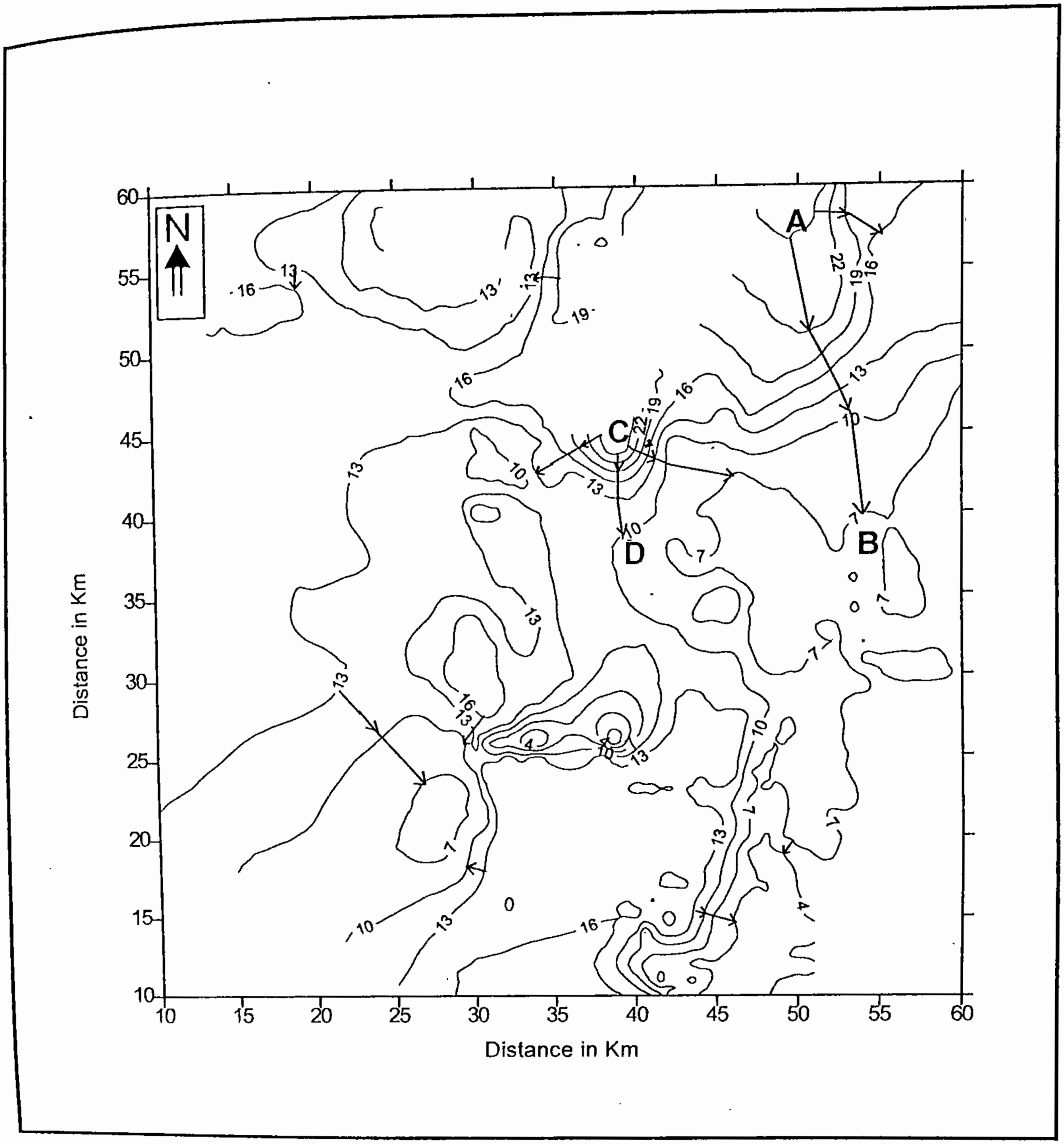


Fig.6.5 Contour map of water head position showing groundwater flow directions in dry '95 (interval 3m).

groundwater flow through cross-sectional area of the boundaries. The flow velocity varies directly with the hydraulic gradient. The lateral sub-surface inflow and outflow to the boundaries of an area would easily be calculated knowing the hydraulic characteristics of the area with the information of the transmissivity of the water bearing material as well as the width of the water bearing formation. The flow rates have been analyzed along profiles AB and CD as shown in Fig.6.5. The estimated flow rate in different parts of the profiles are presented in Table-6.1 and Table-6.2. The graphical presentation of the variation of flow rate in different parts along the profiles AB and CD are also shown in Fig.6.6 and Fig.6.7 respectively. It is observed from the above figures that the flow rate along the profile CD is comparatively higher than that of the values along profile AB. However, the hydraulic conductivity of the sub-surface formation plays an important role in the flow rate of the underground water.

Table-6.1 Flow rate in different parts of profile AB.

Distance of midpoints between adjacent contours from A (km)	Distance between two successive contours, L (km)	Change in water head, Δh (m)	Gradient $i=\Delta h/L$	Transmi-ssivity, T (m^2/day)	Width, w (m)	Flow Rate Q=Tiw (m^3/day)
2.79	5.58	3	0.54	750	1	402.75
6.67	2.17	3	1.38	750	1	1036.50
8.29	1.08	3	2.78	1250	1	3471.25
9.37	1.08	3	2.78	1250	1	3471.25
10.04	1.86	3	1.61	1250	1	2015.00
14.71	5.89	3	0.51	1000	1	509.00

Table-6.2 Flow rate in different parts of profile CD.

Distance of midpoints between adjacent contours from C (km)	Distance between two successive contours, L (km)	Change in water head Δh (m)	Gradient i=Δh/L	Transmissivity, T (m^2/day)	Width, w (m)	Flow Rate Q=Tiw (m^3/day)
0.23	0.46	3	6.52	1250	1	8151.25
0.69	0.46	3	6.52	1250	1	8151.25
1.23	0.62	3	4.84	1250	1	6047.50
2.00	0.93	3	3.23	1250	1	4031.25
3.63	2.32	3	1.29	900	1	1163.70

6.5 GROUNDWATER POTENTIAL ZONE

Although water is continuously passing on through the hydrologic cycle, man as a living thing must store enough or depend on natural storage to meet continuing or recurring demands. Groundwater reservoir provides all the water yielded and constitute the source of the base flow and sustained through out the periods. These reservoirs probably hold several times as much as usable water as the surface reservoirs but it is very difficult to provide a reliable estimate due to insufficient information. The term groundwater reservoir is commonly used to disignate the water bearing material from which water could be extracted. An essential characteristics of groundwater reservoir is the movement of water through them but very slowly. Groundwater reservoir thus provide slow moving storage from which water can be obtained as for requirements. Nevertheless, usable groundwater does not remain at rest under a piece of land for its exploitation but is moving continually to some point of discharge at the surface.

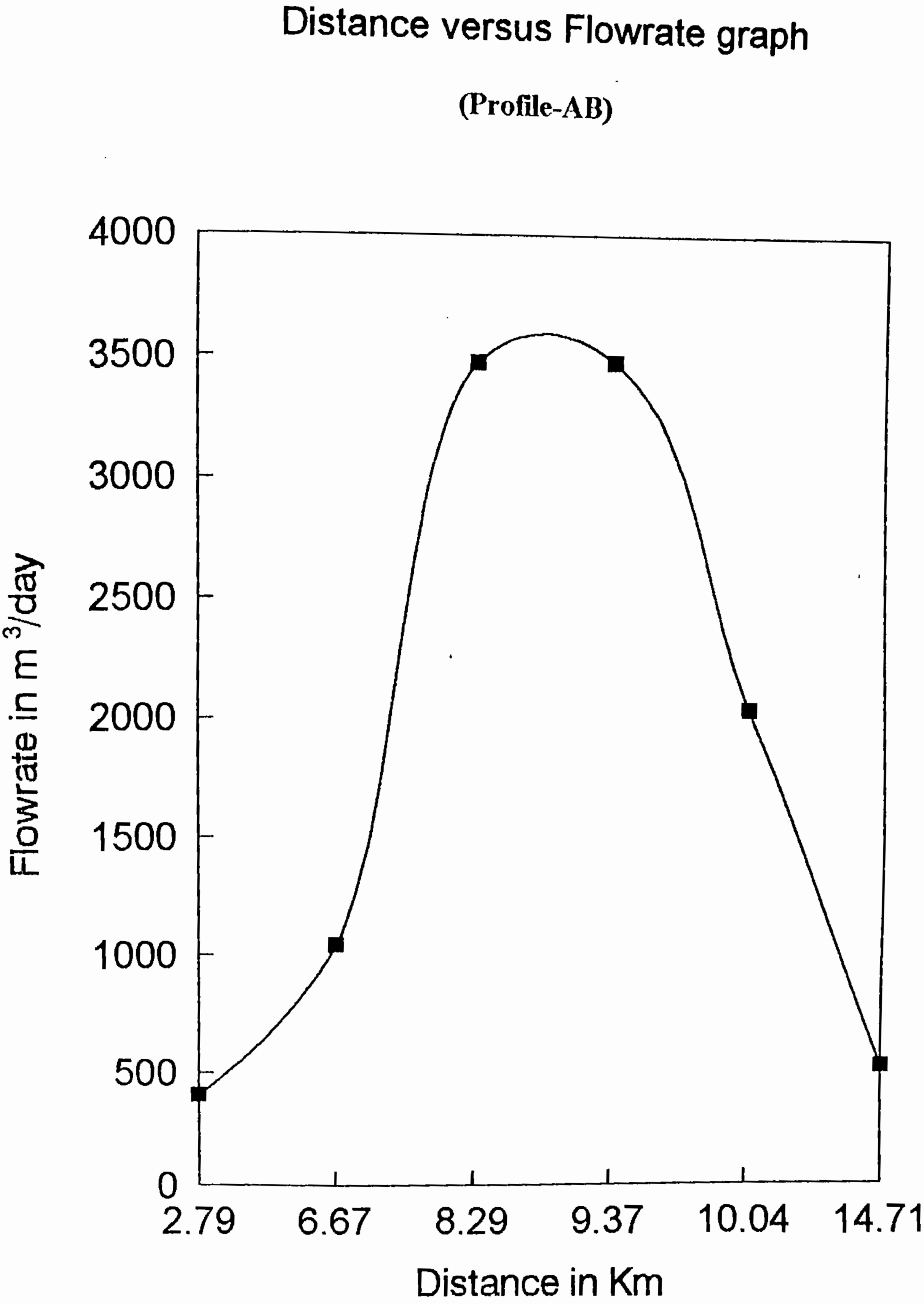


Fig.6.6 Flow rate analysis along profile-AB.

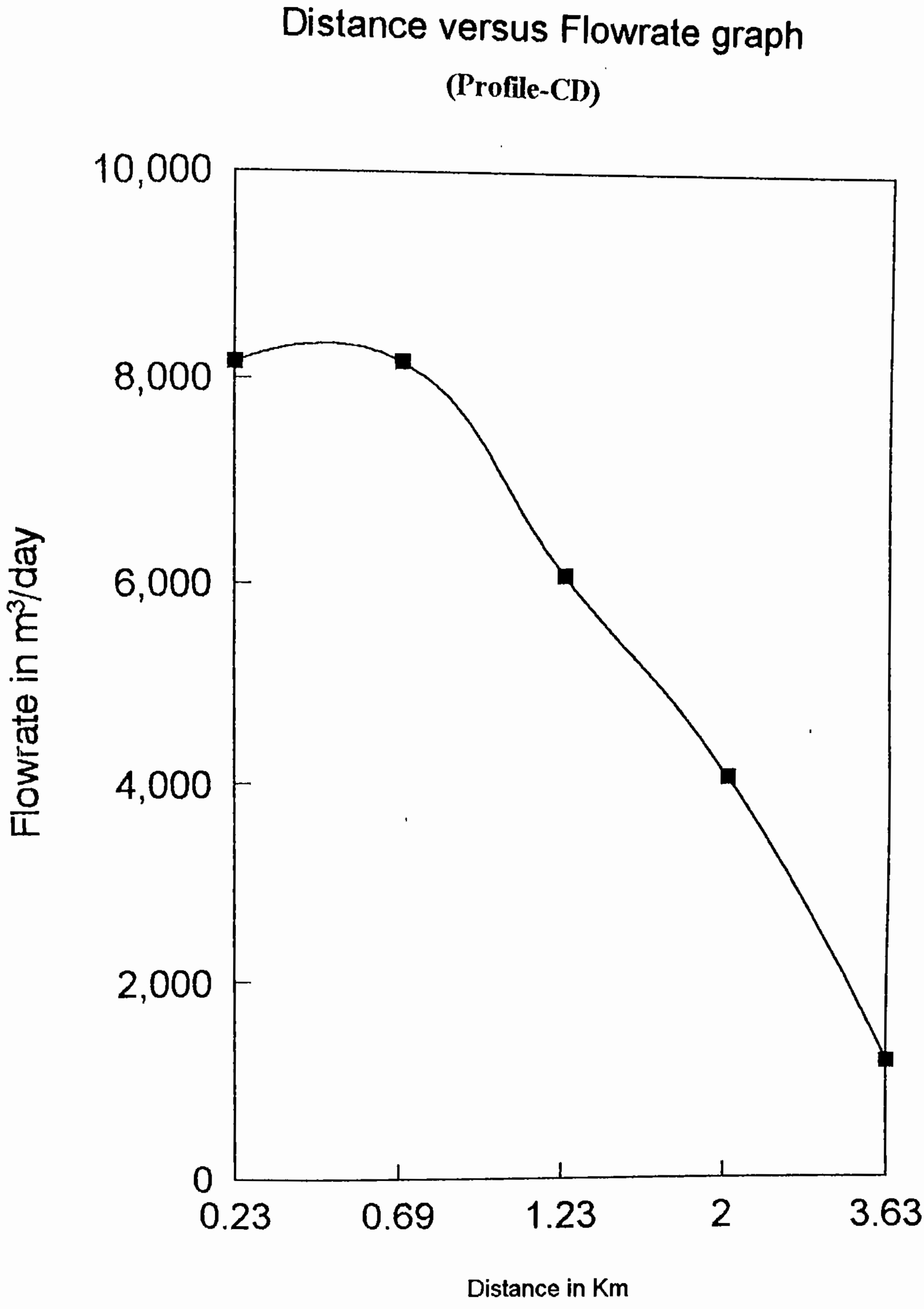


Fig.6.7 Flowrate analyssis along profile-CD.

In areas where surface water bodies are very limited, like Barind Tract of greater Rajshahi district, the groundwater is the only source of fresh water. The amount of water extracted depends on the storage and yield capacity of sub-surface water saturated formation and the continuous and steady water supply is established if the natural groundwater flow direction is directed towards the point of discharge. In different sections of previous discussions groundwater potentialities in various parts of the investigated area have been identified considering only the singular parameter. Finally, the analysis of all individual potentialities have resulted some favorable zones of groundwater exploration as marked in the Fig.6.8.

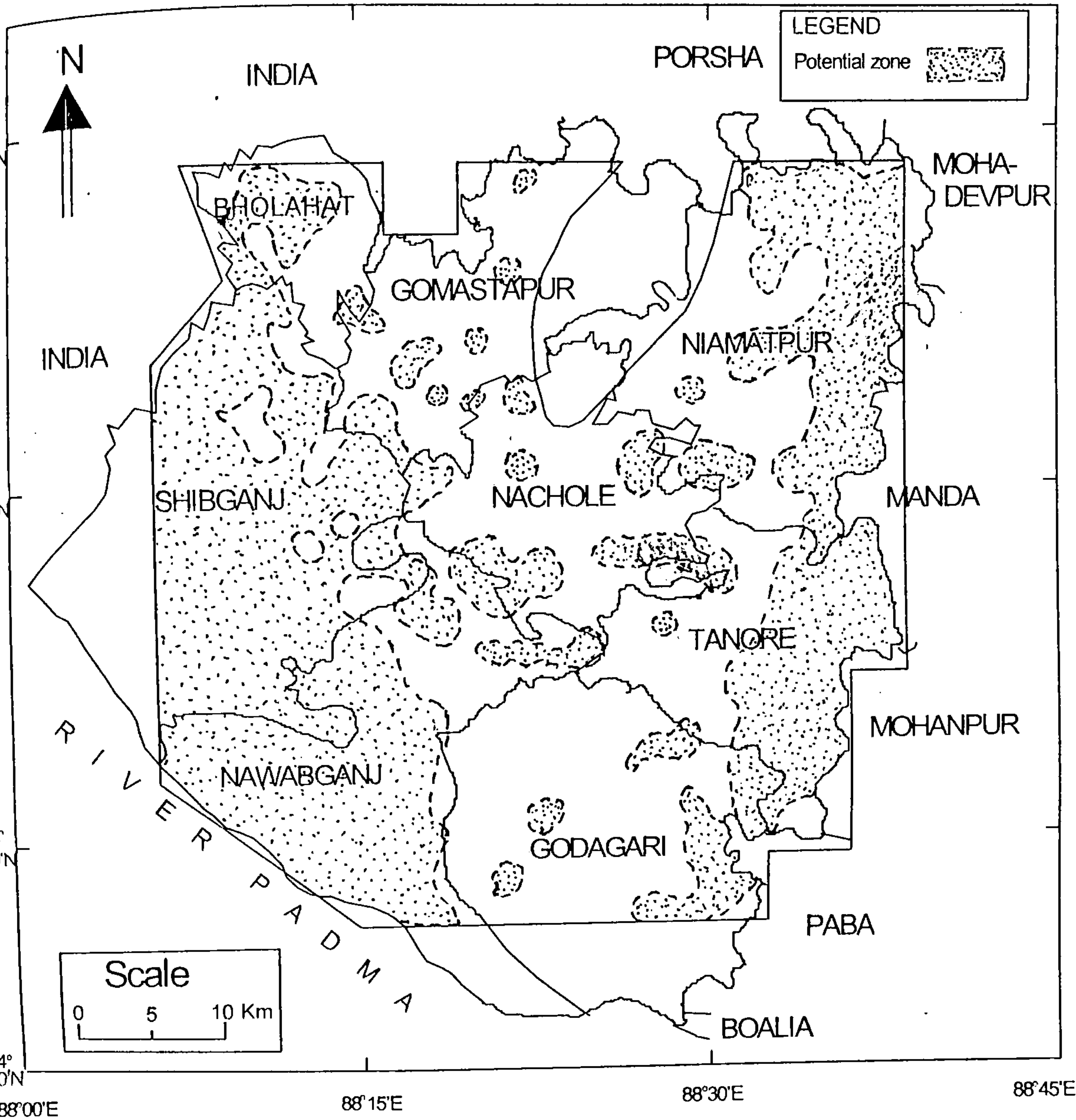
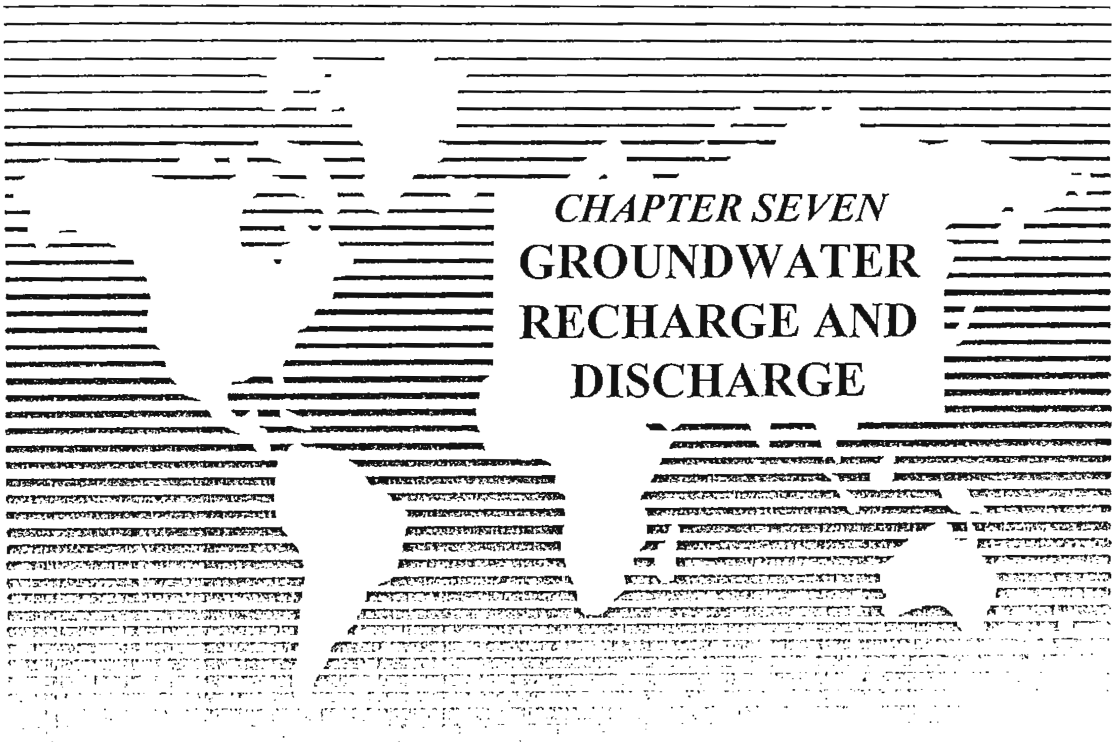


Fig.6.8 Study area showing groundwater potential zone.



CHAPTER SEVEN

GROUNDWATER RECHARGE AND DISCHARGE

GROUNDWATER RECHARGE AND DISCHARGE

The proper assessment of potential, present use and additional exploitabilities at optimal level of groundwater resources, requires thinking in terms of the entire groundwater system. In order to maintain this resource indefinitely, a hydrologic equilibrium must exist between all waters entering and leaving the system. Groundwater balance deals with aspects of balancing various components of groundwater supply (recharge) and disposal (discharge) with storage changes in the groundwater reservoir. Generally, the recharge areas are those where water can enter the aquifer from land surface or from a stream bed by percolation through permeable materials. Discharge of groundwater in a location inevitably lowers the water-table in the vicinity. If this lowering of water is diverted from a point of natural recharge or if a greater amount of water is induced to enter the recharge area to replace the water withdrawn, that place would be considered in the natural circulating system and yield water perennially. The storage changes may directly reflected in variation of groundwater level. When recharge exceeds discharge, water level will rise, and if discharge exceeds recharge, the water level will fall. In most natural circumstances, recharge to and discharge from the same groundwater catchment occur simultaneously. Groundwater level fluctuation, in fact, reflects the net change of the storage resulting from the interaction of these two components.

7.1 STUDY OF GROUNDWATER LEVEL FLUCTUATION

A groundwater level, whether it may be water-table of an unconfined aquifer or the piezometric surface of a confined aquifer, indicates the elevation of atmospheric pressure of the aquifer. Any phenomenon which produces a change in pressure on the groundwater will cause the groundwater level to change (Todd, 1980).

The fluctuation of groundwater level may be caused due to (i) change in groundwater storage, (ii) direct fluctuation of atmospheric pressure in contact with the groundwater surface, (iii) deformation of aquifers, and (iv) secular and seasonal variation.

A decline water-table is a characteristic of the region that has used its water resources not wisely and is taking more from its groundwater reservoir than is replenished naturally. In such a region the reservoir will eventually be emptied unless abstraction is reduced or an artificial means can be found to put more water into that reservoir than is done by nature. Annual precipitation is the prime source of replenishment for all water resources, and climatic variations have a profound effect upon the position of the water-table.

In the study area most of the groundwater abstractions take place in the dry months starting from January and continues up to May also June in some dry years. During this period the recharge is almost nil, the rate of evaporation and evapotranspiration is high and most of the river flow is derived from groundwater reservoir as base flow. As a result of all these natural and artificial withdrawal, the water table decline sharply and reaches to maximum depth in May/June. Rain starts in the pre-monsoon period and at the same time begins to recharge to the underground storage. The major artificial abstraction of groundwater is also stopped by this time and high relative humidity in the atmosphere reduces the rate of evaporation and evapotranspiration. All these causes a gradual increase in the groundwater reservoir which is reflected by the change of the water-table. The water-table starts moving upward and reaches to minimum depth from the land surface in September/October.

For studying the annual fluctuation of water level during the period 1986-95, well hydrographs have been prepared with the information of eight observatories [Fig.4.2] covering each thana of the area investigated. Fig.7.1 shows the annual fluctuation of groundwater in the observatories. The analysis of the hydrographs show a declination of groundwater level during the period of observation in the study area which is clearly observed in the observatories of Bholahat, Gomastapur, Nawabganj, Tanore and Godagari thana. Also the well hydrograph of Godagari thana indicates that the amount of annual recharge of this area has decreased since 1992.

7.2 VOLUMETRIC ANALYSIS OF RECHARGE AND DISCHARGE

The safe yield of a groundwater reservoir is the amount of water which can be withdrawn from it annually without producing an undesired result. The water supply to an aquifer system is limited either by the physical dimension of the underground water system or by the rate at which water moves through the system from the recharge area to the withdrawal area. Determination of safe yield thus refer to the quantity concept or the rate concept. The quantity concept usually more important for unconfined aquifers where supply and disposal areas are near, whereas the rate concept is more applicable to confine system where supply and disposal areas may many Kilometers apart.

A quantitative assessment of groundwater recharge and discharge has been made for the study area. A variety of techniques can be used for estimating groundwater recharge and discharge. Generally, recharge due to rainfall, surface

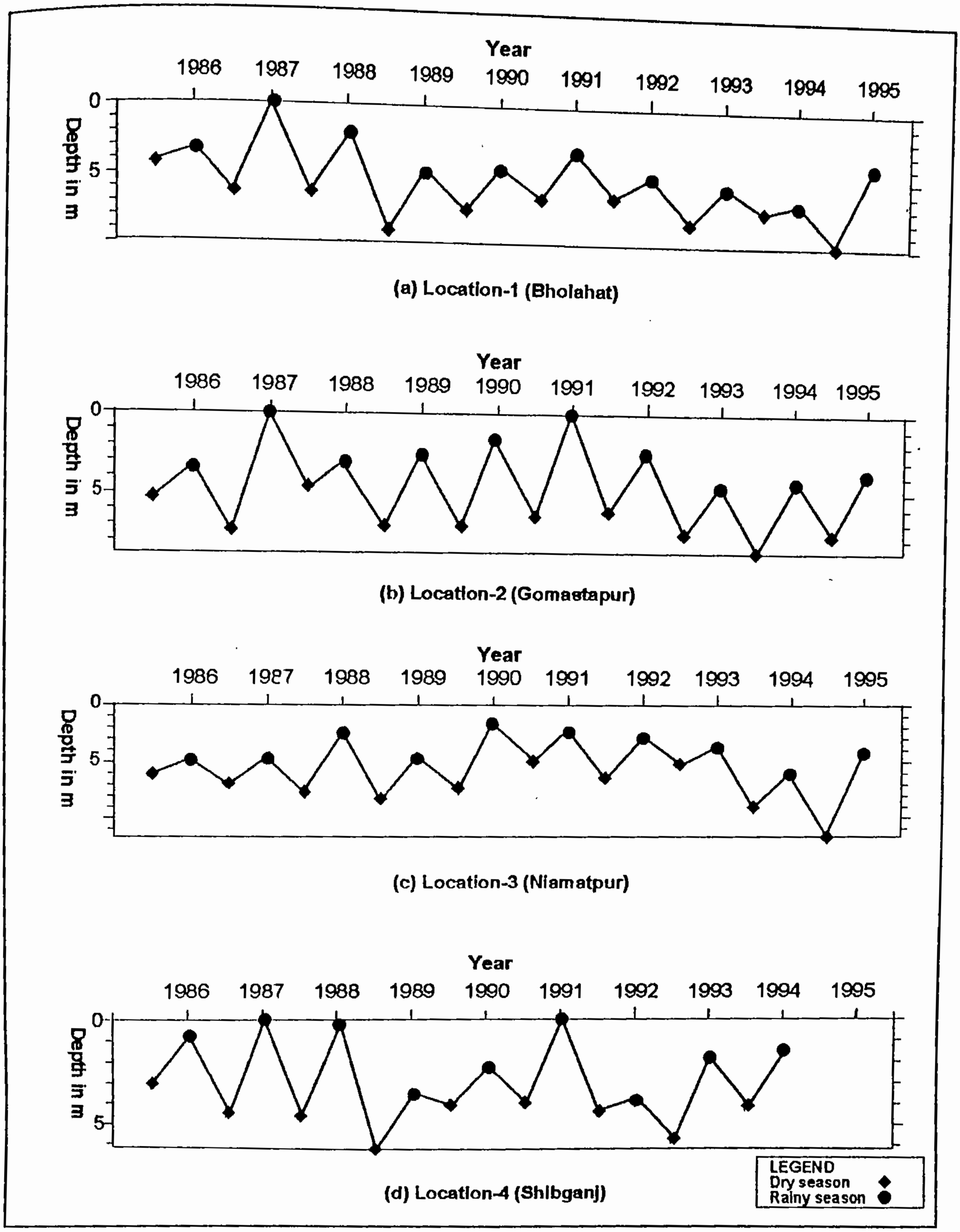


Fig.7.1(a) Annual water level fluctuation in Bholahat, Gomastapur, Niamatpur and Shibganj thana.

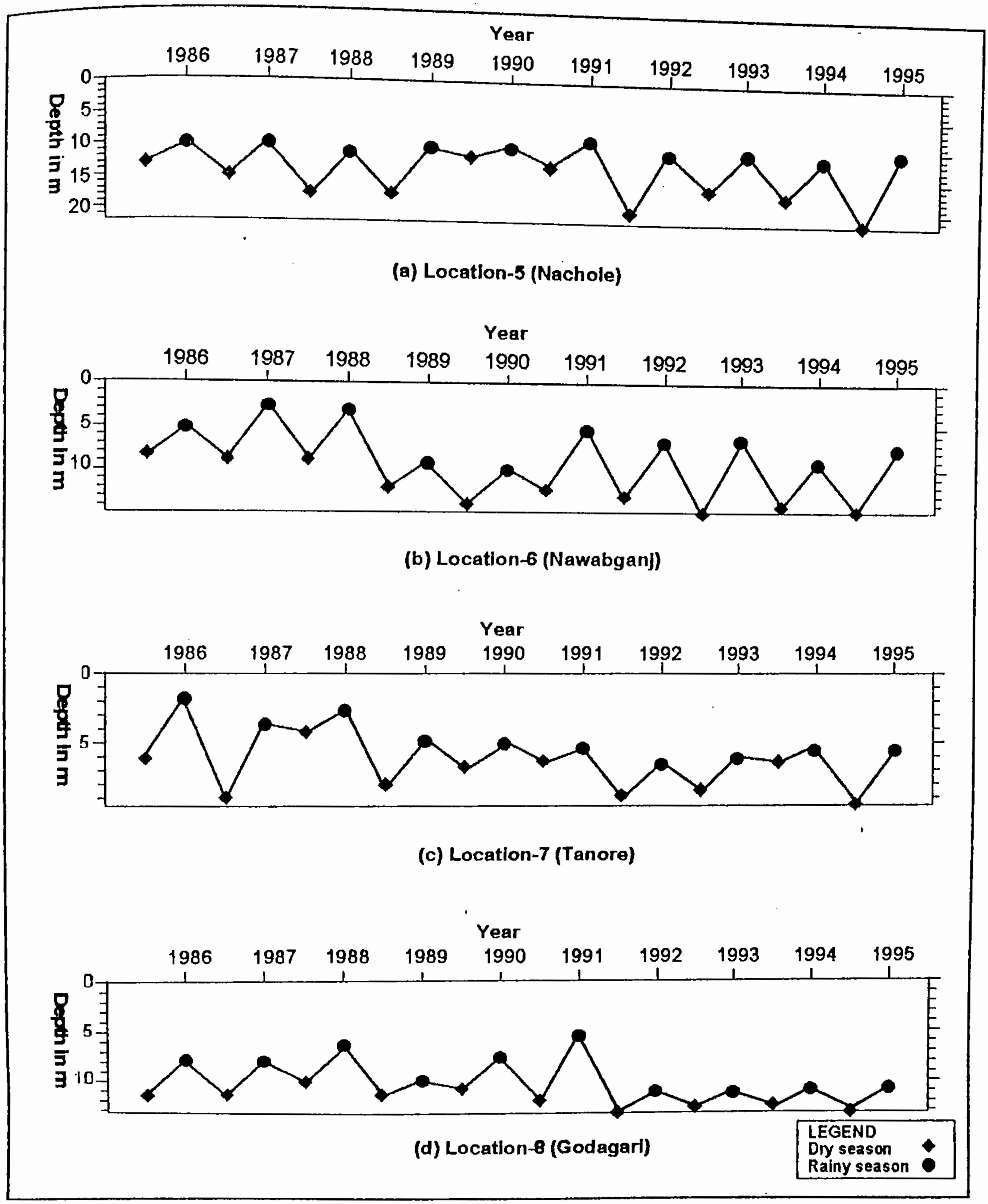


Fig.7.1(b) Annual water level fluctuation in Nachole, Nawabganj, Tanore and godagari thana.

water bodies and irrigation return are estimated individually using different formulas to have the total amount of annual recharge. Similarly, discharge is measured taking evaporation loss, evapotranspiration loss, natural discharge and leakage into account. But in the present process annual recharge and discharge have been estimated only considering the fluctuation of groundwater table. In the case of recharge, the rising of groundwater table from dry to rainy is considered and volume between them is calculated with the aid of available computer software. Then, this volume is multiplied by the specific yield of that formation filled with groundwater to have the recharged volume of water. But the calculated volume may be within the formations of different specific yields. So, for more accuracy, the partial volumes of different formations are calculated. Similarly, for discharge estimation, volume covered by shifting water-table from rainy to dry season is considered. This can be formulated as follows:

$$Q = V.S_y$$
$$= V_1.S_{y1} + V_2.S_{y2}$$

where, Q = recharged/discharged volume of water,

V = total volume between water tables,

S_y = specific yield of the formation,

V_1 = partial volume within first formation,

S_{y1} = specific yield of first formation,

V_2 = partial volume within second formation,

S_{y2} = specific yield of second formation.

As the water-table in the study area fluctuates within two formations- top clay and fine sand; so, during recharge and discharge calculations only these two formations have been taken into account. In the present computation the specific yields of clay and fine sand are considered as 06% and 26% respectively. For the estimation of total volume of water recharged and discharged during the period 1986-87, first the amount of water recharged is estimated considering the water level fluctuation between dry and after rainy season of 1986 [Fig.7.2] and similarly, the volume of water discharged is calculated with the fluctuation of water level between the pre-monsoon of 1986 and dry season of 1987. The estimated annual recharge and discharge of the year 1986 to 1995 have been tabulated in the Table-7.1.

Table-7.1 Annual estimation of groundwater recharge and discharge.

Period	Annual Recharge			Annual Discharge		
	Volume in clay (km^3)	Volume in fine sand (km^3)	Recharged water, $Q=V_1.S_{y1}+V_2.S_{y2}$ (km^3)	Volume in clay (km^3)	Volume in fine sand (km^3)	Discharged water, $Q=V_1.S_{y1}+V_2.S_{y2}$ (km^3)
1986-87	6.3992	0.7110	0.5688	9.1166	1.0129	0.8103
1987-88	11.3125	1.2569	1.0056	10.3977	1.1553	0.9242
1988-89	10.5939	1.1771	0.9416	14.8243	1.6471	1.3177
1989-90	7.8662	0.8740	0.6992	4.7593	0.5288	0.4230
1990-91	7.1349	0.7927	0.6342	6.4164	0.7116	0.5693
1991-92	10.0469	1.1163	0.8930	12.4812	1.3868	1.1094
1992-93	6.3293	0.7032	0.5626	7.9851	0.8872	0.7097
1993-94	8.8533	0.9837	0.7869	8.1539	0.9059	0.7247
1994-95	7.0164	0.7796	0.6236	9.6574	1.0730	0.8548

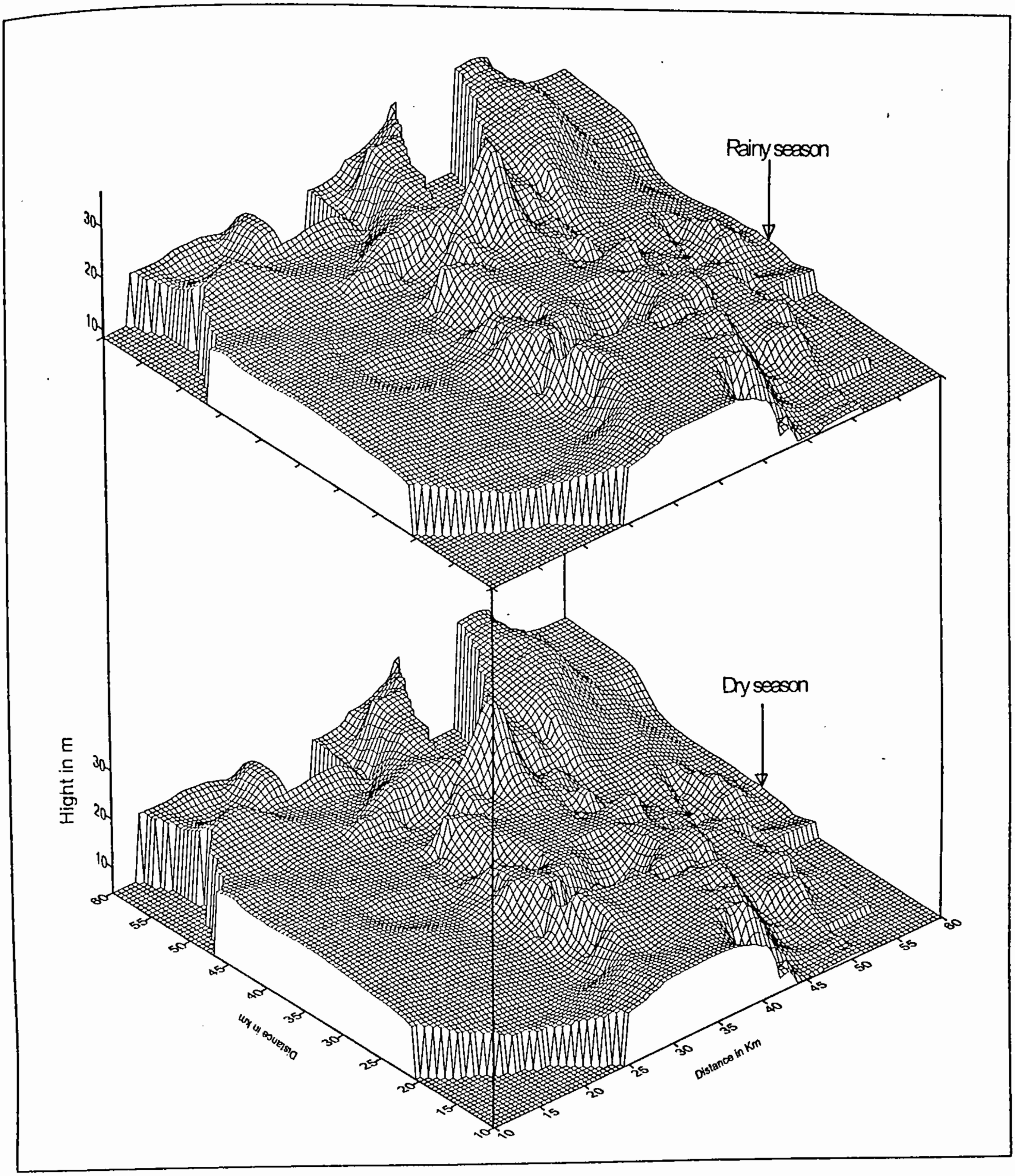


Fig.7.2 Dry and rainy water-table of the year 1986 with respect to m.s.l.

The Histogram of Fig.7.3 shows the total volume of recharged and discharged water along with rainfall of the investigated area during the period 1986-95. The amount of water recharged and discharged in different water years (1st June to 31st May) are clearly observed from the above figure. Only in the year 1989-90 the discharge is significantly less than recharge but in many years the reverse situation is prevailed.

7.3 GROUNDWATER BALANCE STUDY

Groundwater is a renewable natural resource. Groundwater reservoirs receive their greatest replenishment from precipitation and stream flow. Thus, a groundwater reservoir is said to be used effectively if its operation is on the basis of a balance each year between recharge and discharge. If the balance is achieved during a climatic cycle of several years' duration, however, the groundwater reservoir can provide hold over storage from wet years for the drier years when the need for water is greatest (Thomas, 1951). But if groundwater is withdrawn at a rate exceeding the recharge, mining yield exists and if mining continues different types of hazards may occur such as (i) declination of water level, (ii) deterioration of water quality, and (iii) destruction of hydraulic properties, etc..

Since 1984 the present study area suffers from some of the above problems for large scale abstraction of groundwater due to irrigation purposes. So, with a view to management and further development of groundwater an assessment of groundwater resources of the study area has been made on the basis of input-output stresses.

Groundwater balance for the study area is worked out using the following relation assuming the natural groundwater inflow to be equal to the groundwater outflow,

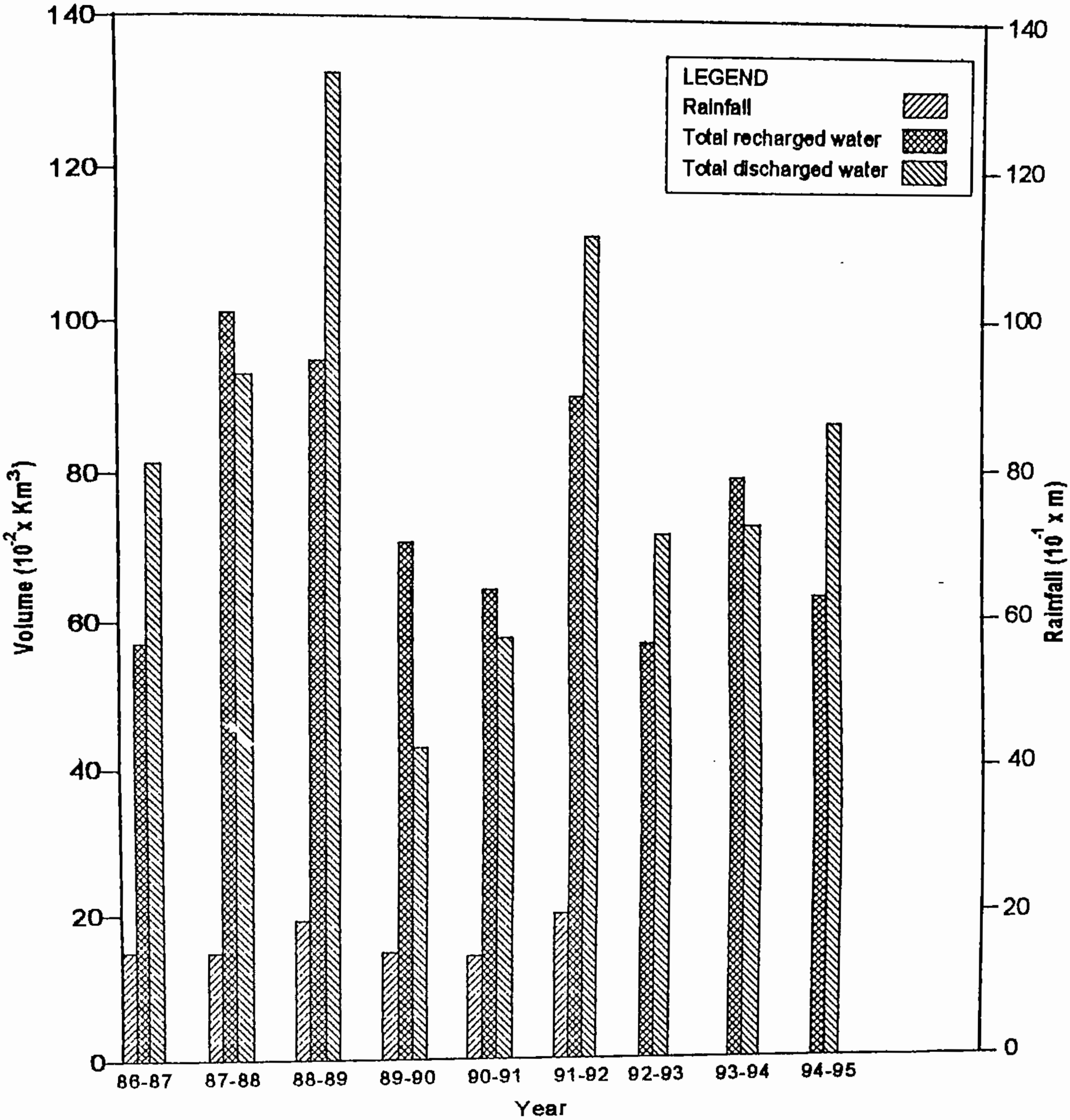


Fig.7.3 Comperative study of recharged and discharged groundwater of the study area along with rainfall.

$$\Delta S = I - O$$

where, ΔS= change in storage,

I= annual input to groundwater system,

O= annual output from groundwater system.

Adopting the above methodology, the groundwater balance is carried out with the observed data for the period 1986 to 1995 and presented in Table-7.2.

Table-7.2 Groundwater balance of the period 1986 to 1995.

Period	Annual recharge water (km^3)	Annual discharge water (km^3)	Balance = Recharge - Discharge (km^3)	Total balance (km^3)
1986-87	0.5688	0.8103	- 0.2415	
1987-88	1.0056	0.9242	+ 0.0814	
1988-89	0.9416	1.3177	- 0.3761	
1989-90	0.6992	0.4230	+ 0.2762	
1990-91	0.6342	0.5693	+ 0.0649	- 0.7312
1991-92	0.8930	1.1094	- 0.2164	
1992-93	0.5626	0.7097	- 0.1471	
1993-94	0.7869	0.7247	+ 0.0622	
1994-95	0.6236	0.8548	- 0.2348	

It is clearly observed from the table that the amount of water overdraft during the tenure (1986-95) is 0.7312 km^3. This over exploitation of underground water has resulted an average declination of 0.3m of water-table in the area studied. The annual recharge and discharge of groundwater of different water years have been presented in the Fig.7.4. Here, the surface pattern of water head position of dry 1986 has been considered as the reference level and the amount of water recharged and discharged in various years have been plotted in successive way. Fig.7.4 clearly indicates that the amount of groundwater reserve in the investigated area is decreasing continuously, that is during the period of study groundwater mining is observed.

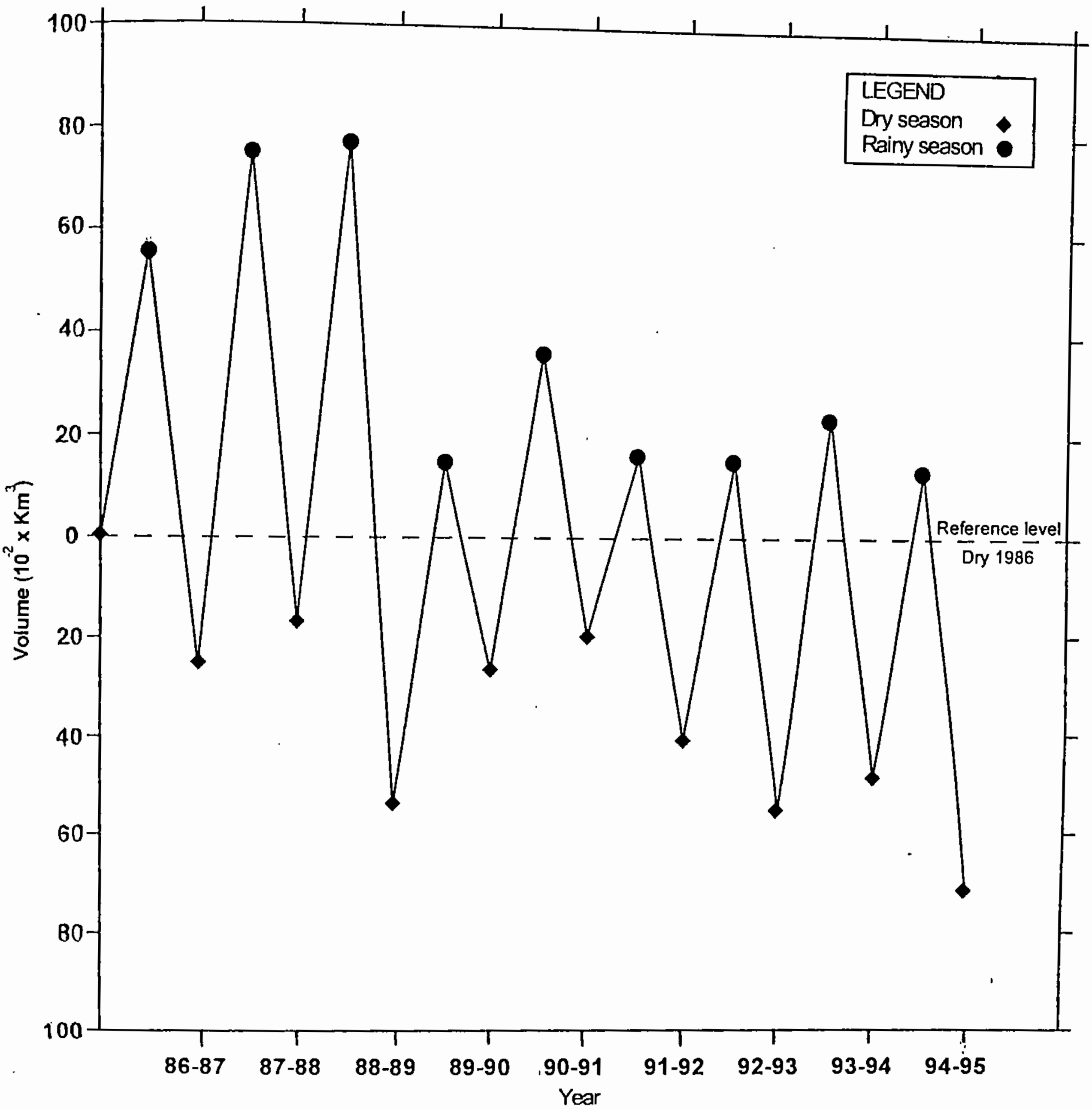


Fig.7.4 Volumetric fluctuation of groundwater.

CHAPTER EIGHT
CONCLUSION

CONCLUSION

The natural supply of groundwater, like that of other renewable resources, is usually limited with regard to time and place. In recent years, the use of this limited supply has grown enormously. Due to this excessive stress upon the groundwater resource, the yield capacity is being reduced, and the need to conserve them is now generally recognized. This recognition is a timely step in the right direction. But clearly much more is required for sound development, wise use and protection of this resource.

Utilization of groundwater reservoirs for greater benefit is dependent on adequate hydrogeological data, from which the full potential of development is determined. Nevertheless, the occurrence of usable groundwater in some parts of the area is usually controlled in large measure by geologic formations.

The investigated area is a semi-arid zone situated in the North-Western part of Bangladesh where groundwater is the only source of fresh water. Although it is not an easy task to provide a quantitative assessment of groundwater reservoirs with reference to their potentialities and limitations for development, an attempt has been made to evaluate the groundwater potentialities of the study area with the available borehole data. The physical and geometrical parameters as well as the natural flow direction have been studied. The hydrographs of eight observatories have been prepared to observe the water level fluctuation during the period of 1986-95. Also the total amount of water recharged and discharged during the same period has been estimated in order to find out the groundwater balance of the area studied. The result of this work can be summarized as follows:

(i) The exploitable aquifer is unconfined in nature and exists within the depth of 68 meter.

(ii) During the period 1986-95, the natural groundwater flow direction does not show any appreciable change. It is directed towards various parts of the area originating from North-East corner.

(iii) Water bearing materials, chiefly medium and coarse sand, are being used as productive aquifer. The overall thickness of this composite sandy formation is suitable. But South-Eastern and South-Western regions are more favorable for groundwater exploration.

(iv) Transmissivity and specific draw down indicate that the whole Eastern and Western sides are potential areas of well development.

(v) A gradual fall of groundwater level since 1992 is illustrated in well hydrograph.

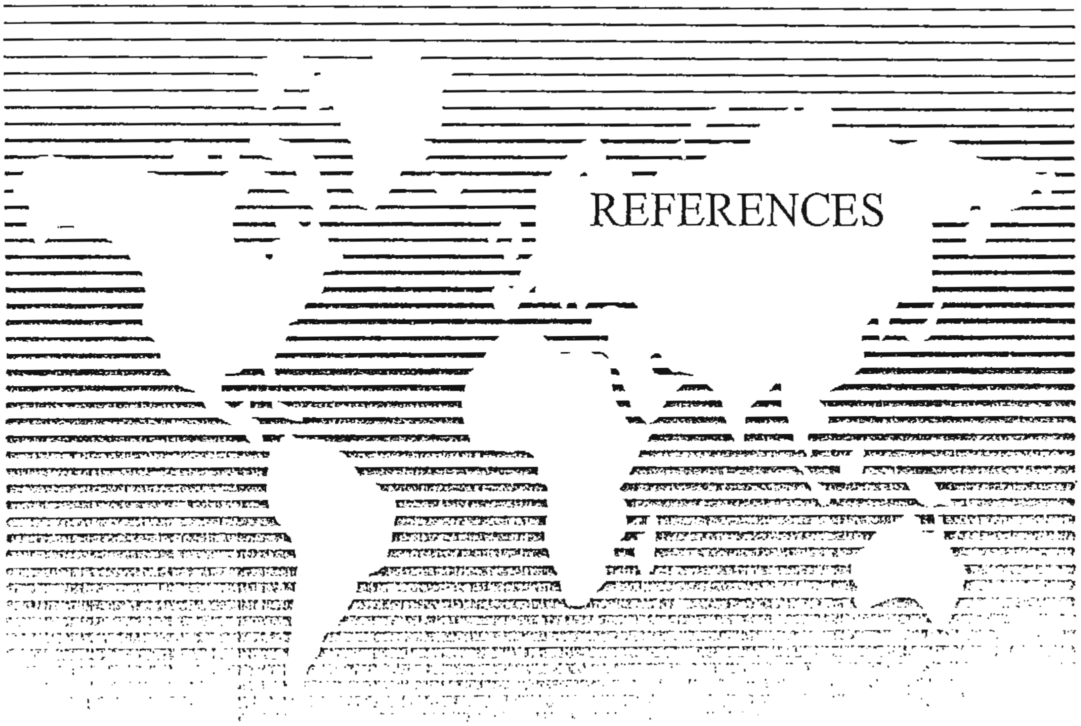
(vi) During the period 1986-95, the amount of groundwater recharged to and discharged from the aquifer give a net negative groundwater balance, i.e., the area is overdeveloped.

The development of groundwater alters the natural condition so greatly as to produce significant modification in the quantity of groundwater exploration. It is, therefore, essential to regulate the present groundwater situation of the investigated area through-

(i) planning the number and pumping rates of the wells for optimal exploration,

(ii) conjunctive use of surface and sub-surface water resources, and

(iii) exploration and exploitation of deeper aquifers.



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