CS - 110

GROUNDWATER QUALITY MODELLING STUDY IN UPPER PALAR ZONE OF PALAR RIVER BASIN IN TAMILNADU

Phase - I Data Processing and Analysis

NATIONAL INSTITUTE OF HYDROLOGY

HARD ROCK REGIONAL CENTRE

BELGAUM

PREFACE

Stresses on groundwater , both in terms of quality and quantity , are growing rapidly due to increasing trend of demands, significant changes in landuse pattern and a vast increase in the quantities and type of industrial and agricultural and domestic effluent entering the hydrological cycle . Therefore over the last two decades there has been substantial move towards mere complete understanding of groundwater contamination and how the impacts of contaminant can be mitigated by appropriate management actions and technological developments.

In the majority of the developing countries of Africa and Asia , only 25% of the rural population now have an adequate supply of safe drinking water. In many parts of the developing world increasing industrialisation is accelerating the deterioration of water quality both in terms of surface water and as well as groundwater. Appropriate technology for treatmet of industrial waste and polluted river water is often sophisticated and complex. This leads to the study of groundwater quality and modelling studies before opting for any remedial measures to ensure the safety of a water supply or to detect and monitor the parameters.

With the advent of advanced technology , considerable use is now being made of models which allow the prediction of groundwater flow paths and contaminated migration pathways. Development of a model is an exercise in conceptualising the true nature of the groundwater regime from the available data. Present phase of the study deals with the preliminary data processing and analysis of ground water flow and contamination of Upper Palar zone of Palar river basin in Tamilnadu to have a feel of real system and visual conceptualisation before proceeding for much more complex operations of mathematical models in the subsequent phase.

The study has been carried out by shri. P. K. Majumdar , Scientist 'C', Hard rock regional Centre , Belgaum under the guidance of Dr. P.V. Seethapathi , Scientist 'F' , with an able assistance from Dr. B.K.Purandara , SRA of Hard Rock Regional Centre , Belgaum.

Satish Chandra

(SATISH CHANDRA)
DIRECTOR

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1.0 INTRODUCTION

In most parts of the world groundwater has generally been considered to be readily available good quality source of water for drinking and for agricultural and industrial uses.In fact,determination of safe yield for a groundwater resource must consider both its quantity and quality.

A programme of study of the quality of groundwater envisages field observations regarding the source and environment of groundwater occurrences,source of pollution and other related aspects having a bearing on the quality of groundwater.Some of the properties like temperature and Ph have to be recorded in the field itself.Detailed analysis of chemical and bacteriological properties can be done in the laboratory.

1.1 Groundwater pollution may usually be traced back to four sources:

(i) Environmental -> This type of pollution is due to the environment through which the flow of groundwater takes place.

(ii) Domestic -> Domestic pollution may be caused by accidental breaking of sewers , by percolation from septic tanks , by rain infiltrating through sanitary landfills,or by artificial recharge of aquifers by sewage water , after being treated to different levels.

(iii) Industrial -> In many cases , a single sewage disposal system serves both industrial and residential areas though the sewage composition and hence the type of treatment they require and the pollution they cause are completely different.

(iv) Agricultural -> This source is due to irrigation water and rain water dissolving and carrying fertilizers , salts , herbicides , pesticides etc. as they infiltrate through the ground surface.

In Upper Palar zone of Palar River basin surface water as well as ground water are getting contaminated and rendering it unusable for drinking and irrigation in several parts of the river basin. Pollution may be one of the causes for the reported occurrences of various water borne diseases confronted by human population and poor production capability of agricultural land.Industrial effluents which are untreated or partially treated are let out into the river and extensive application of fertilisers in the agricultural areas are the main source of pollution which needs special study. Monitoring of the rate of pollution in already affected areas will be the most handy test with which ,control could be effected either by reducing or by eliminating such areas,as source of water supply.

In the present phase of the case study,available Physical,Meteorological,Hydrogeological,Geohydrological and Chemical data of Upper Palar zone of Palar river basin in Tamilnadu,has been processed and analysed to formulate a complete background which will be usefull in the subsequent phase of mathematical modelling.Recommendations based on the conclusion of the preliminary data analysis has been included.On the spot situation has been depicted through some photographs taken at the time of site visit.

2.0 REVIEW

Groundwaters are generally free of suspended solids and objectionable colour. In some instances , however,the water may be associated with underground beds of peat and decay of vegetation which contribute substantial amounts of colour producing organic groundwater by sewage or industrial wastes except in fissured aquifers where surface pollution may be easily transmitted to the groundwater reservoirs.Contamination may also result from the use of reclaimed waste to recharge groundwater supplies.

The temperature of groundwater is a highly desirable characteristics of such supplies for cooling and other purposes . Groundwater is uniformly cool and usually has a low temperature for the region. It is common for deeper groundwaters to show increasing temperature with increasing depth.

Groundwater generally contains higher dissolved solid concentrations than surface water of the same locality. Most of the minerals present in greater amounts are those which contribute to hardness (Calcium & Magnesium) and alkalinity (Bicarbonate, Carbonate and hydroxide). This is due to largely the increased amounts of carbon dioxide in the groundwater.

The decomposing organic materials in the soil remove dissolved oxygen and contribute carbon dioxide to underground water. These conditions are favourable to the solution of iron and manganese which are not uncommon in groundwater supplies . Hydrogen sulphide may also be present in some well waters . It should be recognized that overdraft on the groundwater aquifer may lead to contamination of the supply. This is not uncommon in coastal areas.

Most frequently , contaminants are present in groundwater in solution and consequently are carried with the flowing water. However , as the contaminants pass through the voids of the rock they also come into contact with rock itself and with other chemical species as well as microbial populations. Thus contaminants are frequently retarded and altered by interactions with in the groundwater environment. Such interactions may include adsorption (where the contaminant adheres to the rock surface) , precipitation by chemical reaction, decay and reduction by bacterial activity and even volatilization as gases which are released back to the atmosphere (Bear &

Verruijt , 1987). Additionally contaminant concentrations will be changed by dilution and dispersing. Dilution arises from the mixing of the contaminated water with uncontaminated infiltering waters . Dispersion occurs because of the tortuous flow paths the water takes through the rock. In general the hydraulic properties of a rock vary considerably from point to point with in a formation . This result in migrations of elements of the contaminated water at velocities different from the average rate of movement of the bulk water and causes the development of a mixing front or transition zone. Dispersion occurs both in the direction of groundwater flow and transverse to it, where a point source of contamination occurs , a groundwater contamination plume develops.

The density of groundwater can be significantly altered by contaminant concentrations. Even relatively small increases in the density of groundwater may result in migration of the contaminant plume to the base of the formation. Furthermore where relatively insoluble contaminants such as oils enter the formation , the migration pathways may be substantially exhibit a strong tendency to remain at or near the top of the saturated zone.

All of the processes of migration and alteration present in groundwater are also present in the unsaturated zone. However, the flow of water through the unsaturated zone is considerably more complex due to the presence of the air water vapour phases . Nevertheless it is important to note that the attenuation mechanisms in the unsaturated zone can provide a powerful barrier to the passage of contaminants to the saturated zone.

Potential of contaminants can be considered from two stand points . First, whether a groundwater abstraction zone is liable to contamination and secondly, whether a potential source of pollution is contaminating the aquifer. In either case the present and or future conditions applicable to the migration of contaminants must be determined.For analysis of pollution potential at a particular site , data describing contaminants , their migration characteristics and the characteristics of groundwater regime must be collected. Annexure A shows the variables influencing contaminant migration from a pollution source.

Whilst inspection of the available data can provide a strong insight in to a potential pollution hazard , the use of models may provide more appropriate and rigorous method for integrating all the available data together and for evaluation of the response of the aquifer system to a contamination event. The models are generally derived from the expression of the flow and transport processes to terms of mathematical equations which may then be solved by incorporating appropriate parameter values and boundary conditions derived from the collected field data Development of a model is an exercise in conceptualizing the true nature of the groundwater regime from the available data.

Use must be considered both for present and future demands , to define acceptable contamination levels of a resource . Drinking water quality guidlines (WHO 1987) define the percieved acceptable limits with regard to the physical , chemical , bacteriological and radiological content of potable water. Todd et al (1976) , subdivides contamination sources into six categories . Against each category the potential hazards in terms of the primary parameters for water quality standards are presented in annexure B .Tabulation of this type provides a useful indicator of the relative pollution of a contamination source against a particular water use. IS 10500-1983 stipulates the Indian standards for drinking and other in land surface water for various uses. US Environmental Protection Agency (1973) and (1977) indicates the component of industrial waste as enclosed through annexure C & D respectively.

Although avoidance of contamination from all the sources would be the most satisfactory solution , such an option is neither practicable nor economically justifiable. However , future planning must address the problem of minimising the creation of such sources by improved industrial technology for waste reuse (Heath & Lehr, 1987) , better , agricultural management (Schepers ,1982) and better engineered containment of contaminants , including appropriate citing of waste facilities away from susceptible groundwater source (Legrand , 1983).

3.0 PROBLEM DEFINITION

The present research problem can be defined by a single question i.e. "when does contamination become pollution?" Contamination is used here to indicate the presence of chemical, species in the groundwater at levels greater than the back ground values whilst pollution indicates the presence of species at levels harmful in term of the use of the water.

The question put up in earlier para, may be answered properly by posing and answering a range of further questions, which in turn are the objectives of the study. Among these questions are:

-What contaminations are present in the groundwater ?

-What are harmful levels for specific contaminants ?

-How will the contaminant levels in the groundwater system change with time.

-Can the contamination levels be controlled ?

-Can the source of contamination be controlled effectively?

-How will future plans for development and use of the aquifer system be affected by the contamination .

In the following sections an attempt has been made to establish a basic frame work for providing answer to the above question and to define strategies for management of groundwater quality in Upper Palar zone of Palar river basin in Tamilnadu.

4.0 DESCRIPTION OF STUDY AREA

1. Location :

Upper Palar zone in Palar river basin is located in North Arcot Ambedkar district in Tamilnadu . The area of the Palar river basin within Tamil nadu is about 10880 sq.km.,whereas the total area including the basin area lying in Karnataka (3022 sq.km) and Andhra pradesh (4568 sq. km) comes out to be 18470 sq.km) . Length of the river is 270 km and its width varies from 37 to 135 km . Study area named as upper Palar zone lies between longitude 79 22 30 and latitude 15 13 05 . Location map is appended as Fig 4.1.

2 Morphometric Characteristics :

Linear Aspects :

This zone lies in the upper reach of Palar basin and starts from the north western boundary of the river basin from Chinthamani and Kolar area of Karnataka state. It mainly contains plain area with water spread bodies and the mountainous region called Ambur Durg, is mainly at Vaniyambadi taluk in Tamilnadu.

Stream orders. As the bifurcation ratio is high, the basin yield will be low but with extended peak flows. The length ratio varies from 0.31 to 3.87 which is on the lower side.

Areal Aspect

Area of the zone is 1255 sq. miles. The form factor and circularity ratio of the zone is 0.34 and 0.37 respectively. This confirms that the zone is an elongated one. The elongation ratio is 0.66 which indicates that the zone is the one among the climatic and geological type. This also indicates that the basin has strong relief and steep ground slope. The drainage density of 2.05 shows the surface is low and coarse texture. The drainage frequency is 4.46 which indicates the terrain is hard rock and impermeable spare vegetation and mountainous relief. The length of overland flow is 0.24 which is a low value and indicate that the basin has good drainage .

Relief Aspects

The relief ratio is 1.46 The southern part is the hilly area and northern part is plateau region where there are number of-watershed bodies . As the relief ratio is high possibilities of recharge is less and it influences flood peak flow . The erosion is also likely to occur. Though top soil in the lower region is red loamy soil with good permeability possibility of recharge is less as the slope is very high. The overall percentage of slope for this zone is 2.65% which indicates hilly region with steep slope.

3.Soils:

Generally two type of soil covers are encountered in the zone. They are visible in soil map enclosed as Fig 4.2.

(1) Red Loamy Soil

Soil is light yellowish brown in colour with good permeability. A clay-horizon will be occurring in this soil profile and well drained. This is neutral to acidic in nature and insitu in origin. Thickness ranges from 25 to 45 cm.

(2) Alluvial Soil

This is commonly seen in flood plains of rivers and along the stream courses. These are very deep coarse , loamy dark brown to yellowish brown, non-calcareous in the surface and calcareous in the sub surface horizons, permeability is high . Thickness is more than 90 cm.

4. Geology:

Three rock types are available in Upper Palar zone.

(1) Peninsular Gneiss

This is younger than the Dharwarian rocks . The rock embraces a variety of granitic rocks such as massive or porphyritic biotite granite, biotite granite gneiss and foliated varieties. They are massive, coarse grained granites containing quartz , felspar in varying proportions with biotite and hornblende as the common ferro magnesium minerals. They have a general trend of NNE - SSW , and dip at fairly steep angles to the ESE , available at area around Vaniyambadi, Ambur, Gudiyattom, Arani and Arcot.

(2) Charnockite

This is an important group of rocks under Dharwarian . It is holocrystalline, granite, hypersthene bearing rocks. The general constituents of the rock include blue coloured quartz, plagioclase , augite , hornblende and biotite with zircon, iron-ores and graphite as accessories. The general trend of the rock type is NE - SW and dips southeastern direction with amounts of 40 to 50 degrees.

(3) Leptynites :

Generally occurs as an associated rock type with charnockite. It is a leucocratic , granulitic rock and essentially made of quartz and potash felspars with grains of garnets. It is inferred to be a reconstituted and recrystallised facies of Khondalites (garnetiferous silliminite gneiss). In the study area it is found in isolated patches surrounded by charnockite on the eastern side of Vellore town in the hills.

All these rock types are differentiated in the geological map numbered as Fig 4.3.

5. Landuse:

Landuse pattern in Fig 4.4 reveals that 62.7% of the total area of the Upper Palar is covered by cultural command area and the rest is covered by forest which , as compared to the landuse pattern of whole Palar river basin having 79.39% forest and 2.09% of waste land , which seems to be dominated by forest land. Agricultural land is generally double cropped (Khariff + Rabi). Mostly the forest land is deciduous , but small patches of evergreen/semi evergreen, degraded/scrubs are also existing in the zone.

6. Climate & Meteorology:

Rainfall is the only source of recharge to groundwater storage. Average annual rainfall in the region is 930 mm. A representative isohyetal map of the region is appended in Fig 4.5 . Rainfall occurs due to SW and NE monsoon from June to December. River flows only for about 15 days in a year during normal monsoon season Maximum temperature ranges from 30 to 41 and minimum 16 to 25. Hottest month is May . Maximum monthly humidity varies from 85% to 95% and minimum 20 % to 65% . Maximum Humidity prevails in the month of December and January .

7. Water Level Fluctuation:

(1) Short term fluctuation

Monsoon prevails in the region from June to December due to SW & NE monsoon. Groundwater elevation above m.s.l. varies from 320 to 150 . Location of all the observation wells and bore wells are shown in Fig 4.1.

(2) Long Term Fluctuation

Observation at Vaniyambadi (well no. 23023) , and Vellore (well no. 23074) for the year 1972 to 1987 reveal that in well no 23023 the lowest water level recorded is 342.36 m in February 1972 and highest level is 347.9 m in December 1977.Fluctuation in this well is 5.54 m and it is located in weathered granitic gneiss formation and is very close to Palar river . In well no 23074 lowest water level is observed as 231.86m in April 1983 and highest in December 1977 as 243.75 m . Fluctuation is 11.89 m and the well is located in weathered charnockites formation close to the confluence of local drains.

8. Groundwater Process:

The seasonal fluctuation of water level in alluvial aquifer ranges from 0.6m to 4.5 m below GL depending upon the distance from the infiltration galleries and infiltration wells where the maximum fluctuation occurs. The minimum fluctuation occurs at distance greater than about 3 kms from the galleries and infiltration wells. During the average monsoon the water rises with in about 0.6 mt below the surface of the river. In the immediate vicinity of the gallereis, the water does not rise except where there is surface water flow.

In Palar river alluvium,the GWL decline for about first 250 days of the year (Jan to Oct) and then NE monsoon push the recharge rate above infiltration galleries in a locality results in a maximum draw down of about 4 m over 250 days period . During remaining 4 months of the year (Sept to Dec) the GWL is raised by rainfall recharge and eventually reaches its original position . Hence the limiting factor in safe yeild in this case is the effective seasonal recharge and not the depth at which the infiltration gallery is set. GW.development in palar river basin is mainly from large diameter shallow dug wells but their yield are low . The major limitation in the construction of high yielding wells is the absence of good permeable rock . Although the stor age capacity of the rock may be considerable , water is released only slowly . There is only occasional surface flow in the Palar river, above the Palar anicut there is flow for a few days almost every year, however, surplus overflow in Palar anicut occurs only once in about 10 years for a short period. Therefore , the township along the river depended largely on the GW table for the river bed itself by pumping stations which shows that generally full recovery is reached during the recharge period if the draw-down has not been more than 4.2 m , allowing for additional rainfall, recharge of about 1.2 mts in the relatively dry Jan-Sept period. Particularly during SW monsoon rainfall in May , the designed maximum drawdown for a replenishment 25 days period should not be more than 5.4 meters. As the replenishment of the aquifer depends entirely on the direct precipitation , aquifer available potential will be considerably low in years following below average rainfall and in years with complete failure of monsoon rainfall.

9. Agricultural Practices:

This study area lies in the north Arcot district of Tamilnadu. There is hardly any tank in the zone , so mostly the irrigation is done through groundwater only. Crop production largely depends upon the rainfall pattern. Single dry crop is cultivated under rainfed conditions without irrigation. Paddy of medium duration is grown predominantly in the well distributed rainfall areas. In poor water retention areas (upland areas) millets, such as cholum, cumbu, ragi and groundnut are sown.

10. Hydrogeology :

Hydrogeological map shown in Fig 4.6 shows the lineament, faults and dykes . Bed rocks available at a depth ranging from 20 m to 40 m .

Upper Palar zone covers 14 sub basins. According to the well census conducted in December 1991, 80136 numbers of wells are existing in 12 blocks of the region , in which 62 % are electrically driven , 5 % on diesel and 33 % by bullock. In ayacut area the depth of wells ranges from 4 to 18 m. Maximum summer water level is 14 m. Weathered thickness ranges from 2 to 18 m. Pumping during summer ranges from 1 to 8 hours.

In non-ayacut area the depth of wells varies from 5 to 27 m and weathered thickness ranges from 2 to 25m. Summer water level goes down upto 24 m and general pumpintg hours during summer ranges between 1 to 2 hours. Recouperation generally occur within 20 to 24 hours during summer.

In elevated areas, the depth of wells ranges from 5 to 30 m and weathered zone varies from 2 to 23 m. Drawdown during summer is 10m and pumping hour varies from 1/2 hours to 7 hours . In alluvial part of the zone namely in Ramanayakanpatti, Ambur, Begalur and Tuttalam , the depth of wells varies from 7 to 39 m. Summer water level is 35 m below ground level. Duration of pumping during summer varies from 1/2 to 12 hours. Recouperation occurs within 3 to 4 hours during winter and during summer it occurs within 24 hours.

11. Location of Industries :

Number of industries are located in Vaniambadi-Walajapet area , of which tanneries constitute 90 % and rest are chemicals , sugar , soaps , leather goods and paper industries . No treatment plant is in existence,therefore the tannery effluents are disposed directly in to the river . Fig 4.7 shows the location of various types of industries in Upper Palar zone.

5.0 DATA AVAILABILITY

(A) Maps:

The study area is an integral part of Palar river basin. Following maps have been colleted in significance to the physical, hydrological, meterological , geological features .

(1) Index map
(2) Location map of Meterological stations,
(3) Geological Map,
(4) Landuse Map,
(5) Drainage Map,
(6) Hydrogeological Map,
(7) Hydrological Map,
(8) Polygon Map of Observation well,
(9) Location Map of bore wells,
(10) Isoheytal Map,
(11) Industrial Map,
(12) Water Table contour Map for year 1974-75,
(13) Water table contour Map for 1987-88,
(14) Monthly Rainfall and water table fluctuation map for Vaniyambadi and Vellore for the period 1971 to 1988.

(B) Data Informatics:

Various types of data pertains to study area has been collected from Institute for Water studies , State Statistical Department and state ground water department. These available data can be catagorised in five groups.

(a) Meteorological and Surface Water details.

(1) Rainfall Data :

There are 11 raingauges in the upper Palar zones they are vaniyambadi, Ambur, Vellore, Ranipet , Poiney anicut, Odukalathur, Sainagunta, Alangayan, Katpadi, Jolarpet, and Gudiyattam. Monthly data for the period from 1971 to 1990 were available and has been collected .

(2) Climatic data :

There are two meteorological stations existing in the zone. Vellore is the first and is at the tail end of the region and second one, Tarapathur is at the head reach of the study area. Parameter like temperature , humidity , wind velocity , evapotranspiration and evaporation are available on average basis based on the data from 1983 to 1989.

(3) Discharge Data:

Two gauge stations are located in the study area , maintained by state Public works department namely Poiney anicut and Palar anicut . Data for the period 1924-25 to 1987-89 is available with Institute of water studies and hence same is collected. Apart from these two discharge gauge site, Central Water commission is also maintaining two gauge site at Avargikuppam and Arcot respectively.

The data for these two gauge stations are available for the period 1987-88.

(b) Ground Water details.

(1) Exploratory Drilling Data :

Drilling data of 76 borewells existing in the region is available alongwith observations like Depths, static water level, lithology and discharge for some wells. Lithology has been catagorised by layer like Top soil, Kankar , weathered zone, fractured zone and fresh zone.

(2) Ground Water levels :

There are 25 observation wells set up by the state groundwater department, monthly water levels are available from June 1971 to May 1992 alongwith the well characteristics.

(3) Pumped Test data:

To determine the aquifer parameters of granular, fractured and semiconfined to confined aquifer in the basin pump test was carried out by the State Groundwater Department. Pump test data for four dug wells located at Lakshmiammalpuram village of Gudiyattam taluk , Vepankuppam and Pakkampalayam village of vellore taluk and Agaramcheri village of vellore taluk are available. Pumped test data results for 7 bore wells inside the study area, located at Vellore, Thuthukodi Ransupuram, Madhanur, Usur , Arumpaakkam and Narasingapuram are available. All the aquifer details based on these pump test of dug wells and bore wells are summarised at Table I .

(4) Well Census data:

Well census was carried out by State departments in December 1991. These data for the blocks namely Madhanur , Anaicut , Gudiyattom, Pernampet, KV-Kuppan, Vellore, Natrampalli, Kanniyampadi, Alangayan, Katpadi, Tirupattur and walajapet is of interest for the current study. Census details are enumerated in Table II . The trend for the increase in the number of wells has been 5% every year as per the conclusion made and suggested by Institute for water studies.

(5) Ground Water Draft:

Net ground water draft for 13 blocks under Upper Palar zone in North Ambedkar district as on January 1992 has been supplied by the State Ground Water Department. This can also be appreciated from Table II .

(c) Agricultural Details.

Landuse pattern , Irrigation practices , Cropping pattern, Irrigation water requirement details are collected from seasons crop report of Tamilnadu published by Directorate of Statistics, Madras for North Arcot-Ambedkar district as a whole. The report shows that in the year 1990-91 the region has 778 Ha irrigated by canal, 683 Ha irrigated by Tanks and 76330 Ha irrigated by ordinary private wells. As compared to that the study area which is a part of the above said region is solely irrigated by groundwater . All these details are summerized in Table - III of this report. No details were available for consumption of fertilizers and its chemical components.

(d) Industrial Details.

Village wise number and type of industries present in North Arcot district is available based on Survey carried out in the year 1980. Where as total number of small scale industries present during year 1991 is 778 as per statistical department. There is no treatment plant yet commissioned in the region , therefore no details are available pertaining to treatment and disposal of effluents. However, some of the photographs taken on the spot during the site visit is enclosed for ready recurrence of the situation pertaining to the industrial waste disposal. Available details are given in Table IV .

(e) **Water Quality Data.**

Chemical analysis Data for 25 representative control wells are available for the period 1972 to 1990. Number of parameters available are 14 for both pre and post mansoon . Surface water quality data for few locations are available only for December 1979 and 1990. No surface water quality data available at the disposal point of tannery effluent in Palar river basin. Some of the available surface water quality details are appended in Table V.

6.0 METHODOLOGY

Ground water quality study comprises of scientifically aspired surveillance system of continuity observation, data collection and evaluations. It may not only include the analysis of water quality but also determination of ground water levels and flow directions, measurement of moisture in the unsaturation zone, geophysical surveys and evaluation of wastes and other materials contributing subsurface pollution.

(A) Data collection:

Based upon the nature a complexity of the problem following data are required for the analysis.

(1) Surface/Subsurface	(1) Topography (2) Lithology - (1) bore data (3) Town /dums
(2) Hydraulic Data	(1) Permeability (2) Porosity/storativity (3) Piezometry (4) Stream/Aquifer interactions
(3) Water Balance Data	(1) Meteorology (2) Agriculture (3) River, Lakes (4) Evaporation (5) Evapotranspiration (6) Springs (7) Pumped Abstraction (8) Aquifer interflows (9) Lateral inflow
(4) Chemical Data	(1) Polluton sites (2) Water quality (3) Leathal chemistry (4) Absorption/desorption (5) Hydrochemical reaction

(B) Data Preparation :

It can be divided into two components:

(1) Spatial components
(2) Temporal components

(1) Spatial component

Under this catagory following maps are to be prepared.

(1) Aquifer structure
(2) Aquifer priexometry
(3) Surface Activities
(4) River

(2) Temporal component

This includes :

(1) Preparation of Hydrographs
(2) Tabulation of changes in (1)Abstraction
(2)Population
(3)Agriculture
(4)Operating policy
(5) chemical inputs.

(C) Analysis of Available Data:

Analysis of data is to be done to define:

(i) Flow systems
(ii) Water Balance volumes
(iii) Reactance of system
(iv) Areas of uncertainity

(i) Flow System

The directions of flow are largely dependant on the geometry of the geological formations comprising the Aquifer, their hydraulic characteristics and the topography of the land surface overlyng the formations coupled to the available sources of infiltration or recharge water. The ground water flow distribution within an aquifer may vary substantially over time in response to change in the natural recharge/discharge distribution and through development of the aquifer system as a source of water supply.

(ii) Water Balance Volumes

Estimation of water Balance volumes consist of Estimation of two basic component of Hydrological cycle, they are :

(1) Recharge
(2) Discharge

(a) Estimation of Ground Water Recharge

(1) Recharge from Rainfall (Ri):

Adhoc norms are as stipulated below.

(i) Alluvial Areas

(a) In sandy areas -- 20 to 25 percent of normal rainfall

(b) In areas with higher clay content-- 10 to 20 percent of normal rainfall.

(ii) Semi consolidated sandstones-Friable and highly porous --10 to 15 percent of normal rainfall.

(iii) Hard Rock Areas

(a) Granitic Terrain

Weathered and fractured--10 to 15 percent of normal rainfall.

Unweathered -- 5 to 10 percent of normal rainfall.

(b) Basaltic Terrain

Vesicular and jointed --10 to 15 percent of normal rainfall.

Weathered Basalt -- 4 to 10 percent of normal rainfall.

(c) Phyllites, limestones, sandstones, quartzites, shales, etc. -- 3 to 10 percent of normal rainfall

(2) Recharge due to seepage from unlined canals (Rc):

Ground water over Exploitation committee has recommended following norms for considering recharge due to seepage from unlined canals

(i) For unlined canals in normal type of soil with some clay content along with sand - 1.8 to 2.5 cumec/Msqm of wetted area of canal.

(ii) For unlined canals in sandy soils.- 3 to 3.5 cumec/Msqm of wetted area of canal.

(iii) For lined canals the seepage losses may be taken as 20 percent of the above value.

(3) Return seepage from Irrigation fields (Rr):

(i) Irrigation by surface water sources

(a) 35 percent of water delivered at the out let for application in the field. The variation in percentage of seepage may be guided by studies undertaken in the area or in a similar area

(b) 40 percent of water delivered at outlets for paddy irrigation only

(ii) Irrigation by Groundwater sources

(a) 30 percent of water delivered at out let
(b) 35 percent for paddy irrigation

(4) Seepage from Tanks (Rd):

(i) 44 to 60 cm per year over the total wider spread area.

(ii) 50 percent of Gross storage for percolation tanks.

(5) Contribution from influent seepage (Si):

Influent seepage from the river with a definite influent nature may be computed by using Darcy's law.

Q = T*I*L where Q= rate of flow
T= Transmissivity of the aquifer
I= Hydraulic Gradient
L= Length of section through which flow is taking place.

(6) Inflow into the basin from other basins (Ig):

The same can also be calculated through Darcy's law mentioned at (5) considering L as length of interconnected basin boundaries.

(b) Estimation of Groundwater Discharge.

(1) Evapotranspiration (ET) :

Transpiration by deep rooted trees result in depletion of groundwater equivalent to supplementary water requirement of tree for its growth.

(2) Draft from ground water (Tp):

Draft is the amount of water lifted from the aquifer by means of various lifting devices The withdrawal can be made by means of (i) deep tube wells (ii) shallow tube wells (iii) pumping sets (iii) rahat and other measure.Well census data is the prerequisite for computation of the ground water draft.This includes:

(1) No of wells present in the area including all types like state, private and open etc

(2) Use

(3) Type of Pumps

(4) Running Hour of pumps

(5) Average discharge

(3) Effluent seepage to rivers (Se):

A river may have a going reach depending upon the relative water levels in the river and the adjoining aquifers. Contribution is confined to a relatively small strips adjoining the stream.

(4) Outflow from the Basin to other basin (g):

Process is same but in opposit directions that of mentioned at (a)(6).

(5) Evaporation from shallow water table (E):

This is the loss of water from capillary zone. These losses reduce to negligible proportion once the water table falls about 3 metres below ground level.

Taking all the above factors into account ground water balance equation will be :

$$Ri + Rc + Rr + Rd + Si + Ig = Et + Tp + Se + Og + E + S$$

Where S is the change in ground water storage.

Groundwater recharge calculation on the basis of water level fluctuation may be carried out through the following relationship.

Recharge = Sp. yield * Waterlevel Fluctuation * topographic area

(iii) Reaction of the system

The wide range of contamination sources is one of many factors contributing to the complexity of ground water quality assessment . It is important to know the geochemistry of the chemical-soil-ground water interactions in order to assess the fate and impact of chemicals discharged on to the ground . Chemicals will pass through several hydrologic zones as they migrate through the soil to the water table.

The water table (the level at which water stands in a shallow well) is the upper surface of the ground water system. The pore spaces between soil particles above the water table are occupied by both air and water (the unsaturated zone). Flow in this zone is vertically downward, as liquid contaminants or solutions of contaminants and precipitation move under the force of gravity.

The uppermost region of the unsaturated zone (the soil zone) is the site of important processes leading to pollutant attenuation. Some chemicals are trapped in this zone by adsorption onto organic material and chemically active silt and soil particles; there they are decomposed through oxidation and microbial activity. Many end-products are taken up by plants or released into the atmosphere.

Below the soil zone , the pore spaces are also unsaturated, and as chemical bearing precipitation percolates through this zone, oxidation and aerobic biological degradation continue to take place. Some chemicals are also adsorbed in this zone. and precipitates may be filtered out.

In the capillary zone, spaces between soil particles may be saturated by water rising from the water table under capillary forces. Certain chemicals that are lighter than water will float on top of the water table in this zone. These floating chemicals may move in different directions and at different rates than contaminants dissolved in the percolating recharge.

Once dissolved contaminants reach the water table, they enter the ground water flow system- the direction of which depends upon the hydraulic gradients. All pore spaces between soil particles below the water table are saturated. The relative unavailability of dissolved oxygen in the saturated zone limits the potential for oxidation of chemicals. Varying levels of attenuation may take place, depending on the geologic conditions.

Unlike the turbulent flow of surface water systems, ground water flow is laminar; particles of fluid move along distinct and separate paths, with little mixing occuring as the ground water moves . Dissolved chemicals in the saturated zone will flow with the ground water. The direction of flow is governed by hydraulic gradients, and ground water will move in response to differences in hydrostatic head.

The major componens of the flow system are the recharge area (where flow is generally downward) and the discharge area)where flow may be generally upward). The direction of flow in a shallow, local flow system could in some cases be opposite to flow in a deeper flow system. The ability of a monitoring well to detect the presence of a plume is therefore based on the location and depth at which the well is set. Knowledge of the flow system is an essential precondition in assessing chemical contamination problems, and a monitoring program implemented without adequate hydrogeological information can be very misleading.

Groundwater flow rates in aquifers generally range from a few inches to a few feet per day. A body of contaminated ground water may contain the accumulation of decayes of luachate discharge; and it may take many years to contaminants to be detected in a nearby water supply.

Because ground water flows in a laminar fashion, dissolved chemicals will follow ground water flow lines and form distinct plumes. Plumes of contaminated ground water have been traced from a few feet to several miles downstream of the pollution source.

The shape and size of a plume depends on number of factors, including the local geologic framework, local and regional ground water flow. the type and concentration of contaminants, and variations in the rates of leaching. illustrates the shapes of two plumes of contamination in different geologic settings and lengths of time it took for them to develop.

The fact that chemicals are attenuated in the soil through adsorption and chemical interaction with other organic and inorganic constituents of the aquifer makes it difficult to predict the movement and fate of chemicals in the ground water. Volatile organic chemicals in ground water are extremely mobile while other chemicals are not so mobile. There are differences in attenuation through sorption, and some chemicals are less changed in the ground water environment than are others.

The density of contaminated fluids is another important factor in the formation and movement of a plume. Some chemicals will tend to flow on top of the water table, while others will tend to sink to the bottom.

Discontinuous discharges may result in slugs of contaminated water, causing wide spatial and temporal fluctuations in well water quality Lenses of sand and clay can cause other variations by stratifying the contaminants.

Therefore conceptual appraissal of the aquifer system based upon the spatial and temporal components assign the reaction of system.It includes the mobilization of the ideas about following factors.

(1) Source of pollutants.
(2) Balance of pollutants.
(3) Mechanism behind the process of contamination.
(4) Spatial variation of the contaminants
(5) Temporal variation of the contaminants.
(6) Break up details of the contaminant.
(7) Remedial measures,if any.

(iv) Areas of uncertainities.

Identification of the areas,which are no more a certain source of water supply ,in terms of ground water quality,so that it can be eliminated or treated to bring to acceptable level of contamination for a particular use,while dealing with groundwater management problem ,is of prime importance .

7.0 APPLICATION AND OUTPUT

In uper Palar zone of palar river basin changes in quality of water may be due to the discharge of untreated effluents from tanneries and other industries located in the region or due to extensive use of fertilizers in the command areas for agriculture or may be due to both simultaneously. To provide appriate answers to the questions put up at the time of defining the problem, various, operations with the available data have been carried out. Outline of these operations are listed below.

(1) Details of the aquifer structure, aquifer priexometry; land use and river

(2) Yearly rainfall pattern

(3) Representative Hydrographs along with respective periodical TDS value

(4) Water Table contour

(5) Groundwater Recharge estimation through water level fluctuation details

(6) Yearly ground water balance operation

(7) Yearly balance of Total dissolved solids

(8) Isoplate for average TDS variation over the entire zone

(9) Horizontal Pattern diagrams

(10) Relation between ground water balance and TDS balance

(11) Ground water recharge and Balance of TDS variation for individual wells

(12) Plot for the trend of yearly variation of TDS

(13) Variation of TDS concentration with rainfall.

Following outputs have been worked out from the operation as discussed above.

7.1 Based on the lithology of the bore hole dıilled along the two banks of Palar river, aquifer structure and proximetry has been plotted as shown in fig. 7.1(a) and 7.1(b) Out crop boundaries have also been located to define the aquifer boundaries . Aquifer structure mainly consist of very thin layer of soil cover, followed by weathered zone and fractured zone in considerable fractions. Landuse pattern or surface activities on this aquifer basin is depicted in fig. no.4.4

7.2 Vaniyambadi, Ambur and Gudiyattam are the three R.G. stations inside the region, which is experiencing acute groundwater quality pollution problems. Yearly rainfall pattern of these raingauge stations are plotted along with the yearly average precipitation values for the entire basin. 75% dependable rainfall demarcation has also been drawn in the same plot depicted as fig. 7.2.

7.3 Hydrographs on the basis of monthly groundwater levels have been drawn for 7 selected wells at vaniyambadi (well no. 23023) Minnur(well no.23000), Ambur (well no. 230274), Vengili (well no.23081), Kailasagri(well no. 23049), Gudiyattom (well no. 23029) and Pernampet (well no. 23030).. Pre-monsoon and post-monsoon TDS values have also been traced on the same plot as shown in fig. 7.3(a), 7.3(b), 7.3 (c), 7.3(d), 7.3 (e), 7.3 (f), 7.3 (g) respectively.

7.4 To observe periodical variation in the region, water table contours on the basis of Pre- monsoon and post- monsoon water tables for the observation wells are drawn for the year 1974-75, 1987-88 and 1990-91. These are depicted in fig. 7.4(a), 7.4 (b) and 7.4 (c)

7.5 Yearly ground water Recharge estimation has been done on the basis of monthly water level fluctuation data of the observation wells of the region. These calculations have been done on tabular form as in Table vi. Specific yield values are taken up well wise, suggested by Institute of Water studies on the basis of pumping test results. Polygon area from fig. 7.5 under each well has been considered for topographic area.

7.6 Yearly ground water balance has been calculated as depicted in Table vii based on rainfall recharge. Parameters considered are given below.

(a) Polygon map of the basin is as shown in fig. 7.6.

(b) Recharge from Rainfall is 15% of Average rainfall, as recharge is from granitic weathered and fractured terrain.

(c) Recharge from Return seepage is considered as 25% for Paddy crop and 15% for other dry crops. Reason being that the cultivation is done through well irrigation and also it is mostly rain dependant.

(d) Influent and effluent seepage contribution for tanks, canals, rivers and other basins have been considered as nil, because there is no tanks or canals are existing in the study area and river flows for only 15 days in a year and ground water level is below bed level.

(e) Draft of ground water has been calculated block wise shown in table vii for well census year 1991. Trend of ground water increase has been considered as 5% every year as per the guidelines given by Institute for water study

(f) Evapotranspiration and evaporation from the capillary has not been considered because there is no deep rooled trees in the study area and water table remains well below 1-5 m. from the ground level in most part of a year.

7.7 Yearly balance of dissolved solids have been estimated yearwise and well wise in table viii considering unit volume of water.
Notations used are as below -

Balance + ive if Premansoon is > Post monsoon
Balance - ive if Premansoon is < Post monsoon.

7.8 Spatial variation of average TDS values based on data from the year 1971 to 1990 over the study area has been depicted premonsoon and post monsoon basins in fig. 7.8 (a) and 7.8 (b) respectively.

7.9 Break-up details of the total dissolved solide at selected 7 locations i.e. Vaniyambadi, Ambur, Minnur, Vengili, Kailasagiri, Pernampet and Gudiyattam, are expressed in terms of Horizontal

Pattern diagram (stiff 1953) for the year 1972, 1977, 1982, 1987 and 1990 for premansoon and post monsoon. All these details are depicted vide fig. 7.9 (a), 7.9 (b), 7.9 (d), 7.9 (e), 7.9 (f) and 7.9 (g).

7.10 Yearly ground water balance as calculated in para 7.6 and yearly average balance of total dissolved solid as estimated in para 7.7 are plotted on the same plote to have an idea about the relation between the two natural phenomenon. This operation has been carried out for the entire basin as a Groundwater system. The plot has been numbered as fig. 7.10 .

7.11 Groundwater recharge estimated in para 7.5 have been plotted well wise for 7 most polluted wells of the region alongwith the balance of total dissolved solid estimated, well wise in para 7.7 of this report. This wells are located at Vaniyambadi, Ambur, Minnur, Vengili, Kailasagiri, Pernampet and Gudiyattam. This has been included in fig no. 7.11 (a), 7.11 (b), 7.11 (c), 7.11 (d), 7.11 (e), 7.11 (f), and 7.11 (g) respectively.

7.12 Figure 7.12 (a), 7.12 (b), 7.12 (c), 7.12 (d), 7.12 (e) ,7.12 (g) and 7.12 (g) shows the trend of yearly variation of total dissolved solids at the location; Vaniyambedi, Ambur, Gudiyattam, Pernampet, Kailasagiri, Vengili and Minnur respecively.

7.13 To observe the influence of precipitation on the TDS concentrations three stations named as Vaniyambadi, Ambur and Gudiyattam has been selected which has both observtion well and R.G. station very close to each other. Total yearly rainfall has been an abscissa and corresponding TDS concentration of the ordinate. Best fit line has been achieved based on power transformation to see the trend of the convey. They are depicted at fig. 7.13 (a), 7.13 (b) and 7.13 (c) respectively.

8.0 DISCUSSION

Hydrological features of the Palar river basin is an unique one, as the river flows only 15 days in a year i.e. only during heavy and long durational storm . Moreover the Upper Palar zone lies in the head reach of the basin in Tamilnadu. This region has no other source of domestic and irrigation water supply other than subsurface water. Not long back in North Arcot district, of which the study area is an integral part , had a reputation of being one of the best for its agricultural production capability , but subsequently during last 5 to 10 years groundwater qualty deteriorated to such an extent that the socio economic condition of the locality got badly effected to large extent.Results of the analysis are stipulated below.

8.1 Aquifer structre and Priexometry reveals that the study area has good groundwater potential which is locally recharged by rainfall. A soil cover of 25 cm to 90 cm of Redloamy to Alluvial soil provide a good permeable media to act as an appropriate recharge zone. Two layers of weathered and fractured zone is followed by bed rock of gneiss which is an impermeable strata and thereby heaving good water retention capacity. In all geologic condition give rise to the formation of a unconfined aquifer of very good zone of replenishment and transmission.

8.2 Rainfall pattern in the study area is more or less of well distributed nature. 75% dependable rainfall on the basis of last 20 years data comes out to be 800 mm. Monsoon starts some times in the month of May-June and lasts upto December- January. Pattern of the record reveals that , year 1973, 1980 and 1982 experienced less rainfall than the dependable, and maximum precipitation occurred in the year 1983.In fact , hardly any period of dry years lasted for more than one year. Always there is year of less rainfall followed by good rainfall year.

8.3 Ground water level fluctuation in the key locations suggest that ground water level attains the original status after the monsoon. There have been steep fall in the water levels in the year of less rainfall but it has subsequently recoverd in the next year having sufficient rainfall . no noticeable over extraxction is seen in the study area.

8.4 Ground water level contours for the year 1974-75 and 1987-88 and 1990-91 reveals that the direction of groundwater movement is from NW to SE. Trend of the gradient of water table contours is more or less same as the ground level contours plotted in fig 7.1(a) . Hydraulic gradient of ground water is 2.39 m/km.

8.5 The network of observation wells available are not uniformly distributed in the region there by some polygon areas are representing quite a large areal extent ranging from 183 sq.km to 216 sq.km. Groundwater recharge in these area may not project the actual picture. However Ground water recharge has been claculated considering all the 25 observation wells from year 1974 - 1975 to 1989-1990, as per the availabilty of water level fluctuations. Table vi shows that minimum recharge occurs in year 1980-81 and maximum in year 1981-82 and then in year 1983-84 which is quite relavent with the rainfall pattern of the region.

8.6 Theissen polygon method has been used as far as possible for estimating the average precipitation value over the region. However , there is no much difference between the average precipitation value calculated through Arithmetic mean and theisson polygon method.Raingauges are quite well distributed but mostly on the plains . therefore average value of precipitation may lack the weightatge of the topography.Ground water balance through rainfall recharge has been estimated yearwise. Again year 1980-81 shows the over extraction year and maximum balalnce being in the year 1983-84.

8.7 Yearly balance of TDS is estimated well wise and then it has been averaged over the entire area. Missing data in some of the years confine the output to the period of 11 years, i.e., 1976-77 to 1986-87. During this period average balance show that premonsoon TDS was more in the year 1980-81, 1984-85 and 1986-87 and post monsoon TDS is more in the year ,1976-77,1985-86 and 1982-83. However averaging the balamce may not pridict the authentic subsurface water quality environment, but may lead to overall picture of the system.

8.8 Spatial variation for years 1975-1990 with a five year interval reveals that pollution is spreading in the region with a slow and steady rate. However, the conditions seems more improved in the year 1990 due to the wide range of variation in the TDS values of the well 23030,in Permampet which ultimately was found misused by local people since long time. Apart from that TDS values are quite high in Vaniyambadi, Ambur, minnur, Pernampet and Vengili locations.

8.9 Pattern diagrams prepared for 7 badly effected locations depict that generally sodium and chloide contents are comparatively more in all the loctions and condition is deteriorating with time. In some place like Vaniyambadi, Ambur,Minnur, Vengili, Kailasagiri and Gudiyattam, bicarbonate is more but seems to be fluctuatig with time. Megnisim content is more, especially at Pernampet , Gudiyattam and Kailasagiri and also showing a increasing trend with the time.

8.10 Yearly balance of ground water and TDS plotted in the same plot shows that when ground water balance is more . TDS balance is less and vice versa except few data locations where same lag between respective peaks and troughs are noticed. This shows the reaction of the system as a whole.

8.11 Yearly variation of Recharge values for 7 selected wells in the region which are doubted to be badly effected when plotted along with the TDS fluctuation reveals the same fact , when the wells are getting good recharge, TDS concentrations are reducing. In some cases time lag between the two phenomenon has been observed.

8.12 Observation of trend of TDS variation over the last 20 years for 7 most badly effected wells depicts that there is overall an increasing pattern of TDS existing but gradient is , drastic in Minnur , Ambur and Pernampet, and not much in Vengili and Gudiyattom. In Vaniyambadi and Kailasagiri it is in the transition zone. However, site inspection guides to the fact that well at Pernampet is unused since long and badly effected due to misuse by the local people.

8.13 Best Fit plot between Rainfall and TDS concentration of respective locations and years states that in general concentration is reducing when rainfall is increasing. Effect is significant in the case of Ambur.

9.0 CONCLUSION

Basic aim of this phase of the study is to cover the preliminary date collection processing and analysis of various details of Upper Palar zone in Palar River basin to have an solid conceptional base before proceeding for the complex, methodology of mathematical modelling. Through various types of operations and analysis series of basic questions put up at Para 3.0 has been tried to be answered to possible extent which in turn becomes the concluding point of present phase.

- Total dissolved solids are much more in the locations like ,Ambur, Minnur, Vengili, Kailasagiri, Gudiyattam and Pernampet. Breakup details shows that sodium and chloride concentration are more in all the above said locations and with an increasing temporal trend. Bicarbonate is found more in Vaniyambadi, Vengili, Kailasagiri and Gudiyattam. In Ambur and Minnur it is more in some years but reduced subsequently with good amount of rainfall.

- IS 10600-1983 depicts that for drinking purpose desirable limit for TDS is 500 mg/l and tolerance level is 1500 mg/l. Therefore locations like Vaniyambadi, Ambur, Minnur, Vengili, Pernampet has already crossed the tolerance limit. Gudiyattam and Kailasagiri has also crossed the desirable limit but yet to reach the tolerance limit as far as drinking purpose is concerned. Water for some of the wells may well be used for irrigation but overall picture is grim as bicarbonate content is more in most of the locations.

- In general contaminant level of the ground water system has been on the increasing trend. Most effected areas are Ambur and Minnur.

- The study reveals that contanminants are more when groundwater recharge is less that is when rainfall is less. Therefore it may be concluded that if proper flushing arrangement of the surface and sub-surface contaminants can be made during dry periods, the contaminant levels may be controlled.

- Overall picture of the deteriorating phenomenon reveals that source of pollution may be largely due to the disposal of untreated affluence from tanneries and other small scale industries. This may be joined hands by some non- point source created through excess use of fertilisers in the command area. Increase of the numbers of tanneries are manifold in the Vaniyambadi- Ambur region. Effluent tanneries should be treated before disposal to the river which is the only way to protect further deterioration.

10.0 RECOMMENDATIONS

Preliminary data analysis reveals following recommendations however it has to be supported by thorough and finer approach of mathemtical modelling techniques.

(1) Source of pollutant seems to be untreated effluents from tanneries to a larger extent. Till this date no treatment plant has been commissioned in this region. First common treatment plant ready for commissioning covers only 80 tanneries which has to be increased manifold.

(2) Problem of contamination is more acute due to no surface flow available for flushing of the untreated tanneries. Some storage arrangement has to be developed in the upstream of Vaniyambadi so that recharge and flushing can be done during water scarce periods and years.

(3) Unused wells like Pernampet (well numbr 23030) should not be monitored which misleads the overall strategies for quality control measures. More frequent sampling may be done atleast in the worst affected areas and the areas just adjacent to it .

(4) Number of observation wells may be increased to have an well distributed overall picture.

(5) Water quality samples at industrial affluent disposal point is recommended . Which has been checked on the spot in various points and in most of the places the value was more than 10,000 mg/l.

(6) Management studies may be carried out incorporating hydrological model and optimisation techniques.

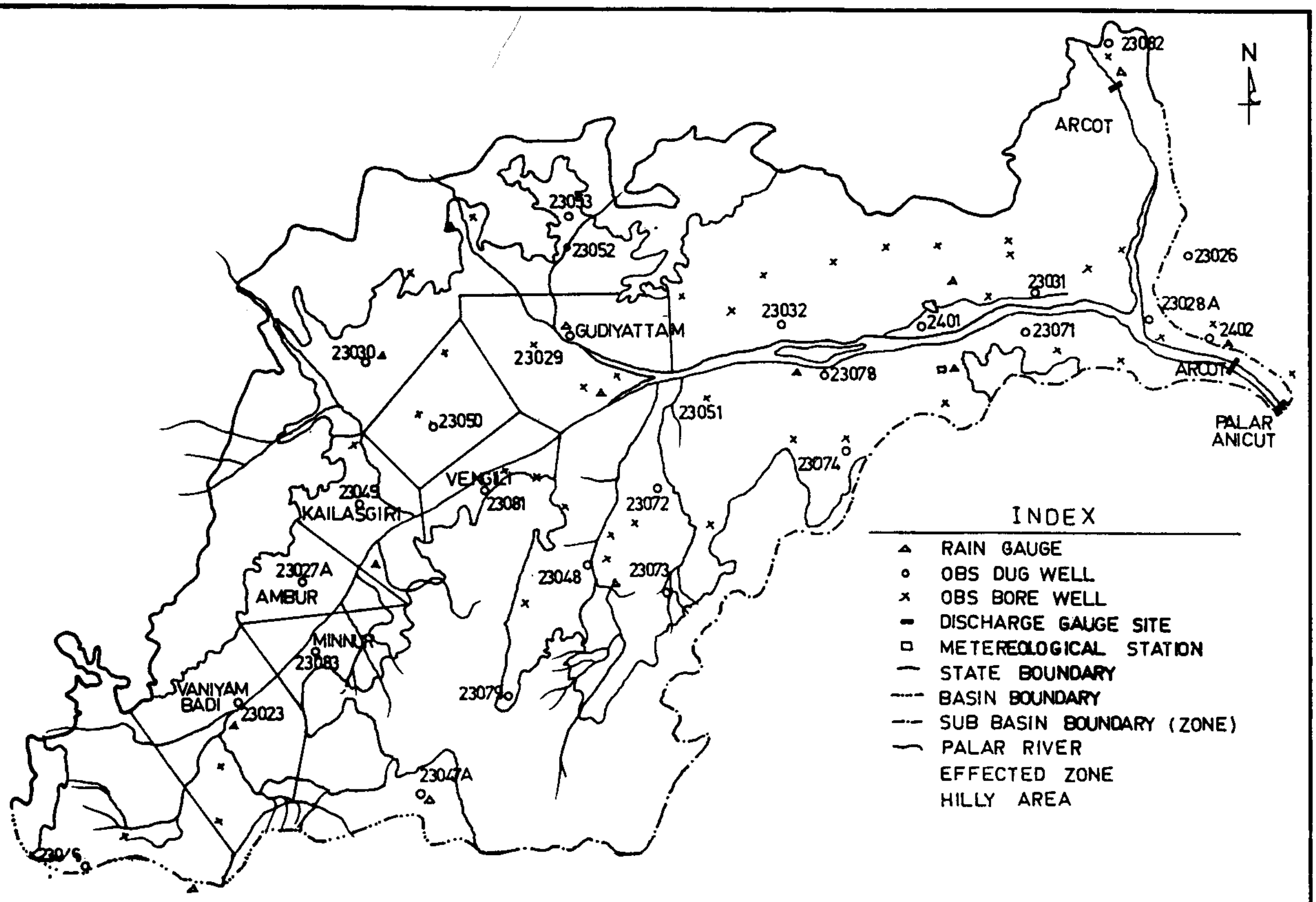


FIG. 4·1. PALAR RIVER BASIN UPPER PALAR ZONE.
DATA COLLECTION SITE AND LOCATION MAP.

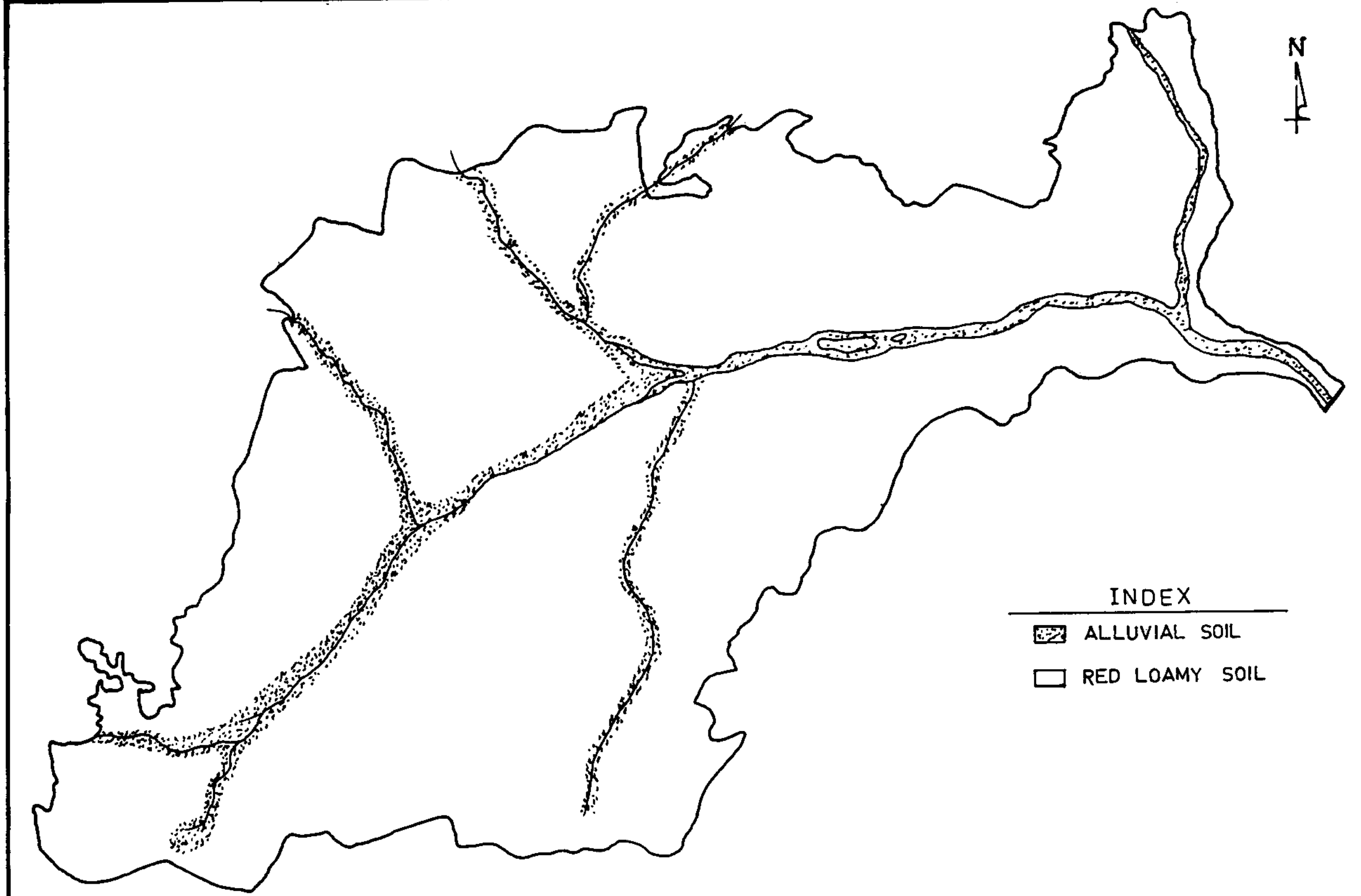


FIG. 4·2. PALAR RIVER BASIN UPPERPALAR ZONE.
SOIL.

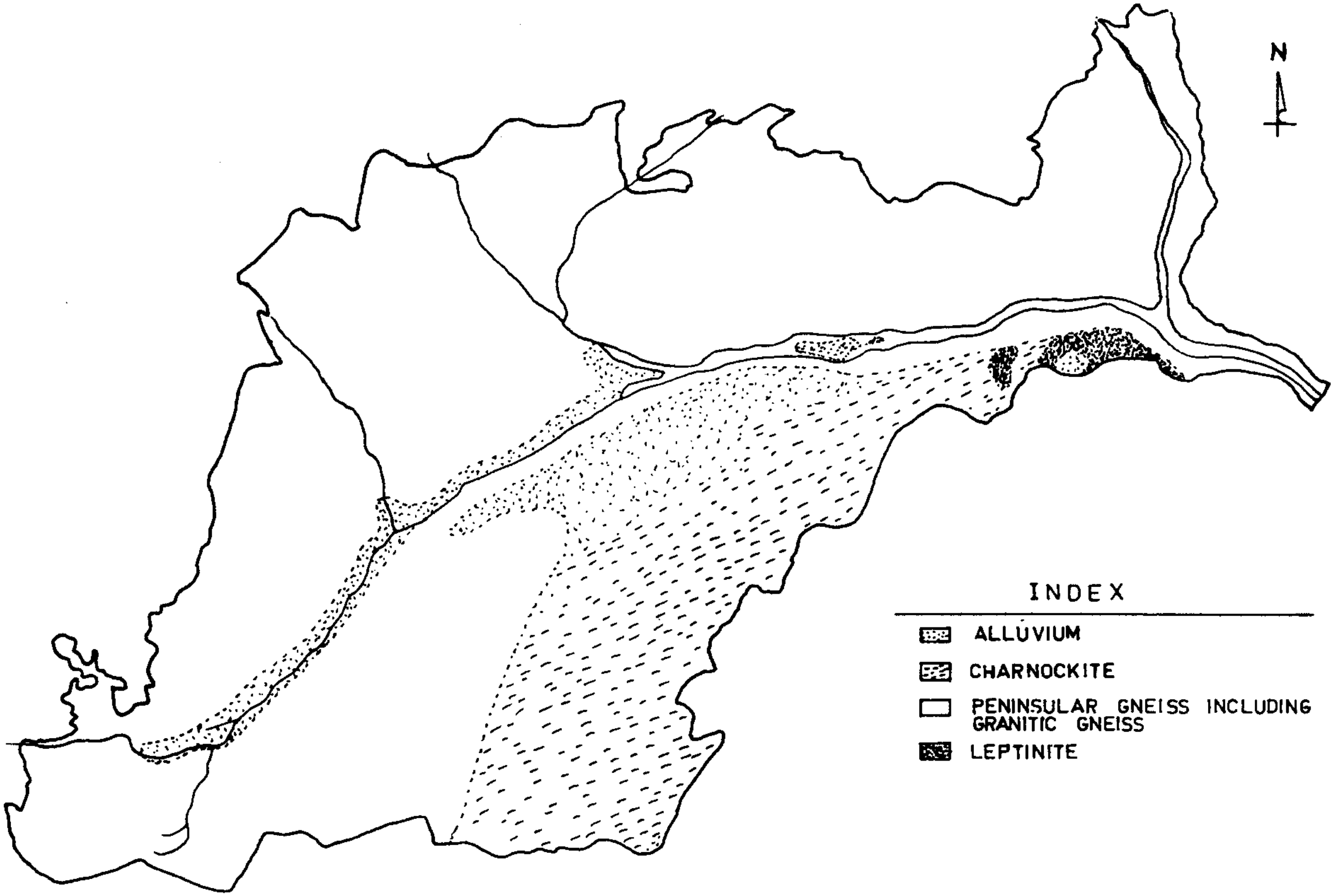


FIG. 4·3. PALAR RIVER BASIN, UPPER PALAR ZONE. GEOLOGY

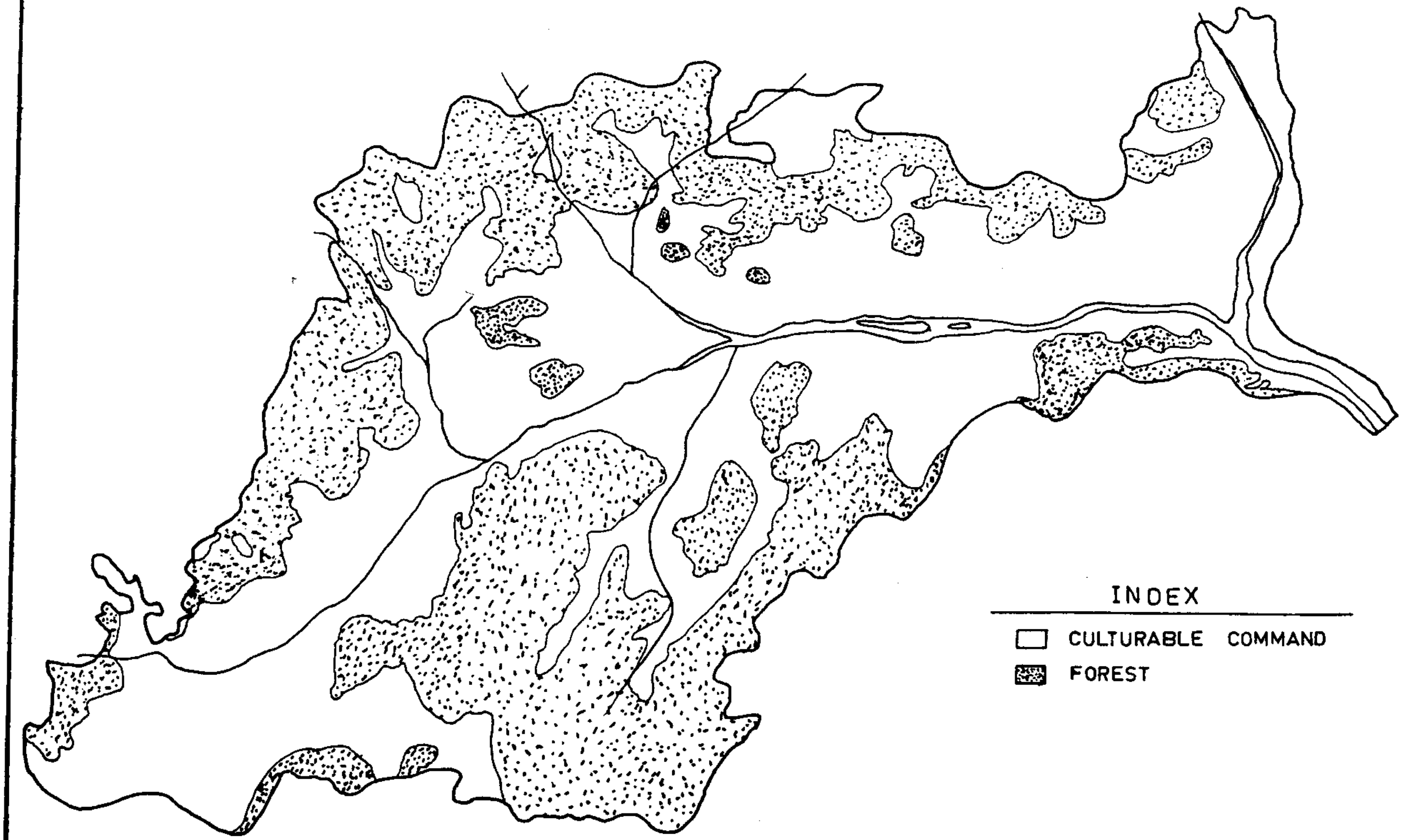


FIG. 4-4. PALAR RIVER BASIN, UPPER PALAR ZONE.
LANDUSE MAP.

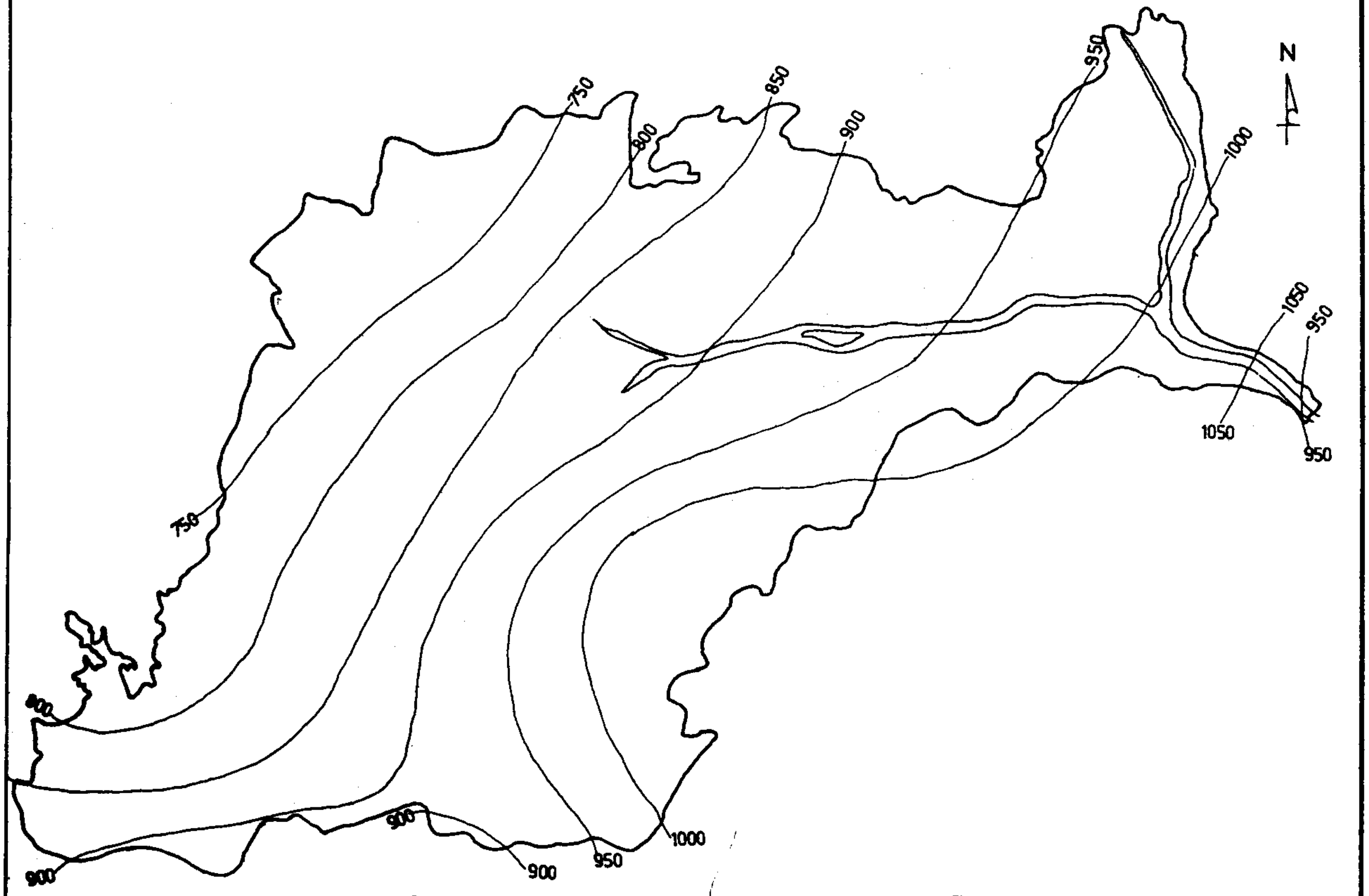


FIG. 4·5. PALAR RIVER BASIN. UPPER PALAR ZONE.
ISOHYETS (IN MM)

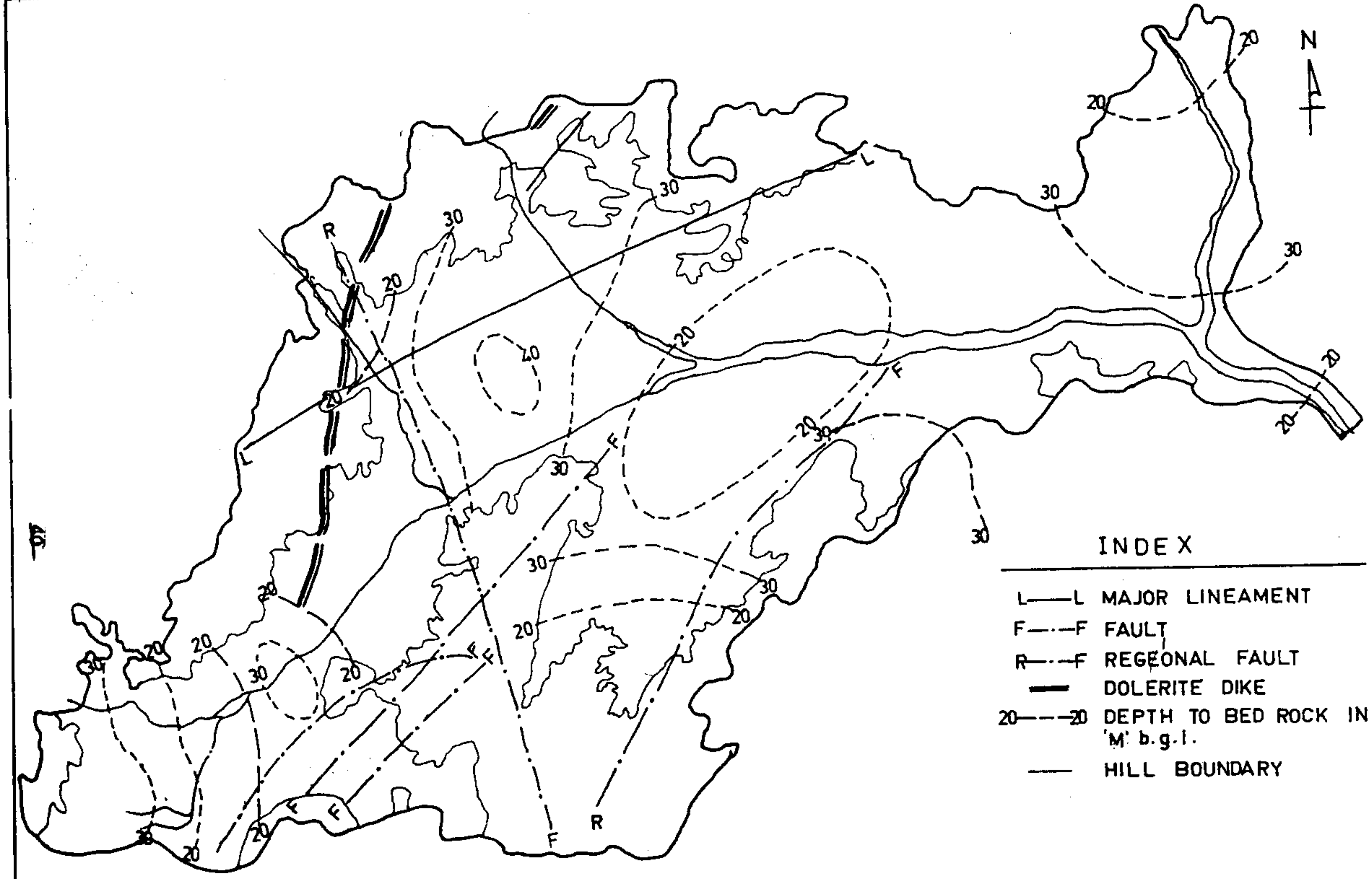


FIG. 4·6. PALAR RIVER BASIN; UPPER PALAR ZONE. HYDROGEOLOGICAL MAP.

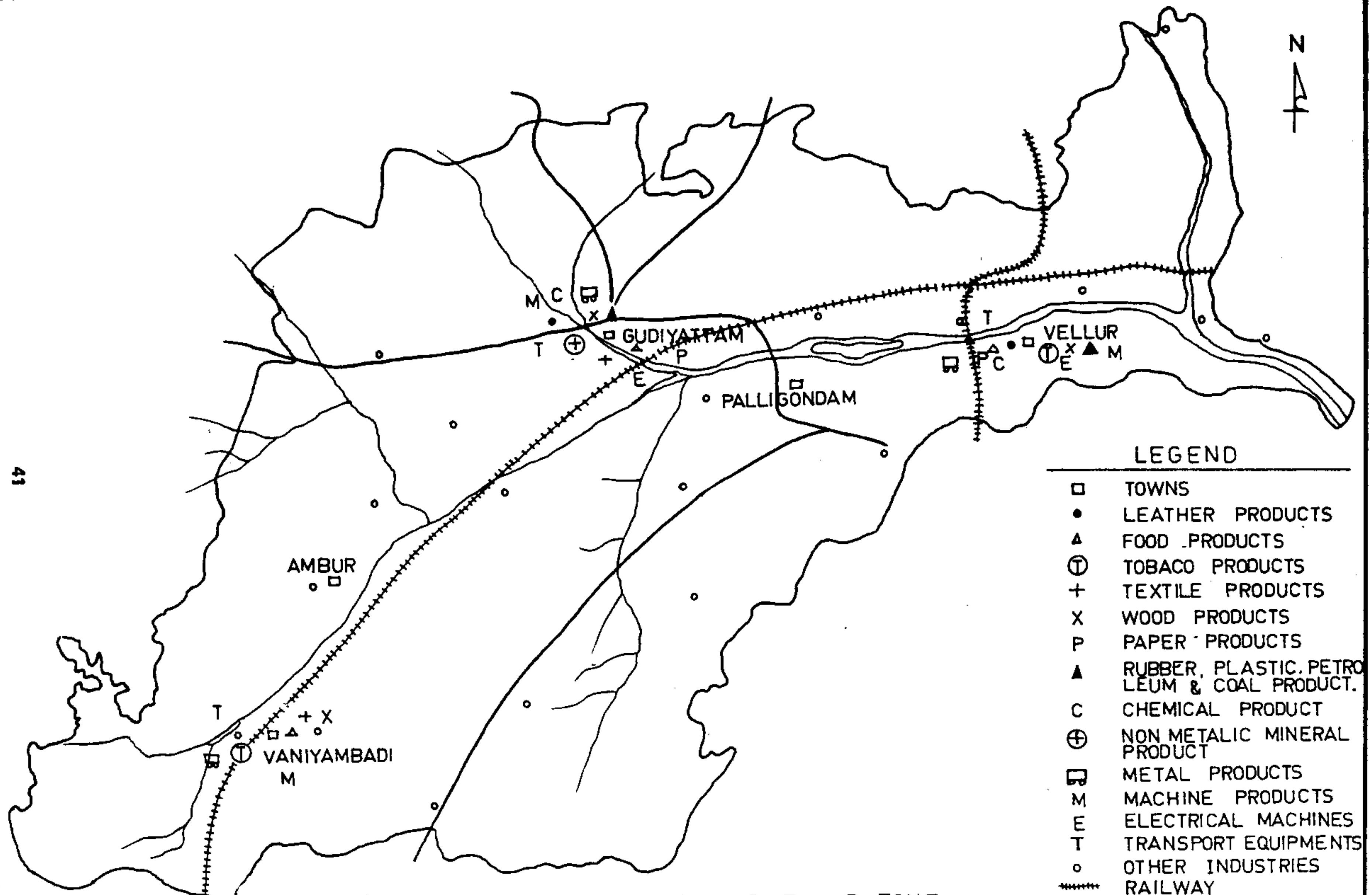
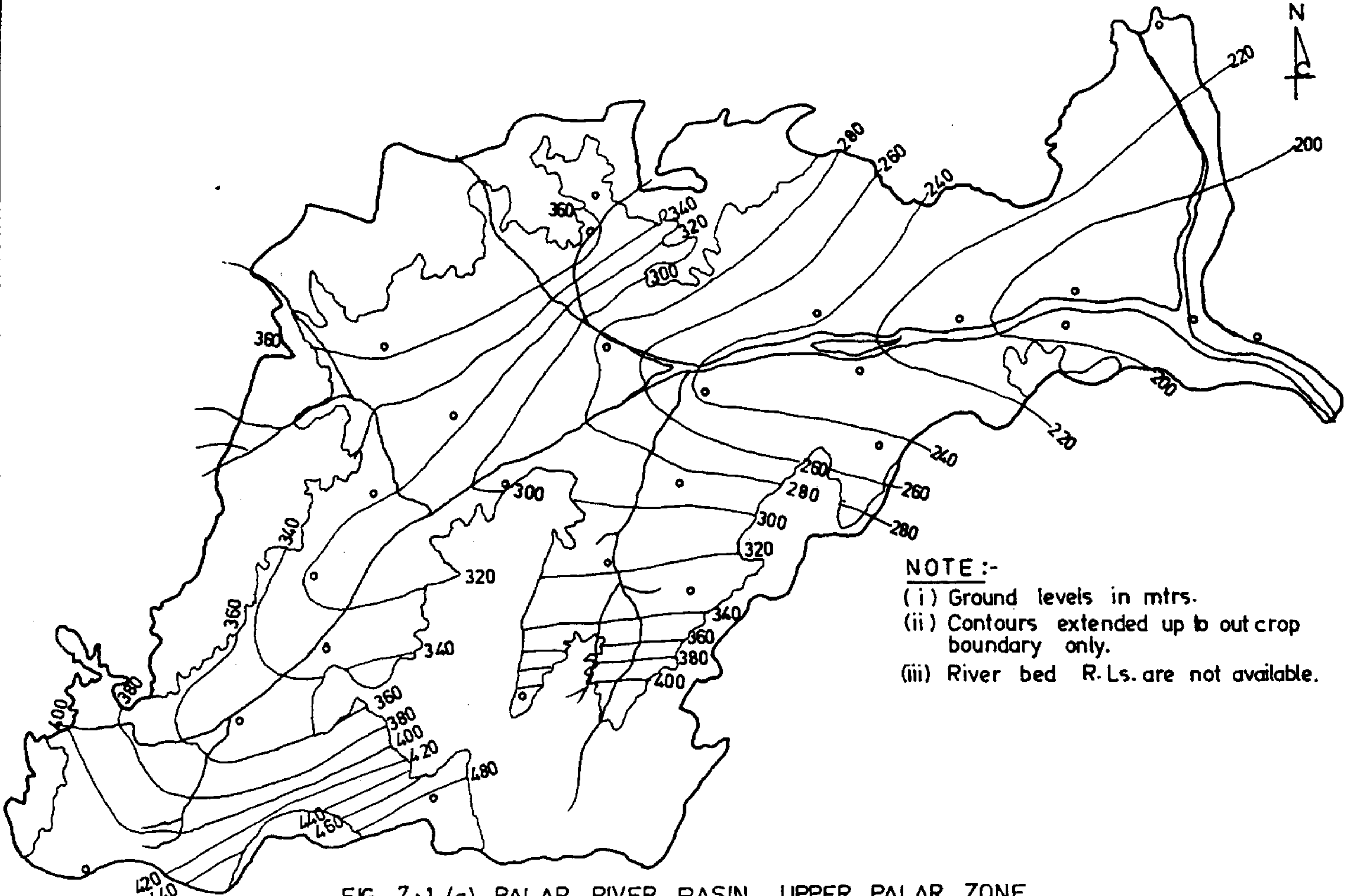


FIG. 4·7. PALAR RIVER BASIN; UPPER PALAR ZONE.
INDUSTRY LOCATION MAP

41



NOTE :-

(i) Ground levels in mtrs.

(ii) Contours extended up to out crop boundary only.

(iii) River bed R.Ls. are not available.

FIG. 7·1 (a). PALAR RIVER BASIN: UPPER PALAR ZONE.
GROUND LEVEL CONTOURS.

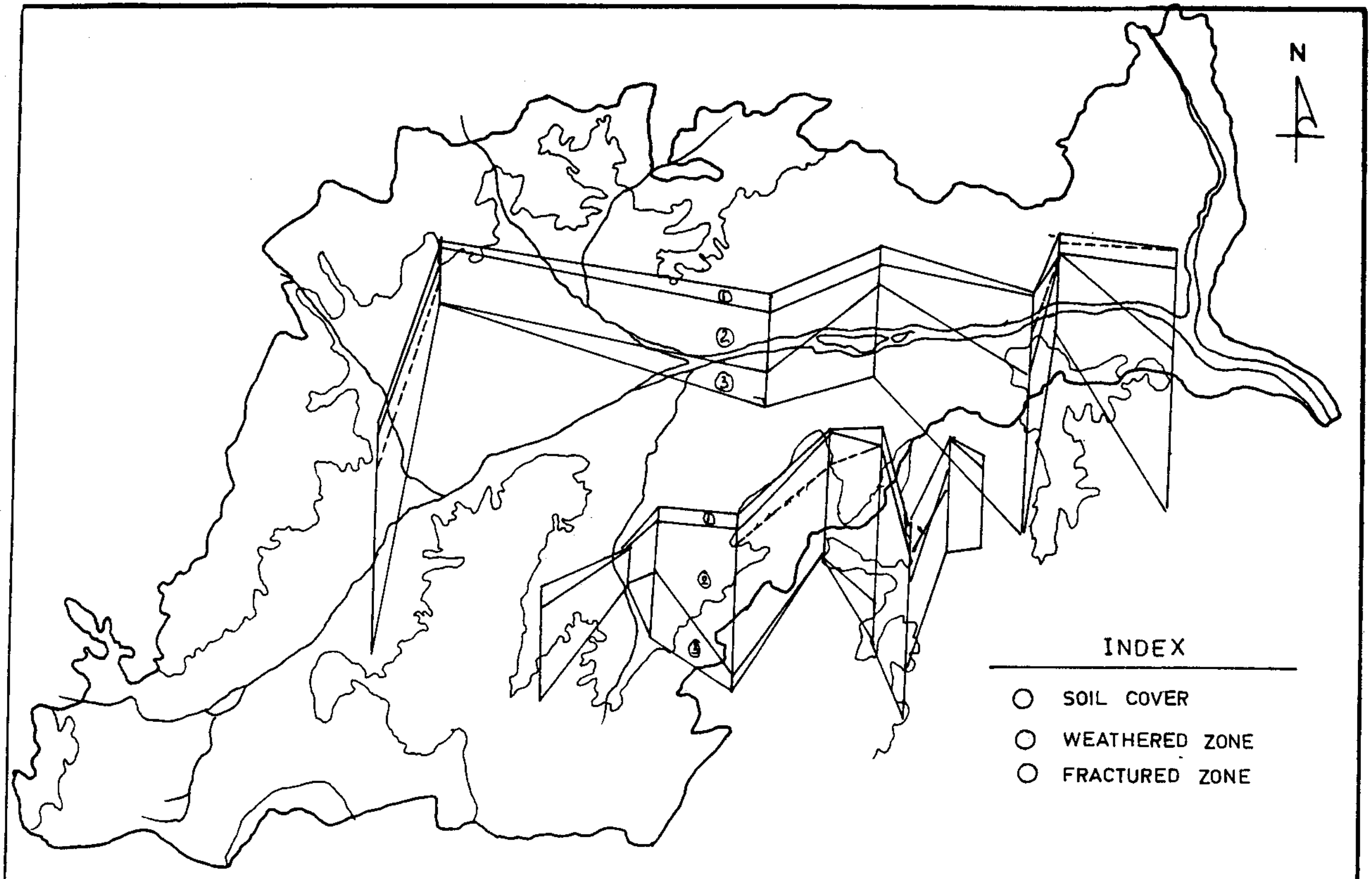


FIG. 7·1 (c). PALAR RIVER BASIN; UPPER PALAR ZONE.
AQUIFER STRUCTURE.

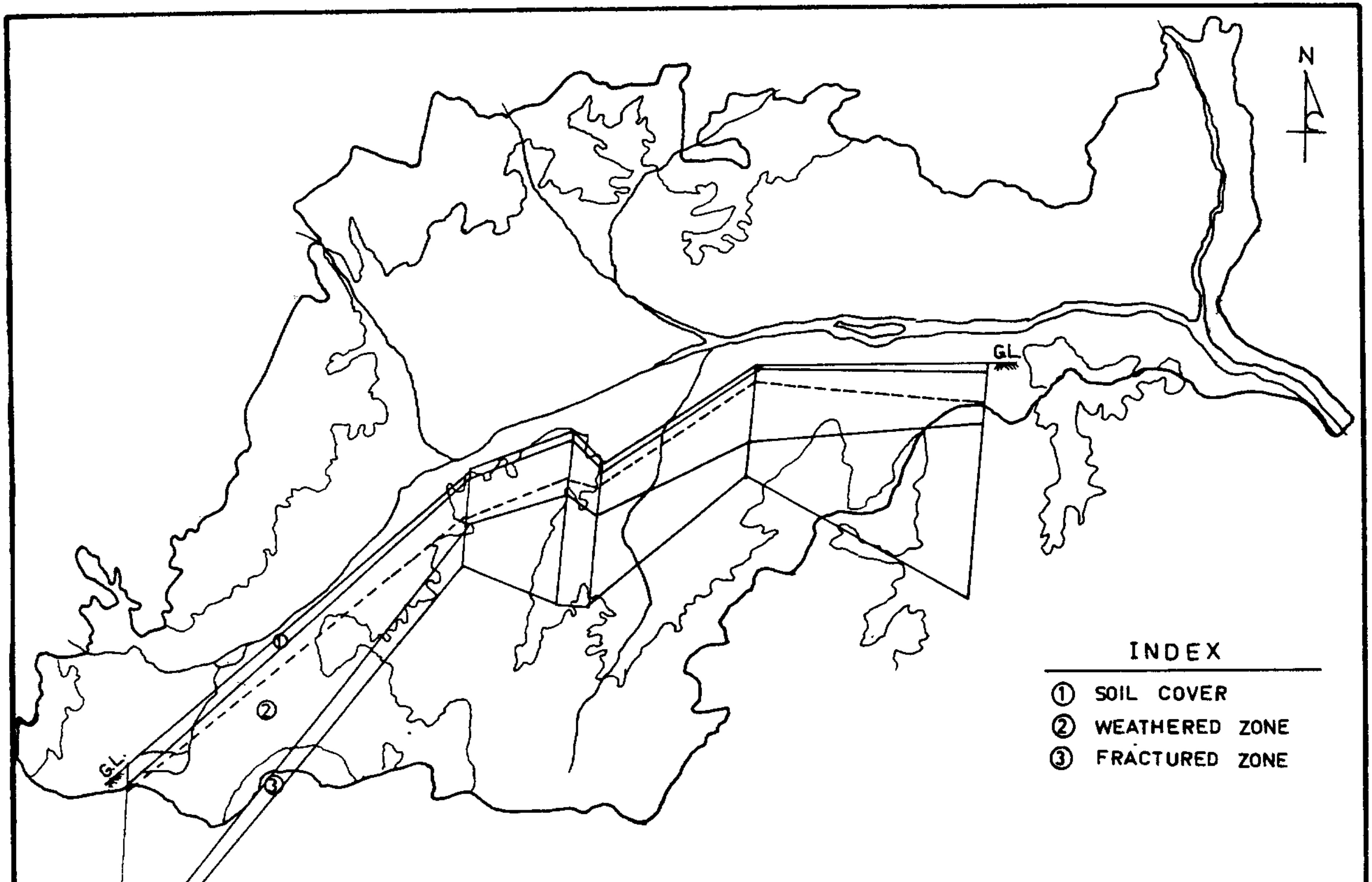
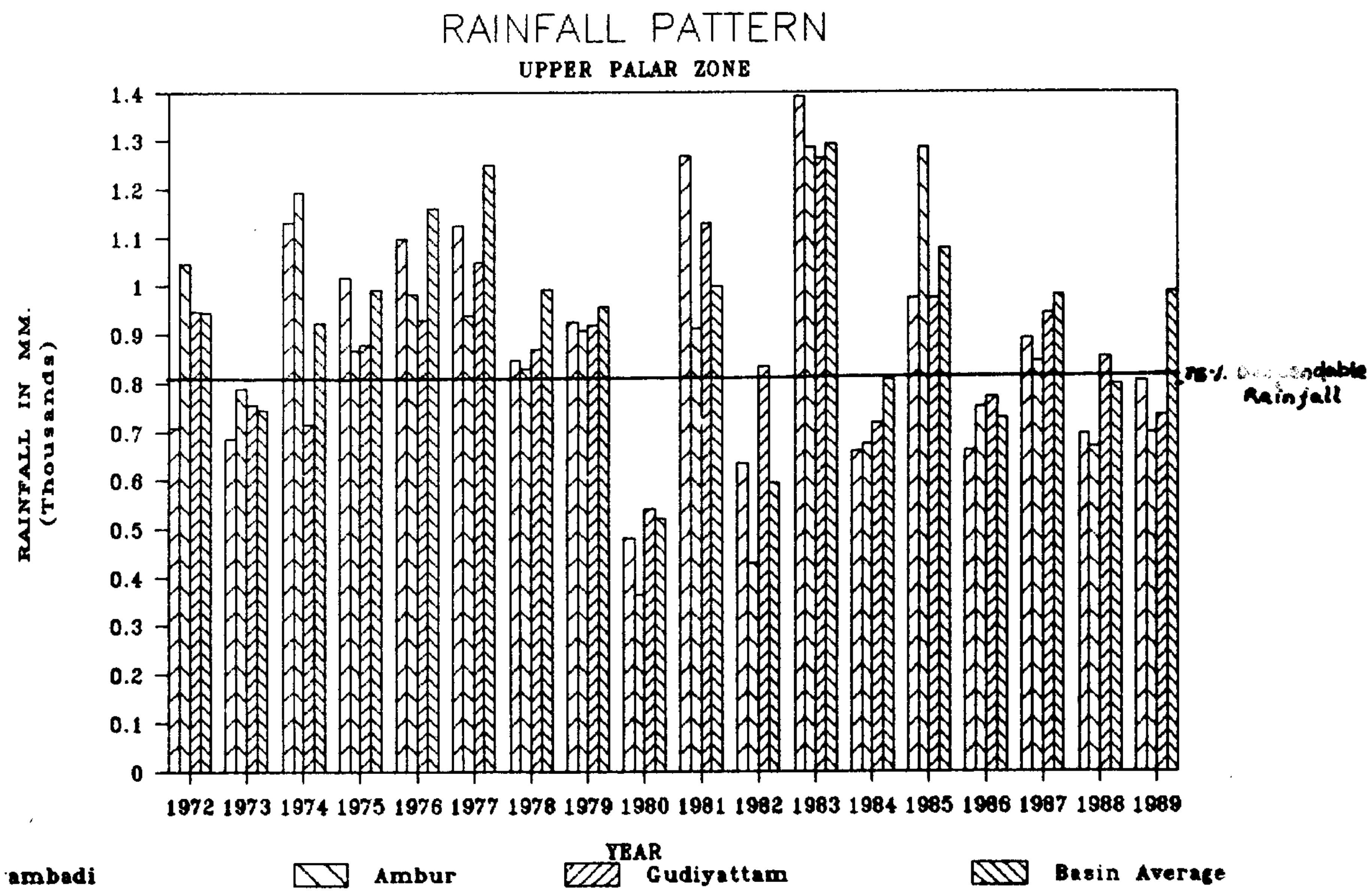


FIG. 7·1. (b). PALAR RIVER BASIN; UPPER PALAR ZONE.
AQUIFER STRUCTURE.

Fig 7.2



RAINFALL PATTERN
UPPER PALAR ZONE
RAINFALL IN MM.
(Thousands)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
Rainfall
'ambadi
Ambur
Gudiyattam
Basin Average

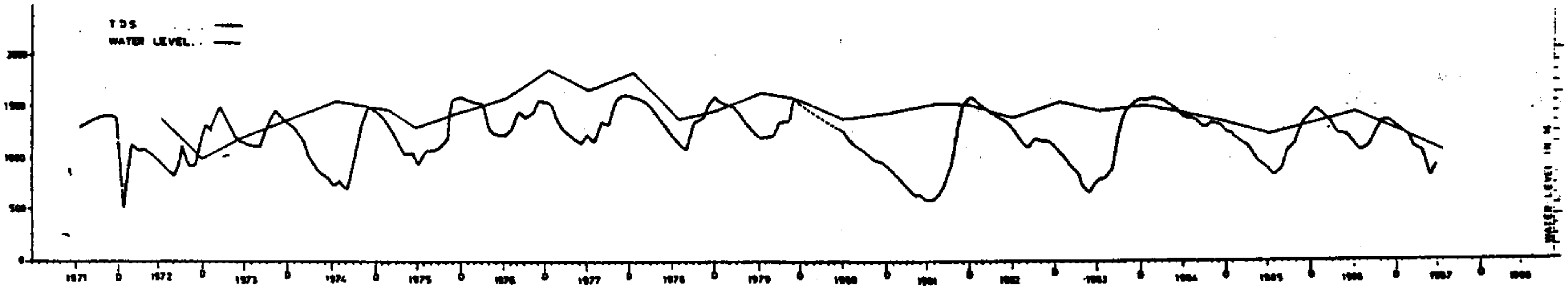


FIG. NO. 7·3 (a). HYDROGRAPH Vs T D S VARIATION AT VANIAMBADI.

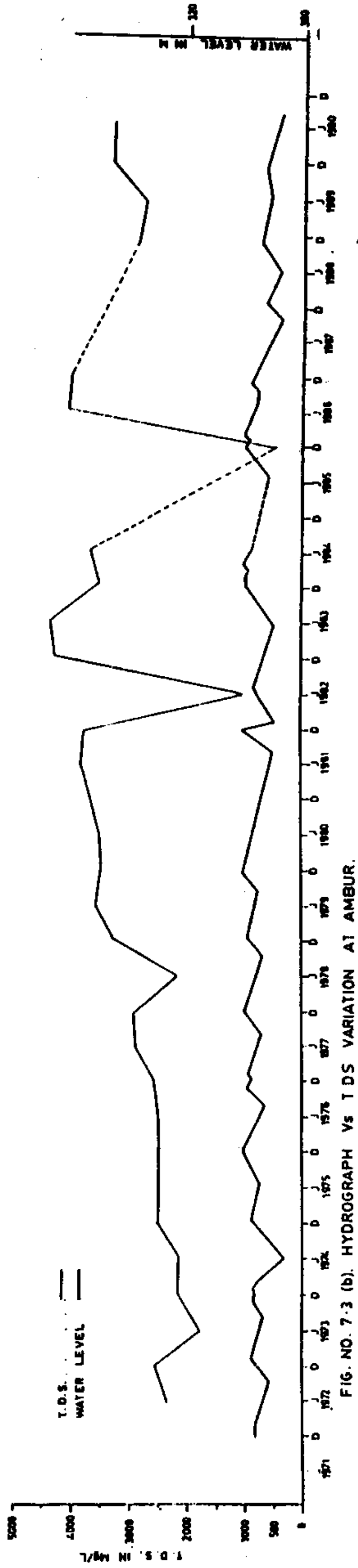


FIG. NO. 7·3 (b). HYDROGRAPH Vs TDS VARIATION AT AMBUR.

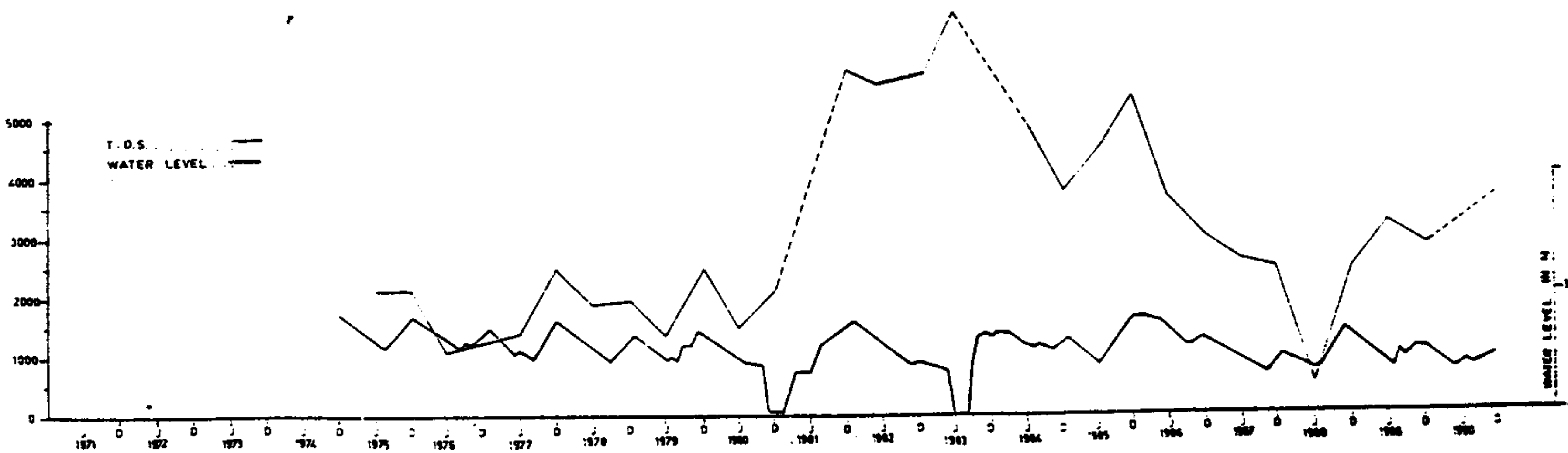


FIG.NO. 7·3 (c). HYDROGRAPH Vs TDS VARIATION MINNUR

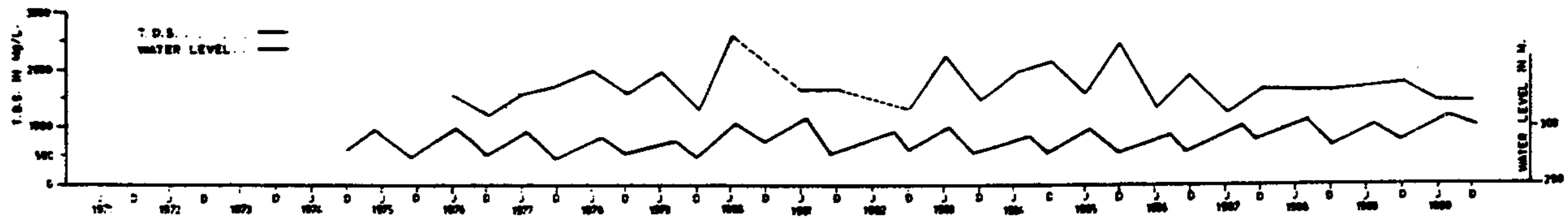


FIG. NO. 7·3 (d) HYDROGRAPH Vs T D S VARIATION AT VENGILI.

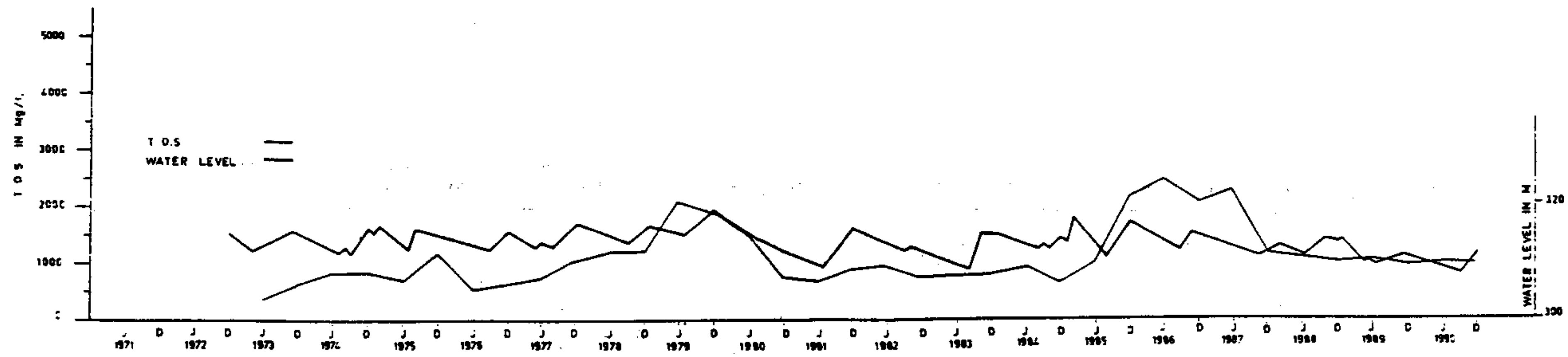


FIG. NO. 7·3 (e). HYDROGRAPH Vs TDS VARIATION AT KAILASAGIRI.

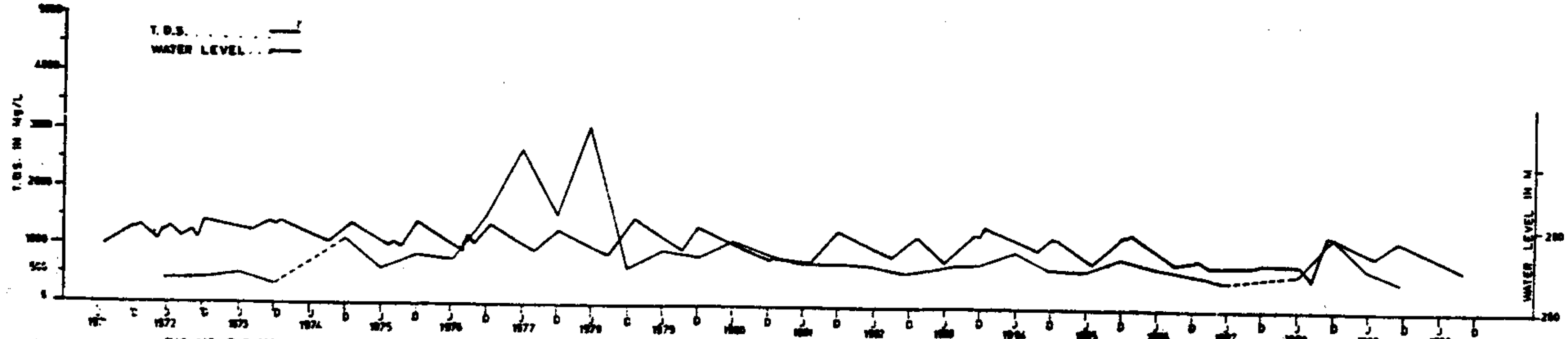


FIG. NO. 7·3 (f). HYDROGRAPH Vs TDS VARIATION AT GUDIYATTAM.

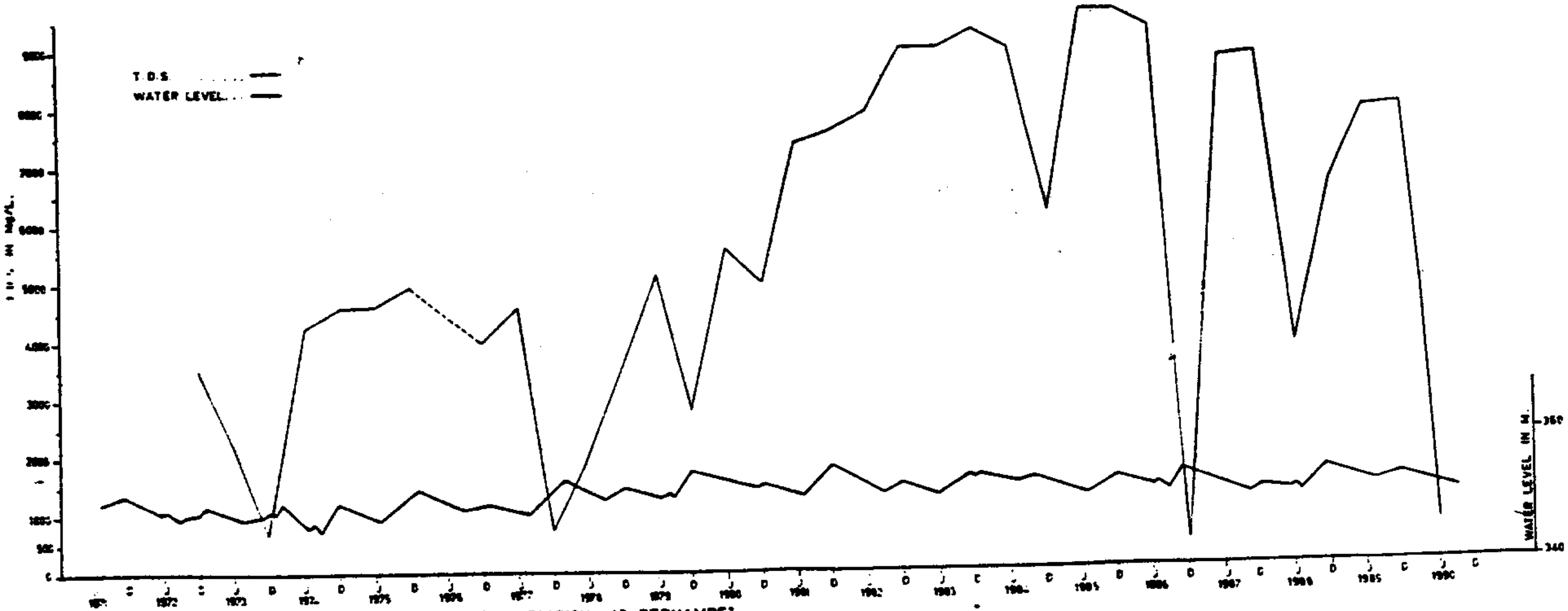


FIG NO. 7-3 (g). HYDROGRAPH Vs TDS VARIATION AT PERNAMPET

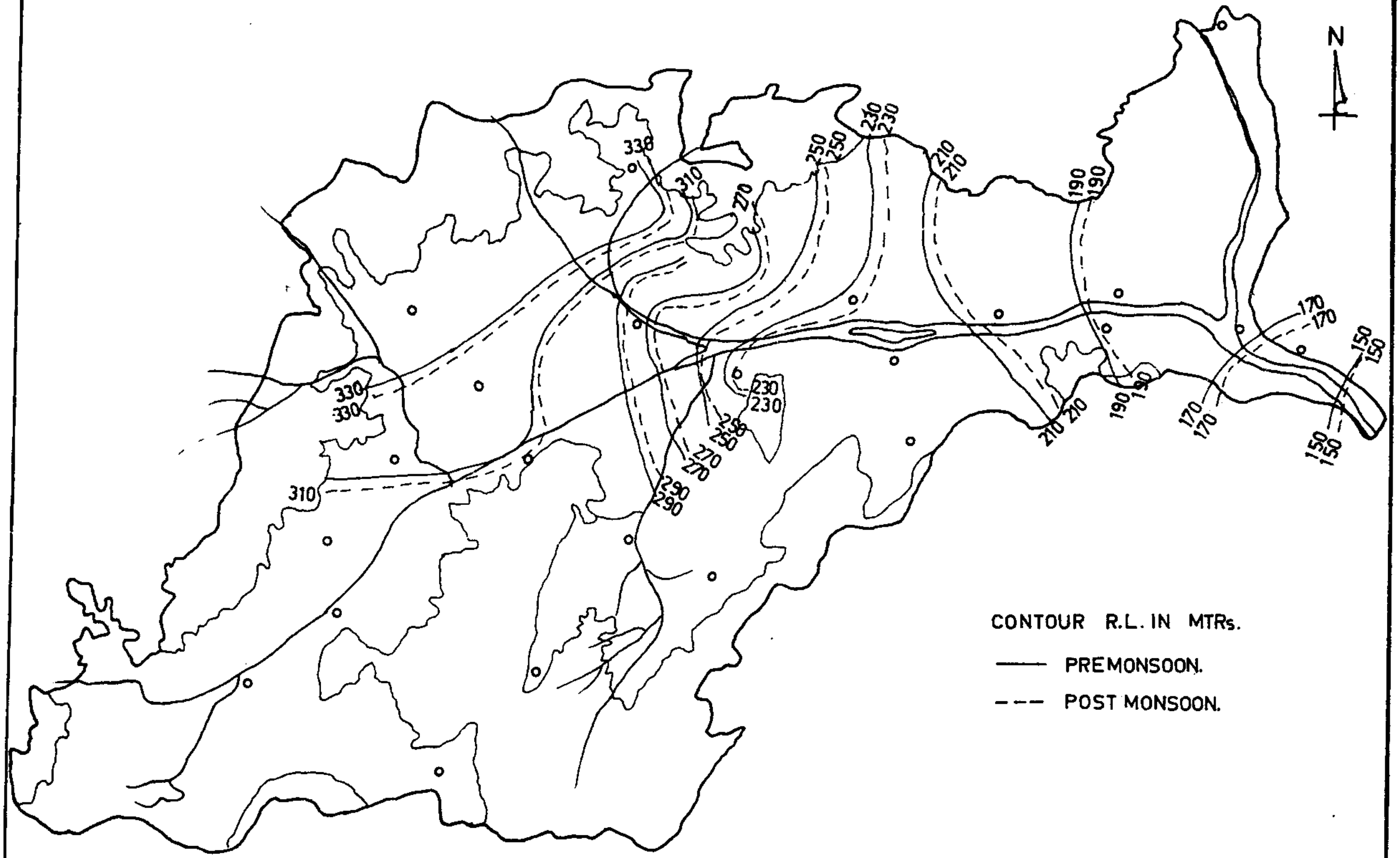


FIG. 7·4 (a). PALAR RIVER BASIN; UPPER PALAR ZONE.
WATER TABLE CONTOUR 1974-1975.

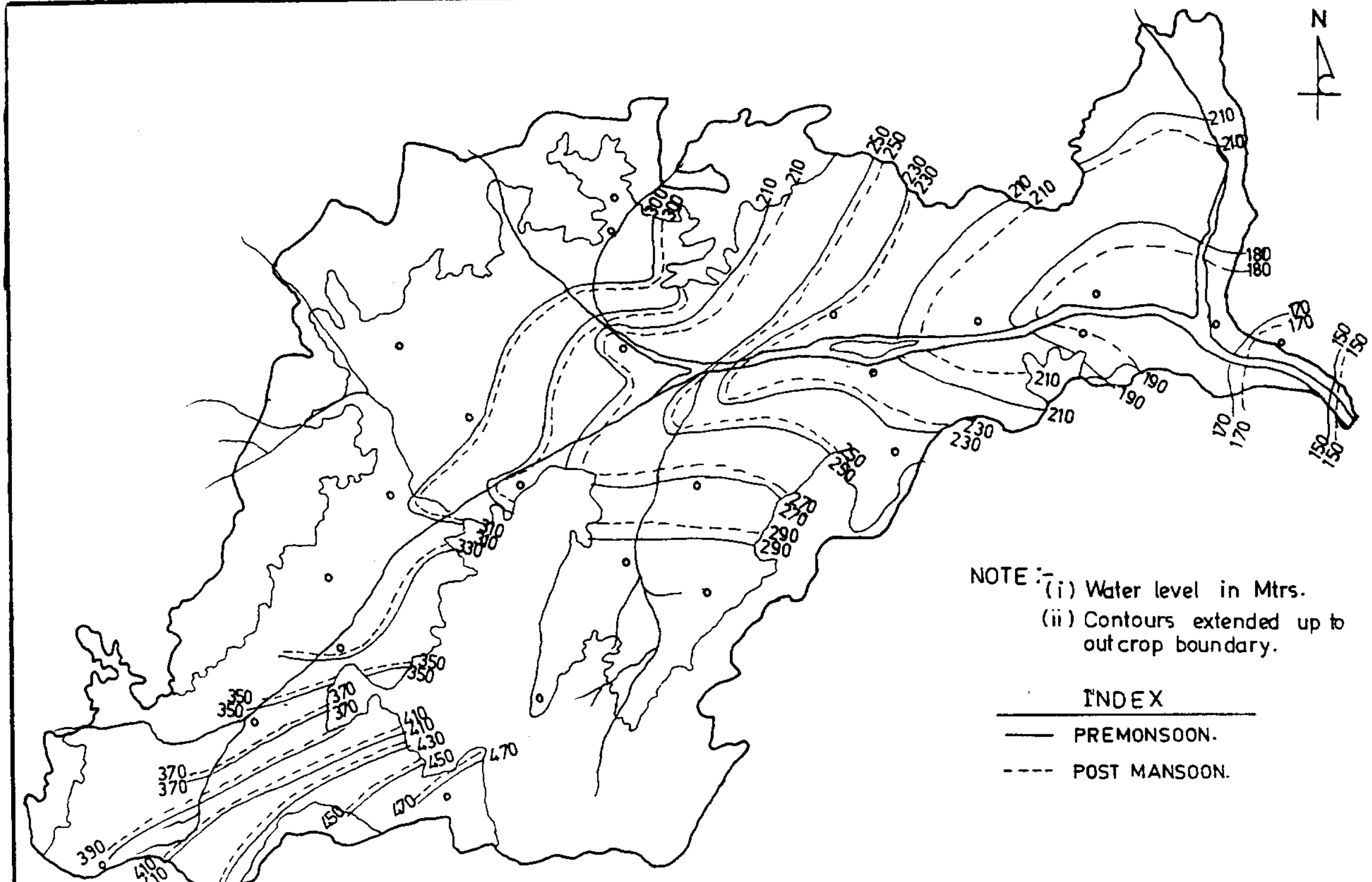


FIG. 7·4 (b). PALAR RIVER BASIN; UPPER PALAR ZONE.
WATER TABLE CONTOUR 1987-88.

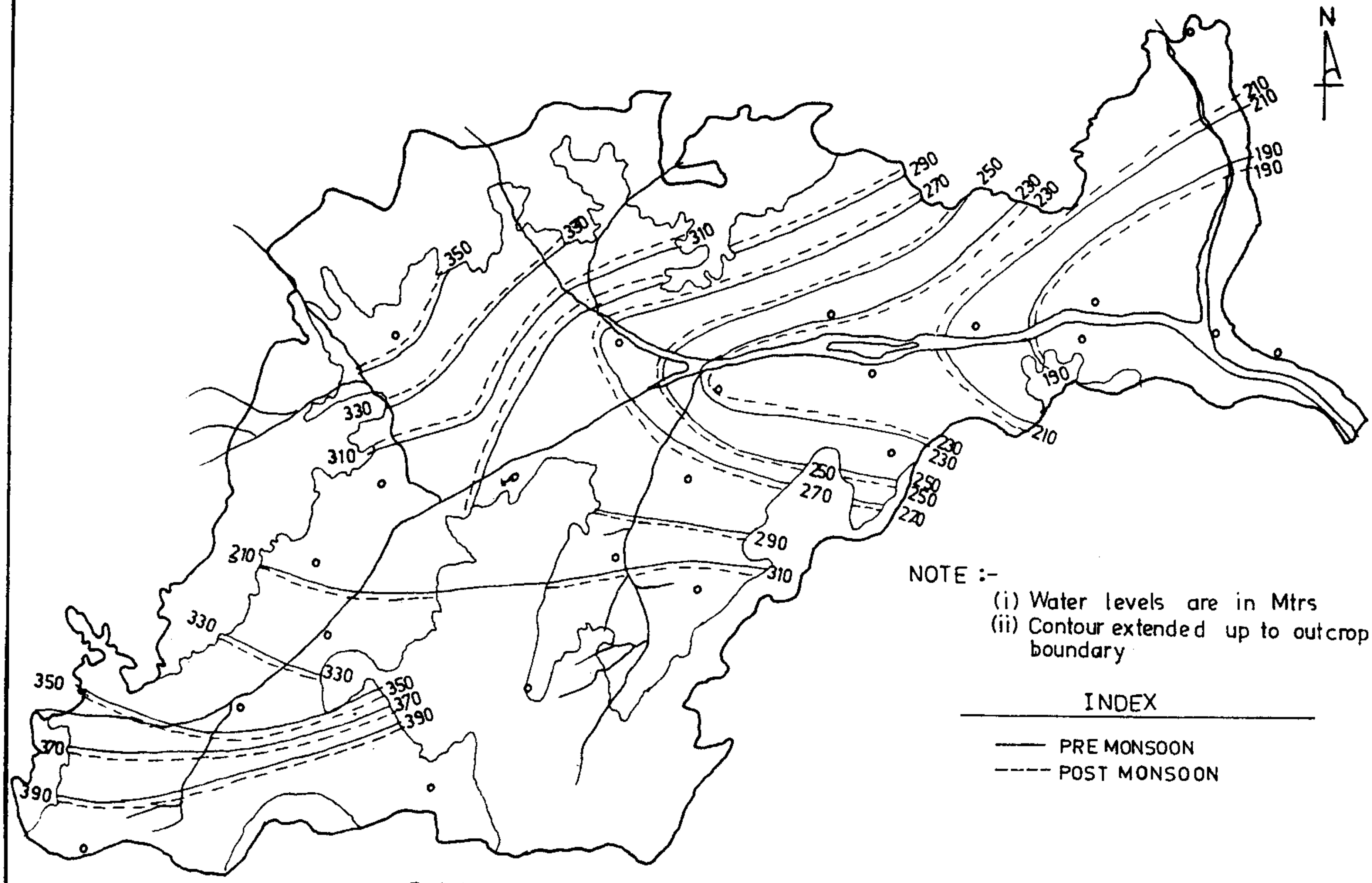


FIG. 7·4 (C). PALAR RIVER BASIN; UPPER PALAR ZONE.
WATER TABLE CONTOUR 1990-91.

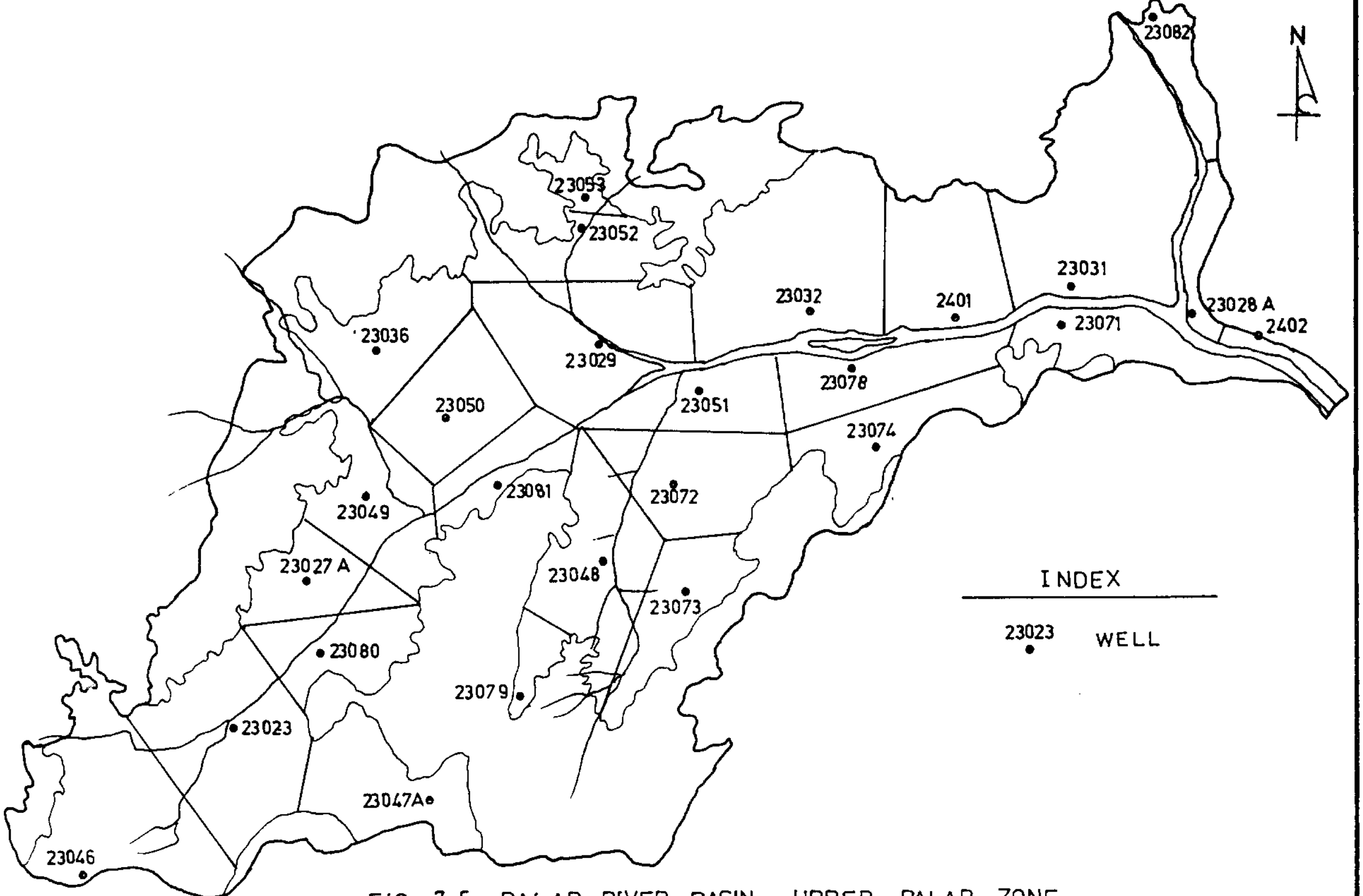


FIG. 7·5. PALAR RIVER BASIN; UPPER PALAR ZONE.
WELL POLYGON MAP.

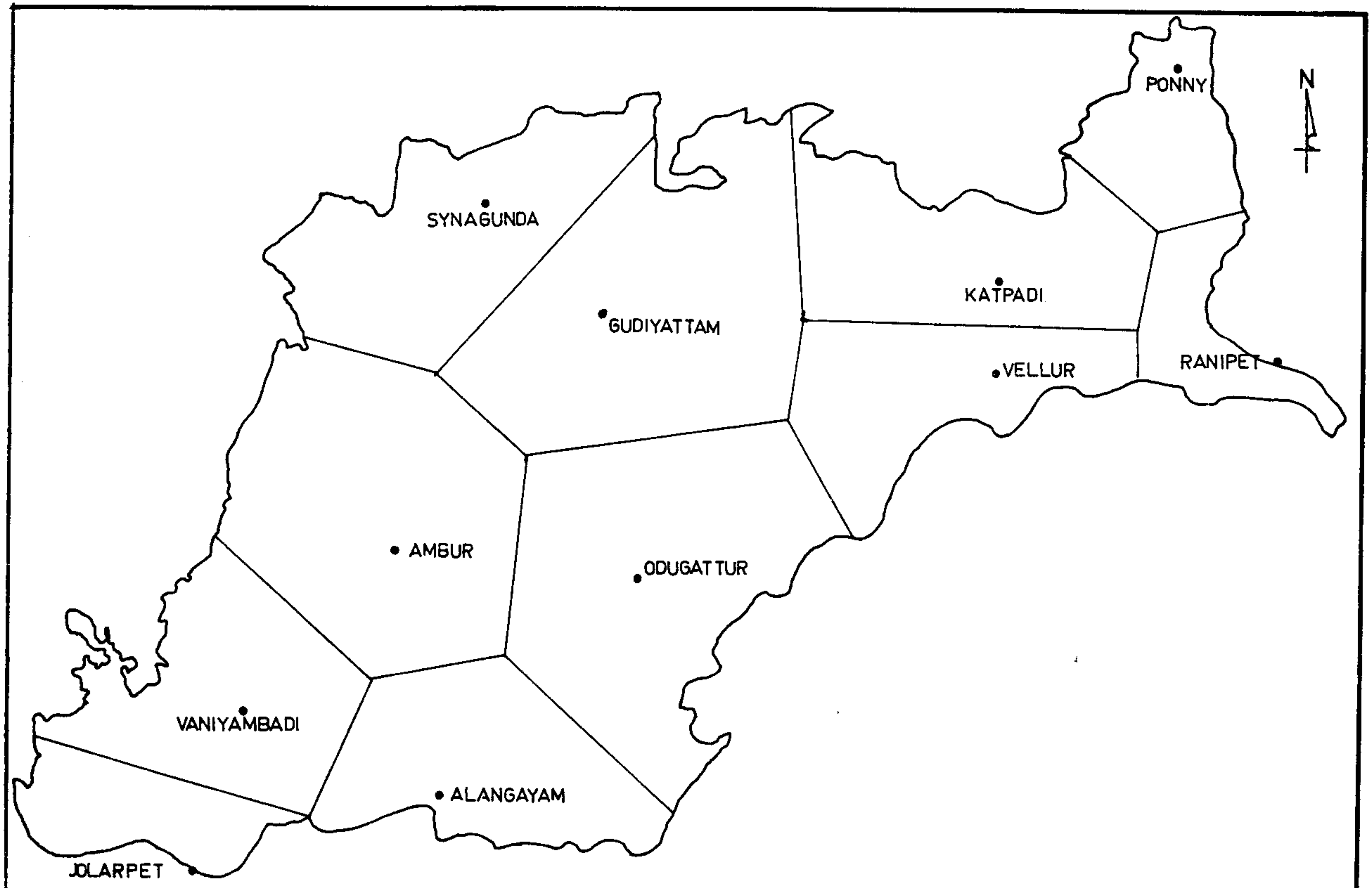


FIG. 7·6. PALAR RIVER BASIN: UPPER PALAR ZONE.
POLYGON MAP.

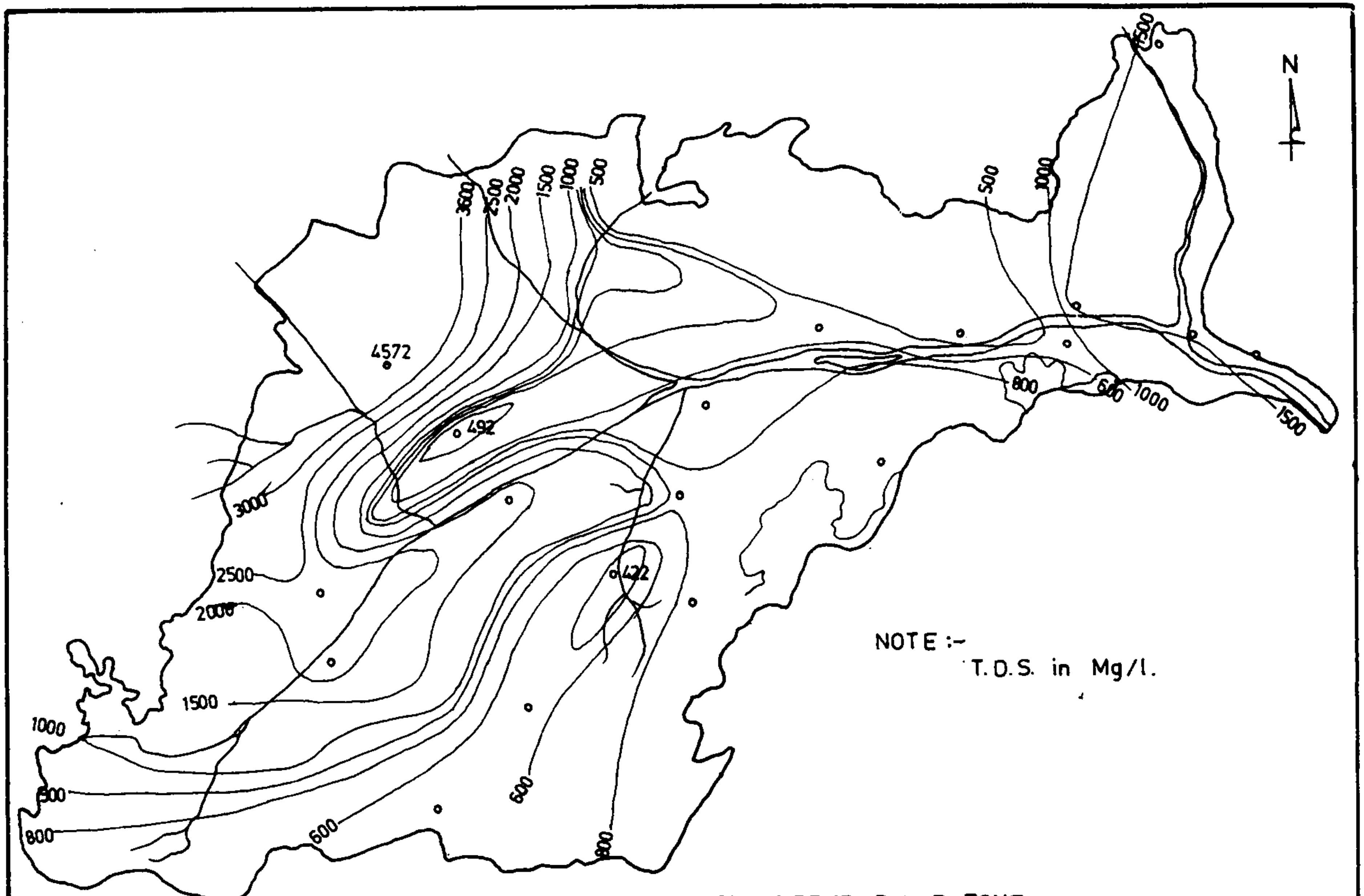


FIG. 7·8 (a). PALAR RIVER BASIN; UPPER PALAR ZONE.
T.D.S. YEAR - 1975.

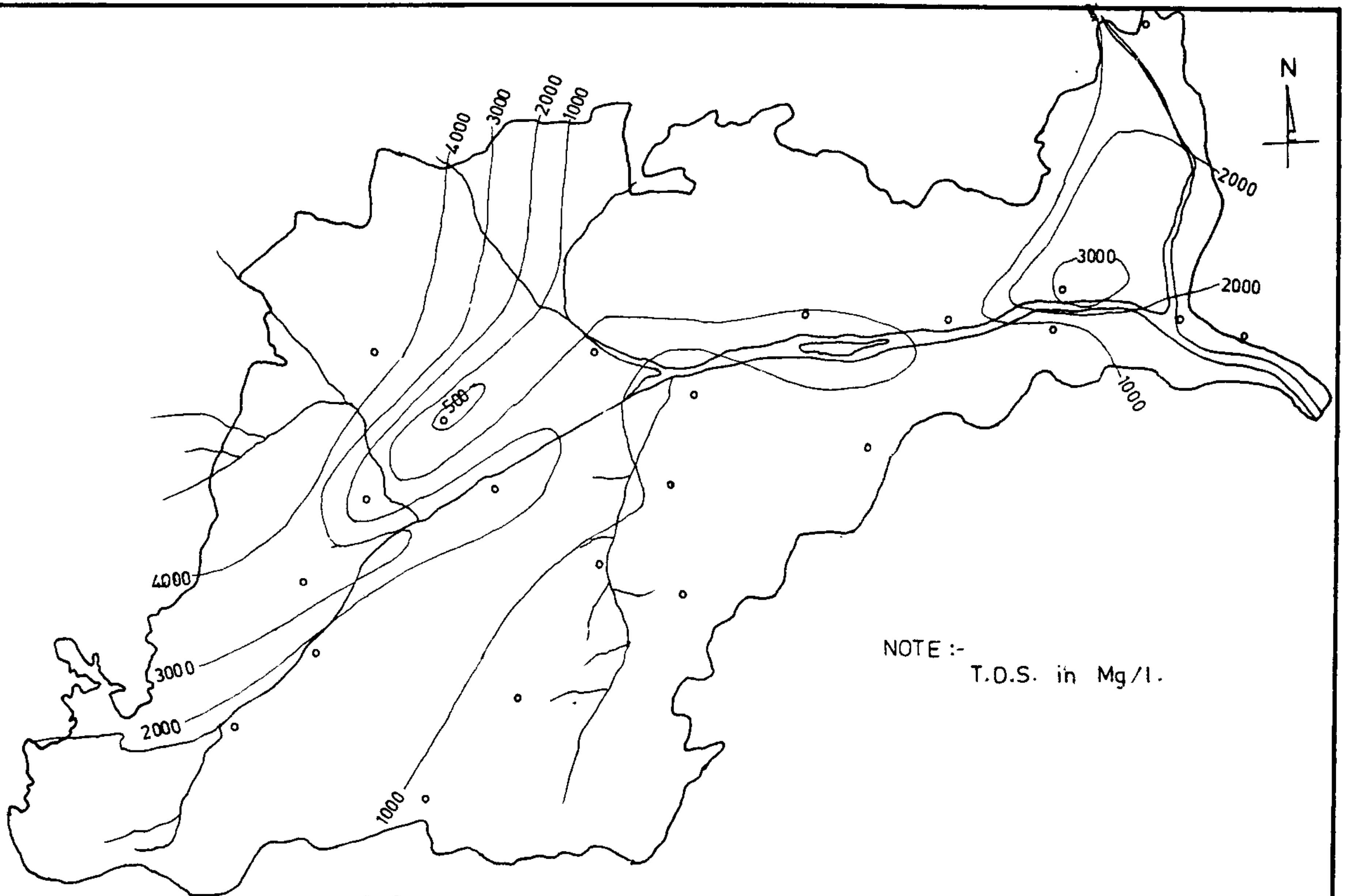


FIG. 7·8 (b). PALAR RIVER BASIN; UPPER PALAR ZONE.
T.D.S. YEAR-1980.

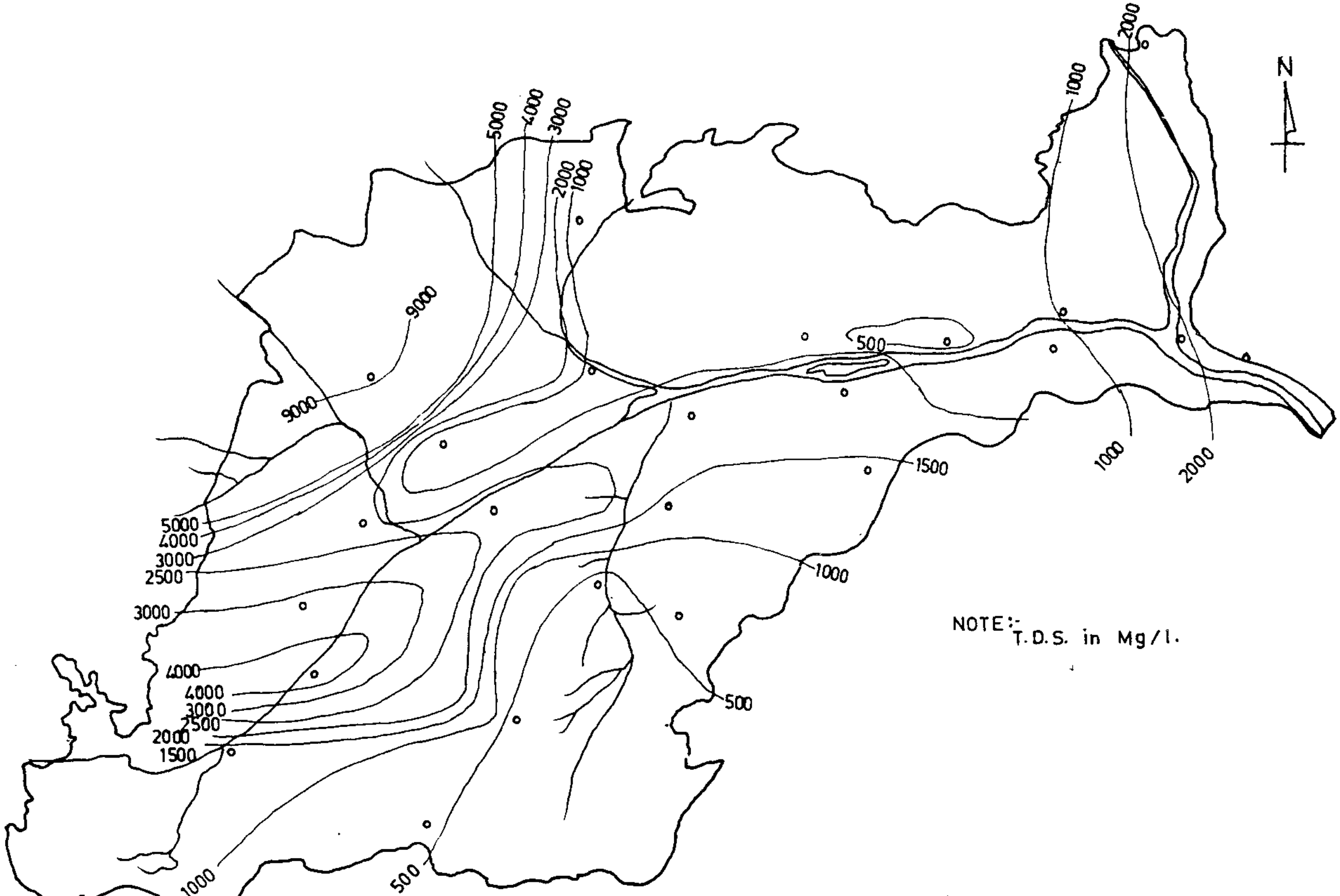


FIG. 7·8 (c). PALAR RIVER BASIN; UPPER PALAR ZONE.
T.D.S YEAR - 1985.

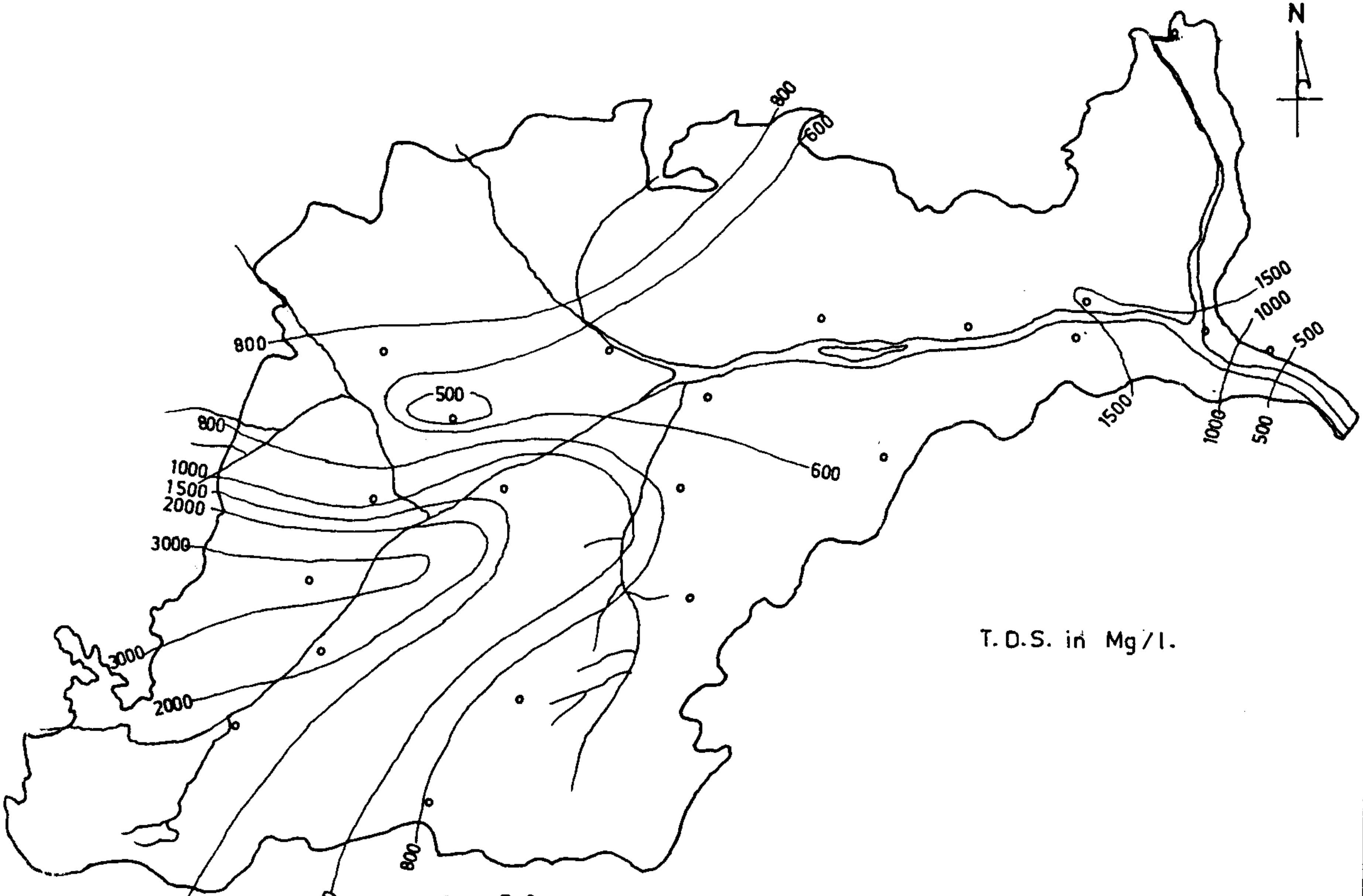


FIG. 7·8 (d). PALAR RIVER BASIN; UPPER PALAR ZONE.
T.D.S. YEAR - 1990

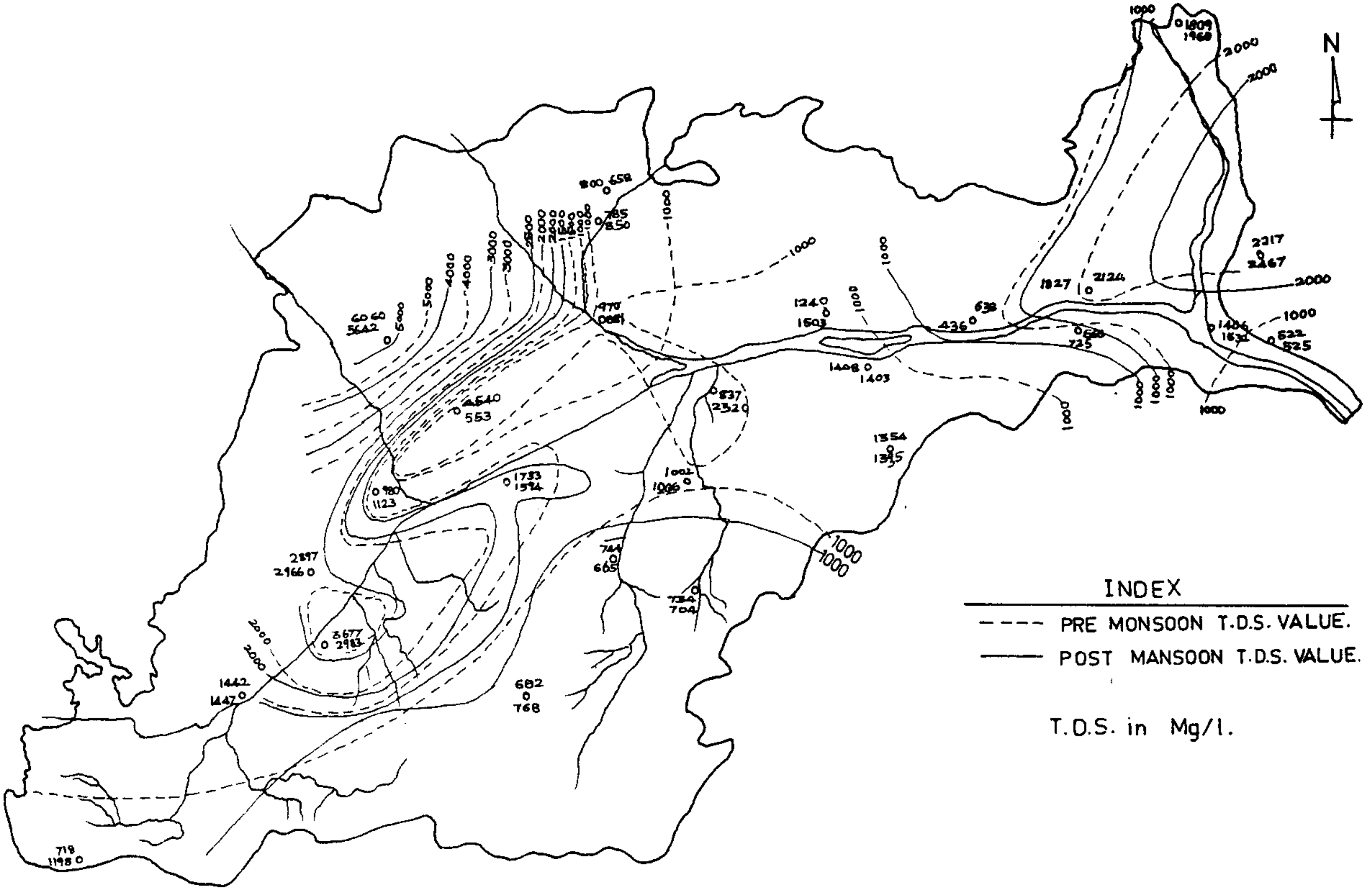


FIG. 7·8 (e). PALAR RIVER BASIN; UPPER PALAR ZONE.
T.D.S. CONTOURS (1972 - 1991).

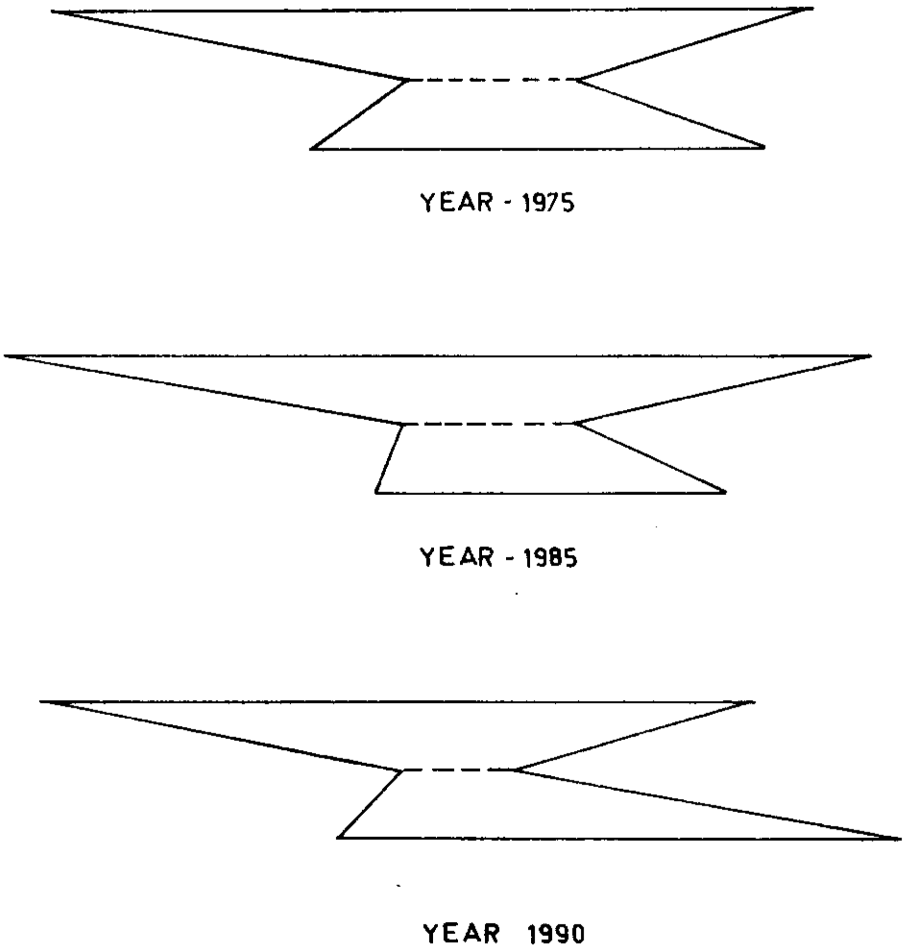


FIG. 7·9 (a). HORIZONTAL PATTERN DIAGRAM FOR VANIYAMBADI.

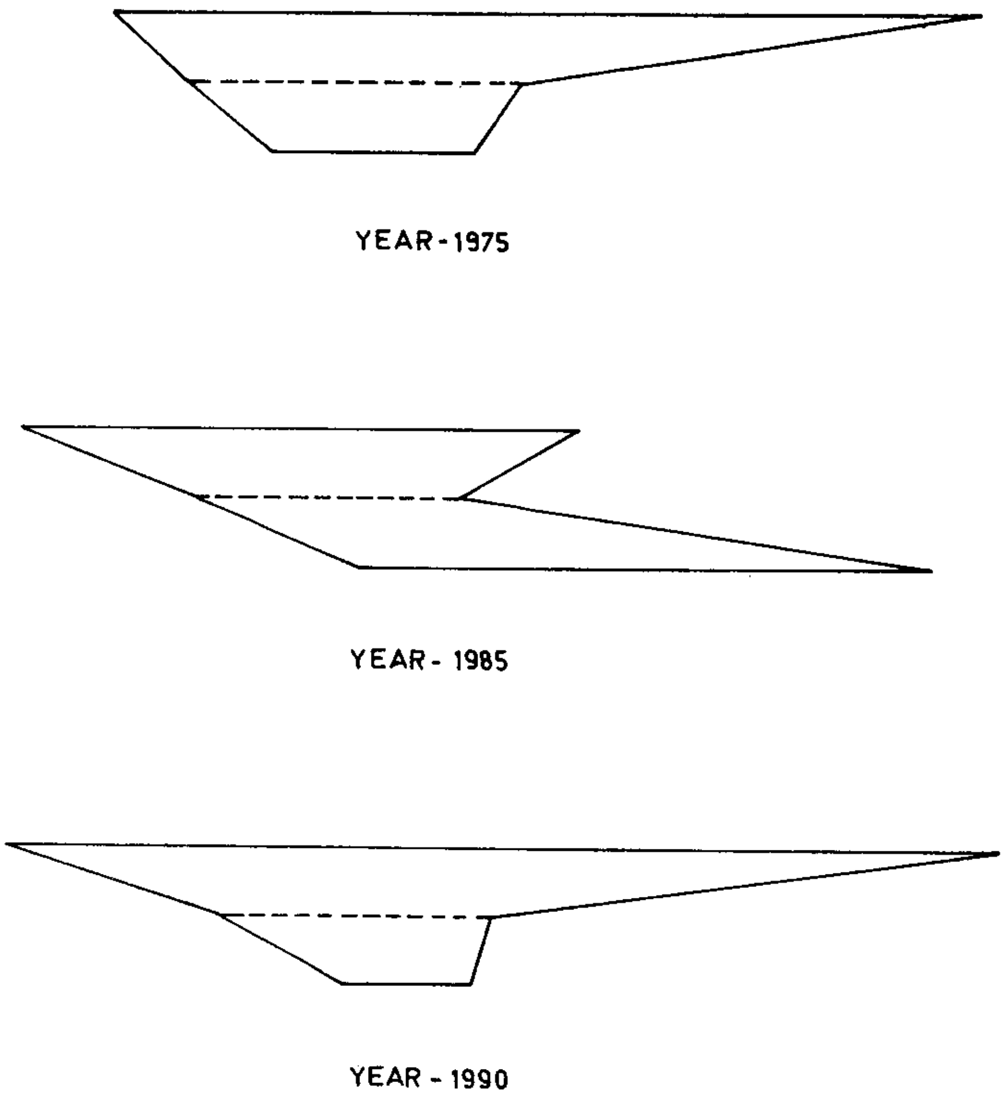
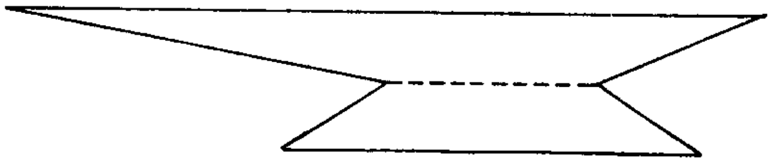
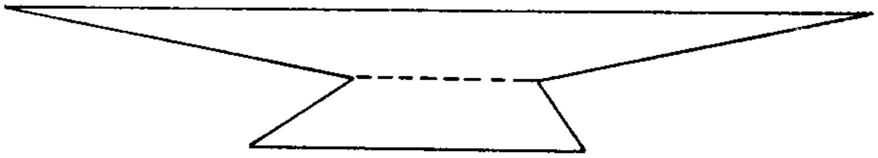


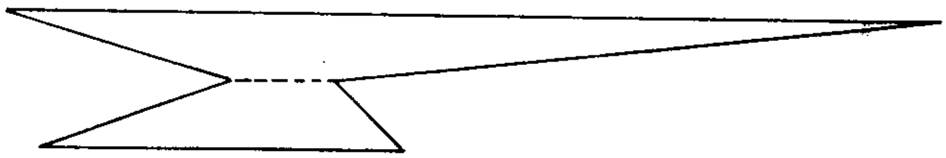
FIG. 7·9 (b). HORIZONTAL PATTERN DIAGRAM FOR AMBUR.



YEAR - 1975



YEAR - 1985



YEAR - 1990

FIG. 7·9 (c). HORIZONTAL PATTERN DIAGRAM FOR MINNUR

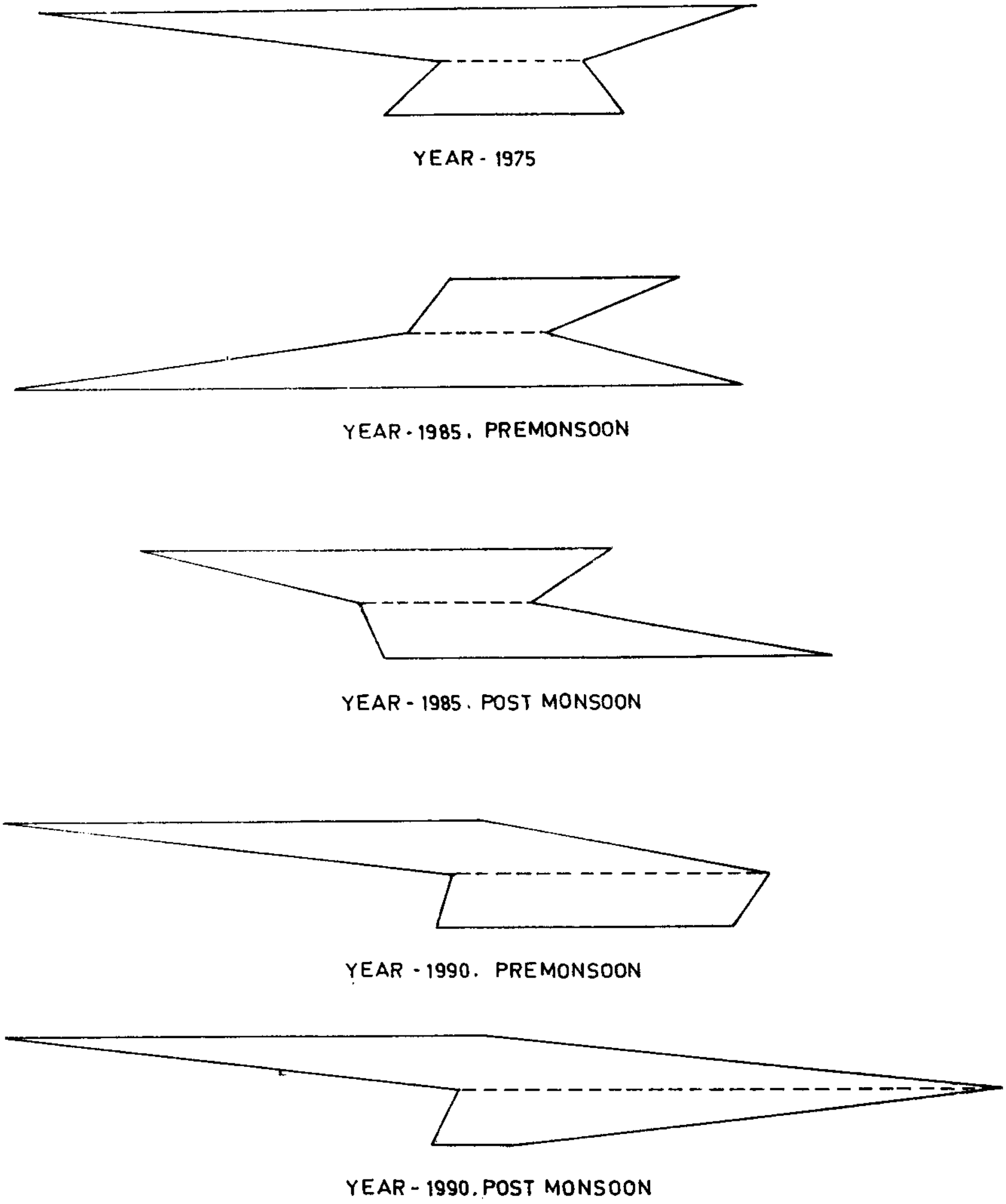


FIG. 7·9 (d). HORIZONTAL PATTERN DIAGRAM FOR VENGILI.

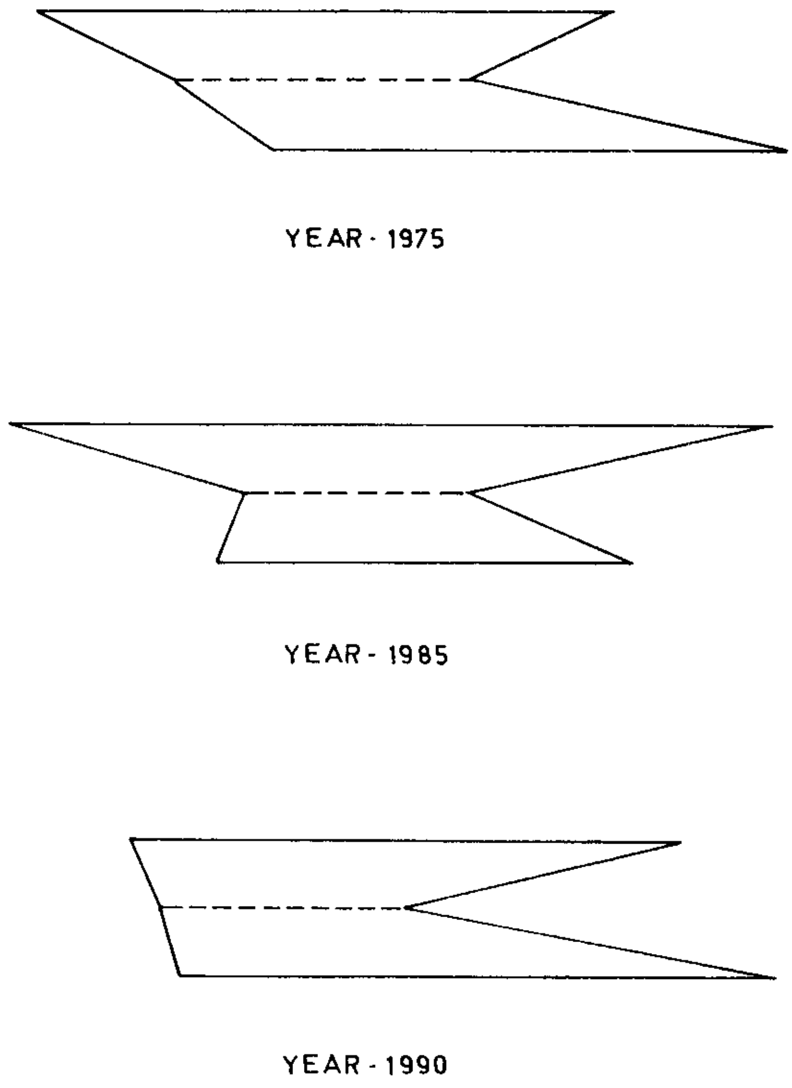


FIG. 7·9(e). HORIZONTAL PATTERN DIAGRAM FOR KAILASAGIRI.

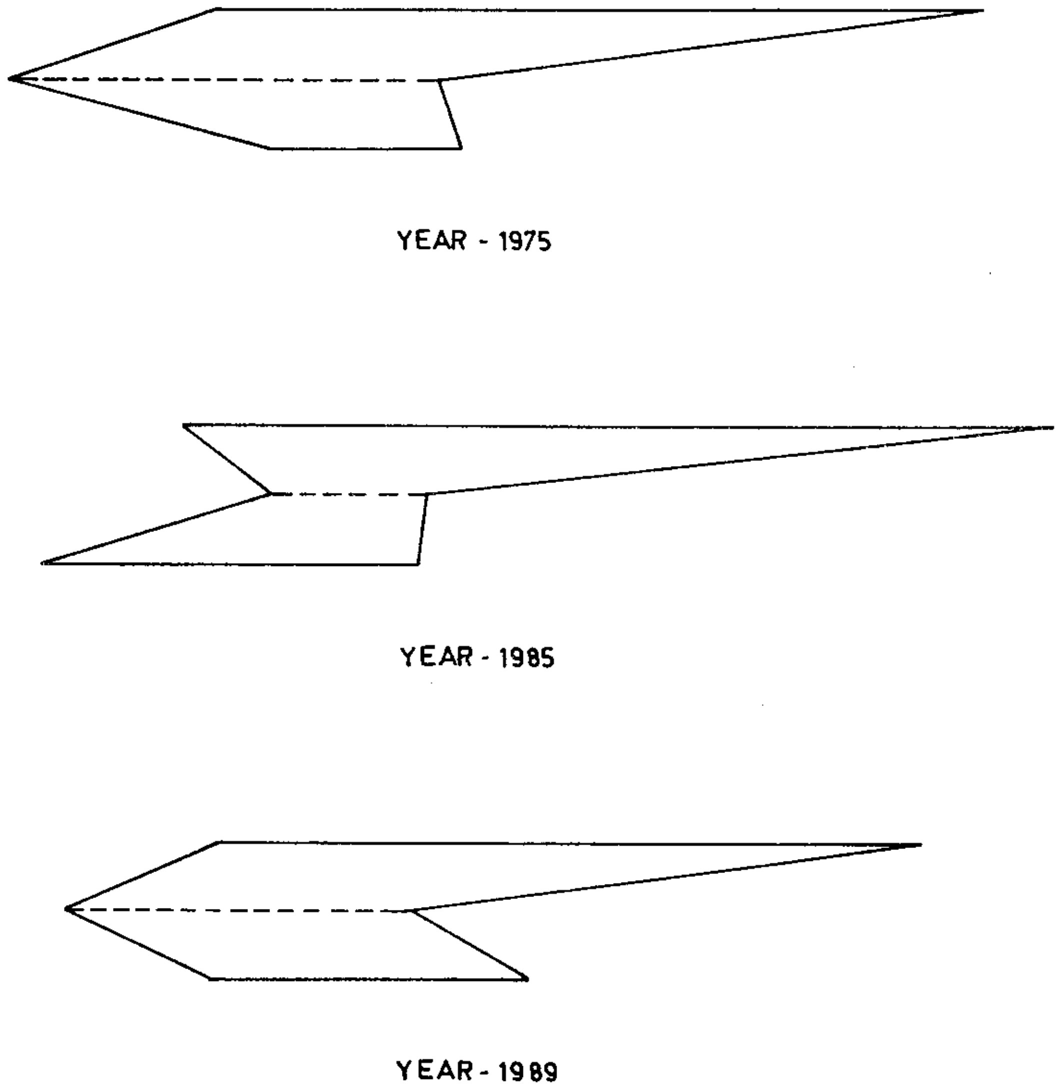


FIG. 7·9 (f). HORIZONTAL PATTERN DIAGRAM FOR PERNAMPET.

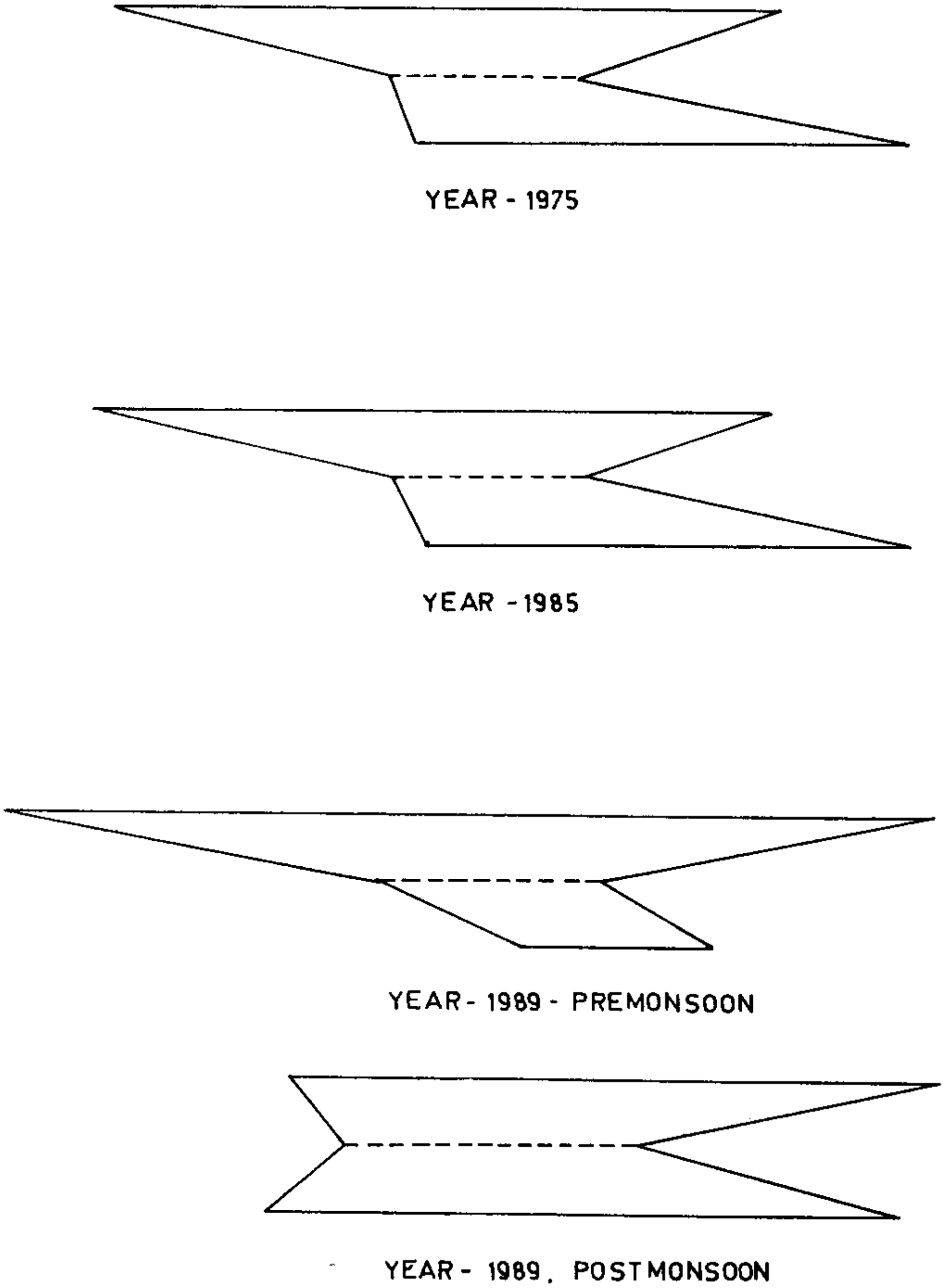


FIG. 7·9(g). HORIZONTAL PATTERN DIAGRAM FOR GUDIYATTAM.

Fig 7.11(a)

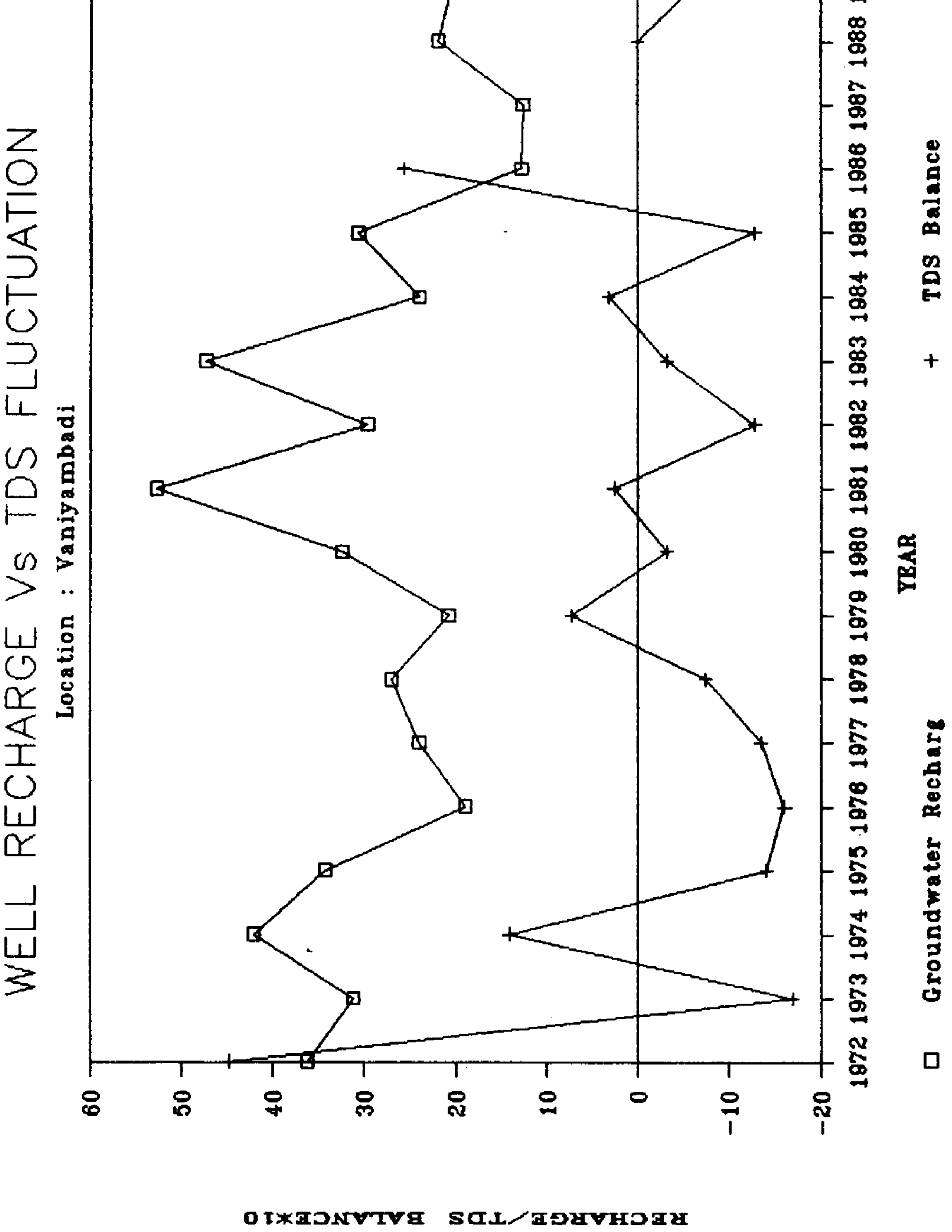

WELL RECHARGE Vs TDS FLUCTUATION
Location : Vaniyambadi
60
50
40
30
20
10
0
−10
−20
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
RECHARGE/TDS BALANCE*10
Groundwater Recharg
TDS Balance

Fig 7.11 (b)

WELL RECHARGE Vs TDS FLUCTUATION

Location : AMBUR

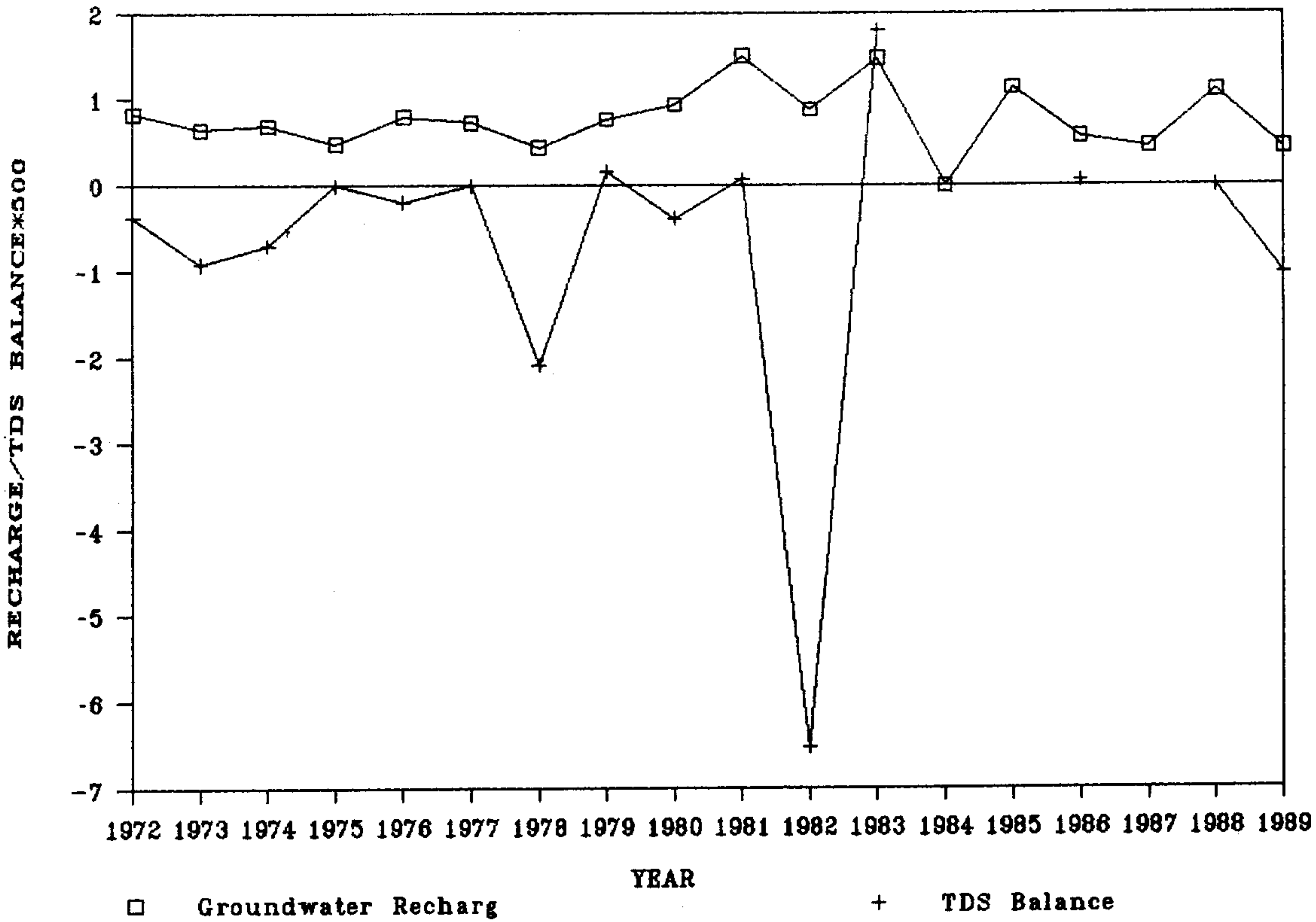


Fig 7.11(c)

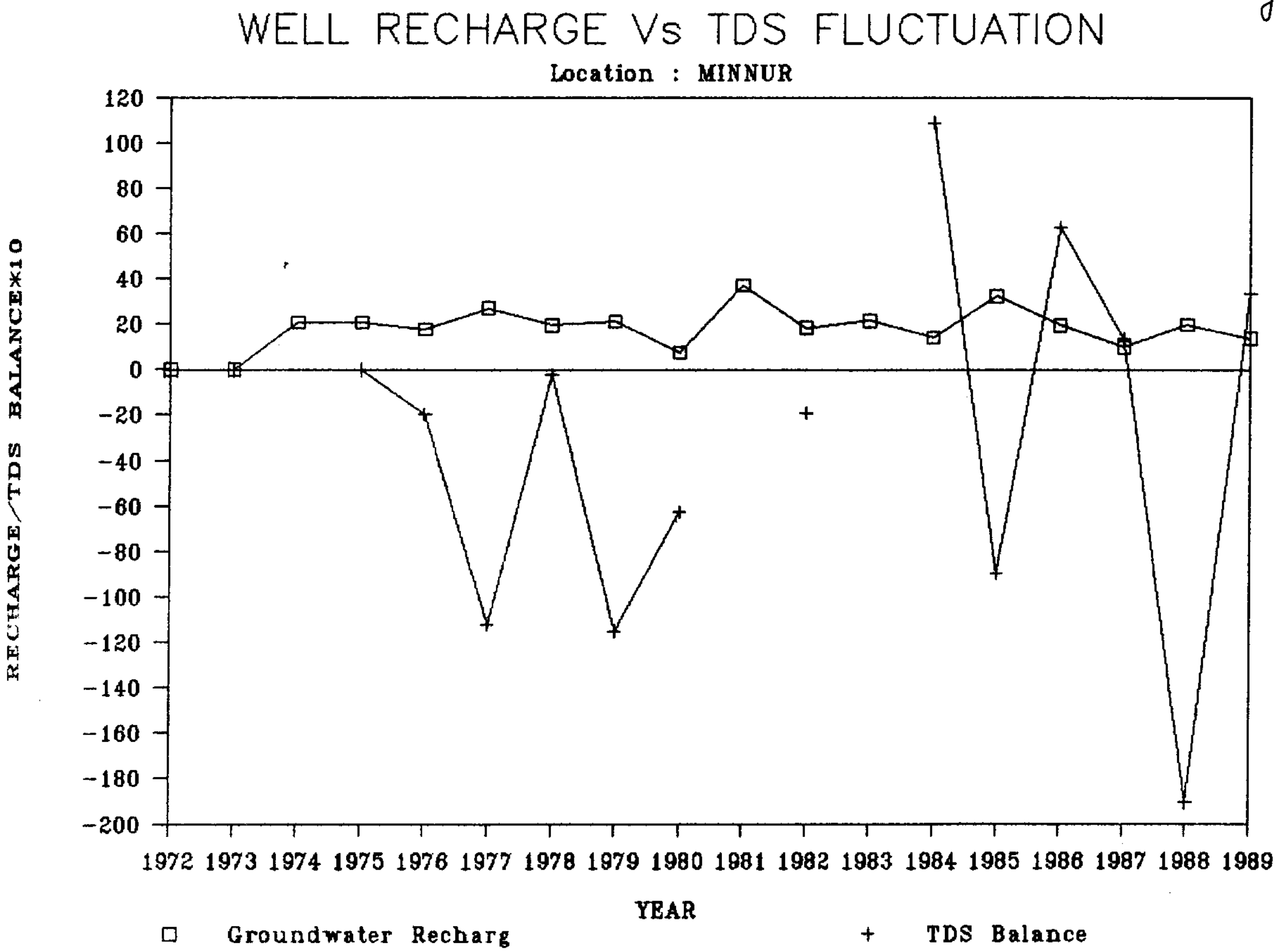
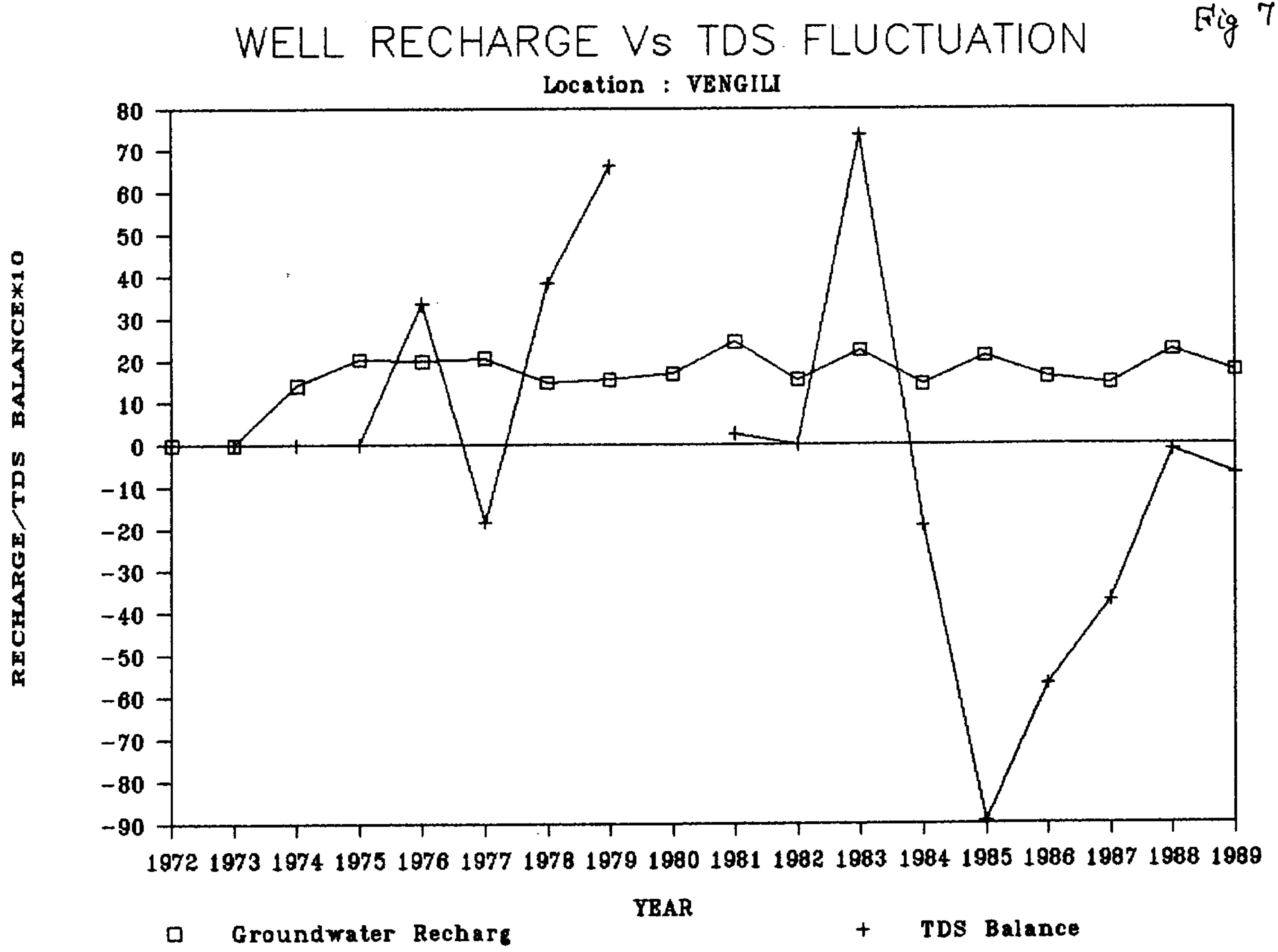

WELL RECHARGE Vs TDS FLUCTUATION
Location : MINNUR
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
RECHARGE/TDS BALANCE*10
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
Groundwater Recharg
TDS Balance

Fig 7.11(d)


WELL RECHARGE Vs TDS FLUCTUATION
Location : VENGILI
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
RECHARGE/TDS BALANCE*10
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
Groundwater Recharg
TDS Balance

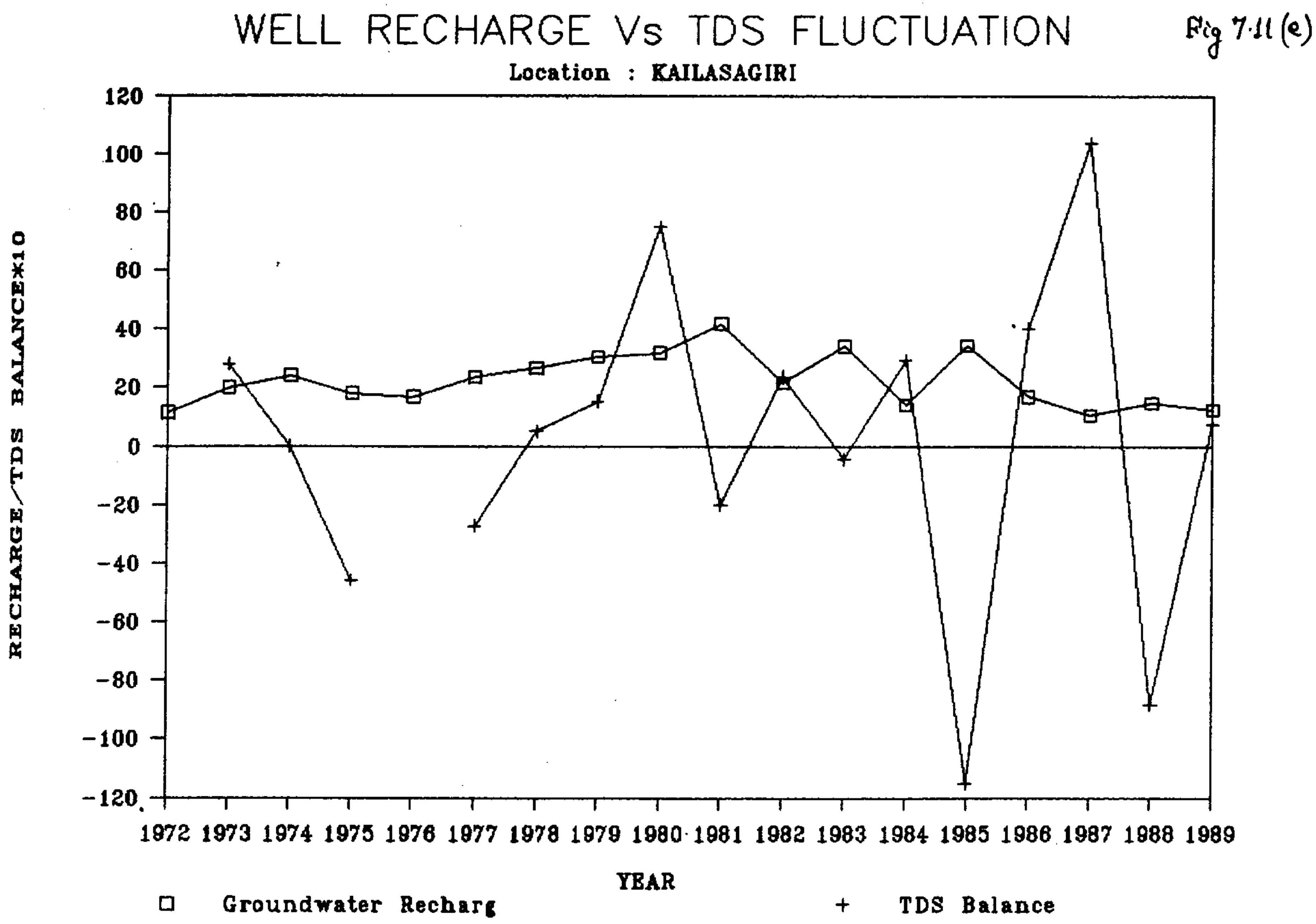

WELL RECHARGE Vs TDS FLUCTUATION
Fig 7.11 (e)
Location : KAILASAGIRI
RECHARGE/TDS BALANCE*10
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
Groundwater Recharg
TDS Balance

Fig 7.11(f)

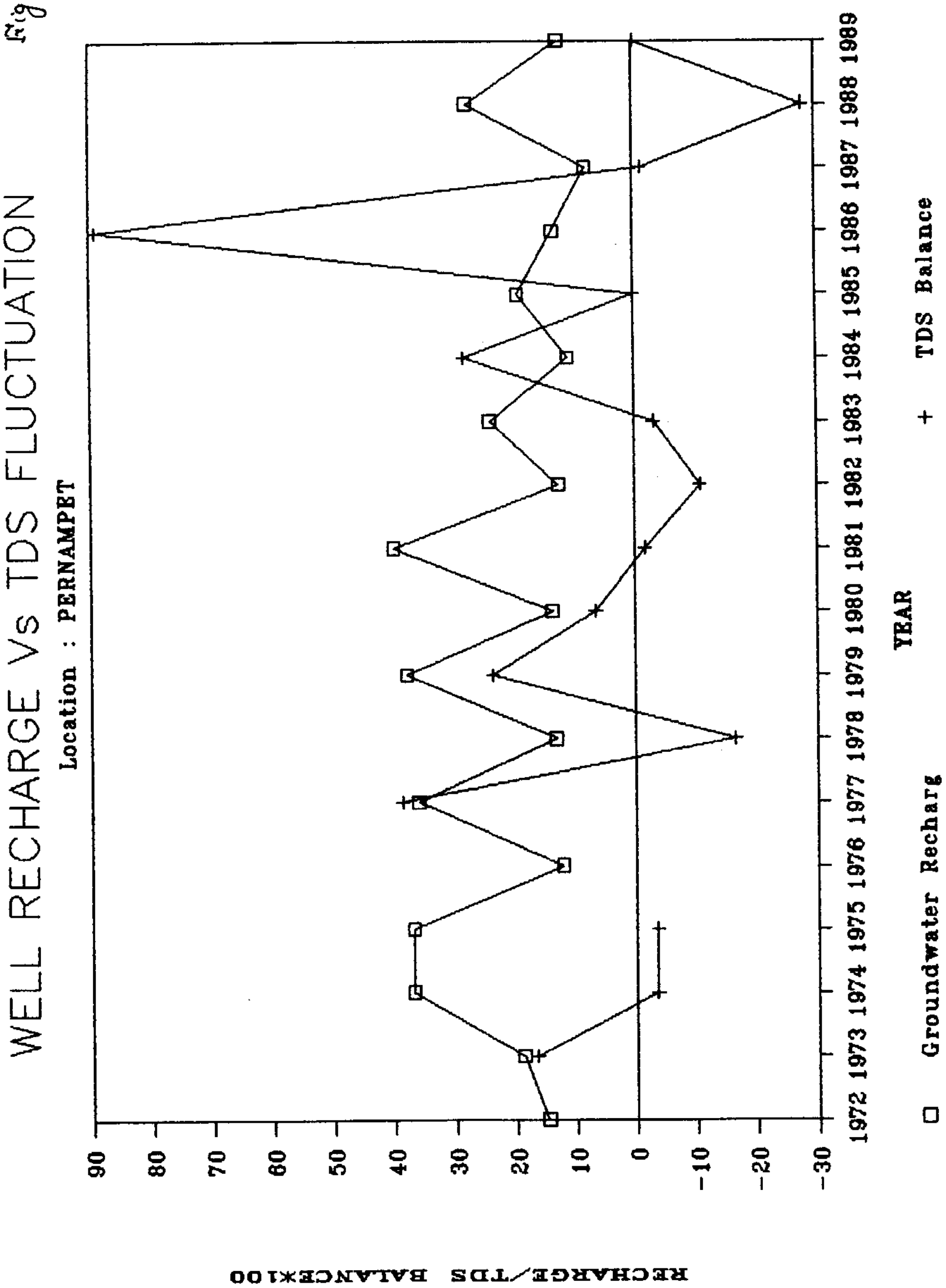

WELL RECHARGE Vs TDS FLUCTUATION
Location : PERNAMPET
RECHARGE/TDS BALANCE*100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
□ Groundwater Recharg
+ TDS Balance

Fig 7.11(g)

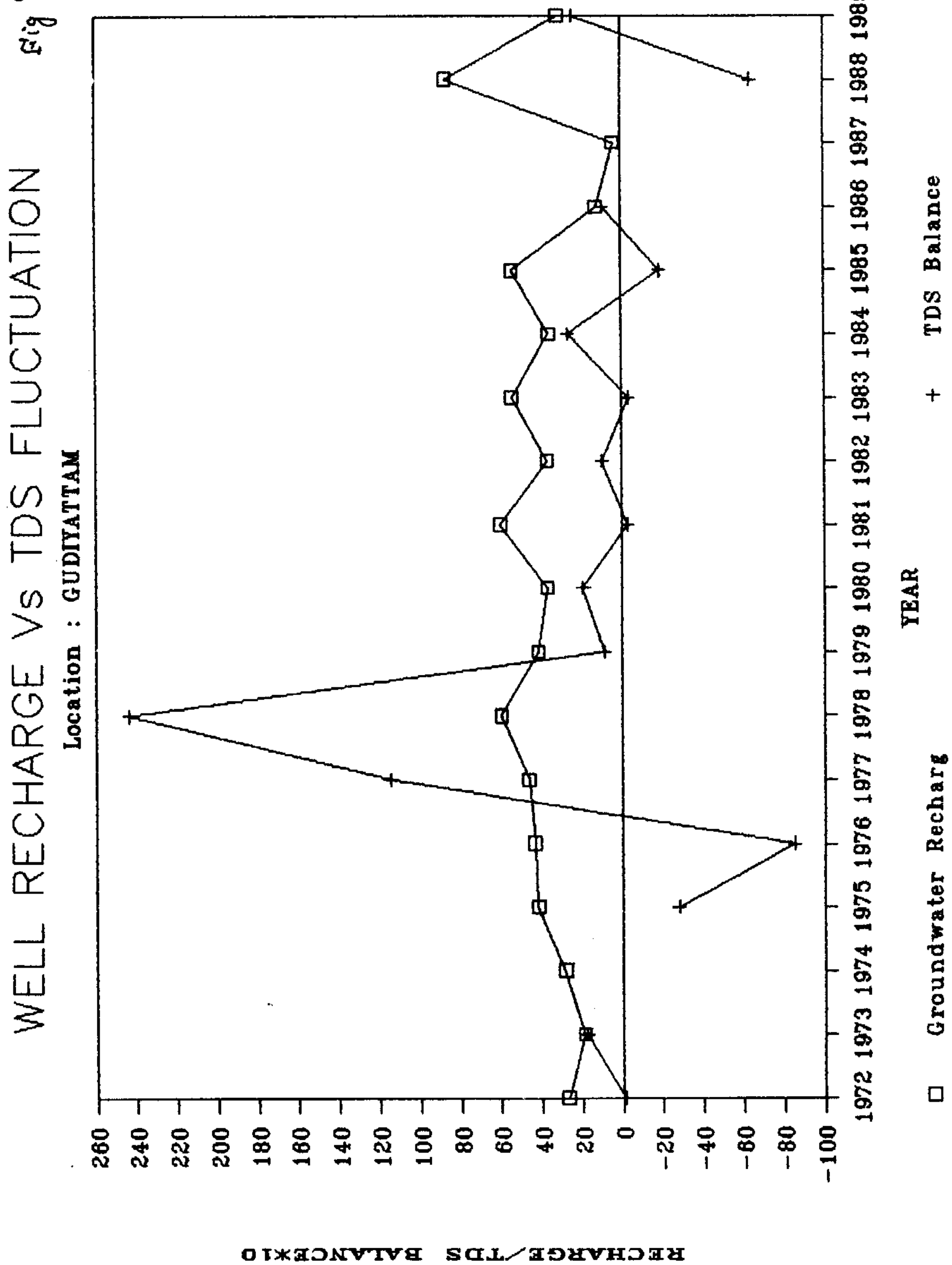

WELL RECHARGE Vs TDS FLUCTUATION
Location : GUDIYATTAM
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989
YEAR
Groundwater Recharg
TDS Balance
RECHARGE/TDS BALANCE*10

Fig 7.12 (a)

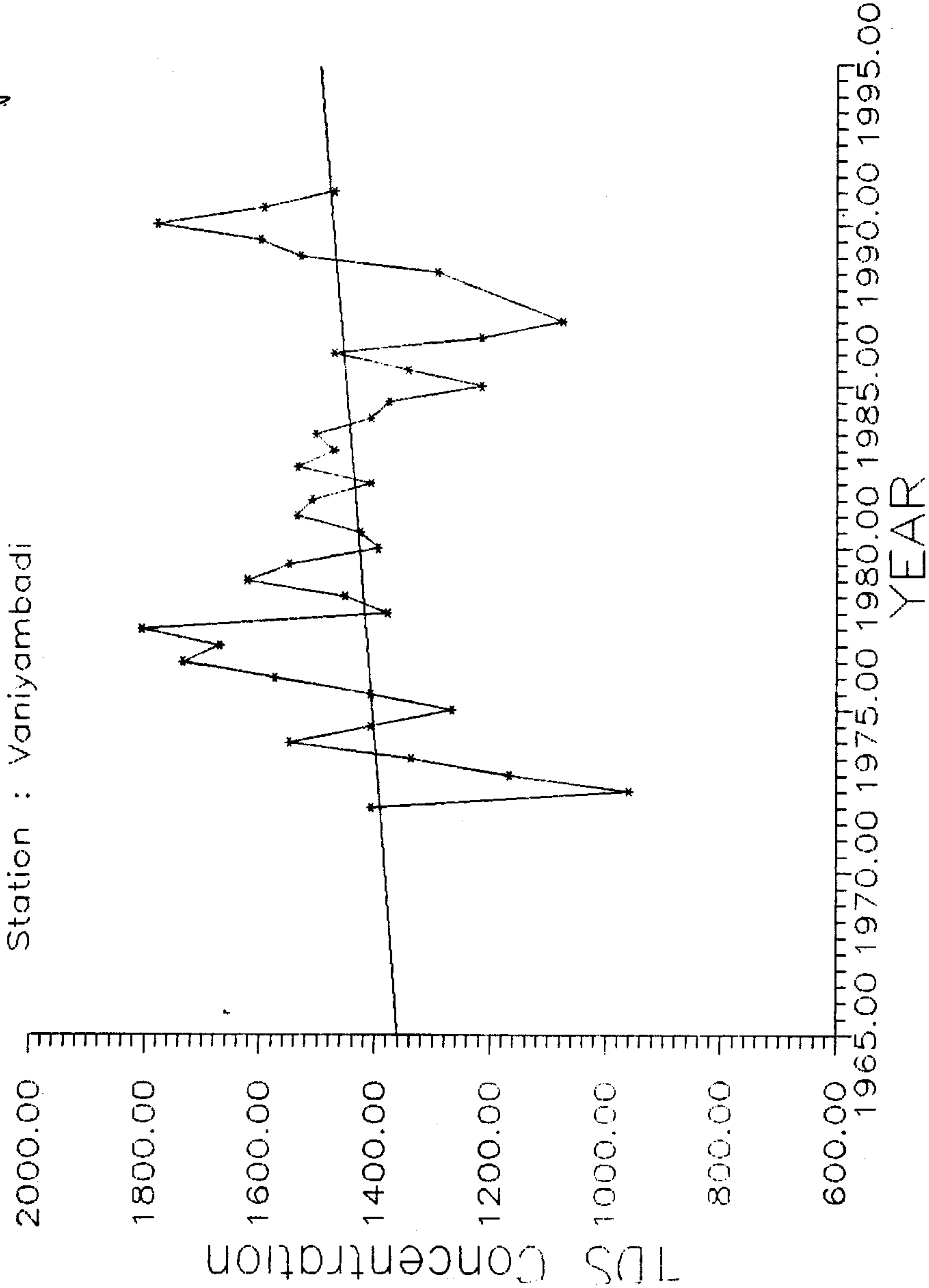

Station : Vaniyambadi
TDS Concentration
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
1965.00 1970.00 1975.00 1980.00 1985.00 1990.00 1995.00
YEAR

Fig 7.12(b)

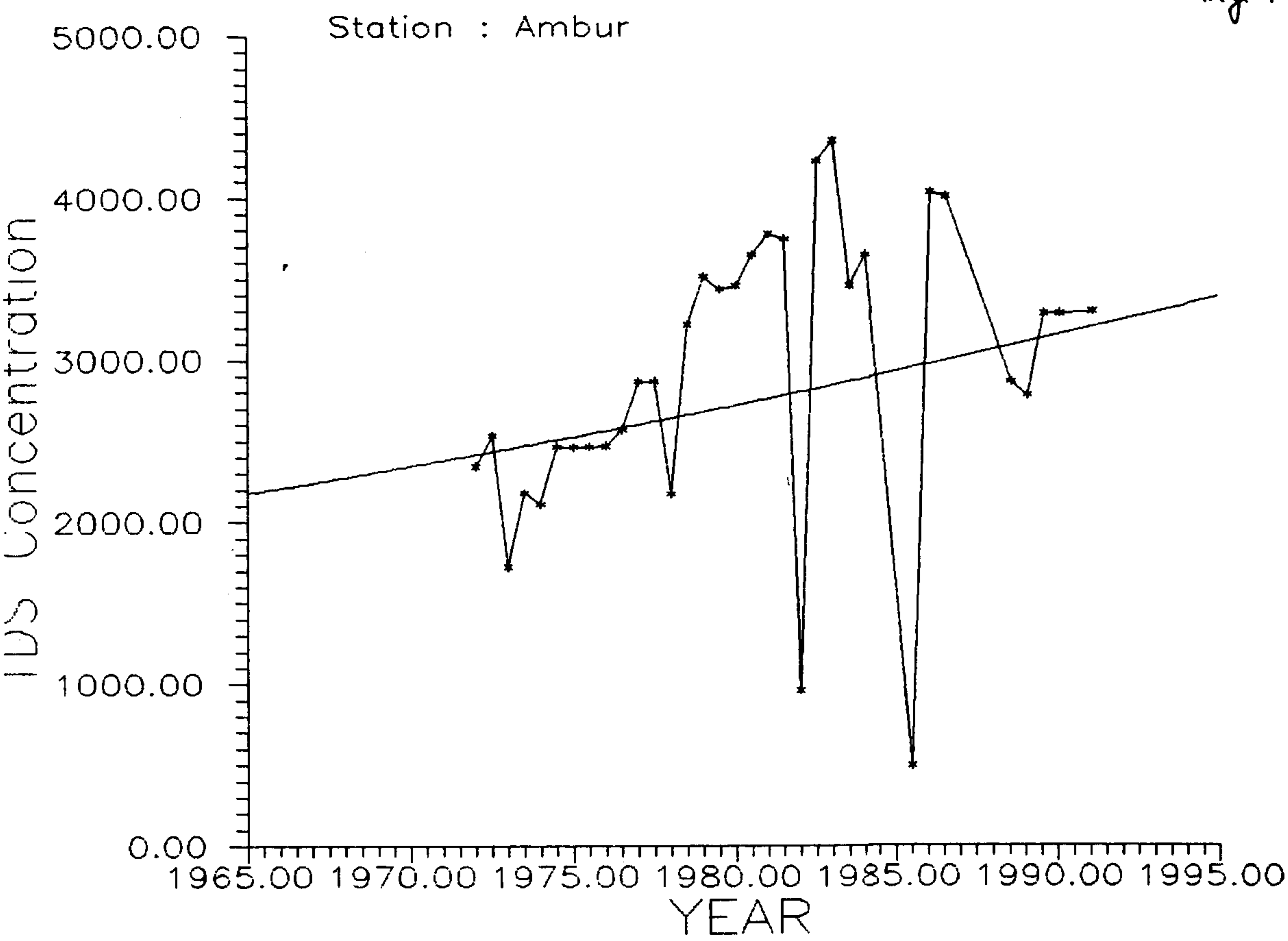
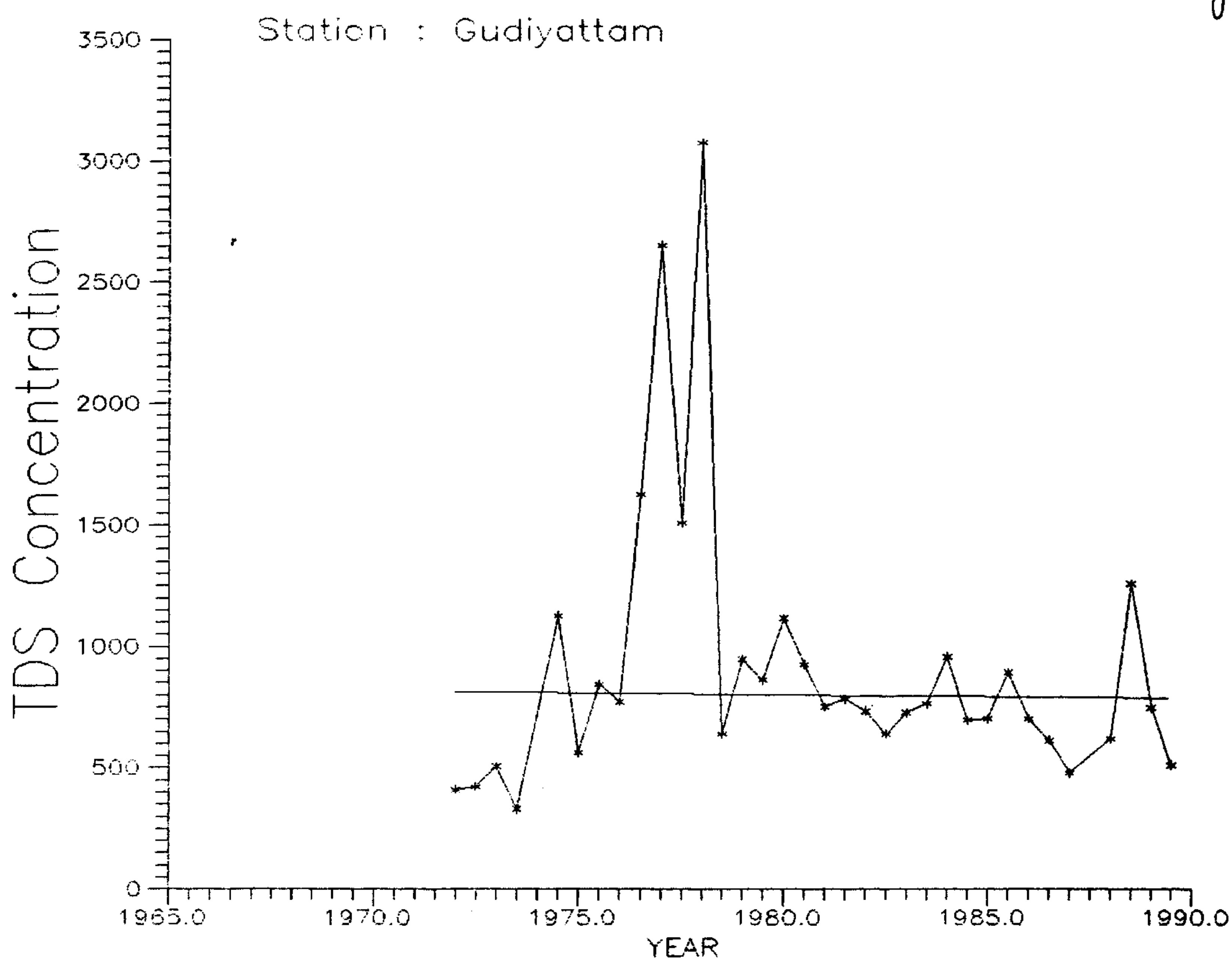

Station : Ambur
TDS Concentration
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
1965.00
1970.00
1975.00
1980.00
1985.00
1990.00
1995.00
YEAR

Fig 7.12(c)



Station : Gudiyattam
TDS Concentration
3500
3000
2500
2000
1500
1000
500
0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
YEAR

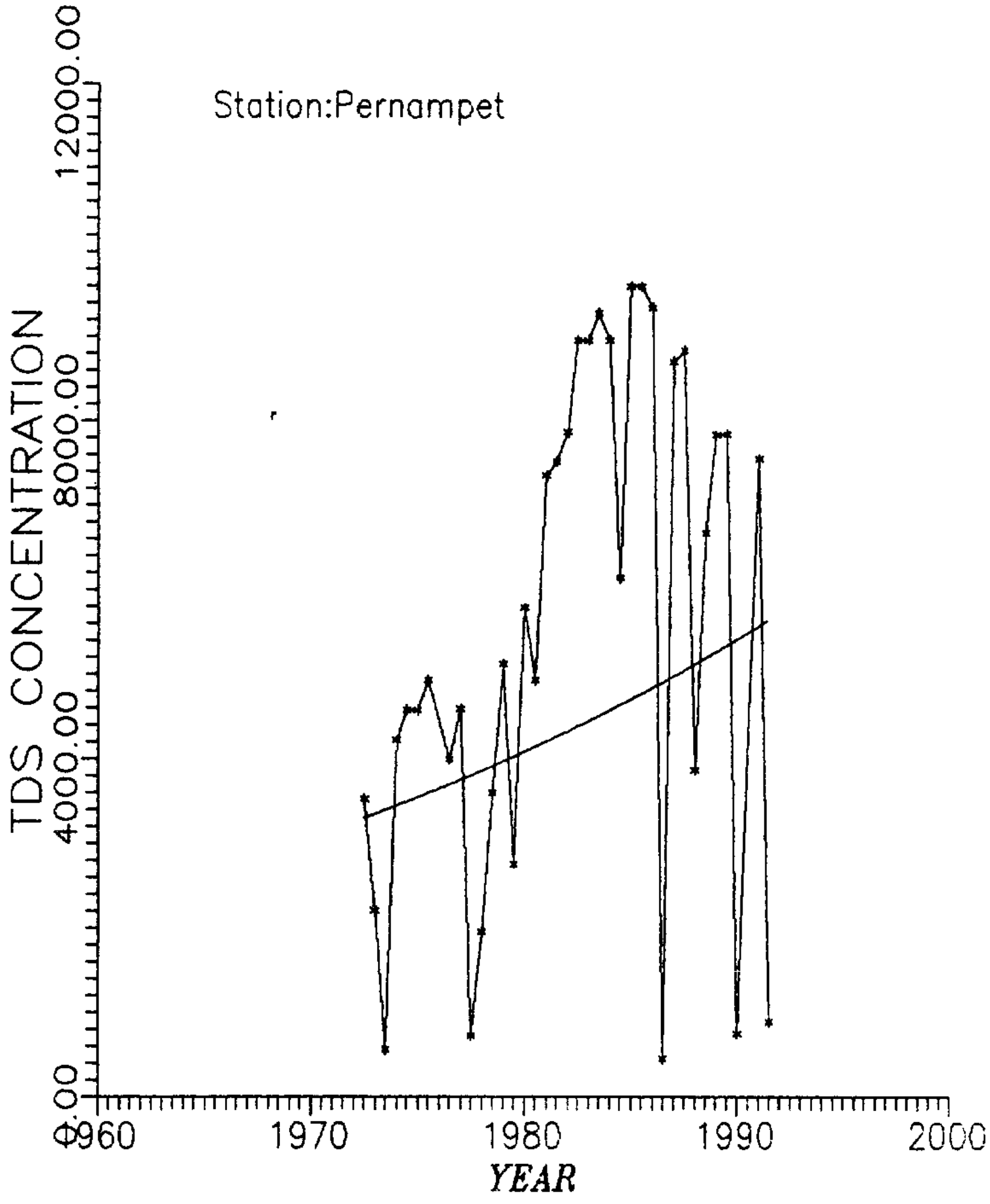
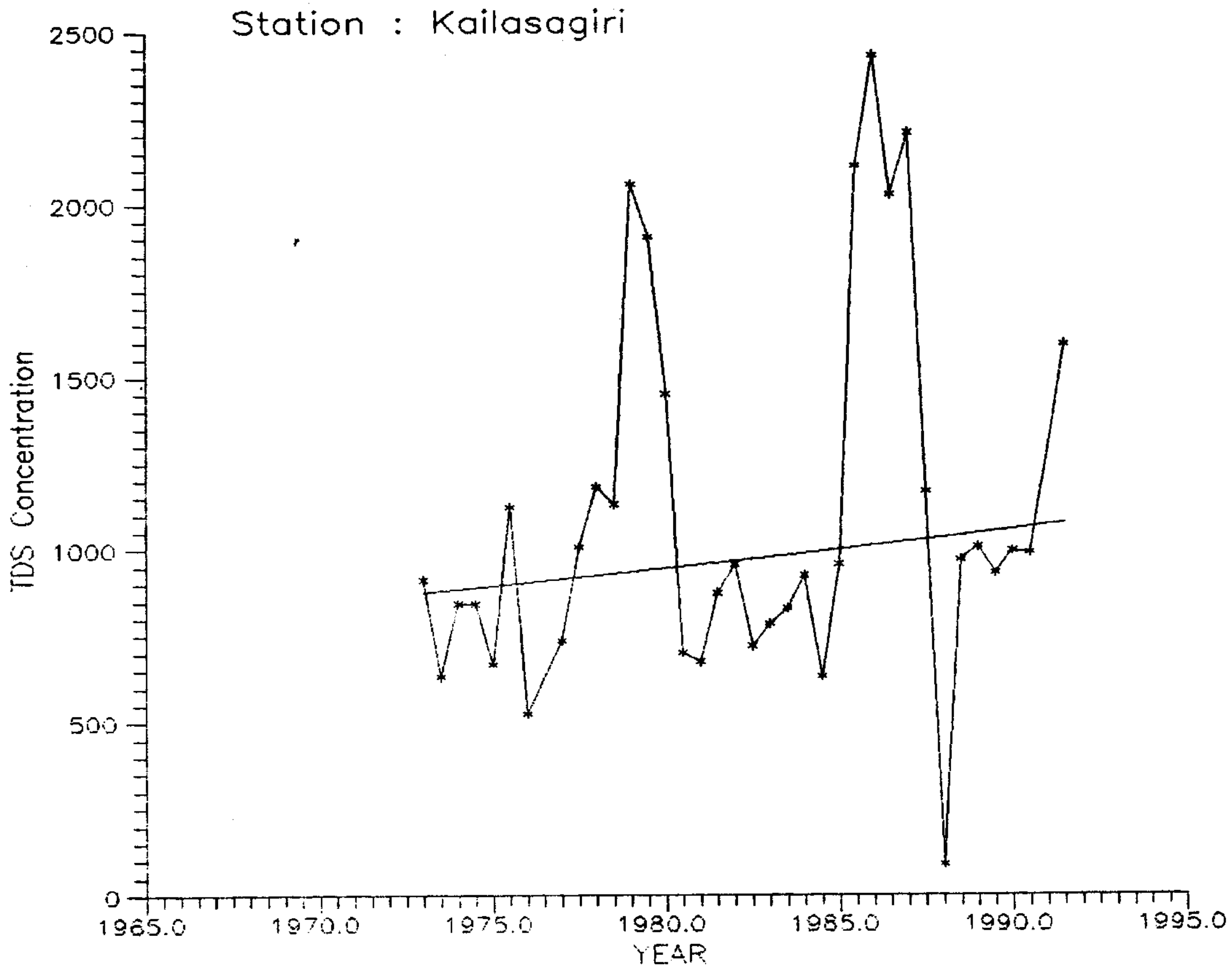

Station:Pernampet
TDS CONCENTRATION
12000.00
8000.00
4000.00
0.00
1960
1970
1980
1990
2000
YEAR

Fig 7.12(d)

Fig 7.12(e)


Station : Kailasagiri
TDS Concentration
2500
2000
1500
1000
500
0
1965.0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
YEAR

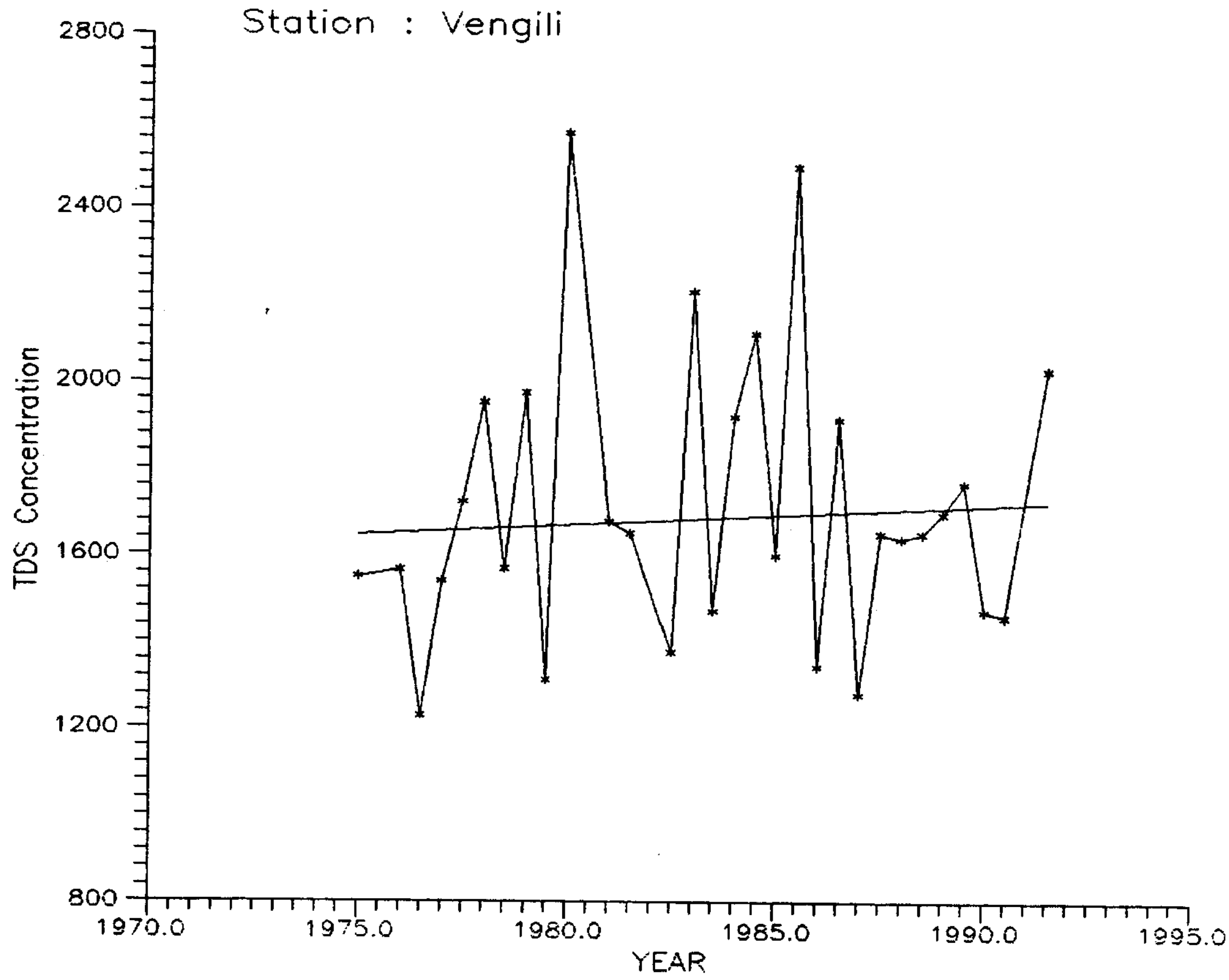
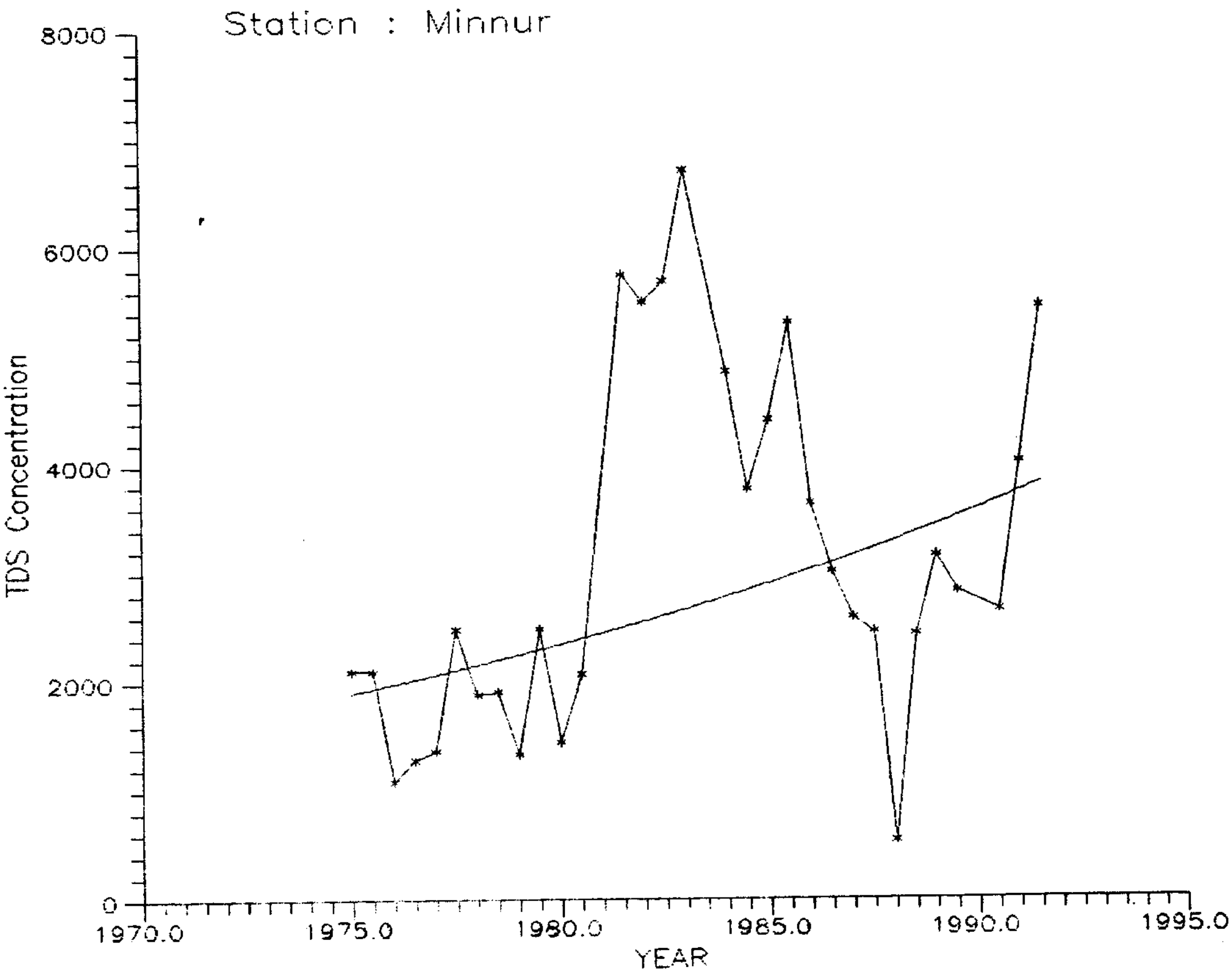

Station : Vengili
TDS Concentration
2800
2400
2000
1600
1200
800
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0
YEAR

Fig 7.12 (g)



Station : Minnur
TDS Concentration
YEAR
8000
6000
4000
2000
0
1970.0
1975.0
1980.0
1985.0
1990.0
1995.0

84

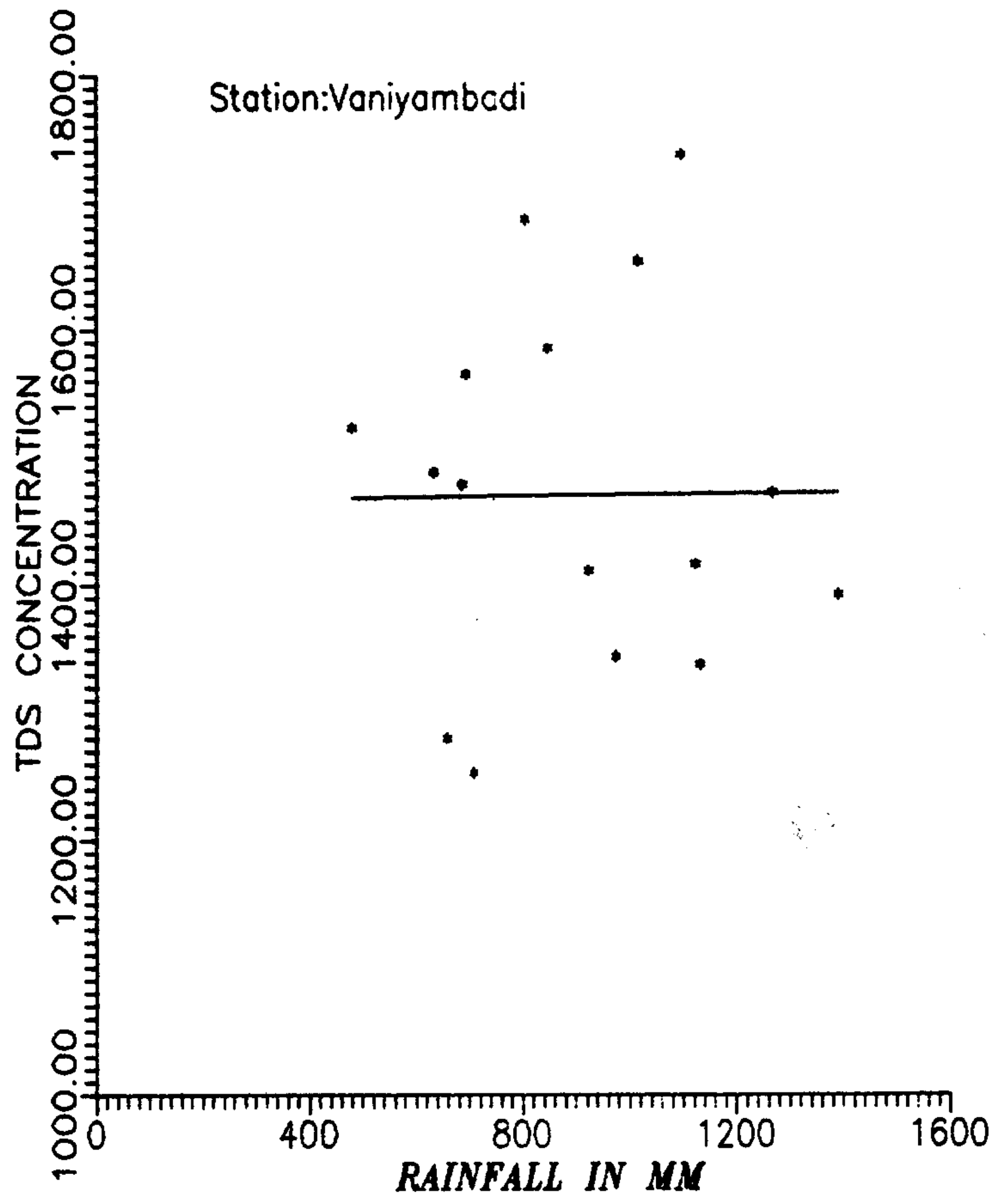

Station:Vaniyambadi
TDS CONCENTRATION
1000.00
1200.00
1400.00
1600.00
1800.00
0
400
800
1200
1600
RAINFALL IN MM

Fig 7.13 (a)

Fig 7.13 (b)

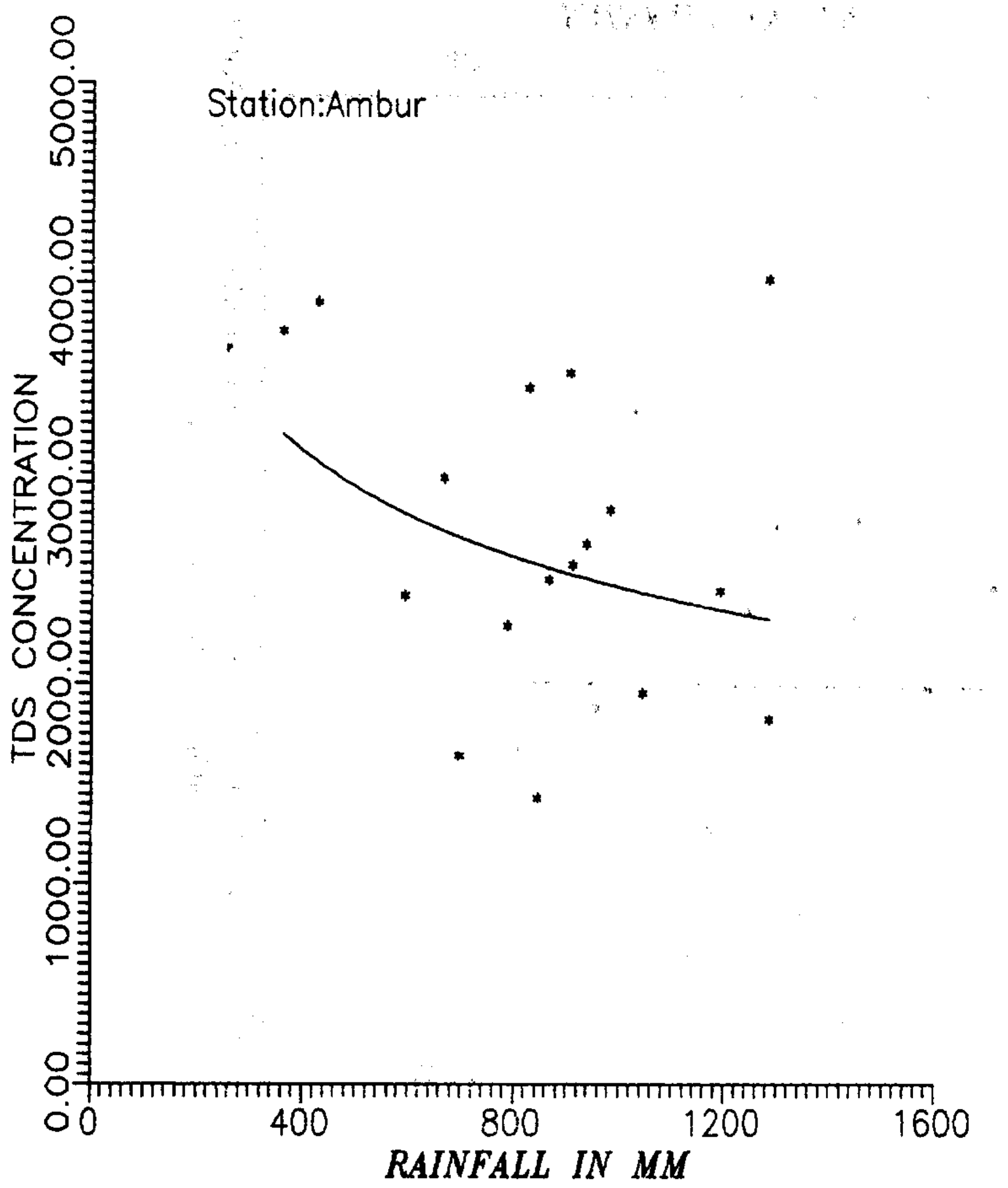

Station:Ambur
TDS CONCENTRATION
0.00
1000.00
2000.00
3000.00
4000.00
5000.00
0
400
800
1200
1600
RAINFALL IN MM

Fig 7.13(c)

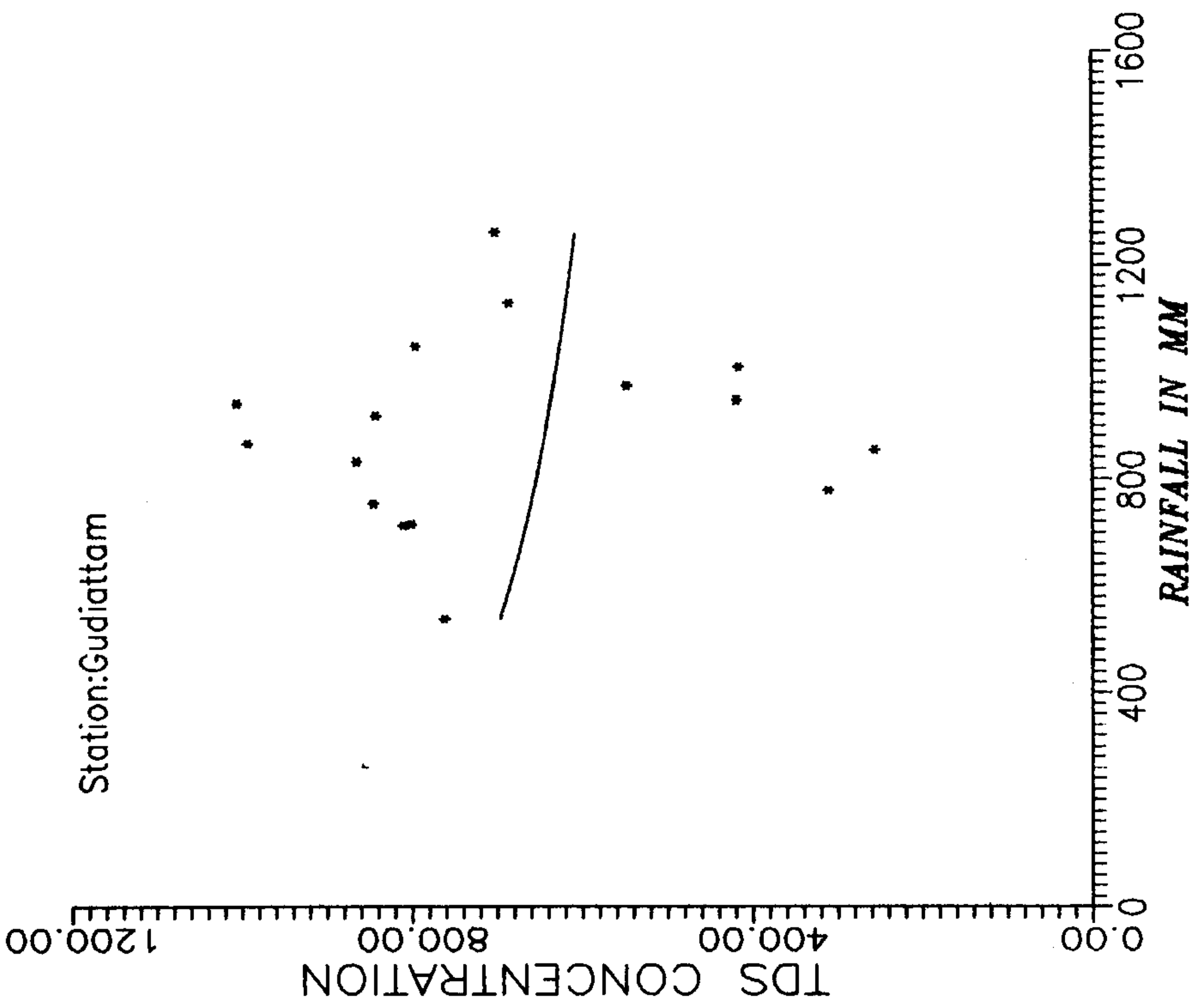

Station:Gudiattam
TDS CONCENTRATION
0.00
400.00
800.00
1200.00
RAINFALL IN MM
0
400
800
1200
1600

TABLE I

PUMPED TEST DATA

SR. NO.	WELL NO & TYPE	LATITUDE & LONGITUDE	LOCATION	DISCHARGE 'Q' IN gpm	TRANMIS-SIVITY'T' IN gpd/ft	PERMEABI-LITY'K'IN gpd/Sq.ft	DURATION OF PUMPING
1	21030 BORE	12 42 40 79 23 25	VELUR	41	110000	353.13	60 min
2	_ BORE	2 47 43 70 05 20	THUTHI-KODI	55	452	249	60 min
3	21176 BORE	12 53 00 78 52 05	RANSUPU-RUM	8	35	0.938	30 min
4	21177 BORE	12 53 05 78 51 00	MADHANUR	9	30.7	0.748	30 min
5	21009 BORE	12 51 45 79 03 40	USUR	11	44000	259.47	50 min
6	21029 BORE	12 49 00 79 27 08	ARUMPAK-KAM	9.95	10.73	7.42	240
7	21077 BORE	12 59 18 79 05 15	NARASINGA-PURAM	30	10500	140.4	855
8	238/1B DUG	12 51 35 78 47 54	LAKSHMIA-MMALPURAM	77	4024	217.14	180 min
9	11/7 DUG	12 47 06 78 53 40	VEPPAAN-KUPPAM	1139	6590	652.32	95 min
10	21/2 DUG	12 44 39 78 49 23	PAKKAMPA-LAYAM	119	5234	201.99	120 min
11	478/B DUG	12 47 06 78 53 40	AGARAM-CHERI	158	5411	272.67	120 min

SOURCE: INSTITUTE OF WATER STUDIES,MADRAS(TAMILNADU)

TABLE II

WELL CENSUS DATA & GROUNDWATER DRAFT
DECEMBER 1991

SR. NO.	NAME OF THE BLOCK	NUMBER OF IRRIGATION DUG WELLS E.D.	D.D.	B.D.	NET GROUNDWATER DRAFT	REMARKS
1	ALANGAYAM	1856	130	4304	2586	
2	ANAICUT	3860	863	5987	5258	
3	GUDIYATAM	5905	76	797	5233	
4	KATPADI	3318	302	1389	3358	
5	KANIYAM-PADI	3381	655	2089	3857	
6	K.V.KUPAM	8514	71	380	7351	
7	MADANUR	4381	360	920	5233	
8	NATRAM-PALLY	2948	223	1309	2962	
9	PERNAMBET	6962	118	720	5594	
10	TIRUPATUR	5304	566	2579	5512	
11	VELLORE	2029	114	3254	2498	
12	WALAJAPET	1400	417	2694	2106	

SOURCE: INSTITUTE OF WATER STUDIES, MADRAS (TAMILNADU).

NOTE: E.D.--Electrically driven
D.D.--diesel driven
B.D.--Bulock driven
Net Groundwater draft in ha.mt.

TABLE III

REPRESENTATIVE CROPPING PATTERN

North Arcot-Ambedkar District:

(a) Culturable Area

Geographical area	--	592018 Ha.
Forest area	--	161829 Ha.
Barren area	--	26359 Ha.
Net area sown	--	208838 Ha.
Area sown more than once	--	34790 Ha.
Total cropped area	--	243628 Ha.

(b) Irrigation Practices

Area irrigated by canal	--	778 Ha.(CCA)
Area irrigated by tanks	--	683 Ha.(CCA)
Area irrigated by wells	--	76330 Ha.(CCA)
Area irrigated by other	--	221 Ha.(CCA)

(c) Percentage Area Irrigated

Paddy	--	14.2%
Cholam	--	10.2%
Combu	--	1.9%
Ragi	--	3.4%
Cereals	--	2.9%
Pulses	--	14.1%
Sugarcane	--	8.5%
Groundnut	--	30.4%
Gingelly	--	0.6%
Coconut	--	5.0%
Cotton	--	1.0%

(d) Water Requirement:

Paddy	--	1.2 mts.
Sugarcane	--	1.75 mts.
Other dry crops	--	0.36 mts.

(e) Cropping Pattern

Kharif - Paddy.
Rabi - Paddy,Pulses,Groundut,Ragi,Gingelly,Vegitables.
Perenial - Sugarcane.

TABLE IV

NUMBER & TYPES OF SMALL SCALE INDUSTRIES IN UPPER PALAR ZONE
YEAR 1980

SL. NO.	TYPE OF INDUSTRY	VELLORE	GUDIYATAM	VANIYAMBADI	KATPADI	VANIYAMBADI MADHAVANCHERY	AMBUR	PALLIKONDAN
1	FOOD PRODUCTS	44	9	9	4	1		
2	BEVERAGE & TOBACCO	4						
3	COTTON TEXTILES	3	2	3		2		
4	TEXTILE PRODUCTS	4		2		15		
5	WOOD SILK & SYNTHETIC FIBRES			2				
6	WOOD & WOOD PRODUCTS	15	5	10	2		2	
7	PAPER&PAPER PRODUCTS	39	10			3	2	
8	LEATHER AND LEATHER PRODUCTS	19	9	63	1		29	1
9	RUBBER PLASTIC PETROLEUM&COAL PRODUCTS	24	8		1		1	
10	CHEMICAL AND CHEMICAL PRODUCTS	25	210	34	1		9	
11	NONMETALIC MINERAL PRODUCTS	23	4	6			2	
12	BASIC METAL AND ALLOY INDUSTRIES	7	2				1	
13	METAL PRODUCTS	72	8	5	7		4	
14	MACHINERY MACHINE TOOLS	22	7	14	2		16	1
15	ELECTRICAL MACHINERY APPARATUS AND PARTS	5	1					
16	TRANSPORT EQUIPMENT	21	1	1				
17	OTHER INDUSTRIES	7	1					

TABLE V

REPRESENTATIVE SURFACE WATER QUALITY DATA

SL. NO.	LOCATION	TALUK	DATE OF SAMPLING	E.C.	pH	Ca	Mg	Na	HCO3	CO3	Cl	TDS	TH	RSC	SAR
1	Vishamangalam (Korathu River)	Thirupa-thur	4/12/79	860	8.6	20	32	106	366	18	78	550	200	2,6	3.3
2	Pachakuppam(Palar & Malatar River)	Thirupa-thur	5/12/79	920	8.1	40	24	120	268	18	120	509	200	1.8	3.7
3	Marigam(GoddarRiver)	Gudiyatam	5/12/79	570	7.9	32	13	69	287	-	392	365	135	2.8	2.6
4	Othiyathur (Othiyathur odai)	Vellore	4/12/79	600	8.2	40	29	55	354	-	46	435	220	1.4	1.6
5	Palar anicut (Palar river)	Walajapet	3/12/79	730	8.4	36	16	97	232	24	89	467	155	1.5	3.4
6	Ponnai anicut (Ponnai river)	Walajapet	3/12/79	630	8.6	24	18	83	262	24	60	403	135	2.4	3.1
7	Ranipet bridge (Palar river)	Walajapet	3/12/79	600	8.5	20	12	92	177	30	64	305	100	1.9	4.0
8	Pernampet river	Gudiyatam	/12/91	750	8.5	16	38	78	222	48	53	377	195	1.3	2.4
9	L. Manokoppam river	Gudiyatam	/12/91	1060	8.6	36	18	166	232	30	131	602	165	1.5	5.6

TABLE VI

GROUND WATER RECHARGE THROUGH WATER LEVEL FLUCTUATION

WELLNO	SPYEILD	AREA	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90
W23023	0.08	129.89	48.42299	36.16137	31.1736	42.08436	34.29096	10.91198	24.00367	27.01712	20.7824	32.42054	52.68338	29.61492	47.27996	23.89976	30.65404	12.70117	12.57335	21.02152	20.26284
W23027A	0.05	5.94	0.4752	0.82566	0.64152	0.6831	0.47817	0.79002	0.72468	0.43362	0.76329	0.93555	1.49985	0.87615	1.47015	ERR	1.13454	0.3643	0.4455	1.0989	0.43065
W23028A	0.08	37.53	ERR	ERR	ERR	7.986384	11.85948	9.45756	10.44835	8.346672	10.89871	13.42072	23.23857	16.21296	20.59646	7.05564	6.045472	7.20576	9.30744	14.41152	13.06044
W23029	0.08	132.2	36.69072	26.9600	18.82528	28.44944	41.56368	43.25584	46.11136	59.54288	41.35216	36.59296	60.07168	36.00448	54.14912	35.9584	53.9376	12.05664	3.49000	86.7232	31.1992
W23030	0.08	94.11	21.98409	14.68116	18.67142	36.81583	36.81583	12.04608	35.91237	13.1754	37.71928	13.70241	39.90264	12.57309	23.86629	10.91676	19.19844	13.32597	7.90524	27.40012	12.42252
W23031	0.07	216.49	68.19435	61.37491	63.64806	76.22612	95.01746	84.10636	82.59093	62.13263	70.77050	79.56007	92.89585	69.10360	78.04464	73.64989	71.90292	65.92120	79.86316	75.7715	66.67092
W23032	0.06	183.58	40.97505	79.30656	56.83636	86.79662	55.18414	87.23721	115.1046	83.49218	66.96998	31.39218	82.611	26.32537	112.5712	44.60994	35.24736	15.97146	20.37738	64.90732	41.3055
W23046	0.04	124.12	0	15.63912	37.40424	48.55574	35.9948	24.92329	29.29232	50.54166	38.00001	16.33419	62.06	37.90072	49.39976	24.07928	37.90072	29.04408	4.9640	41.20784	21.84512
W23047A	0.08	76.79	0	27.09151	31.08459	19.78110	27.15294	21.00974	44.29247	35.26196	27.95156	25.18712	63.88928	31.33032	46.32116	20.27256	51.60288	16.8930	16.03375	29.1882	14.12936
23048	0.06	79.67	0	11.61500	24.04440	30.25866	25.19165	42.11356	34.08282	32.26635	30.92789	28.92021	52.82121	17.92575	32.02734	25.81308	32.50536	18.00179	17.20872	17.68674	16.96971
23049	0.07	81.4	0	11.396	19.943	24.15952	18.00568	16.86608	23.53274	26.66664	30.65524	31.85182	41.76634	21.6524	34.188	13.9601	34.35894	16.92306	10.5413	14.8148	12.5356
23050	0.07	79.67	0	12.93840	26.76912	29.61333	24.09220	18.79415	48.40749	24.81720	49.80171	46.17673	40.71137	23.31144	42.66328	23.14413	36.24985	18.68261	9.40073	30.11526	17.84608
23051	0.06	45.61	0	6.814134	9.879126	13.24514	13.35460	24.30100	13.92929	9.249708	9.058146	9.98859	22.65904	-6.786768	22.44012	4.78905	12.77992	10.53591	19.56669	16.28277	11.49372
23052	0.02	60.7	0	1.9923	6.1143	7.0761	4.56168	8.3814	10.19508	5.20746	8.3127	6.7326	8.931	3.0915	12.4347	6.5952	3.7098	2.8167	0.2061	12.366	5.3586
23053	0.06	21.94	0	1.77714	2.76444	5.19978	5.449896	5.98962	5.13396	8.082696	5.00232	8.266992	13.95384	3.22518	7.63512	3.55428	5.33142	3.9492	2.76444	10.00464	3.291
23071	0.08	72.74	0	0	0	17.05025	29.38696	28.74684	29.50334	25.89544	20.83273	13.20958	37.53384	11.6384	37.76660	16.58472	22.98584	11.92936	35.20616	16.87568	21.76380
23072	0.07	96.99	0	0	0	34.62543	38.08797	38.08797	26.47827	33.81071	27.49666	20.57157	51.66657	22.94783	53.97493	24.44148	34.96489	24.44148	31.57024	25.45987	20.02843
23073	0.08	67.55	0	0	0	19.1842	32.58612	47.71732	31.6134	32.74824	32.9644	19.02208	43.5022	8.3762	37.828	22.4266	42.1512	24.8504	35.23408	25.9392	31.073
23074	0.08	74.48	0	0	0	37.53792	42.72172	64.23155	31.10284	22.16524	18.35187	37.12083	56.54521	11.97638	63.87404	21.74816	47.25011	34.55872	44.39008	45.87968	40.39795
23070	0.07	87.18	0	0	0	60.47676	64.26037	69.32553	28.80427	29.71966	48.63772	1.464624	64.80961	0.671286	6.40773	56.75418	54.31314	58.27983	68.34912	61.20907	60.53779
23079	0.04	17.32	0	0	0	1.59344	1.136192	1.93984	1.544944	1.205472	2.56336	2.050688	2.32088	1.76664	3.1176	0.93528	3.04832	1.57331	1.45488	1.66272	0.866
23081	0.1	47.92	0	0	0	14.1364	20.07848	19.83888	20.50976	14.80726	15.47816	16.772	24.4392	15.3344	22.2828	14.376	20.98896	16.0532	14.6156	22.2828	17.4908
23080	0.07	61.2	0	0	0	20.52036	20.64888	17.69292	27.07488	19.53504	21.03444	- 7.2828	37.0566	18.33552	21.42	14.1372	32.3442	19.4922	9.76752	19.7064	13.7088
23082	0.05	36.95	0	0	0	4.748075	13.5237	13.11725	11.54687	8.590875	10.16125	3.380925	10.47532	6.558625	9.514625	6.68795	8.31375	6.5032	9.79175	4.98825	4.095875
2401	0.16	96.99	77.12644	39.88228	65.40764	93.42076	75.10905	90.00672	119.1813	123.9920	130.3545	24.82944	132.5271	35.38195	109.0943	69.8328	96.21408	58.96992	72.16056	122.5953	46.5552
TOTAL		2036.96	ERR	ERR	ERR	760.2248	766.5526	809.8087	851.1221	758.7041	776.9211	527.1872	1120.571	469.8019	950.4280	ERR	796.0937	502.2334	537.2606	810.5513	546.1469

TABLE VII

GROUNDWATER BALANCE THROUGH RAINFALL

RG NAME	AREA	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90
VELLORE	0.072	920.1	1125.4	666.1	714.5	944.9	1321.3	1451.1	1158.3	921.7	701	1069.3	540.3	1475.1	895	1044	651.6	1187.5	870.7	1196.5
VANIAMBADI	0.091		700.4	686.8	1131.9	1017.7	1098	1123.2	847.1	923.9	400.8	1268.2	633.9	1391.2	660	975.2	662.4	892	695	805
RANIPET	0.034	1047.4	806	870	937.7	1200.5	1197.4	1293.9	1101.9	828	662.7	1139.5	819.7	1285.4	934	1196.7	543.6	1229	953.2	1057.4
POINEY	0.044	831	1234.7	1023.8	699.6	1195.8	1379.2	1672.8	1261.8	984	640.2	746.4	636.8	1135.6	936.6	933.9	890.4	1062.3	760	1440.8
ODUKALATHUR	0.144									1142	607	1194.5	784	1395	787	1232	867.6	1047		
SAINAGUNTA	0.096									829.5	196	564	335	920	581.1	1334.7	705.6	554.6		
ALANGAYAN	0.067									1026	394	998	437.5	1355	1034.2	1009	864	1022	811.6	
KATPADI	0.094	769	785.8	513.5	617	900	1176.8	1220	1030.5	994.5	527	878.8	535.6	1359.7	832.7	807.2	554	1061.6	711.3	
JOLARPET	0.042	825	912	653	1367	930	1199.1	1242.3	836.9	1046.3	601.5	1005.1	540.4	1346.2	817.3	970.9	677.7	941.6	862.8	
GUDIATTAM	0.167	1009.3	947.6	755.8	714.4	878	928.9	1049.5	868.8	919.6	539.7	1129.8	834.1	1264.1	716.8	974.9	770.1	943.4	854.4	732.8
AMBUR	0.149	594	1045.5	788	1192.8	867	983	938.6	827.9	906.9	362.4	911.5	429.1	1286	675.6	1286	749.5	845.2	667.2	697.4
TOTAL mean	1.00	856.5420	945.675	744.625	921.8625	992.7375	1160.462	1240.925	991.65	956.5818	520.0272	998.6454	594.0363	1292.118	806.3909	1076.772	728.7727	980.5636	798.4666	988.3166
polygon										960.8362	496.8279	1009.669	603.6938	1293.532	760.8418	1095.269	743.9152	950.583		
RECHARGE FROM RAINFALL		423.1321	467.1634	367.8447	455.4000	490.4123	573.2684	616.9689	489.8750	474.6530	245.4329	498.7759	298.2247	639.0049	379.8078	541.0632	367.4941	469.5484	394.4425	488.2284
RETURN SEEPAGE (IRRIGATION)		42.83851	44.98044	47.22946	49.59093	52.07048	54.67400	57.40771	60.27809	63.29200	66.45660	69.77943	73.26840	76.93182	80.77841	84.81733	89.05820	93.51111	98.18666	103.096
DRAFT(BLOCK TOTAL)		203.9929	214.1925	224.9022	236.1473	247.9546	260.3524	273.3700	287.0385	301.3904	316.4600	332.2830	348.8971	366.3420	384.6591	403.8920	424.0866	445.2910	467.5555	490.9333
RECHARGE		465.9706	512.1438	415.0742	504.9910	542.4828	627.9424	674.3766	550.1531	537.9450	311.8895	568.5563	371.4931	715.9367	460.5862	625.8805	456.5523	563.0595	492.6291	591.3244
GROUNDWATER STORAGE		261.9777	297.9513	190.1719	268.8436	294.5281	367.5900	401.0066	263.1146	236.5546	-4.57042	236.2733	22.59598	349.5947	75.92714	221.9884	32.46563	117.7685	25.07364	100.3910

TABLE VIII

TDS BALANCE CALCULATION

WELLNO	SPYEILD	AREA	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90
W23023	0.08	129.89		447	-170	141	-141	-160	-435	-74	73	-32	26	-128	-32	32	-128	256			-70
W23027A	0.05	5.94		-190	-458	-352	0	-100	0	-1046	77	-192	32	-3264	896			26			-512
W23028A	0.08	37.53				-352	634	-365	-102	-200	1129	45	-525	-384	-832	838	-1178	1466	-190	109	-275
W23029	0.08	132.2		-42	176		-282	-855	1146	2430	86	192	-32	96	-38	262	-192	90		-640	237
W23030	0.08	94.11			1645	-352	-352		3866	-1640	2362	659	-160	-1088	-320	2816	0	8890	-128	-2803	-13
W23031	0.07	216.49		845		-211	141	1264	-90	-1402	768	410	1728	928	704	2272	-576	1037	474	-679	-26
W23032	0.06	183.58		150	528	352	141	-759	-4886	4912	656	198		154	-896	1082	256				
W23046	0.04	124.12			366	0		-6760	-115	-282	64	243	-256	32	-160	32		-19			
W23047A	0.08	76.79																			
23040	0.06	79.67			451	317	-36	-170	282	76	29	326	-1312		-154		6	1760	-32	-51	
23049	0.07	81.4			281	0	-457		-272	51	154	749	-199	237	-45	294	-1152	403	1037	-883	77
23050	0.07	79.67			71		141	-64	32	126	-90	-71	-179	51	-326	173	-179	128	39	-288	-51
23051	0.06	45.61			-422		106		-1587	-1073	-1901	-179		-45	960		-896	-384			
23052	0.02	68.7			140	-422	352	-160	-617	-298	-278	256	-173	134	-230	160	-96	154	-96		-301
23053	0.06	21.94			-43	0	-141	-9	186	-139	-1053	-6	-487	-32	-256	25	-224	-166	-166		25
23071	0.08	72.74					-2253	-157	-90	-154	64	166	-83	160	-307	-320	64	90			
23072	0.07	96.99					-141	74	-301	-666	-327	-192	-218	-141	-96	-192	-320	141	-122	-64	557
23073	0.08	67.55					0	141	96	-298	-57	230	-19			-128	32	160	-12	416	147
23074	0.08	74.48							-25	-208	10			0	160						
23078	0.07	87.18						-368	-131	324	519		422	192	-704	-224		640			
23079	0.04	17.32						-61	13	-105	-51	243	13		-250	-128	-256	0	-51	531	13
23061	0.1	47.92						336	-183	384	662		26		736	-192	-896	-570	-371	-13	-70
23080	0.07	61.2					0	-196	-1120	-23	-1152	-627		-192		1080	-896	627	134	-1987	333
23082	0.05	36.95					-528	3680	-134	170	-57	-442	576		-960	1517	-755	-1530			
2401	0.16	96.99						16	-80	13	67	64	147		160	51	39	-512	-106	116	154
AVERAGE				248	213.75	-79.9090	-156.444	-234.05	-176.958	36.29166	73.00333	97.14285	-33.65	-102.777	-90.4545	472.9	-367.35	576.6818	28.71428	-473.538	14.0625

ANNEX NO. A

Variables influencing contaminant migration analysis from a pollution source

Variable	*Distribution*	
	Spatial	*Temporal*
Geological		
Aquifer media	×	
Form of porosity	×	
Aquifer geometry	×	
Confining beds	×	
Hydraulic		
Effective porosity	×	
Hydraulic conductivity/intrinsic permeability	×	×
Moisture/tension curves		
Storage coefficient	×	
Infiltration mechanisms	×	×
Discharge mechanisms	×	×
Stream/aquifer interactions	×	
Contaminated fluid density	×	
Hydrological		
Precipitation	×	×
Evapo-transpiration	×	×
Surface flow distribution	×	×
Contaminants		
Types	×	×
Adsorption		
Degradation		
Growth		
Dispersion	×	
Alteration		
Anthropogenic		
Demands	×	×
Abstraction designs		
Water supply economics	×	×
Surface water regulation	×	×
Agricultural practice	×	×
Contaminant source management		×

ANNEX NO. 8

Major sources of groundwater contamination and types of contaminants and their relative significance

Source	Type of pollutant				
	Physical	*Inorganic chemical*	*Trace elements*	*Organic chemical*	*Bacteriological*
Municipal					
Sewer leakage	Minor	Primary	Secondary	Primary	Primary
Sewage effluent	Minor	Primary	Secondary	Primary	Primary
Sewage sludge	Minor	Primary	Primary	Primary	Primary
Urban runoff	Minor	Secondary	Variable	Primary	Minor
Waste disposal	Minor	Primary	Primary	Primary	Secondary
Septic tanks and cesspools	Minor	Primary	Minor	Secondary	Primary
Agricultural					
Leached salts	Minor	Primary	Minor	Minor	Minor
Fertilizers	Minor	Primary	Secondary	Secondary	Minor
Pesticides	Minor	Minor	Minor	Primary	Minor
Animal waste	Minor	Primary	Minor	Secondary	Primary
Industrial					
Cooling water	Primary	Minor	Primary	Minor	Minor
Process waters	Variable	Primary	Primary	Variable	Minor
Water treatment plant effluent	Minor	Primary	Secondary	Minor	Minor
Hydrocarbons	Secondary	Secondary	Secondary	Primary	Minor
Tank and pipeline leakage	Variable	Variable	Variable	Variable	Minor
Oilfield wastes					
Brines	Primary	Primary	Primary	Minor	Minor
Hydrocarbons	Secondary	Secondary	Secondary	Primary	Minor
Mining	Minor	Primary	Variable	Minor	Minor
Miscellaneous					
Surface water	Variable	Variable	Variable	Variable	Variable
Sea water intrusion	Primary	Primary	Primary	Minor	Minor
Transport	Minor	Minor	Minor	Primary	Variable

(Based on data from Todd *et al.* 1976)

ANNEX NO. C

Industrial wastewater components having or indicating significant groundwater contamination potential

Pulp and Paper Industry			
Ammonia	Heavy metals	pH	TDS
COD	Nutrients	Phenols	TOC
Color	(nitrogen	Sulfite	
	and phosphorus)		
Petroleum Refining Industry			
Ammonia	Cyanide	Odor	TDS
Chloride	Iron	pH	TOC
Chromium	Lead	Phenols	Total Phosphorus
COD	Mercaptans	Sulfate	Turbidity
Color	Nitrogen	Sulfide	Zinc
Copper			
Steel Industries			
Ammonia	Cyanide	Phenols	Tin
Chloride	Iron	Sulfate	Zinc
Chromium	pH		
Organic Chemicals Industry			
COD	pH	TDS	Total Nitrogen
Cyanide	Phenols	TOC	Total Phosphorus
Heavy metals			
Inorganic Chemicals, Alkalies, and Chlorine Industry			
Acidity/	Chlorinated	Fluoride	Sulfate
Alkalinity	Benzenoids	Iron	TDS
Aluminum	and Polynuclear	Lead	Titanium
Arsenic	Aromatics	Mercury	TOC
Boron	Chromium	Phenols	Total Phosphorus
Chloride	Cyanide		
	COD		
Plastic Materials and Synthetics Industry			
Ammonia	COD	Organic	Phosphorus
Chlorinated	Cyanide	Nitrogen	Sulfate
Benzenoids	Mercaptans	pH	TDS
and Polynuclear	Nitrate	Phenols	Zinc
Aromatics			
Nitrogen Fertilizer Industry			
Ammonia	COD	pH	Sulfate
Calcium	Iron, Total	Phosphate	TDS
Chloride	Nitrate	Sodium	Zinc
Chromium	Organic Nitrogen		
Phosphate Fertilizer Industry			
Acidity	Fluoride	Nitrogen	Sulfate
Aluminum	Iron	pH	TDS
Arsenic	Mercury	Phosphorus	Uranium
Calcium			

COD Carbon oxygen demand
TOC Total organic carbon
TDS Total dissolved solids
From *U. S. Environmental Protection Agency* [1973]

ANNEX NO. D

Components of industrial waste

	Metals mining	Primary metals	Pharmaceuticals	Batteries	Inorganic chemicals	Organic chemicals	Pesticides	Explosives	Paints	Petroleum refining	Electroplating
Ammonium salts		X								X	
Antimony	X				X				X		
Arsenic	X	X	X		X					X	
Asbestos					X				X		
Barium									X		
Beryllium	X									X	
Biological waste			X								
Cadmium	X	X		X	X				X	X	X
Chlorinated hydrocarbons					X	X			X		X
Chromium		X	X	X	X				X	X	X
Cobalt									X	X	
Copper	X	X	X	X					X	X	X
Cyanide		X			X					X	X
Ethanol waste, aqueous			X								
Explosives (TNT)								X			
Flammable solvents						X			X		
Fluoride		X			X						
Halogenated solvents			X								
Lead solvents	X	X		X	X				X	X	X
Magnesium	X										
Manganese		X									
Mercury		X	X	X	X				X	X	
Molybdenum										X	
Nickel		X		X	X					X	
Oil		X								X	X
Organics, misc.						X					
Pesticides (organophosphates)							X				
Phenol		X								X	X
Phosphorus					X						X
Radium	X										
Selenium	X	X	X							X	
Silver				X						X	X
Vanadium										X	
Zinc	X	X	X	X	X				X	X	X

From *U. S. Environmental Protection Agency* 1977

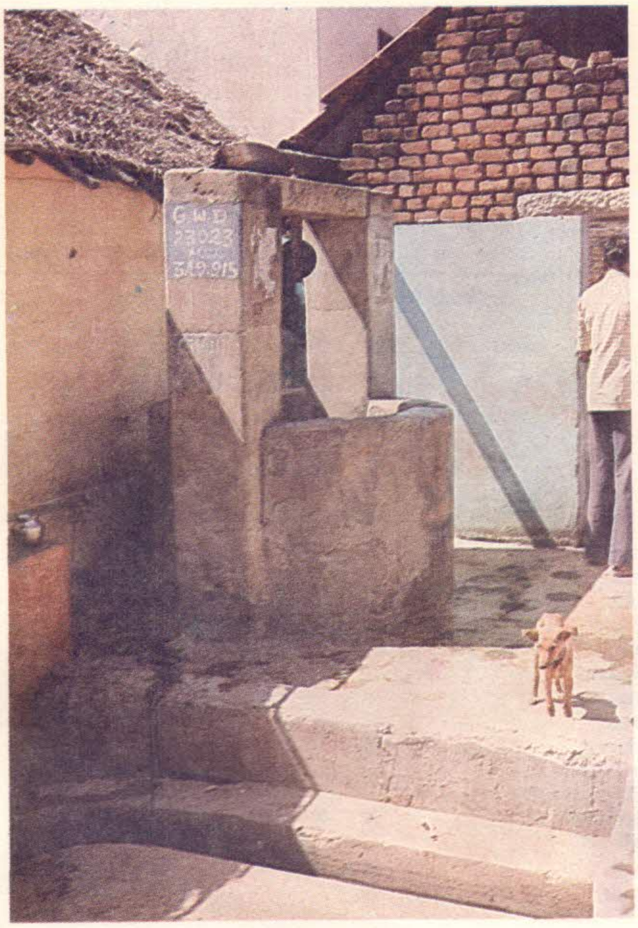


PHOTO 1: OBSERVATION WELL AT VANIYAMBADI (WELL No. 23023)

PHOTO 2 : 'FREE FOR ALL' EFFLUENT DISPOSSAL AT VANIYAMBADI

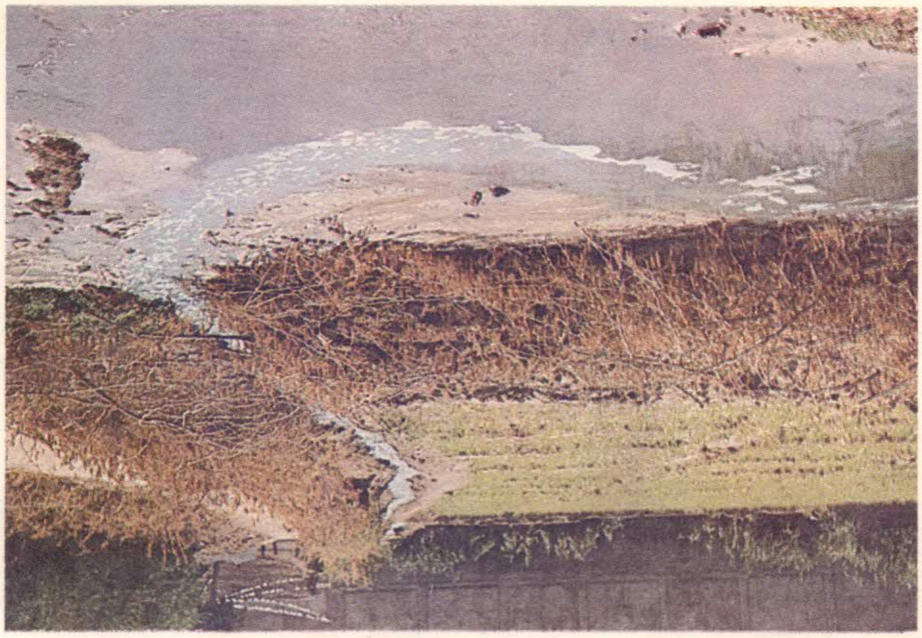


PHOTO 3: TENNARY EFFLUENT DISPOSSAL TECHNIQUE NEAR MINNUR

PHOTO 4 : PALAR RIVER AT MINNUR.

PHOTO5: TENNARY EFFLUENT DISPOSSAL AT AMBUR

PHOTO 6 : PALAR RIVER AT AMBUR.

PHOTO 7 : DRY WASTE DISPOSSAL FROM INDUSTRIES ON RIVER BANK

PHOTO 8 : MIS-USED WELL AT PERNAMPET (23030)