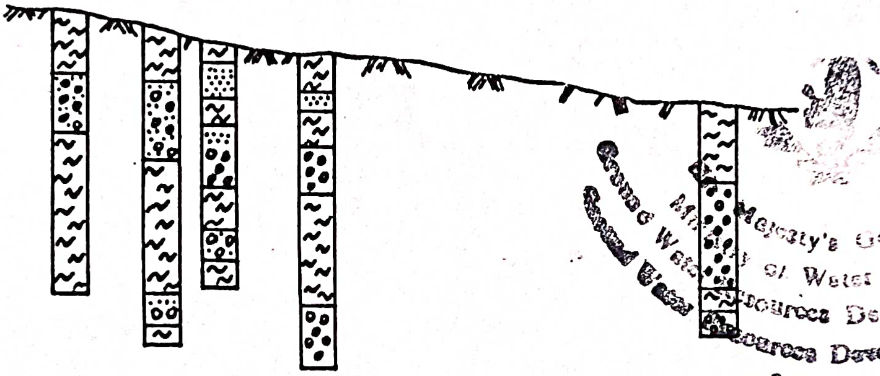
UNITED NATIONS DEVELOPMENT PROGRAMME
AND
HIS MAJESTY'S GOVERNMENT OF NEPAL
NEP/86/025

SHALLOW GROUND WATER INVESTIGATIONS IN TERAI

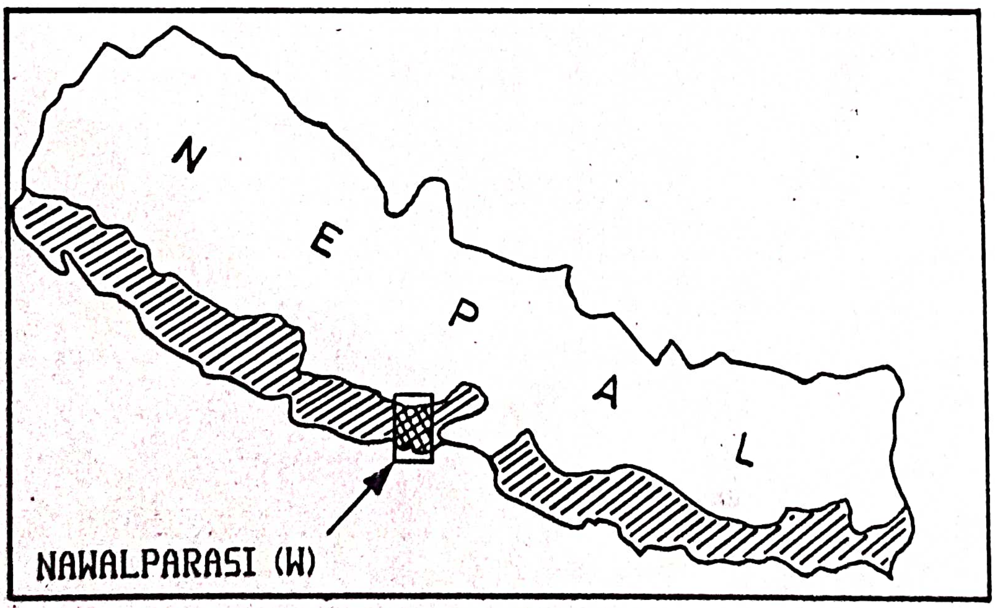
NAWALPARASI (WEST)

SHALLOW WELLS DRILLING, TESTING AND MONITORING IN 1987/88

BASIC DOCUMENTATION AND PRELIMINARY INTERPRETATION



TECHNICAL REPORT NO.5



KATHMANDU, MARCH 1989

GWRDB-UNDP NEP/86/025

SHALLOW GROUND WATER EXPLORATIONS IN TERAI

TECHNICAL REPORT No. 5

NAWALPARASI DISTRICT (WEST)

SHALLOW WELLS DRILLING, TESTING AND MONITORING IN 1987/1988
BASIC DOCUMENTATION AND PRELIMINARY INTERPRETATION

Executing Agency: United Nations Department of Technical Co-operation for Development

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KATHMANDU, MARCH 1989

EARLIER TECHNICAL REPORTS:

1. **Bhairawa-Lumbini** Ground Water Irrigation System Preliminary Mathematical Modelling. May 1988.
2. **Shallow Ground Water Level Fluctuations** in the Terai in 1987. Preliminary Report. May 1988.
3. **RAUTAHAT DISTRICT.** Shallow Wells Drilling, Testing and Monitoring in 1987/88. Basic Documentation and Preliminary Interpretation. November 1988.
4. **RAUTAHAT DISTRICT.** Mathematical Model of Shallow Ground Water System. December 1988.

ABBREVIATIONS:

UN/DTCD - United Nations Department of Technical Co- operation for Development

UNDP - United Nations Development Programme

GWRDB - Ground Water Resources Development Board

GDC - Groundwater Development Consultants (International) Ltd.

ADBN - Agricultural Development Bank of Nepal

ADB - Asian Development Bank

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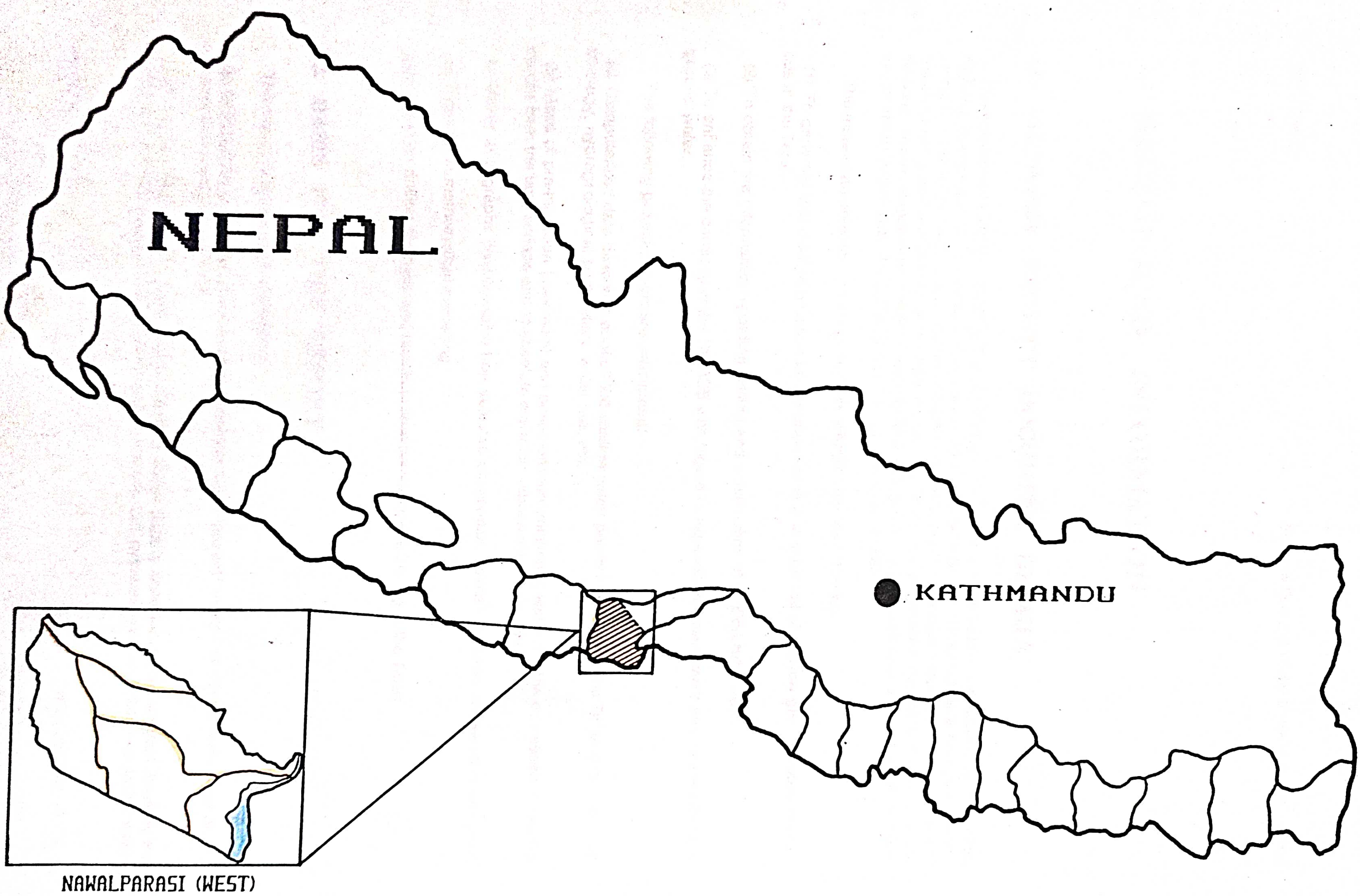


FIGURE 1

1. BACKGROUND INFORMATION

1.1. NEP/86/025 PROJECT DOCUMENT DETAILS

The project NEP/86/025 - Shallow Ground Water Investigations in the Terai - is executed by the United Nations Department of Technical Co-ope ration for Development. It is designed as a four-year project primarily ori ented to field-data collection, establishment of ground water data base, and to assessment of development potentials of shallow aquifers all over the Terai. The government counterpart agency is the **Ground Water Resources Development Board** (GWRDB) of the Department of Irrigation of the Ministry of Water Resources. The project's activities started in June 1987.

The immediate objectives of the project NEP/86/025 are the following.

(1) To generate technical information on the occurrence and potential of shallow ground water resources in the Terai.

(2) To obtain the information regarding drilling and construction of shallow tube wells.

(3) To enhance the capacity of the GWRDB with regard to exploration, assessment and development of ground water.

The following project outputs are anticipated:

(a) Computerized data base with about 2000 shallow water points from all over the Terai. Information on lithology, hydrogeological parameters, water use, etc.

(b) Maps of pre-monsoon (maximum) and post-monsoon (minimum) water depths expressed in relative depths from the land surface and in absolute elevations above mean sea level.

(c) Water level graphs (hydrographs) from selected observation points in a minimum period of one year.

(d) Reports on mathematical modelling.

(e) Report on drilling methods and results in shallow water well drilling in the Terai.

1.2. BASIS FOR THIS REPORT

This report is based on the following:

(a) NEP/86/025 project wells (for ease of reference called "project" wells) - 17 new shallow wells drilled between January and June 1988.

(b) Shallow drilled wells for the Nepal Drinking Water Supply Scheme in the Narayani Zone by the Japanese Red Cross Society and its contractor Nissaku Co., Ltd. between 1983 and 1986 - about 200 wells.

(c) Pumping tests conducted in project wells in 1988.

(d) Water level observations since May 1987.

(f) Groundwater Resources Development Strategies for Irrigation. Groundwater Development Consultants (UK), Ltd. 1987.

(g) Duba,D. 1982. Groundwater Resources in the Terai of Nepal.

(h) Tillsen, D. 1985. Hydrogeological Technical Assistance to the Agricultural Development Bank of Nepal. ADB-UNDP report.

(i) Several Mission Reports by the Chief Consultant in this project.

(j) Several field trips by NEP/86/025 project staff.

The report of Japanese Red Cross Society on drilling in Narayani Zone (1985) is presented in the form of Basic Documentation, with lithological and well construction logs, static and dynamic water level data during the drilling, water chemistry. This report is important but its usefulness is diminished by the lack of appropriate maps to show the exact locations of wells. (Lithological cross- sections, presented in this report as **Appendices 4**, are based equally on new "project" wells and on "Japanese Red Cross Society" wells.)

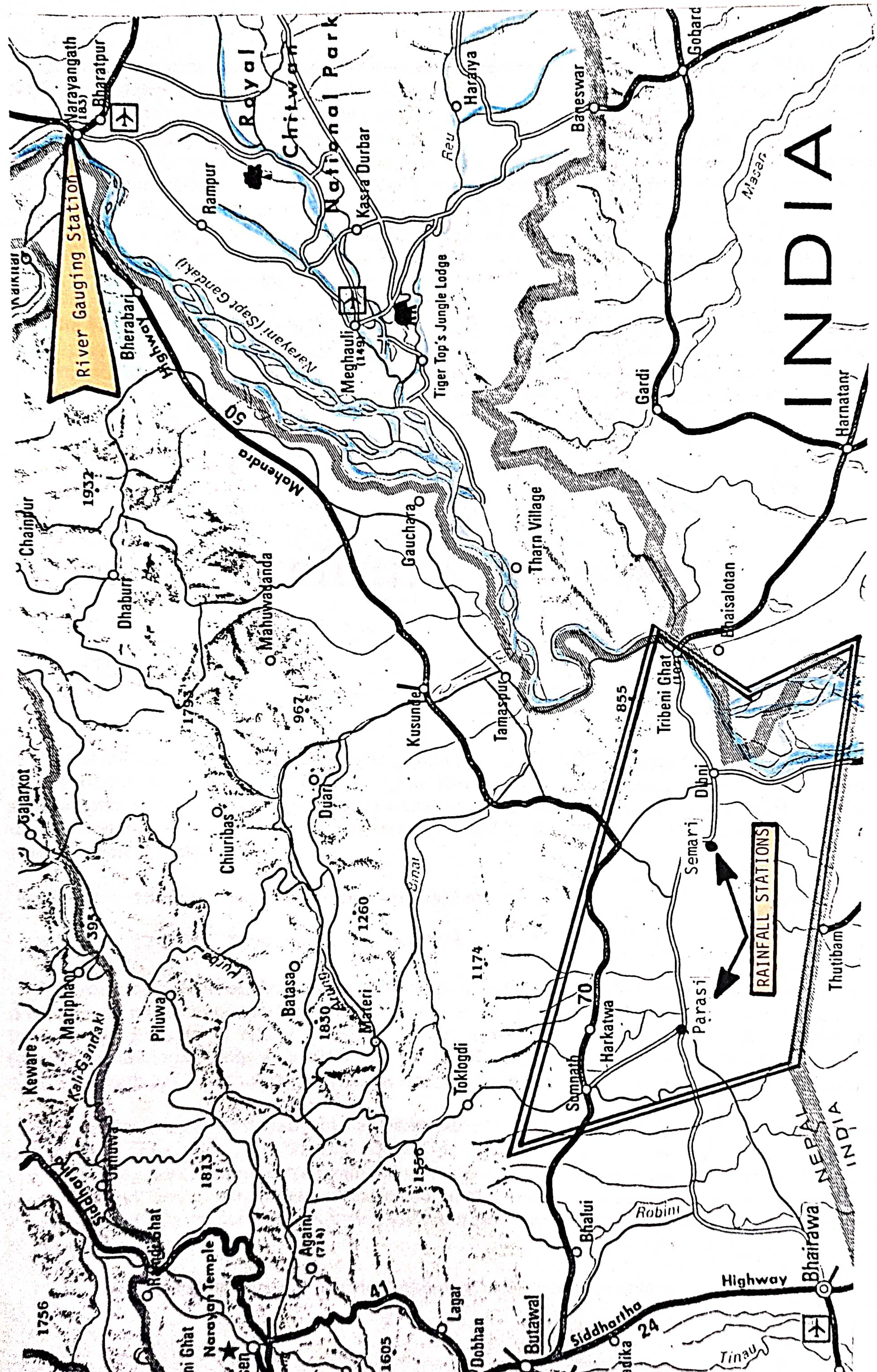
1.3. LOCATION, SIZE, CLIMATE, RIVER FLOW

Nawalparasi district belongs to the Western Region (in addition to Kapilvastu and Rupandehi districts). The district's total area is 520 km^2. According to Land Resources Mapping Project by Kenting Earth Sciences Ltd., completed in 1986 for the whole of Nepal, a total of 418 km^2 of the Nawalparasi area is suitable for irrigation of wet season paddy and of diversified dry season crops. The location of Nawalparasi district within Nepal is shown in **Figure 1**. For the purpose of studying the shallow ground water system of the Terai, the contour line 150 m is considered to be the physical end of the Terai's Quaternary sediments. This Report covers only the drilling activities, lithology, and hydrogeological characteristics of the shallow aquifer in the western portion of the Nawalparasi District. Since only six wells have been drilled in the northeastern part of the district, and none was pump tested, there is no basis for reporting on the whole district. The area under study is shown in **Figure 2** (the double-line polygon).

The main characteristics of the climate in Nawalparasi district, as well as in the whole Terai, is monsoon rainfall which occurs between June and September and which delivers an average of 85% of the total annual rainfall. For the purpose of this report the data were collected in two rainfall stations, **PARASI** and **SEMARI (Figure 2)**. It is to be understood that the data are not officially cleared by the HMG Meteorological Service, but rather used in a draft form as an indication for the correlation between shallow water level fluctuation and the rainfall.

Although the Terai of Nepal is in the subtropical zone, the mean monthly temperature reaches a low of 16.1 °C in January compared to a high of 30.5°C in May.

Evolution of shallow ground water levels is heavily dependent on the distribution of rainfall. Most of the recharge to shallow aquifers comes from fan deposits near the Siwalik hills and mountains. The amounts of rainfall in the years 1987 and 1988 will be discussed in Section 4.2. The mean annual rainfall is about or more than 1500 mm and pan evaporation is also close to 1500 mm. Average monthly rainfall exceeds average evapotranspiration during only 4 months, June to September. Because of the large moisture deficit during the remaining months a second rice crop cannot be grown under normal conditions. The low winter temperatures preclude a third rice crop even with the addition of irrigation.



River Gauging Station
RAINFALL STATIONS
INDIA
NEPAL
Royal Chitwan National Park
Narayangath
Bharatpur
Bherabari
Rampur
Kasra Durbar
Meghauli
Tiger Top's Jungle Lodge
Narayani (Sapt Gandaki)
Mahendra Highway
50
Chaimpur
Dhaburi
Mahuwadanda
Gauchara
Tharn Village
Kusunde
Tamaspur
Tribeni Ghat
Bhaisalotan
Gardi
Harnatanr
Baneswar
Haraiya
Gobard
Gajarkot
Chiuribas
Dujari
Semari
Dhni
Parasi
Harkatwa
Sumnath
Thutibari
Mariphant
Kewaré
Piluwa
Batasa
Maleri
Toklogdi
Binai
Kali Gandaki
Ramdi Ghat
Narayan Temple
Again
Lagar
Butawal
Bhalui
Robini
Bhairawa
Siddhartha Highway
24
41
70
Tinau
Masan
Reu
1932
1753
967
855
1260
1174
1830
1813
1550
1605
1756
595

FIGURE 2

The major potential surface water source for supplementing natural rainfall is the Narayani River which makes the eastern boundary to the area under study. The Narayani River is one of the most important rivers in Nepal. Unfortunately, the only river flow record that was available comes from a site at Narayangath, which is some 60 km northeast of the Tribeni Ghat, the place where the Narayani enters the study area (**Figure 2**). The land surface elevation at the gauging station in Narayangath is 183 m, while the elevation of the river at the Tribeni gath is 102 m. The average monthly flows of the Narayani River at Narayanigath are shown in **Figure 5**. In between the two locations the Narayani River receives the flow from the Rapti River. Almost ninety percent of the annual flow of the Narayani River occurs in the months June to October and only ten in the remaining 7 months. The flow in the months from January through May is mostly base flow, or ground water contribution.

The Narayani River is important for the shallow ground water system of the Terai in western part of Nawalparasi district because it makes a hydraulic barrier to shallow ground water flow. It is believed that the ground water from one side of the river cannot flow across the river course into the other side. Since the minimum average river flow in dry months is above 300 m3/sec 60 km upstream of the study area, it is clear that within the study area the minimum river flow is more than 300 m3/sec.

2. PROJECT ACTIVITIES IN 1987/88

2.1. DRILLING

Out of the total planned scope of drilling within this project, which amounts to about 200 shallow wells for the whole Terai, the program of drilling for Nawalparasi district was prepared about a year-and- half ago providing for drilling of 16 wells (in the western part) with an average drilling depth of 50 m. The total drilling metrage in Nawalparasi (West) was estimated at 800 m. Here below the planned and actual implementation is shown:

Planned: 16 STW Total drilling metrage: 800 m

Actual: 17 STW Total drilling metrage: 573 m

With respect to number of drilled wells, the implementation was about what had been programmed, but it was below expectations in the sense of drilled metrage. The implementation compared to the design is illustrated in **Figures 6** and **7**. The map with locations of all "project" wells is shown in **Appendix 1**. Seventeen lithological logs with other well construction data are appended in the group of **Appendices 3** (3/1 through 3/17). Lithological cross-sections are presented in **Appendices 4** (4/2 through 4/6).

The actual number of drilled wells in Nawalparasi district by this project is 17. None of the wells was abandoned. Their average depth was 33.7 m. However, some of early wells (STW- 1,2,3) were deficient in the following: (a) improper screen with 0.5 mm openings, low overall "porosity" of 11%; (b) poor development which left behind a mud cake on the screen and prevented the water from entering the well. This has in turn resulted with unsuccessful pumping tests and less-than-expected transmissivity values for such kind of permeable formation.

The table here below presents the most pertinent data on well drilling.

No.	Name	X	Y	Z	Depth (m)	Comment
1	Rampurwa	758300	3056250	129.87	28.0	0.5 mm screen
2	Badera	765400	3055000	127.52	23.0	0.5 mm screen
3	Parasi	762900	3048000	111.39	38.5	0.5 mm screen
4	Jamuniya	771900	3049600	113.20	40.0	1.5 mm slots
5	Paldanda	777750	3048120	123.65	50.0	slotted pipe
6	Dabila	772870	3044370	112.08	45.0	slotted pipe
7	Kuniya	782500	3040300	107.62	12.0	slotted pipe
8	Raninagar	786880	3039630	110.20	5.5	slotted pipe
9	Kharahani	775630	3041500	105.83	33.5	slotted pipe
10	Banjariya	758250	3051250	114.60	63.0	slotted/0.5 mm
11	Parsawal	758120	3053120	119.55	38.0	slotted/0.5 mm
12	Lalpati	756370	3045375	107.90	38.0	slotted/0.5 mm
13	Gobrahiya	770620	3042000	107.98	39.0	coconut rope
14	Surajpura	775000	3036250	103.30	33.0	slotted pipe
15	Guthi Parsauni	777000	3034750	103.50	19.5	slotted pipe
16	Bisnupura	760370	3040870	106.10	17.0	slotted pipe
23	Sunwal	761000	3054370	125.15	50.5	slotted pipe

Notes. (1) X and Y coordinates are taken from the 1:500,000 map of Nepal, as a composite of LANDSAT imagery. On that map, the Universal Transverse Mercator grid overlay is based on the Everest Geodetic System. Latitude is measured and numbered northward and southward to the equator; and longitude is measured and renumbered every 6 degrees. For Nepal the 6 degree break in numbering occurs at approximately 84 degree East longitude.

(2) Z, which is the absolute elevation of the well above the mean sea level, was supplied by SWISS-AIR Photo+Surveys Ltd., under a subcontract. The land-surface surveying was completed in January-February 1989. The deepest well is 63.0 m deep, and the shallowest only 5.5 m! The 5.5-m deep well was drilled by a drilling rig, not manually! What is common to both, the deepest and shallowest wells, is that there are no results from pumping tests!

At least five wells out of 17 are poorly constructed. This mostly refers to the screen used (Japanese-manufactured wire- wrapped screen with 0.5 mm opening and an estimated open area of 11%), but also to the method of drilling with plenty of bentonite and improper and inefficient development. Both factors contributed to extremely poor yield of wells, which is absolutely in contradiction with the lithology encountered. For example, the well STW-1, Rampurwa, penetrated about 16 m of gravel. One would expect transmissivity of about 500 m2/day. Yet, the pumping test failed and the well was reported dry! Similarly, the well STW-11, Parsawal, reported 28 meters of gravel, plus 4 meters of sand. Yet, its pump-test discharge was only 1 l/sec, and the level immediately dropped from 4 m to 8 m below the ground level.

In some other wells, the static water level at the drilling time was too deep to permit testing with a centrifugal pump which normally has a limit of suction head of about 7 meters. For example, the well Gobrahiya (STW-13), which was drilled through 33 m of sand and 5 m of gravel, could not be tested in May 1988 because the level was about 6 m below the land surface. (The same well could have been tested in August when level rose to about 4 m from the measuring point, see **Appendix 10/7**.) The same comment applies to well STW-6, Dabila, in which at the time of drilling the static water level was at 6.54 m below ground level, and the test was not conducted in spite of 16 m of gravel (**Appendix 10/3**).

Out of 17 drilled wells, 16 wells were constructed by a drilling rig, and only one well by indigenous (manual) methods of drilling. It may be too early to conclude on advantages and disadvantages of a particular method of shallow wells constructions in the Terai. Manually-drilled wells have a better control over lithology of penetrated strata; they are cleaner and pumping tests are more reliable because aquifers and well screens are less clogged than in bentonite-drilled wells. However, these advantages fade when the total depth of penetration is taken into account. Likewise, it is difficult under Terai conditions to construct a well with gravel pack and to penetrate through the whole thickness of coarse-grained layer (gravel, pebble, boulders).

As a conclusion of the drilling program in Nawalparasi district the following may be inferred. The drilling of shallow wells should be done with as little as possible bentonite mud. The screens should be best pre-packed with gravel, or alternatively the drilling diameter should be minimum 10 inches to accommodate 4 or 6-in casing and minimum 4-in gravel pack. In an exploration-drilling project such as this UN assistance project, the first saturated sand-and-gravel layer should be screened to offer the possibility of testing and monitoring the first directly recharged zone. In a water-supply and/or irrigation well, all permeable layers within the depth of drilling should be screened to produce as much water as available.

More attention should be given to well development. Screens with slot opening less than 1.0 mm should not be used. Better supervision of drilling and development activities is needed to produce better wells.

2.2. TESTING SHALLOW WELLS

The program of testing called for pump testing of 16 newly drilled and 7 shallow wells to be selected from existing shallow wells. Only eight wells had been successfully tested. In five pumping tests one observation well was available and the test produced the values of storage coefficient in addition to transmissivity. For the location of all tested wells see **Appendix 1** - the location map of all project wells and wells with pumping tests. The northwestern part of the study area has not a single pumping test. This is the area in which wells were improperly developed (STW-1,2,3), or poorly constructed (STW-23, Sunwal). This is also an area of locally inferior aquifer (STW-10, Banjariya)

Out of 17 newly drilled "project" wells, in nine wells the pumping test could not be executed for various reasons: (a) in two wells the static water level (in the month of April when levels are at about the minimum elevation and maximum depth from the land surface) was too deep to run a test with a centrifugal pump, (b) in six wells the test was attempted but the discharge was very low and drawdown excessive in short time, (c) one well was too shallow to attempt the test (STW-8, 5.5 m deep). (Some tests were repeated in October-November 1988, but the levels were already declining and soon dropped to below the pump suction.)

All pumping test interpretations are appended to this report in the group of **Appendices 5**. The interpretation is based on the proprietary UN/DTCD computer program which includes a measure of appropriate formula fit (standard deviation).

In running pumping tests the following problems have been identified:

(a) Pumping equipment not adequate for all situations. The suction range of centrifugal pump limited to about 7 m below the pump discharge point restricts the possible dynamic depth of pumping. Pump discharge is fluctuating during the test.

(b) Pump discharge measuring instrumentation unreliable. When the results by two methods of measurement are compared, the match is sometimes more than 20%. 200-l barrel is probably better than "V"-notch weir. The best would have been a 3-in flowmeter with direct reading of the flowrate in liters per second.

(c) Measurements of water level during the pumping and/or recovery periods are sometimes questionable (late, improvised).

would have been very useful would be to have had more observation wells included in the testing program. For that reason some of "project" wells have been located nearby an existing drilled well equipped with hand pump (either ADBN or Japanese Red Cross Society well) which was then used as observation well during the test.

2.3. MONITORING WATER LEVELS

In Technical Report No. 2 three maps from Nawalparasi district were presented showing the maximum and minimum depths to water table in 1987 and the rise of water levels between the minimum and maximum of 1987. In May 1987, water levels were monitored in dug wells. The network of observation wells in May 1987 is shown in **Appendix 2** (circles filled with a cross). Each newly drilled "project" well was included into the monitoring network. The idea was to gradually replace the original network of dug wells with newly drilled wells of which lithology was known, transmissivity eventually calculated and land surface elevation surveyed. This "new" monitoring network is also shown in **Appendix 2**. As of the month of February 1989, both networks are still under observations but, soon, only newly drilled wells shall remain under active monthly observations. Some "old" wells shall be retained to fill the gap and provide the continuity for presenting hydrographs of longer-than-one-year duration. Tentatively the proposed network shall include 17 "project" drilled shallow wells, plus five wells equipped with hand pump, and one dug well near the banks of the Narayani River.

Depth to water levels is observed in either monthly or bimonthly intervals. In the month of January 1989, the network includes 18 dug wells and 17 project-drilled wells. The evolution of water table in shallow aquifers of the Nawalparasi Terai is illustrated with several appendices in this report (**Appendices 8**: depths to water table in May and September 1988, the rise of water table between May and September 1988, and, for comparison, the rise in the same time period of 1987). Individual hydrographs for most of monitored wells are presented in **Appendices 10**.

3. SHALLOW AQUIFER LITHOLOGY AND AQUIFER PARAMETERS

3.1. LITHOLOGY

Project wells have penetrated through the upper 50 or so meters of an alluvial sequence, which is commonly known as the Terai Plain. The Plain is composed of interlocked alluvial deposits of the wider Ganges Plain and that of fans, channels, flood plains of numerous rivers flowing from the Siwalik Range and across the Terai Plain, as well as colluvial deposits at the foothills of the above range. The most prominent lithological- morphological unit is the Bhabar Zone.

The Bhabar Zone is a stretch of torrential deposits nearby Siwalik hills, being composed of outwash, boulders, cobbles, gravel and sand, and characterized by extremely poor sorting. Because it was formed as a result of river fan and colluvial deposition, the Bhabar Zone is not continuous. Between fans the Bhabar is often not present.

Very high permeabilities of the Bhabar sediments have been reported (50 to 200 meters per day) in other districts. Tillsen in his 1985 report speculates about the area occupied by the Bhabar sediments for each of the Terai districts. Interestingly, in his report the Bhabar Zone in Nawalparasi is the second smallest of all districts, being shown as covering only 80 km2 area. (The smallest Bhabar zone is in Rautahat, only 10 km2.)

The bulk of the Terai sedimentary basin belongs to Holocene alluvium which includes present day alluvial deposits, channel sand-and-gravel deposits, outwash deposits. Due to their fluviatile origin and constant shifting of stream channels, these deposits are crossbedded, eroded, reworked, and redeposited.

The lithology of the shallow ground water system in Nawalparasi district is known from at least 17 "project" wells and from nearly 200 wells drilled in 1983 (Phase I and II) and in 1986 (Phase IV) by the Japan Red Cross drilling program. Some of these wells were used to produce lithological cross sections presented in **Appendices 4/2** through **4/6**. Unfortunately, only some "Japanese" drilled wells could be located on maps. Out of about 200 shallow wells drilled by Japan Red Cross Society, about 30 wells are located in Nawalparasi Northeast, the area which is excluded from the present reporting.

There was no attempt to connect permeable layers in lithological cross sections. This is a "risky" undertaking in Quaternary deposits near to the foothills of sediment-supplying mountains and in an area cross-cut by many present rivers and buried channels. It is believed that the lithology of the

upper 30 or so meters is rapidly changing over very small distances. Present- day and past-time rivers have been changing their streambeds; they have been either depositing or eroding sediments, leaving behind either coarse sediments or impermeable fine deposits.

Out of the total drilled metrage in 17 "project" wells of 573 m, 276.3 m are sand and gravel deposits. This means that about 48% in an average shallow well is composed of sand and/or gravel. (An "average" well in this drilling program was 33.7 deep, out of which 16.2 m were composed of permeable, and 17.5 m of impermeable deposits.)

One of common earlier interpretations is that going from north to south the lithology of shallow aquifer becomes less favorable for ground water accumulation because grain size becomes finer. It is questionable whether this is true for the upper 30 or so meters. As shown in lithological cross sections I- I', III-III', and IV-IV' (from north to south, see **Appendices 4/2, 4/4,** and **4/5**), some wells close to the Nepal- Indian border show quite good lithology. For example, the well Lalpati has 24 m of sand and gravel; the well Surajpura has 19 m of gravel and sand (it was terminated in gravell); and the well Guthi Parsauni is completely drilled through sand and gravel (19.5 m). The zone near the Narayani River is characterized with more sand and gravel than clay. The northwestern corner of the reported area is very permeable from the surface down to some 15 m (Machharmara, Rampurwa, Sunwal). The zone belongs to Bhabar formation, and streams cutting the Siwalik hills must have contributed permeable materials. The Bhabar formation normally contains the greatest proportion of coarse grained material but it is poorly sorted and generally overlain by silty and to some extent clayey deposits. Greater depths to water table, especially in the pre-monsoon sea sons, make the upper portion of the permeable sequence unsaturated, so that a portion of otherwise favorable lithology is of no use for accumulating and storing ground water. As will be clear from the text that follows, in spite of favourable lithology this northwestern corner is the least favourable zone for shallow ground water development. Several deep wells have been drilled near the Sunwal village. In their upper 50 m, only the zone deeper than 30 m shows favourable lithology.

The sudden changes of lithology are best illustrated with the zone near the village Banjariya. Three wells are characteristic: Banjariya (STW-10), Parsawal (STW-11), and Patherdewa. The distance between the wells is hardly more than 3 km. Yet, the well Banjariya has only 6 m of sand and gravel out of 63 drilled meters. The other two are the "winners": Parsawal with 32 m of gravel and sand out of 38 drilled meters, Patherdewa with 17 m of sand out of 19 drilled meters. With this in mind it is difficult to declare the zone around Banjariya as "dry".

Considering the lithology of the shallow aquifer in Nawalparasi district, one may conclude that almost everywhere the chances of getting at least 5 meters of sand and/or gravel deposits are good, and that a shallow well to supply drinking water to villages can be constructed without too much uncertainty. It is difficult to say whether large-capacity irrigation wells can be forecast with equal certainty without a more detailed exploration program.

The chances of finding excellent aquifers at shallow depths are tied to locating buried channels in which coarse sediments have been deposited. As a support to this conclusion comes the fact that out of 51 wells drilled by Japanese Red Cross Society in Nawalparasi district in 1986, only 3 wells were declared dry. Two wells were drilled in Ramnagar Panchayat, which is between Badera and Jamuniya **(Appendix 1)**, and one was drilled in Daunnedevi Panchayat, which is north of Kuniya and Raninagar at the foot of the mountain (**Appendix 1**). The first Ramnagar well discovered only 9 m of fine sand within the depth of 81 m, and the second Ramnagar well only 6 m of fine sand within the upper 65 m. It is not clear why the well in Daunnedevi Panchayat (village Dharmbasti) was abandoned, unless it was for too deep water table, considering that the well probably drilled through the Bhabar zone.

In earlier drilling phase by Japan Red Cross Society (1983) several more wells in Panchayat Makar, which is about 5 km west of Paldanda, or at halfway between Jamuniya and Paldanda, were declared dry. One of wells in Makar drilled through 15 m of clay and the remaining 5 m of gravel were not producing enough water; another drilled 25 m but discovered only 3 m of sand and 3.5 m of gravel. Some wells in Makar panchayat were completed as water-supply wells, but their discharge was low and drawdowns excessive.

In several wells drilled in this project, drillers reported siltstone, either as a layer or in gravel and sand beds. Improper determination of drilling samples, especially in mixed beds (gravel with siltstone), makes difficult to appreciate the role of silty component in shallow permeable layers.

3.2. HYDROGEOLOGICAL PARAMETERS

Hydrogeological parameters of the shallow aquifers were obtained from eight pumping tests run on "project" wells. The wells used in this interpretation are shown in **Appendix 6,** which is the map of transmissivity. In the same time, this report contains a group of appendices (**Appendix 5**) with some 13 pumping tests. Each test is interpreted in the same way, using a rather objective computer match between field data and theory. A comparison was made between the classical non-leaky theory of Theis and Jacob with the leaky-aquifer theory of Hantush. The result with lower standard deviation, or a better fit, was accepted. Except in two tests the classical Theis-Jacob interpretation produced quite a good fit. In two tests, the better fit was obtained by Hantush leaky methods. Perhaps a longer testing, with more drawdown during the test, would have changed the above conclusion. However, longer testing would have required a higher pumping rate during the test, higher decline of the level which would eventually drop to below the suction reach of centrifugal pumps that were used in testing. There is very little doubt that numerous permeable layers are mutually interconnected either vertically (leakage through semipermeable beds) or laterally (see lithological cross-sections in **Appendices 4**). The short-term testing as applied in this project has resulted in transmissivity values that are representative only for the layer directly being screened and tested.

The transmissivity of the upper 35 or so meters (with an average depth of about 33.7 m as reported earlier) is shown in **Appendix 6** (the transmis sivity map). The map is the creation of a computer contouring program, which interpolates and extrapolates random individual values. This inter-extrapolation process is based on only 8 values which is by far insufficient to accurately describe the whole district. As mentioned earlier, several more wells are available for testing but due to static water levels below 6 meters and inappropriate pumping equipment the testing was postponed. With 23 pumping tests in the western part of the Nawalparasi district, which was the target of the program, the transmissivity distribution would have been much more accurate.

The interpretation shall be attempted with information in hands.

There is a clear distinction between western and eastern parts of the study area. In the east three wells have shown good transmissivities: Kuniya (986 m^2/day), Kharahani (882 m^2/day), Surajpura (between 494 and 635 m^2/day). If one adds the well STW- 13 (Gobrahiya), which is about 5 km west of Karahani and which has 38 m of sand and gravel with probable transmissivity of over 600 m^2/day, then the whole eastern half of the reported area can be classified as the one with good transmissivity.

The western part of the area is with much lower transmissivity as demonstrated by pumping tests in the following wells: Lalpati (124 m^2/day), Bisnupura (55 m^2/day), Jamuniya (156 m^2/day). When unsuccessful wells are added to this (STW-1, Rampurwa; STW-2, Badera; STW-3, Parasi), and two abandoned "dry" wells drilled by Japanese Red Cross Society in Ramnagar Panchayat, it becomes evident that the western part of the reported area is hydrogeologically inferior to the rest of the district. Whether transmissivities are indeed that low, as shown in **Appendix 6**, is disputable, but, in general, they are lower than in the eastern part. One should expect that coming closer to the Narayani River the grain size of aquifer shall become larger and consequently the transmissivity even higher.

The hydraulic conductivities of shallow aquifer materials in the more permeable eastern part are from 33 m/day (Surajpura) to 140 m/day (Kuniya). In some other wells in this part the hydraulic conductivities are the following: Kharahani 48 m/day, Guthi Parsauni 47 m/day. These values are evidently acceptable and promising. The values of about 40-50 m/day are characteristic for clean medium to coarse-grained sand. The values of over 100 m/day (Kuniya) are characteristic for clean coarse-grained sand and gravel.

In the western part of the reported area the hydraulic conductivities are much inferior. The following values are obtained from pumping tests: the minimum at Bisnupura 6.4 m/day, and the maximum at Jamuniya 18.0 m/day. All transmissivities, thicknesses, and hydraulic conductivities are presented in the table here below.

Well	Thickness m	Trans. m2/day	Conduct. m/day
STW-4 Jamuniya	8.5	156	18.4
STW-5 Paldanda	12.0	142	11.8
STW-7 Kuniya	7.0	986	140.8
STW-9 Kharahani	22.5	1037	46.1
STW-12 Lalpati	14.0	146	10.4
STW-14 Surajapura	19.0	635	33.4
STW-15 Guthi Parsauri	10.5	500	47.6
STW-16 Bishunpurawa	8.6	55	6.4

The values of the storage coefficient, which were obtained from 5 wells, are representative for a temporary hydraulic state during the pumping test, and should not be taken for hydrogeological parameters of the aquifer. In all tests, except in Guthi Parsauni, the static water level was in the upper, confining, semi-permeable layer (sandy clay, silt). The values of storage coefficient for other 6 tests are the following:

STW 7, Kuniya, 0.012
STW 9, Kharahani, 0.00037
STW 12, Lalpati, 0.0014
STW 14, Surajpura, 0.0019
STW 15, Guthi Parsauni, 0.0011

Such values of the storage coefficient are typical in short-duration pumping tests of semiconfined aquifers. This proves that the shallow aquifer is overlain by several meters of less permeable material in which vertical permeability dominates over the horizontal one (anisotropic medium), and which may permit the exchange of water in vertical direction (recharge from infiltrated water and evapotranspiration) but which offers very little storage of water. Even in such a medium, should the test have lasted longer there would be more water drained by gravity, resulting, consequently, with a higher storage coefficient.

4. FLUCTUATIONS OF SHALLOW WATER TABLE

4.1. MONITORING NETWORK

Nawalparasi district is well covered with observation network. As shown in **Appendix 2**, in May 1987 when observations of shallow water table started (GDC) the network included 46 dug wells plus 3 hand-pump wells. In May 1988 the network included 12 dug wells and 7 shallow tube wells. In February 1989 the network includes 16 project-drilled shallow wells, plus 14 dug wells, plus 5 hand-pump wells. This number shall be reduced to 17 project-wells, plus 5 hand-pump wells, and 1 dug wells shall be selected from 16 currently monitored. The final network in Nawalparasi (West) shall have a total of 23 wells.

4.2. RAINFALL IN NAWALPARASI IN 1987/88

To understand better the rise of shallow water levels from the month of May through the month of September (either 1987 or 1988) one should look at rainfall in the June-September period. As shown in **Figure 2**, there are two rain gauging stations within the Terai portion of Nawalparasi district: Parasi in the west-central, and Semari in central part of the reported area. The monthly and annual rainfall for the two stations is presented in **Figure 3**. The annual sum in Semari is 1530 mm for the year 1987. The sums for Parasi station are the following: 1651 mm in 1987, and 2371 mm in 1988.

The comparison between the rainfall in two parts of the district is shown in **Figure 4** (upper part) for 1987. The data are not available for Semari station for the whole of 1988. Considering the distance between two stations, which is about 12 km, one may expect that in Semari in 1988 the rainfall was much above the 1987, and a long-term average which for the Lumbini-Narayani zone is close to 1600 mm/year. It may be concluded that the rainfall in 1987 was about average, but in 1988 it was about 50% above the average. As shown in **Figure 4**, there is very little difference in monthly rainfall in 1987 between the two stations. In 1988, the two events deserve attention. The first is the extraordinary high rainfall in the months of July and August, totalling 1474 mm, with the monsoon coming strong in June (317 mm), and plenty of rain even in May (117 mm). The second event is rather high rain in December 1988, with 54 mm in Parasi. This December rainfall is clearly noticeable on hydrographs (presented in **Appendices 10**).

The monthly rainfall is plotted alongside water table fluctuations in Appendix **7** to indicate the relationship between the rainfall and water table rise and decline in the period from May 1988 through February 1989.

4.3. SHALLOW GROUND WATER SYSTEM HYDRODYNAMICS

Hydrodynamics of the shallow ground water system in Nawalparasi district in 1987 and 1988 is presented in **Appendices 8/1** through **8/4, 9/1** and **9/2**, and **10**. The group of **Appendices 8** refers to the depth to water table in relative terms (pre- monsoon, post-monsoon, rise of levels in 1987 and 1988). Similar maps have been already presented in Technical Report No.2 for the year 1987. Actually, **Appendix 8/4** is directly taken from that report.

The map of maximum depth to water table (**Appendix 8/1**, May 1988) shows the following. The deepest water table is near Dabila in the central part of the reported area, 7.4 m. However, this is because the land surface in Dabila is higher than in its surroundings: Dabila 112.08, Kharahani 105.83, Gobrahiya 107.98. The shallowest water table in May 1988 was in Banjariya, 1.2 m. The elevation of Banjariya is 5 m lower than that of the Parsawal well 2 km to the north. As shown in **Appendices 10** (hydrographs), the month of May is not the month of minimum water levels everywhere. In some wells the minimum is in June. Only in two wells in May 1988 the level was within 2.0 m from the land surface (Rampurwa, 1.7 m; Banjariya, 1.1 m). In most of the area the levels in May 1988 are about 3.0 m under the land surface.

The rise of levels started in the second week of June as a direct response to June rainfall. The near-maximum water levels were established by the end of July. In August the levels rose only marginally and the decline started in September. Correlating the hydrographs with rainfall the following may be concluded: (a) the high July and August levels are the response to rainfall in excess of 1200 mm/60 days (see Figure 3); (b) the rainfall in September of 311 mm is not sufficient to keep the water at such high levels and the levels slowly but steadily decline; (c) the December rainfall of 54 mm was reflected in several observation wells as the rise of January 1989 levels: Badera 15 cm, Paldanda 105 cm, Kharahani 12 cm, Banjariya 3 cm, Parsawal 46 cm, Lalpati 13 cm, Guthi Parsauni 17 cm.

The map of minimum depth to water table (**Appendix 8/2**, September 1988) shows the following. The water table is closer to the land surface in the western and in eastern parts of the reported area. It is deeper in the central part. In the western part, up to the line Badera-Parasi-Lalpati, the level in September is within 1.0 m from the land surface. The same is in the eastern part (Paldanda- Karahani-Guthi Parsauni), but the levels are again slightly deeper near the Narayani River (Kuniya-Ranlnagar). The deepest levels are in Gobrahiya (4.05 m) and Dabila (3.25 m). The rise of shallow water levels in the monsoon season (from May through September 1988) is shown in **Appendix 8/3**, and the rise of water levels in the same period but in the year 1987 in **Appendix 8/4**.

In 1988 the water table rose generally between 2 and 3 m in the whole area. The rise is the greatest in the central part near Dabila. The picture in 1988 is different than in a year before (**Appendix 8/4**). In 1987, the fluctuation amplitude was more pronounced than in 1987. However, the maps of levels in 1987 were based on dug well record which may not be as reliable as the data from drilled wells. For the sake of comparison, three hydrographs appended to the end (**Appendices 10**, Parasi, Sunwal, Tribeni) belong to dug wells and show the period of record from May 1987 through February 1989. Unfortunately the level in July 1987 is missing in Parasi, so it is impossible to speculate about the rise and the amplitude of the rise in 1987. The dug well in Sunwal has the same maximum in both years (near the land surface), and the dug well in Tribeni has much higher rise in 1988 than in 1987.

Appendix 7 present the hydrographs at selected locations correlated with monthly rainfall. The correlation is obvious. There is a greater rise of levels in 1988 than in 1987, but the rainfall in 1988 is much above the rainfall in 1987. The final two **Appendices, 9/1** and **9/2**, present the water level contour maps in May and September 1988, respectively. As expected the general di rection of ground water flow is from north to south. In May 1988 the gradient of flow is mostly about 0.002, or 2 m per 1 km. From the contour line 105 m, the gradient of flow becomes suddenly much flatter: between Kharahani and Surajpura 0.0004 m/m. The change in gradient may be another proof of greater transmissivity of the area south of Gobrahiya-Kharahani, down to Surajpura-Guthi Parsauni. With the Darcy law in mind, the equal ground water flow will demand twice smaller gradient if transmissivity of the area is twice higher.

The map of contours in September 1988 is about the same as the map in May, except that the contour lines are higher everywhere for 2 to 3 m. The flow pattern is the same.

5. ASSESSMENT OF WATER RECHARGE AND DISCHARGE

5.1. PRELIMINARY ASSESSMENT FROM BASIC DOCUMENTATION

The flow pattern as presented in May and September 1988, respectively, leads to the following conclusions about the recharge and discharge of the ground water system in reported area.

(1) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits. The percentage of infiltration may be high, but there may be plenty of rejected recharge in monsoon season because of oversaturation of the soil immediately underlying the land surface.

(2) The Bhabar zone is not that important in the reported area. Maybe it is locally important in the northwestern corner where water level contours are highest.

(3) The outflow of shallow ground water is generally across the border into neighboring India, and locally to the Narayani River. The river stage was surveyed by this project on 1 February 150 m south of the Tribeni bridge and was found to be at 104.7 m absolute elevation. The ground water level nearby, in Raninagar in February 1989, was at 107.4 m elevation, which is 2.7 m above the river level. The Raninagar well is about 500 m far from the river bank.

(4) The outflow into India across the border is calculated approximately with gradients from **Appendices 9/1** and **9/2**, and transmissivities from **Appendix 6**. The length of outflow section is 26 km. The transmissivity is increasing from 100 m^2/day near Bisnupura to 500 m^2/day in the middle of the section, and remaining at 500 m^2/day until the Narayani River. The gradient is changing from 0.001 in the western part to 0.0004 m/m in the eastern part of the outflow section. The volume of water that may be outflowing is about 6,000 m^3/day or 2.2 MCM/year (million cubic meters in one year). This is a small fraction of potential annual recharge from infiltrated rainfall. If, conservatively, only 10% of annual rainfall of 1600 mm infiltrate and recharge the shallow aquifer, the volume of recharge over an area of about 500 km^2 could be about 80 MCM/year. The difference between this hypothetic recharge of 80 MCM and outflow into India of about 2.2 MCM is discharged through evaporation process (dominantly), into the Narayani River (locally very high), and withdrawals from dug and drilled wells (minor component at present).

5.2. ASSESSMENT OF WATER BALANCE BY MATHEMATICAL MODELLING

There appears to be enough data that make possible the construction of a mathematical model of the Nawalparasi shallow ground water system. The model may provide quantitative answers to the following:

(a) Recharge from rainfall in the Bhabar Zone and elsewhere.

(b) The connection with the Narayani River in minimum and maximum flow conditions.

(c) The importance and magnitude of the evapotranspiration process.

(d) The correct order of magnitude of hydrogeological parameters (permeability and transmissivity, storage coefficients).

(e) The volume of outflow across the district boundary into India.

The aquifer system to be modelled has two natural and two artificial boundaries. The natural ones are the impermeable boundary in the north and northeast, being the physical termination of the shallow (and deep) ground water system of the Terai, and the eastern boundary being represented as a constant-head line coinciding with the Narayani River. The artificial boundaries of the district in the sense of the regional ground water system are the boundaries to the south (Nepal-India border) and west (district boundary with Rupandehi).

The final outcome of the model could be the amount that can be annually developed by shallow wells considering the recharge, the induced flow from the river, and the salvaged water on account of ground water evaporation.

The basis for the model calibration, i.e. for the verification of all system parameters, should be the rise of water levels from May through September, correlated with rainfall. The two maps of water flow, i.e. **Appendices 9/1** and **9/2**, should be matched by the model.

Only at the end of the modelling study the water balance of the shallow ground water system and its development potential can be formulated. Without a comprehensive evaluation of the whole system, including all its components (recharge-flow-discharge), any quantification of the shallow ground water system behavior and development potential is only a speculation.

The main components of the model shall be the following:

(a) *Size.* The whole Terai portion of western part of the Nawalparasi district shall be modelled, with the Narayani River on its eastern boundary, India-Nepal state border as the south boundary, the contour line 150 m on its north, and the district boundary with Rupandehi on its west. The area involved in the model shall be about 20 km by 41 km (**Figure 8**). The discretization shall be 1000 m in each direction, creating a uniform mesh network of 1 km2 each cell.

(b) The model shall be two-dimensional. The geometry of the shallow ground water system shall demand the following data input for each cell: (i) land surface elevation, (ii) top of aquifer elevation, (iii) bottom of aquifer elevation, (iv) initial water level elevation. Other input matrices (one value for each cell) shall be the following: hydraulic conductivity of the shallow aquifer, storage coefficient of the shallow aquifer, recharge from rainfall infiltration, discharge through evapotranspiration process. The elevation of the Narayani River cells shall also be required.

(c) Model calibration process shall have two stages: (i) steady-state calibration of modelled output in the month of May 1988 (minimum water levels), (ii) unsteady-state calibration of the period May 1988 - September 1988 (the rise of water levels as a consequence of monsoon rains and increased recharge).

(d) The model output shall be the following: (i) improved distribution of aquifer parameters (hydraulic conductivity, storage coefficient), (ii) sums of recharge from rainfall and the river, as well as of discharge through evapo ration, outflow into the river if any, and outflow across the southern border into India, (iii) assessment of available shallow water for increased develop ment on account of avoiding evapotranspiration losses and inducing the river recharge.

6. CONCLUSIONS AND RECOMMENDATIONS

The objective of this report is to present technical information on the occurrence of shallow ground water in Nawalparasi district. It is given in a form of a basic documentation, which shall be used for future evaluation of the ground water system (mathematical modelling); however, some preliminary interpretation is also included herein.

The drilling program which was formulated about a year-and- half ago, was completed according to the expectations. Seventeen holes were drilled with the total drilling metrage of 573 m. The average depth of newly completed wells is 33.7 m. Considering the lithology of shallow ground water system, this depth is probably adequate for the project purpose. Some of wells, especially at the beginning of the drilling campaign, were not absolutely efficiently developed. Too much bentonite was used, and the screen of only 0.5 mm openings and about 11% open area was found to be inadequate. As a consequence, pumping tests failed in such wells. Only eight successful tests have been performed. Out of 17 drilled wells, 16 wells were constructed by a drilling rig, and only one well by indigenous (manual) methods of drilling. It may be too early to conclude on advantages and disadvantages of a particular method of shallow wells constructions in the Terai. Manually-drilled wells have a better control over lithology of penetrated strata; likewise, they are cleaner and pumping tests are more reliable because aquifers and well screens are less clogged than in bentonite-drilled wells. However, these advantages fade when the total depth of penetration is taken into account.

As a conclusion of the drilling program in Nawalparasi district the following may be inferred. The drilling of shallow wells should be done with as little as possible bentonite mud. The screens should be best pre-packed with gravel, or alternatively the drilling diameter should be minimum 10 inches to accommodate 4 or 6-in casing and minimum 2-in gravel pack. In an exploration-drilling project such as this UN assistance project, the first saturated sand-and-gravel layer should be screened to offer the possibility of testing and monitoring the first directly recharged zone. In a water-supply and/or irrigation well, all permeable layers within the depth of drilling should be screened to produce as much water as available.

More attention should be given to well development. Screens with slot opening less than 1.0 mm should not be used. Better supervision of drilling and development activities is needed to produce better wells.

In addition to lithology of shallow aquifers, which becomes known from the drilling operation, pumping tests provide most of knowledge on aquifer parameters. Although one cannot be absolutely satisfied with the results of pumping tests, they did produce the values of transmissivity and, in few cases, storage coefficient. The quality of testing must be improved, as well as the accuracy of equipment used.

In running pumping tests the following problems have been identified:

(a) Pumping equipment not adequate for all situations. The suction range of centrifugal pump limited to about 7 m below the pump discharge point restricts the available dynamic range (depth) of pumping. Pump discharge is fluctuating during the test.

(b) Pump discharge measuring instrumentation unreliable. When the results by two methods of measurement are compared, the "mismatch" is sometimes more than 20%. 200-l barrel is probably better than "V"-notch weir. The best would have been a 3-in flowmeter with direct reading of the flowrate in liters per second.

(c) Measurements of water level during the pumping and/or recovery periods are sometimes questionable (late, improvised).

The interpretation of lithology on the basis of driller's log is sometimes difficult. The terminology such as "gravel and siltstone" has no sense in hy drogeology. Few percents of silty components in otherwise coarse- grained material may make the formation completely impermeable. Thus a large component of gravel has to be proved by pumping tests and matched with transmissivity values.

There is a clear distinction between western and eastern parts of the study area. In the east three wells have shown good transmissivities: Kuniya (986 m^2/day), Kharahani (882 m^2/day), Surajpura (between 494 and 635 m^2/day). If one adds the well STW- 13 (Gobrahiya), which is about 5 km west of Karahani and which has 38 m of sand and gravel with probable transmissivity of over 600 m^2/day, then the whole eastern half of the reported area can be classified as the one with good transmissivity.

The western part of the area is with much lower transmissivity as demonstrated by pumping tests in the following wells: Lalpati (124 m^2/day), Bisnupura (55 m^2/day), Jamuniya (156 m^2/day). When unsuccessful wells are added to this (STW-1, Rampurwa; STW-2, Badera; STW-3, Parasi), and two abandoned "dry" wells drilled by Japanese Red Cross Society in Ramnagar Panchayat, it becomes evident that the western part of the reported area is hydrogeologically inferior to the rest of the district. Whether transmissivities are indeed that low, as shown in **Appendix 6**, is disputable, but, in general, they are lower than in the eastern part. One should expect that coming closer to the Narayani River the grain size of aquifer shall become larger and consequently the transmissivity even higher.

The hydraulic conductivities of shallow aquifer materials in the more permeable eastern part are from 33 m/day (Surajpura) to 140 m/day (Kuniya). The values of about 40-50 m/day are characteristic for clean medium to coarse-grained sand. The values of over 100 m/day (Kuniya) are characteristic for clean coarse-grained sand and gravel.

In the western part of the reported area the hydraulic conductivities are much inferior. The following values are obtained from pumping tests: the minimum at Bisnupura 6.4 m/day, and the maximum at Jamuniya 18.0 m/day. The values of storage coefficient obtained from pumping tests are not representative for shallow aquifer. Rather than being real aquifer parameters (equivalent to effective porosity), these values reflect a hydraulic state du ring testing, i.e. the semiconfinement of first permeable layer by less perme able overlying bed.

The pump testing program in Nawalparasi district should be continued. There are many wells which lend themselves to testing. Most of hand-pump equipped wells (drilled by ADBN and/or Japan Red Cross Society in recent years) could be easily tested. If out of 200 shallow drilled wells 20 are tested, the wealth of information and knowledge about the district would be enormously improved.

Nawalparasi district is well covered with water-level monitoring network. In the month of January 1989, the network includes 18 dug and hand-pump wells and 17 project-drilled wells. Tentatively the proposed network for future monitoring shall include 17 "project" drilled shallow wells, plus five wells equipped with hand pump, and one dug well near the banks of the Narayani River.

In most of the area the levels in May 1988 are about 3.0 m under the land surface. Between May and September 1988 the levels rose in all area between 2 and 3 m. The rise of levels started in the second week of June as a direct response to June rainfall. The near- maximum water levels were established by the end of July. In August the levels rose only marginally and the decline started in September. The high July and August levels are the response to rainfall in excess of 1200 mm/60 days. The rainfall in September of 311 mm is not sufficient to keep the water at such high levels and the levels slowly but steadily decline. The December rainfall of 54 mm was reflected in several observation wells as the rise of January 1989 levels. As expected the general direction of ground water flow is from north to south. In May 1988 the gradient of flow is mostly about 0.002, or 2 m per 1 km. From the contour line 105 m, the gradient of flow becomes suddenly much flatter: between Kharahani and Surajpura 0.0004 m/m. The change in gradient may be another proof of greater transmissivity of the area south of Gobrahiya- Kharahani, down to Surajpura-Guthi Parsauni. Although an assessment of shallow aquifer water balance is not attempted in this report, some preliminary evaluation is presented. A parallel study is being currently run by this project in which a mathematical model is under construction and testing. The model shall provide some answers to the following: (a) recharge from rainfall in the Bhabar Zone and elsewhere, (b) the connection with the Narayani River in minimum and maximum flow conditions, (c) the importance and magnitude of evapo transpiration process, (d) the correct order of magnitude of hydrogeological parameters, (e) the volume of outflow across the district boundary into India.

The following is concluded from the flow pattern in May and September 1988, and from all other information collected for this report:

(1) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits. The percentage of infiltration may be high, but there may be plenty of rejected recharge in monsoon season because of oversaturation of the soil immediately underlying the land surface.

(2) The Bhabar zone is not that important in the reported area. Maybe it is locally important in the northwestern corner where water level contours are highest.

(3) The outflow of shallow ground water is generally across the border into neighboring India, and locally to the Narayani River.

(4) The outflow into India across the border is calculated approximately with gradients from **Appendices 9/1** and **9/2**, and transmissivities from **Appendix 6**. The volume of water that may be outflowing is about 6,000 m^3/day or 2.2 MCM/year (million cubic meters in one year). This is a small fraction of potential annual recharge from infiltrated rainfall. If, conservatively, only 10% of annual rainfall of 1600 mm infiltrate and recharge the shallow aquifer, the volume of recharge over an area of about 500 km^2 could be about 80 MCM/year. The difference between this hypothetic recharge of 80 MCM and outflow into India of about 2.2 MCM is discharged through evaporation process (dominantly), into the Narayani River (locally very high), and withdrawals from dug and drilled wells (minor component at present).

For a better understanding of the relationship between the Narayani River and shallow aquifer the following program of investigations is recommended:

(a) Continuous monitoring of water table in the Raninagar well in the period from May through September in one year period. Description and measurement of river stage in the same period at the Tribeni bridge. It is important that the river flood stage is correctly monitored.

(b) Establishment of one additional river-stage gauging station at the south (near the Nepal-India border), and measuring surface water elevation during a pre-monsoon and monsoon season. Measuring of river discharge in the dry season.

(c) Correlation of water table in the Raninagar well with the river level height.

(d) Calculation of the base flow at the Tribeni bridge station and down stream station, if established, in the dry season.

Finally, on the basis of the presented information, the feasibility of shallow ground water development in the reported area is as shown in **Figure 9**. The best area for development is in the eastern half, starting midway between Parasi and Dabila, and extending to the Narayani River to the east, and to the Nepal- India border to the south. To the north, the promising area appears to be limited by a strip of "dry" wells, or missing shallow aquifer. The promising area is about 17 km long and 11 km wide, or it occupies a surface of about 180 km2, or one third of the whole district area. The western part may be good for individual wells for water supply but not for large-scale development for irrigation. The northern area near the foot of mountains is not clear. One well, Paldanda, was not encouraging, but locally there may be accumulations of fan deposits (Bhabar) which could make the development promising.

To complete this investigations it is recommended to do the following:

(a) Perform pump tests in the wells that have been drilled but not tested, or unsuccessfully tested: Dabila, Raninagar, Gobrahiya.

(b) Repeat testing in the wells: Parsawal and Sunwal.

(c) Use turbine pumps which can lower dynamic depth during pumping to minimum 12 m.

(d) Perform pumping tests in as many as possible shallow wells drilled by Japan Red Cross Society, especially in the western part of the area which is declared as not very suitable for shallow ground water development.

(e) Drill one well halfway between Parasi and Dabila to prove the boundary between "good for development" and " inferior" zones.

(f) Continue with monitoring of water table in 23 wells (17 project-drilled, 5 hand-pump equipped, one dug well near the Narayani River - Tribeni). The frequency of monitoring in the June-September period should be biweekly. In the rest of the year once-a-month measurement suffices.

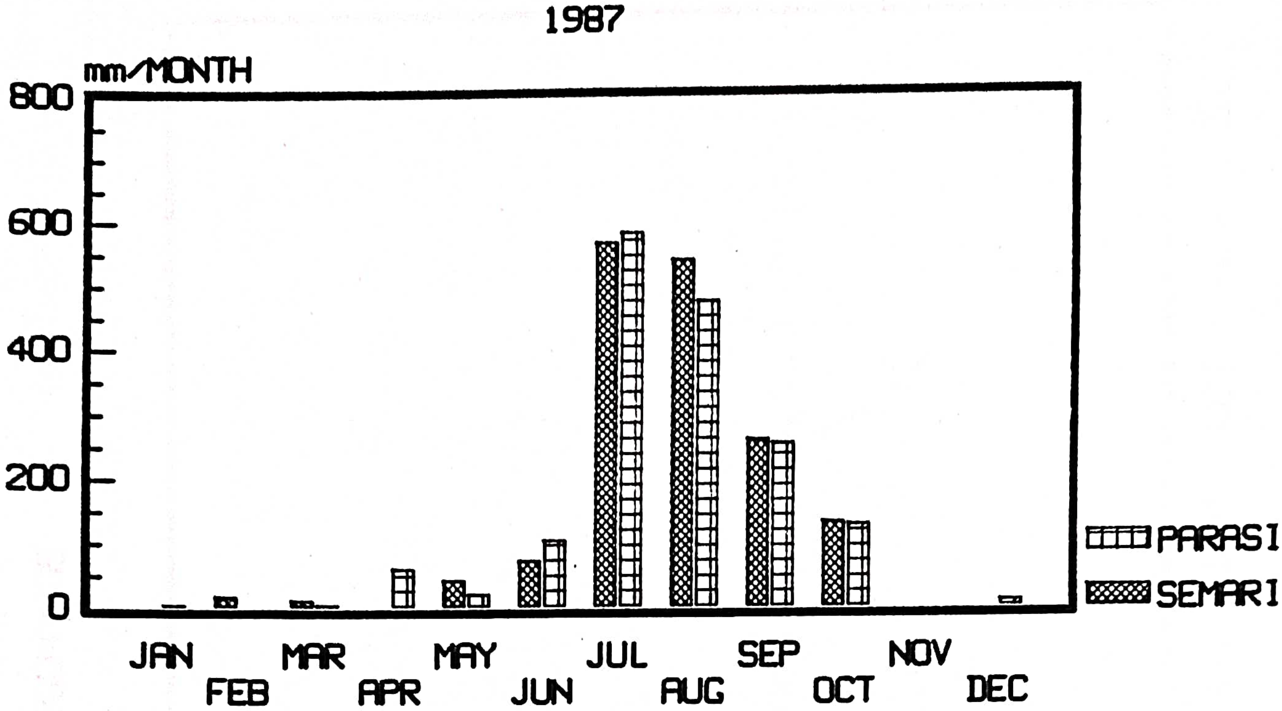
MONTHLY RAINFALL IN NAWALPARASI (WEST)
IN 1987 & 1988

1987: SEMARI / PARASI			1988: PARASI	
JAN:	0 /	1	JAN:	0
FEB:	17 /	0	FEB:	4
MAR:	11 /	4	MAR:	22
APR:	0 /	61	APR:	59
MAY:	43 /	21	MAY:	117
JUN:	73 /	105	JUN:	317
JUL:	569 /	585	JUL:	791
AUG:	542 /	477	AUG:	683
SEP:	262 /	256	SEP:	311
OCT:	134 /	130	OCT:	13
NOV:	0 /	0	NOV:	0
DEC:	0 /	11	DEC:	54

(in mm/month)

FIGURE 3

NAWALPARASI (WEST) - MONTHLY RAINFALL



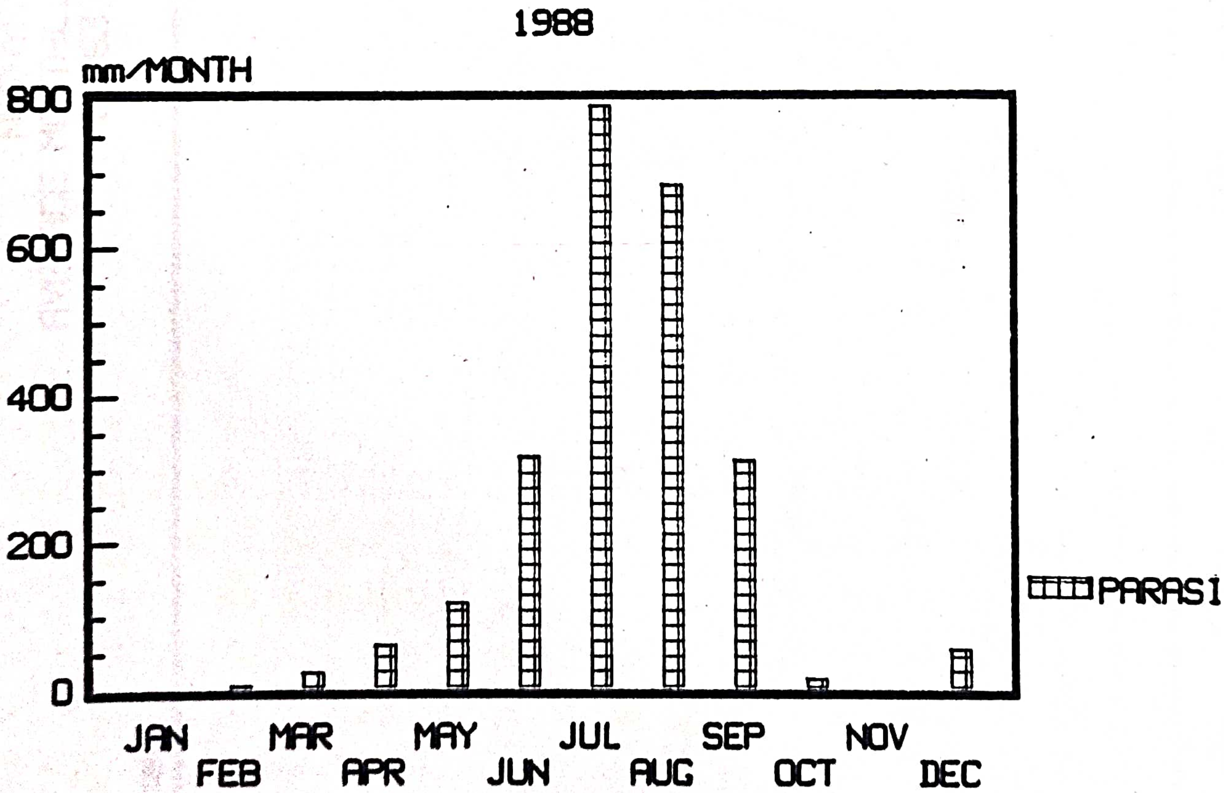


FIGURE 4

NARAYANI RIVER
AVERAGE MONTHLY RIVER DISCHARGE
(1963 - 1985)

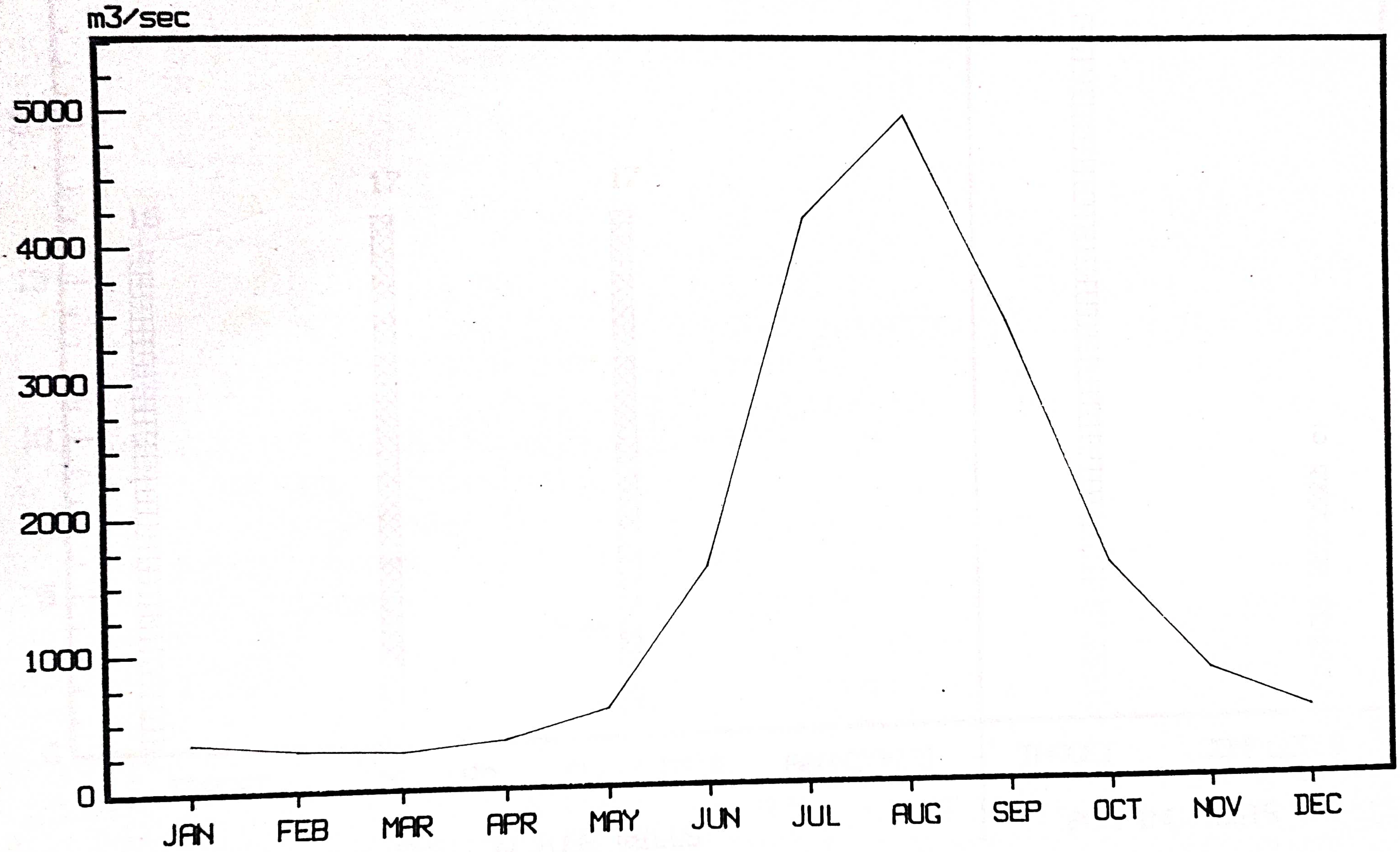


FIGURE 5

NEP/86/025 NUMBER OF WELLS &
PUMPING TESTS IN NAWALPARASI-W (1987/88)

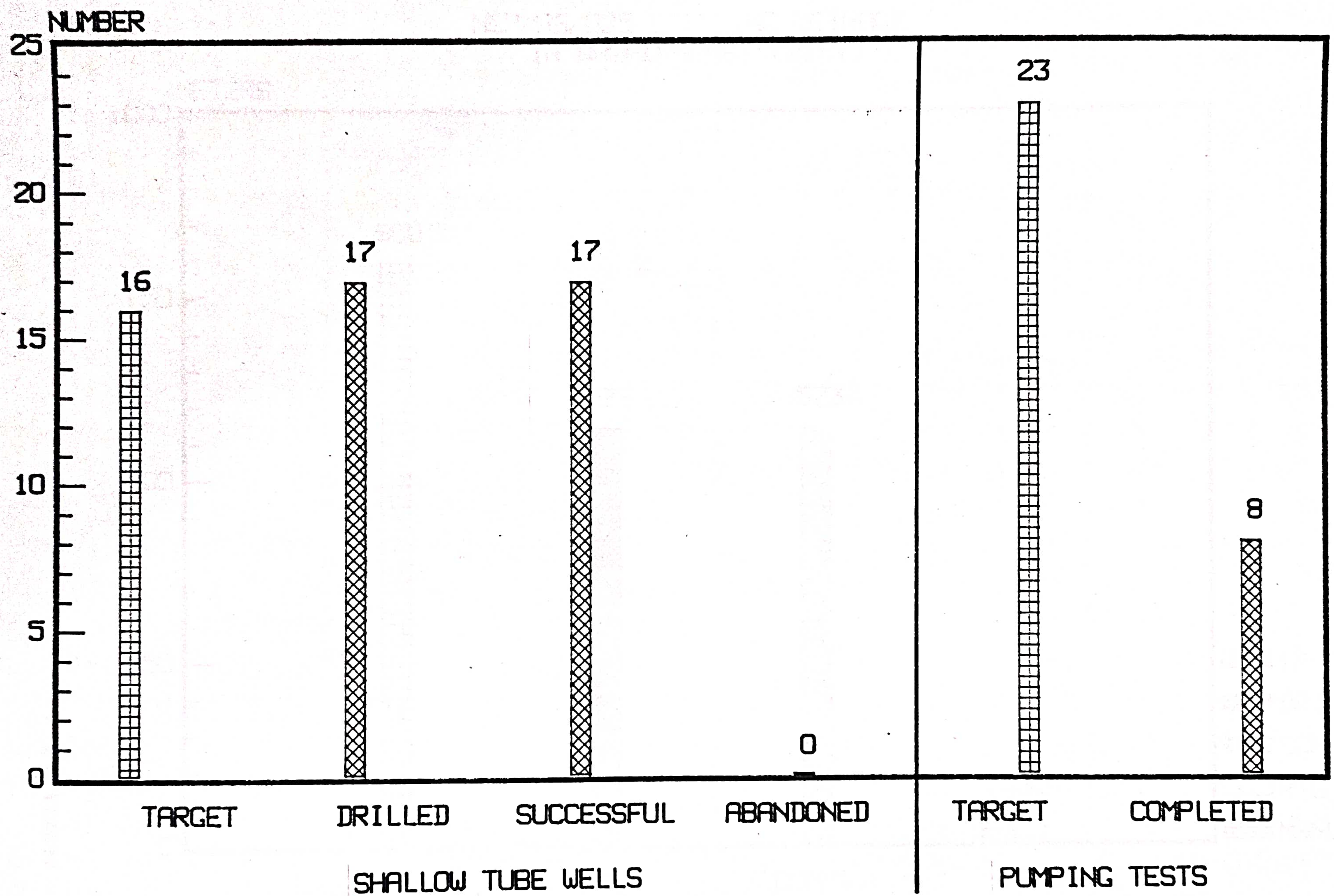


FIGURE 6

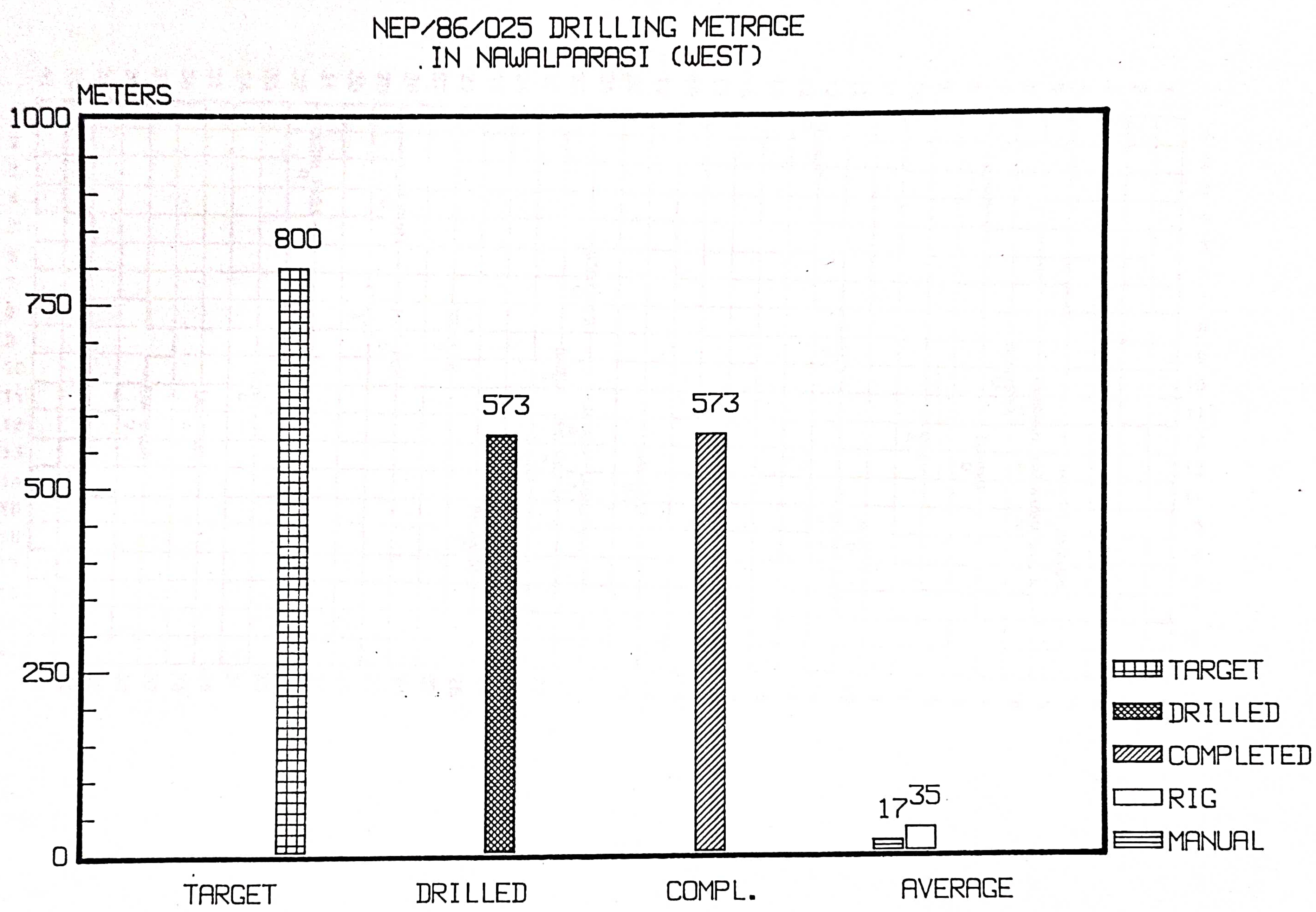
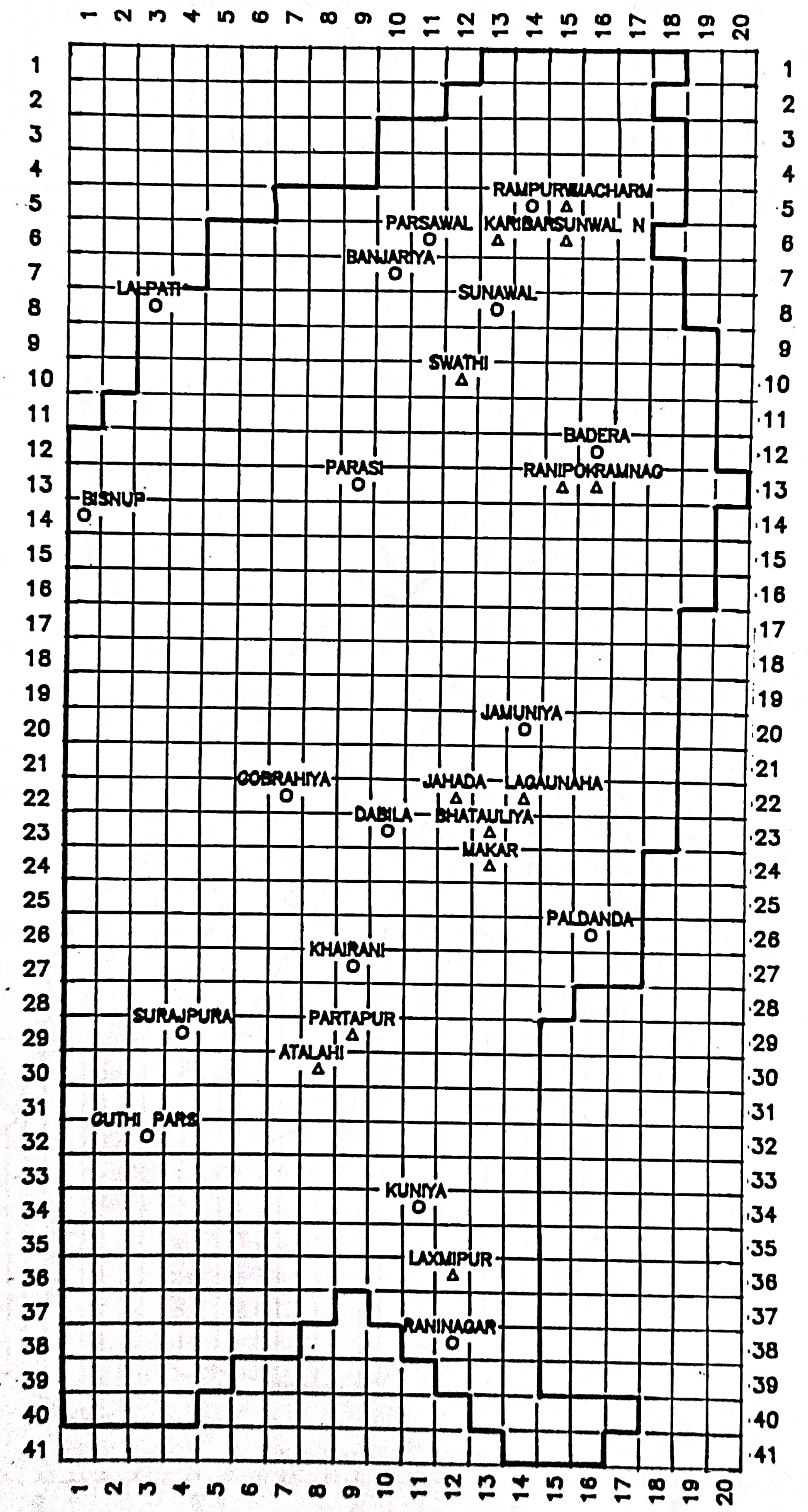

NEP/86/025 DRILLING METRAGE
IN NAWALPARASI (WEST)
METERS
1000
750
500
250
0
800
573
573
17
35
TARGET
DRILLED
COMPL.
AVERAGE
TARGET
DRILLED
COMPLETED
RIG
MANUAL

FIGURE 7



RAMPURWA
MACHARM
PARSAWAL
KARIBAR
SUNWAL
N
BANJARIYA
LALPATI
SUNAWAL
SWATHI
BADERA
PARASI
RANIPOKRA
MNAG
BISNUP
JAMUNIYA
GOBRAHIYA
JAHADA
LAGAUNAHA
DABILA
BHATAULIYA
MAKAR
PALDANDA
KHAIRANI
SURAJPURA
PARTAPUR
ATALAHI
GUTHI PARS
KUNIYA
LAXMIPUR
RANINAGAR

FIGURE 8

FEASIBILITY FOR SHALLOW GROUNDWATER DEVELOPMENT

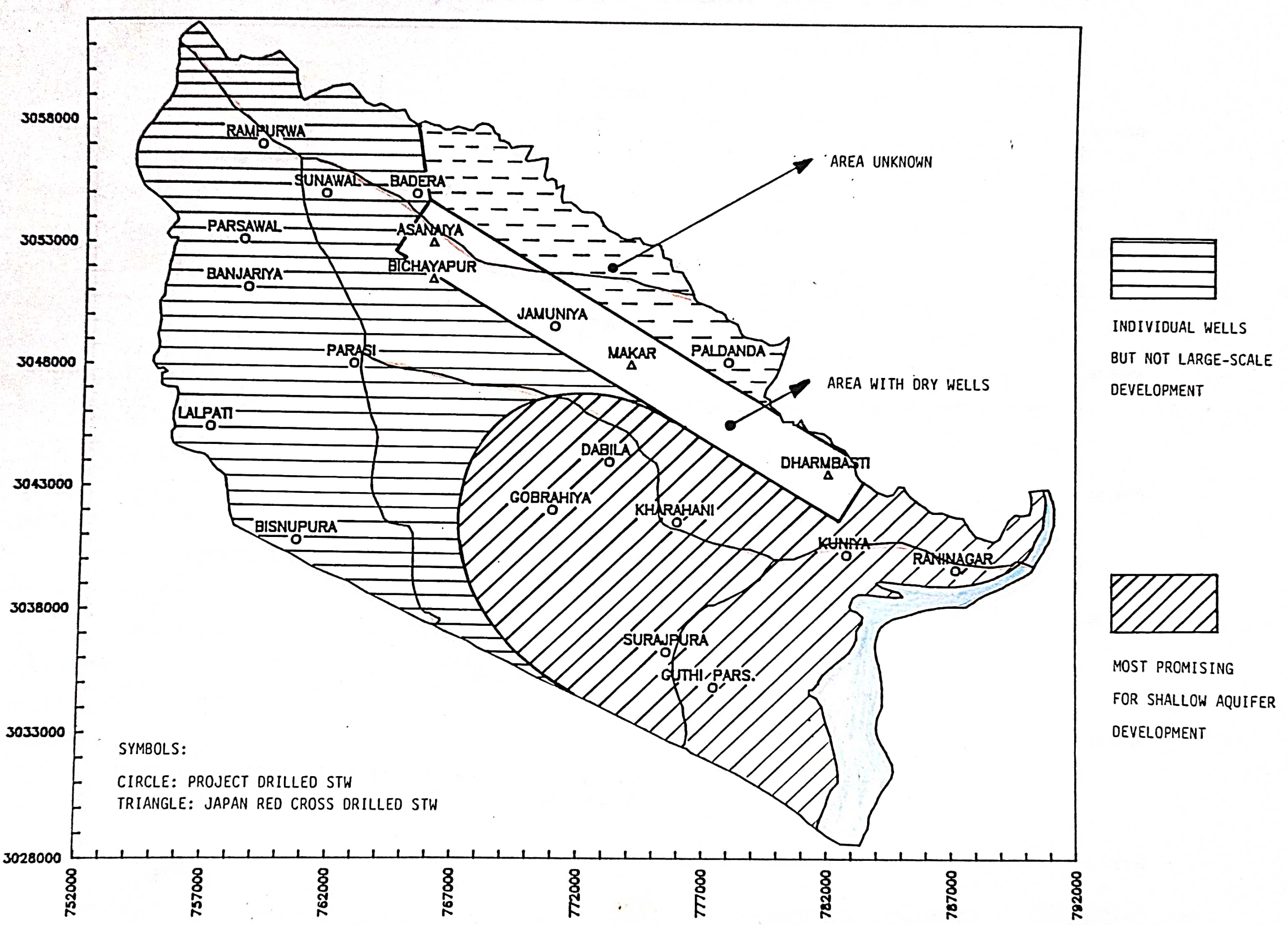
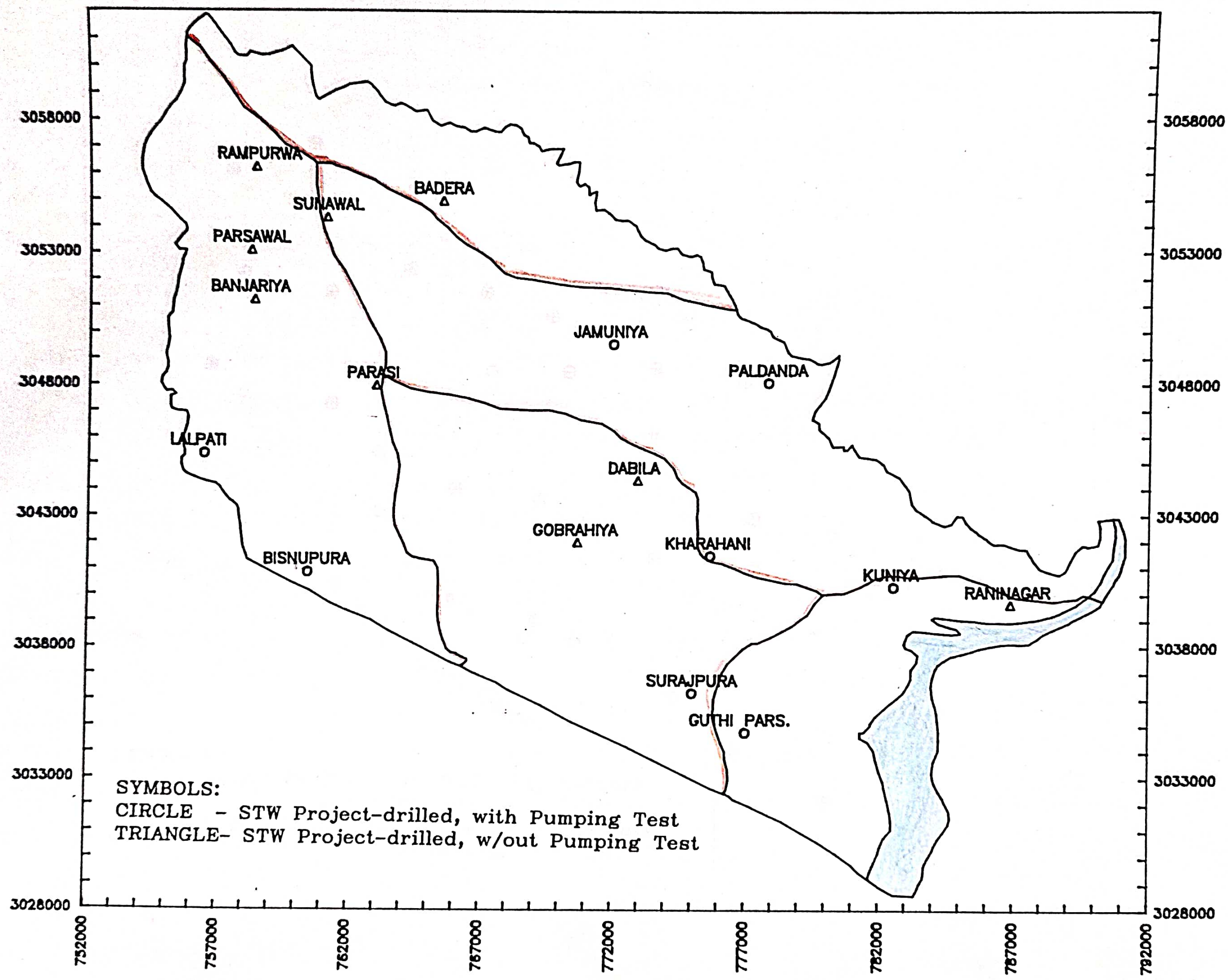


FIGURE 9

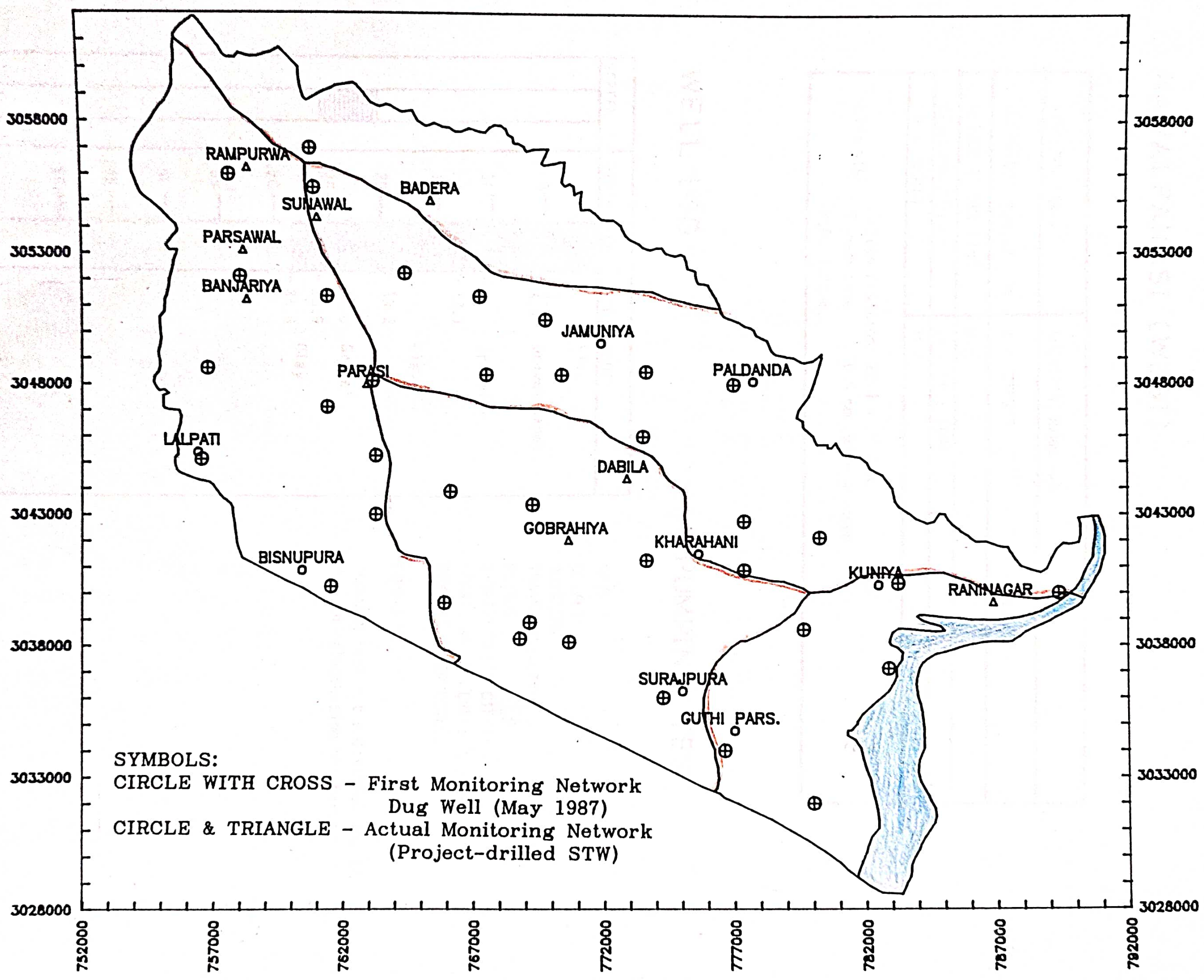
NAWALPARASI (WEST) PROJECT WELLS AND PUMPING TESTS

APPENDIX 1



APPENDIX 2

NAWALPARASI (WEST) LOCATION MAP FOR MONITORING NETWORK

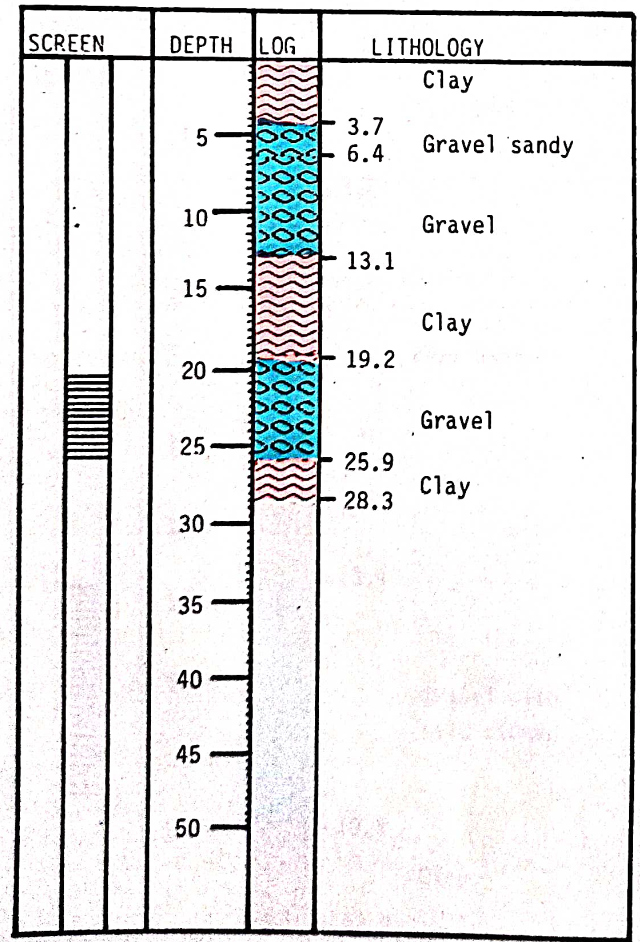


GWRDB - UNDP NEP/86/025
SHALLOW GROUNDWATER EXPLORATION IN TERAI

NAWALPARASI (WEST)

WELL NO. STW-1	LOCATION Rampurwa
ELEVATION 129.87 m	X = 758300 Y = 3056250
METHOD OF DRILLING	Rig
DRILLING DATES	15 - 19.1.1988
TOTAL DEPTH	28 m.
COMMENTS	Screen position: 20.4 - 25.9 m. Screen type : 0.5 mm. Wire wrapped M.P. 0.31 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 1.25 m.
DYNAMIC WATER LEVEL:

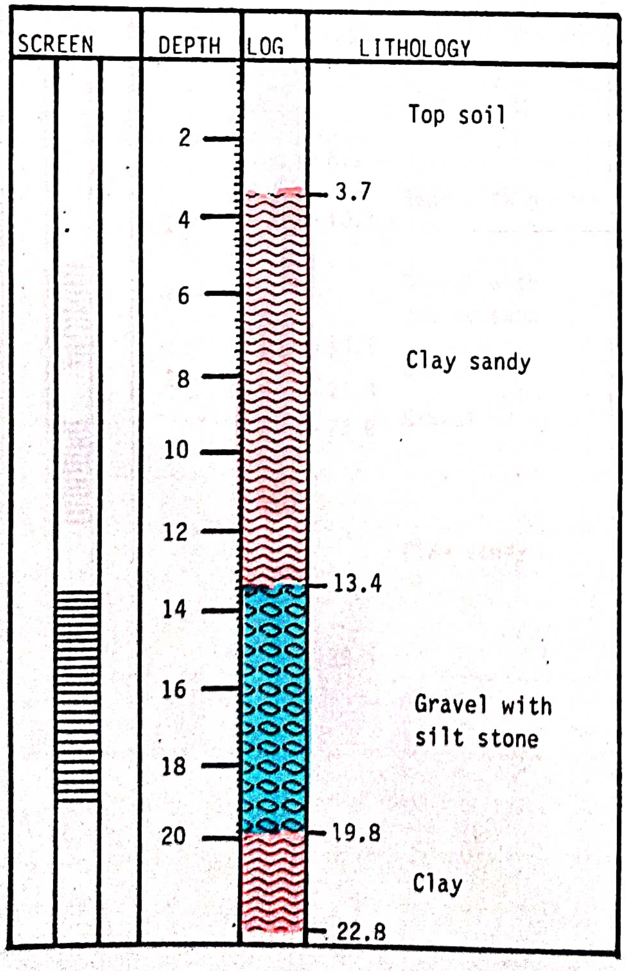
COMMENTS:

Pumping test not successful due to low and fluctuating discharge

NAWALPARASI (WEST)

WELL NO. STW-2	LOCATION Badera
ELEVATION 127.52 m	X = 765400 Y = 3055000
METHOD OF DRILLING	Rig
DRILLING DATES	20 - 24.1.1988
TOTAL DEPTH	23 m.
COMMENTS	Screen position: 13.5 - 19 m. Screen type : 0.5 mm. Wire wrapped M.P. : 1.19 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 1.05 m.
DYNAMIC WATER LEVEL:

COMMENTS:

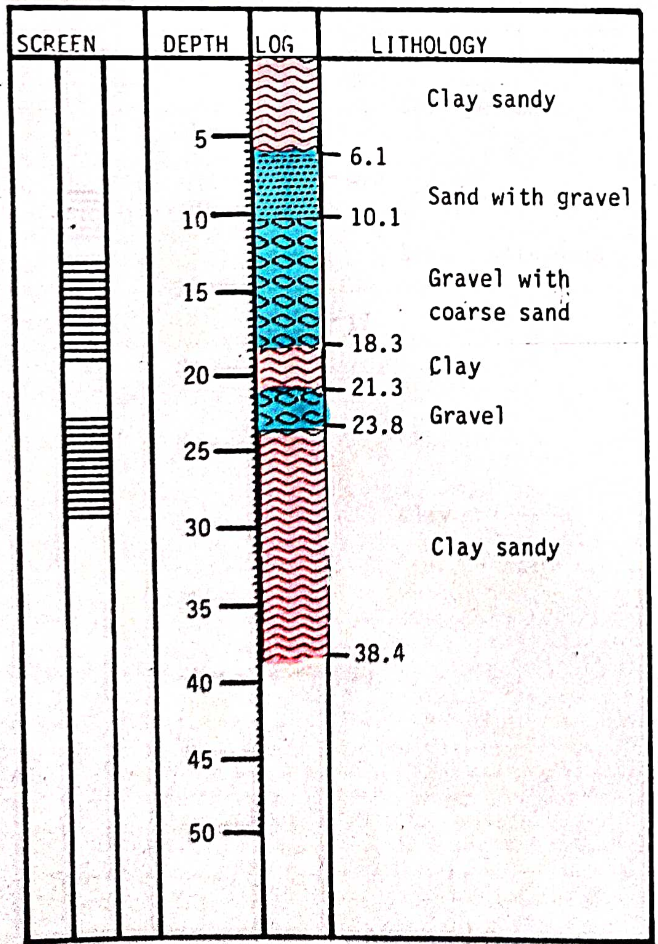
Pumping Test not successful due to low and fluctuating discharge

APPENDIX 3/2

NAWALPARASI (WEST)

WELL NO. STW-3	LOCATION Parasi	
ELEVATION 111.39 m	X = 762900	Y = 3048000
METHOD OF DRILLING	Rig	
DRILLING DATES	25 - 29.1.1988	
TOTAL DEPTH	38.5 m.	
COMMENTS	Screen position: 13.5 - 19 m., 23.5 - 29 m. Screen type : 0.5 mm. Wire wrapped M.P. : 0.64 m.	

WELL LOG



PUMPING TEST

DATE:
Q(1/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 2.45 m.
DYNAMIC WATER LEVEL:

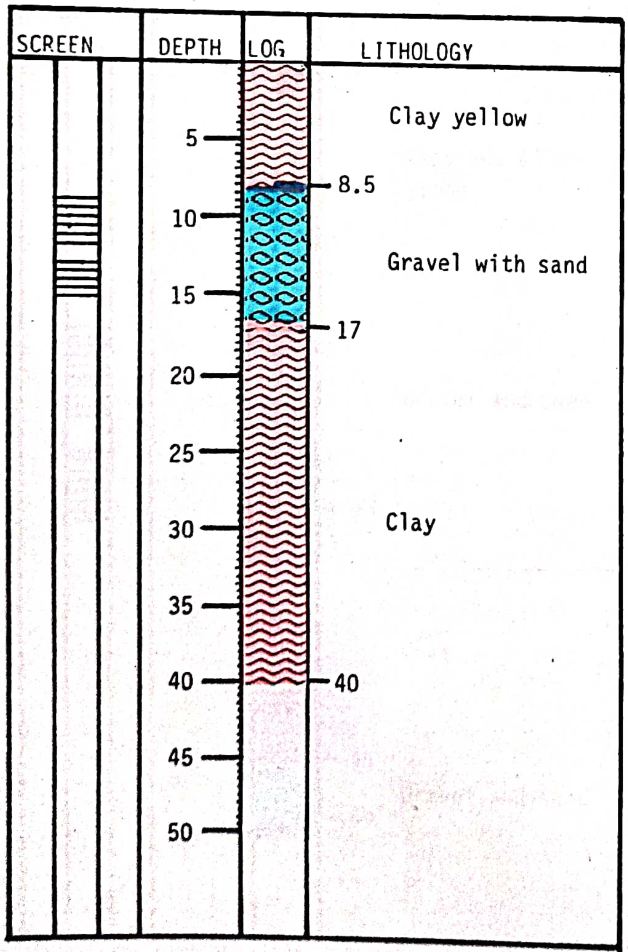
COMMENTS:

Pumping Test not successful due to low and fluctuating discharge.

NAWALPARASI (WEST)

WELL NO. STW4	LOCATION Jamuniya
ELEVATION 113.20 m	X = 771900 Y = 3049600
METHOD OF DRILLING	Rig
DRILLING DATES	28.2 - 3.3.1988
TOTAL DEPTH	40 m.
COMMENTS	Screen position: 9-12.5/13-15.5 m. Screen Type: Slotted Pipe (1.5 mm slots) M.P. : 0.80

WELL LOG



PUMPING TEST

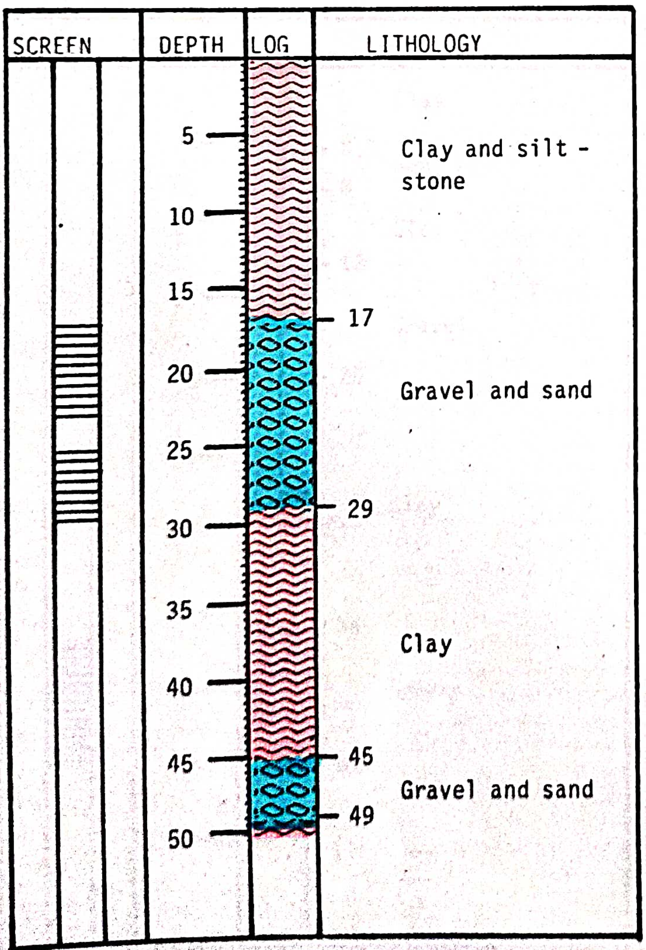
DATE:
Q(l/s): 3.5
DURATION: 16 min.
TRANSMISSIVITY: 156 m^2/day
METHOD: Jacob
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 3.25 m.
DYNAMIC WATER LEVEL: 7.6 m.

COMMENTS:

NAWALPARASI (WEST)

WELL NO. STW-5	LOCATION Paldanda
ELEVATION 123.65 m	X = 777750 Y = 3048120
METHOD OF DRILLING	Rig
DRILLING DATES	4.3 - 8.3.1988
TOTAL DEPTH	50 m.
COMMENTS	Screen position: 17 - 23/25 - 29 m. Screen type : Slotted screen M.P. : 0.50 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 6
DURATION: 1 h
TRANSMISSIVITY: 35 m^2/day
METHOD: Hantush Leaky
STORAGE COEFFICIENT: 0.05
STATIC WATER LEVEL: 3.6 m.
DYNAMIC WATER LEVEL: 9.17 m.

COMMENTS:

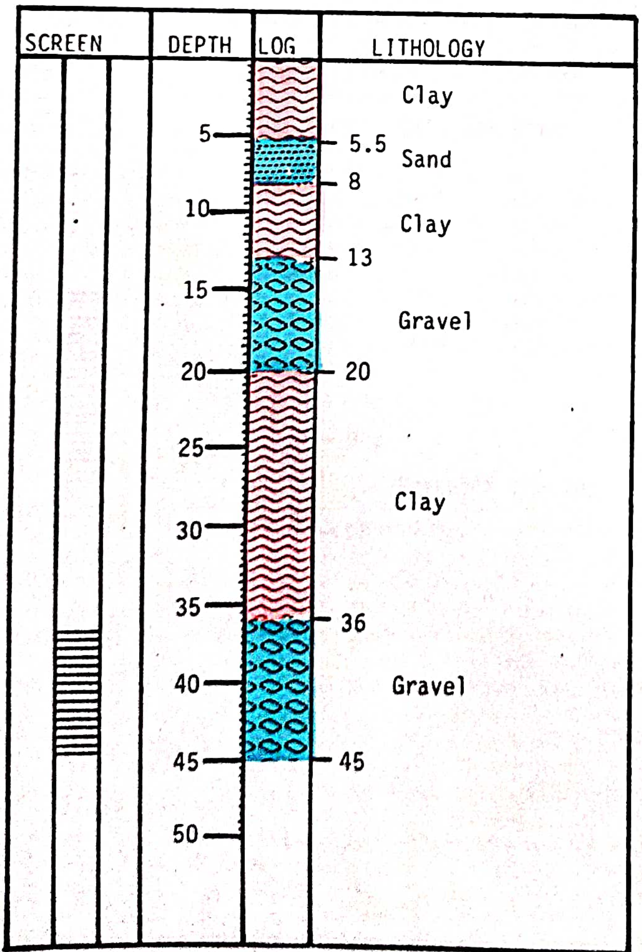
Leakance : 0.884 1/d

NAWALPARASI (WEST)

WELL NO. STW-6	LOCATION Dabila	
ELEVATION 112.08 m	X = 772870	Y = 3044370
METHOD OF DRILLING	Rig	
DRILLING DATES	9.3 - 15.3.1988	
TOTAL DEPTH	45 m.	

COMMENTS Screen position: 37 - 44.5 m.
Screen type : Slotted pipe
M.P. : 0.68 m.

WELL LOG



PUMPING TEST

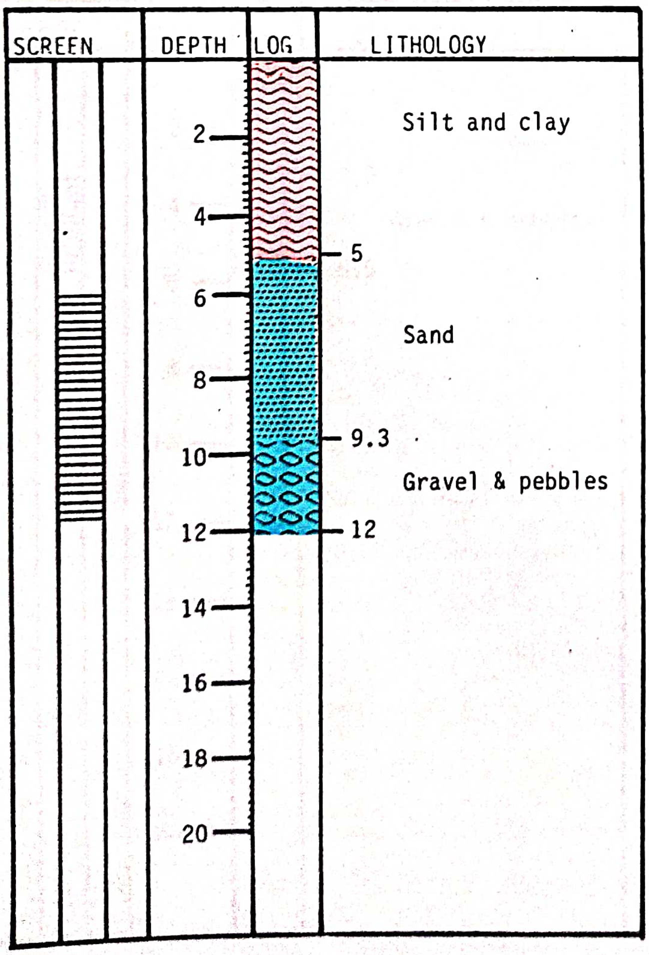
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 6.54 m. (B.G.L)
DYNAMIC WATER LEVEL:

COMMENTS:

NAWALPARASI (WEST)

WELL NO. STW-7	LOCATION Kuniya	
ELEVATION 107.62 m	X = 782500	Y = 3040300
METHOD OF DRILLING	Rig	
DRILLING DATES	14.3 - 18.3.1988	
TOTAL DEPTH	12 m.	
COMMENTS	Screen position: 6 - 11.5 m. Screen type : Slotted pipe M.P. : 0.37 m.	

WELL LOG



PUMPING TEST

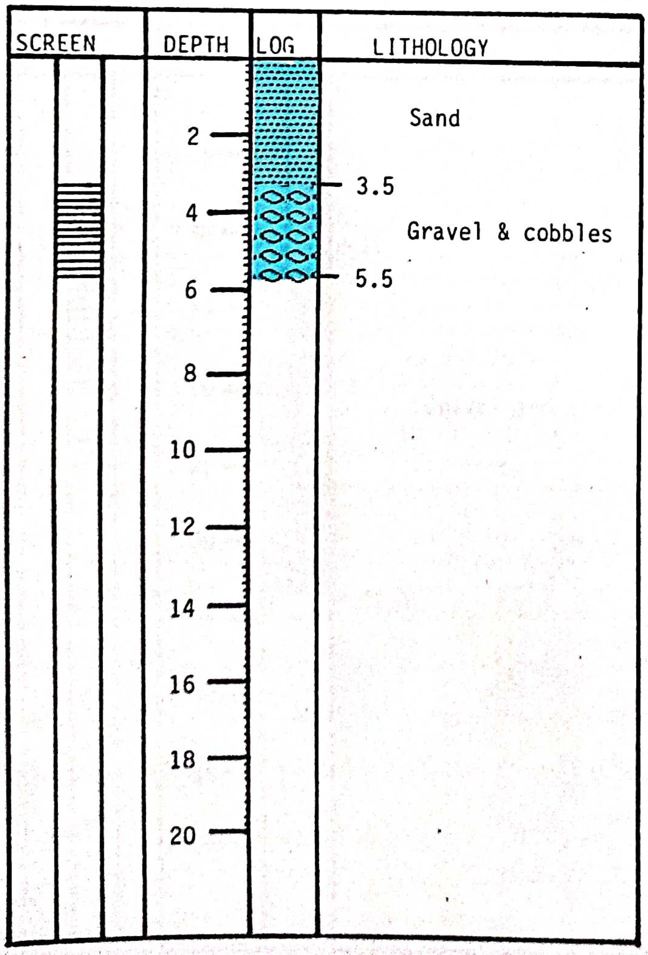
DATE:
Q(l/s): 14
DURATION: 35 min.
TRANSMISSIVITY: 950 m^2/day
METHOD: Theis
STORAGE COEFFICIENT: 0.012
STATIC WATER LEVEL: 2.79
DYNAMIC WATER LEVEL: 5.46

COMMENTS:

NAWALPARASI (WEST)

WELL NO. STW-8	LOCATION Raninagar	
ELEVATION 110.20 m	X = 786880	Y = 3039630
METHOD OF DRILLING	Rig	
DRILLING DATES	19.3 - 23.3.1988	
TOTAL DEPTH	5.5 m.	
COMMENTS	Screen position: 3.5 - 5.4 m. Screen type : Slotted pipe P.M. : 0.79 m.	

WELL LOG



PUMPING TEST

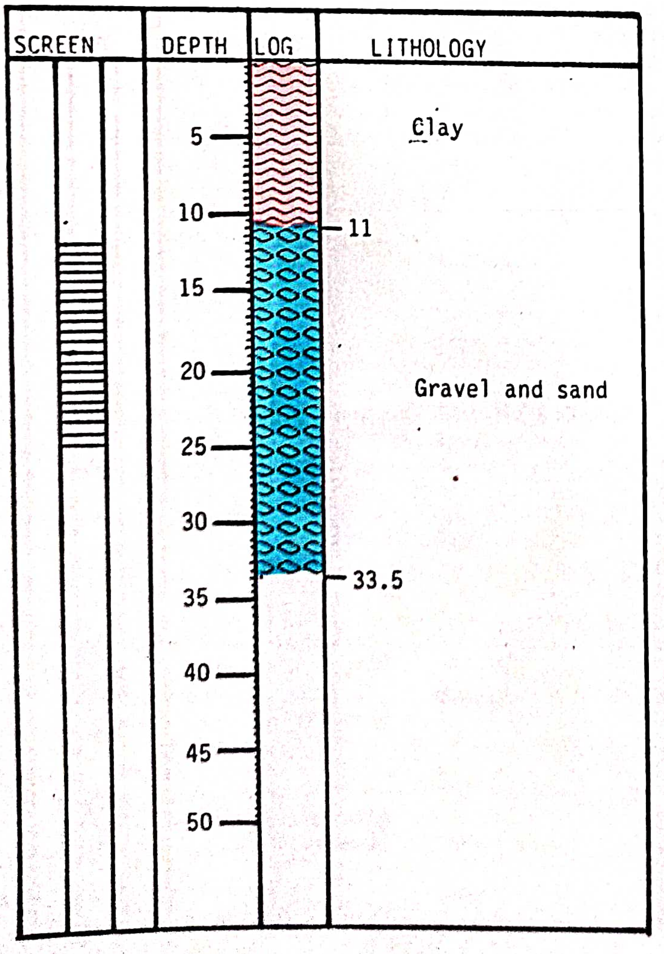
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 3.8 m. (B.G.L)
DYNAMIC WATER LEVEL:

COMMENTS:

NAWALPARASI (WEST)

WELL NO. STW-9	LOCATION Kharahani
ELEVATION 105.83 m	X = 775630 Y = 3041500
METHOD OF DRILLING	Rig
DRILLING DATES	24.3 - 28.3.1988
TOTAL DEPTH	33.5 m.
COMMENTS	Screen position: 12 - 25 m. Screen type : Slotted pipe P.M. : 0.50 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 20
DURATION: 100 min.
TRANSMISSIVITY: 900 m^2/day
METHOD: Jacob
STORAGE COEFFICIENT: 0.00055
STATIC WATER LEVEL: 3.23 m.
DYNAMIC WATER LEVEL: 6.2 m.

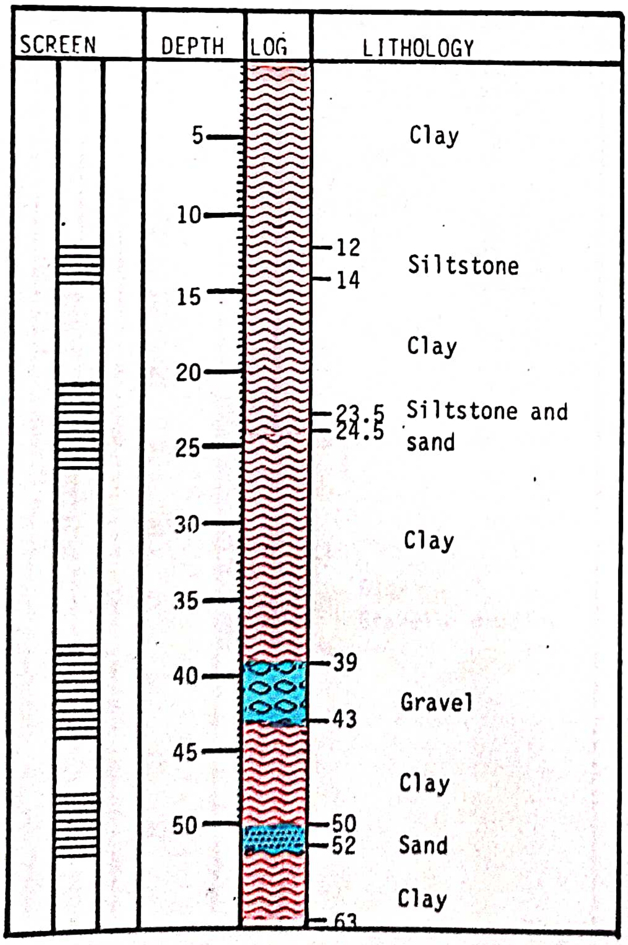
COMMENTS:

GWRDB - UNDP NEP/86/025
SHALLOW GROUNDWATER EXPLORATION IN TERAI

NAWALPARASI (WEST)

WELL NO. STW-10	LOCATION Banjariya	
ELEVATION 114.60 m	X = 758250	Y = 3051250
METHOD OF DRILLING	Rig	
DRILLING DATES	29.3 - 2.4.1988	
TOTAL DEPTH	63 m.	
COMMENTS	Screen position: 12-15 m. (Slotted pipe) 21-26.5 m. (Wire wrapped) 38-44 m. (Slotted pipe) 47.5-53 m. (Wire wrapped) M.P.: 0.88 m.	

WELL LOG



PUMPING TEST

DATE:
Q(1/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 3.63 m. (B.G.L)
DYNAMIC WATER LEVEL:

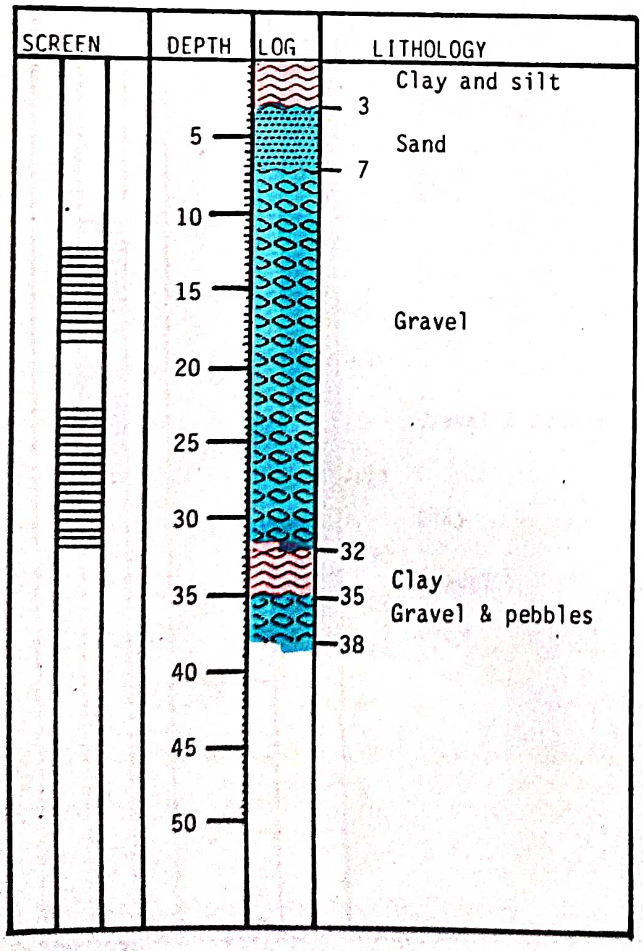
COMMENTS:

Pumping discharge: 1.25 l/s

NAWALPARASI (WEST)

WELL NO. STW-11	LOCATION Parsawal
ELEVATION 119.55 m	X = 758120 Y = 3053120
METHOD OF DRILLING	Rig
DRILLING DATES	14.4 - 18.4.1988
TOTAL DEPTH	38 m.
COMMENTS	Screen position: 12.5 - 18 m. (Wire wrapped) 23.5 - 32 m. (Slotted pipe) M.P.: 0.90

WELL LOG



PUMPING TEST

DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 3.96 m. (B.G.L)
DYNAMIC WATER LEVEL:

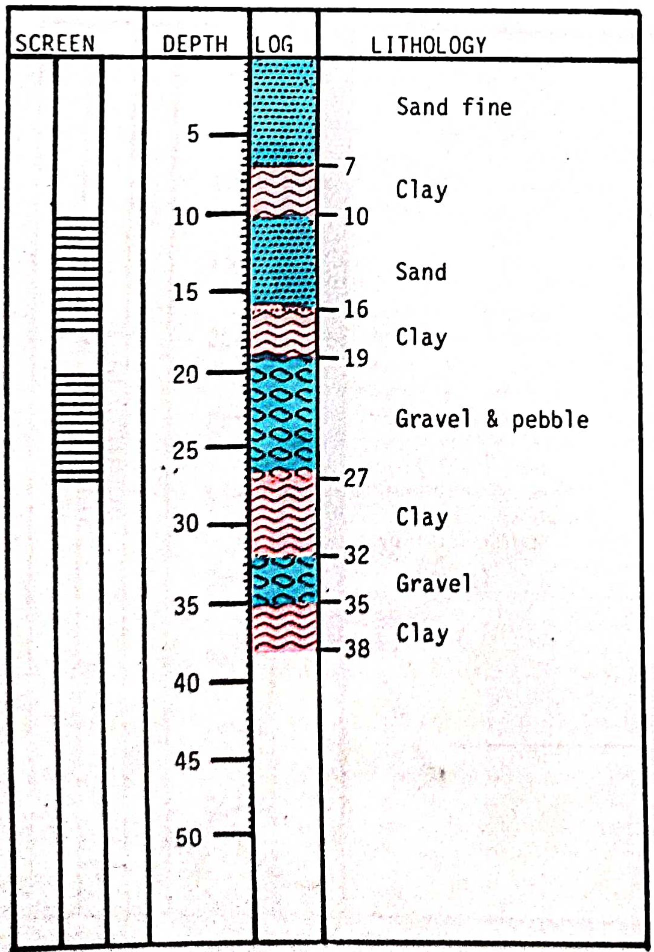
COMMENTS:

- Fluctuation in discharge (1 l/s)
- Immediate drawdown to 8 m.

NAWALPARASI (WEST)

WELL NO. STW-12	LOCATION Lalpati	
ELEVATION 107.90 m	X = 756370	Y = 3045375
METHOD OF DRILLING	Rig	
DRILLING DATES	19.4 - 23.4.1988	
TOTAL DEPTH	38 m.	
COMMENTS	Screen position: 10.5-17.5 m. (Slotted pipe) 20 - 25.5 m. (Wire wrapped) 25.5 - 27 m. (Slotted pipe) M.P.: 0.73	

WELL LOG



PUMPING TEST

DATE:
Q(1/s): 3
DURATION: 25 min.
TRANSMISSIVITY: . 135 m^2/day
METHOD: Jacob (Pump Well)
STORAGE COEFFICIENT: 0.0014
STATIC WATER LEVEL: 3.73 m.
DYNAMIC WATER LEVEL: 7.55 m.

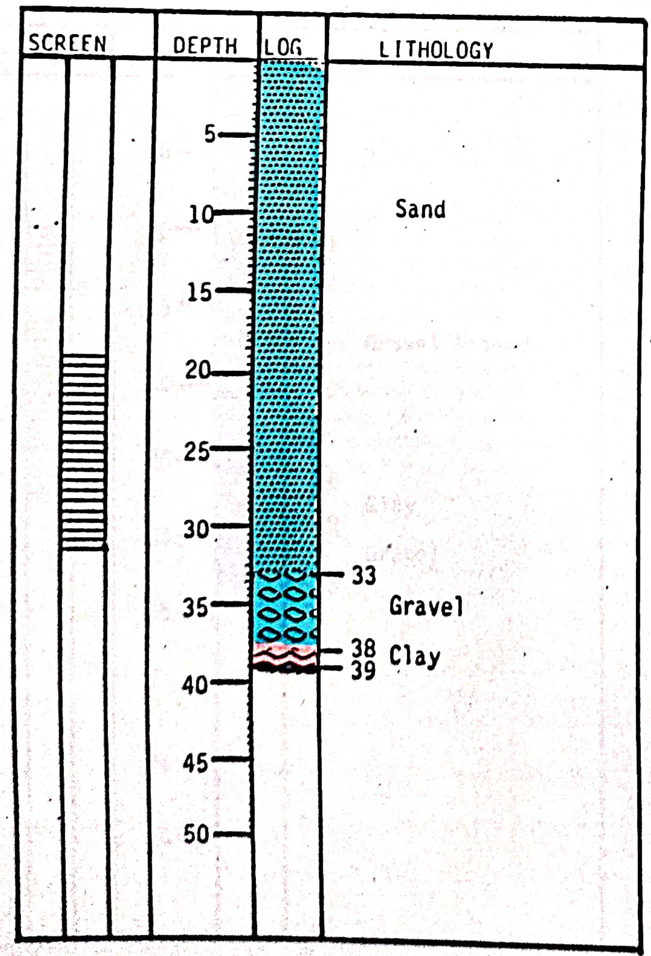
COMMENTS:

Theis - Method used in observation well

NAWALPARASI (WEST)

WELL NO. STW-13	LOCATION Gobrahiya	
ELEVATION 107.98 m	X = 770620	Y = 3042000
METHOD OF DRILLING	Rig	
DRILLING DATES	24.4 - 28.4.1988	
TOTAL DEPTH	39 m.	
COMMENTS	Screen position: 19 - 32 m. Screen type : Wire rod with coconut rope MP: 0.60 m	

WELL LOG



PUMPING TEST

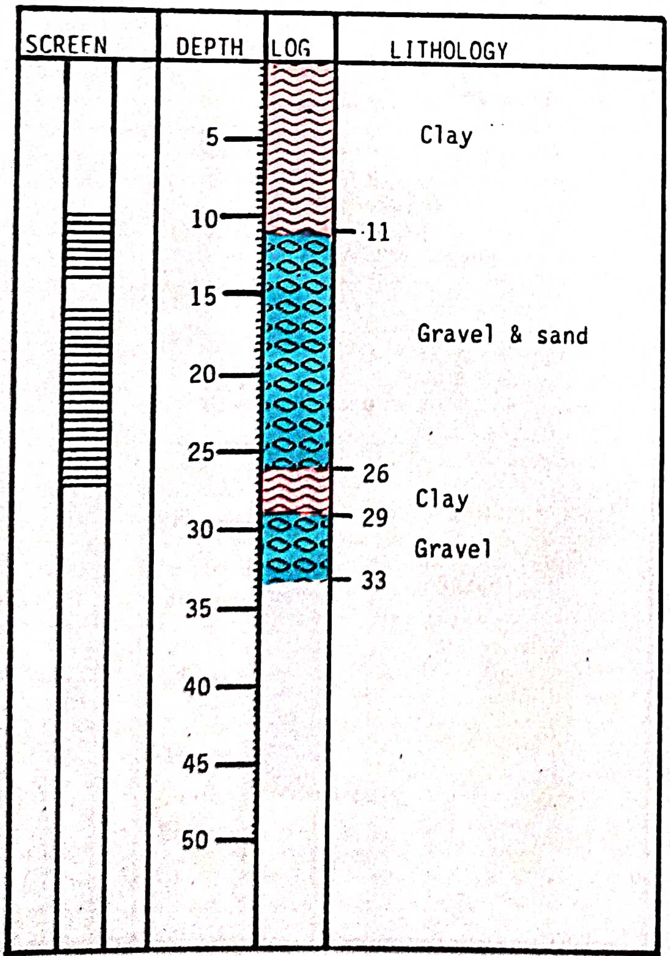
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL:
DYNAMIC WATER LEVEL:

COMMENTS:

NAWALPARASI (WEST)

WELL NO. STW-14	LOCATION Surajpura	
ELEVATION 103.30 m	X = 775000	Y = 3036250
METHOD OF DRILLING	Rig	
DRILLING DATES	28.4 - 1.5.1988	
TOTAL DEPTH	33 m.	
COMMENTS	M.P.: 0.67 Screen position: 10 - 14 m. 16 - 27 m. Screen type : Slotted pipe	

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 20
DURATION: 80 min.
TRANSMISSIVITY: 560 m^2/day
METHOD: Jacob (Pump Well)
STORAGE COEFFICIENT: 0.0019
STATIC WATER LEVEL: 2.92 m.
DYNAMIC WATER LEVEL: 7.46 m.

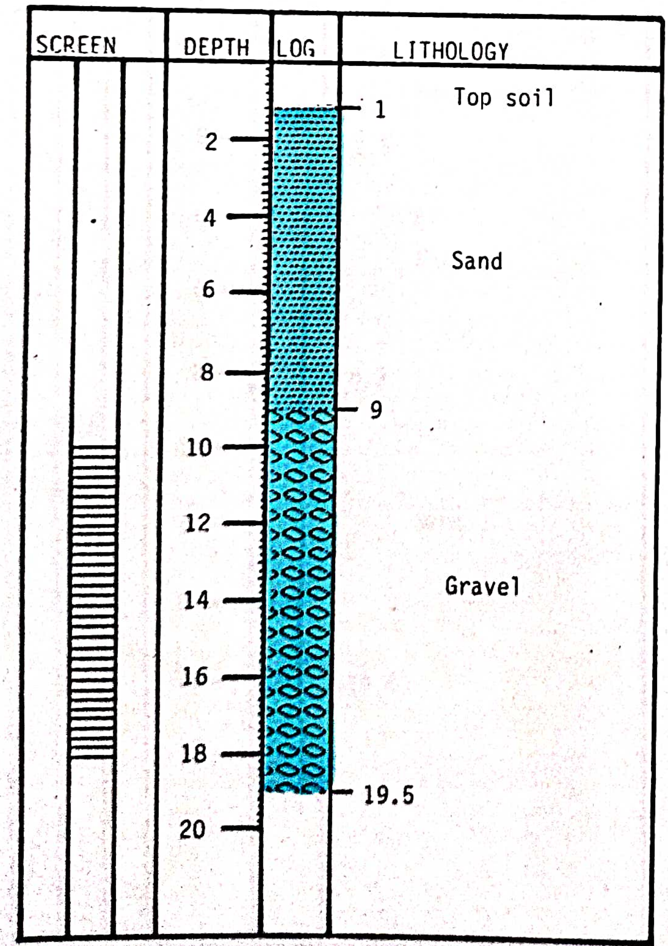
COMMENTS:

Theis - Method in observation well

NAWALPARASI (WEST)

WELL NO. STW-15	LOCATION Guthi Parsauni
ELEVATION 103.50 m	X = 777000 Y = 3034750
METHOD OF DRILLING	Rig
DRILLING DATES	3.5 - 7.5.1988
TOTAL DEPTH	19.5 m.
COMMENTS	Screen position: 10 - 18 m. Screen type : Slotted pipe M.P. : 0.65 m.

WELL LOG



PUMPING TEST

DATE:
Q(l/s): 12
DURATION: 1 hr.
TRANSMISSIVITY: 470 m^2/day
METHOD: Jacob (Pumping Well)
STORAGE COEFFICIENT: 0.0011
STATIC WATER LEVEL: 3.68 m.
DYNAMIC WATER LEVEL: 9.0 m.

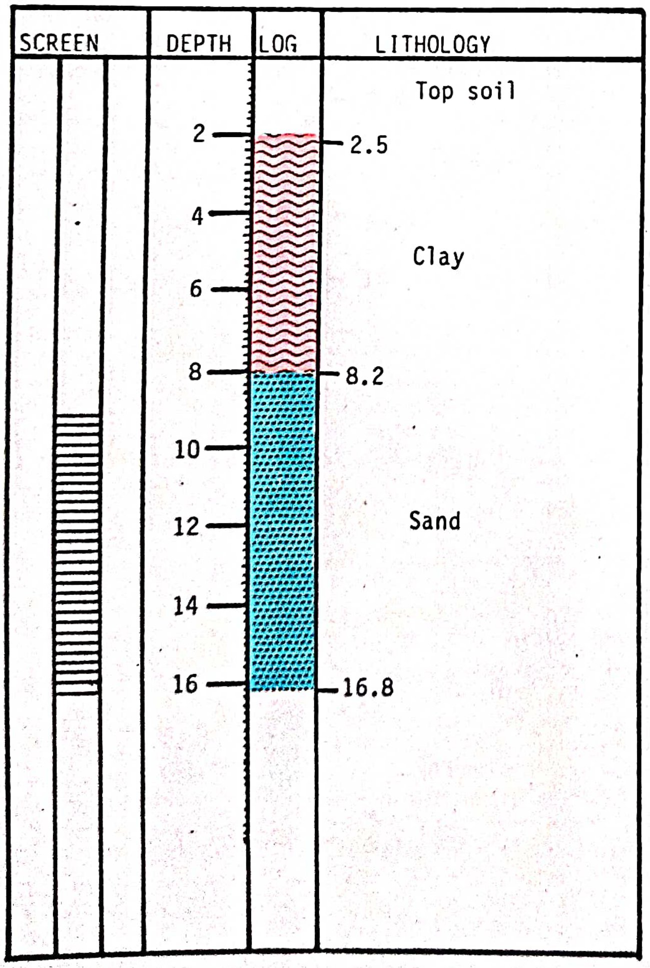
COMMENTS:

Theis method in observation well

NAWALPARASI (WEST)

WELL NO. STW-16	LOCATION Bisnupura	
ELEVATION 106.10 m	X = 760370	Y = 3040870
METHOD OF DRILLING	Manual	
DRILLING DATES		
TOTAL DEPTH	17 m.	
COMMENTS	Screen position: 9.2 - 17 m. Screen type : Slotted pipe M.P. : 0.32 m.	

WELL LOG



PUMPING TEST

DATE:
Q(1/s): 4
DURATION:
TRANSMISSIVITY: 55 m^2/day
METHOD: Hantush Leaky
STORAGE COEFFICIENT: 0.00056
STATIC WATER LEVEL: 4.8 m.
DYNAMIC WATER LEVEL: 8.68 m.

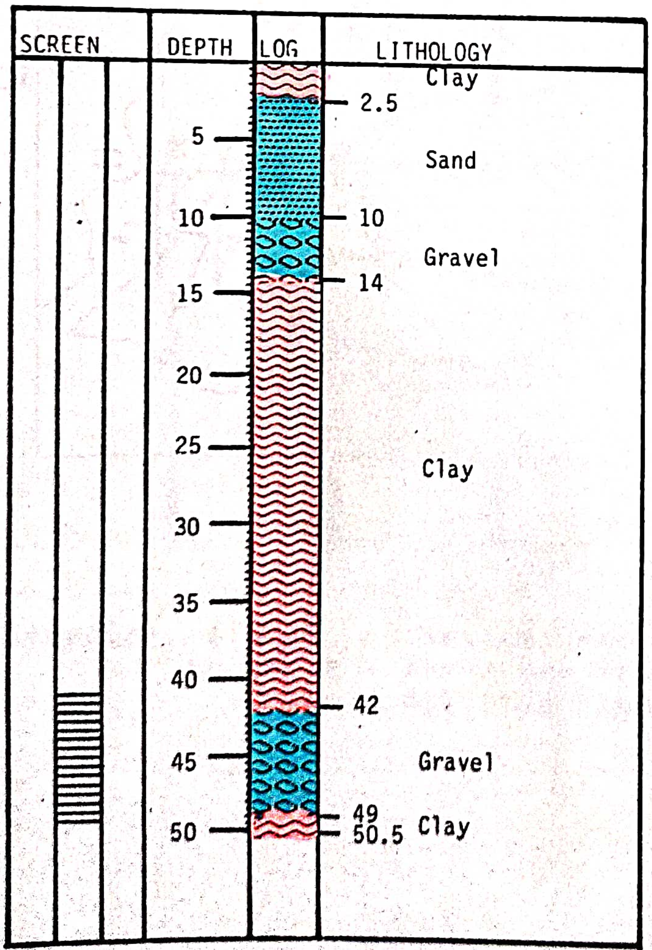
COMMENTS:

Leakance: 0.0518 (1/day)

NAWALPARASI (WEST)

WELL NO. STW-23	LOCATION Sunwal	
ELEVATION 125.15 m	X = 761000	Y = 3054370
METHOD OF DRILLING	Rig	
DRILLING DATES	I6.6 - 19.6.1988	
TOTAL DEPTH	50.5 m.	
COMMENTS	M.P.:0.55 Screen position: 41 - 49 m. Screen type : Slotted pipe Diameter of pipe: 6 (in)	

WELL LOG



PUMPING TEST

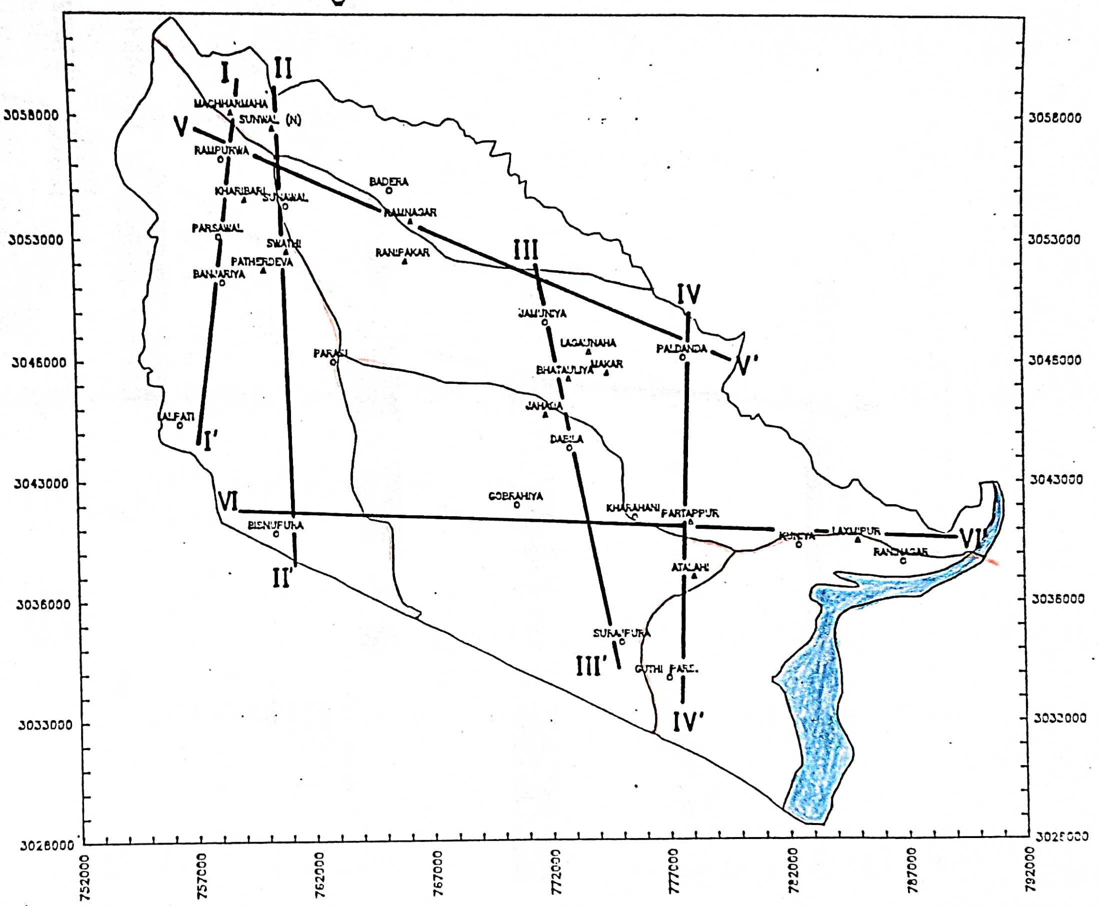
DATE:
Q(l/s):
DURATION:
TRANSMISSIVITY: m^2/day
METHOD:
STORAGE COEFFICIENT:
STATIC WATER LEVEL: 0.5 m (B.G.L)
DYNAMIC WATER LEVEL:

COMMENTS:

-Compressor discharge by 2 l/s

-Immediate drawdown at pumping test to 9 m.

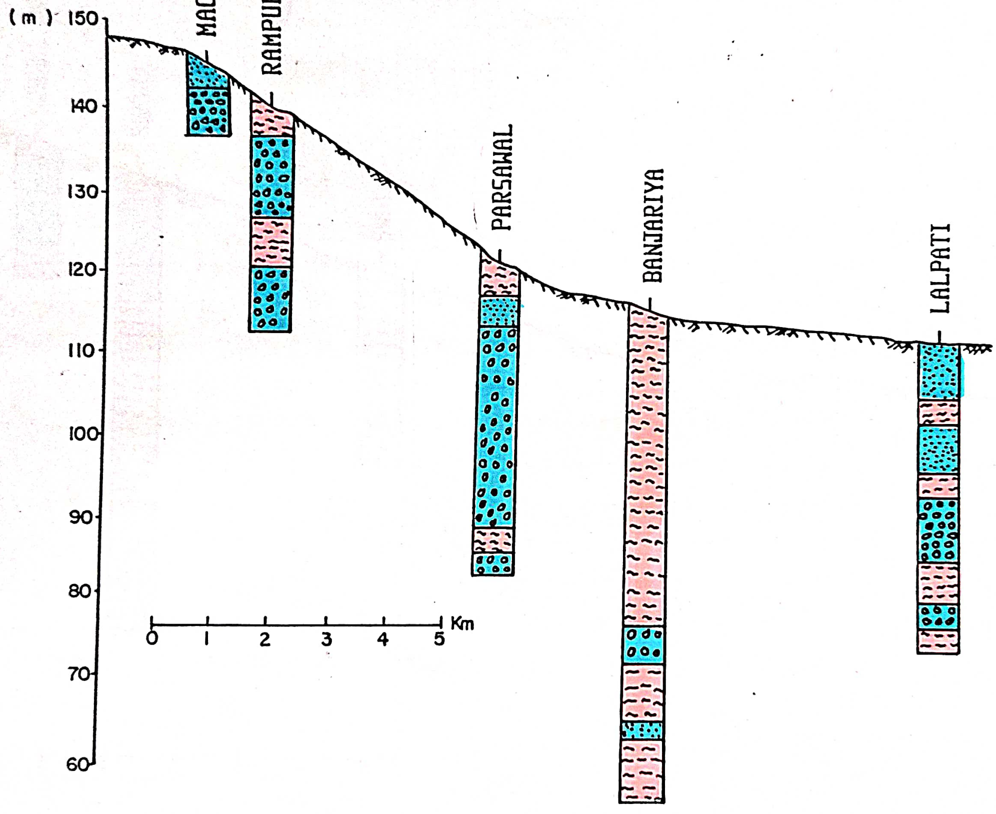
NAWALPARASI (W) - LOCATION OF WELLS
LITHOLOGICAL CROSS SECTION (I - VI)



SYMBOLS: CIRCLE - "Project Wells (UN)"
TRIANGLE - Japan Red Cross Drilling Program

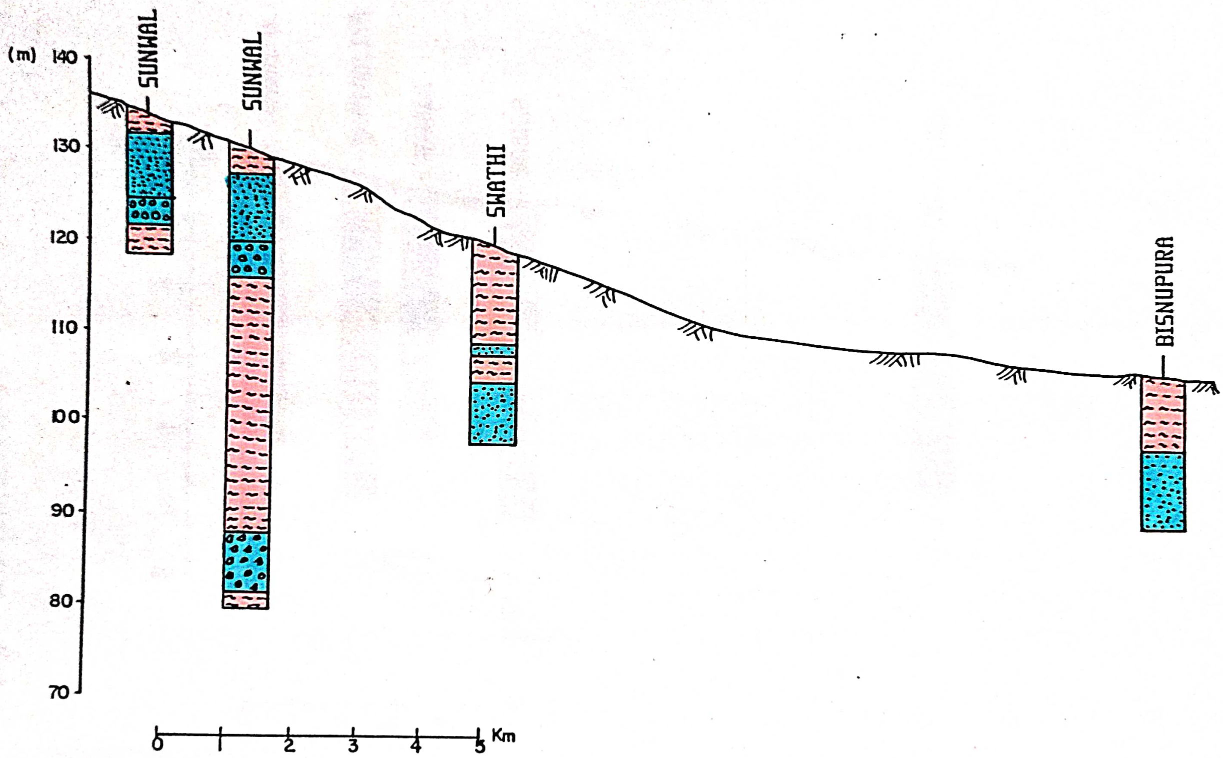
APPENDIX 4 / 1

LITHOLOGICAL CROSS SECTION I - I'



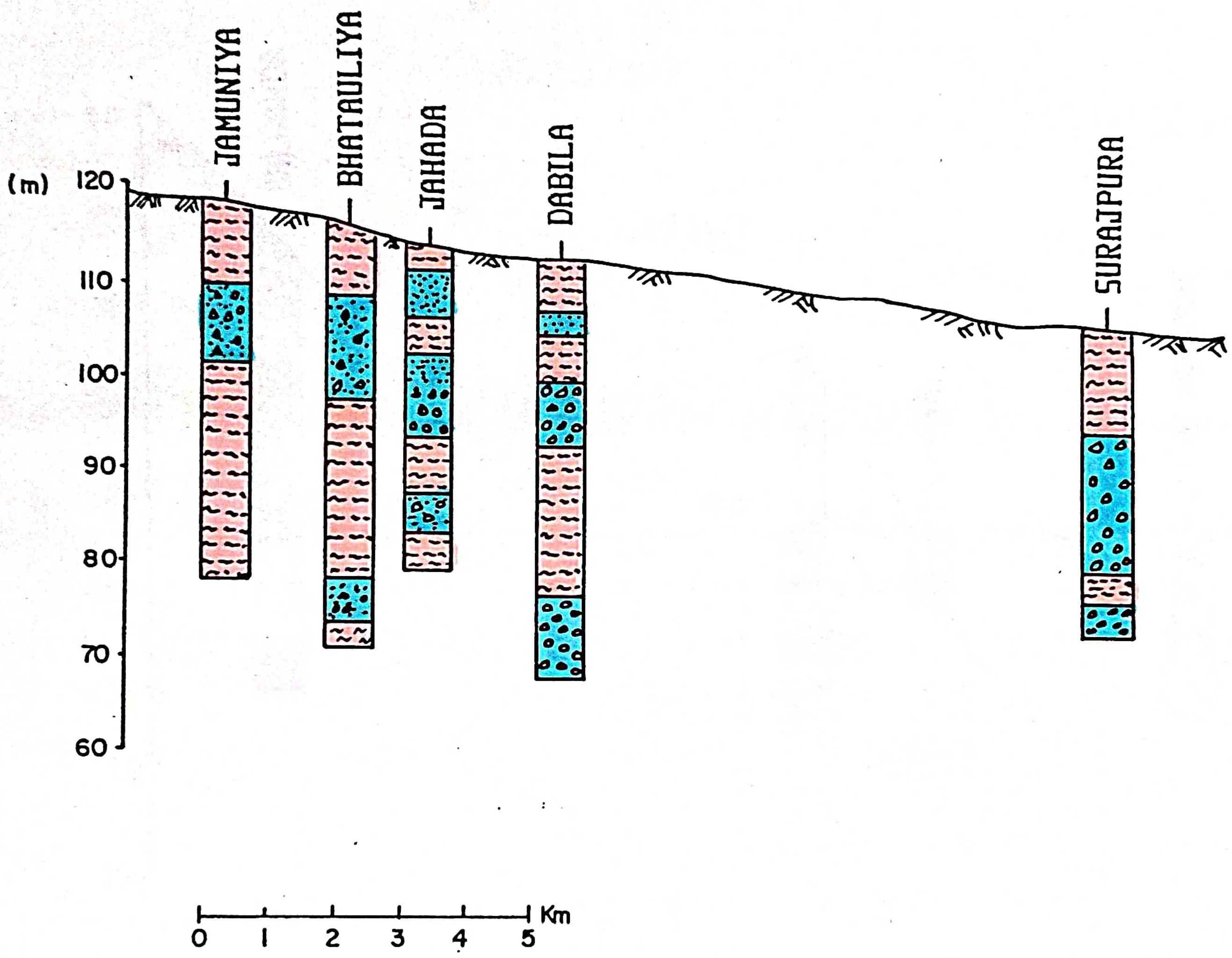
APPENDIX 4/2

LITHOLOGICAL CROSS SECTION II - II'



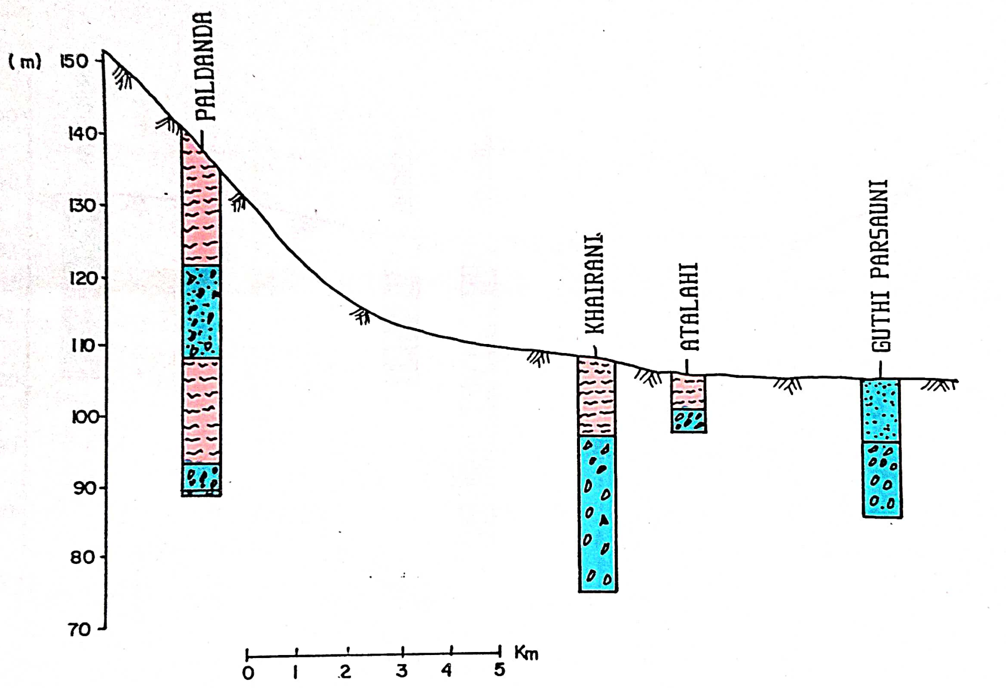
APPENDIX 4/3

LITHOLOGICAL CROSS SECTION III - III'



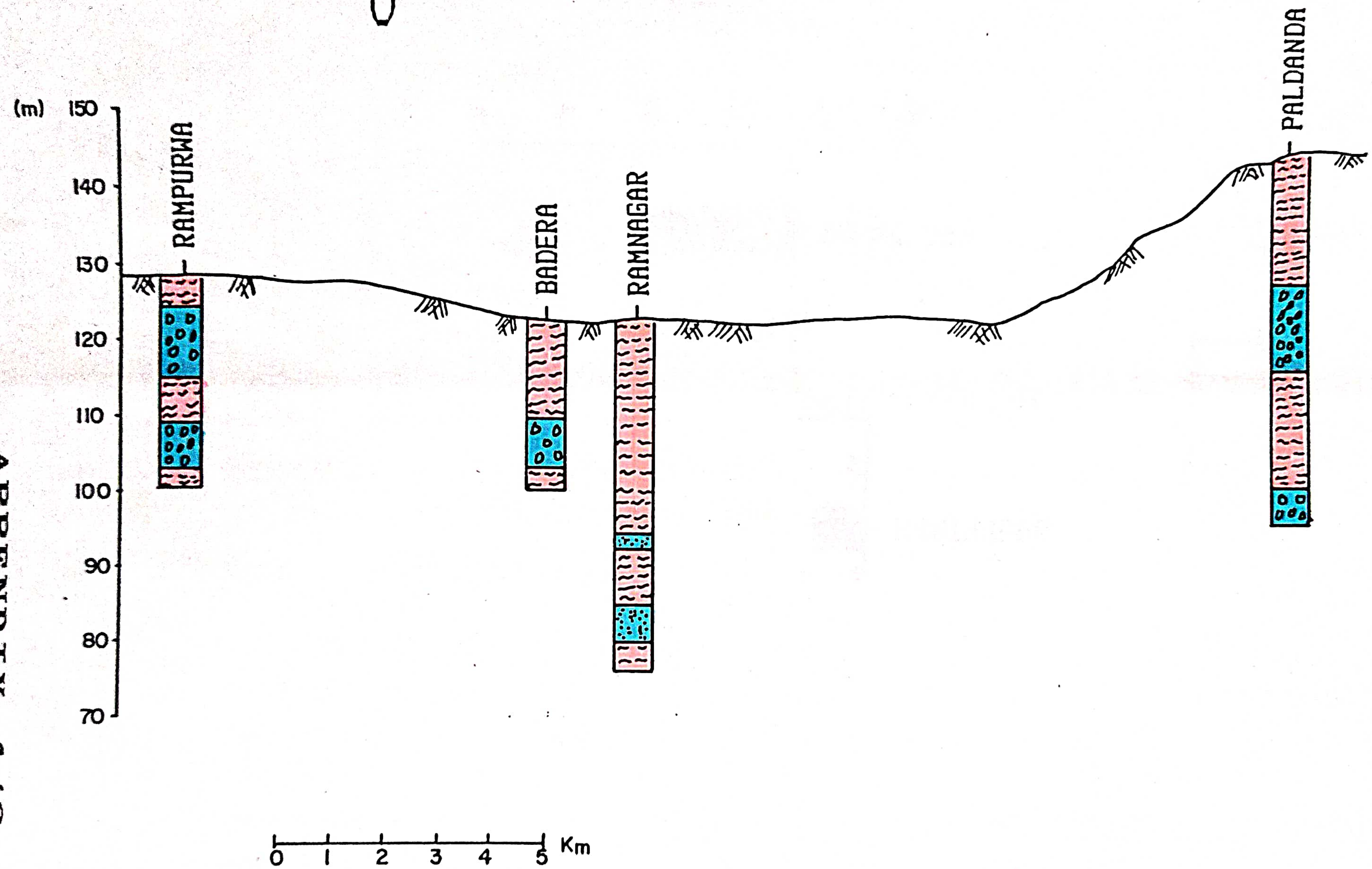
APPENDIX 4/4

LITHOLOGICAL CROSS SECTION IV – IV'



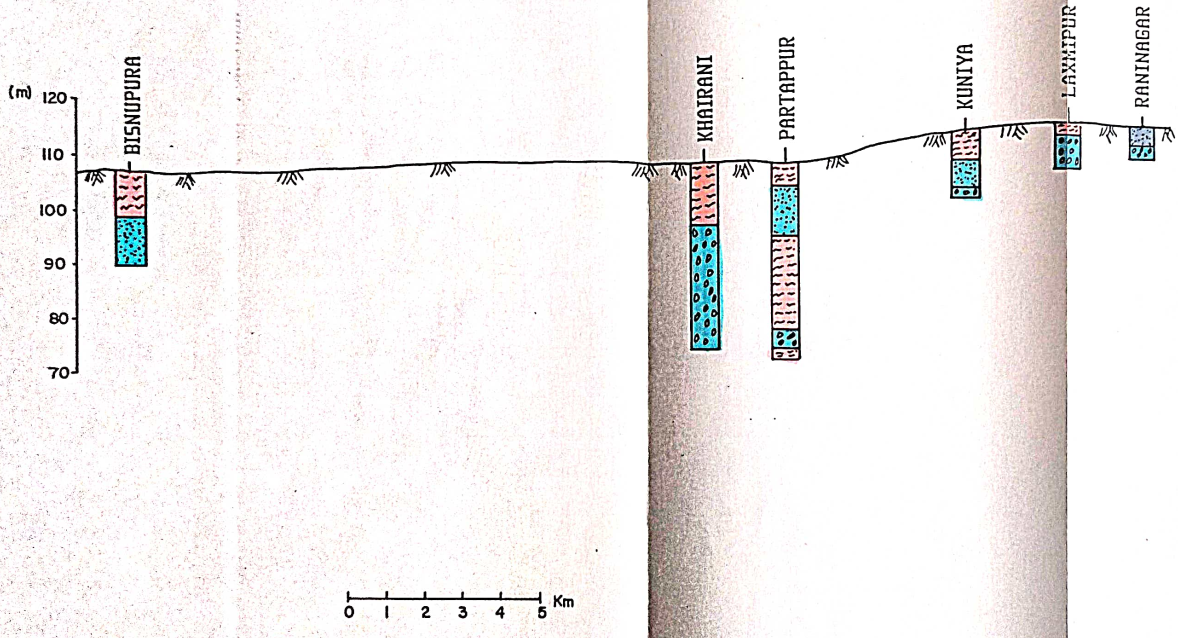
APPENDIX 4/5

LITHOLOGICAL CROSS SECTION V - V'



APPENDIX 4/6

LITHOLOGICAL CROSS SECTION VI – VI'



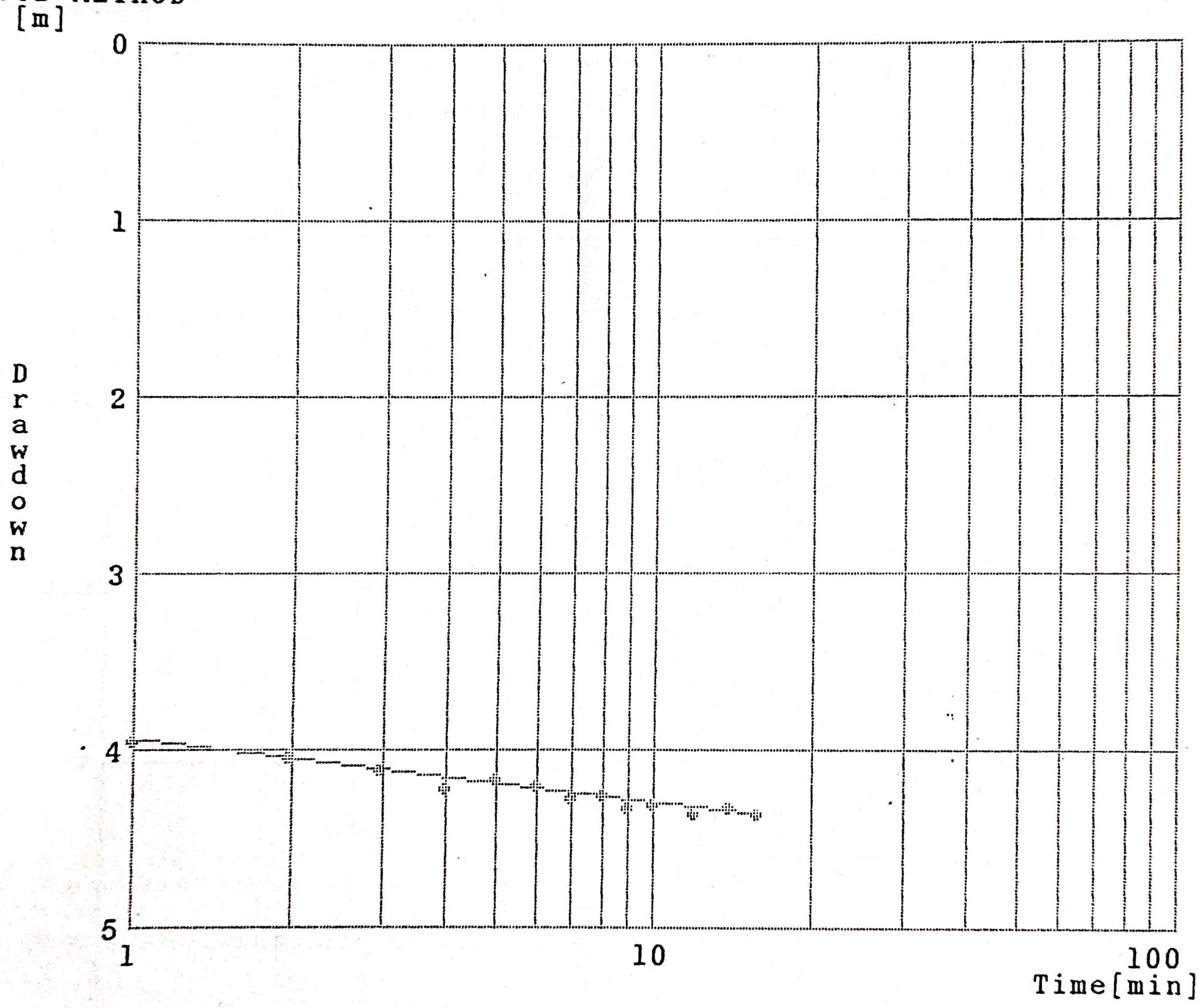
APPENDIX 4/7

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWDB

Test : STW 4 JAMUNIYA

Constant Pumping Rate = 3.500 [l/sec]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.25 [m]
Well Type = STANDARD

JACOB METHOD



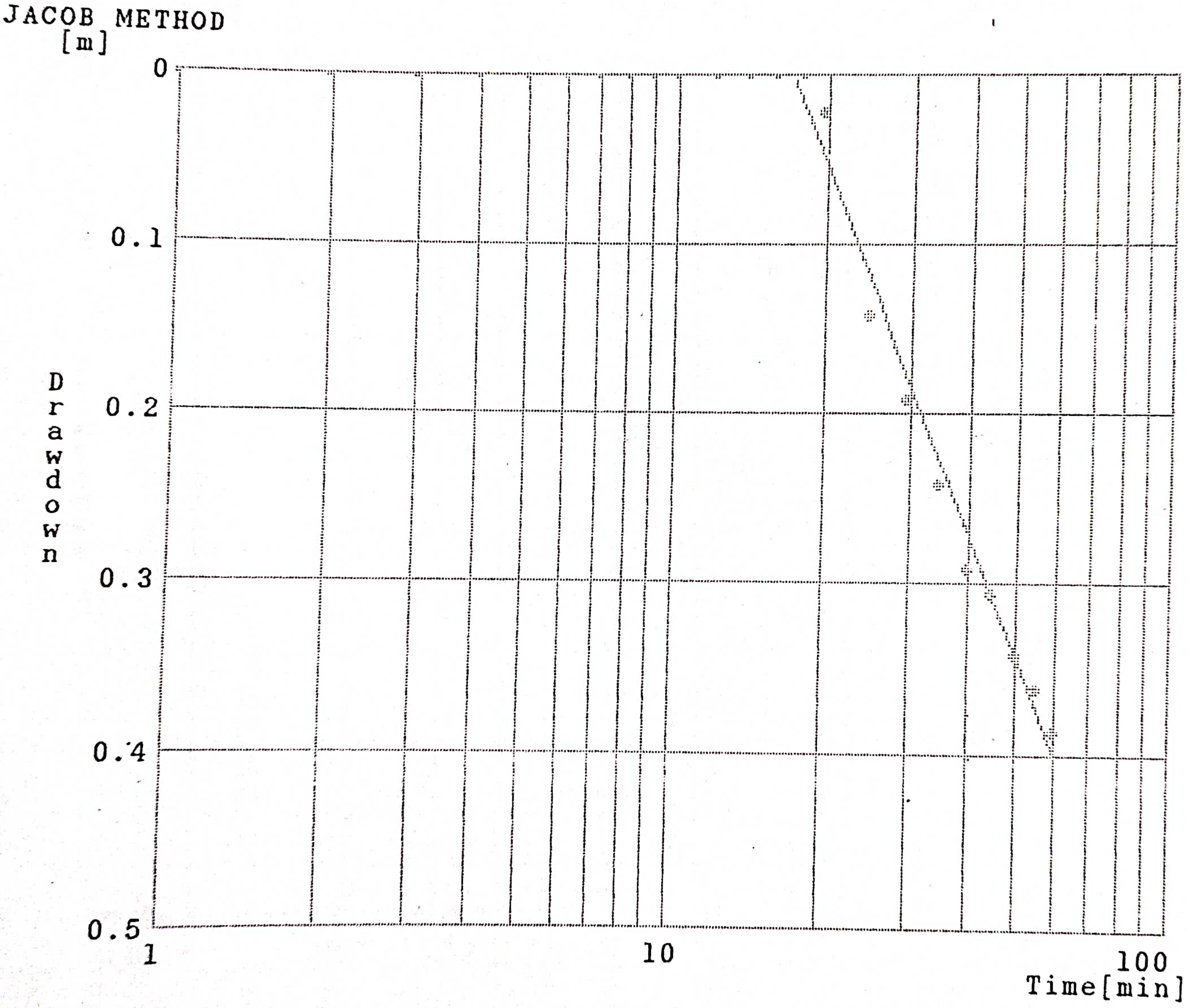
Transmissivity = 156. [m2/day]
Storage Coefficient = 0.00000000
Standard Deviation = 0.0287 [m]
A0 = 0.393775E+01
A1 = 0.354802E+00
Number of Points = 13 of 13

APPENDIX 5/1

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 5 PALDANDA (OBS.WELL)

Constant Pumping Rate = 6.500 [l/sec]
Distance from Pumping Well = 8.25 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.60 [m]
Well Type = STANDARD



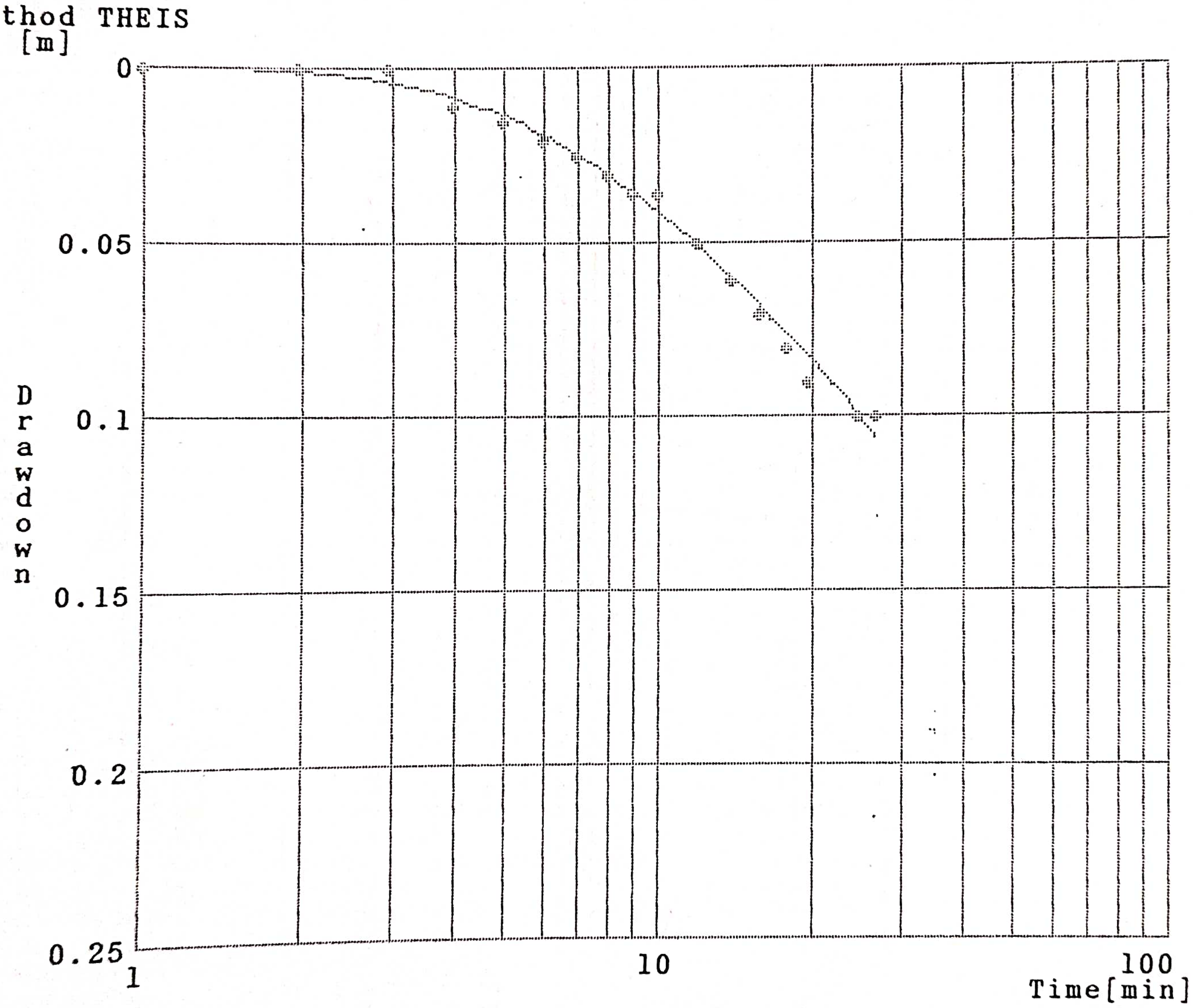
Transmissivity = 142. [m2/day]
Storage Coefficient = 0.05496281
Standard Deviation = 0.0158 [m]
A0 = -0.892429E+00
A1 = 0.725845E+00
Number of Points = 9 of 23

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWDB

Test : STW 7 KUNIYA (OBS. WELL)

Constant Pumping Rate = 14.000 [l/sec]
Distance from Observation Well = 38.15 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.07 [m]
Well Type = STANDARD

Method THEIS



Transmissivity = 986. [m2/day]
Storage Coefficient = 0.01205940
Standard Deviation = 0.0030 [m]

Number of Points = 17 of 17

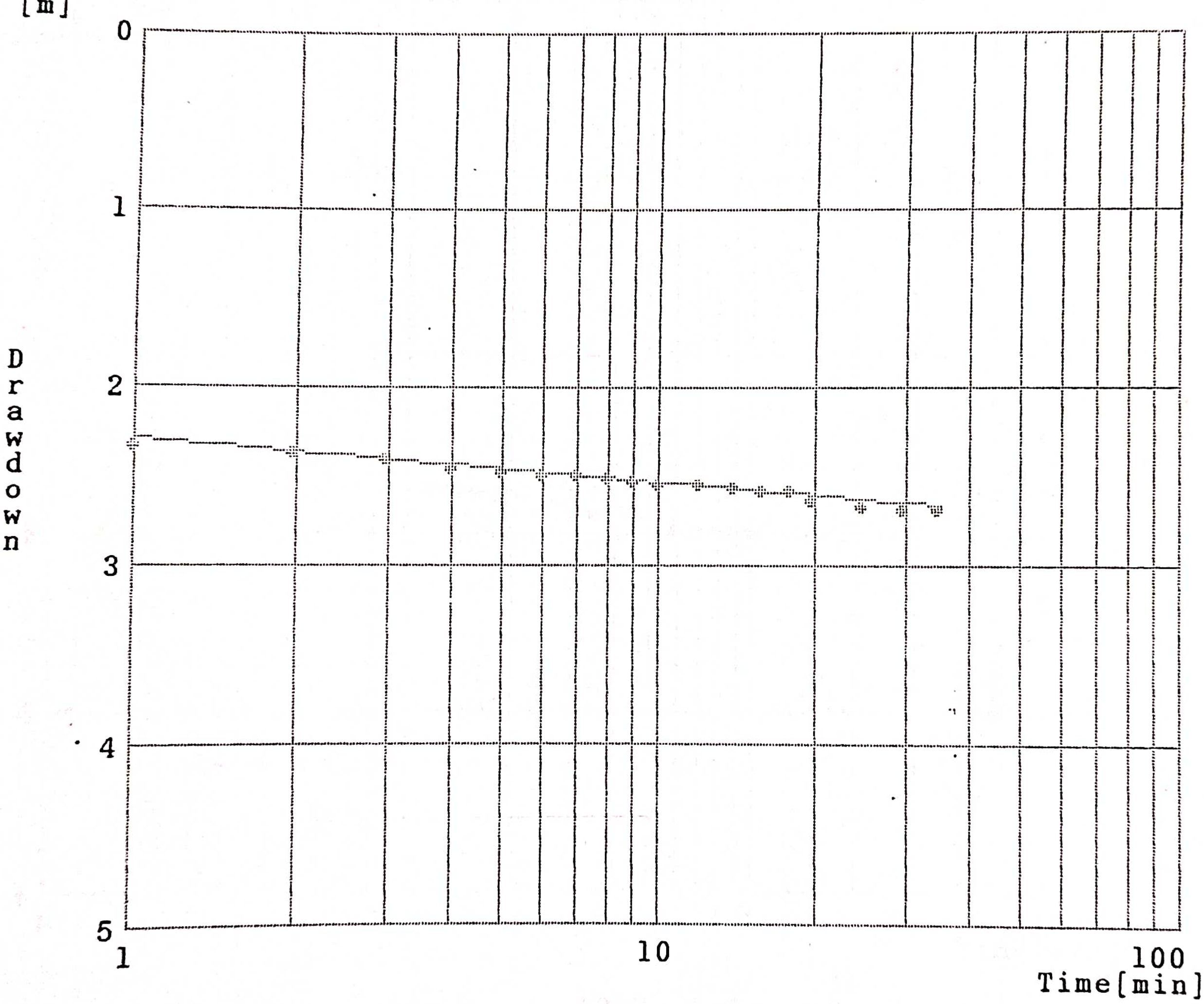
APPENDIX 5/3/A

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWDB

Test : STW 7 KUNIYA

Constant Pumping Rate = 14.000 [l/sec]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -2.79 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 916. [m2/day]
Storage Coefficient = 0.00000021
Standard Deviation = 0.0169 [m]
A0 = 0.228415E+01
A1 = 0.241702E+00
Number of Points = 18 of 18

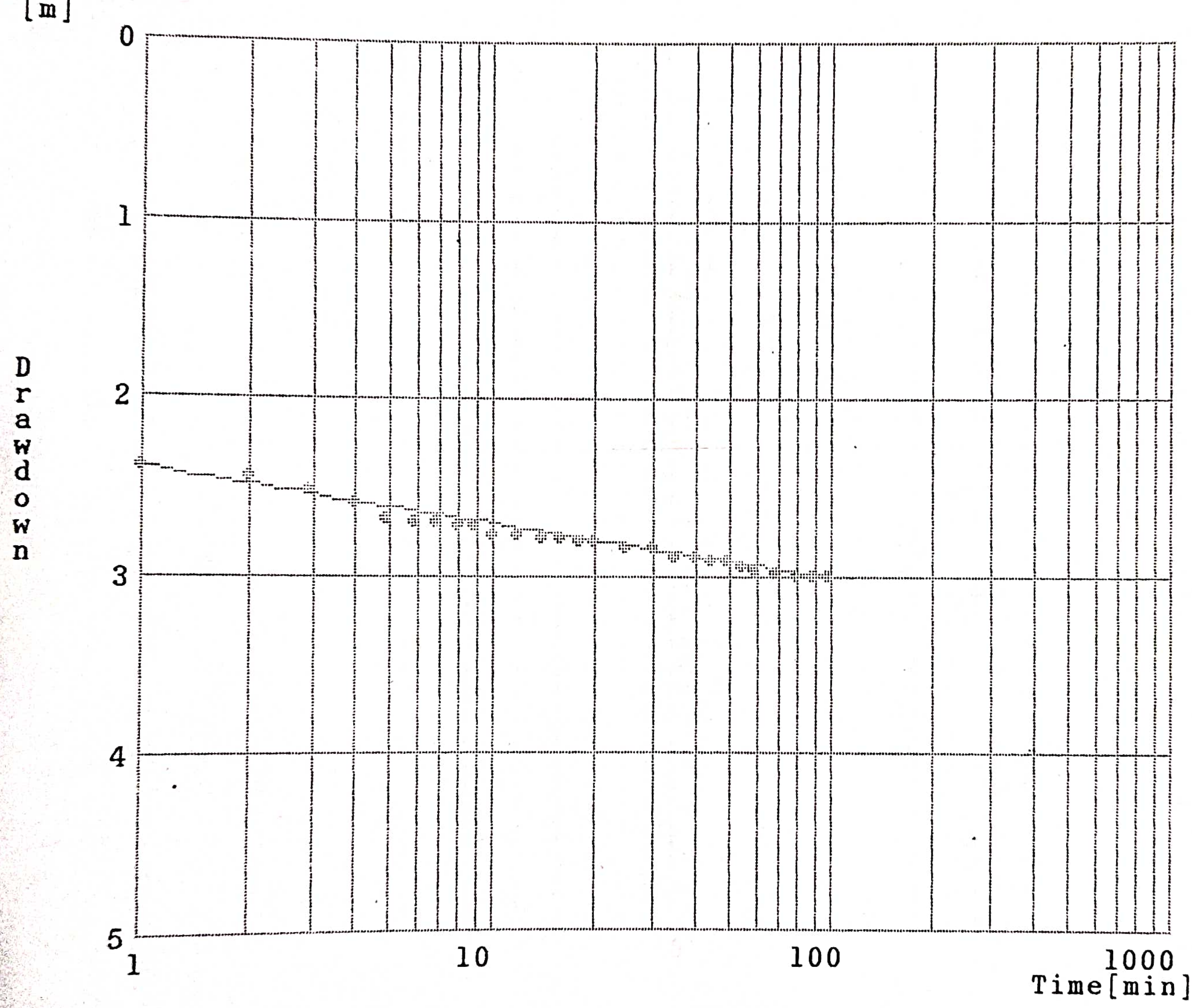
APPENDIX 5/3/B

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWDB

Test : STW 9 KHARAHANI

Constant Pumping Rate = 20.000 [l/sec]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = DRAWDOWN
Well Type = STANDARD

JACOB METHOD



Transmissivity = 1037. [m2/day]
Storage Coefficient = 0.00000970
Standard Deviation = 0.0245 [m]
A0 = 0.238901E+01
A1 = 0.304974E+00
Number of Points = 27 of 27

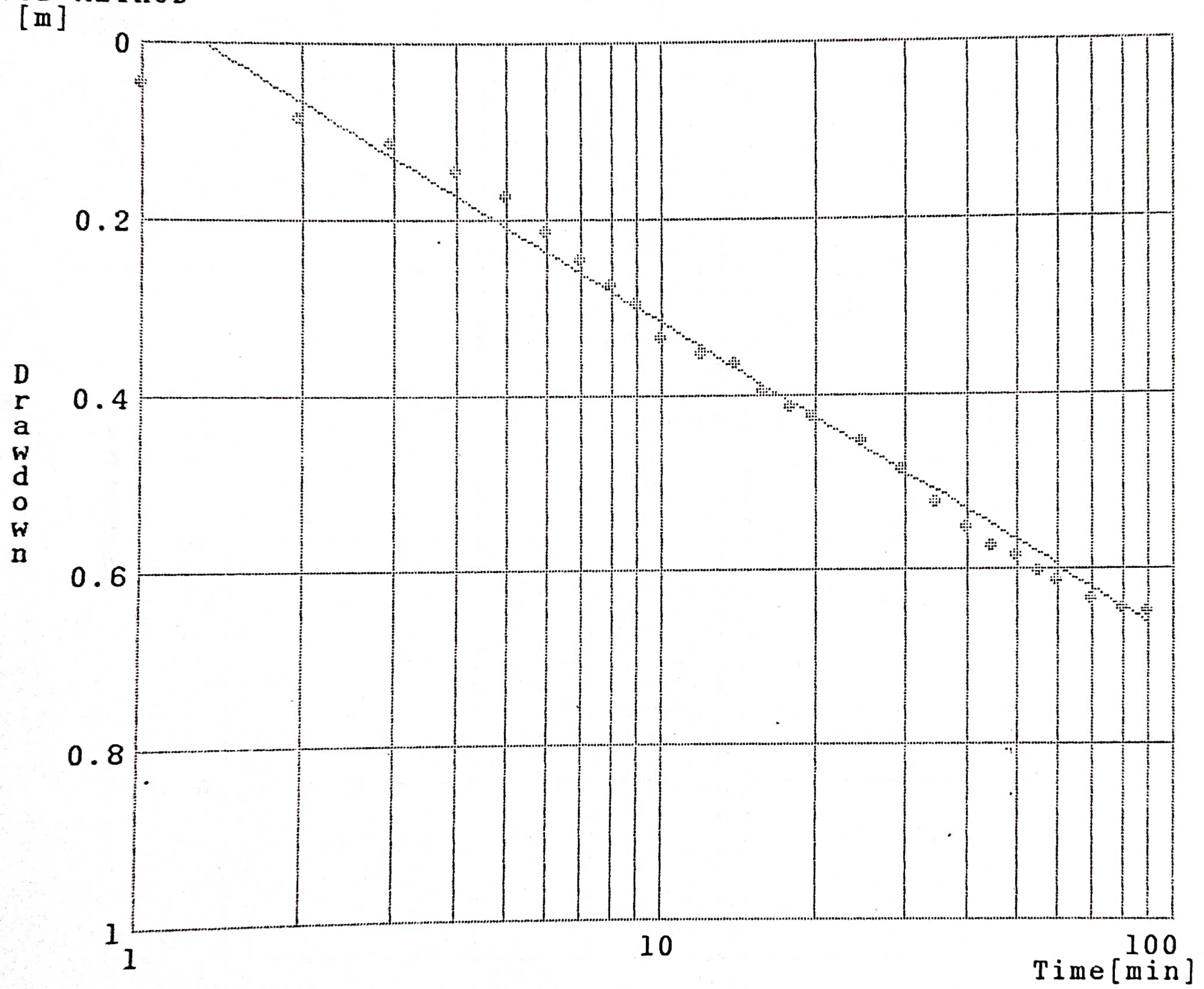
APPENDIX 5/4/A

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWDB

Test : STW 9 KHARAHANI (OBS. WELL)

Constant Pumping Rate = 20.000 [l/sec]
Distance from Observation Well = 70.00 [m]
Type of Aquifer = CONFINED
Type of Input Data = DRAWDOWN
Well Type = STANDARD

JACOB METHOD



Transmissivity = 882. [m2/day]
Storage Coefficient = 0.00036699
Standard Deviation = 0.0228 [m]
A0 = -0.414431E-01
A1 = 0.358465E+00
Number of Points = 26 of 26

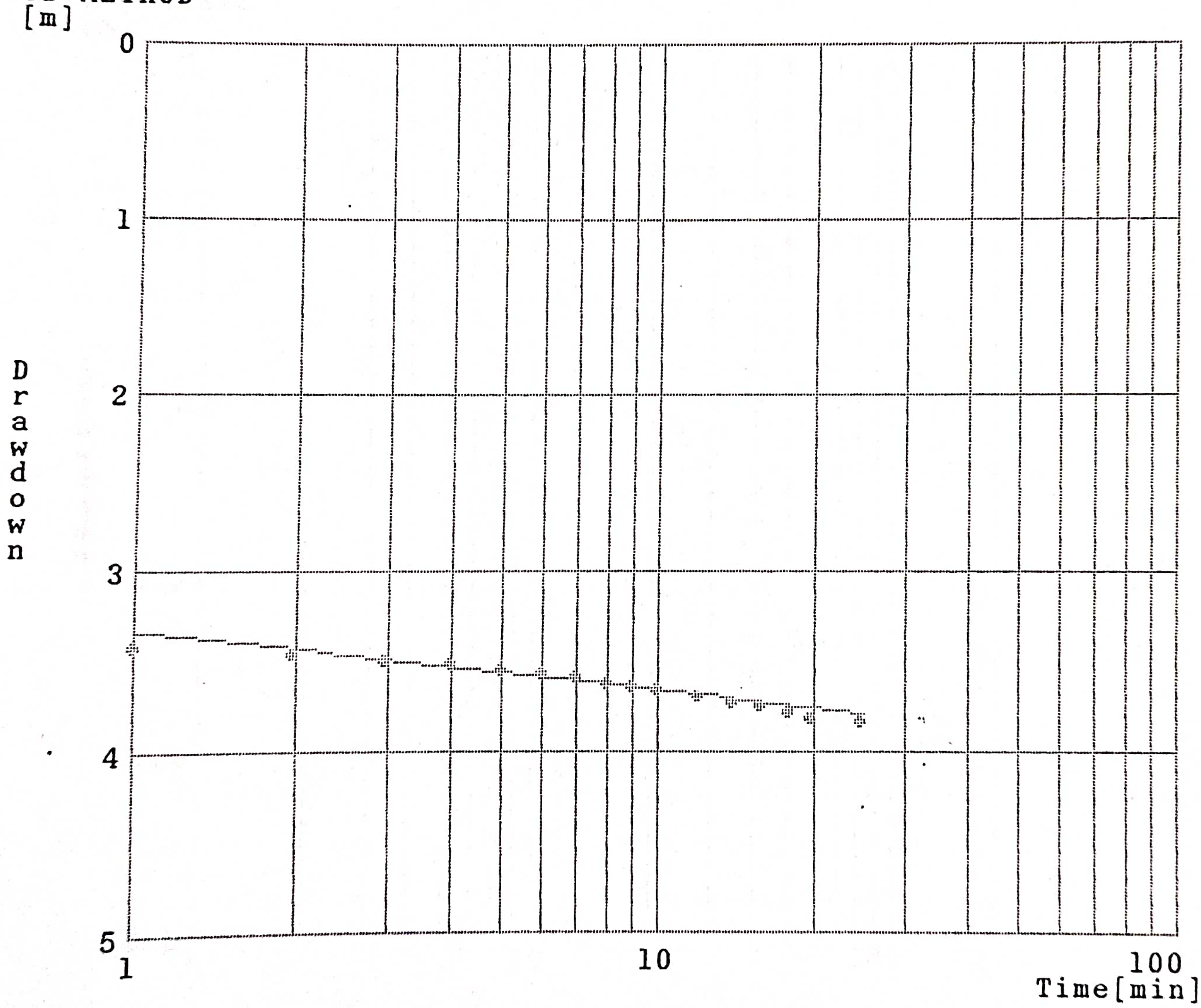
APPENDIX 5/4/B

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 12 LALPATI

Constant Pumping Rate = 3.000 [l/sec]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.73 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 146. [m2/day]
Storage Coefficient = 0.00000001
Standard Deviation = 0.0321 [m]
A0 = 0.332662E+01
A1 = 0.324462E+00
Number of Points = 16 of 16

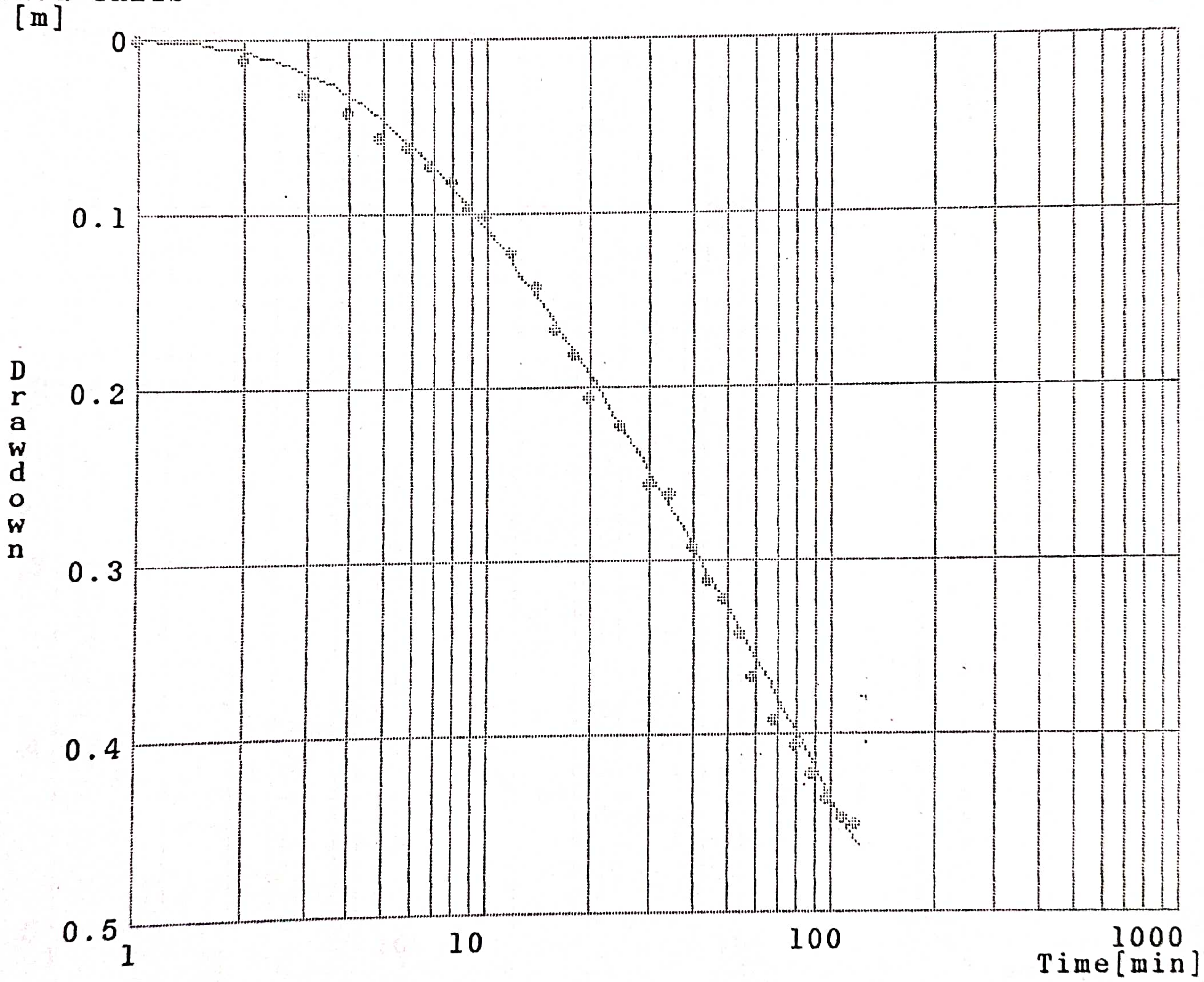
APPENDIX 5/5/A

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 12 LALPATI (OBS. WELL)

Constant Pumping Rate = 3.000 [l/sec]
Distance from Observation Well = 32.30 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -3.28 [m]
Well Type = STANDARD

Method THEIS



Transmissivity = 124. [m2/day]
Storage Coefficient = 0.00142907
Standard Deviation = 0.0070 [m]

Number of Points = 29 of 29

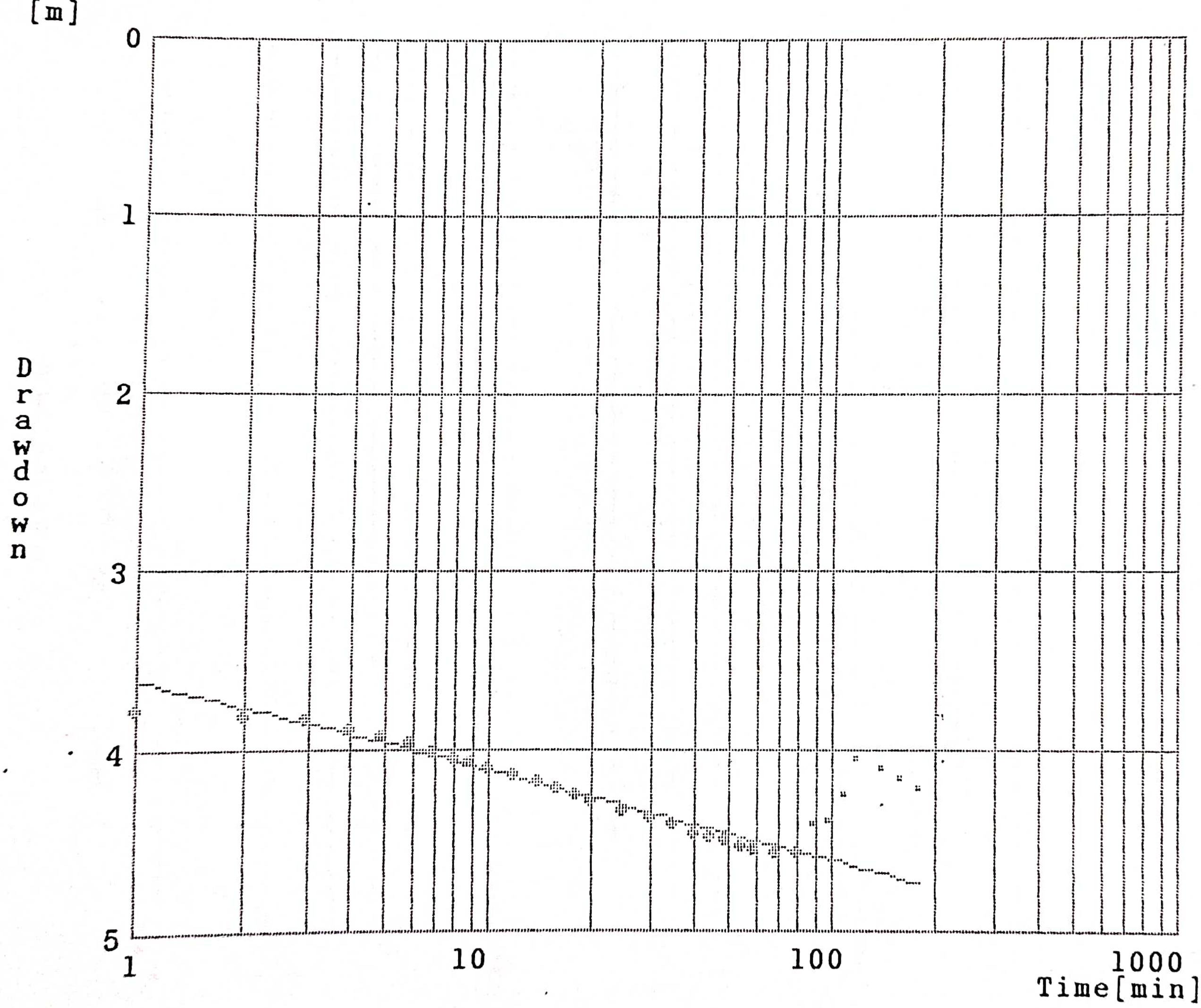
APPENDIX 5/5/B

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 14 SURAJAPURA

Constant Pumping Rate = 20.000 [l/sec]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -2.92 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 635. [m2/day]
Storage Coefficient = 0.00002290
Standard Deviation = 0.0417 [m]
A0 = 0.360714E+01
A1 = 0.497729E+00
Number of Points = 25 of 32

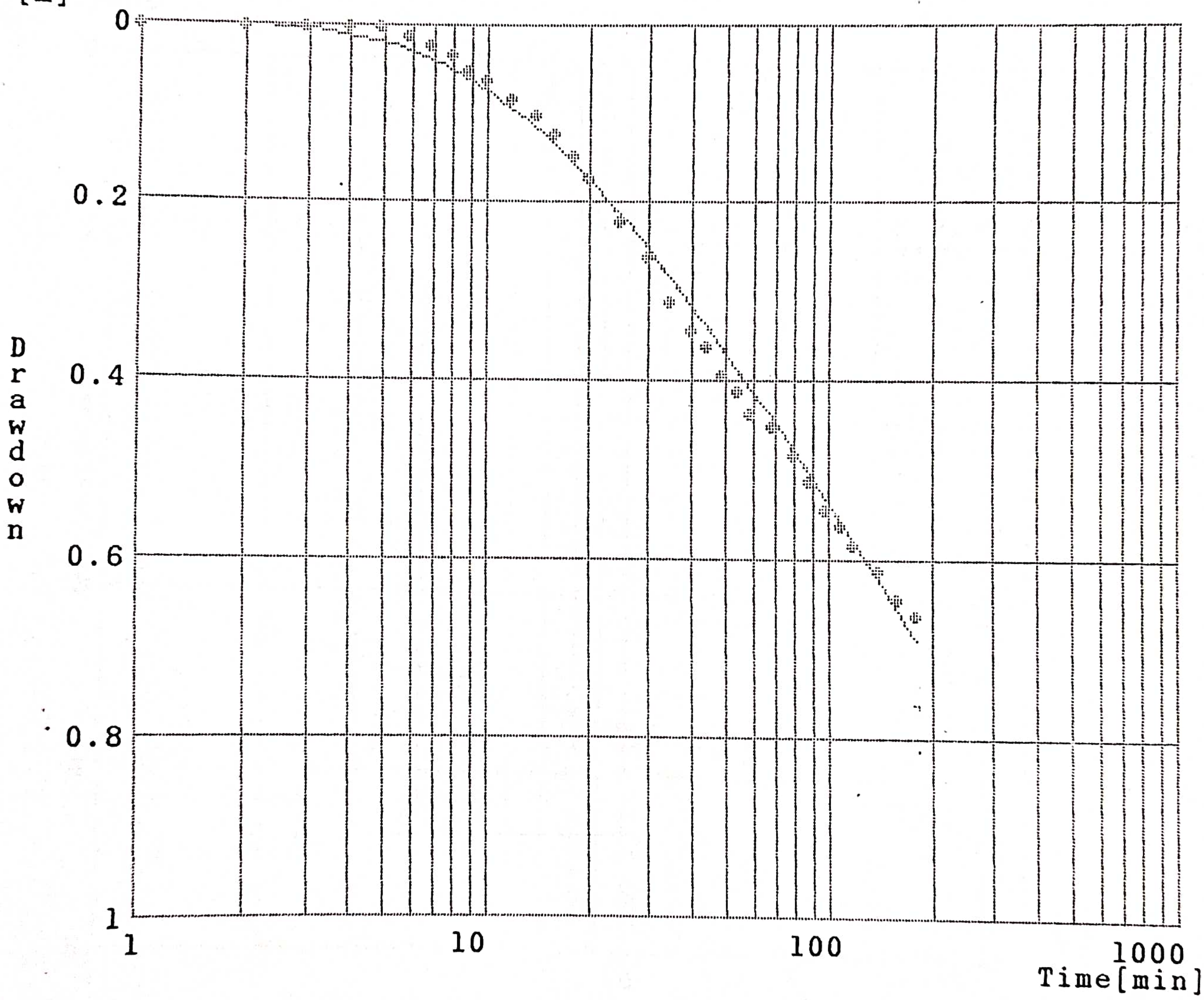
APPENDIX 5/6/A

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 14 SURAJAPURA (OBS.WELL)

Constant Pumping Rate = 20.000 [l/sec]
Distance from Observation Well = 79.90 [m]
Type of Aquifer = CONFINED
Type of Input Data = LEVEL
Static Water Level = -2.09 [m]
Well Type = STANDARD

Method THEIS



Transmissivity = 494. [m2/day]
Storage Coefficient = 0.00191973
Standard Deviation = 0.0153 [m]

Number of Points = 32 of 32

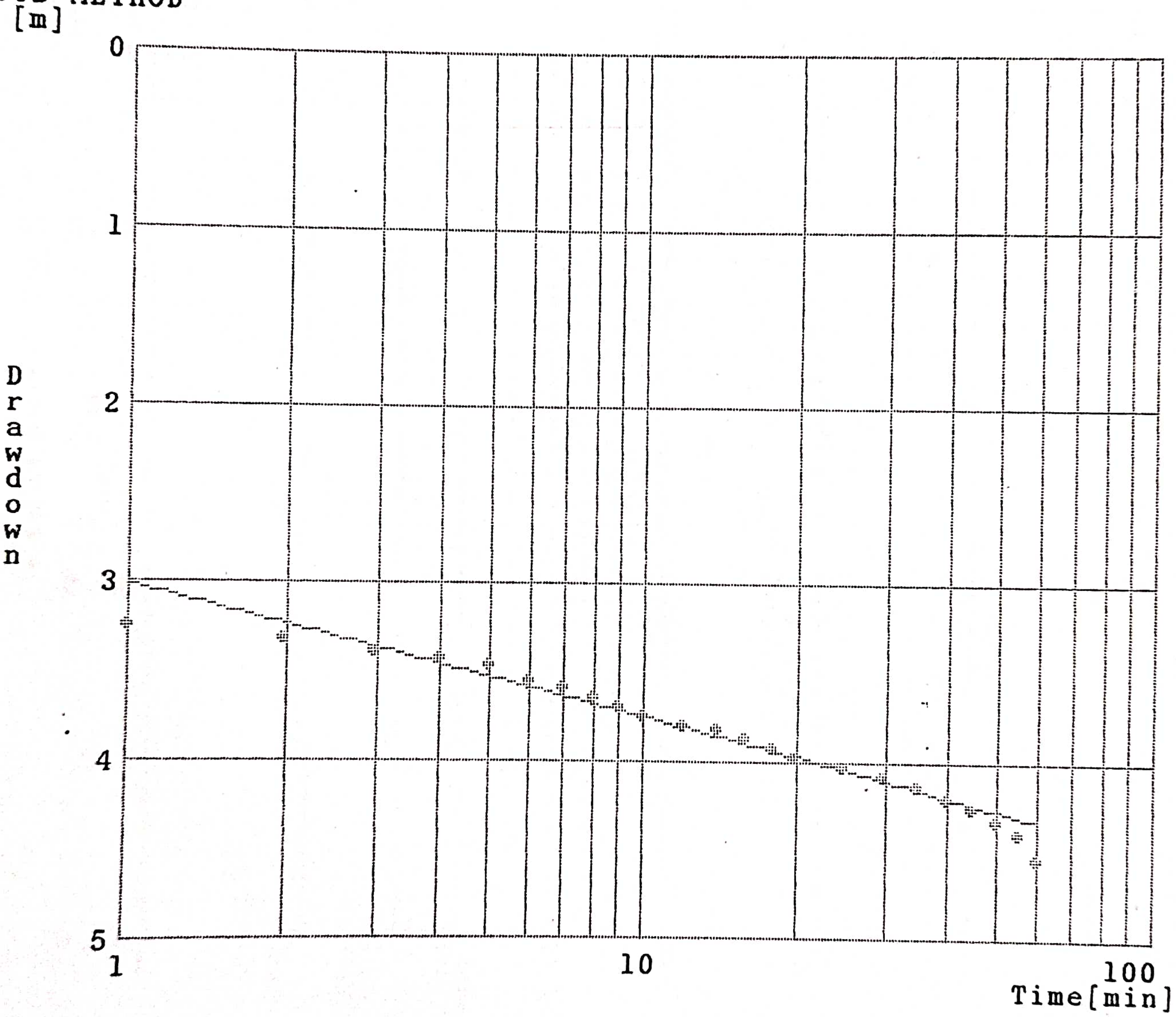
APPENDIX 5/6/B

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 15 GUTHI PARSAURI

Constant Pumping Rate = 12.000 [l/sec]
Distance from Observation Well = 0.05 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 18.00 [m]
Type of Input Data = LEVEL
Static Water Level = -3.68 [m]
Well Type = STANDARD

JACOB METHOD



Transmissivity = 255. [m2/day]
Storage Coefficient = 0.01480801
Standard Deviation = 0.0767 [m]
A0 = 0.300122E+01
A1 = 0.743465E+00
Number of Points = 23 of 23

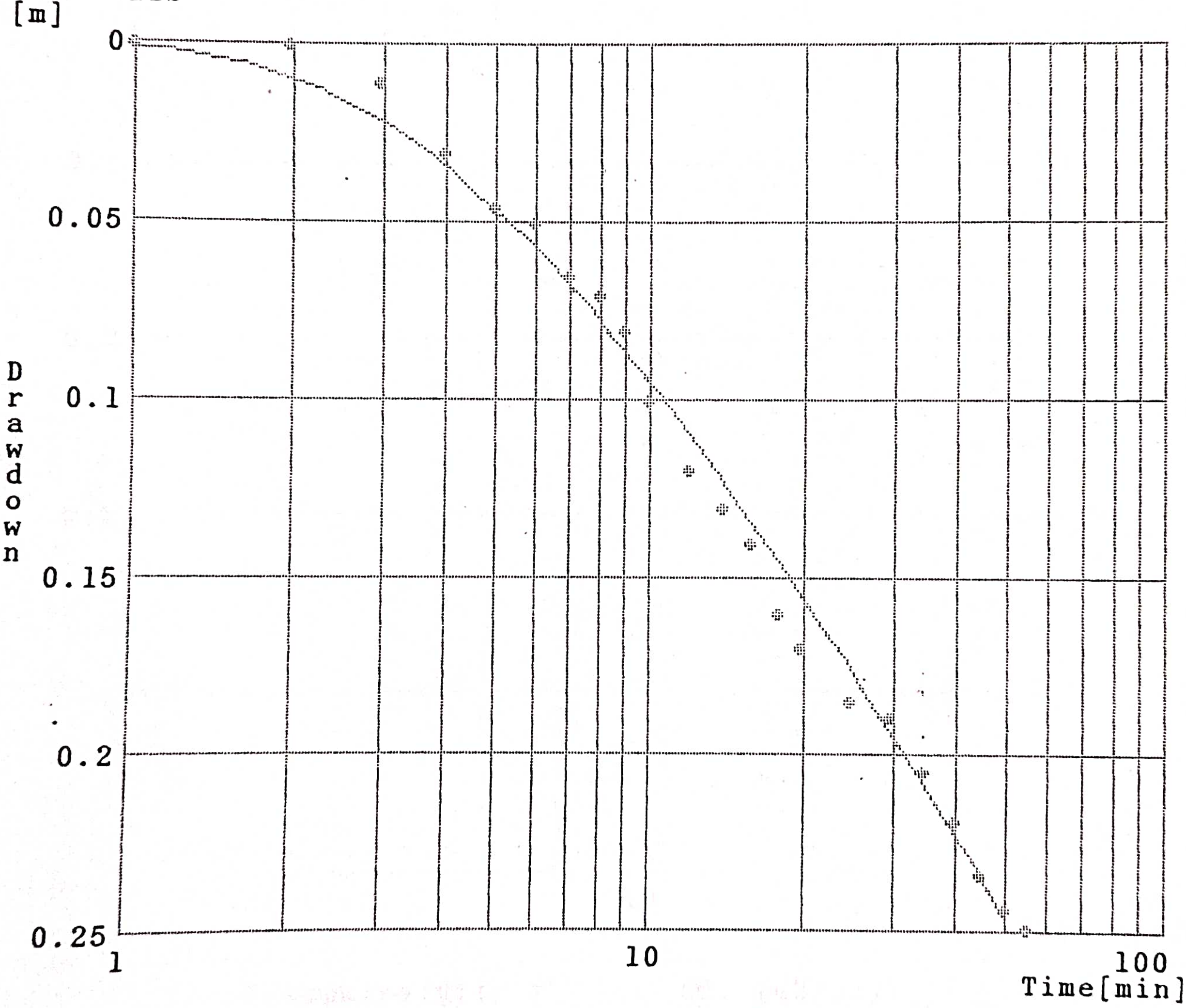
APPENDIX 5/7/A

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWRDB

Test : STW 15 GUTHI PARSURI (OBS.WELL)

Constant Pumping Rate = 12.000 [l/sec]
Distance from Observation Well = 76.60 [m]
Type of Aquifer = UNCONFINED
Initial Saturated Thickness = 18.00 [m]
Type of Input Data = LEVEL
Static Water Level = -2.93 [m]
Well Type = STANDARD

Method THEIS



Transmissivity = 753. [m2/day]
Storage Coefficient = 0.00113019
Standard Deviation = 0.0074 [m]

Number of Points = 22 of 22

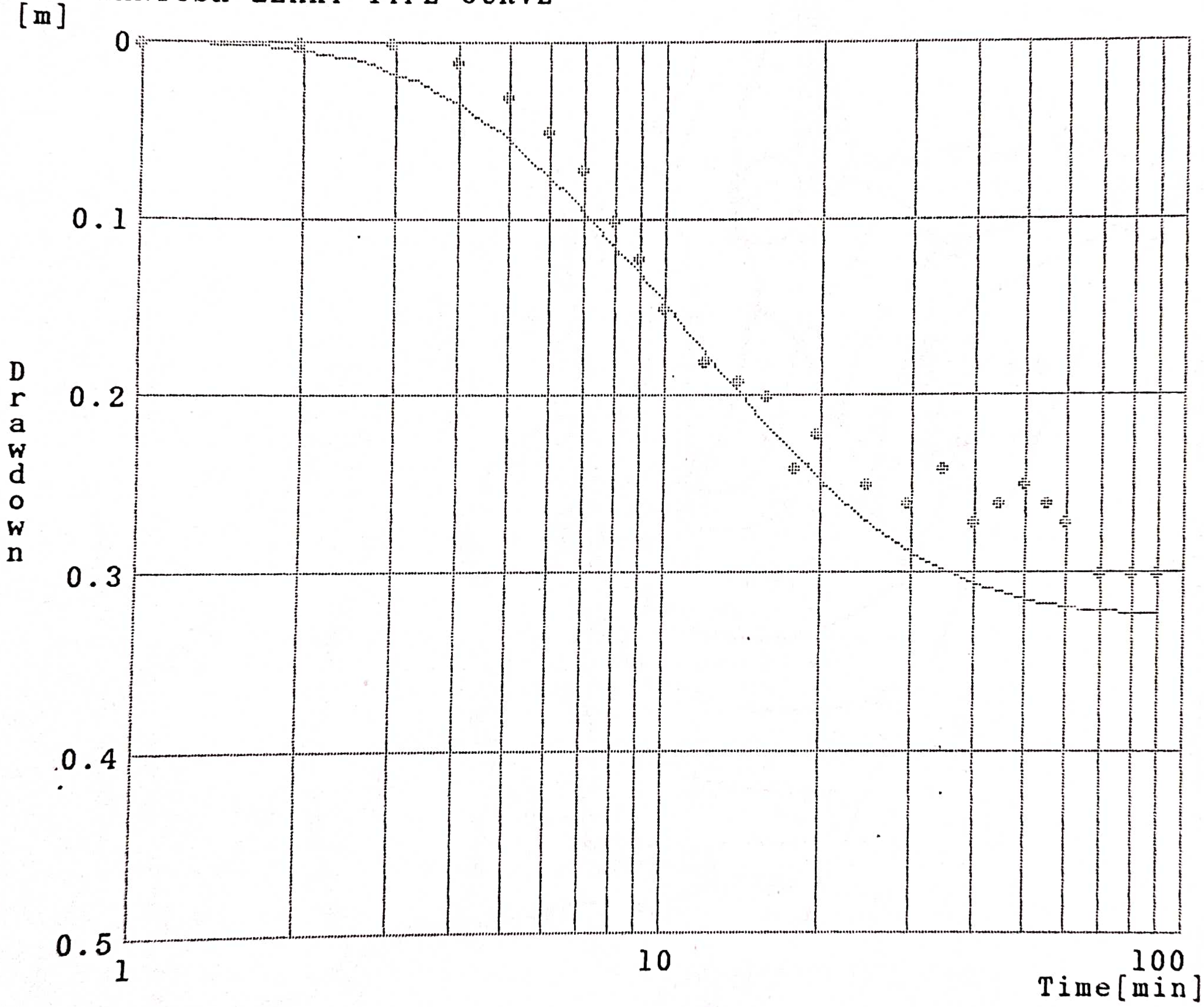
APPENDIX 5/7/B

Project : NEP/86/025 (NAWALPARASI WEST)
Organization : UNDP/GWDB

Test : STW 16 BISHUNPURAWA (OBS.WELL)

Constant Pumping Rate = 4.000 [l/sec]
Distance from Observation Well = 42.00 [m]
Type of Aquifer = CONFINED
Type of Input Data = DRAWDOWN
Well Type = STANDARD

Method HANTUSH LEAKY TYPE CURVE



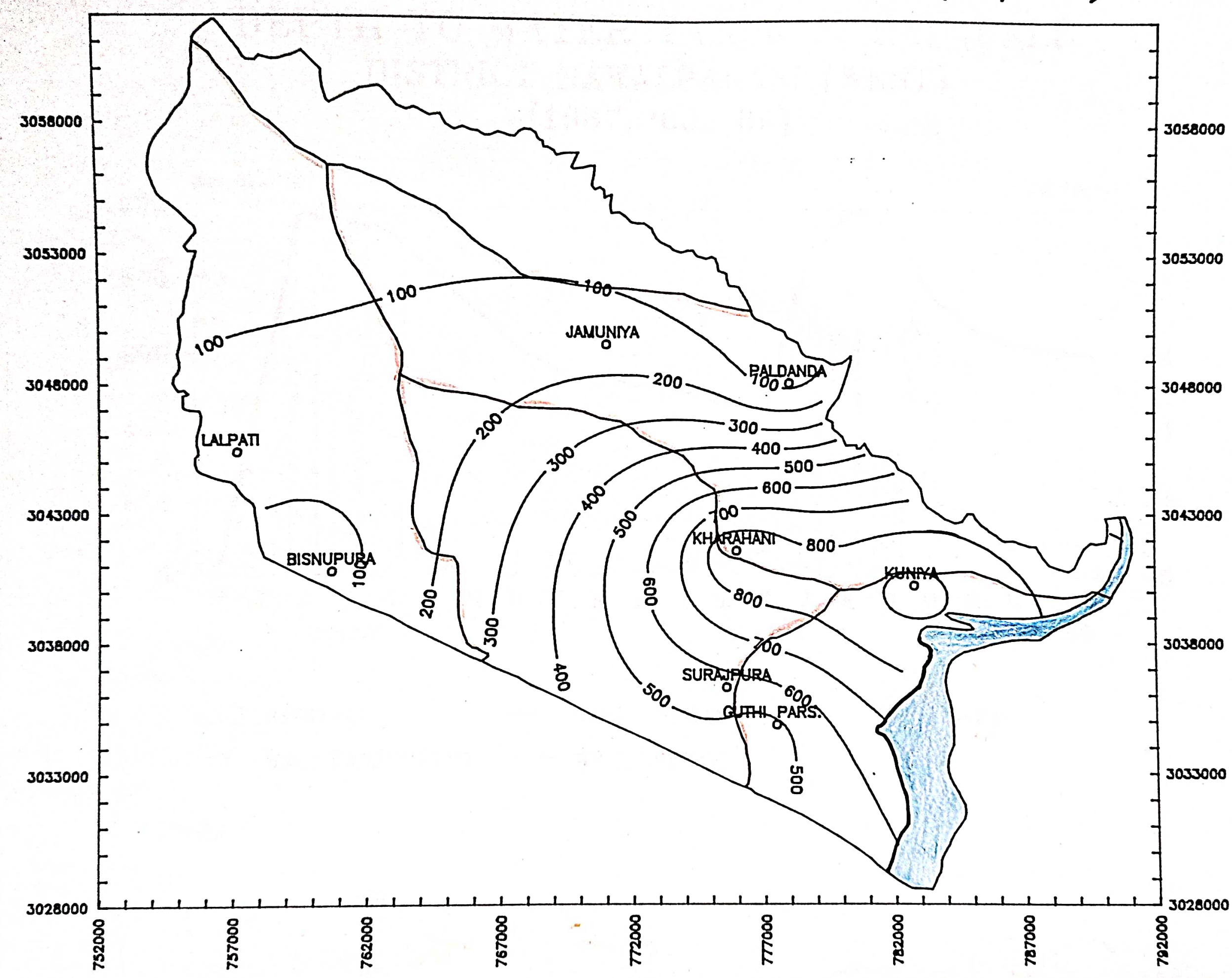
Transmissivity = 55. [m2/day]
Storage Coefficient = 0.00056457
Standard Deviation = 0.0171 [m]

Number of Points = 26 of 26

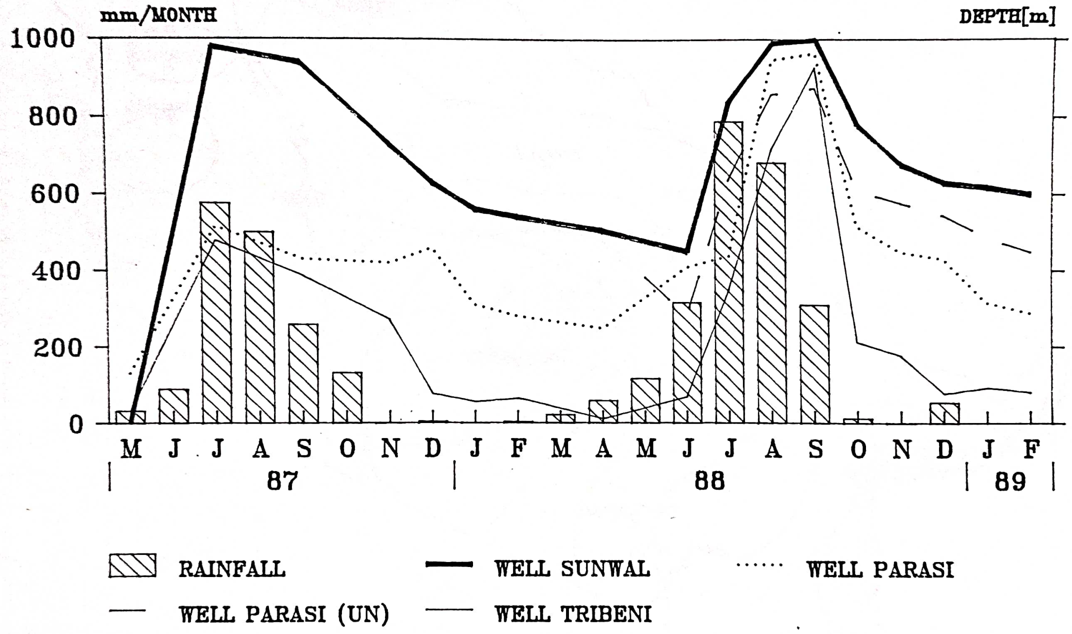
APPENDIX 5/8

APPENDIX 6

NAWALPARASI (WEST) TRANSMISSIVITIES (M2/DAY)



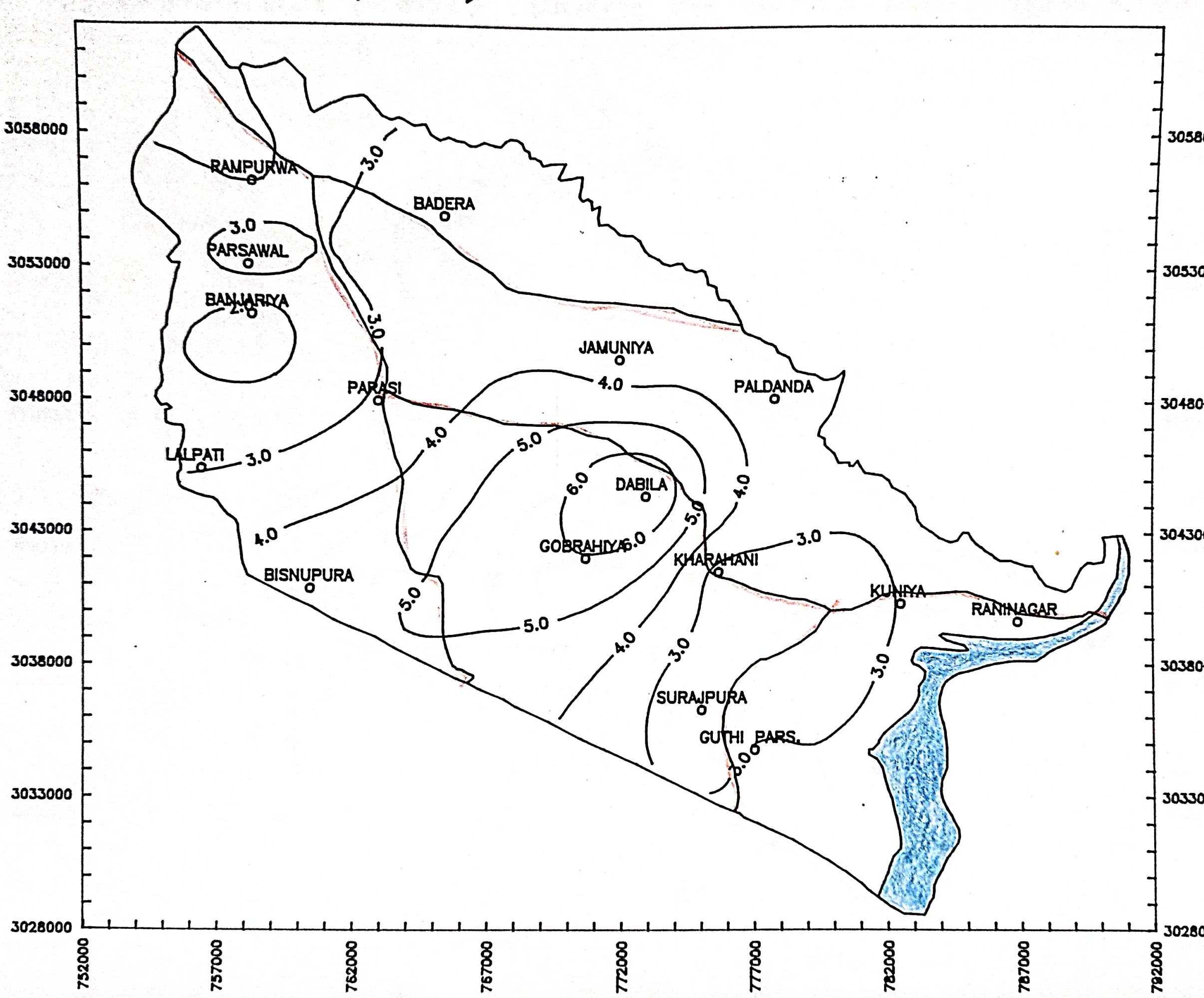
DEPTH TO WATER TABLE & RAINFALL
DISTRICT NAWALPARASI (WEST)
(1987, '88, '89)



APPENDIX 7

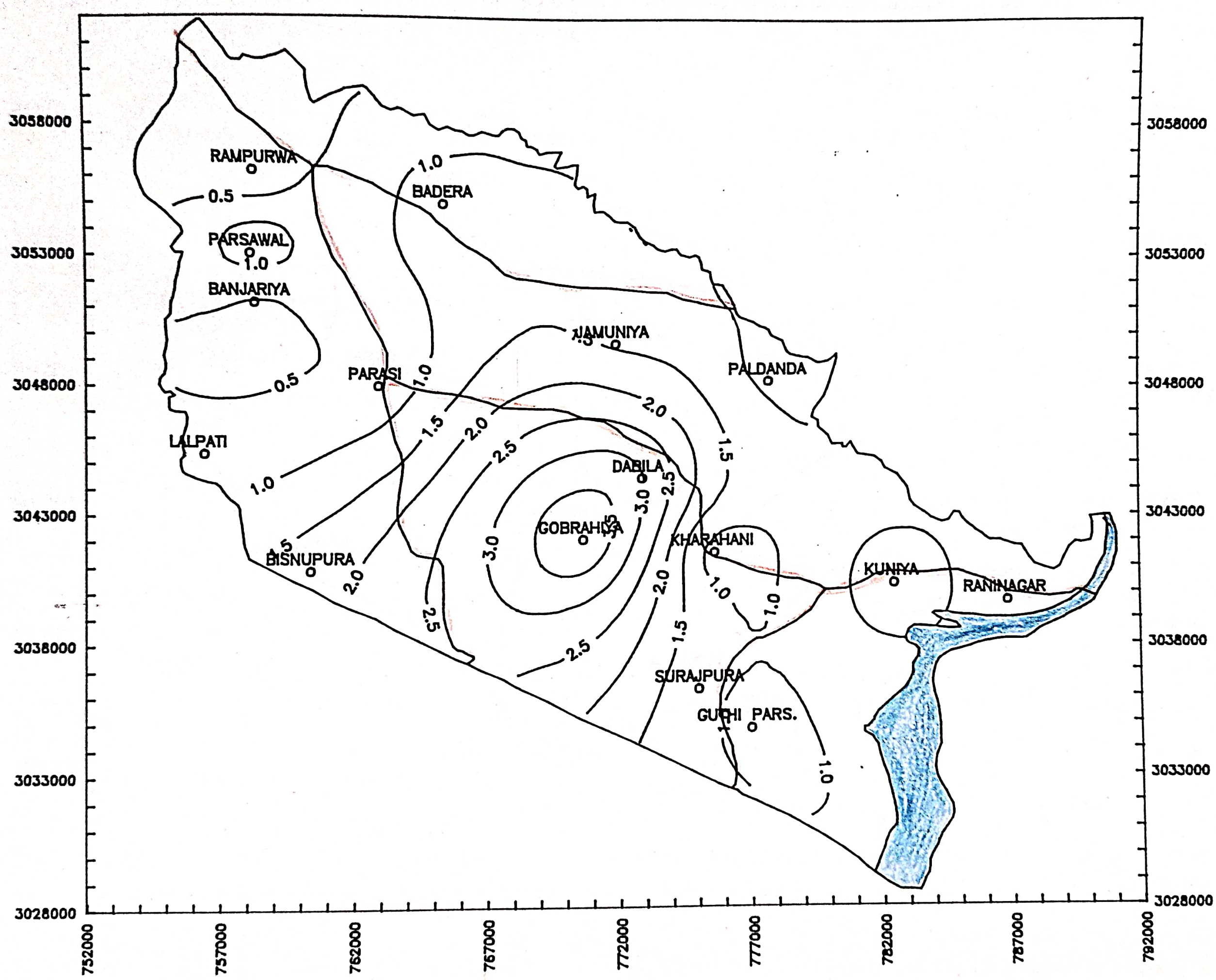
APPENDIX 8/1

NAWALPARASI (WEST) DEPTH TO WATER TABLE MAY 1988

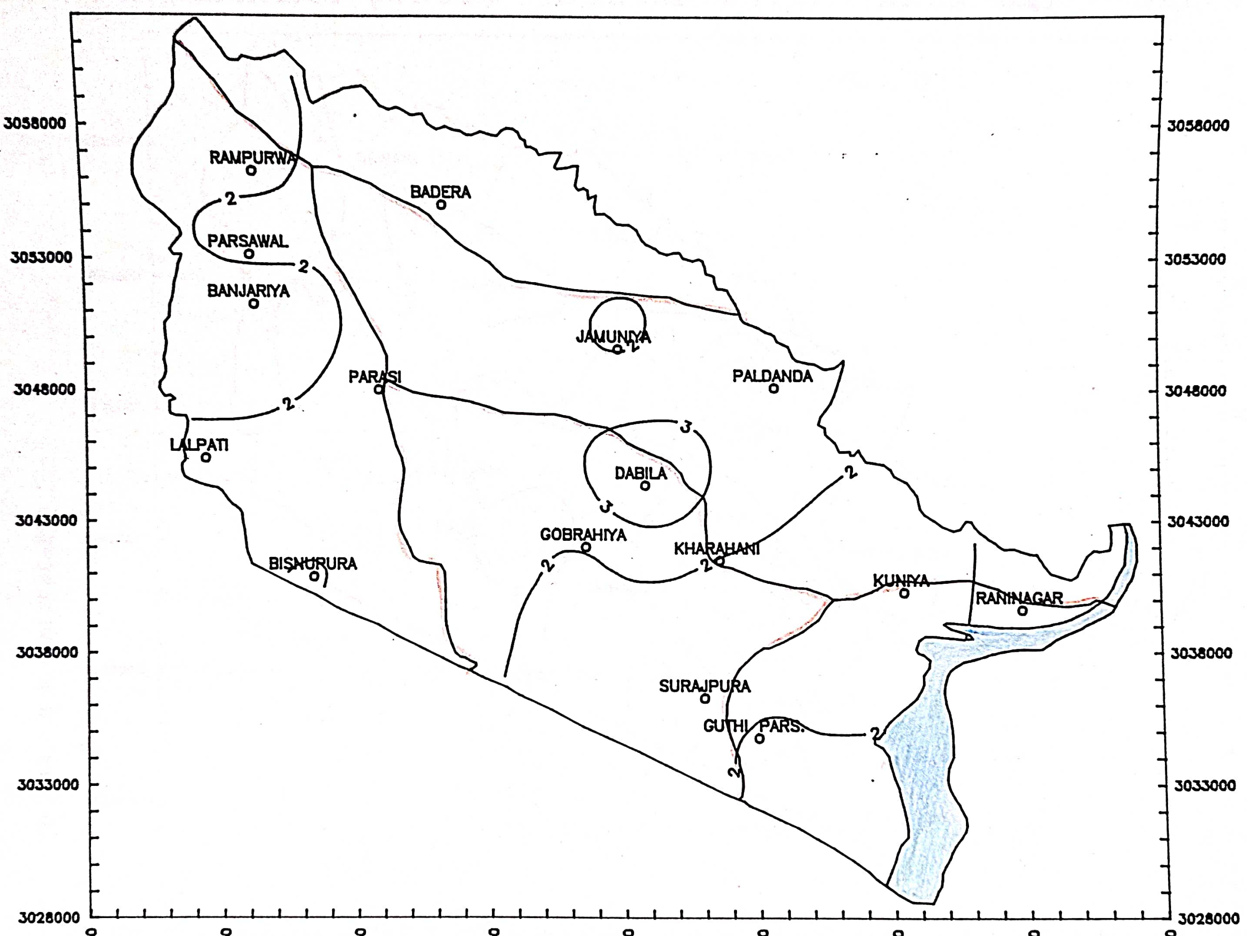


APPENDIX 8/2

NAWALPARASI (WEST) DEPTH TO WATER TABLE SEP 1988

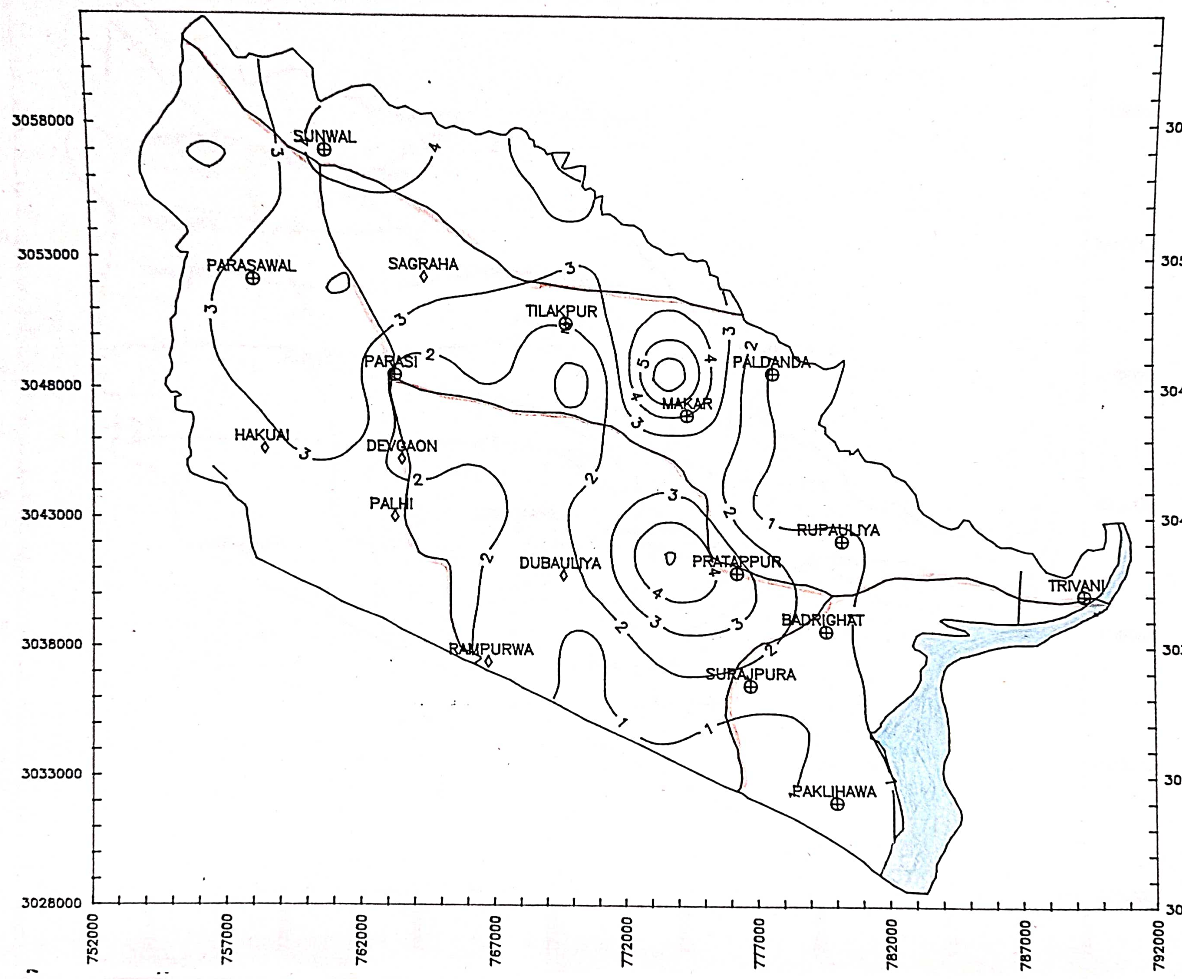


NAWALPARASI (WEST) RISE OF WATER TABLE MAY - SEP 1988



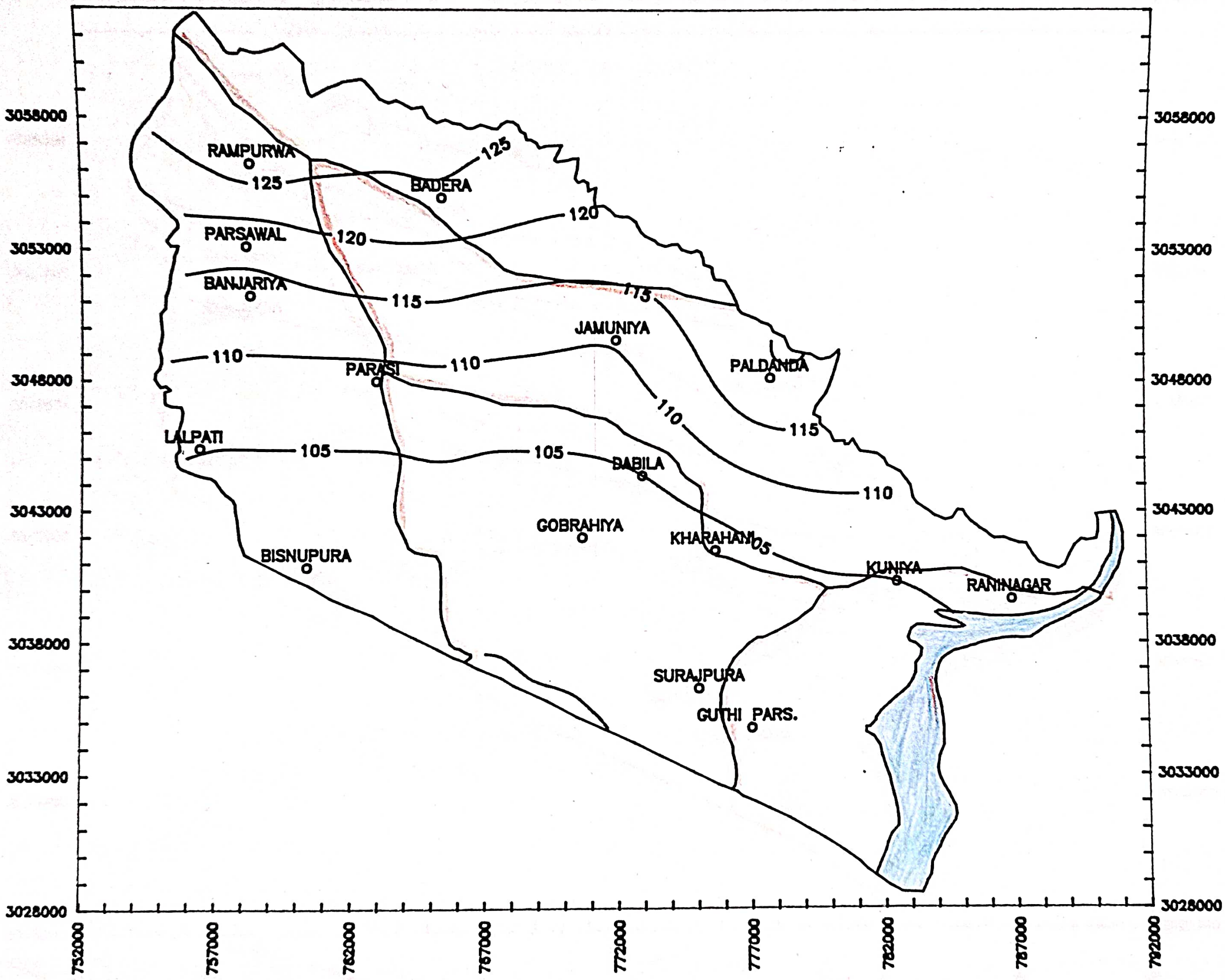
APPENDIX 8/3

NAWALPARASI (WEST) RISE OF WATER TABLE MAY - SEP 1987



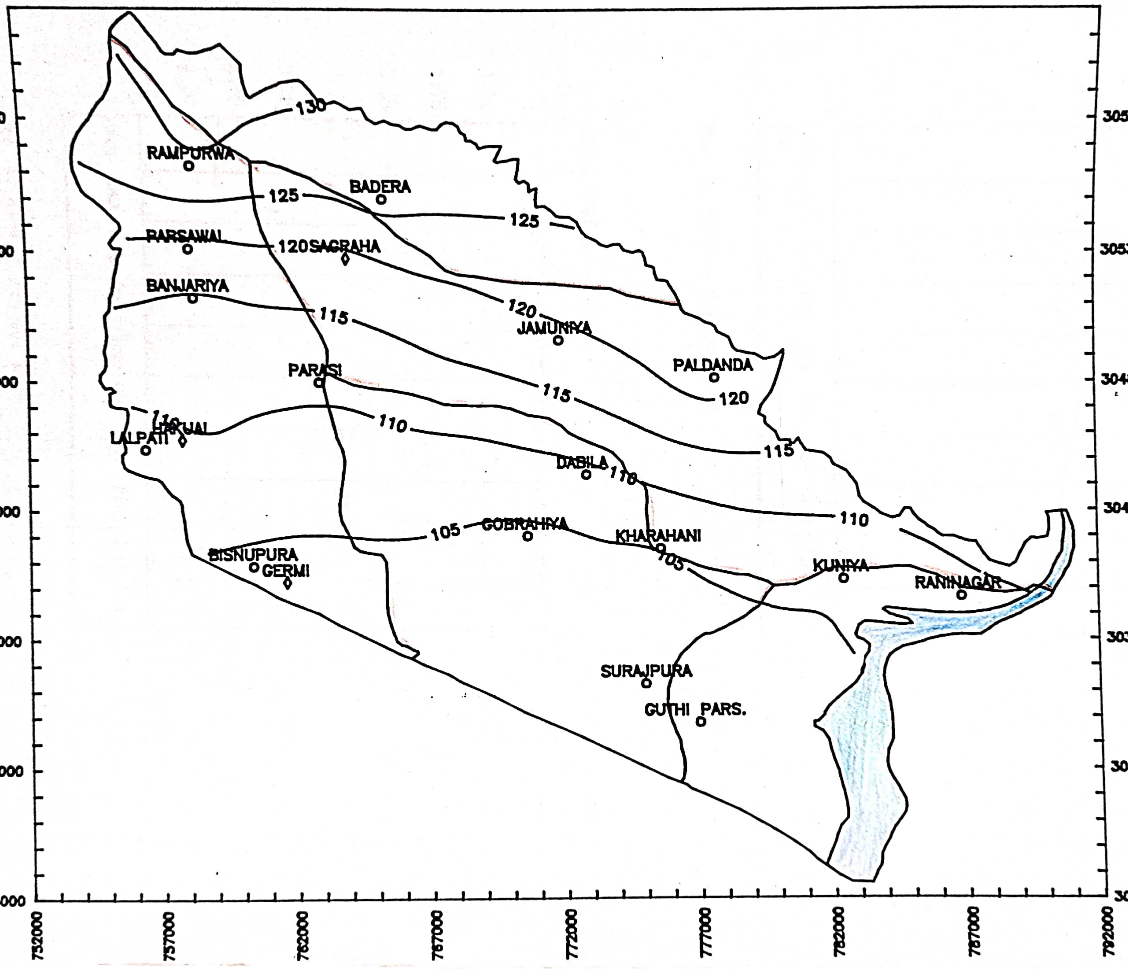
APPENDIX 8/4

NAWALPARASI (WEST) WATER LEVEL CONTOUR MAP MAY 1988



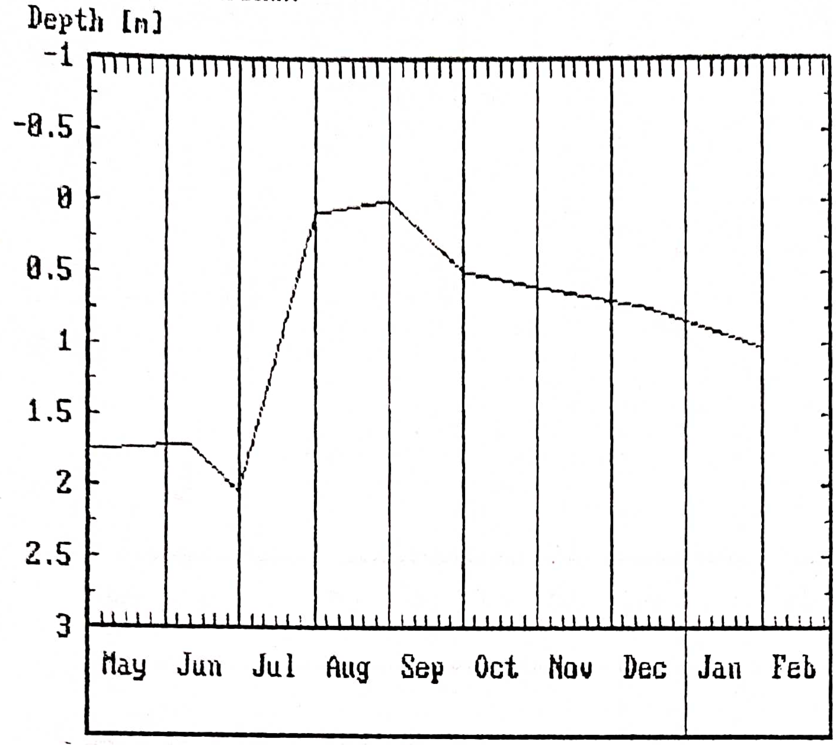
APPENDIX 9/1

NAWALPARASI (WEST) WATER LEVEL CONTOUR MAP SEP 1988



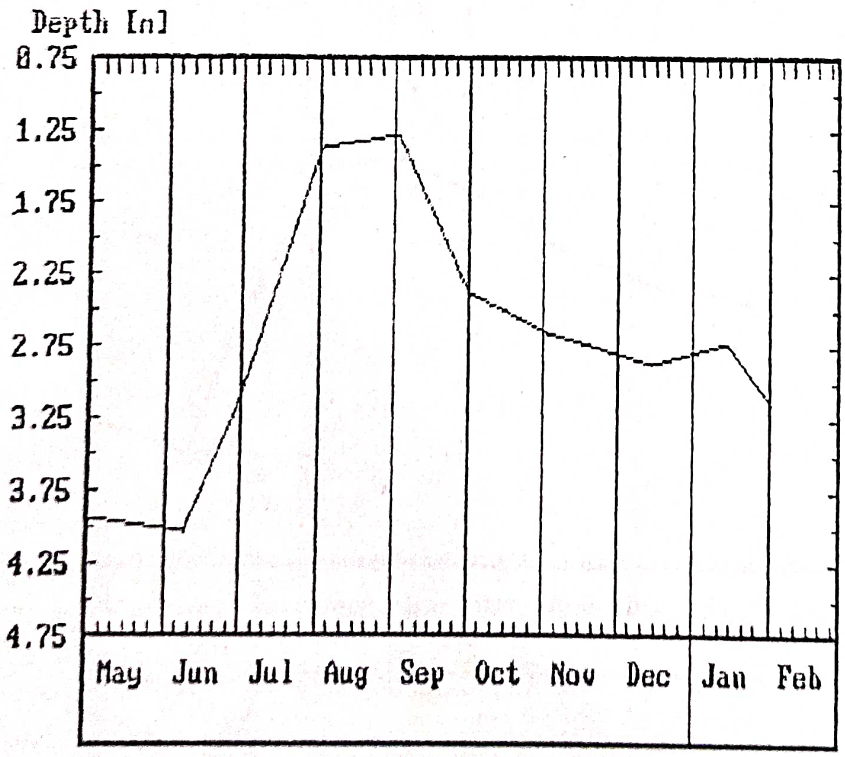
APPENDIX 9/2

STW-1 RAMPURWA

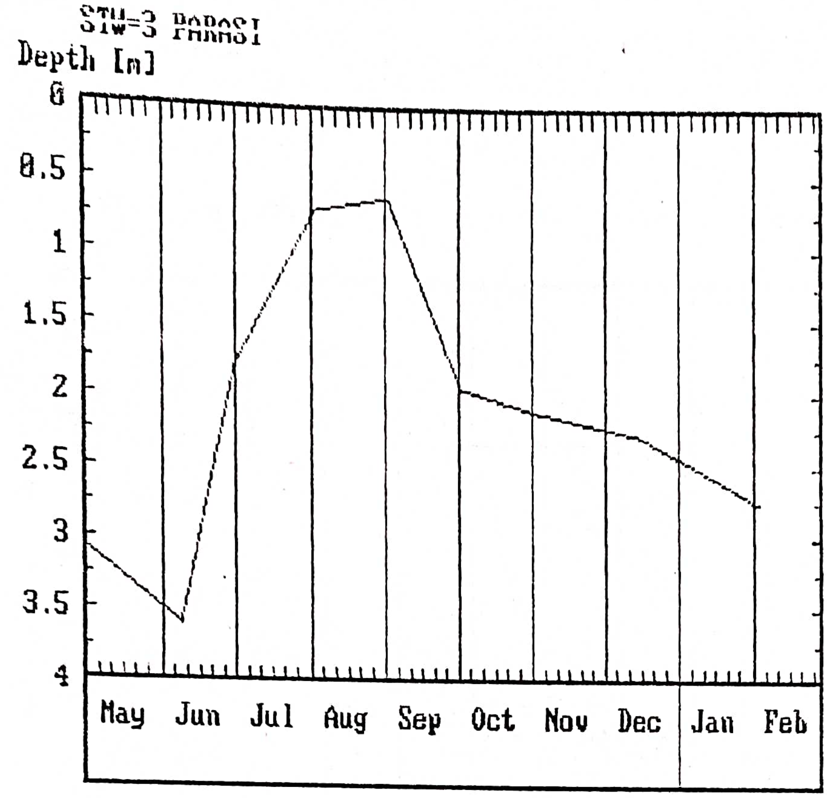


May 1, 1988 -- Feb 28, 1989

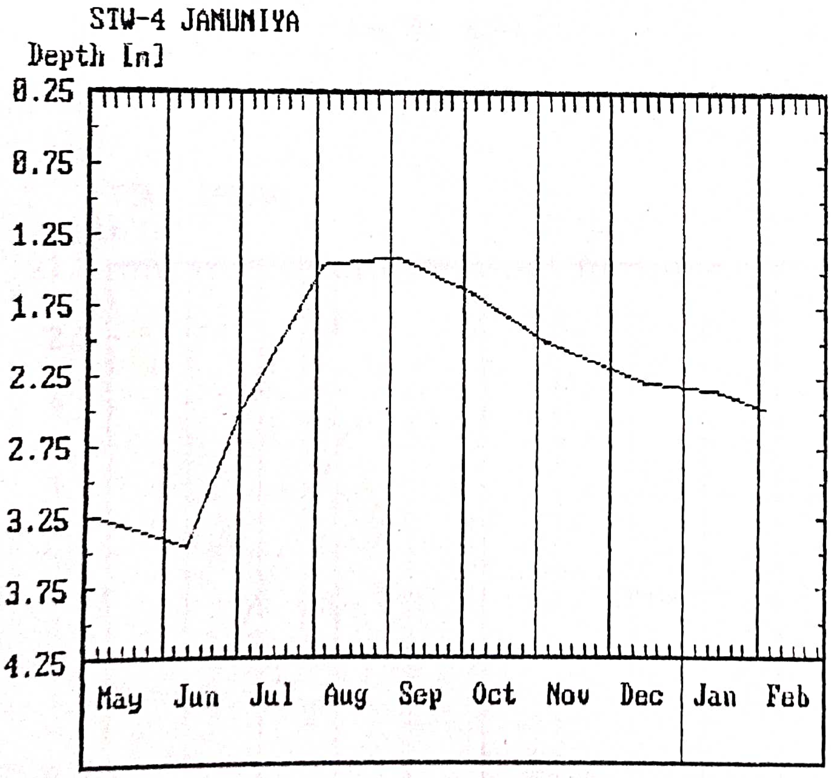
STW-2 BADERA



May 1, 1988 -- Feb 28, 1989

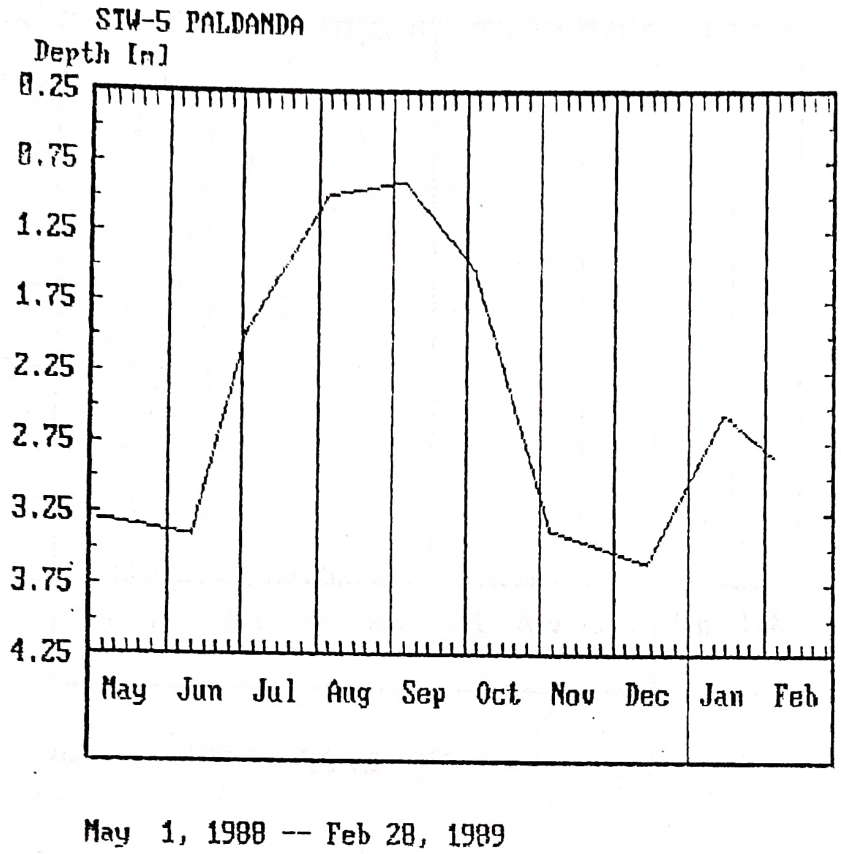


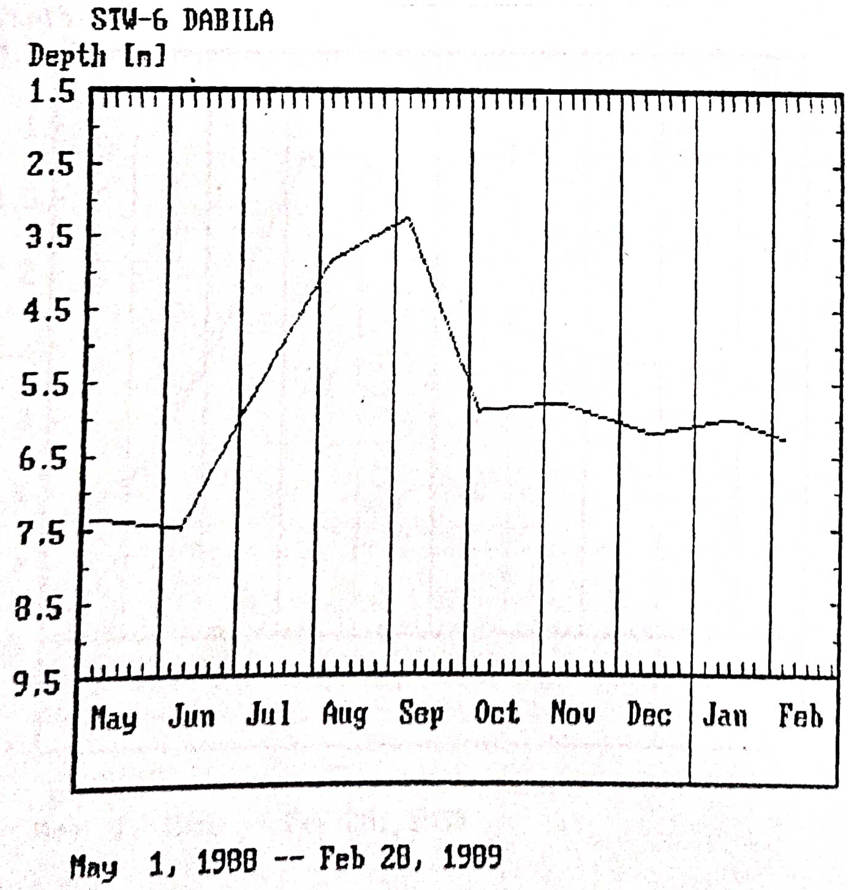
May 1, 1988 -- Feb 28, 1989

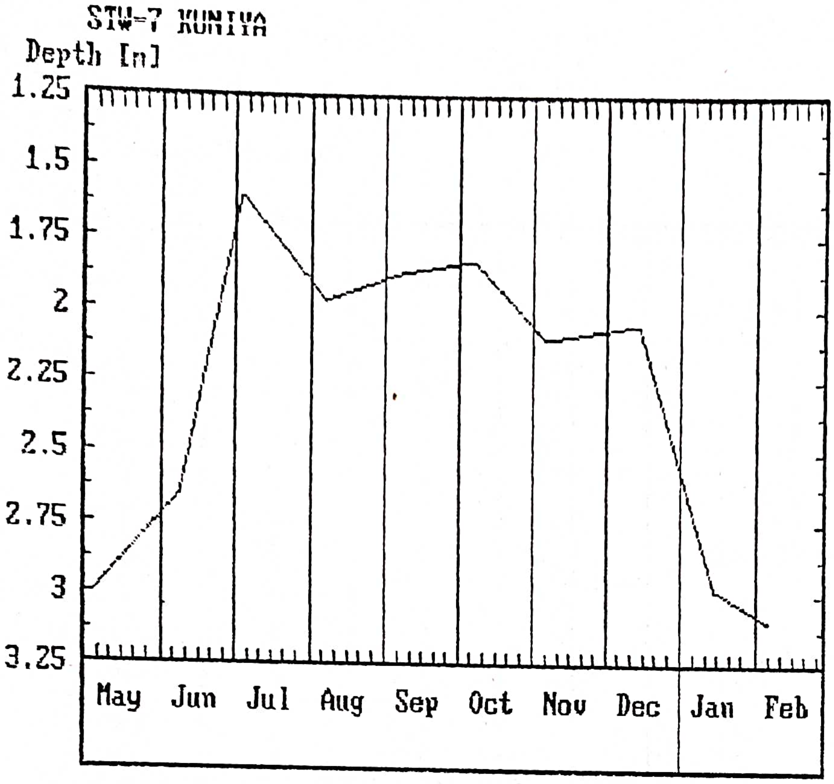


May 1, 1988 -- Feb 28, 1989

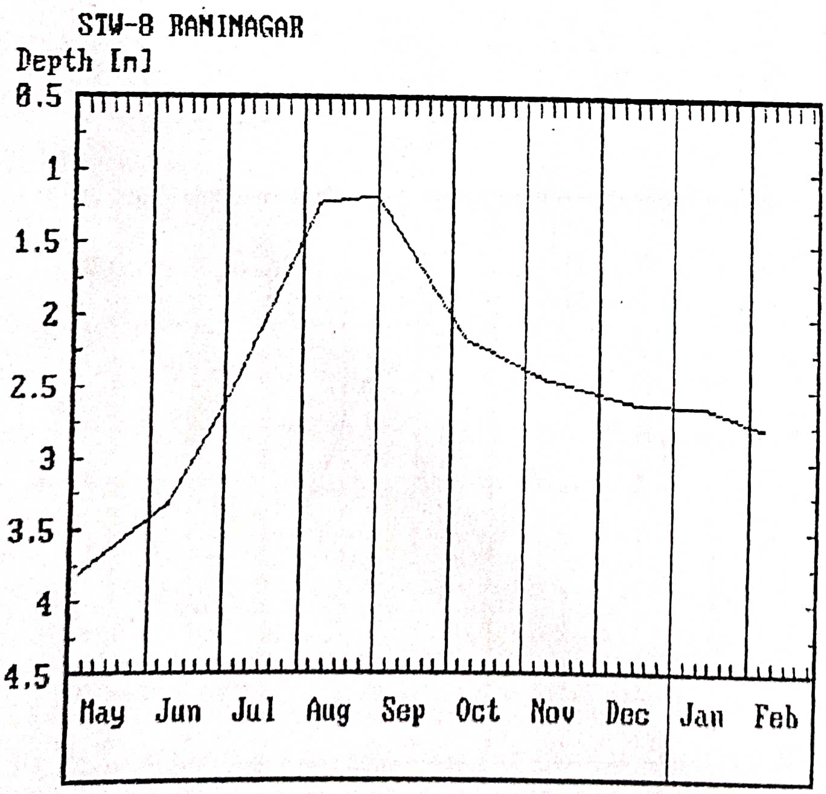
APPENDIX 10/2


STW-5 PALDANDA
Depth [m]
0.25
0.75
1.25
1.75
2.25
2.75
3.25
3.75
4.25
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
May 1, 1988 -- Feb 28, 1989


STW-6 DABILA
Depth [m]
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
May 1, 1988 -- Feb 28, 1989

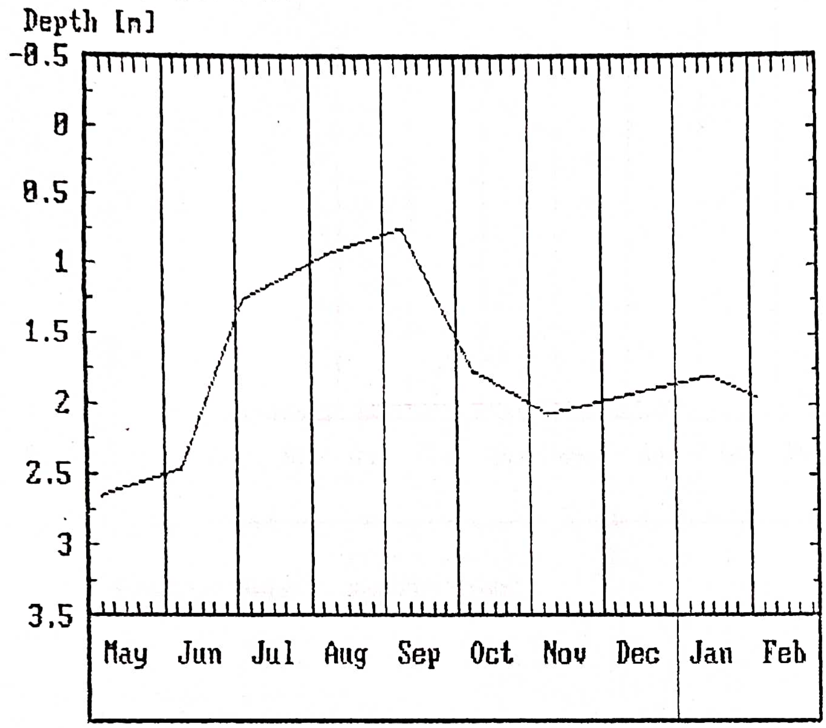


May 1, 1988 -- Feb 28, 1989



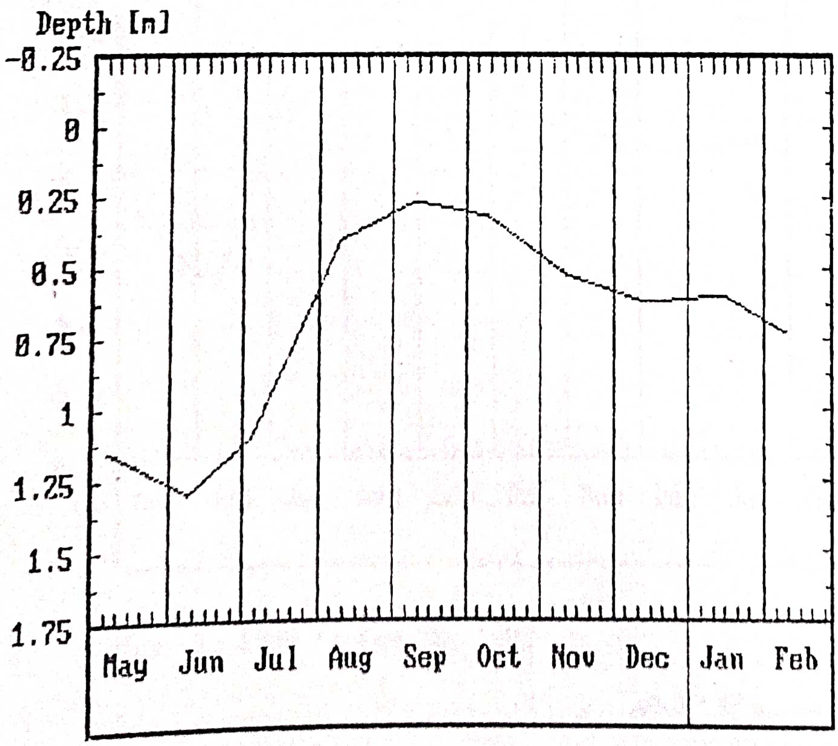
May 1, 1988 -- Feb 28, 1989

STW-9 KHARAHANI

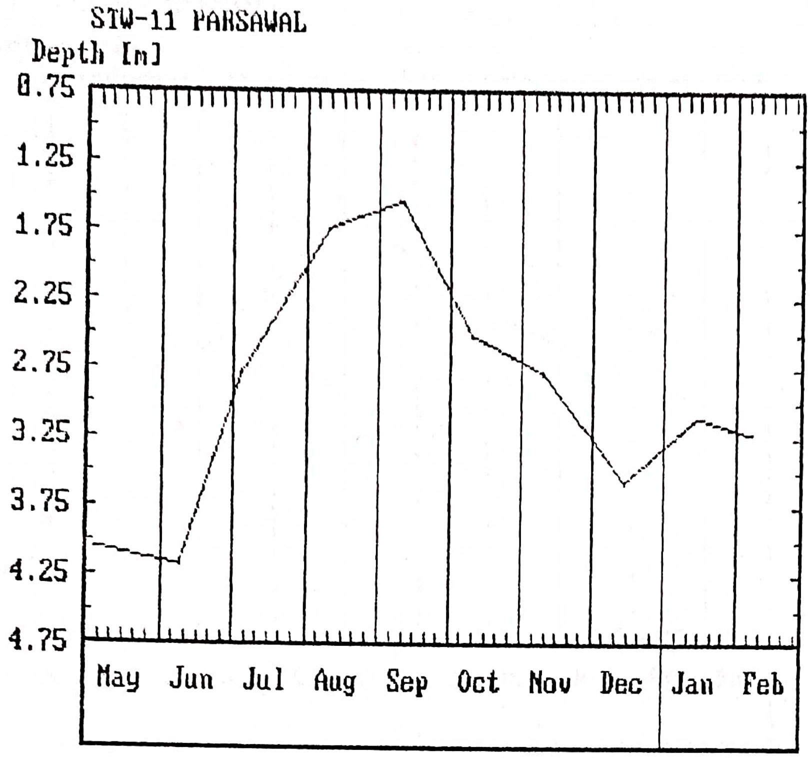


May 1, 1988 -- Feb 28, 1989

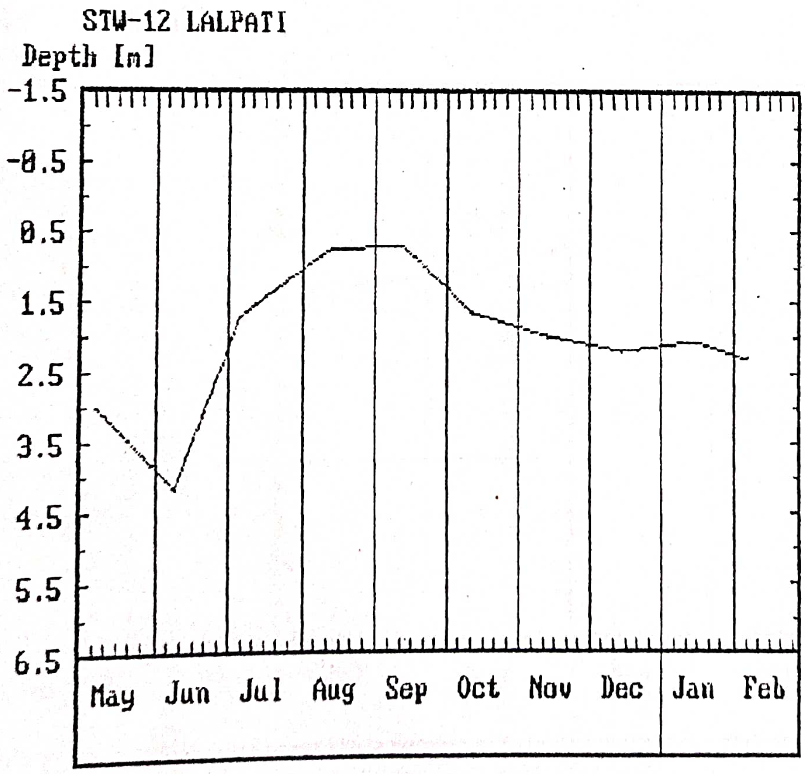
STW-10 BANJARIYA



May 1, 1988 -- Feb 28, 1989

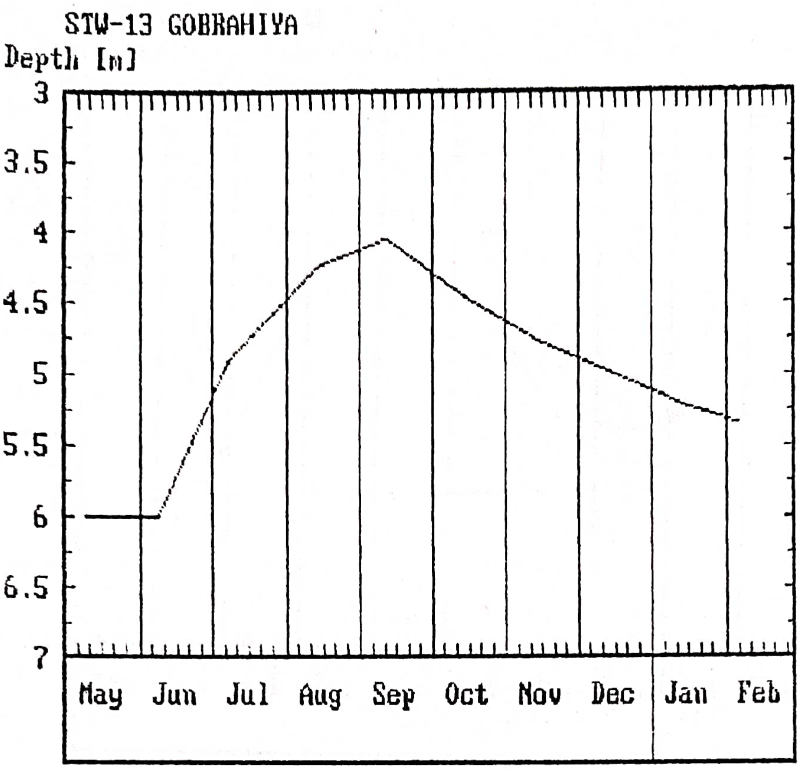


May 1, 1988 -- Feb 28, 1989

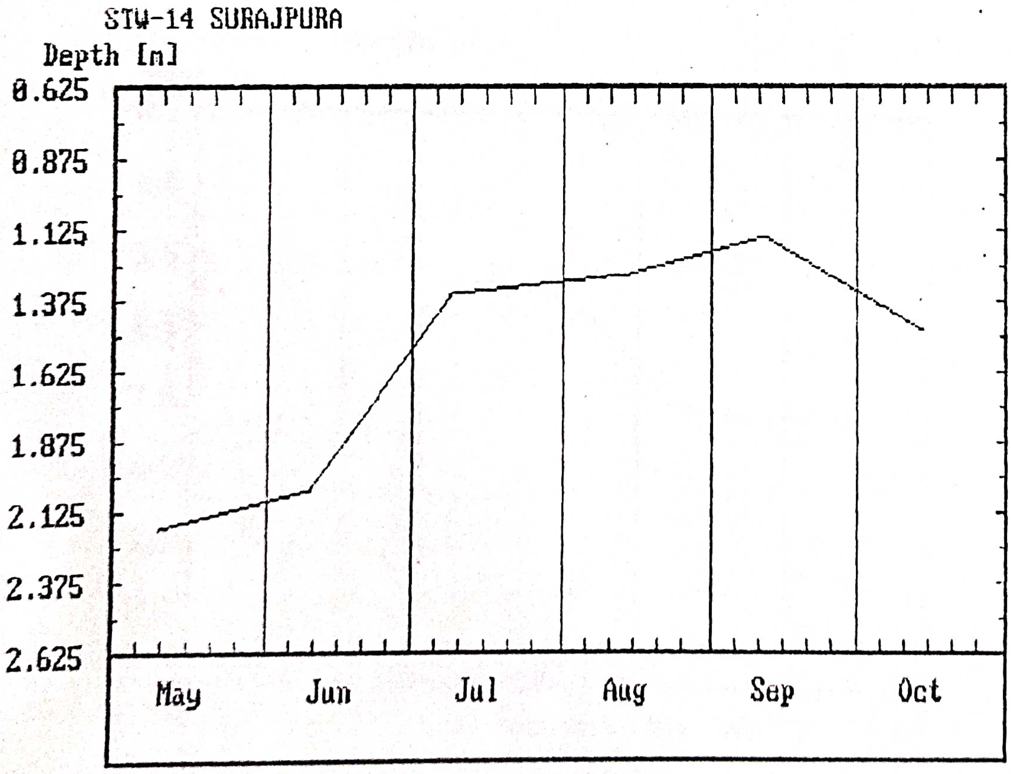


May 1, 1988 -- Feb 28, 1989

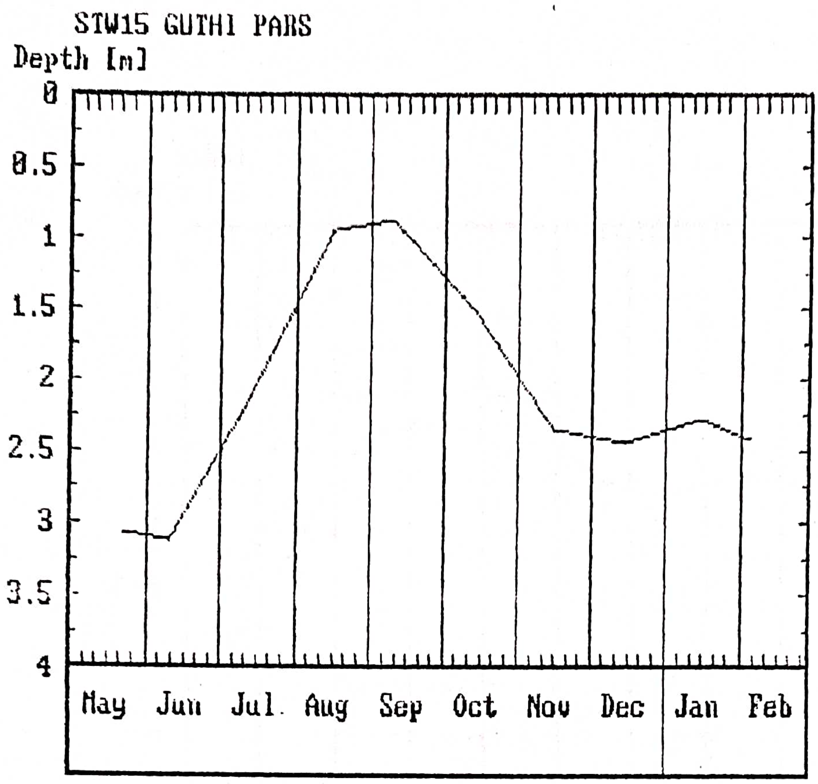
APPENDIX 10/6



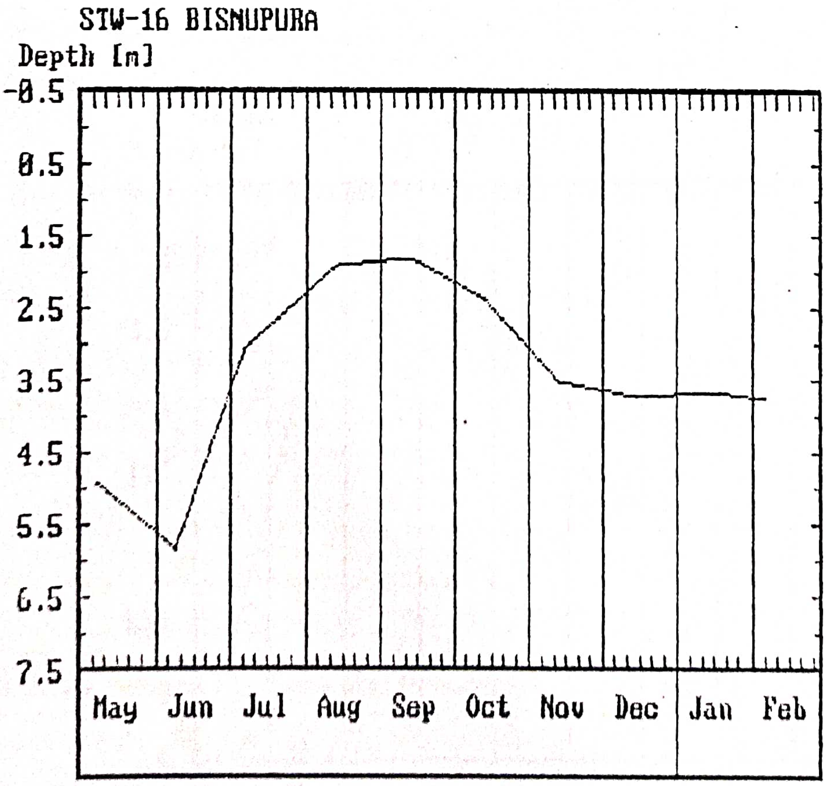
May 1, 1988 -- Feb 28, 1989



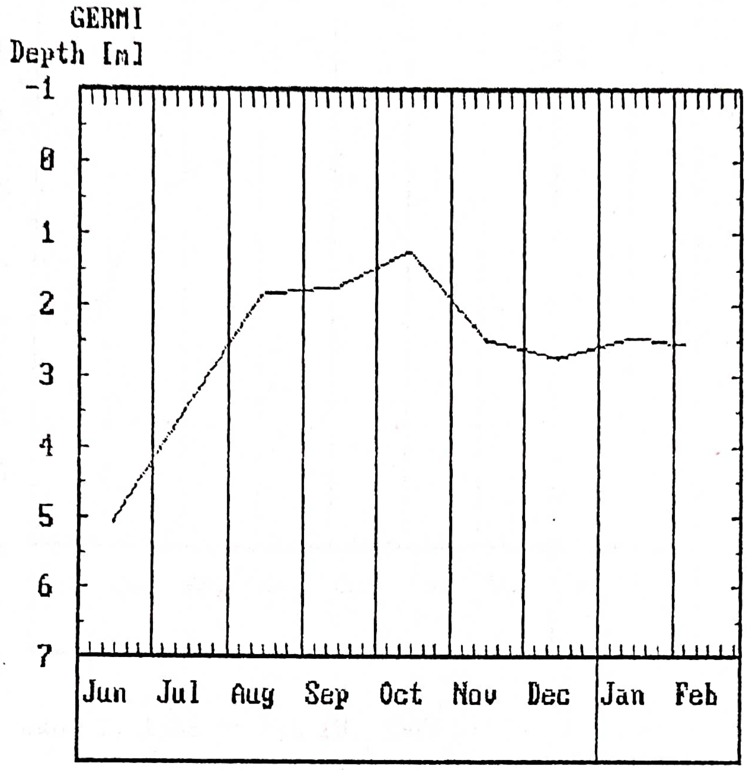
May 1, 1988 -- Oct 31, 1988



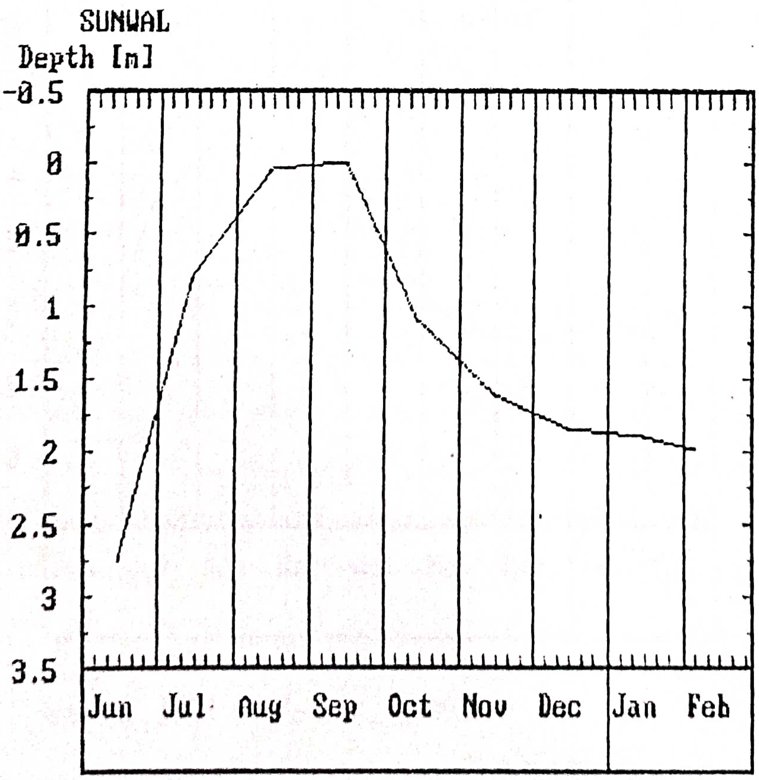
May 1, 1988 -- Feb 28, 1989



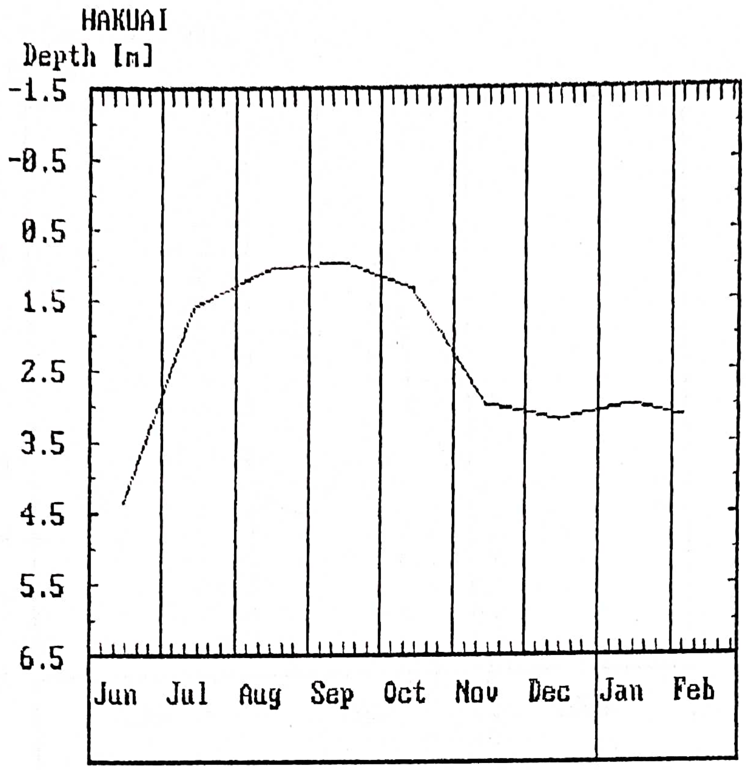
May 1, 1988 -- Feb 28, 1989



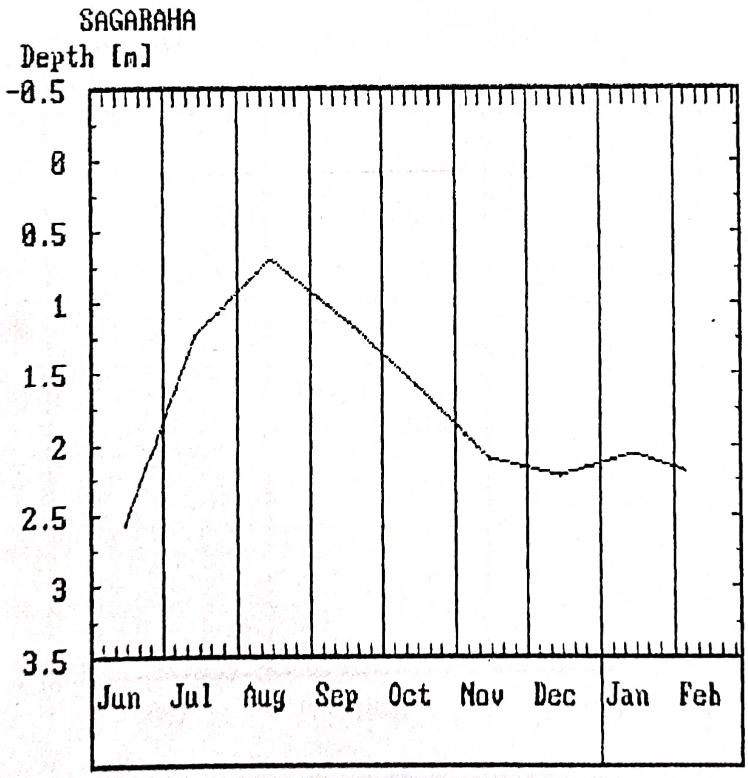
Jun 1, 1988 -- Feb 28, 1989



Jun 1, 1988 -- Feb 28, 1989

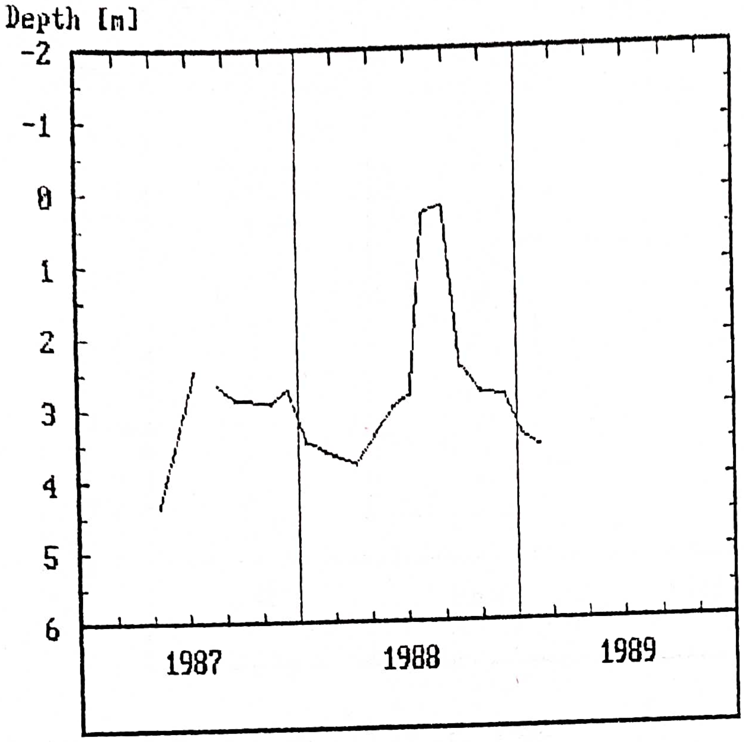


Jun 1, 1988 -- Feb 28, 1989



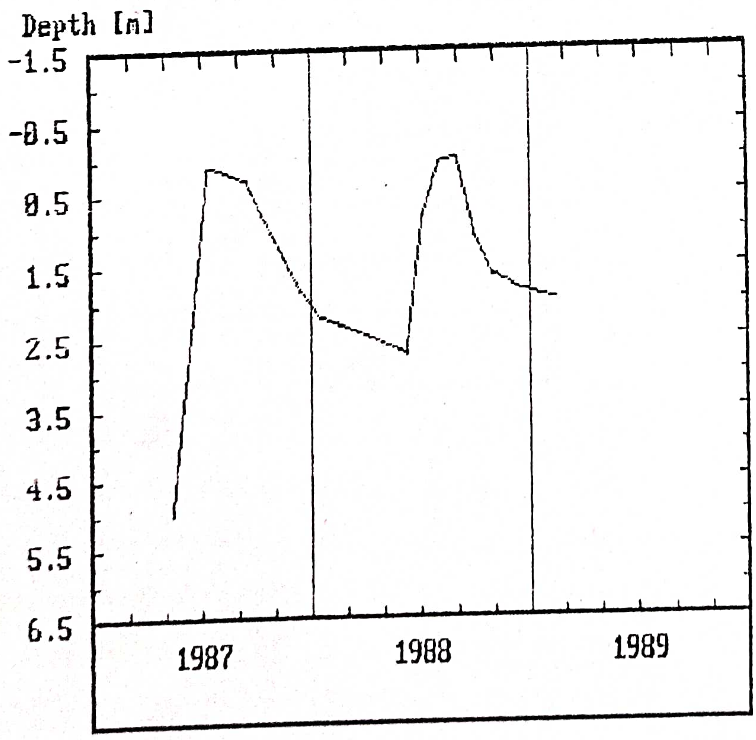
Jun 1, 1988 -- Feb 28, 1989

PARASI DUG WELL



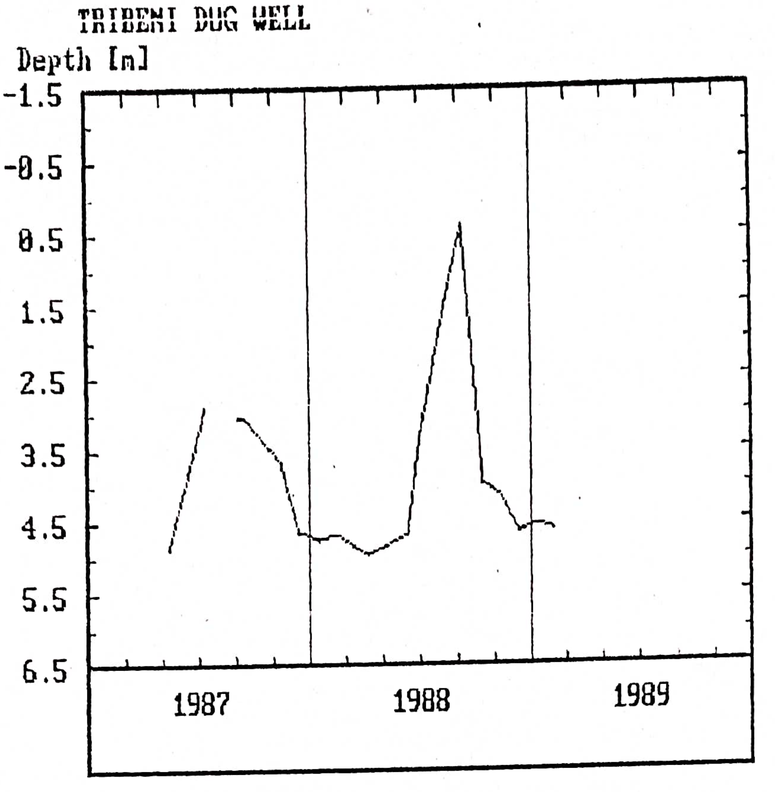
May 1, 1987 -- Feb 28, 1989

SUNWAL (N)



May 1, 1987 -- Feb 28, 1989

APPENDIX 10/11



May 1, 1987 -- Feb 28, 1989