Shallow Ground Water Resources of The Terai
Bara District
Central Development Region, Nepal

Technical Report No. 21

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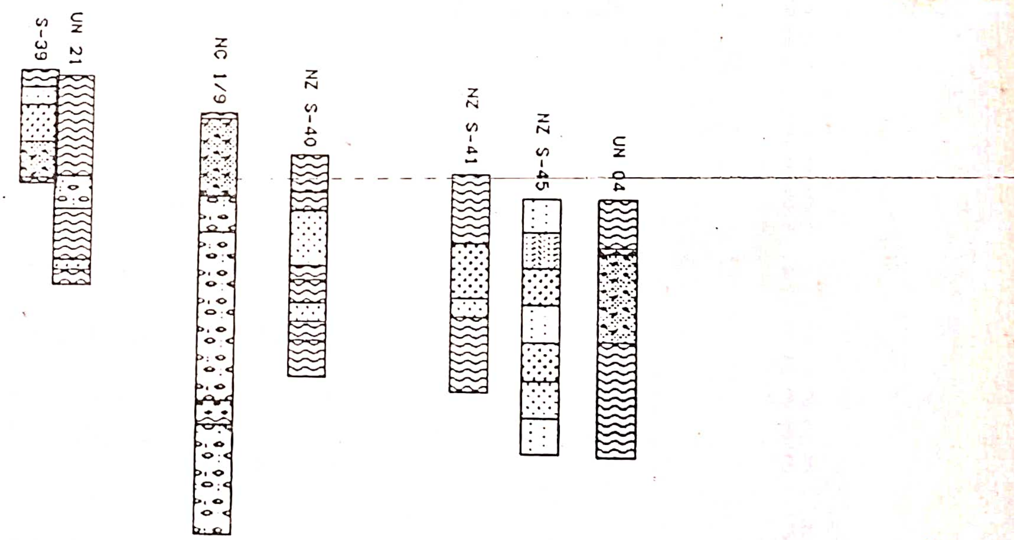

United Nations Development Program and
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NEP/86/025
Shallow Ground Water Investigation in terai

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ABBREVIATIONS

ADB - Asian Development Bank
ADBN - Agriculture Development Bank of Nepal
DTW - Deep Tube Well
GDC - Groundwater Development Consultants (International) Ltd.
GWRDB - Ground Water Resources Development Board
GWS - Ground Water Software, UN/DTCD
JR - Wells drilled by Japanese Red Cross Society
MCM - Million Cubic Meters
NC - Nippon Koei Drilling Company
NRSC - National Remote Sensing Center, Nepal/GTZ/World Bank, 1984.
NZ - Wells drilled by Narayani Zone Irrigation Development Project.
STW - Shallow Tube Well
UNDP - United Nations Development Programme
UN/DTCD - United Nations Department of Technical Cooperation for Development

ABSTRACT

Bara District is in the Central Region of Nepal, and comprises an area of 1190 km^2, of which the Terai is 1100 km^2. The four year average annual precipitation of 1987 to 1990 from about 1800 millimeters of which more than 85% comes during the monsoon. The population in 1981 was 318,957 of which 15% was urban. Agriculture is the dominant economic activity in the district. Approximately 30% of the potential irrigation farm land is irrigated for a whole year, leaving 70% or about 42,000 hectares that could be irrigated the whole year. The aquifer in Bara has the potential to provide water to irrigate the remaining 70% of unirrigated or single crop irrigated land.

The aquifer is comprised of an indeterminate number of interconnected permeable lenses of sand, gravel and pebbles intercalated with some silts and clays which comprise a very large ground water reservoir. Twenty three pumping tests were done and transmissivities were determined to range from less than 20 to more than 7000 m^2/day. Yields of existing wells range from less than 5 to 25 liters per second (l/s). The yield potential map indicates the northern part of the district should yield 10-25 l/s.

Fluctuations observed in the water level change maps are relatively small and are due to seasonal variation and are not due to pumping stress on the aquifer.

Recharge in the district is principally from local precipitation. Estimates of potential recharge from (Duba) about range from 193 MCM to. This compares favorably with the estimated ground water outflow to India of 4 MCM per year and a hypothetical pumpage of 121 MCM per year calculated from 14,000 wells pumping 12 l/s for 2,000 hours per year, and 330 MCM of water potentially evaporatranspired.

1. INTRODUCTION

1.1 Purpose and Scope

A project, NEP/86/025, to investigate the shallow ground water resources of Terai districts began in 1987. The United Nations Department of Technical Co-operation for Development and the Ground Water Resources Development Board, HMG, Nepal are the responsible entities. Project document information is presented in Appendix A. This report on Bara District is one of a series of reports from the project. The status of the project is shown in Figure 1.

The purpose of the project is to conduct an orderly and defined investigation of shallow ground water in each Terai district. A major goal of NEP/86/025 is to develop scientific procedures for the collection, interpretation, and presentation of ground water data throughout the Terai in Nepal. A principal component is development of a computerized Ground Water Information System (GWIS) to manage the ground water information obtained in this project. The GWIS will become a major tool in many aspects of ground water data storage, retrieval and dissemination for all ground water information collected by DOI.

A second major goal is to train Nepalese hydrologists to implement the procedures. This will facilitate optimum water resource development of the Terai and Nepal.

A third major goal is to define the areal extent of each Terai district where a shallow irrigation well (SIW) may be developed. A SIW is defined in the section on shallow ground water vailability.

Figure 1. Index Map Showing Technical Reports from the Ground Water Investigations in the Terai

Ground water must be utilized in the best possible manner to ensure availability of this most important natural resource now and in the future. Irrigation by wells in Bara District will help Nepal increase agricultural production for an increasing population and for export for valuable foreign exchange.

This report should be considered in relation to the above goals. Ground water data has been collected, placed in an information system, interpreted and presented. Training takes place during these activities. Finally, a SIW area is defined.

1.2 Location and Extent of Area

Bara District is in the Central Region of Nepal and is bordered by Rautahat District to the east and Parsa District to the west as shown in Figure 1. The Terai occupies an area of 1100 Km2 (Tilson, 1985) out of 1190 Km2 for the district. It lies between LANDSAT IMAGERY (NRSC, 1984) co-ordinates: X = 288000 - 328000 and Y=2970000 - 3020000.

1.3 Previous Investigations

Bara and surrounding districts have been investigated and studied previously by several workers and projects. Reports by these investigators and other reports are listed in the Selected References.

1.4 Methods of Investigation

Field work for this report began in the Spring of 1987 and for the most part was completed in 1990. The work consisted of water level measurements, drilling wells, altitude surveys of land surface at wells, and aquifer tests.

Water level measurements were began in April 1987, in dug wells and private shallow tubewells. The network included 13 dug wells and 10 private shallow tube wells in the month of September 1989. The monitoring network has become a combination of those 23 wells and 25 UN STW.

The project drilled 25 wells, collected and examined drill cuttings, and collected logs, and other information on 26 additional drilled wells.

Aquifer or pumping tests were conducted on 20 of the new wells and 3 private wells.

Most of the illustrations, analyses, and data utilize micro computers and UN/DTCD Ground Water Software (GWS) developed by Karanjac (1989).

1.5 Well Identification System

Wells in this report are identified in several ways: 1) they are numbered sequentially and given a location name; 2) each has a computer file name or number which includes the letters BR for Bara District and the sequence number; 3) identification (ID) also is provided by another secondary number to differentiate wells drilled for this project (UN and a sequential number), wells drilled by Junior Red Cross (JR and a number), wells drilled by Narayani Irrigation Zone (NZ and a number) and deep wells drilled by Nippon Koei (NC and a number); 4) X and Y coordinates have been digitized from the 1:500,000 LANDSAT imagery map of Nepal and are another ID.

1.6 Topography and Drainage

Bara District is in the Terai Physiographic Province of Nepal in the south and in the Siwalik Hills in the north. Altitudes in Bara District range from more than 900 meters in the north to about 70 meters at the border with India.

There are several rivers in the district, generally flowing from northeast to southwest. The major ones are Dudhaura Khola, Pashahathakur Nadi, Thalhi Nadi, Tiar Nadi, Jamuni Nadi, and Arwan Nadi. There are no river gauging stations in the district, and flow rates are not known.

1.7 Climate

The main characteristics of climate in Bara District, as in the whole Terai, is monsoon rainfall which occurs between June and September. About 85% of the total annual rainfall falls during those 4 months. This report uses the data collected at Simra Airport, Figure 1. The mean annual rainfall is about 1760 mm and pan evaporation is about 1500 mm. Average rainfall exceeds average evapotranspiration only during the monsoon. Monthly and annual rainfall at Simra airport for 1987 through 1990 are listed in Table 1, and shown in Figure 2. The Terai of Nepal is in the subtropical zone. Monthly mean maximum and minimum temperature at Simra airport for 1988 are listed in Table 2, and shown in Figure 3. The mean monthly temperature reaches a low of about 8.4°C in January compared to a high of about 33°C in April and May.

Table 1. Monthly and Annual Rainfall at Simra Airport, 1987-90.

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1987	-	-	-	12	49	-	763	830	383	145	-	4	2186
1988	0	18	71	110	175	490	587	452	167	24	0	40	2134
1989	4	12	5	0	174	140	450	304	260	36	0	2	1388
1990	0	3	21	65	229	176	423	343	420	55	0	0	1735

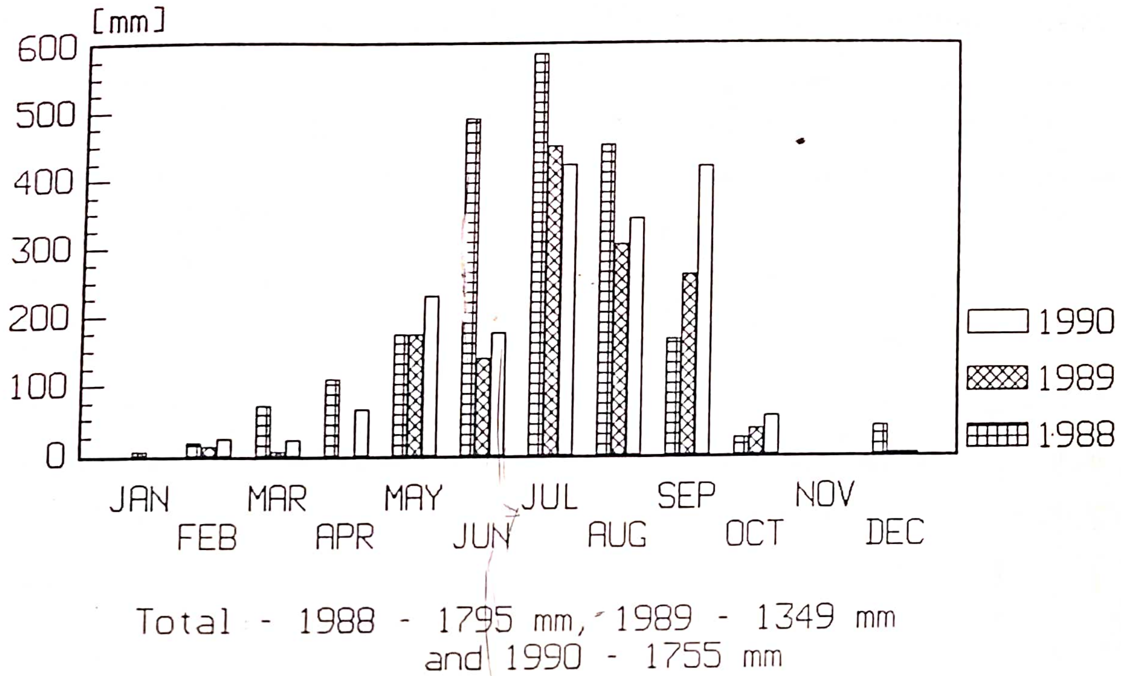


Figure 2. Bar chart showing monthly rainfall at Simra Airport, 1988-91.

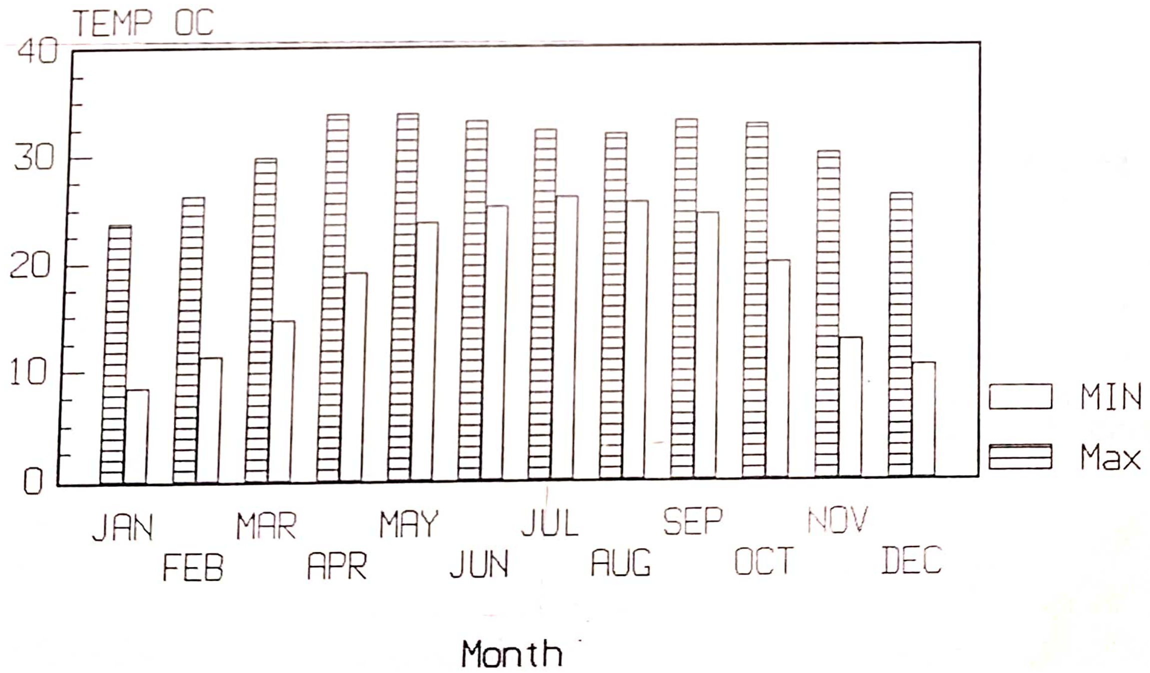


Figure 3. Bar chart showing mean minimum and maximum monthly temperature at ~~Simra Airport~~, 1988

Table 2. Monthly Max. and Min. Temperature at Simra Airport.

YEAR	MONTH	TEMPERATURE MIN.	MAX	YEAR	MONTH	TEMPERATURE MIN.	MAX
	JAN	8.8	22.2		JAN	8.4	23.7
	FEB	11.0	27.1		FEB	11.2	26.1
	MAR	14.6	29.8		MAR	14.6	29.7
	APR	18.4	34.0		APR	18.9	33.8
1	MAY	21.6	35.1	1	MAY	23.6	33.8
	JUN	25.6	34.9		JUN	25.1	33.1
9	JUL	25.2	31.5	9	JUL	25.9	32.2
8	AUG	25.0	31.3	8	AUG	25.5	31.8
	SEP	24.9	31.9		SEP	24.4	33.1
7	OCT	20.7	30.4	8	OCT	19.8	32.7
	NOV	14.9	28.7		NOV	12.6	30.0
	DEC	10.6	25.1		DEC	10.3	26.1

1.8 Population

There were 318,957 people in Bara District in 1981 giving an average density of about 268 people per Km2 (SPBN). About 15% were living in an urban setting and 85% in a rural setting.

1.9 Agriculture

Rice, wheat, maize, oil seeds, pulses and other crops are grown in Bara District. Table 3 shows the principal crops harvested in fiscal year 1988-89. (ASN, 1990).

Table 3. Principal crops harvested in 1988/1989 in Bara District.

Crop	Area (Hectare)	Prod (Metric Ton)	Annual Ave.Retail Price(Rs/Kg)	Yield (Kg/ha)
Paddy	61180	188910	5.78	3088
Maize	8040	18800	4.73	2338
Millet	110	110	5.88	1000
Wheat	23500	42300	5.91	1800
Barley	100	100	Not Available	1000
Oilseed	2350	1750	13.83	614
Potato	4450	57850	4.68	13000
Tobacco	30	20	55.15	667
Sugarcane	4550	163800	Not Available	36000
Pulse	8290	5380	Not Available	649

1.10 Acknowledgments

The present report was prepared from field and office data. Thanks and appreciation are expressed to the Birgunj Field Office, GWRDB, Mr. M.B. Kunwor in charge and his staff, who carried out the Bara District field work. Thanks also to: Mr. Y.L. Vaidya, Deputy Director General, DOI, HMG for his support and encouragement; Dr. Ramesh Man Tuladhar, National Co-ordinator of the Project, and my deserving colleagues in Kathmandu for their help and assistance during preparation of this report; and Mr. J.M. McNellis, Senior Adviser to NEP/86/025 for his help in finalizing the report.

2. GEOLOGY, LITHOLOGY, AND WATER SUPPLY

Investigation of ground water in the Terai considers the area containing the Bhabar Zone but does not include the Siwalik Hills -Terai interface or relationship.

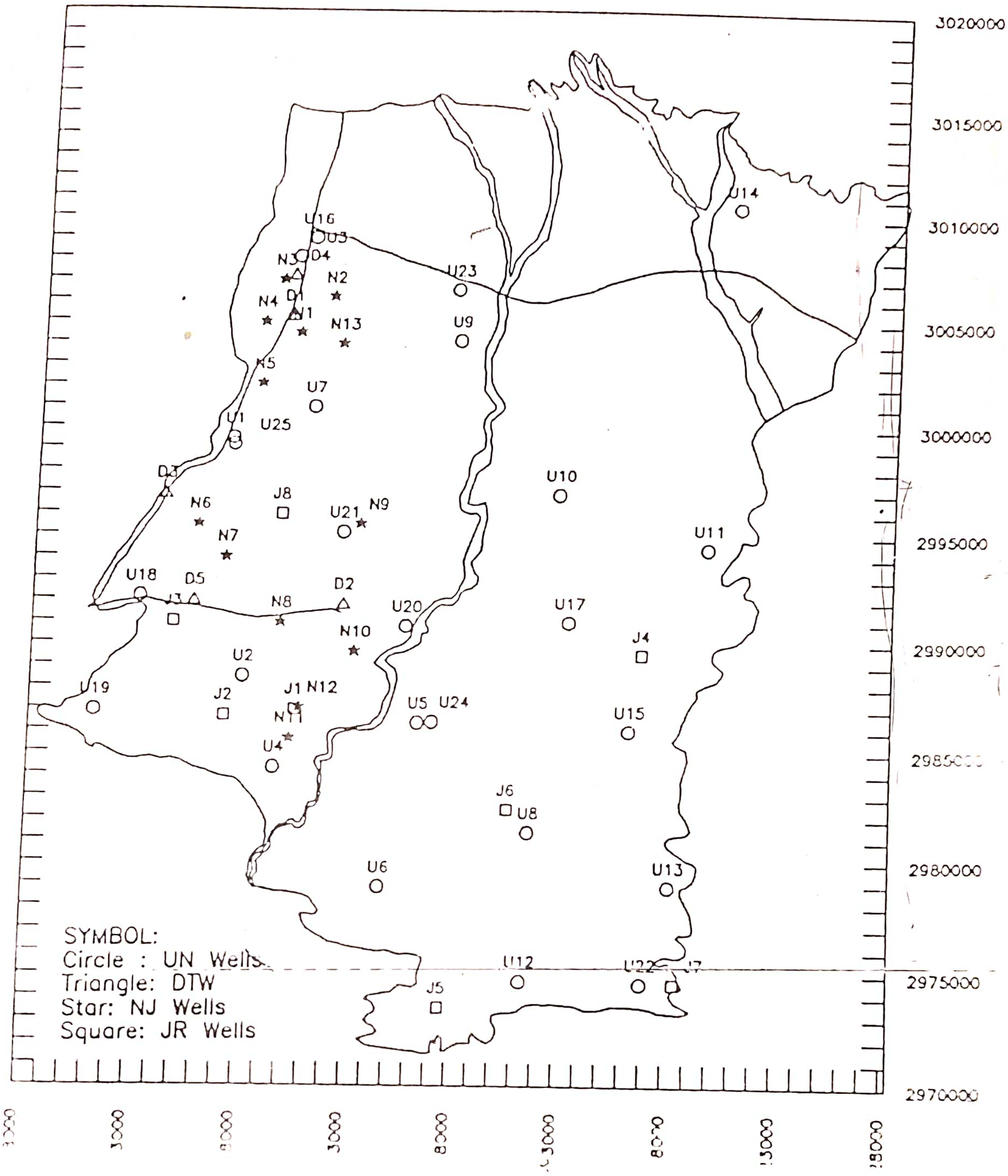
Sediments comprising the Terai plain are thick clastic deposits of Quaternary and Pleistocene age which are accumulating to the present day. The most permeable portions of the Terai sediments are the coarse materials thus sand, gravel and larger fractions will be called aquifer in the discussion. The deposits are placed in two groups for hydrologic and lithologic purposes, the Bhabar Zone deposits and the Terai Plain deposits. Differentiation in the subsurface is difficult because of the nature of the sedimentation processes and the similarity of lithologies.

2.1 Drilling Program

There were 25 successful UN investigation wells drilled during the current project in Bara District. The UN wells were located to obtain distributed geographic coverage and thus maximum information about the nature of the aquifer. The well locations are shown on Figure 4. The project wells and drilling metrage in the Bara District are shown on Figures 5 and 6 respectively. Seventeen of the 25 successful UN wells were drilled manually, and 8 were drilled by rotary rig.

Logs and other information were collected on 26 additional drilled wells including 13 NZ, 8 JR and 5 NC wells. These wells and the UN wells provide important information on the composition and distribution of the Terai deposits. Available pertinent data from the 51 wells are listed in Table 4 and well logs are shown in Appendix B.

Maximum and minimum depth of UN drilled wells by rotary rig is 50.3 m (UN-3, Simara) and 19.8 m (UN-11, Kolvi) respectively. Likewise, by manual is 47 m (UN-13, Paterwa) and 13 m (UN-15, Bishanpurwa). Eight wells were drilled less than 40 m including 2 drilled by rig and 6 drilled manually. Six of the 17 manually drilled wells terminated in permeable material (UN-5, 8, 15, 17, 20 and 23) and 5 of 8 rotary rig drilled wells did likewise (UN-3, 10, 11, 14 and 16). All the project wells were constructed with 4" diameter pipe except one (UN03, 6/4"). Average depth per well is 38 m.



NOTE: The well identification on the map coressponds to the table identification shown below:

Map ID	Table ID
U1-U25	BRS01-BRS25
N1-N13	BRS26-BRS38
J1-J8	BRS39-BRS46
D1-D5	BRD01-BRD05

Figure 4. Well location

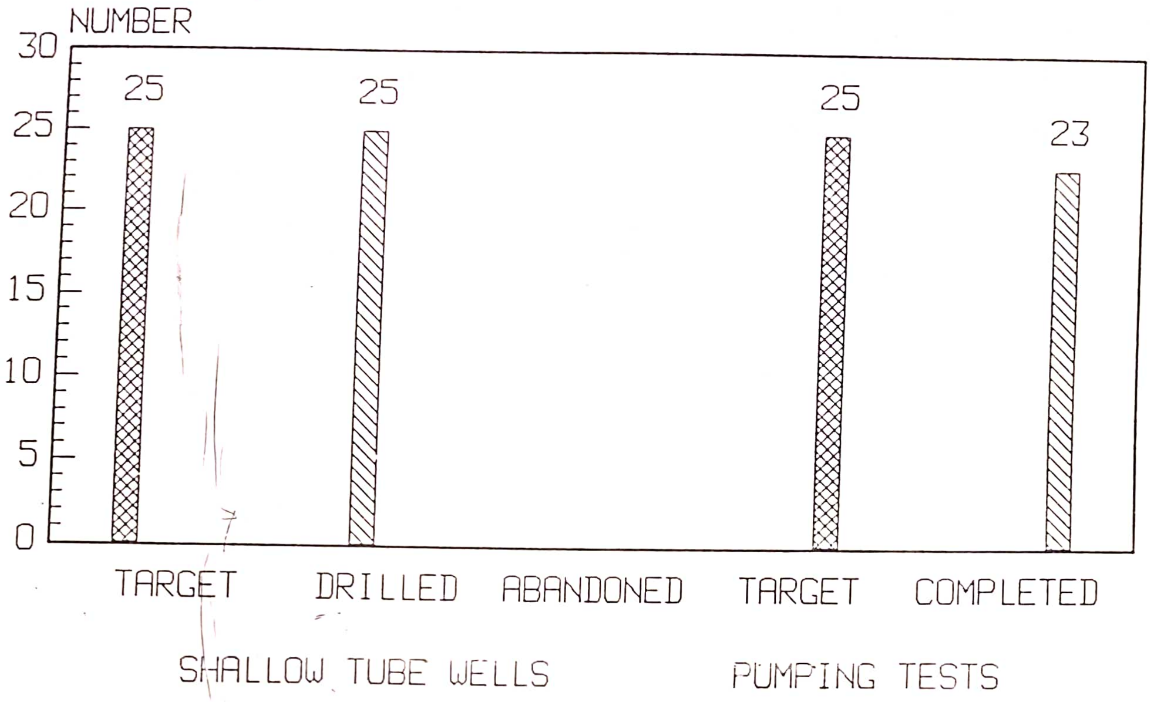


Figure 5. Number of wells and pump tests in Bara District

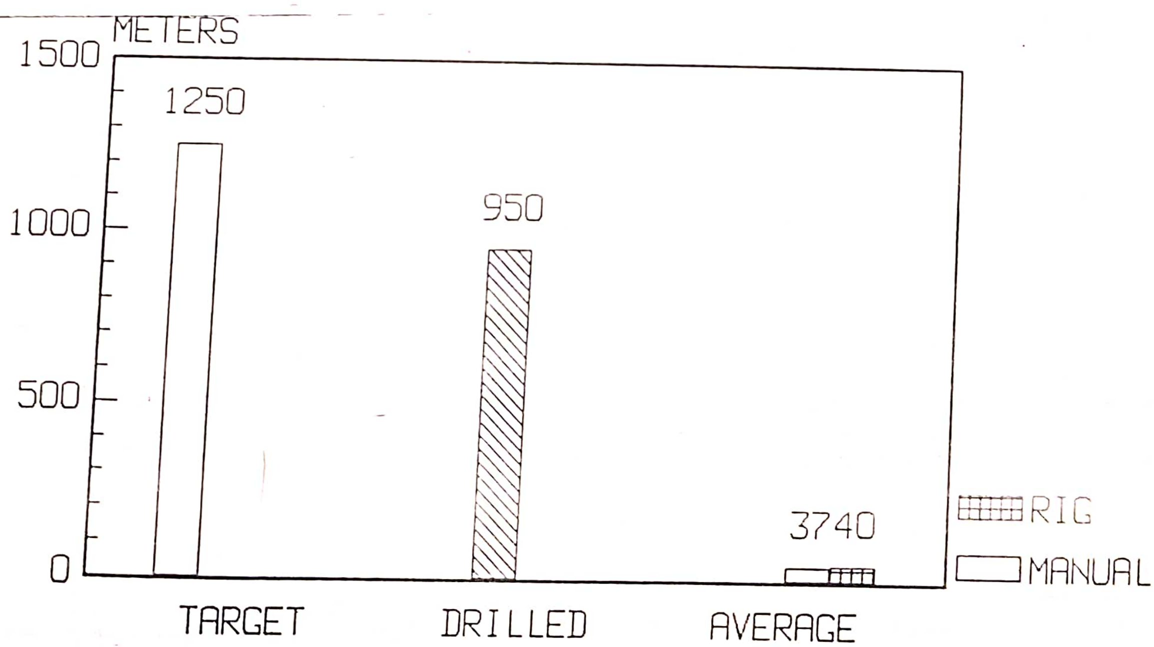


Figure 6. Drilling meterage in Bara District

Table 4.-- Basic Data from wells in Bara District.

No.	FILE NAME	NUMBER	LOCATION	X	Y	Z	DEPTH	SCREEN	PERM	PERCENT
1	BRS01.LTH	UN 01	CHHATA PIPARA	297050.	2999500.	110.00	45.70	7.0	17.4	38.1
2	BRS02.LTH	UN 02	PHETA	297900.	2988500.	90.00	44.80	9.2	12.9	28.8
3	BRS03.LTH	UN 03	SIMARA	299800.	3008100.	137.00	50.30	8.2	36.1	72.2
4	BRS04.LTH	UN 04	MATIARWA	299500.	2984350.	85.00	42.70	11.0	14.7	34.4
5	BRS05.LTH	UN 05	BARIYARPUR	306200.	2986450.	87.00	42.60	5.5	14.5	34.0
6	BRS06.LTH	UN 06	KABAHI GOTH	304600.	2978900.	78.00	45.70	8.5	12.9	28.2
7	BRS07.LTH	UN 07	KHESRAUL	300800.	3001000.	112.00	45.70	6.0	24.4	53.4
8	BRS08.LTH	UN 08	KUDWA	311600.	2981450.	82.00	16.60	5.5	16.0	96.4
9	BRS09.LTH	UN 09	BARDAHAWA	307600.	3004200.	134.00	23.20	6.1	15.8	68.1
10	BRS10.LTH	UN 10	BODHABAN	312600.	2997000.	110.00	43.30	9.1	16.1	37.2
11	BRS11.LTH	UN 11	KOLVI	319000.	2994500.	105.00	19.80	6.1	17.8	89.9
12	BRS12.LTH	UN 12	SHRINAGAR BAIR	311400.	2974700.	70.00	45.70	5.5	9.3	20.4
13	BRS13.LTH	UN 13	PATERWA	318200.	2978950.	84.00	47.00	5.5	13.7	29.1
14	BRS14.LTH	UN 14	NIJGARH	320500.	3010600.	170.00	41.80	6.9	18.9	45.2
15	BRS15.LTH	UN 15	BISHANPURWA	316200.	2986100.	92.00	13.10	3.0	8.5	64.9
16	BRS16.LTH	UN 16	PATHLAIYA	300500.	3009000.	145.00	46.70	3.0	38.7	82.9
17	BRS17.LTH	UN 17	UMJAN	313250.	2991100.	95.00	26.20	5.5	5.5	21.0
18	BRS18.LTH	UN 18	NAUTAN	293000.	2992150.	95.00	47.00	5.5	12.5	26.6
19	BRS19.LTH	UN 19	BISHRAMPUR	291050.	2986900.	85.00	41.20	5.5	3.0	7.3
20	BRS20.LTH	UN 20	BIJALPUR	305500.	2990900.	95.00	39.60	11.6	33.0	83.3
21	BRS21.LTH	UN 21	SURAHI	302400.	2995200.	105.00	35.10	5.5	7.3	20.8
22	BRS22.LTH	UN 22	SIMRAUNGARH	317000.	2974600.	70.00	45.70	5.5	13.4	29.3
23	BRS23.LTH	UN 23	PILWA	307450.	3006600.	145.00	16.60	5.5	11.1	67.0
24	BRS24.LTH	UN 24	MAJHARIYA	306900.	2983500.	82.00	42.68	7.6	11.8	27.7
25	BRS25.LTH	UN 25	PARWANIPUR	297100.	2999200.	100.00	41.73	11.0	10.1	24.1
26	BRS26.LTH	NZ S-5	BARA SIMURA	300000.	3004500.	126.00	34.50	15.0	20.5	59.4
27	BRS27.LTH	NZ S-8	SIMARA WA.NO.6	301500.	3006200.	137.00	33.50	12.0	18.5	55.2
28	BRS28.LTH	NZ S-49	NARABASTI	299100.	3007000.	138.00	38.00	12.0	18.5	48.7
29	BRS29.LTH	NZ S-57	SIMARA WA.NO.5	298300.	3005000.	130.00	33.50	12.0	21.0	62.7
30	BRS30.LTH	NZ S-26	JITPUR	298600.	3002100.	119.00	43.40	11.0	14.6	33.6
31	BRS31.LTH	NZ S-34	LIKMI	295600.	2995500.	102.00	24.80	12.0	11.4	46.0
32	BRS32.LTH	NZ S-35	REHARIYA	296900.	2994000.	100.00	27.00	12.0	18.0	66.7
33	BRS33.LTH	NZ S-37	MOTISAR	299800.	2991000.	95.00	28.00	12.0	21.0	75.0
34	BRS34.LTH	NZ S-39	SURAHI	303200.	2995600.	106.00	19.00	12.0	15.0	78.9
35	BRS35.LTH	NZ S-40	LUXMINIYA	303100.	2989700.	92.00	37.00	12.0	12.4	33.5
36	BRS36.LTH	NZ S-45	PHULAURIA	300200.	2985700.	85.00	42.30	12.0	24.5	57.9
37	BRS37.LTH	NZ S-41	BALRAMPUR	300600.	2987100.	89.00	36.20	12.0	12.2	33.7
38	BRS38.LTH	NZ S-3	BEHRI	302000.	3004000.	122.00	45.50	12.0	20.8	45.7
39	BRS39.LTH	JR C-16	BISAMBHARPUR	300400.	2987000.	93.00	24.00	3.0	8.0	33.3
40	BRS40.LTH	JR B-53	RAGUNATHPUR	297100.	2986700.	93.00	61.00	3.5	9.5	19.0
41	BRS41.LTH	JR B-51	PARSAUNI	294600.	2991000.	93.00	80.00	0.0	10.0	20.0
42	BRS42.LTH	JR B-26	PATHARIYA	316700.	2989600.	93.50	12.50	4.0	11.5	92.0
43	BRS43.LTH	JR B-30	PAKADIYA	307600.	2973500.	68.00	22.00	4.0	9.5	43.2
44	BRS44.LTH	JR B-28	AMARPATTI	310600.	2982500.	83.00	17.50	4.0	8.0	45.7
45	BRS45.LTH	JR C-28	KACHORWA	318500.	2974600.	80.00	25.00	6.0	8.5	34.0
46	BRS46.LTH	JR C-33	INARWA	299500.	2996000.	106.00	22.40	4.0	7.0	31.2
47	BRD01.LTH	NC 1/14	SIMRA FACTORY	299600.	3005300.	137.00	100.00	30.0	36.0	72.0
48	BRD02.LTH	NC 1/9	KALAIYA	302500.	2991900.	99.00	70.00	24.0	49.0	98.0
49	BRD03.LTH	NC 1/8	PARAWANIPUR	294000.	2996900.	107.00	100.50	31.7	21.5	43.0
50	BRD04.LTH	NC 1/6	SIMARA	299600.	3007250.	138.00	102.00	30.5	44.5	89.0
51	BRD05.LTH	NC 1/1	BHARSENI,BARA	295500.	2992000.	95.00	130.00	36.0	10.3	20.6

Notes

(1) X and Y coordinates are taken from the 1:500,000 map of Nepal, 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. The coordinates were read with the help of project-supplied digitizer.

(2) Z is the absolute elevation of the well above the mean sea level. The elevations are interpolated from 1:125,000 scale district map.

Wells listed in Table 4 are further analyzed to Table 5. The percentage of aquifer (permeable) material found in each well and for all wells is listed in Table 6.

Table 5.-- Analysis of lithological data in Table 4.

Item	For UN-STW	For DTW	Total (including rest of the STW)
Total no. of wells	25	5	51
Total drilled depth	950 m	502 m	2160 m
Average depth per well	38 m	100.5 m	42.4 m
Total screen used	169 m	152.2 m	508 m
Average screen used	4.1 m	12.3 m	6.5m
No. of wells with screen	25	5	50

Table 6.-- Analysis of Shallow Aquifer Thickness from Table 4.

Item	For UN - STW	For DTW	Total (Including all)
Depth of calculation	50 m	150 m	50.0 m
Cumulative depth	950.2 m	502 m	1866 m
Total aquifer thickness	395.4 m	336.3 m	857.1 m
Average percent of aquifer thickness	41.6 %	66.9 %	45.9 %

2.2 Lithologic cross sections

Lithologic cross sections within Bara District are located on Figure 7 and presented in Figures 8 - 13. No attempt has been made to connect permeable layers in the cross sections. This is not warranted as the Terai is traversed by many present rivers and buried channels of rivers of the past. The lithology of the sediments changes rapidly over very small distances. Six cross sections are presented to understand and gain an appreciation for the rapid changes within the subsurface of the Terai.

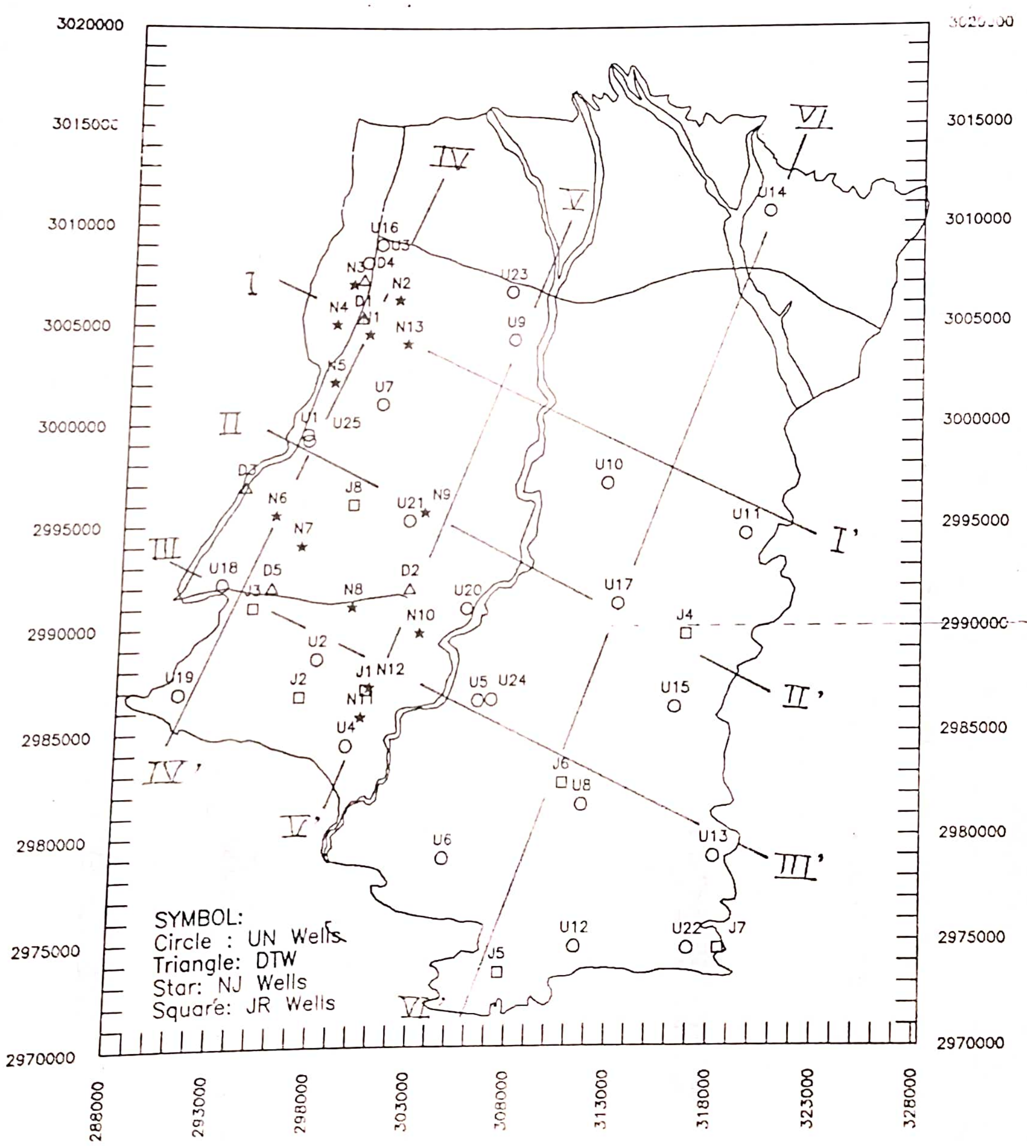


Figure 7. Map showing Locations of lithological cross sections in Bara District

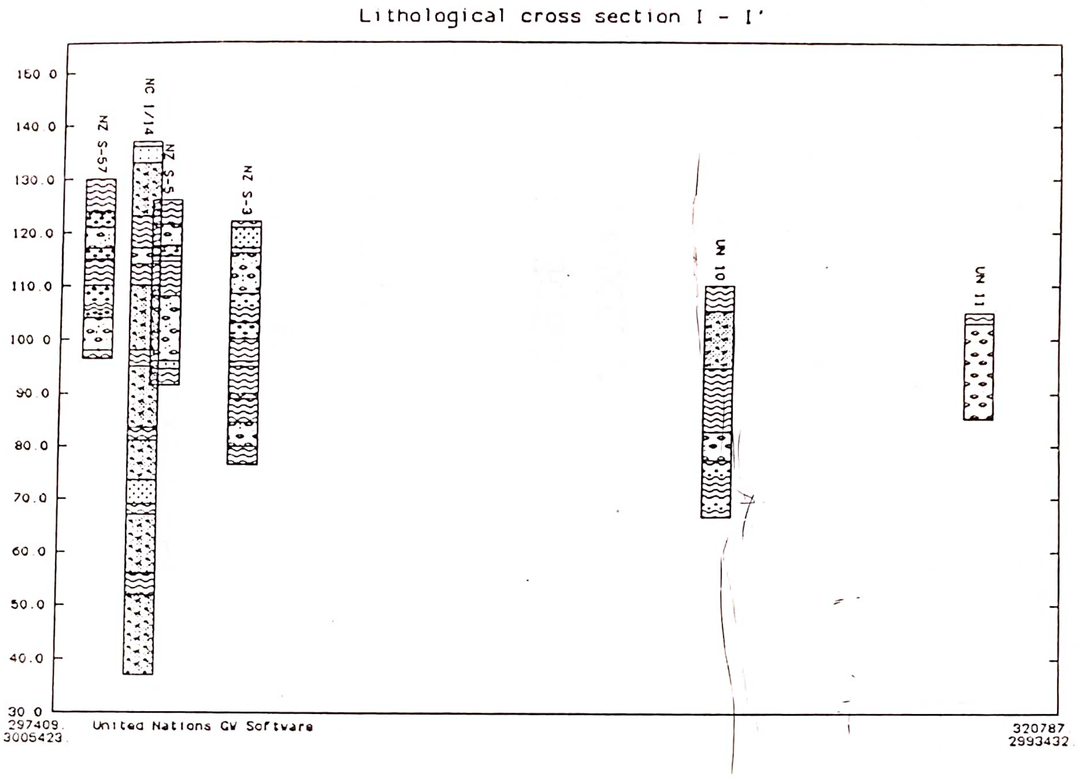


Figure 8. West-East cross section I - I'

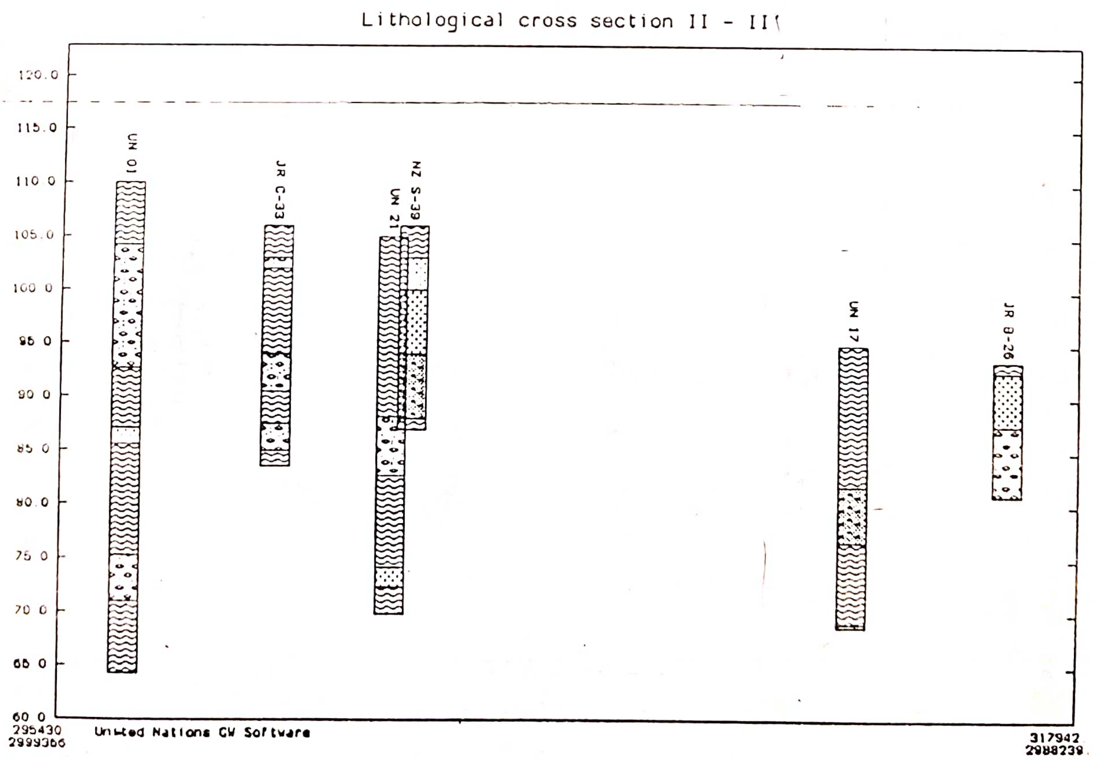


Figure 9. West-East cross section II - II'

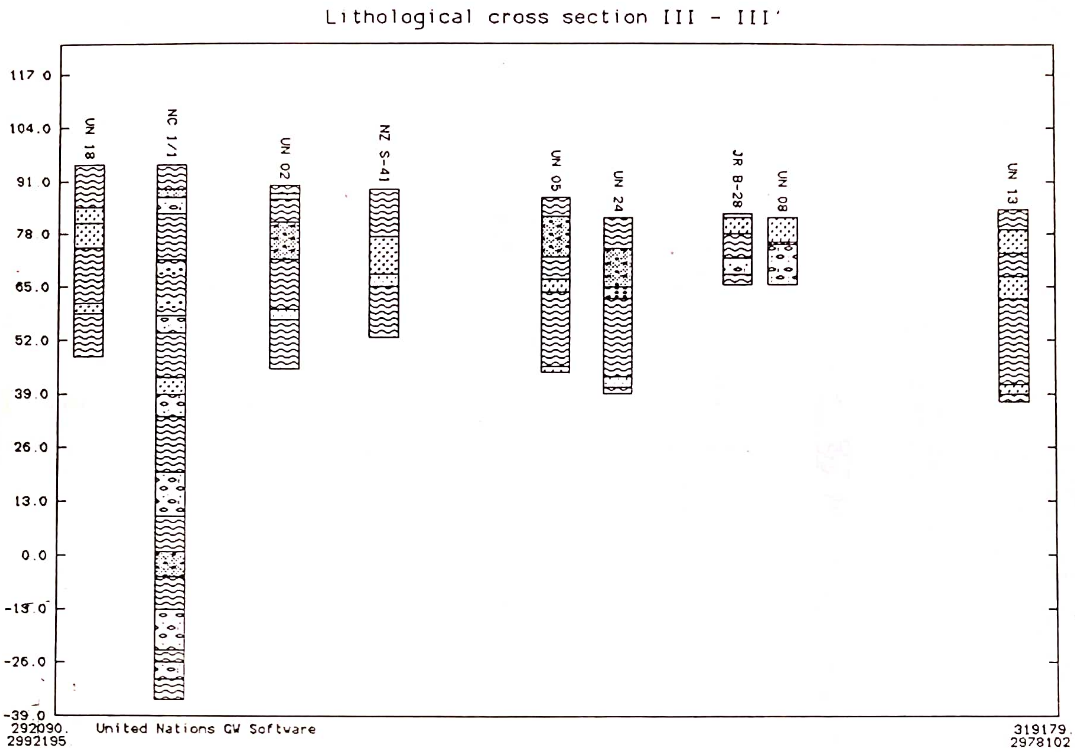


Figure 10. West-East cross section III - III'

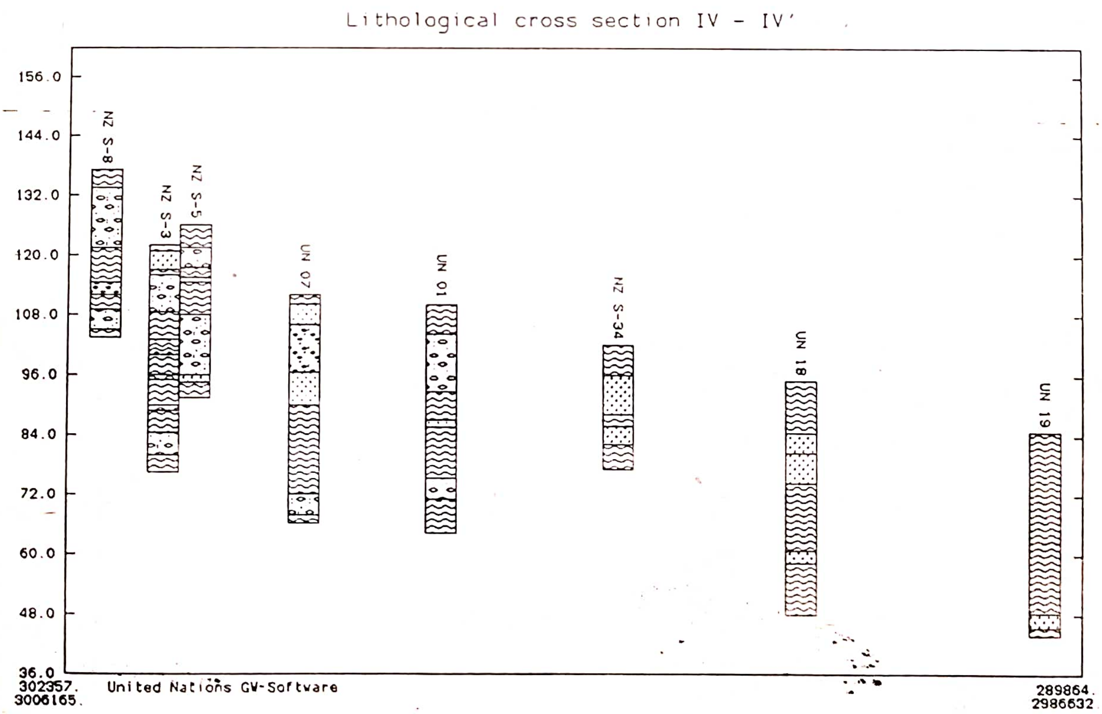


Figure 11. North-South cross section IV - IV'

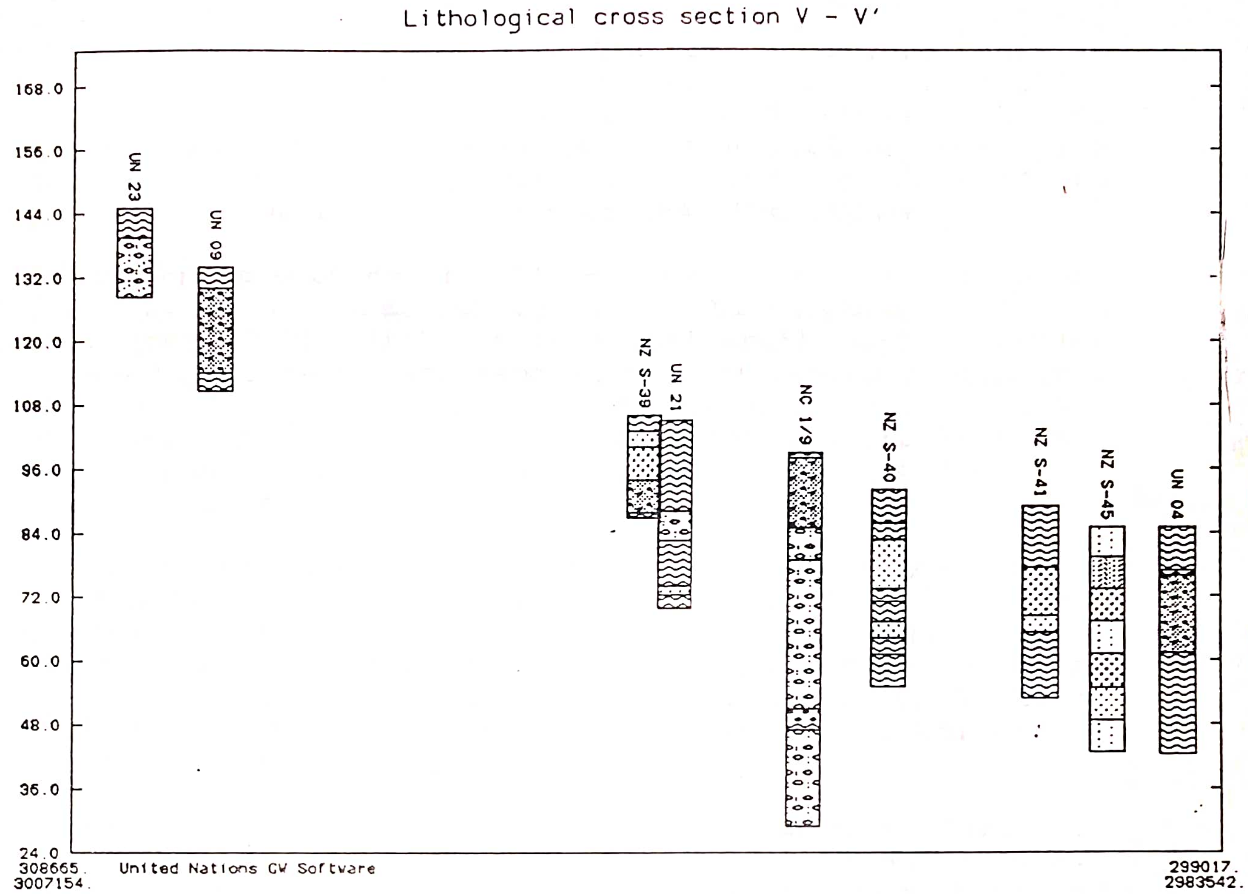
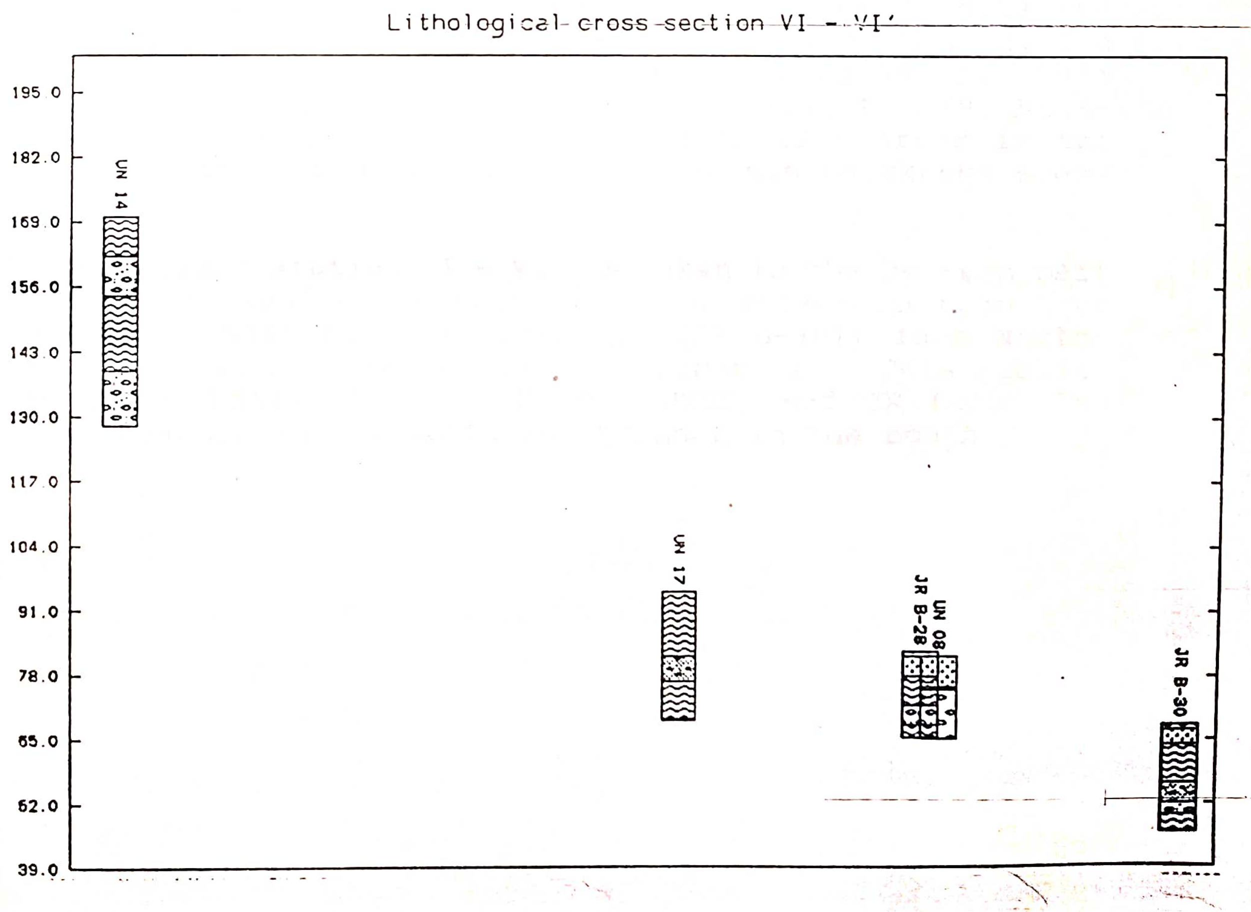


Figure 12. North-South cross section V - V'



Lithological cross section I - I' extends from near Simra in the north west to near Kolvi on the east central border of the district in a north west-south east direction and is shown in Figure 8. The land surface elevation ranges from about 137 m to 105 m. This section contains wells NZ S-57, NC 1/4, NZ S-5, NZ S-3, UN10 and UN11. The wells in the section contain a considerable thickness of sand and gravel. However, the east and west sides of the section are coarser than the middle part.

Lithological cross section II - II' extends from near Chatapipra (UN 01) in the central West corner to near Bishanpurwa (UN15) in the East corner of the district in a west-south east direction and is shown in Figure 9. The land surface elevation ranges from about 110 m to 93 m. This section contains wells UN10, JR C-33, UN21, NZ S-39, UN17, JR B-26. Aquifer materials are less than in cross section I - I' and are mostly sand with some gravel in the 2 central wells.

Lithological cross section III - III' extends from near Nautan (UN18) in the West to near Paterwa (UN13) in the East in a West-East direction and is shown in Figure 10. The land surface elevation ranges from about 90 m to 95 m. This section contains nine lithological logs UN18, NC1/1, UN02, NZ S-41, UN05, UN24, JR B-28, UN08 and UN13. The aquifer is coarser and thicker in the north than in the south.

Lithological cross section IV - IV' extends from near Simra to Balrampur (UN19) in a North-South direction in West and is shown in Figure 11. The land surface elevation ranges from about 137 m to 85 m. This section contains wells NZ S-8, NZ S-3, NZ S-5, UN07, UN01, NZ S-34, UN18, and UN19. The aquifer is coarser in the North and thinner the 2 south.

Lithological cross section V - V' is taken in the central part of the district extending from from near Pilwa (UN23) to Matiarwa (UN04) in a North-South direction and is shown in Figure 12. The land surface elevation ranges from about 145 m to 885 m. This section contains wells UN23, UN09, NZ S-39, UN21, NC 1/9, NZ S-40, NZ S-41, NZ S-45, and UN04. The aquifer is coarser in the North and thinner in the south, and the maximum thickness seems in NC-1/9.

Lithological cross section VI - VI' is taken in the Western part of the district ranging the elevation from extending from from 170 m,Nijgarh (UN14) to 68 m, Pakadiya (JR B-30)) in a North-South direction im East and is shown in Figure 13. This section contains wells UN14, UN17, JR B-28, UN08, and JR B-30. The aquifer is coarser in the North and thinner in the south.

2.3 Bhabar Zone deposits

2.3.1 Lithology, distribution, and thickness

Bhabar Zone deposits are found, but are not continuous, at the surface along the base of the Siwalik Hills at the north edge of the Terai and also along major rivers transecting the Terai. The area of Bhabar is estimated at 360 km2 (Tilson, 1985), and it is a principal recharge area for the Terai.

The Bhabar is derived principally from erosion of the Siwalik Formations found in the Siwalik Hills. Streams cut through the Hills, abruptly debauch onto the much flatter Terai which is the north portion of the Ganges plain, and dump their sediment as alluvial fans. Through time these fans coalesce and are covered with other sediments and comprise the Bhabar. Along major rivers, during flood, similar sediments are carried some distance from the Siwaliks. The Bhabar or its equivalent is found at depth to the south of the Siwaliks.

The Bhabar is very poorly sorted and contains a large volume of coarse grained material, ranging in size from sand to boulders, with intercalated finer sediments. Thickness ranges from a few meters to more than a hundred meters.

2.3.2 Water Supply

Wells screened in the Bhabar adjacent to the Siwalik Hills experience water level fluctuations large enough to place water levels below the lifting capability of centrifugal pumps. Therefore, very few STW obtain water from the Bhabar. Yields from deep tube wells (DTW) in Bara District are reported to 16 l/s. Most DTW are used for irrigation.

2.4 Terai Plain deposits

2.4.1 Lithology, distribution, and thickness

Throughout the Terai a thick sequence of clastic, mostly fluvial sediments have been and are being deposited. These sediments are here called Terai Plain deposits and they cover about 740 Km2 (Tilson, 1985) of Bara District. The coarser size fractions appear lenticular in cross section and are described as sand lenses or sand and gravel lenses contained in finer sediments. They may be visualized from the different lithological cross sections when considered from different perspectives.

These sediments represent the finer-grained portion of the rock material eroding from the Siwalik Hills and the mountains to the north. They range in size from clay to gravel and the proportions vary widely. However, they generally comprise more clay, silt, and fine sand than sand and gravel. Their thickness may exceed 1,000 meters.

2.4.2 Water Supply

Agricultural Development Bank, Nepal (ADBN) and Narayani Zone Irrigation Development Board (NZIDB) drilled 1145 and 30 shallow tube wells respectively in Bara District (GDC, 1987). In addition, there are a large number of dug wells. Some wells provide water for drinking and domestic purposes. Others, STW in particular, provide irrigation water. Yields range from 2 l/s to more than 20 l/s.

Table 7 lists maximum, minimum and average thickness of aquifer material along the trace of each cross section. With reservations on the quality and quantity of information, there is a reasonable chance of drilling into an aquifer within a depth of 50 m. However, a test hole exploration program should be a part of the drilling of production wells whether for water supply or irrigation purposes.

Table 7. Average aquifer thickness along each cross section in Bara District.

Region	Maximum	Minimum	Average	Cross-section No (Figure)
Northern	36	16.1	18.23	I-I' (Fig. 8)
Central	16.1	7	10.4	II-II' (Fig.9)
Southern	16	10.3	12.4	III-III'(Fig.10)
Western	24.4	3	16.1	IV-IV' (Fig.11)
Central	491	7.3	17.8	V-V' (Fig.12)
Eastern	18.9	5.5	11.6	VI-VI'(Fig.13)

3. HYDROLOGIC PROPERTIES OF WATER BEARING MATERIALS

The quantity of water available from an aquifer depends on the ability of the aquifer to store and to transmit water. The ability of an aquifer to store water is measured by its storage coefficient and the ability to transmit water by its transmissivity. These hydraulic properties are in turn dependent upon the dimensional and geological parameters of the aquifer.

3.1 Aquifer or pumping tests

Twenty-three aquifer tests were analyzed to determine the storage coefficient, the transmissivity and the hydraulic conductivity of the shallow Terai Plain aquifer. The analyses were made using GWS. A comparison was made between the 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.

The tests were run on 20 UN project wells and 3 private wells. The hydraulic properties of the project wells are shown in Table 8. The graphs of each of the pump tests are shown in Appendix C. The transmissivity map, Figure 14 was prepared from the 23 values. There are reservations as to the quality and accuracy of the pumping tests attributable to poor well development, fluctuation in pumping rates, inaccurate water level measurements and the screened zones in all the wells are not to the same or similar depth. Therefore, the values of transmissivity should be used with caution.

The hydraulic conductivity of sand should range from 4 to 125 m/day, sand and gravel from 8 to 200 m/day and gravel from 40 to 625 m/day. The hydraulic conductivities calculated from the transmissivities obtained in Bara fall within that range.

The values determined for storage coefficient indicate a confined aquifer. This is unlikely and the values appear so because the time of pumping was not long. The aquifer at depth may be partially or temporarily confined. Almost certainly, the shallow aquifer will behave as unconfined if stressed by pumpage for irrigation.

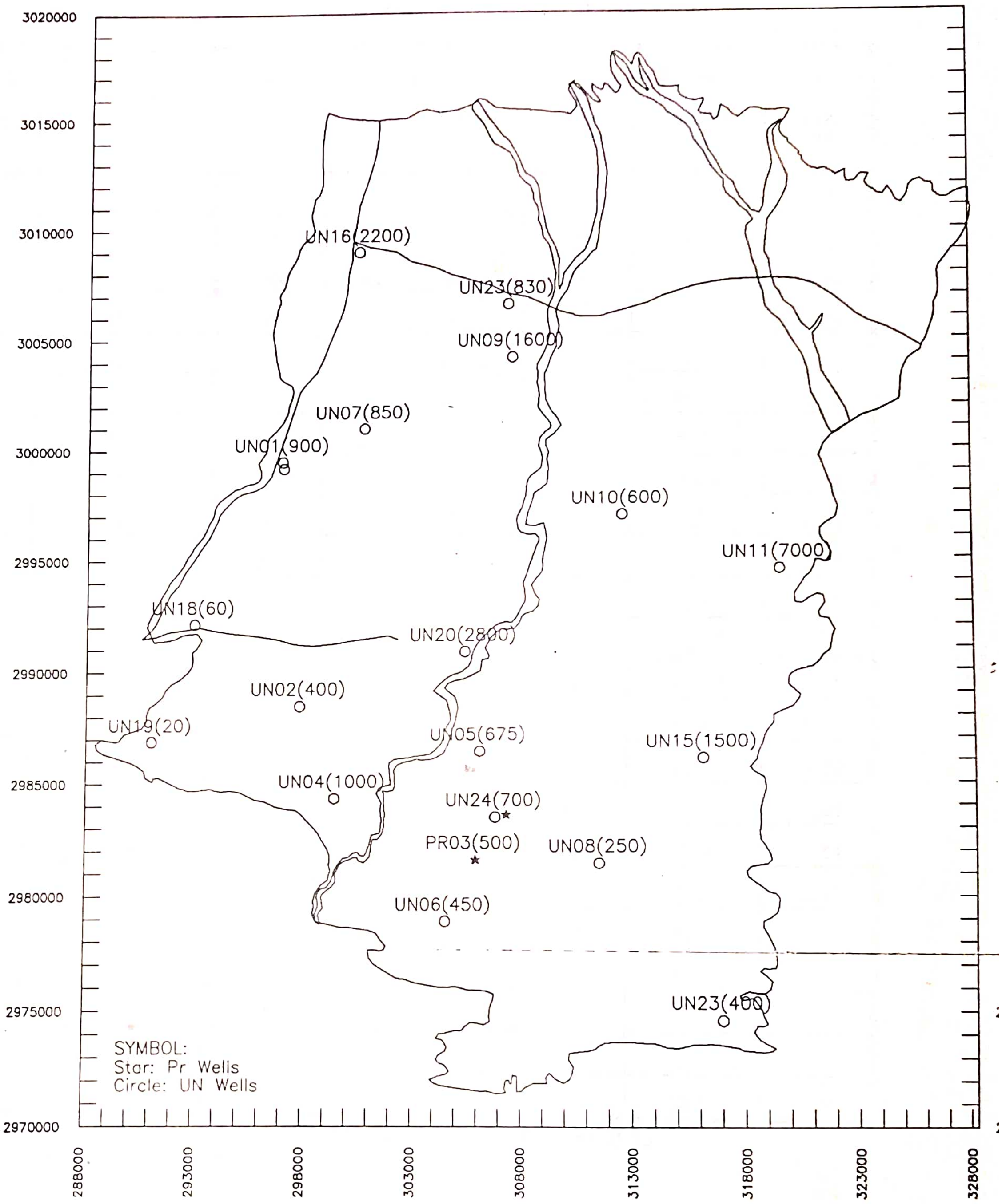


Figure 14. Transmissivity map (m2/day)

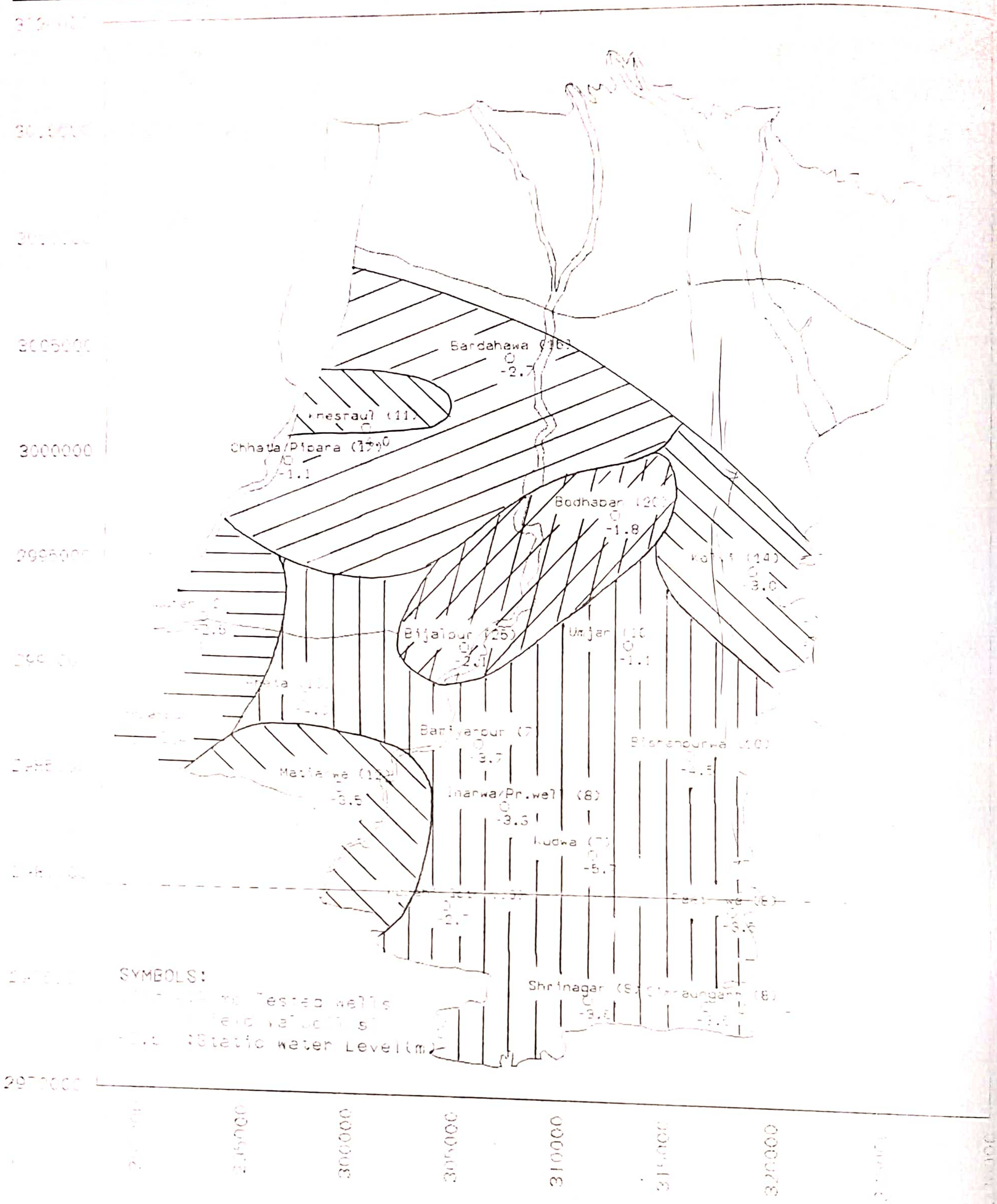
Table 8.-- Hydraulic Properties of Project Wells.

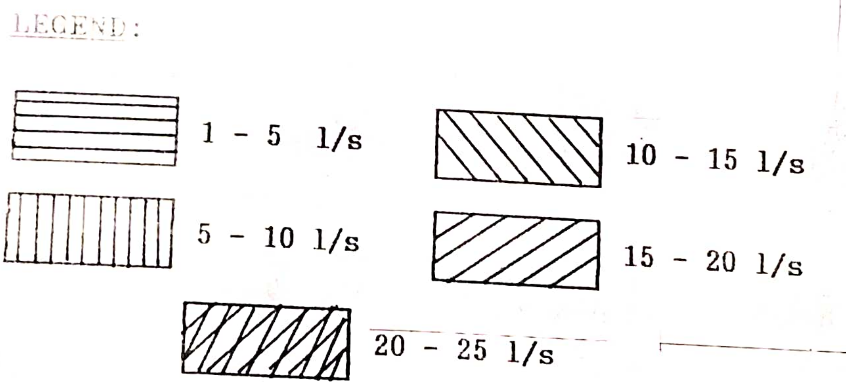
Well No.	TTTransmissivity (m^2/day)	Satu. Aquifer Thickness (m)	Hyd. Condvt. (m/day)	Aquifer Type	Storage Coefficient	Const. Pumping Rate (l/s)	Distance from Pumping Well (m)	Static Water Level (m)
UN01	938	17.4	54	GS	.11E-02	17	49	-1.31
UN02	461	12.9	36	SG	-	10	0.05	-4.03
UN04	728	14.7	50	SG	.20E-02	12	39.05	-3.49
UN05	648	14.5	45	SG	.18E-07	7	36.20	-3.72
UN06	531	12.9	41	SG	.12E-02	10	43.45	-2.97
UN07	1000	24.4	41	G	.27E-03	11	53.30	-4.0
UN08	300	16.0	19	GS	-	7	0.05	-5.70
UN09	1750	15.8	111	SG	-	16	0.05	-2.66
UN10	738	16.1	46	GS	.17E-02	20	42	-2.49
UN11	7000	17.8	393	GS	-	14	0.05	-2.98
UN13	250	13.7	18	GS	-	5	0.05	-3.45
UN15	300	8.5	35	S	.42E-02	6	19	-4.19
UN16	2200	38.7	57	GS	-	22	0.05	-17.76
UN18	100	12.5	8	S	-	2	0.05	-2.50
UN19	20	3.0	7	S	-	1	0.05	-4.77
UN20	1500	33.0	46	GS	.97E-04	25	10.70	-2.01
UN22	300	13.4	22	S	.94E-03	8	25.60	-3.51
UN23	830	11.1	75	GS	-	12.2	0.05	-5.13
UN24	620	11.8	53	SG	-	10	18.1	-3.18
UN25	530	10.1	53	S	-	8.33	0.05	-2.64
Pr01	690				-	12.22		
Pr02	250				.38E-03	10		
Pr03	600				.46E-03	10	38.70	-3.87

Note: G = Gravel, S = Sand, GS = Gravel with sand,
SG = Sand with gravel

3.2 Yield potential

Discharge and static water level were considered in making the yield potential map (Figure 15). The highest yields, 20-25 l/s, and static water levels, 1-2 m, are in the central part of the district. The lowest discharges, less than 2 l/s, and deeper water levels, around 2-4 m of static water level is in the Southwest cormer.





Note:
Yield Potential: Yield Po
of a 4" dia. STW (max.depth
equiped with surface mounte
centrifugal pump.

Figure 15. Yield potential map

4. GROUND WATER

The discussion on ground water will cover general ground water concepts and utilize data acquired and interpreted in this ground water investigation in Bara District. These data will be used to quantify major components of the ground water system.

4.1 Source

The primary source of ground water in Bara District is local precipitation. For example, ground water in the Bhabar deposits and the Terai Plain deposits is derived from precipitation that falls on Bara and the watersheds of the streams that traverse Bara, including the Siwalik areas of those watersheds. Ground water consists of precipitation that percolates through the materials on the earth's surface to the water table. Figure 16 illustrates the relationship between precipitation at Simra and water levels in selected wells.

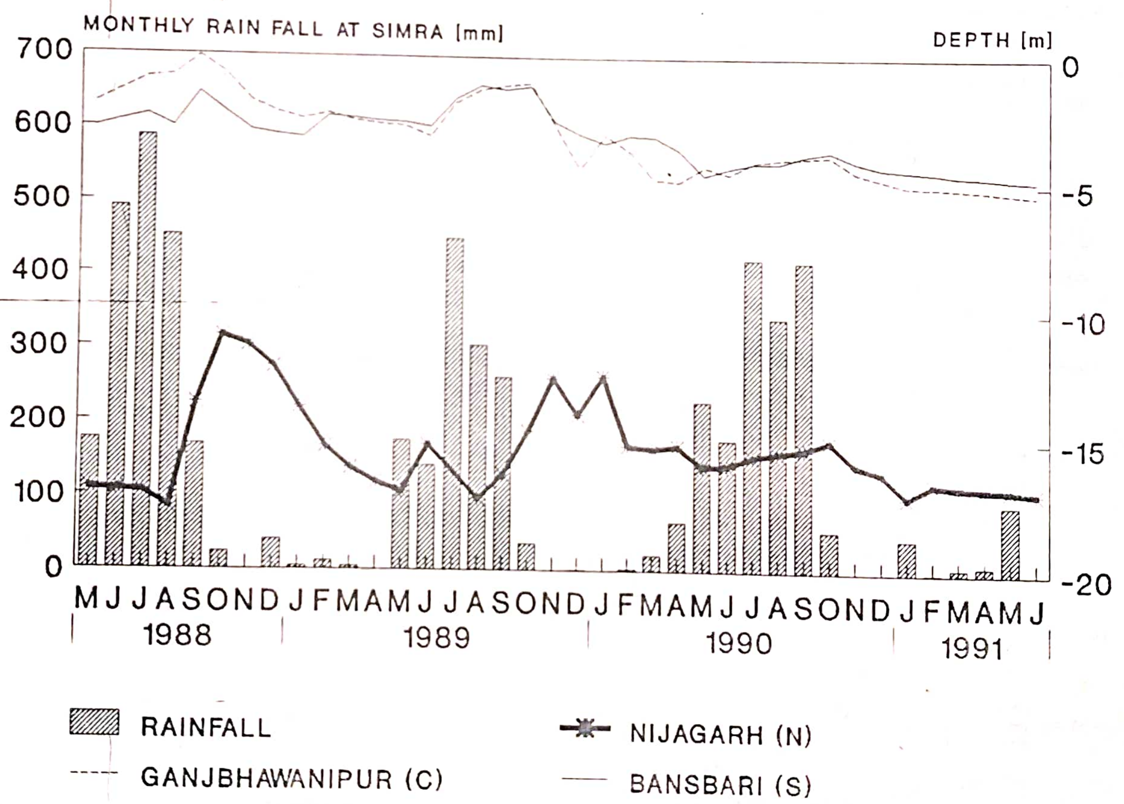


Figure 16. Relation between precipitation and depth to water table in selected wells, 1987-91

4.2 Occurrence and Movement

Water in unconsolidated aquifers occurs in the interstices between rock particles. The rate at which water will move through these aquifers depends on the hydraulic gradient and on the shape, size, and interconnection of the contained voids or interstices. The quantity of ground water available to wells depends on the areal extent and the saturated thickness of the aquifer. Interstices in sand and gravel are larger and better connected than interstices in silt and clay, Thus, water will move freely through a coarse gravel under a low hydraulic gradient, but will move with extreme slowness through clay under a high hydraulic gradient.

The shape and slope of the water table in May, pre-monsoon, and September, post-monsoon, 1990 in Bara District are shown on Figures 17 and 18, respectively, by contours drawn through points of equal altitude of the water table. Ground water moves down gradient at right angles to the contours. The contours indicate that ground water was moving generally from north to south. The spacing of the contours indicates an average hydraulic gradient of about 1 1/4 meters per kilometer or 0.00125.

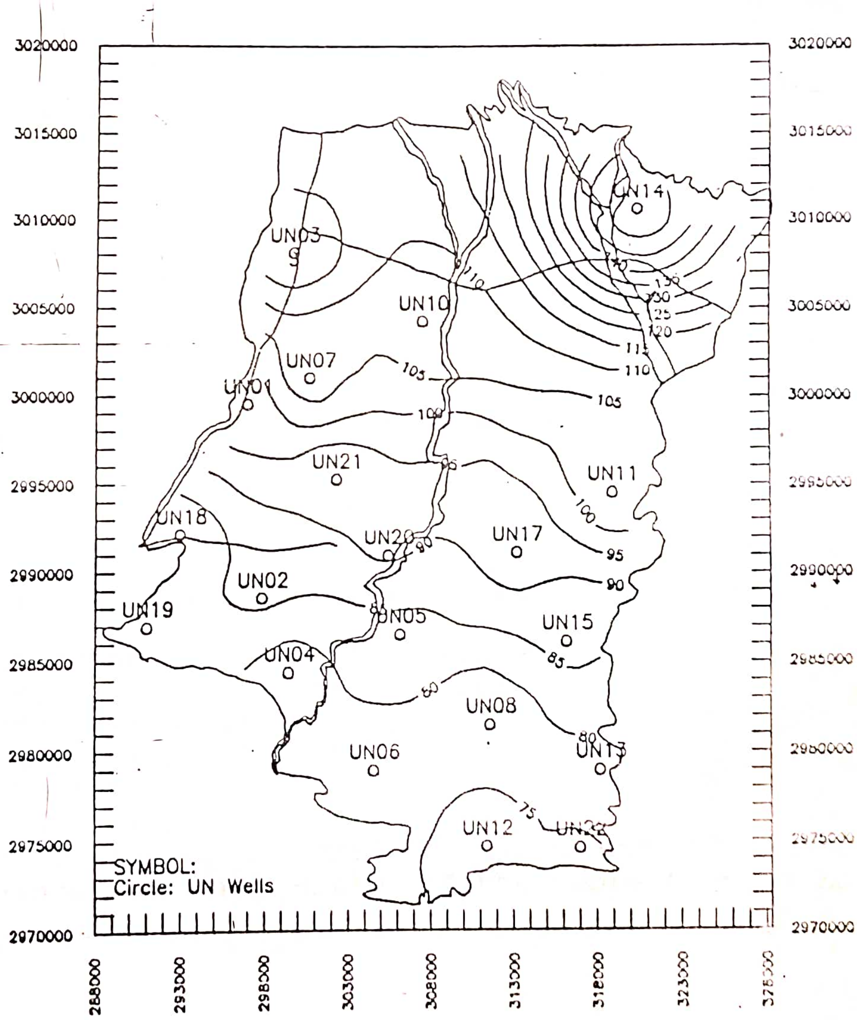


Figure 17. Water level contour in May 1990

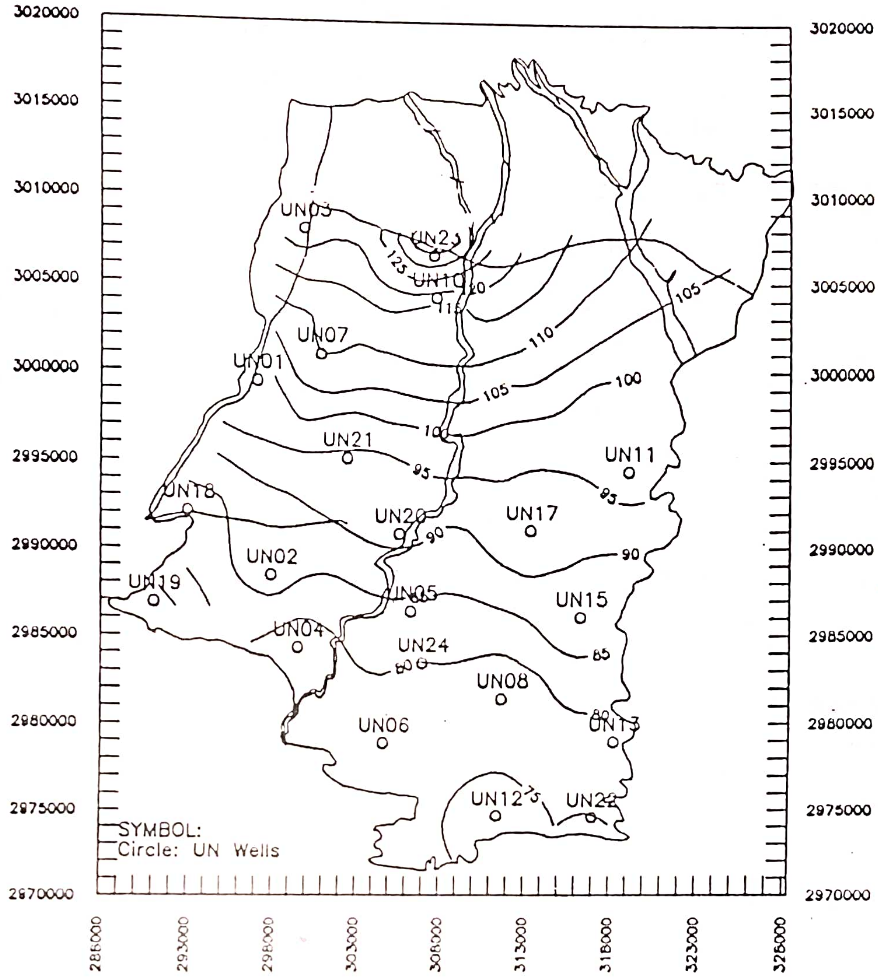


Figure 18. Water level contour map, September 1990

The quantity of water flowing through a given cross-sectional area of an aquifer can be computed by the formula:

$$Q = pAv = KIA = TIL$$

where Q is the quantity of water,
p is the porosity of the aquifer material,
A is the cross-sectional area,
v is the average velocity of ground water,
K is the hydraulic conductivity, and
T is the transmissivity
I is the hydraulic gradient.
L is the length

The approximate rate of movement of ground water through an aquifer is obtained by transposition of the above formula to:

$$v = KI/p$$

An estimate of the quantity of water moving as subsurface outflow to India is calculated using the following assumptions:

Transmissivity along India border is 280 m2/day
Hydraulic gradient of 0.00125
Aquifer width (length of border with India) is 30 km,

Q = TIL = 280 * 0.00125 * 30 = 10,500 m3/day or 3.8 MCM

The rate of flow is calculated using:

Hydraulic conductivity of 31 m/d
Hydraulic gradient of 0.00125
Assumed porosity of 15%

v = KI/p = (31 * 0.00125) / 0.15 = .26 m/day

The value for Q can also be calculated using the velocity above:

Assumed porosity of 15%
Aquifer saturated thickness is the average % of coarse grained material found in cross section II - II' at the south border of the district, about 9 m
Aquifer width is 30 Km
Velocity or rate of flow is 0.258 m/day

Q = pAv = 0.15 * 9 * 30 * 0.258 = 10,450 m3/day or 3.8 MCM

The two values for Q are in agreement.

The volume of water flowing to India through the upper 40 - 50 meters is about 4 MCM per year at a rate of 0.258 m/day.

4.3 Storage

The total thickness of the Terai sediments in Bara District is not known but if only the upper 50 meters are considered the volume of ground water in storage is quite large. The volume of drainable water is a function of thickness and specific yield of the saturated sediments. An average specific yield for sediments from a similar depositional environment and similar lithologies, the High Plains aquifer of the United States is .15 (Gutentag et.al., 1984). The drainable water in storage may be calculated by multiplying aquifer thickness, estimated specific yield and area of the aquifer.

The water levels in the Terai Plain deposits seldom are less than 5 m and in the Bhabar Zone deposits less than 10 m. Therefore, the Terai Plain would have 45 m and the Bhabar 40 m of saturated sediment in the upper 50 m.

The volume of drainable water in storage is not calculated because all the water in storage cannot be recovered and used. The recoverable volume of water is site specific and depends on well construction and design, lithology, saturated thickness, hydraulic conductivity, specific yield and drainage time.

4.4 Changes in Storage

A method to assess changes in the amount of ground water in storage in an aquifer involves periodic water-level measurements, construction of water-level-change maps from the measurements, and computation of the volume of material and water involved in the change. Unless heavy pumping disturbs natural conditions, the changes in storage in an aquifer reflect seasonal changes in evapotranspiration and precipitation. Water-level-change maps may illustrate, by minor fluctuations and trends, essentially static conditions in a relatively undisturbed aquifer.

The ranges of static water level in monitoring wells in different areas of Bara District from 1988 to 1991 are presented in Table 9.

Table 9.-- Range of static water level in m in monitoring wells.

Area	Average range of SWL in Pre-monsoon (1987-1990)	Average range of SWL in Post-monsoon (1987-1990)
NORTH	2.5 - 16	2.5 - 15
CENTRAL	1.8 - 3.5	1 - 2
SOUTH	2.5 - 4	1 - 2

Depth to water maps in May and September 1990 and the rise between them for dug and UN wells are shown in Appendix D. Note the difference in the contours of the two populations of wells.

The maps document pre and post monsoon changes which are attributed primarily to seasonal variations. However, comparision of the maps points out the differences in number of wells used for water level measurements. Not only are the distributions of wells different but also the aquifer may be different. Dug wells tap the very first water encountered in the sediments while STW reflect the water level of the aquifer where the screen is placed in the well. Tables of water level data collected during the project are presented in Appendix E. The fluctuation of water levels are shown by hydrographs for selected wells presented in Appendices F (existing STW), G (Dug) and H (UNSTW). The list of dug and private shallow tube wells are in table 10, below.

Table 10.-List of monitoring Dug wells and private STWs

S.No	Village Name	X	Y
1	NIZAGARH	322250	3007130
2	DUMARBANA	303500	3002500
3	BADAFARKHOLA	306250	3003130
4	BODHABAN	311125	2997630
5	KOLVI	319625	2995380
6	KHOPUWA	314875	2989880
7	BHATTAINIA	316750	2982380
8	BASBARIYA	308000	2973630
9	RAMNAGAR	319000	2977750
10	BISHNUPUR	308625	2975250
11	BELWATOLE	311125	2977880
12	CHHAPAKAIYA	312500	2982630
13	KABAHIGOTH	304875	2977880
14	GANJBHNAWANIPUR	306375	2989630
15	KALAIYA	302500	2992380
16	MATIARBA	298750	2983250
17	TREBENI	294875	2991000
18	BISHRAMPUR	292125	2986500
19	JEETAPUR	298125	3002880

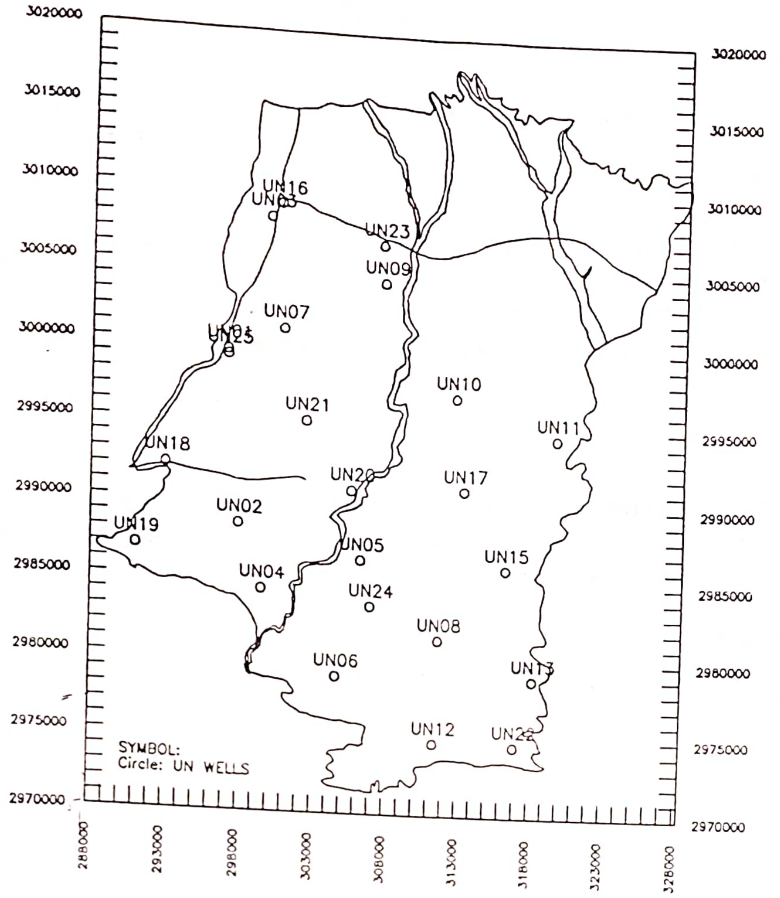


Figure 19. Monitoring network of project STWs

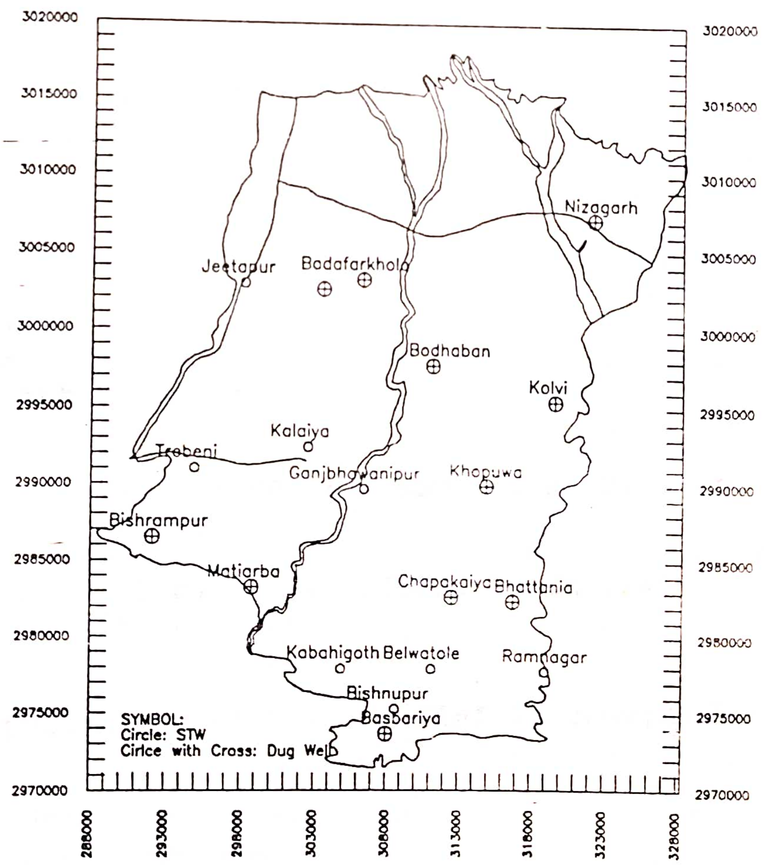


Figure 20. Monitoring network of dug and shallow wells

4.5 Recharge

The aquifer in Bara is recharged by subsurface inflow from stream valleys entering the district, by subsurface inflow from the Siwalik Hills, by seepage losses from streams during high flow and perennial flow, and by precipitation percolating directly through the soil and rock materials on the surface to the water table. These four increments of recharge result from local precipitation. Recharge of the aquifer from percolation of rainfall was calculated in 3 ways.

4.5.1 Percolation of rainfall

Percolation of precipitation into the aquifer is the primary recharge mechanism in Bara. The Bhabar Zone is particularly receptive to direct percolation to the water table because of the large size of the particles comprising the deposits. However, the balance of the Terai Plain is also receptive to direct percolation of precipitation to the aquifer. Finally, the Siwalik exposures may contribute additional recharge through percolation to the aquifer.

Three estimates of recharge from precipitation are calculated. The first method utilizes estimates from Duba (1982); method two assumes 10% of rainfall becomes recharge; the third method assumes a specific yield or effective porosity of saturated sediments and an average water level rise of 2.5 m in the district. Each method uses an area of 1100 km2 for the Terai in Bara District.

Method 1-

Duba (1982) estimated 31.1% of the rain that falls on the Bhabar Zone and 18.8% that falls on the Terai Plain would percolate to the aquifer. No estimate for the Siwaliks was made. The calculation for recharge using Duba estimates:

m3 of recharge = annual rainfall in m * area in Km2 * % rainfall to aquifer

For Bhabar Zone:

1.76 m * (360 * 1,000 * 1,000) [i.e. 360 km2] * .311
= 197 MCM recharge

For Terai Plain:

1.76 m * (740 * 1,000 * 1,000) [i.e. 740 km2] * .188
= 245 MCM recharge

Recharge = Bhabar Zone (197) + Terai Plain (245)
= 442 MCM per year

Method 2- Application of 10% of rainfall provides:

For Terai:

1.76 m * (1100 * 1,000 * 1,000) * .10
= 193.6 MCM per year

Method 3- Assume the storage coefficient or specific yield is .15, the annual water level fluctuation is 2.5 m over an area of 1100 Km2 in the district. The calculation is:

.15 * 2.5 m * (1100 * 1,000 * 1,000)
= 412.5 MCM per year

These estimates do not take into account rejected recharge due to soil saturation nor the increase of recharge possible if water levels were lowered by pumpage for irrigation below the depth of most evapotranspiration losses.

The difference between any of the methods of estimated recharge and the subsurface outflow into India of about 4 MCM per year is very large. The excess potential recharge is considered to be discharged through evapotranspiration (dominant component), inflow to streams (minor component) and also withdrawals from the aquifer by wells (currently a minor component).

4.6 Discharge

Ground water in the Terai of Bara is discharged from the aquifer by wells, evapotranspiration, subsurface outflow, and inflow to streams. The subsurface outflow from the district was determined in the section 4.2 on movement of water.

4.6.1 Pumping By Wells

Pumpage records for irrigation wells are not available, however, an estimate of pumpage may be calculated by assuming a specific number of irrigation wells, the number of hours each well is pumped in a year and the average yield of each well. The number of STW in 1986 was 1175 and has increased since and there are also some deep wells. An estimate of potential pumpage from 1,400 wells with an average estimated yield of 12 l/s pumped for 2,000 hours each year results in the following:

1400 wells * 2,000 hours * 3600 seconds * 12 liters per second
= 121 MCM potentially pumped per year in Bara

At the present time the wells are not pumping 2,000 hours a year, hence this estimate is illustrative of the relatively large volume of water that could be pumped with minimal effect on the aquifer.

4.6.2 Evapotranspiration

Direct evaporation occurs in areas where the water table is near the land surface, such as along stream banks and in stream beds. The potential for evaporation is high during the rice growing season as the paddies are really large bodies of surface water during that time. Finally, during and after the monsoon the water levels are at or near the surface at many places in Bara.

Transpiration by plants from the saturated zone is not confined to the water courses where large vegetation may be found. Rather, transpiration is occurring in the forests and from growing crops.

An estimate of potential evapotranspiration was made using the water table fluctuation between pre and post monsoon periods over the district. This assumes the principal cause of fluctuation to be loss of ground water due to evapotranspiration. The average fluctuation over the district is estimated at 2 1/2 m with 2 m of the fluctuation attributed to evapotranspiration, the specific yield of the saturated sediments is estimated at .15 and the area of Terai in the district is 1100 Km2. Thus:

$$2 \text{ m} * .15 * 1100 * 1000 * 1000 = 330 \text{ MCM}$$ of ground water potentially evapotranspired each year

Lowering the water table below the depth of most evapotranspiration processes would effectively permit the 330 MCM of ground water potentially evapotranspired each year to become recharge. This additional recharge would be available to irrigate crops.

4.7 Summary of Ground Water System

Recharge (addition of water to the aquifers), storage (retention of water in the aquifers), and discharge (diversion of water from the aquifers) are directly related to each other, in a ground water system. When recharge exceeds discharge, (during the monsoon period) the quantity of water in storage increases and the water table rises. Conversely, when discharge exceeds recharge, (during the dry period) the quantity of water stored decreases and the water table declines. The monsoon raises the water table as the aquifer is recharged by percolation of rain, seepage from streams and by subsurface inflow from the Siwaliks. The dry season lowers the water table as the water is pumped, evapotranspired, and moves in the subsurface toward the south.

The water level change maps reflect the recharge, change in storage and discharge of the Bara ground water system. The changes in water level appear to be due to seasonal variations. As agricultural practices replace the forests, no discernible effect has been made on seasonal water levels. Therefore, the ground water system in Bara District is maintaining a quasi-equilibrium state.

The recharge estimates, pumpage estimate and outflow to India estimate seem reasonable. Table 11 brings these figures together. This is not a water balance as a numeric estimate of water in storage is not provided. Water in storage is a large volume and only a part would provide water to wells.

Table 11.--Estimates of ground water recharge and discharge in Bara District.

Item	Recharge per year	Discharge per year
Recharge by 3 methods:		
1) Duba's estimate	442 MCM	
2) Conservative estimate (with 10% of rainfall)	193 MCM	
3) Calculation considering specific yield and fluctuation of W.T.	413 MCM	
Discharge		
Pumpage		121 MCM
Evapotranspiration		330 MCM
Outflow to India		4 MCM

Information on recharge, storage and discharge of the ground water system in Bara District is not complete. Several of the data components have not been measured or observed. However, estimates have been made for some major components with the thought that the estimates may be refined as data are collected in the future. Other components are not known nor estimated as their influence will become measurable during development of the ground water system. Table 12 lists the status of data components ~~required to describe the Bara~~ ground water system.

Table 12.--Status of components required to describe the Bara ground water system.

COMPONENT	AVAILABLE	M(measured) E(estimated)	RELIABILITY	AREAL DISTRIBUTION
Siwalik information	No			
Bhabar Zone delineation	No			
Terai Plain delineation	No			
Detailed well inventory	No			
Lithology of wells	Yes	M	Adequate	Adequate
Aquifer tests	Yes	M	Poor	Poor
Storage coefficient	Yes	E		
Transmissivity	Yes	M	Poor	Poor
Leakage	No			
Water level measurements	Yes	M	Adequate	Adequate
Weather records	Yes	M	Adequate	Adequate
Pumpage records	Yes	E		
Stream flow records	No			
Evaporation and Transpiration data	No	E		

5. UTILIZATION OF GROUND WATER

Ground water in Bara District is utilized by families, villages, towns and schools for drinking water; for watering animals; for business and industrial purposes; but the largest use and the use that seems destined to have a large increase in the future is for irrigation of crops. According to the statistics from Table 13, only 30% of the potential irrigation land in Bara is irrigated the whole year, leaving 70% or about 42,000 hectares that could be irrigated the whole year. The food requirements of the expanding population of Nepal will require more and more year around irrigation in the Terai and therefore in Bara District. Ground water will provide a large part of the water to irrigate the potential irrigation land.

Table 13.-- Status of potential irrigation land in Bara District (1988-89)

Item		Area in Ha
Total Agriculture Land		60666
Land that cannot be irrigated		276
Potential Irrigation Land		60390
Land being Irrigated	By monsoon	23723
	Year round	18413
	Total	42136
Remaining Potential Year Around Irrigation Land		41977

6. SHALLOW IRRIGATION WELL FEASABILITY

Areal delineation of the feasibility of Shallow Irrigation Wells in an area is a major goal of the project. The criteria defining a SIW are listed below:

1) a water level that does not exceed 7 m in depth in the dry season while pumping
2) a discharge adequate to irrigate an individual farm, as required
3) no deeper than 50 m
4) 100 mm or 4 inches (in) in diameter
5) use a centrifugal pump
6) powered by a diesel or electric motor
7) drilled by indigenous methods, if possible

The definition includes depth, diameter, energy source, type of pump and method of drilling a well; all predicated to be within the range of resources a farmer may command.

Figure 21 delineates the area in Bara District where contours of depth to water table have not exceeded 5 m during the dry season (pre-monsoon) since the project began. The May water levels are used as they reflect the pre-monsoon conditions.

The depth to water criterion is the most important hydrologic constraint in the above definition of a SIW. Wells in the Terai will almost always find water but the wells may not yield water to a centrifugal pump during the dry season if the depth to water exceeds 7 m. Thus, the dynamic water level of a well during the dry season should be within the suction limit of lift of a centrifugal pump i.e. water level must be less than 7 m below ground level or more accurately below the pump level. If the 5 m depth to water contour represents the depth to water in most dry seasons there should be 2 m of drawdown to be exceeded before a well would cease to produce irrigation water in the designated areas.

Wells drilled to 50 m should find about 38 m of aquifer material, on average in Bara. This also means that some wells may find practically no aquifer and some wells may find practically all aquifer. In other words, holes will be drilled which will be unsuccessful wells because there is insufficient aquifer at that location.

The practice of drilling test holes to assist in choosing a productive location to place an irrigation well is common and frequently required in many ground water areas in many countries. The depositional environment of the aquifers in the Terai is such that very different lithologies may be encountered in two test holes within relatively few meters of each other.

Discharge of the tube well should be adequate for irrigation, which is considered to be a yield of 3 to 5 l/s or more. The average individual farms in Bara is 1.6 ha in area in 1981 (SPBN). A well that pumps 5 l/s could cover 1.6 ha with about 5 centimeters (cm) of water in 48 hours. Thus the average farm could be irrigated with such a well. However, it is questionable if average size farms in Bara are economically viable, even with the technology limited by the SIW definition. The limiting factor, economically, is the average size of a farm.

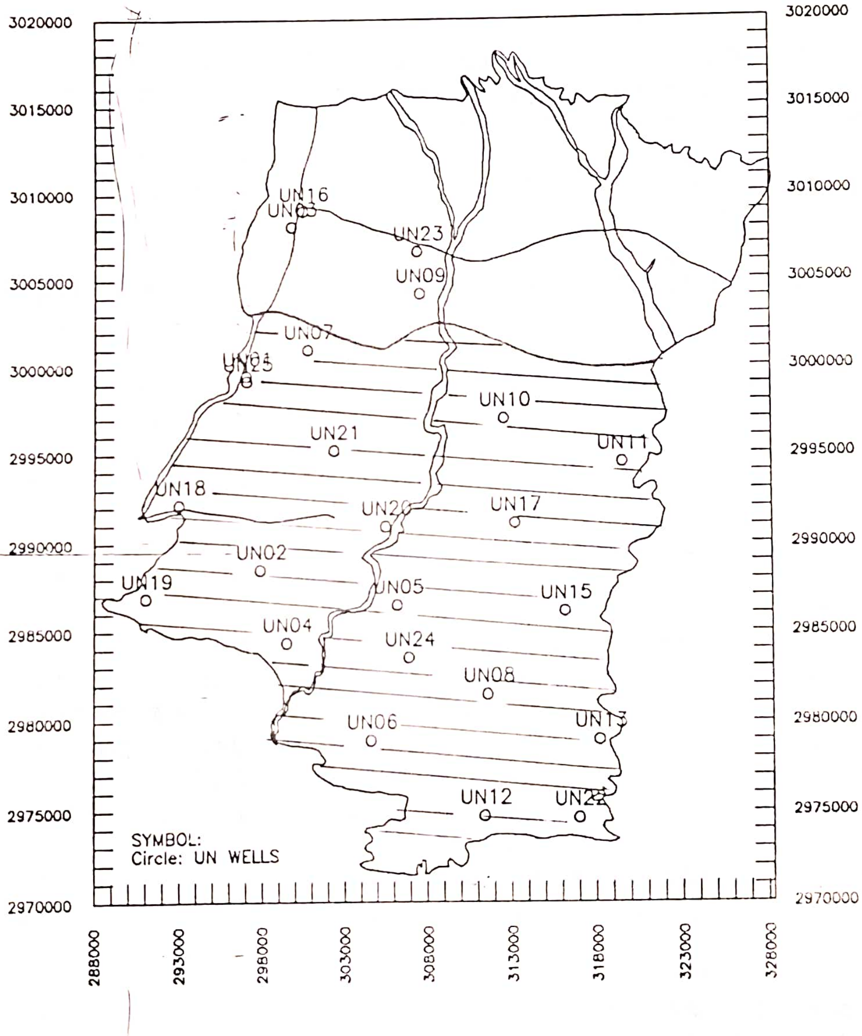


Figure 21.--Shaded pattern area shows probable SIW area in Bara District

7. SUMMARY AND RECOMMENDATIONS

7.1 Summary

The study of the shallow ground water resource of Bara District is part of a study of ground water throughout the Terai. The project, NEP/86/025 is a cooperative effort by the United Nations Department of Technical Co-operation for Development and the Ground Water Resources Development Board, HMG, Nepal.

Field work for this report began in the Spring of 1987 and for the most part was completed in 1989. The work consisted of drilling wells, making water level measurements, lithologic determinations, altitude surveys of land surface at wells, and aquifer tests.

There were 25 wells drilled for this project, 17 were drilled manually and 8 by rotary rig. The average depth of the wells was about 38 meters. About 42% of the sediments encountered were sand and gravel and are considered an aquifer. The central part of the district provides higher transmissivities according to the pumping tests.

Twenty-three pumping tests were completed. Transmissivities range from 20 to 7,000 m^2/day.

The water level monitoring network progressed from dug wells in 1987 to project STW with some private STW in 1991. As expected, the wells have the deepest water levels just prior to the monsoon and the shallowest water levels just after the monsoon. Water level contour maps indicate the ground water flows from north to south with a gradient of about 1 1/4 meters per kilometer at the Indian border.

The aquifer in Bara is recharged primarily by precipitation percolating directly through the soil and rock materials on the surface to the water table. The Bhabar Zone is particularly receptive to direct percolation to the water table because of the large size of the particles comprising the deposits. However, the Terai Plain is also receptive to direct percolation of precipitation to the aquifer. Almost 450 MCM per year may potentially be recharged. A minimum estimate of about 200 MCM compares favorably with the estimated 4 MCM of water flowing to India per year.

The water level change maps reflect the recharge, change in storage and discharge taking place in the Bara ground water system. The change maps indicate the system is maintaining equilibrium as agricultural practices replace the forests. Put another way, stress on the aquifer, for the short period of record of this project, shows no discernible effect on the water level maps.

7.2 Recommendations

Ground water in Bara District is utilized by families, villages, towns and schools for drinking water; for watering animals; for business and industrial purposes; but the largest use and the use that seems destined to have a large increase in the future is for irrigation of crops. This report provides valuable data for planning and continuing development of the ground water resource but large scale development in a specific area should include additional investigative wells and properly designed and completed aquifer tests to help maximize success.

8. GLOSSARY OF TERMS

Aquifer: A rock formation, bed, or zone that contains water that is available to wells. An aquifer is sometimes referred to as a water-bearing rock, or water-bearing bed.

Evapotranspiration: The combined total water evaporated by heat energy and transpired by plants into the atmosphere.

Gaining stream: A stream or reach of a stream whose flow is being increased by inflow of ground water. Replaces the term "effluent stream."

Ground water: Water in the saturated zone or water below the water table.

Hydraulic conductivity: A measure of the rate of flow of water through an aquifer, which is dependent primarily on the nature of the interstices within the aquifer. Expressed in units of length per units of time that are consistent and suitable to the problem involved.

Hydraulic gradient: Gradient of the water table measured in the direction of the greatest slope, generally expressed in meters per kilometer.

Inflow: Movement of ground water into an area in response to a hydraulic gradient.

Interstice: An opening or void in a rock. Interstices may be filled with air, gas, oil, water, or some other material, The interstices in an aquifer are filled with water.

Outflow: Movement of ground water from an area in response to a hydraulic gradient.

Percolation: The movement of water through soil and rock to the saturated zone.

Permeability: The capacity of water-bearing rock or soil to transmit water, which is related to the size and interconnection of interstices. Replaced by the term "hydraulic conductivity."

Porosity: The porosity of a rock is its property of containing openings or interstices. Quantitatively, the porosity of a rock is the ratio (usually expressed as a percentage) of the volume of openings in the rock to the total volume of the rock.

Recharge: The process by which water is absorbed and added to the saturated zone. Also used to designate the quantity of water added to the ground-water reservoir.

Runoff: The discharge of water through surface streams. It includes both surface-water runoff and ground-water runoff. Also used to designate the quantity of water discharged as runoff.

Saturated zone: The zone of porous rocks saturated with water. Ground water is contained in this zone.

Specific yield: also called effective porosity (Johnson, 1967), is defined as the ratio of (1) the volume of water that the saturated sediment will yield by gravity drainage to (2) the total volume of saturated rock. Specific yield is expressed as a dimensionless fraction or percentage. Specific yield depends on particle size, shape, sorting, and cementation of the aquifer material and drainage time.

Specific retention: It is the difference between porosity and specific yield and is defined as the ratio of (1) the volume of water retained in the rock after gravity drainage to (2) the total volume of the saturated rock.

Storage: Water stored in openings in the saturated zone is said to be in storage. Discharge of water from an aquifer not replaced by recharge is said to be from storage.

Storage coefficient: The volume of water released from or taken into storage per unit surface area of an aquifer per unit change in the component of head normal to that surface.

Transmissibility: The transmissibility of a rock or soil is its capacity to transmit water under pressure. Replaced by the term "transmissivity."

Transmissivity: The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Expressed in units of length squared per units of time. Replaces the term "coefficient of transmissibility." To convert a value for coefficient of transissibility to an equivalent value of transmissivity, multiply by 0.134.

Water table: The upper surface of the saturated zone where the pressure is atmospheric. The water table is not a plane surface, but has irregularities much like the land surface.

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APPENDIX A

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-operation for Development. It is designed as a four year project primarily oriented to collect field data to establish a ground water data base and to assess the development potential of shallow aquifers all over the Terai. The government counterpart agency is the Ground Water Resources Development Board (GWRDB) under the Department of Irrigation (DOI), Ministry of Water Resources, HMG, Nepal. The project began in June 1987.

The immediate objectives of project NEP/86/025 are:

(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 technical capacity of GWRDB with regard to exploration, assessment and development of ground water resources.

The following project outputs are anticipated:

(a) Computerized data base with about 2000 shallow water points from all over the Terai. This was expanded in December 1988 to include deep wells. Information on well location, lithology, hydrogeological parameters, water use, water levels, and etc.

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

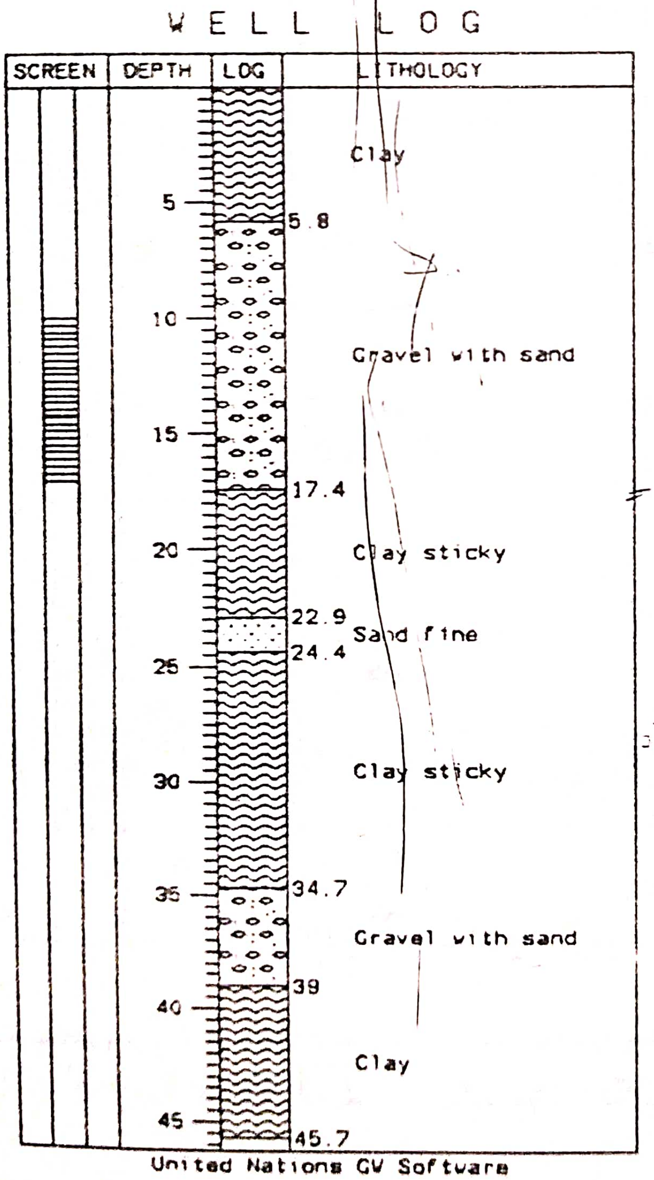
(c) Hydrographs (water level graphs) from selected observation points in a minimum period of eleven months.

(d) Reports on mathematical modelling.

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

APPENDIX B
LITHOLOGICAL LOGS

Well No UN 01	Location: CHHATA PIPARA
Elevation: 110	X = 297050 Y = 2999500
Method of Drilling	RIG
Drilling Dates	29.12.89 - 3.1.90
Total Depth	45.70
Comments .	Well size: 4" Screen position: 10.0 - 17.0 m Screen type: Slotted Drilled under UNDP Project



PUMPING TEST

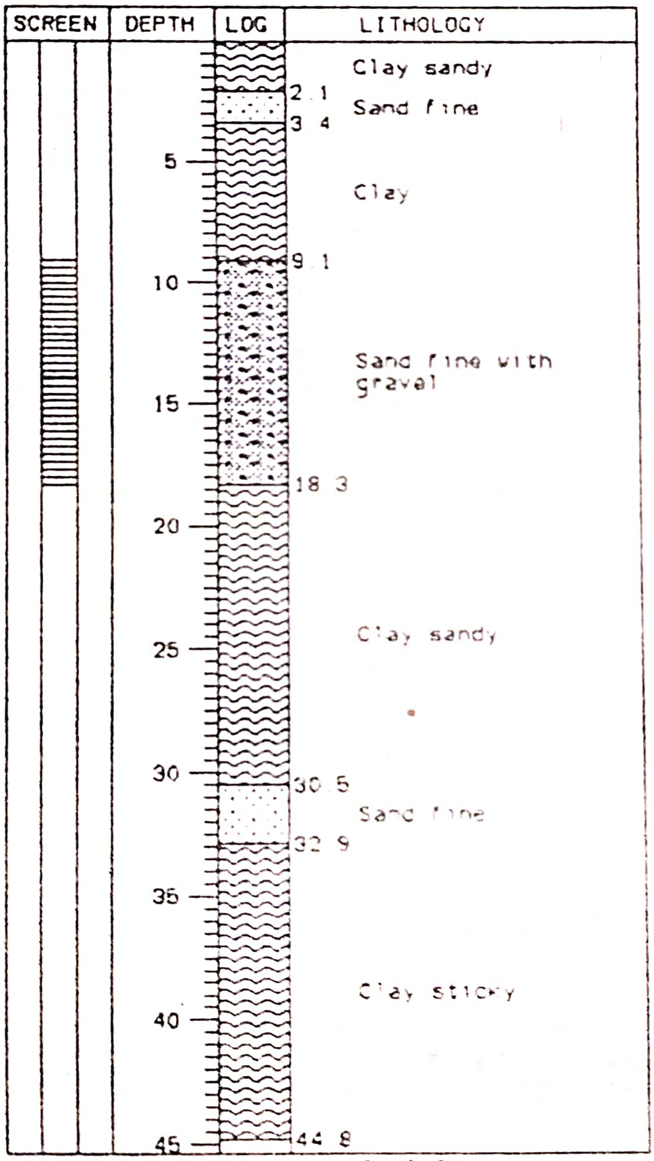
Date: 11.01.1990
Capacity: 17.0 l/s
Duration: 270 min
Transmiss.: 1000 m2/d
Method: JACOB
Stor Coeff.: 0.14E-02
SWL: 1.12 m (B.GR.L)
DWL: 6.15 (B.GR.L)

Evaluation of drawdown result in pumping well is with 8700 m2/day not reliable.

B-1: Well Log of UN 01

Well No: UN 02	Location: PHETA
Elevation: 90	X = 297900 Y = 2988500
Method of Drilling: MANUAL	
Drilling Dates: 5.1.90 - 10.1.90	
Total Depth: 44.80	
Comments: Well size: 4" Screen position 9.1 -15.2 m, 15.2 - 18.3 m Screen type: Slotted and Jonson type Drilled under UNDP Project	

WELL LOG



United Nations GW Software

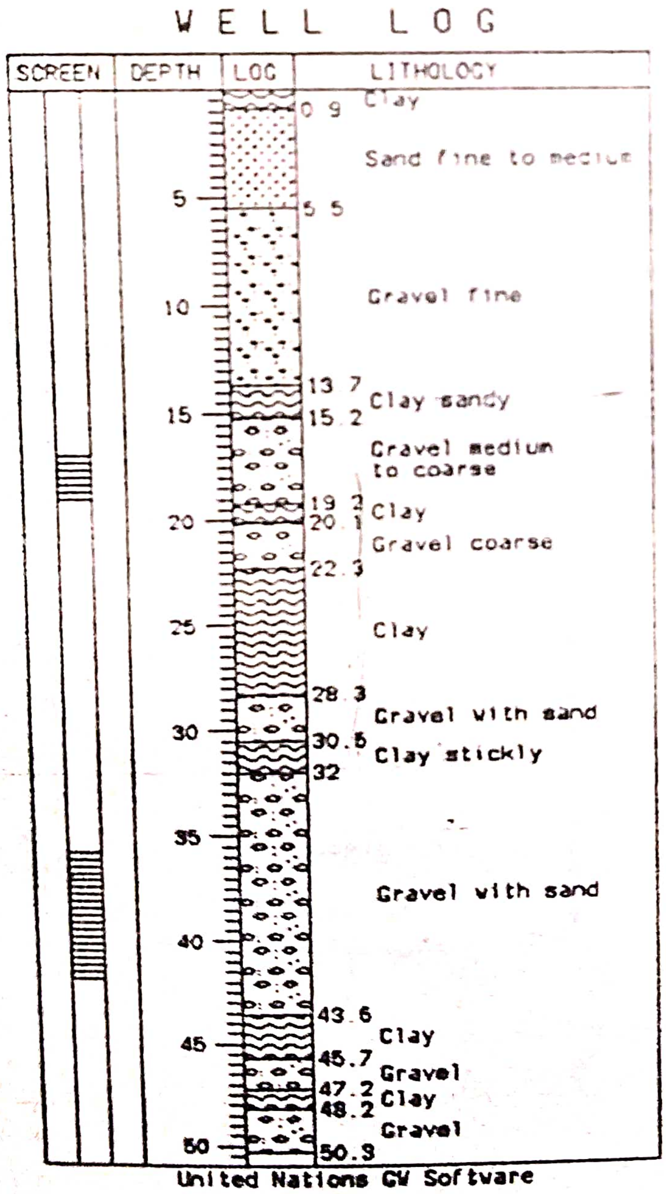
PUMPING TEST

Date: JAN 1990
Capacity: 10 l/s
Duration: 210 min
Transmiss.: 400 m2/d
Method: JACOB
Stor Coeff.: 0.86E-03
SWL: 3.47 m (B.GR.L)
DWL: 6.47 m (B.GR.L)

B-2: Well Log of UN 02

Well No UN 03	Location: SIMARA
Elevation 137	x = 299800 y = 3008100
Method of Drilling: RIG	
Drilling Dates : 11 1 90 - 20 1 90	
Total Depth 50 30	

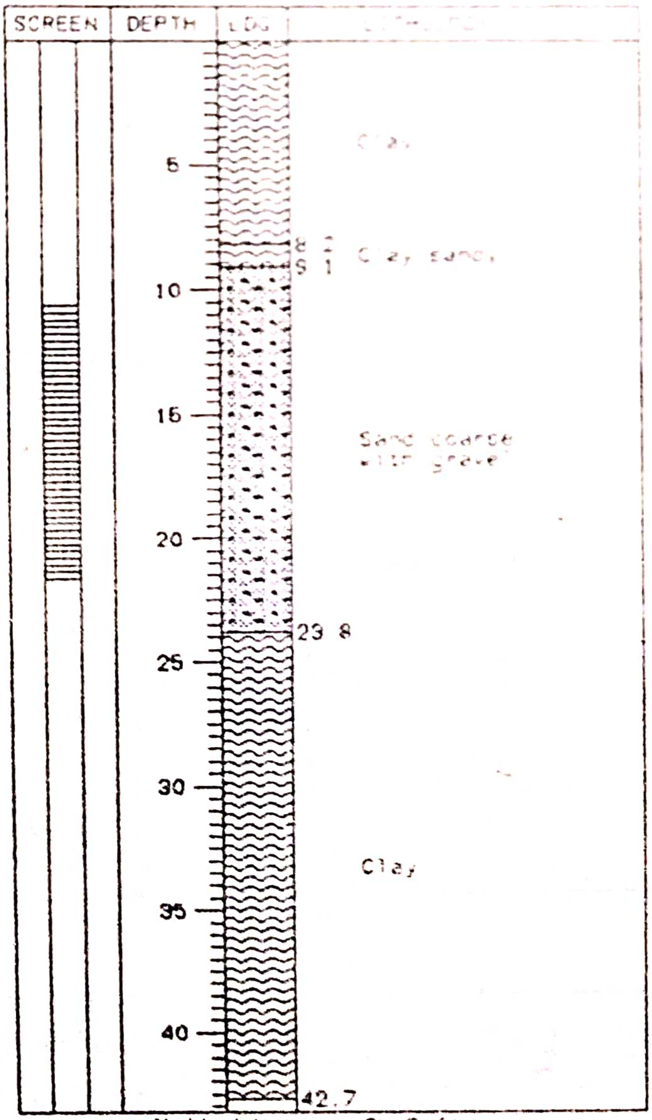
Comments : Well size 6/4"
Screen position 16 8 - 18 9 m
35 7 - 41 8 m
Screen type slotted
Drilled under UNDP Project



B-3: Well Log of UN 03

Well No. UN 04	Location MATIARWA
Elevation: 85	X = 299500 Y = 2984350
Method of Drilling: MANUAL	
Drilling Dates	10 1 90 - 15 1 90
Total Depth	42.70
Comments:	Well size 4" Screen position 10.6 - 21.6 Screen type Johnson Drilled under UNDP

WELL LOG



United Nations GW Software

PUMPING TEST

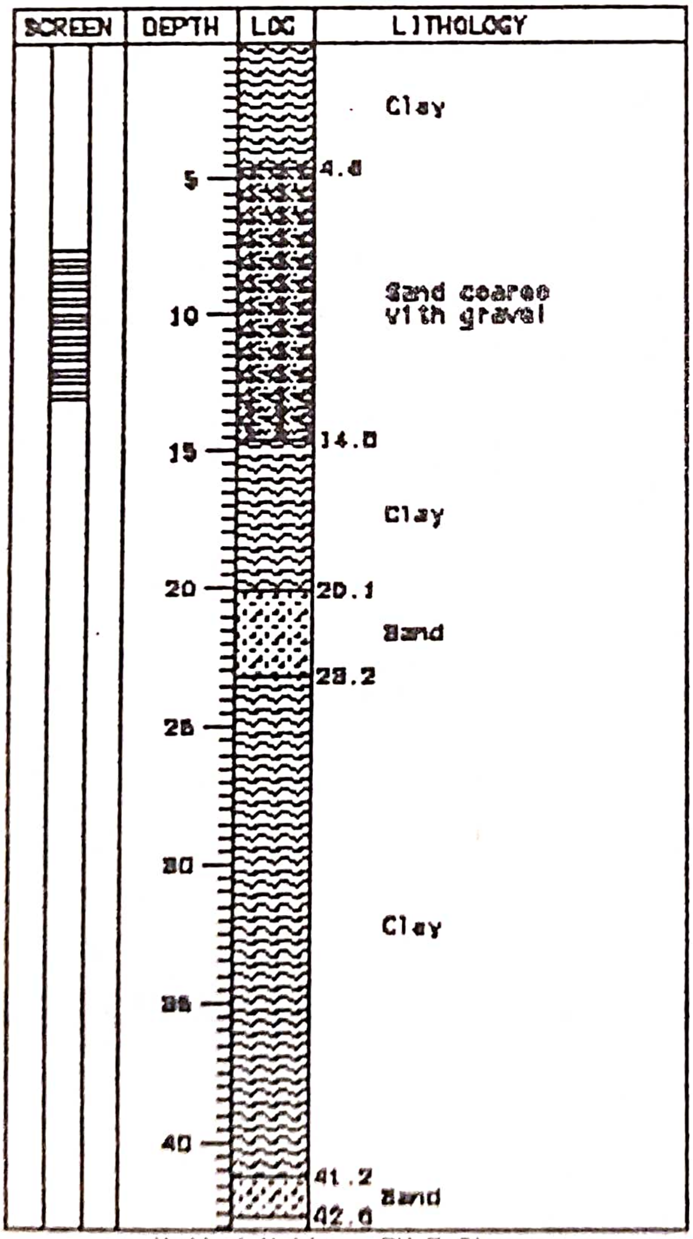
Date: 15.1.90
Capacity: 12 l/sec
Duration: 180 min
Transmiss.: 750 m2/day
Method: H Leaky/Jacob.
Stor Coeff.: 0.20E-02
SWL: 3.50 m (B.Gr.L)
DWL: 3.67 m (B.Gr.L)

Pumping well shows 3700 m2/day

B-4: Well Log of UN 04

Well No. UN 05	Location: BARIYARPUR
Elevation: 87	X - 306200 Y - 2985460
Method of Drilling: MANUAL	
Drilling Dates : 16.1.90 - 22.1.90	
Total Depth : 42.60	
Comments : Well size: 4" Screen position: 7.6 - 13.1 Screen type: Johnson Drilled under UNDP	

WELL LOG



United Nations GW Software

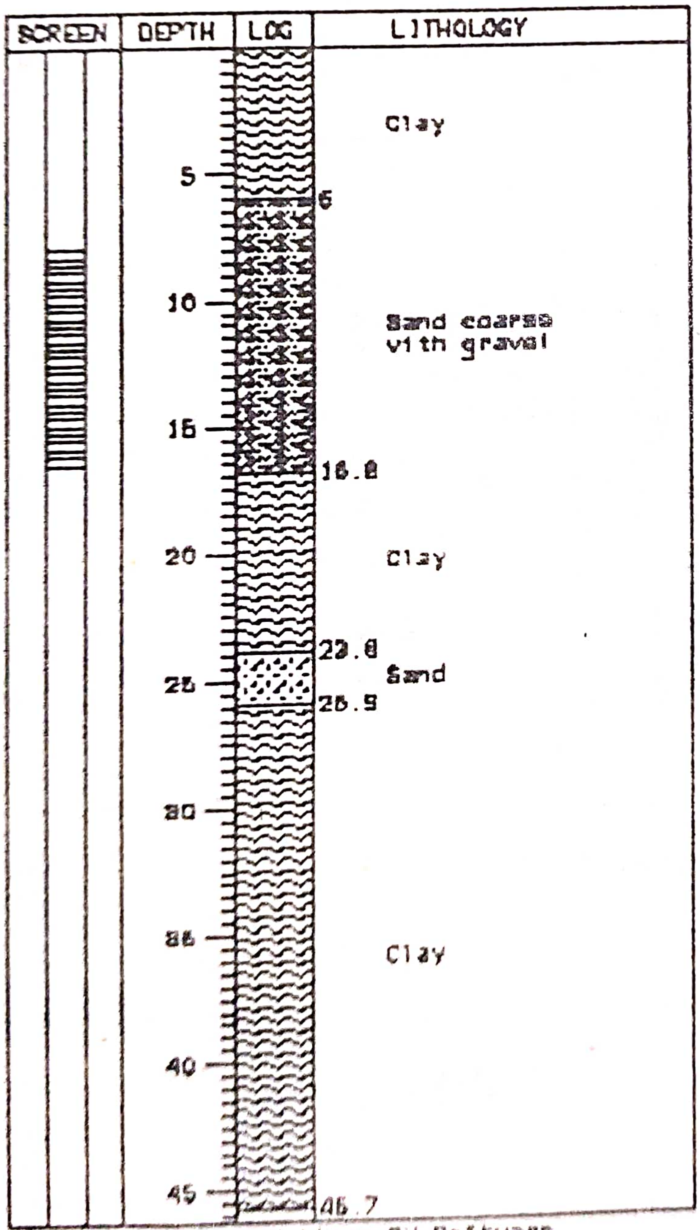
PUMPING TEST

Date: 22.1.90
Capacity: 7 l/sec
Duration: 12 min
Transmiss.: 675 m2/day
Method : THEIS
Stor.Coeff.: 0.35E-03
SWL: 3.72 m (B.Gr.L)
DWL: 4.13 m (B.Gr.L)

B-5: well Log of UN 05

Well No. UN 06	Location: KABAHI GOTH
Elevation: 78	X - 304600 Y - 2978900
Method of Drilling: MANUAL	
Drilling Dates : 24.1.90 - 28.1.90	
Total Depth : 45.70	
Comments : Well size: 4" Screen position: 7.9 - 16.4 m Screen type: Slotted & Johnson Drilled under UNDP	

WELL LOG



United Nations GW Software

PUMPING TEST

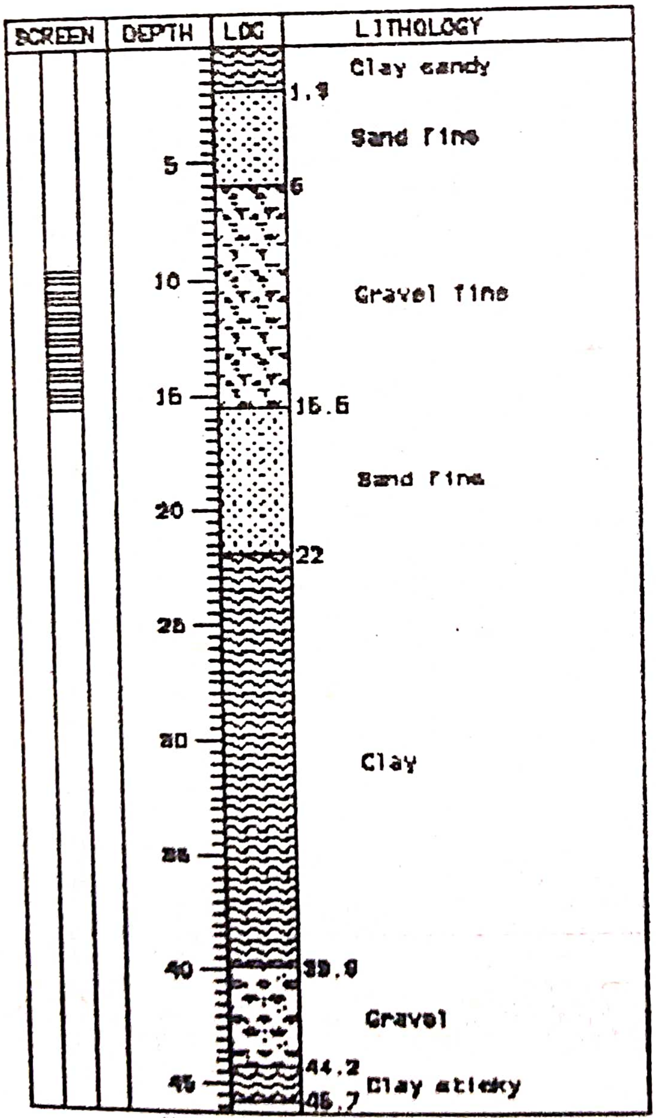
Date: 28.1.90
Capacity: 10 l/sec
Duration: 90 min
Transmiss.: 550 m2/day
Method : JACOB
Stor.Coeff.: 0.43E-06
SWL: 2.02 m (B.Gr.L)
DWL: 5.87 m (B.Gr.L)

B-6: Well Log of UN 06

Well No. UN 07	Location: KHESRAUL
Elevation: 112	X - 300800 Y - 3001000
Method of Drilling: RIG	
Drilling Dates : 23.1.90 - 30.1.90	
Total Depth : 45.70	

Comments : Well size: 4"
Screen position: 9.5 - 15.5 m
Screen type: Slotted
Drilled under UNDP Project

WELL LOG



United Nations GW Software

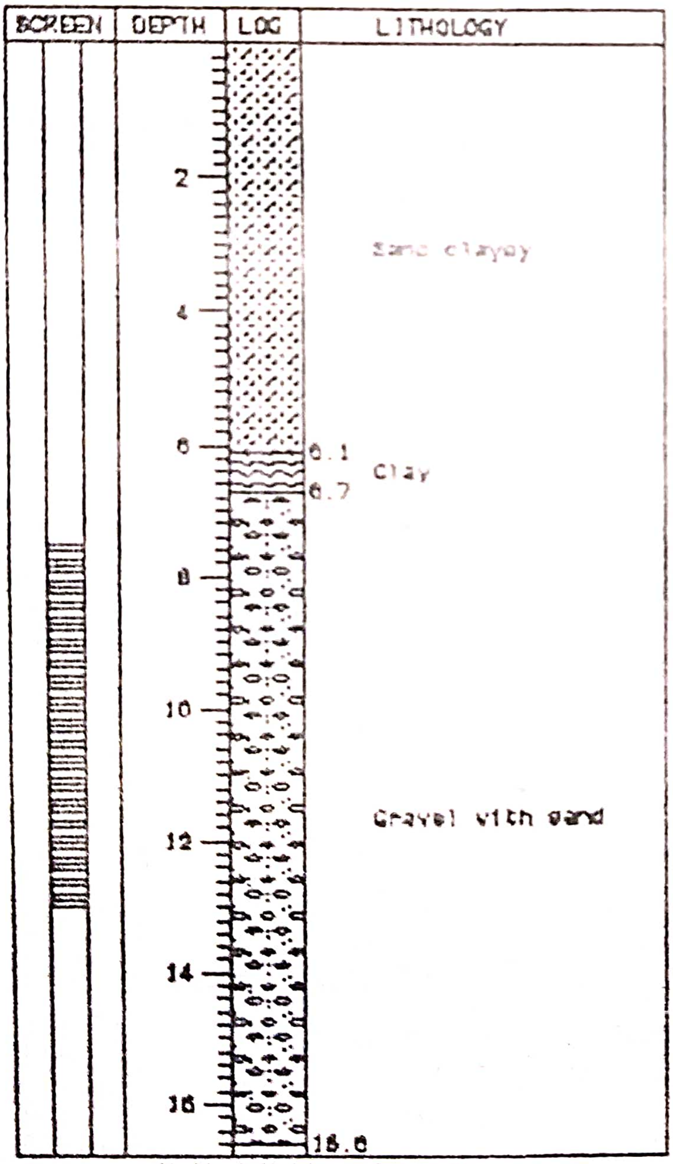
PUMPING TEST

Date: 9.2.90
Capacity: 11.1 l/s
Duration: 240 min
Transmiss.: 1000 m2/day
Method : JACOB
Stor.Coeff.: 0.27E-03
SWL: 2.20 m (B.Gr.L)
DWL: 6.02 m (B.Gr.L)

B-7: Well Log of UN 07

Well No. UN 08	Location: KUDWA
Elevation: 82	X = 311600 Y = 2981450
Method of Drilling: MANAUL	
Drilling Dates : 30.1.90 - 2.2.90	
Total Depth : 16.60	
Comments : Well size: 4" Screen position: 7.5 - 13.0 m Screen type: Johnson Drilled under UNDP	

WELL LOG



United Nations GW Software

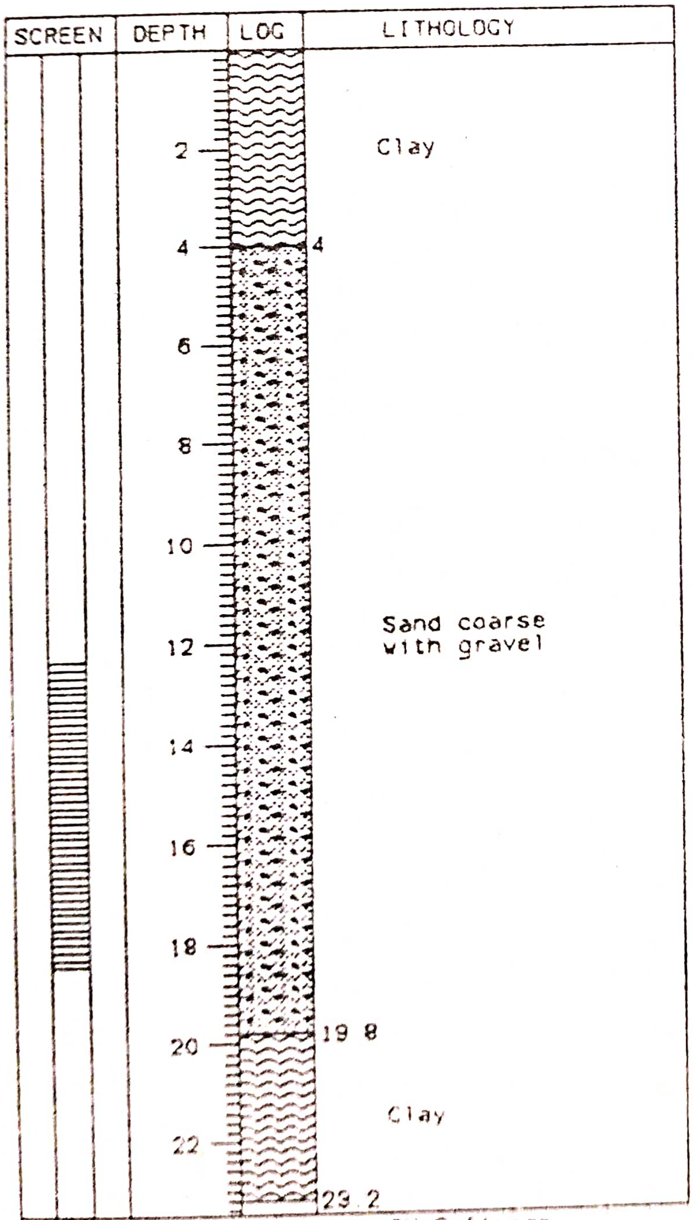
PUMPING TEST

Capacity: 7 l/sec
Duration: 100 min
Transmiss.: 300 m2/day
Method : THEIS
SWL: 4.95 m (B.Gr.L)
DWL: 8.46 m (B.Gr.L)

B-8: Well Log of UN 08

Well No UN 09	Location: BARDAHAWA
Elevation: 134	X = 307600 Y = 3004200
Method of Drilling	RIG
Drilling Dates	31 1 90 - 4 2 90
Total Depth	23 20
Comments	Well size: 4" Screen position 12 3 - 18 4 m Screen type: Slotted Drilled under UNDP Project

W E L L L O G



United Nations GW Software

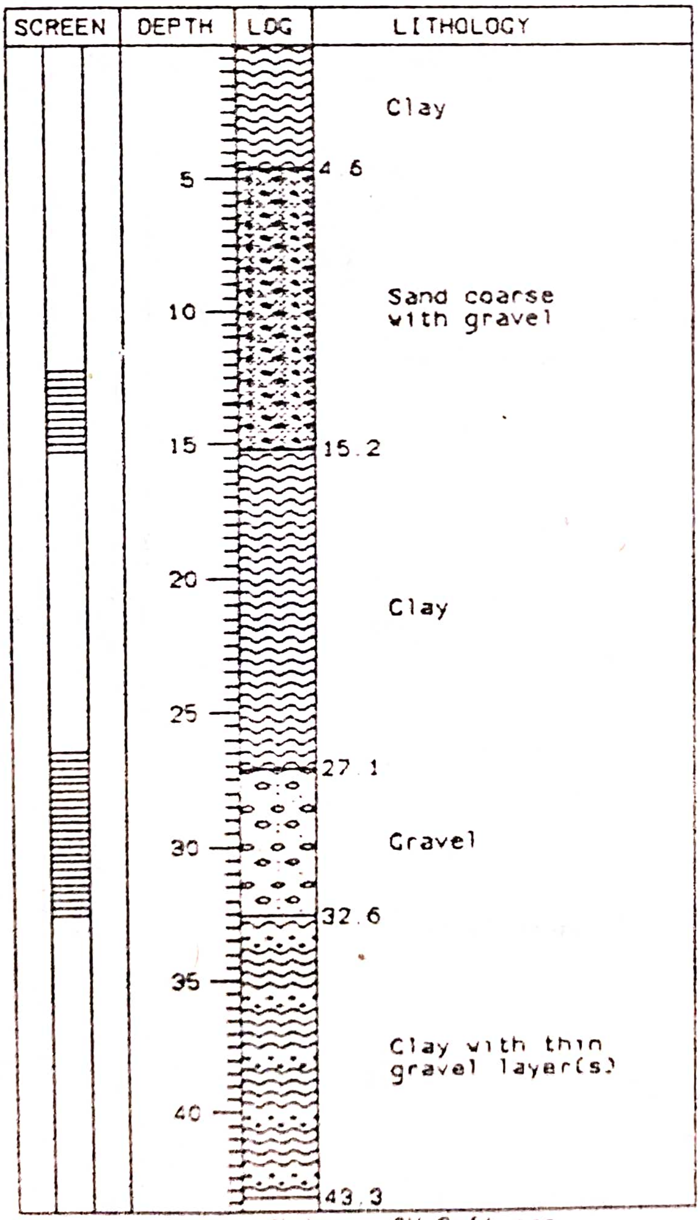
PUMPING TEST

Date: March 90
Capacity: 16 l/sec
Duration: 70 min
Transmiss.: 2000 m2/day
Method: JACOB
Stor Coeff.: 0 31E-03
SWL: 1.84 m (B.Gr.L)
DWL: 3 26 m (B Gr.L)

B-9: Well Log of UN 09

Well No UN 10	Location: BODHABAN
Elevation: 110	X = 312600 Y = 2997000
Method of Drilling: RIG	
Drilling Dates : 5.2.90 - 8.2.90	
Total Depth : 43.30	
Comments : Well size: 4" Screen position: 12.2 - 15.2 m 26.4 - 32.5 m Screen type: slotted pipe Drilled under UNDP Project	

W E L L   L O G



United Nations GW Software

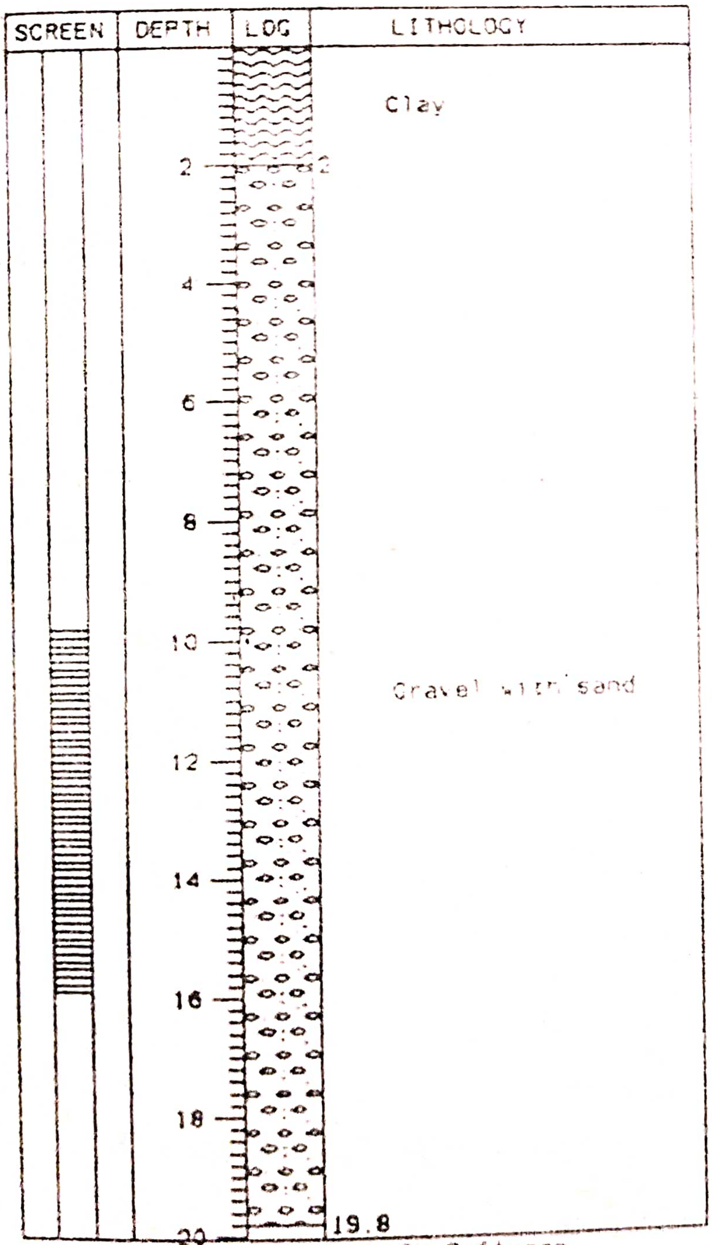
PUMPING TEST

Date: March 90
Capacity: 20 l/s
Duration: 240 min
Transmiss.: 750 m2/day
Method : JACOB
Stor.Coeff : 0.29E-02
SWL: 1.83 m (B.Gr.L)
DWL: 6.80 m (B.Gr.L)

B- : Well Log of UN 10

Well No UN 11	Location: KOLVI
Elevation: 105	X = 319000 Y = 2994500
Method of Drilling: RIG	
Drilling Dates 9 2 90 - 17 2 90	
Total Depth 19.80	
Comments Well size: 4" Screen position 9.8 - 15.9 m Screen type: Slotted Drilled under UNDP	

W E L L L O G



United Nations GW Software

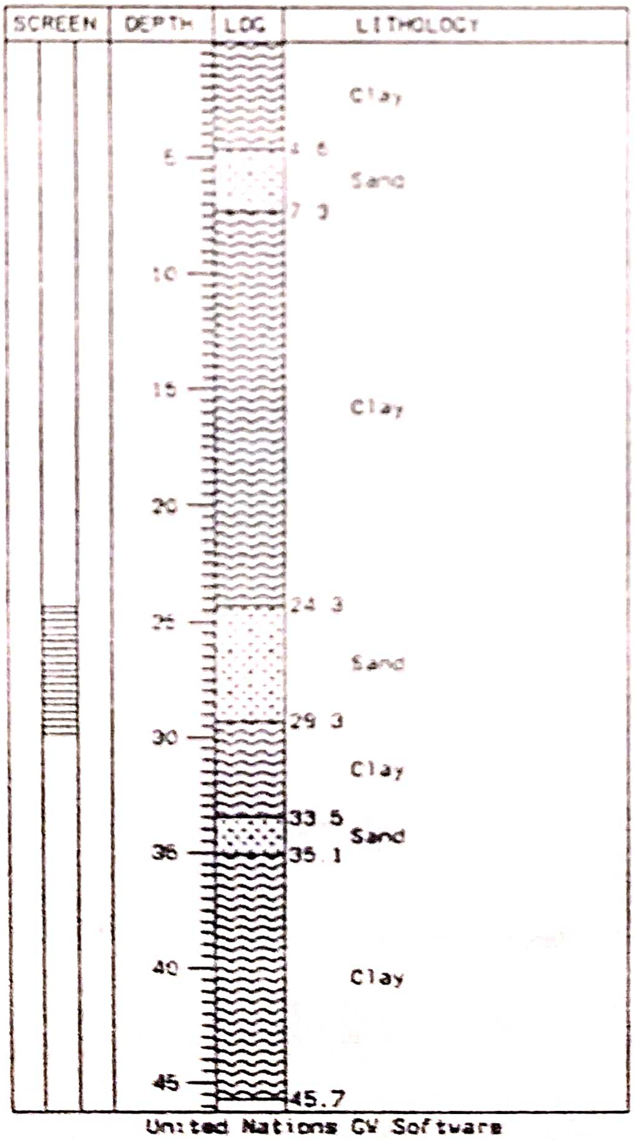
PUMPING TEST

Capacity 14 l/sec
Duration 30 min
Transmiss 7500 m2/day
Method Theis
SWL 2.23 m (B Gr L)
DWL 3.25 m (B Gr L)

B-11: Well Log of UN 11

Well No UN 12	Location: SHRINAGAR BAIRIYA
Elevation: 70	X = 311400 Y = 2974700
Method of Drilling: MANUAL	
Drilling Dates	4 1 90 - 10 1 90
Total Depth	45 70
Comments	Well size 4" Screen position 24 3 - 29 8 m Screen type Johnson Drilled under UNDP

W E L L   L O G



PUMPING TEST

Date 2 11.90
Capacity 8 l/sec
SWL 3 64 m (B Gr L)

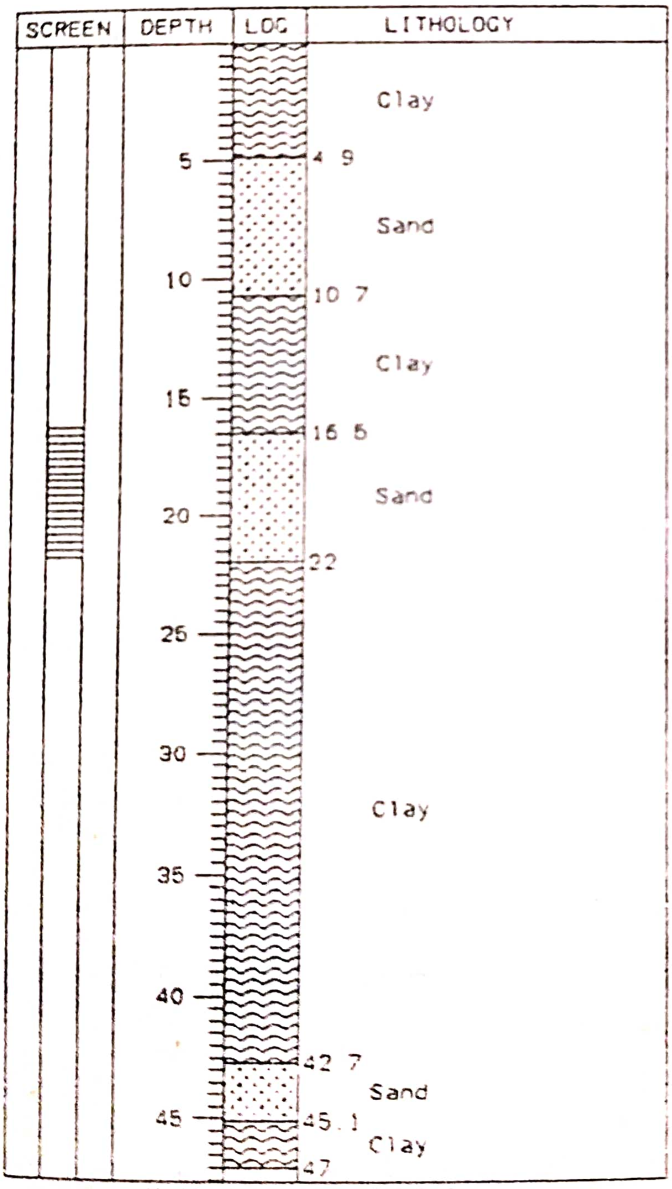
Pump test fell due to fluctuation of water level.

B-12; Well Log of UN 12

Well No UN 13	Location: PATERWA
Elevation: 84	x = 318200 Y = 2978950
Method of Drilling: MANUAL	
Drilling Dates	13 2.90 - 18 2 90
Total Depth	47 00

Comments : Well size: 4"
Screen position. 16 2 - 21 7 m
Screen type: Johnson
Drilled under UNDP

W E L L   L O G



United Nations GW Software

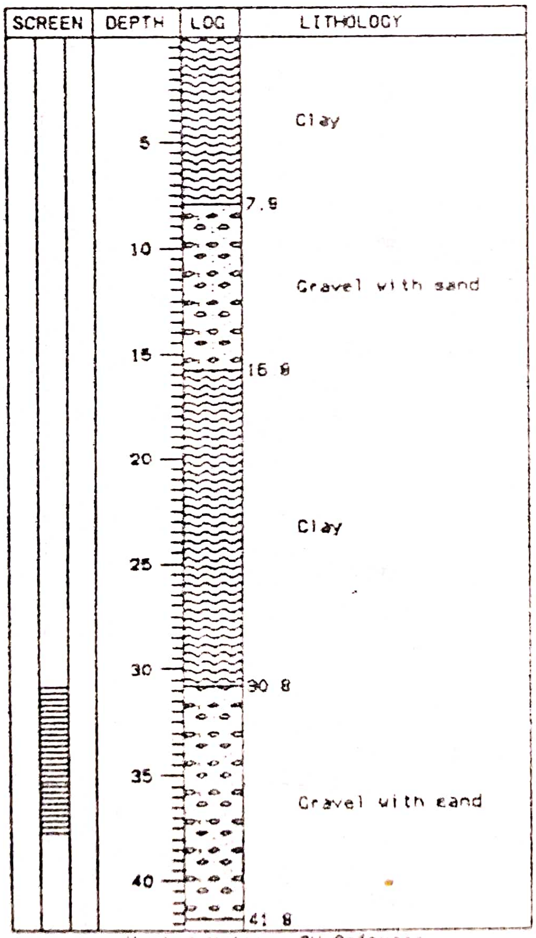
PUMPING TEST

Capacity 8 l/sec
Duration 100 min
Transmiss 250 m2/day
Method . THEIS
SWL : 3 02 m (B Gr L)
DWL : 8 46 M (B Gr L)

B-13: well Log of UN 13

Well No. UN 14	Location NIJGARH
Elevation 170	X = 320500 Y = 3010600
Method of Drilling. RIG	
Drilling Dates : 18 2 90 - 4 3 90	
Total Depth : 41.80	
Comments : Well size: 6/4" Screen position: 30.8 - 37 7 m Screen type: Slotted Drilled under UNDP	

W E L L   L O G



United Nations GW Software

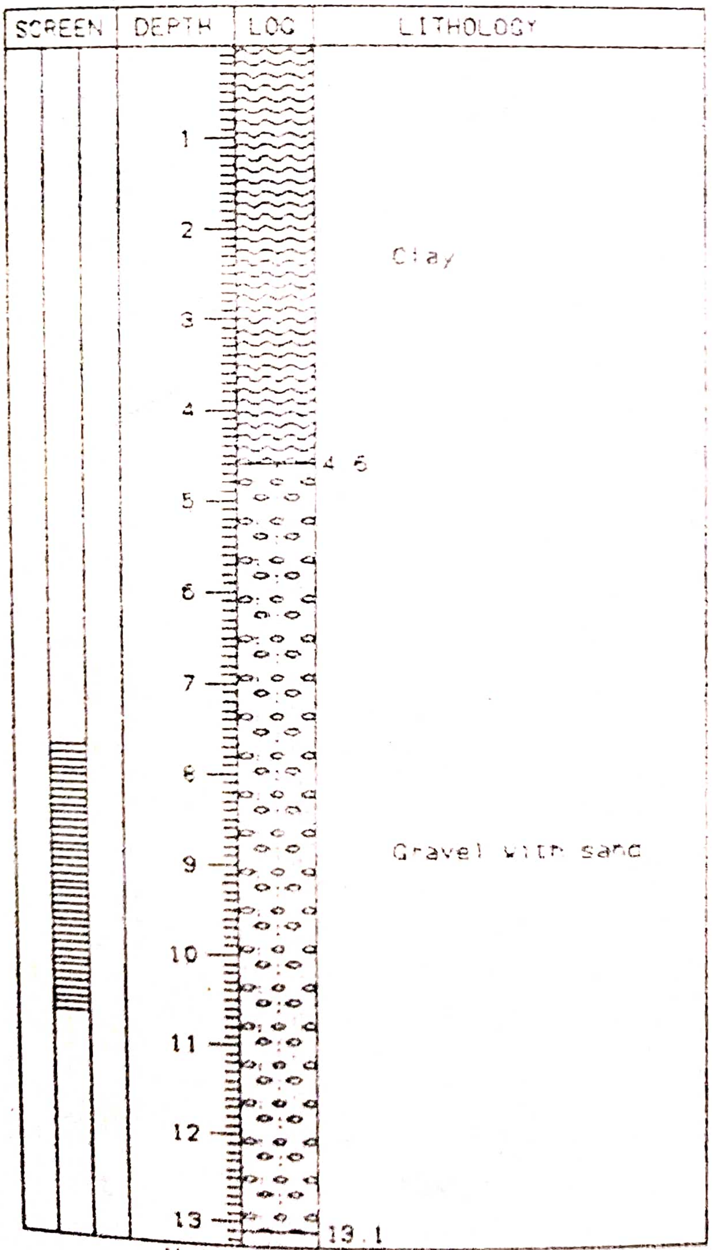
PUMPING TEST

SWL 20 12 m (B GR L), March 1990

B-14: Well Log of UN 14

Well No UN 15	Location BISHANPURWA
Elevation 82	x = 316200 Y = 2986100
Method of Drilling	MANUAL
Drilling Dates	20 2 90 - 3 3 90
Total Depth	13 10
Comments :	Well size 4" Screen position 7.7 - 10.7 m Drilled under UNDP

W E L L   L O G



United Nations GW Software

PUMPING TEST

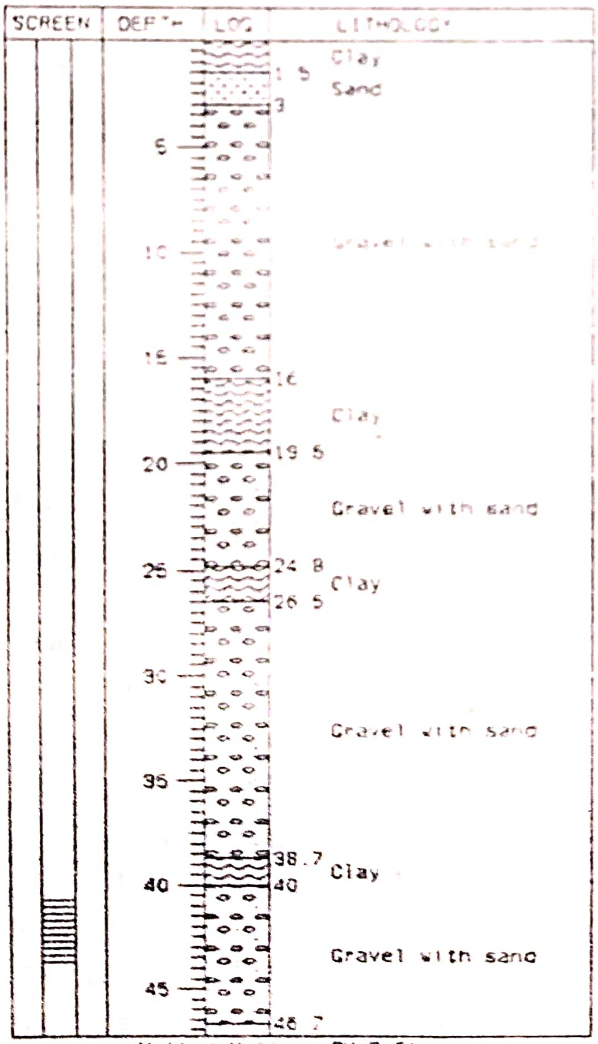
Date	300 m2/day
Capacity	10 l/sec
Duration	35 min
Transmiss	300 m2/day
Method	Theis
SWL	3 70 (B Gr L)
DWL	8 19 (B Gr L)

From Obs.well the T value is 1626 m2/day

B-15: Well Log of UN 15

Well No UN 16	Location PATHLAIYA
Elevation 145	X = 300500 Y = 3009000
Method of Drilling RIG	
Drilling Dates 13 3 90 - 2 3 90	
Total Depth 46 70	
Comments Well size 6/4" Screen position 28 62 - 38 67, 40 7 - 43 7 m; 6" 0 - 26 52 m, 4" 26 52 - 46 86 m; Screen type Slotted	

WELL LOG



United Nations GW Software

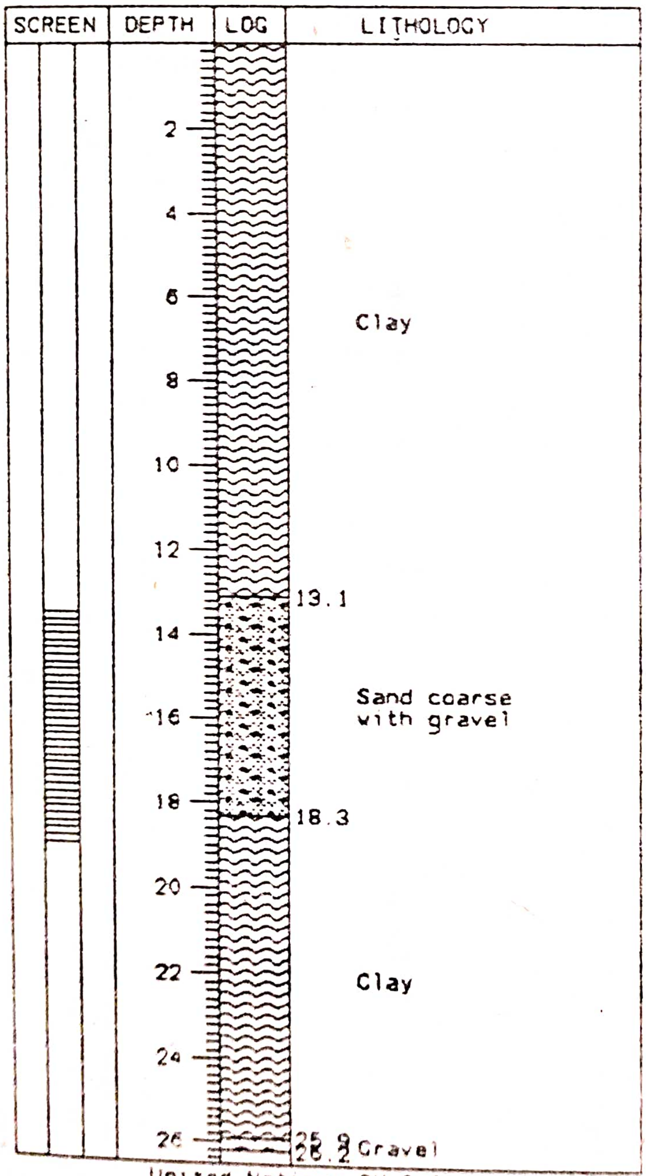
PUMPING TEST

Capacity 22 l/s
Duration 300 mins
Transmiss 2231 m2/day
Method Theis
SWL 17.76 m (B.Gr.L)
DWL 22 44 m (B.Gr.L)

B-16: Well Log of UN 16

Well No UN 17	Location: UMJAN
Elevation: 95	X = 313250 Y = 2991100
Method of Drilling: MANAUL	
Drilling Dates: 4.3.90 - 8.3.90	
Total Depth: 26.20	
Comments: Well size: 4" Screen position 13.5 - 19.0 m Screen type: Johnson Drilled under UNDP	

W E L L   L O G



United Nations GW Software

PUMPING TEST

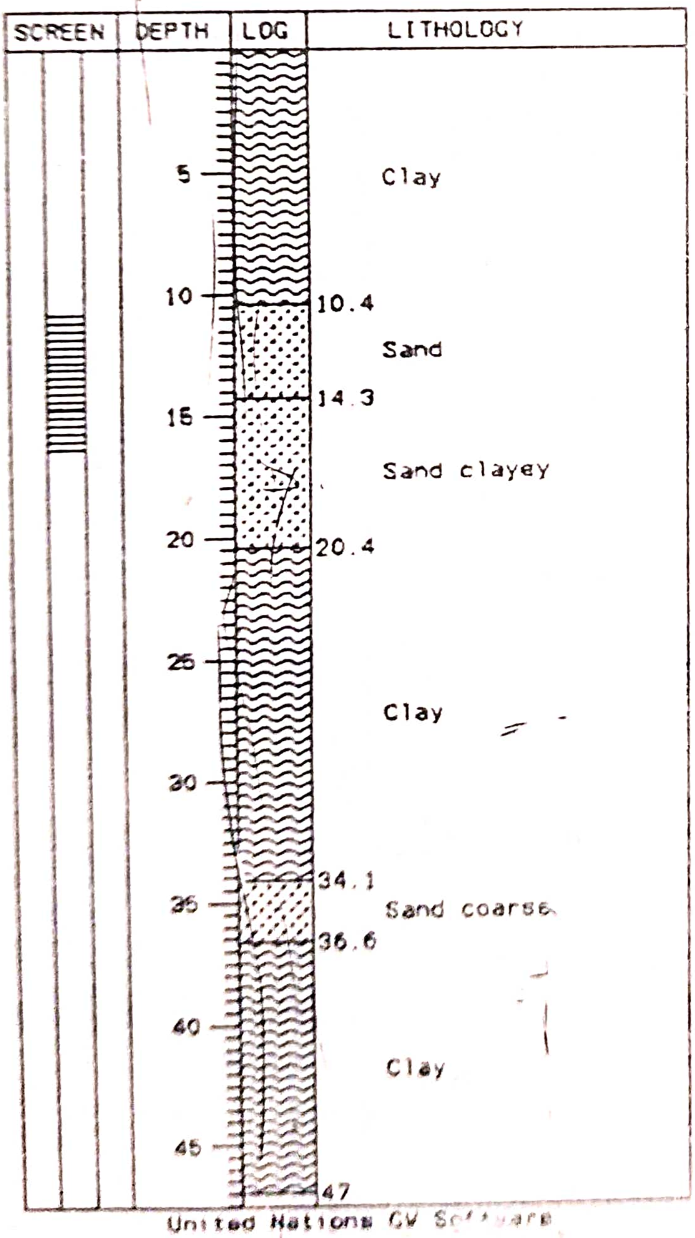
Capacity: 10 l/sec
SWL: 1.07 m (B.Gr.L)
DWL: 8.98 m (B.Gr.L)

Pump test fell due to fluctuation of water level

B-17: Well Log of UN 17

Well No UN 18	Location NAUTAN
Elevation: 95	X = 293000 Y = 2992150
Method of Drilling: MANAUL	
Drilling Dates : 7 3 90 - 9 3 90	
Total Depth : 47 00	
Comments . Well size: 4" Screen position 10 8 - 16 0 m Screen type: Johnson Drilled under UNDP	

WELL LOG



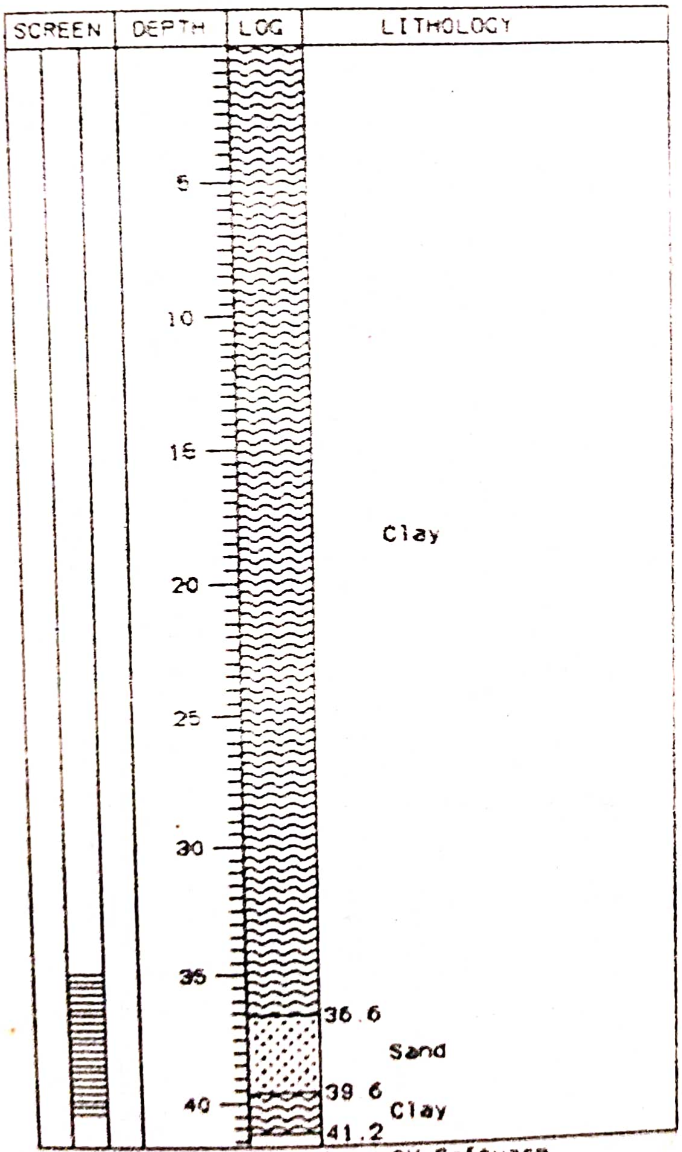
PUMPING TEST

Date. 15.3.90
Capacity: 2 l/sec
Duration: 360 min
Transmiss.: 60 m2/day
Method . Recovery
SWL: 1 92 m (B.Gr.L)
DWL. 6 12 m (B.Gr.L)

B-18: Well Log of UN 18

Well No UN 19	Location: BISHRAMPUR
Elevation: 85	X = 291050 Y = 2986900
Method of Drilling: MANUAL	
Drilling Dates : 9.3.90 - 14.3.90	
Total Depth 41.20	
Comments: Well size: 4" Screen position 34.9 - 40.4 m Screen type: Johnson Drilled under UNDP	

W E L L   L O G



United Nations GW Software

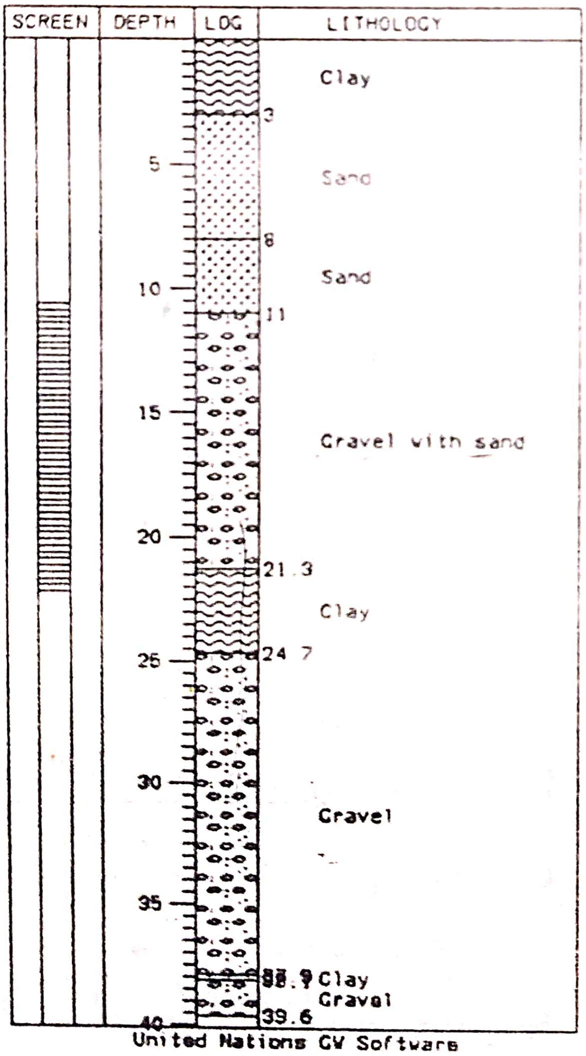
PUMPING TEST

Date: 4.4.90
Capacity: 0.91 l/sec
Duration: 100 min
Transmiss.: 20 m2/day
Method: Theis
SWL: 3.38 m (B.Gr.L)
DWL: 7.71 m (B.Gr.L)

B-19: Well Log of UN 19

Well No. UN 20	Location: BIJALPUR
Elevation: 95	X = 305500 Y = 2990900
Method of Drilling: MANUAL	
Drilling Dates : 9.3.90 - 11.3.90	
Total Depth 39.60	
Comments : Well size: 4" Screen position 10.6 - 22.2 m Screen type: Slotted & Johnson Drilled under UNDP	

W E L L   L O G



PUMPING TEST

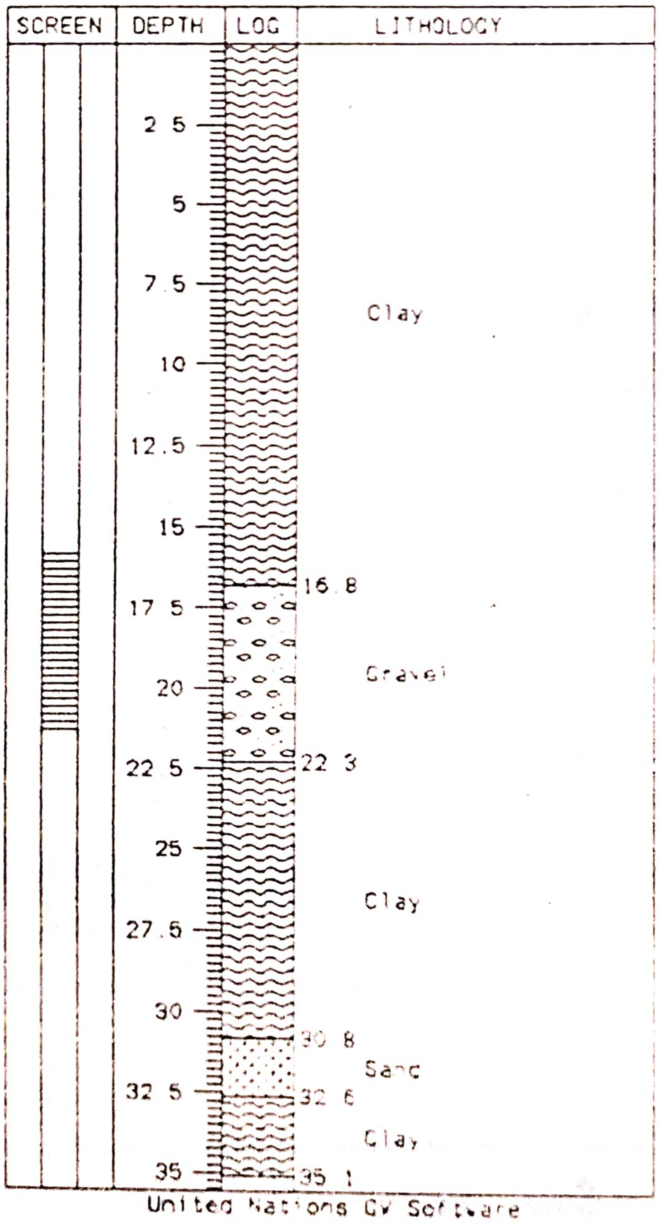
Date. 24.3.1990
Capacity 25 l/sec
Duration 180 min
Transmiss. 1500 m2/day
Method JACOB
Stor Coeff. 0.97E-0.4
SWL. 1.50 m (B.Gr.L)
DWL. 6.16 m (B.Gr.L)

B-20: Well Log of UN 20

Well No UN 21	Location SURAHI
Elevation: 105	X = 302400 Y = 2995200
Method of Drilling: MANUAL	
Drilling Dates : 20.3.90 - 24.3.90	
Total Depth : 35.10	

Comments : Well size 4"
Screen position 15.8 - 21.3 m
Screen type Johnson
Drilled under UNDP

WELL LOG

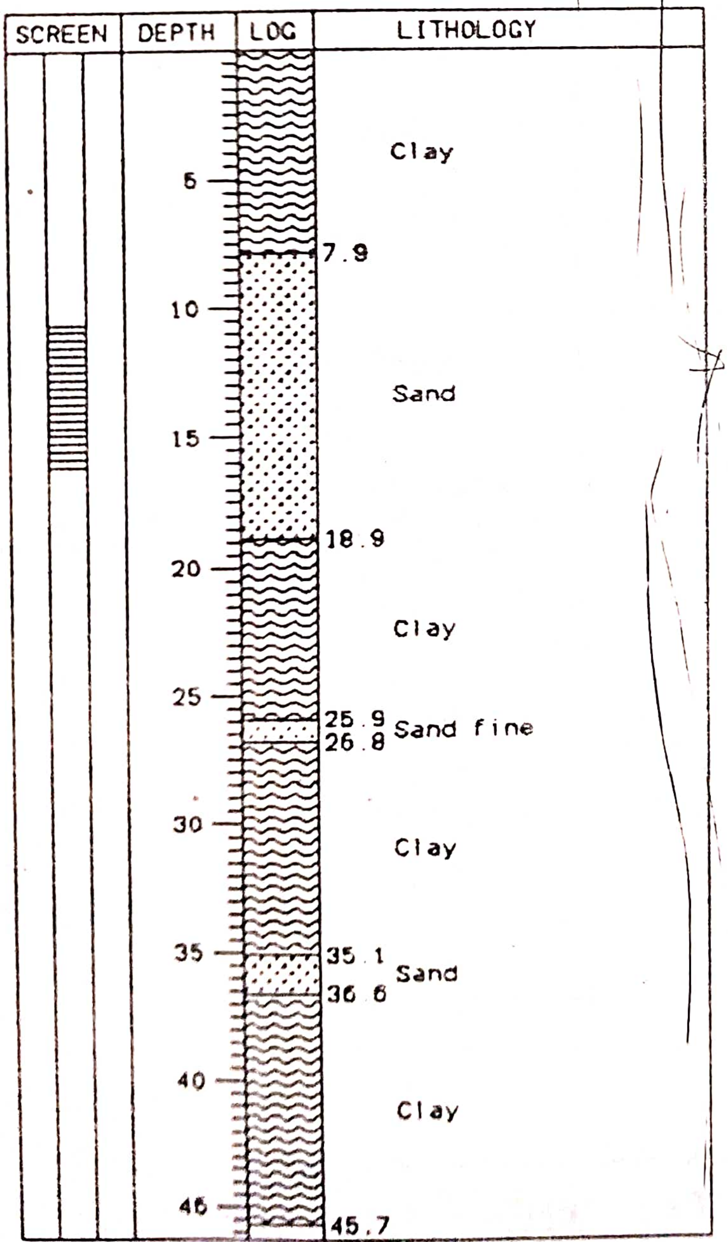


B-21: Well Log of UN 21

Well No UN 22	Location: SIMRAUNGARH
Elevation: 70	X = 317000 Y = 2974600
Method of Drilling: MANUAL	
Drilling Dates : 17.3.90 - 26.3.90	
Total Depth : 45.70	

Comments : Well size: 4"
Screen position: 10.6 - 16.1 m
Drilled under UND

W E L L   L O G



United Nations GW Software

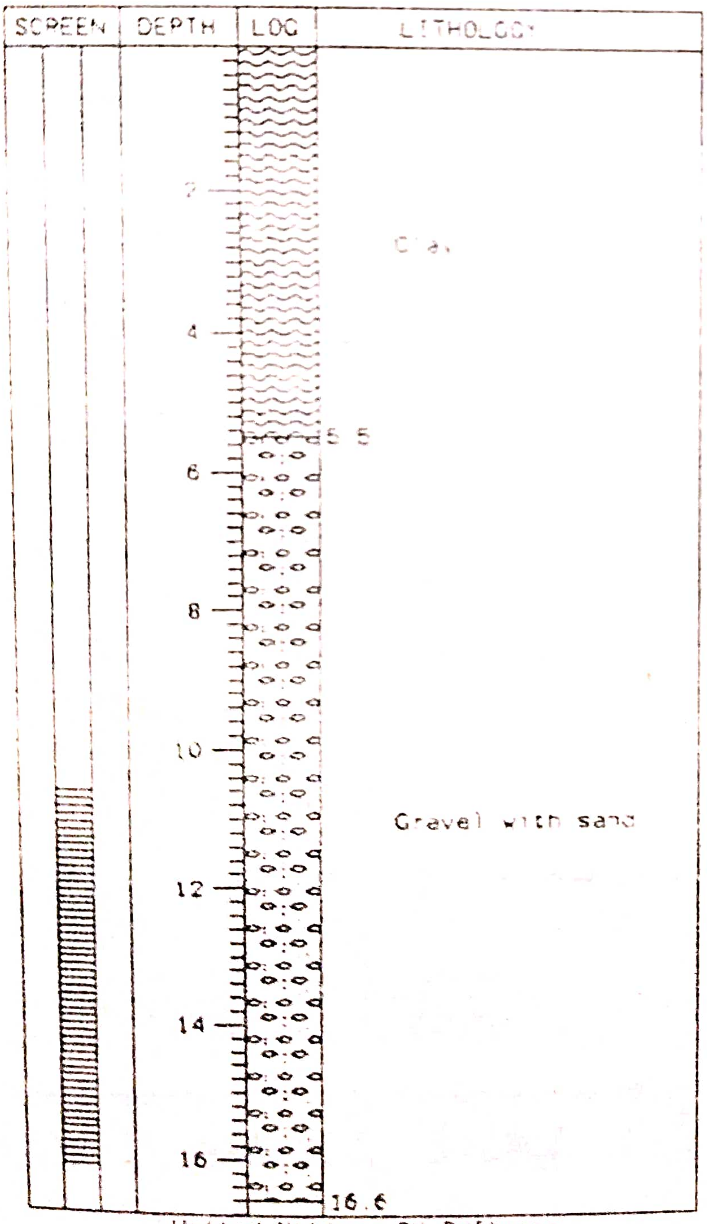
PUMPING TEST

Date 10.4.90
Capacity: 8.33 l/s
Duration: 25 min
Transmiss. 150 m2/day
Method Theis
SWL 3.01 m
DWL: 8.57 m

B-22: Well Log of UN 22

Well No: UN 23	Location: PILWA
Elevation: 145	X = 307450 Y = 3006600
Method of Drilling	MANUAL
Drilling Dates	1.7.1990 - 4.7.1990
Total Depth	16.60
Comments	Well size 4" Screen position 10.6 - 16.1 m Drilled under UNDP

WELL LOG



United Nations GW Software

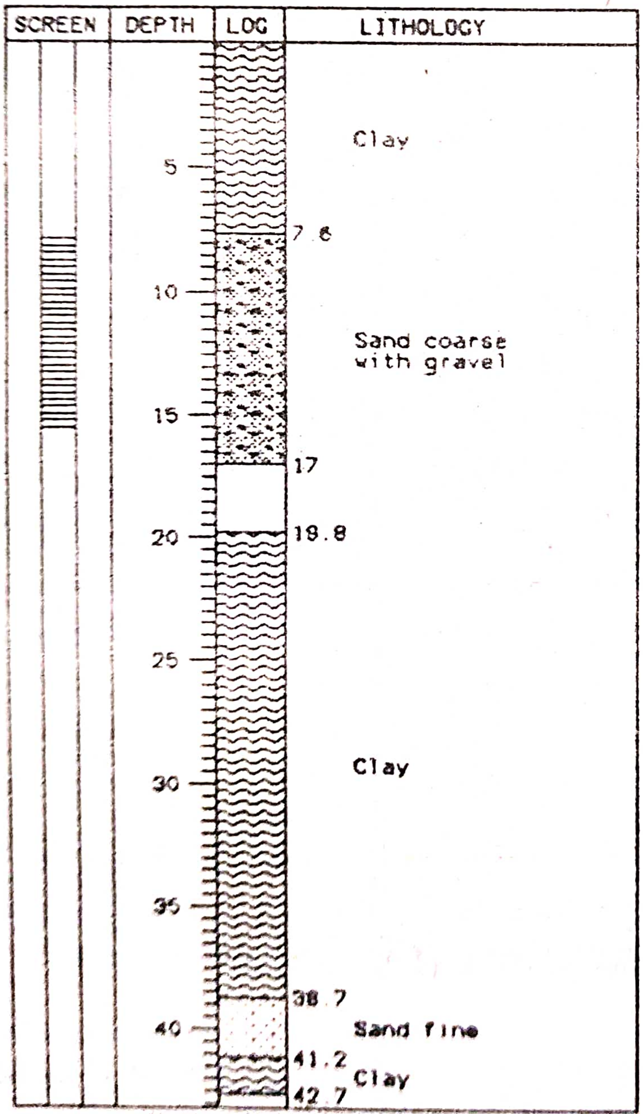
PUMPING TEST

Date: 4.7.1990
Capacity: 12.22 l/s
Duration: 120 min
Transmiss.: 830 m2/day
Method: Theis
SWL: 5.13 m
DWL: 7.35 m

B-23: Well Log of UN 23

Well No. UN 24	Location: MAJHARIYA
Elevation: 82	X = 306900 Y = 2983500
Method of Drilling: MANUAL	
Drilling Dates : 27.6.1990 - 30.6.1990	
Total Depth : 42.68	
Comments : Well size: 4" Screen position: 7.85 - 15.48 m Drilled under UNDP	

WELL LOG



United Nations GW Software

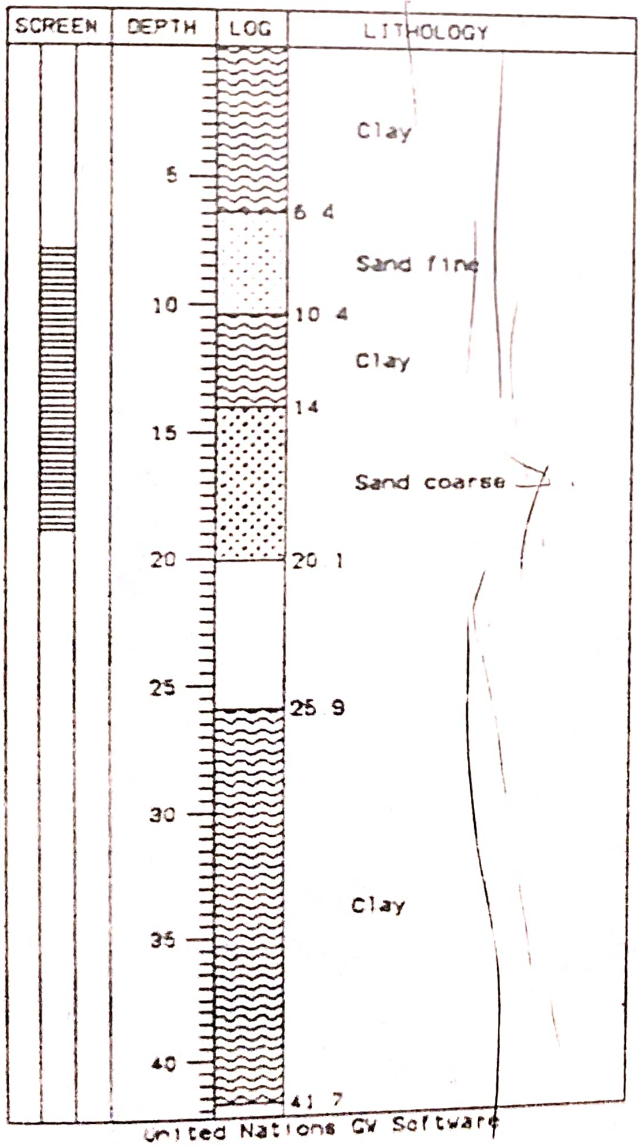
PUMPING TEST

Date: 1.7.1990 - 4.7.1990
Capacity: 10 l/s
Duration: 180 min
Transmiss: 620 m2/day
Method : Theis
SWL: 2.5 m
DWL: 7.73 m

B-24: Well Log of UN 24

Well No UN 25	Location: PARWANIPUR
Elevation 100	X = 297100 Y = 2999200
Method of Drilling MANUAL	
Drilling Dates 26.6.1990 - 29.6.1990	
Total Depth 41.73	
Comments Well size 4" Screen position: 7.86 - 18.86 m Drilled under UNDP	

W E L L   L O G



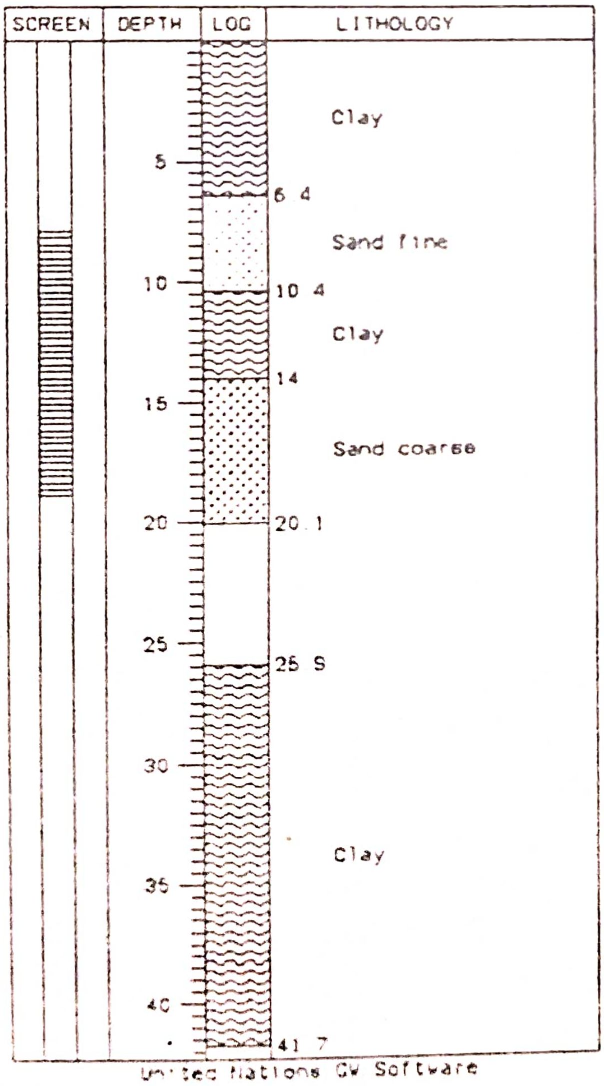
PUMPING TEST

Date: 30.6.1990 - 2.7.1990
Capacity: 8.33 l/s
Duration: 240 min
Transmiss: 530 m2/day
Method: Theis
SWL: 2.69 m
DWL: 8.09 m

B-25: Well Log of UN 25

Well No UN 25	Location PARWANIPUR
Elevation 100	X = 297100 Y = 2999200
Method of Drilling MANUAL	
Drilling Dates 26 6 1990 - 29 6 1990	
Total Depth 41 73	
Comments Well size: 4" Screen position 7.86 - 18.86 m Drilled under UNDP	

WELL LOG



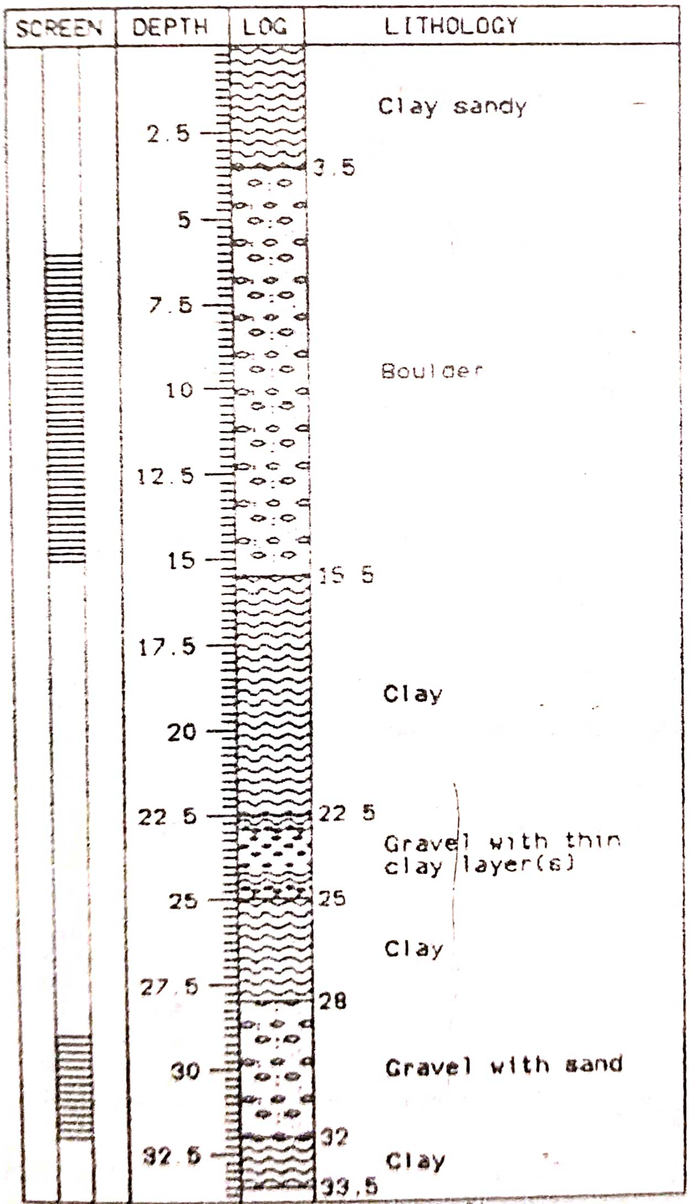
PUMPING TEST

Date: 30 6 1990 - 2 7 1990
Capacity: 8 33 l/s
Duration: 240 min
Transmiss.: 530 m2/day
Method : Theis
SVL: 2.69 m
DVL: 8 09 m

B-26: Well Log of NZ S-5

Well No NZ S-8	Location SIMARA WA NO 6
Elevation: 137	X = 301500 Y = 3006200
Method of Drilling RIG	
Drilling Dates 16 4 85 - 21 4 85	
Total Depth 33 50	
Comments Well size 4" Screen position 6 0 - 15 0 m 29 0 - 32 0 m Screen type Slotted Drilled under NZIDP	

W E L L   L O G



United Nations GW Software

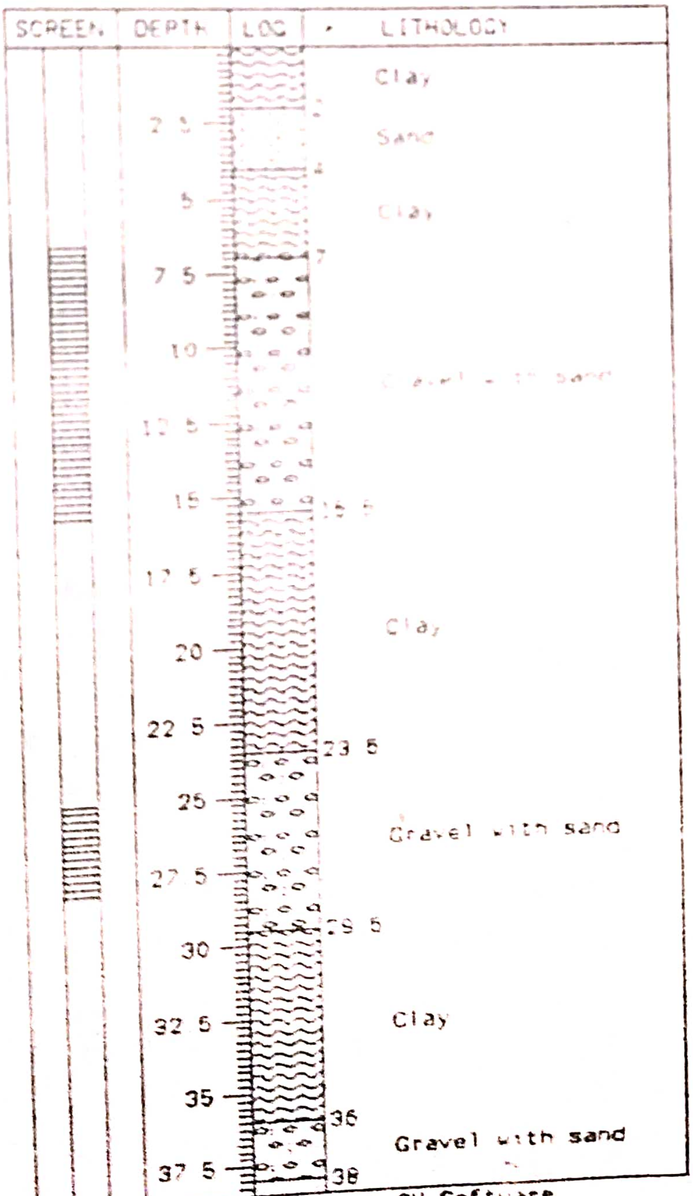
PUMPING TEST

Capacity 10 5 l/s

B-27 Well Log of NZ S-8

Well No NZ S-49	Location: NARABASTI
Elevation 138	X = 299100 Y = 3007000
Method of Drilling RIG	
Drilling Dates 24 5 85 - 30 5 85	
Total Depth 38 00	
Comments	Well size 4" Screen position 6 5 - 15 5 m 25 0 - 28 0 m Screen type Slotted Drilled under NZIDP

WELL LOG



United Nations GW Software

PUMPING TEST

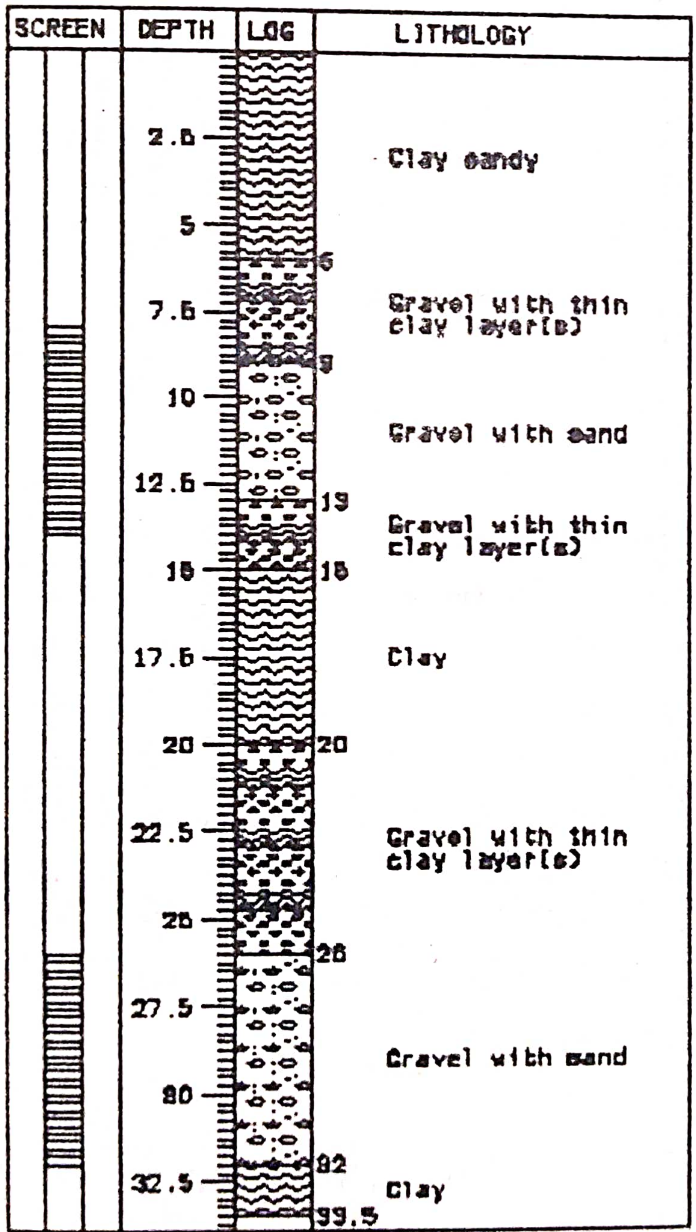
Capacity 10 5 l/s

B-28: Well Log of NZ S-49

Well No. NZ S-57	Location: SIMARA WA.NO 5
Elevation: 130	X - 298300 Y - 3005000
Method of Drilling: RIG	
Drilling Dates : 19.5.85 - 24.5.85	
Total Depth : 33.50	

Comments : Well size: 4"
Screen position: 8.0 - 14.0 m
26.0 - 32.0 m
Screen type: Slotted
Drilled under NZIDP

WELL LOG



United Nations GW Software

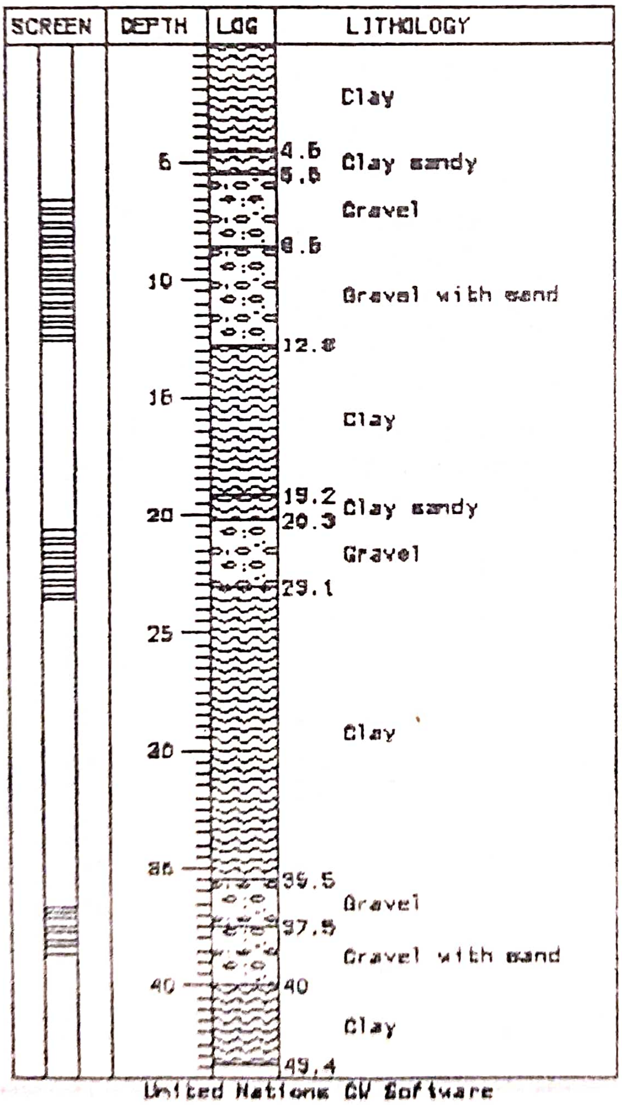
PUMPING TEST

Capacity: 10.5 l/s

B-29: Well Log of NZ s-57

Well No. NZ S-26	Location: JITPUR
Elevation: 119	X - 298600 Y - 3002100
Method of Drilling: RIG	
Drilling Dates : 26.2.85 - 6.3.85	
Total Depth : 43.40	
Comments : Well size: 4" Screen position: 6.6-12.6, 20.6-23.6 m 36.6-38.6 m Screen type: Slotted Drilled under NZIDP	

WELL LOG



PUMPING TEST

Capacity: 10.5 l/s

B-30: Well Log of NZ S-26

Well No.: NZ S-34	Location: LIKMI	
Elevation: 102	X = 295600	Y = 2995500

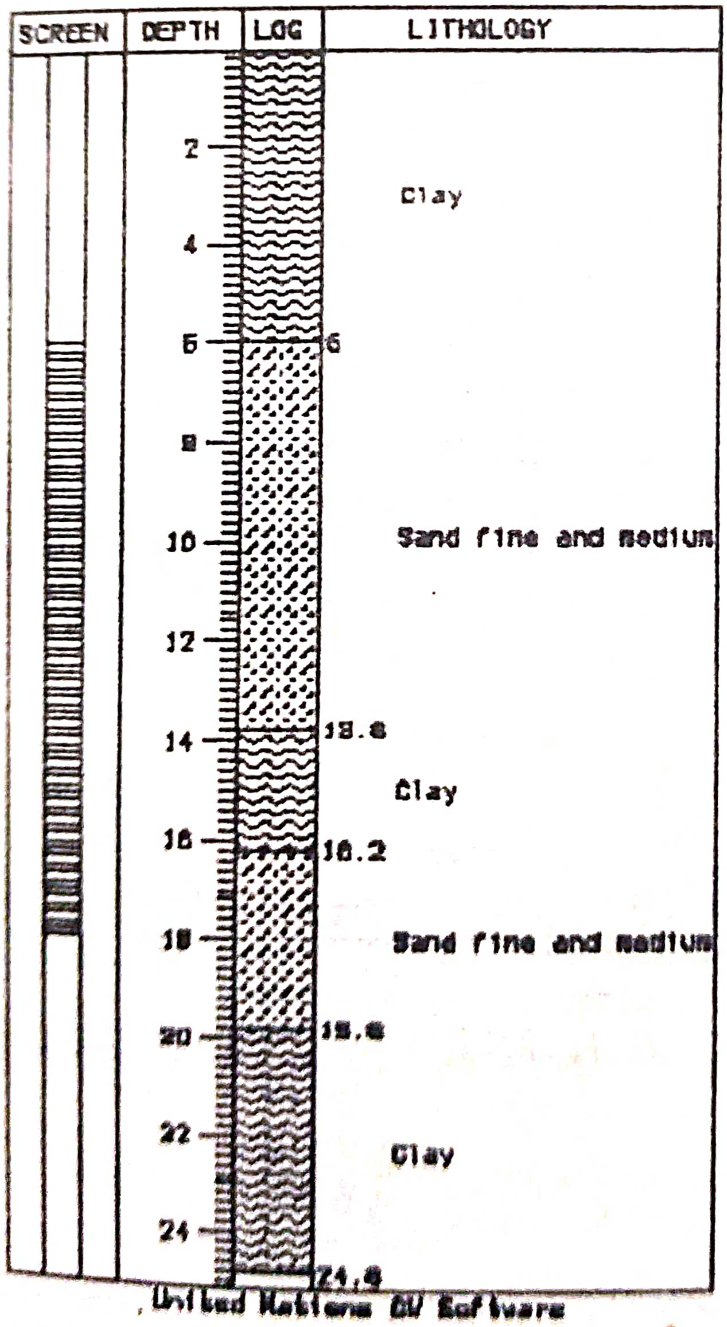
Method of Drilling: MANUAL

Drilling Dates : 26.5.85

Total Depth : 24.80

Comments : Well size: 4"
Screen position: 6.0 - 18.0 m
Screen type: Slotted
Drilled under NZIDP

WELL LOG



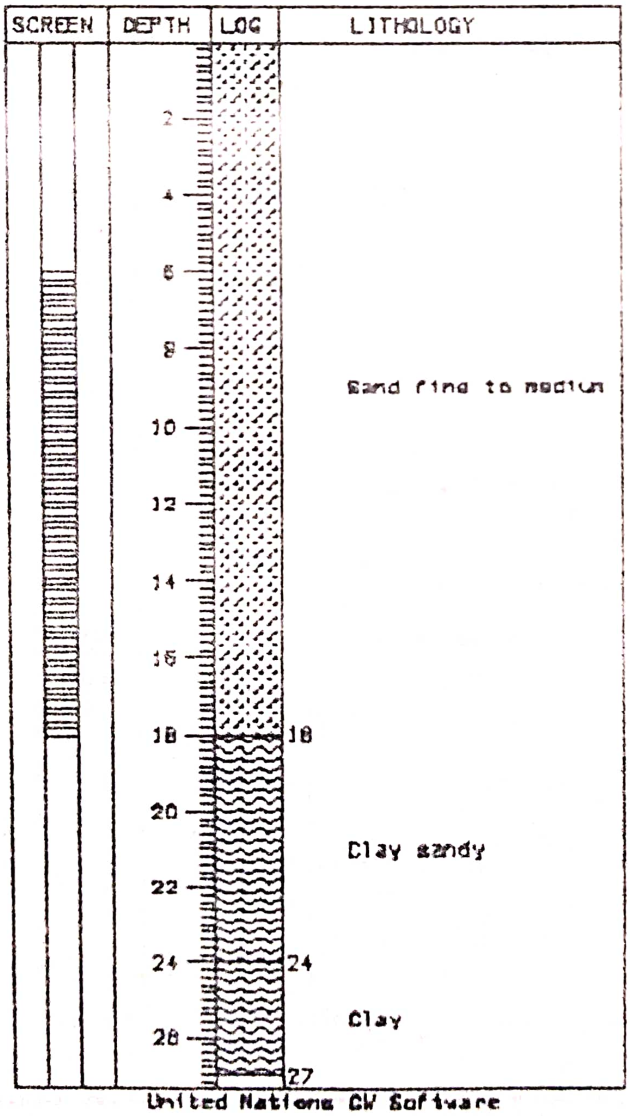
PUMPING TEST

Capacity: 10.5 l/s

B-31: Well Log of NZ S-34

Well No. NZ S-35	Location: REHARIYA
Elevation: 100	X - 296900 Y - 2994000
Method of Drilling: MANUAL	
Drilling Dates : 13.5.85	
Total Depth : 27.00	
Comments : Well size: 4" Screen position: 6.0 - 18.0 m Screen type: Slotted Drilled under NZIDP	

WELL LOG



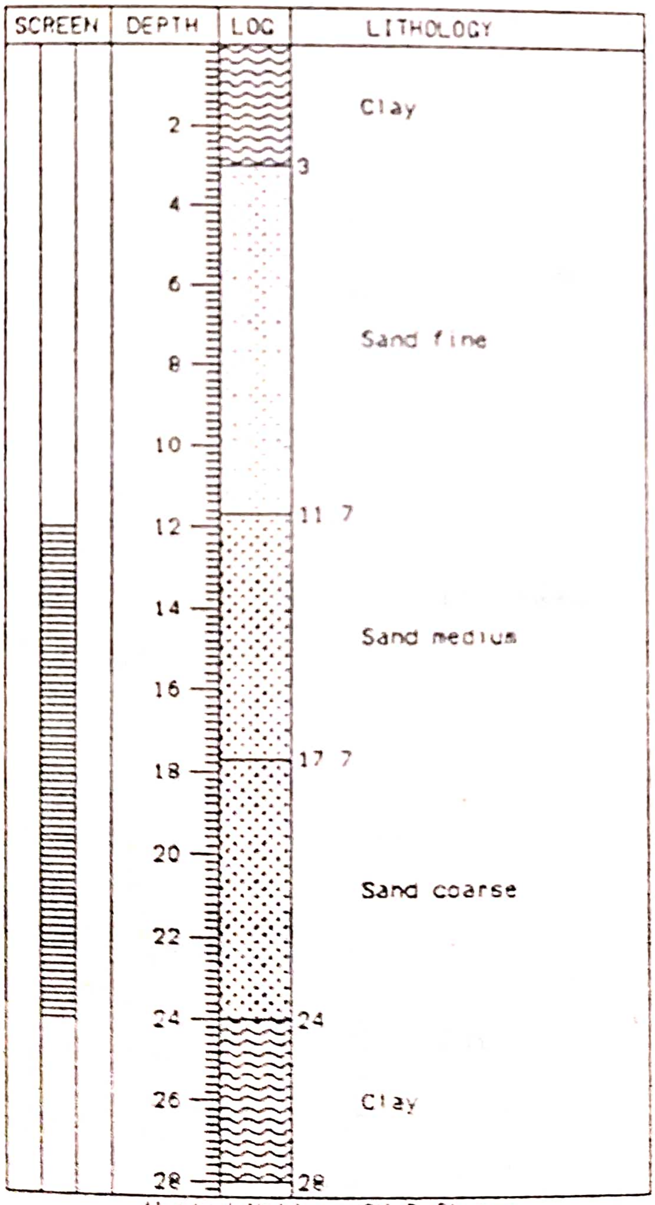
PUMPING TEST

Capacity: 7.5 l/s

B-32: Well Log of NZ S-35

Well No NZ S-37	Location: MOTISAR
Elevation 95	X = 299800 Y = 2991000
Method of Drilling: MANUAL	
Drilling Dates 23 4 85	
Total Depth : 28 00	
Comments: Well size 4" Screen position 12 0 - 24 0 m Screen type Slotted Drilled under NZIDP	

W E L L L O G



United Nations GV Software

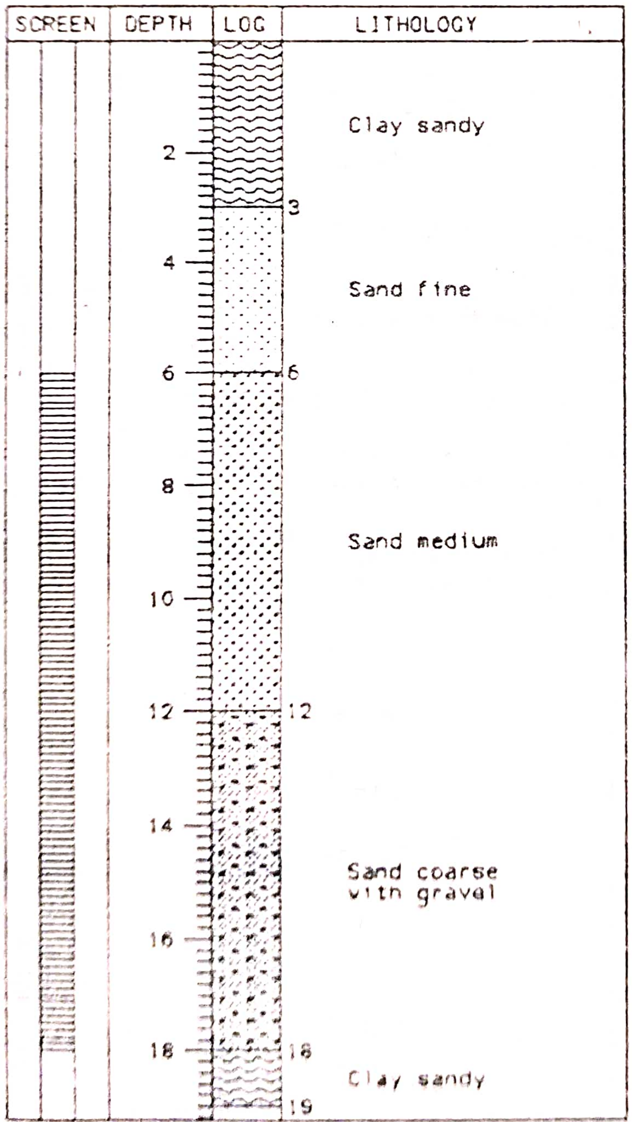
PUMPING TEST

Capacity 11 5 l/s

B-33: Well Log of NZ S-39

Well No NZ S-39	Location: SURAHI
Elevation: 106	X = 303200 Y = 2995600
Method of Drilling MANUAL	
Drilling Dates 13 5 85	
Total Depth 19 00	
Comments: Well size 4" Screen position 6 0 - 18.0 m Screen type: Slotted Drilled under NZIDP	

W E L L L O G

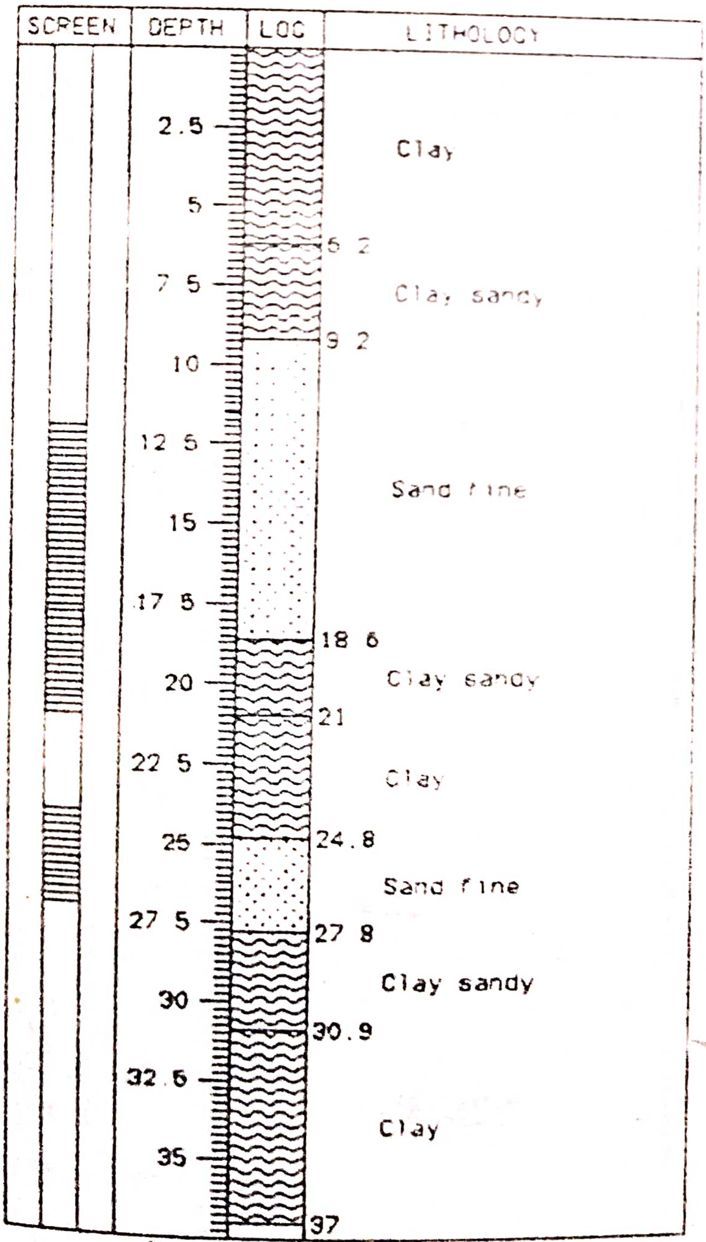


United Nations GW Software

B-34: Well Log of NZ S-39

Well No NZ S-40	Location: LUXMINIYA
Elevation: 92	X = 303100 Y = 2989700
Method of Drilling: MANUAL	
Drilling Dates	
Total Depth 37.00	
Comments : Well size 4" Screen position 12.0 - 21.0 m 24.0 - 27.0 m Drilled under NZIDP	

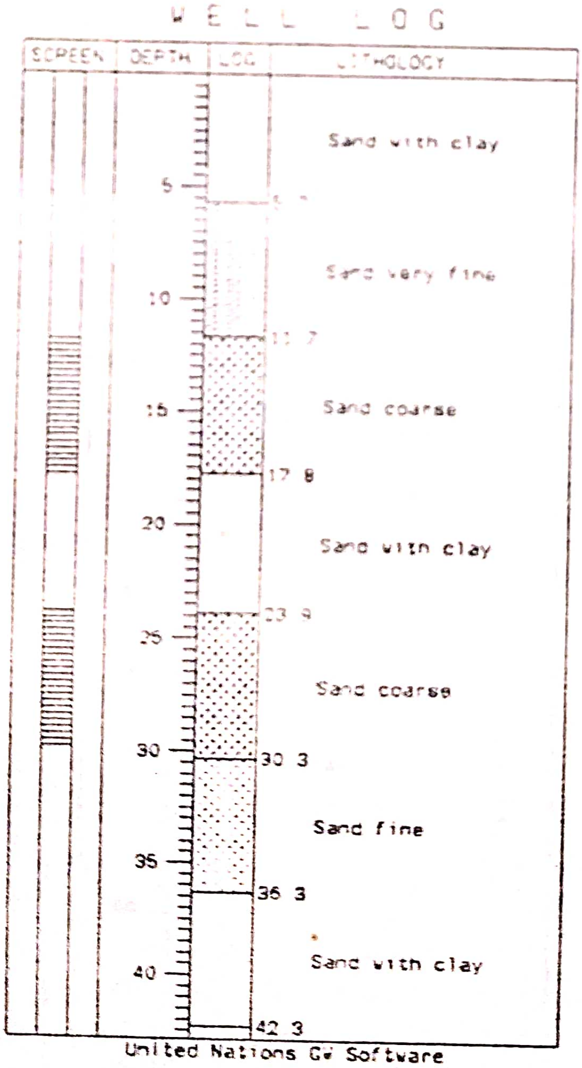
WELL LOG



United Nations GW Software

B-35: Well Log of NZ S-40

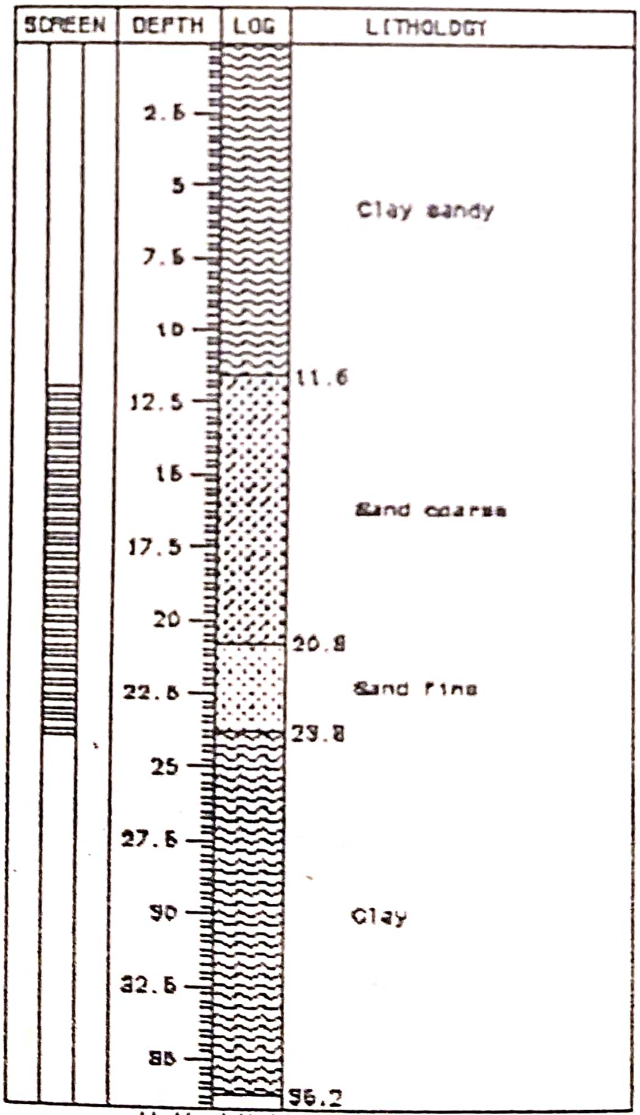
Well No NZ S-45	Location: PHULAURIA
Elevation 85	X = 300200 Y = 2985700
Method of Drilling MANAUAL	
Drilling Dates	
Total Depth 42 30	
Comments: Well size 4" Screen position 11 8 - 17 8 m 23 8 - 29 8 m Drilled under NZIDP	



B-36: Well Log of NZ S-45

Well No. NZ S-41	Location: BALRAMPUR
Elevation: 89	X = 300600 Y = 2987100
Method of Drilling: MANUAL	
Drilling Dates :	
Total Depth : 36.20	
Comments : Well size: 4" Screen position: 12.0 - 24.0 m Drilled under NZIDP	

WELL LOG

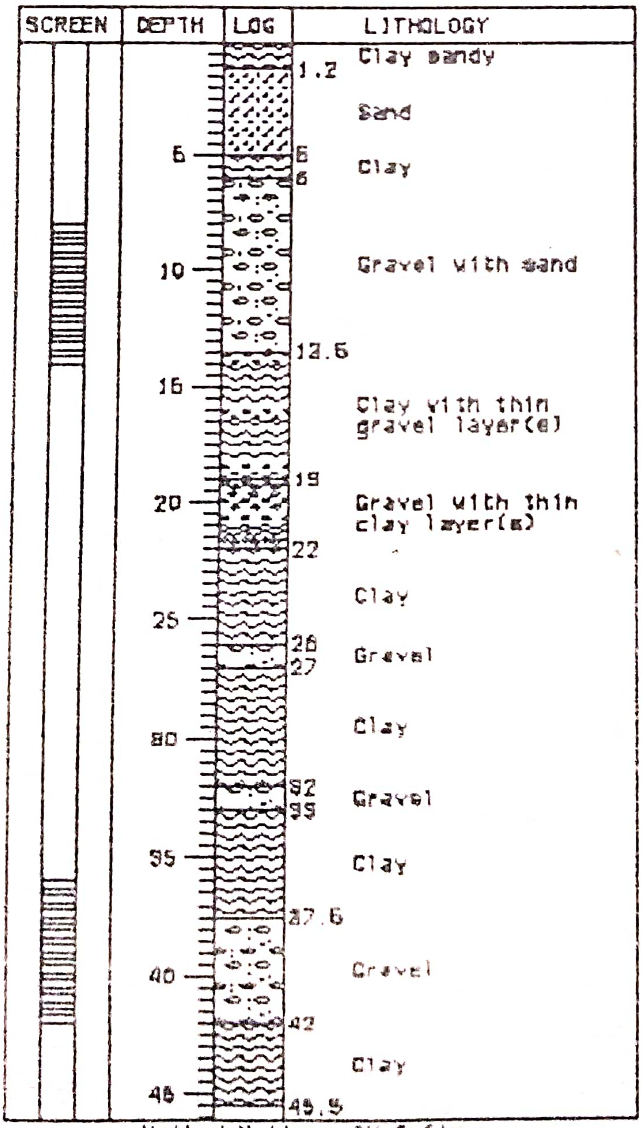


United Nations CW Software

B-37; Well Log of NZ S- 41

Well No. NZ S-3	Location: BEHRI
Elevation: 122	X = 302000 Y = 3004000
Method of Drilling: RIG	
Drilling Dates : 27.3.85 - 2.4.85	
Total Depth : 45.50	
Comments : Well size: 4" Screen position: 8.0 - 14.0 m 36.0 - 42.0 m Screen type: Slotted Drilled under NZIDP	

WELL LOG



United Nations GW Software

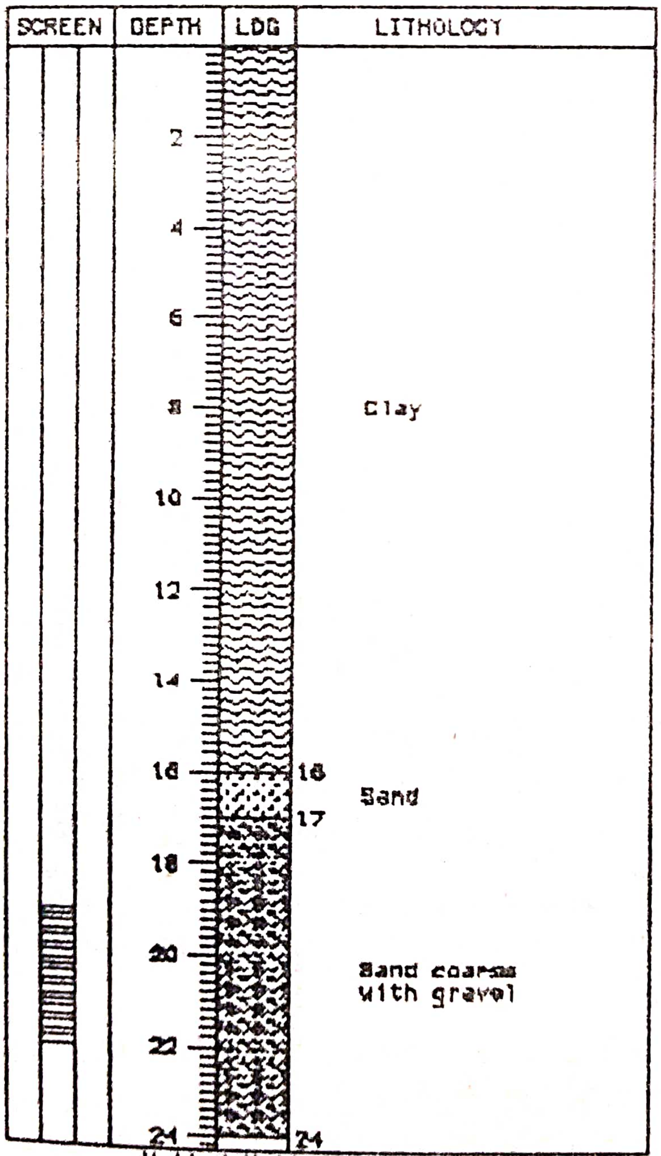
PUMPING TEST

Capacity: 10.5 l/s

B-38: Well Log of NZ S_ 3

Well No. JR C-16	Location: BISAMBHARPUR
Elevation: 93	X - 300400 Y - 2987000
Method of Drilling: RIG	
Drilling Dates : 25.12.84	
Total Depth : 24.00	
Comments : Well size 4" Screen position:19.0 - 22.0 m Drilled under JRCS	

WELL LOG



United Nations GV Software

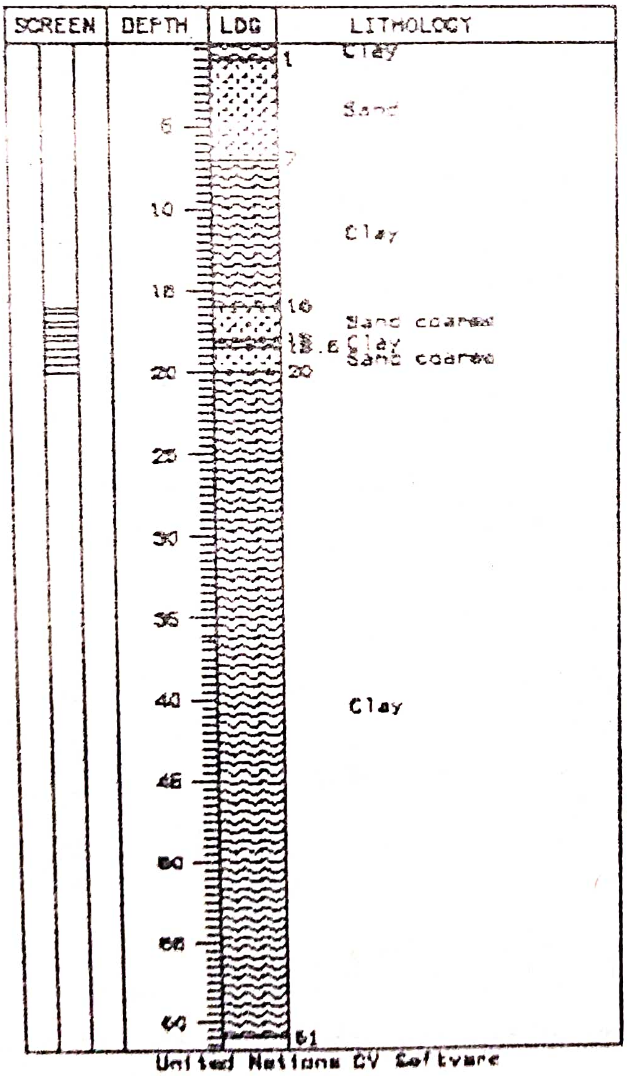
PUMPING TEST

SWL: 4.40 m
DWL: 8.4 m

B-39: Well Log of JR C-16

Well No. JR B-53	Location: RAGUNATHPUR
Elevation: 93	X - 297100 Y - 2986700
Method of Drilling: RIG	
Drilling Dates : 2.4.85 - 4.4.85	
Total Depth : 61.00	
Comments : Well size: 4" Screen position: 16.0-18.0, 18.5-20.0 m Drilled under JRCS	

WELL LOG



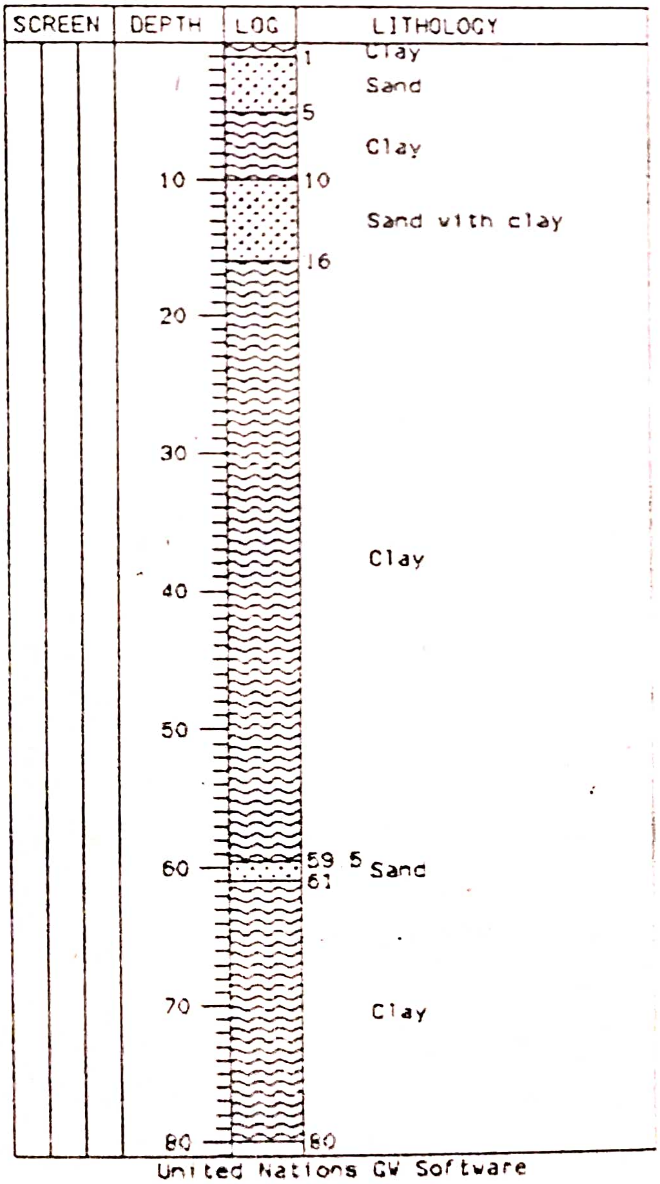
PUMPING TEST

SWL: 4.0 m
DWL: 6.0 m

B-40 Well Log of JR B-53

Well No JR B-51	Location: PARSAUNI
Elevation 93	X = 294600 Y = 2991000
Method of Drilling: RIG	
Drilling Dates : 28.3.85 - 1.4.85	
Total Depth : 80.00	
Comments : Well size 4"	

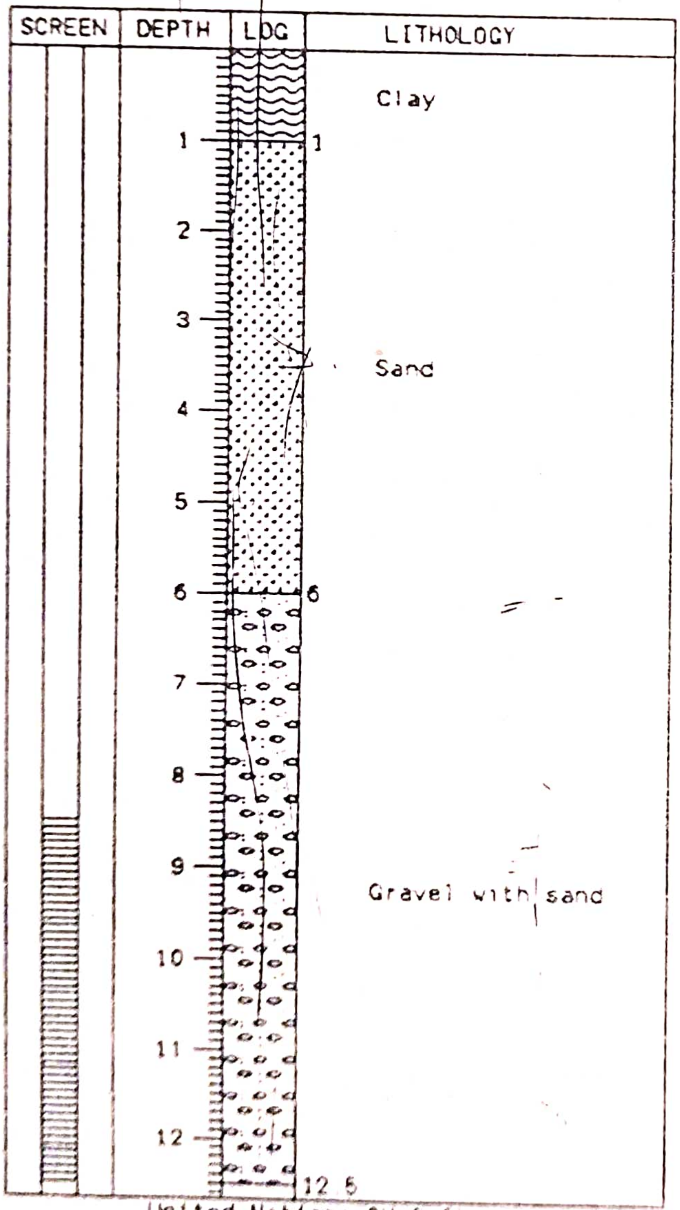
W E L L   L O G



B-41: Well Log of JR B-51

Well No	JR B-26	Location	PATHARIYA
Elevation	93 5	X = 316700	Y = 2989600
Method	Drilling	25 1 85	
Drilling Dates	:		
Total Depth		12 50	
Comment:	Well size 4" Screen position 8 5 - 12 5 m Drilled under JRCS		

WELL LOG



United Nations GV Software

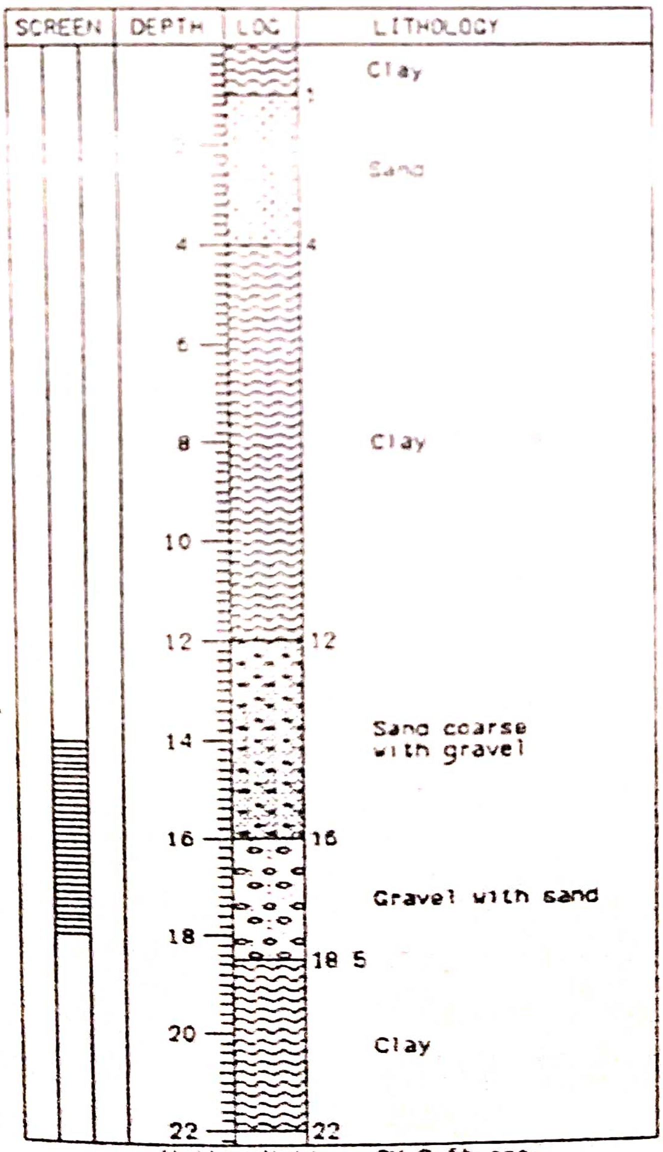
PUMPING TEST

SWL 3 2 M
DWL 6.05 M

B-42: Well Log of JR B-26

Well No JR-B-30	Location PAKADIYA
Elevation 68	X = 307600 Y = 2973500
Method of Drilling RIG	
Drilling Dates 30 1 85	
Total Depth 22 00	
Comments Well size 4" Screen position 14 0 -18 0 m Drilled under JRCS	

W E L L   L O G



United Nations GW Software

PUMPING TEST

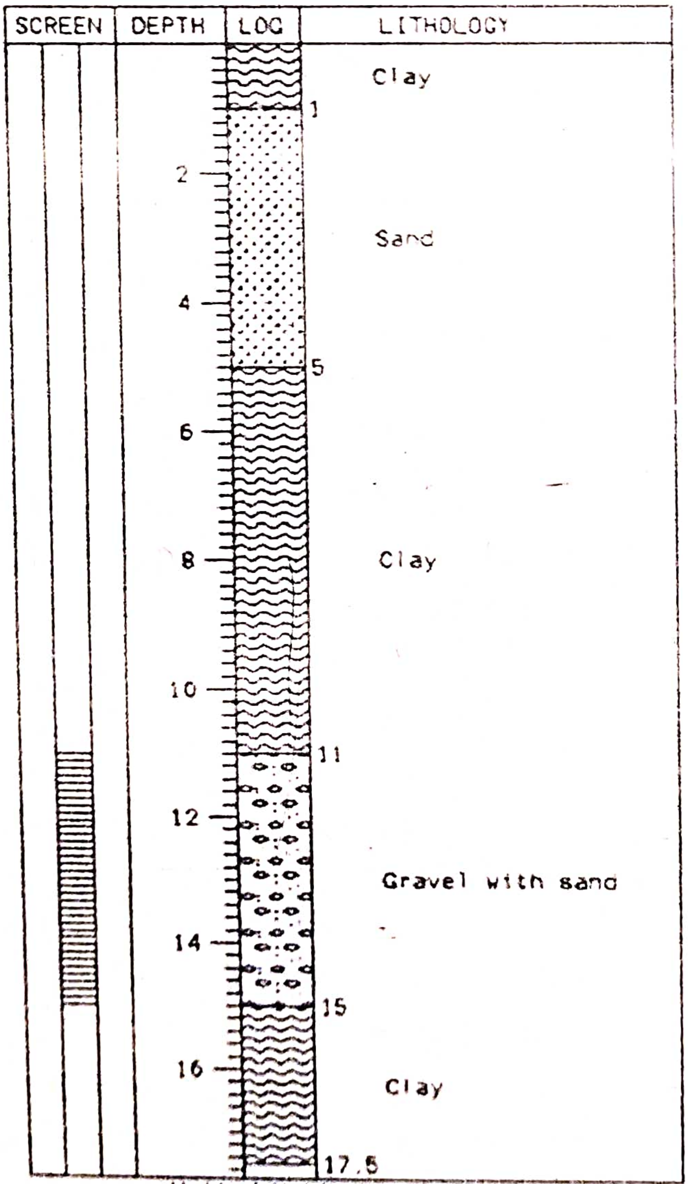
SWL 4 50 m
DWL 5 20 m

B-43: Well Log of JR B-30

Well No.: JR B-28	Location: AMARPATTI
Elevation: 83	X = 310600 Y = 2982500
Method of Drilling: RIG	
Drilling Dates: 27.1.85 - 28.1.85	
Total Depth: 17.50	

Comments: Well size 4"
Screen position: 11.0 - 15.0 m
Drilled under JRCS

WELL LOG



United Nations GW Software

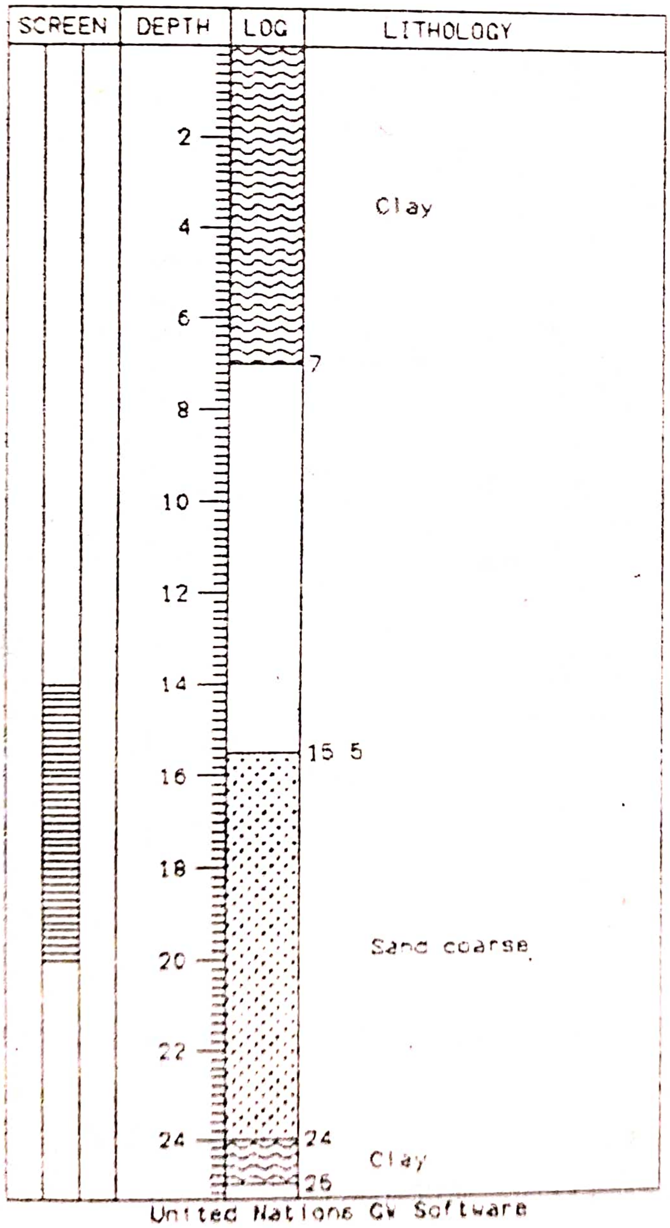
PUMPING TEST

SWL: 5.60 m
DWL: 6.70 m

B-44: Well Log of JR B-28

Well No JR C-28	Location: KACHORWA
Elevation 80	X = 318500 Y = 2974600
Method of Drilling: RIG	
Drilling Dates : 29 1 85	
Total Depth : 25.00	
Comments : Well size: 4" Screen position: 14.0 - 20.0 m Drilled under JRCS	

W E L L   L O G



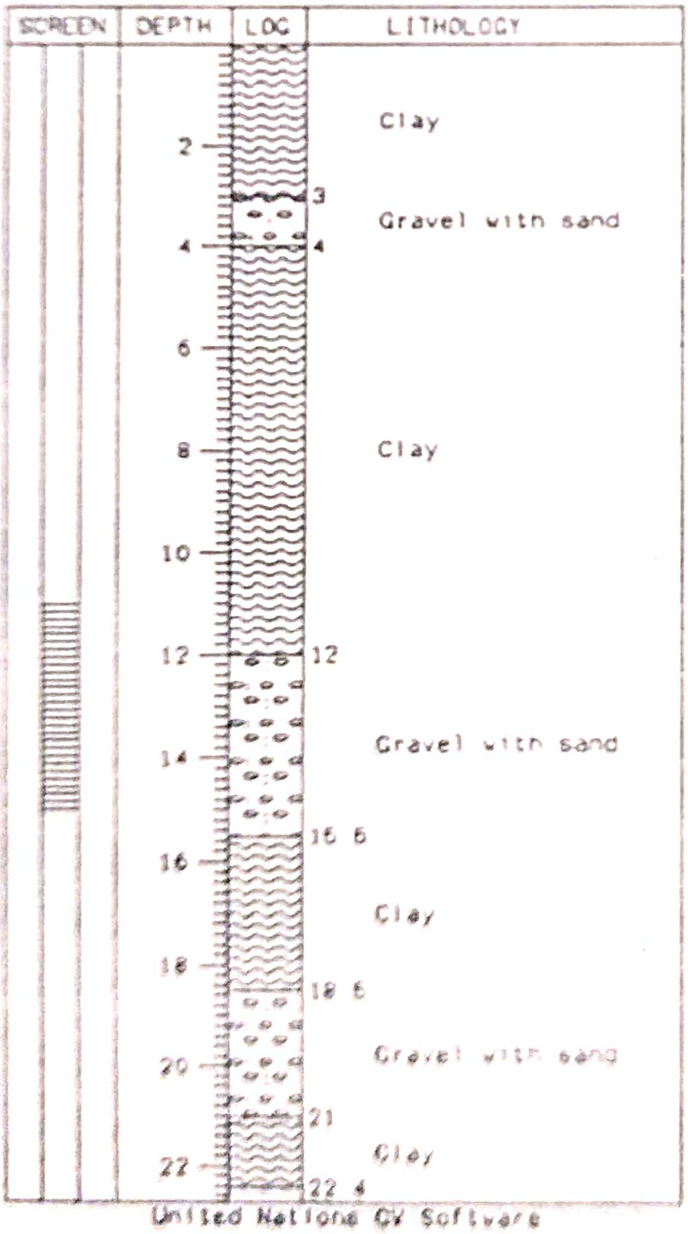
PUMPING TEST

SWL: 4 0 m
DWL: 5 0 m

B-45: Well LOg of JR C-28

Well No JR C-33	Location INARWA
Elevation 108	x = 299500 / y = 2996000
Method of Drilling RIG	
Drilling Dates 6 2 1985 - 8 1985	
Total Depth 22 40	
Comments Well size 4" screen position 11 0 - 15 0 m Drilled under JRCS	

WELL LOG



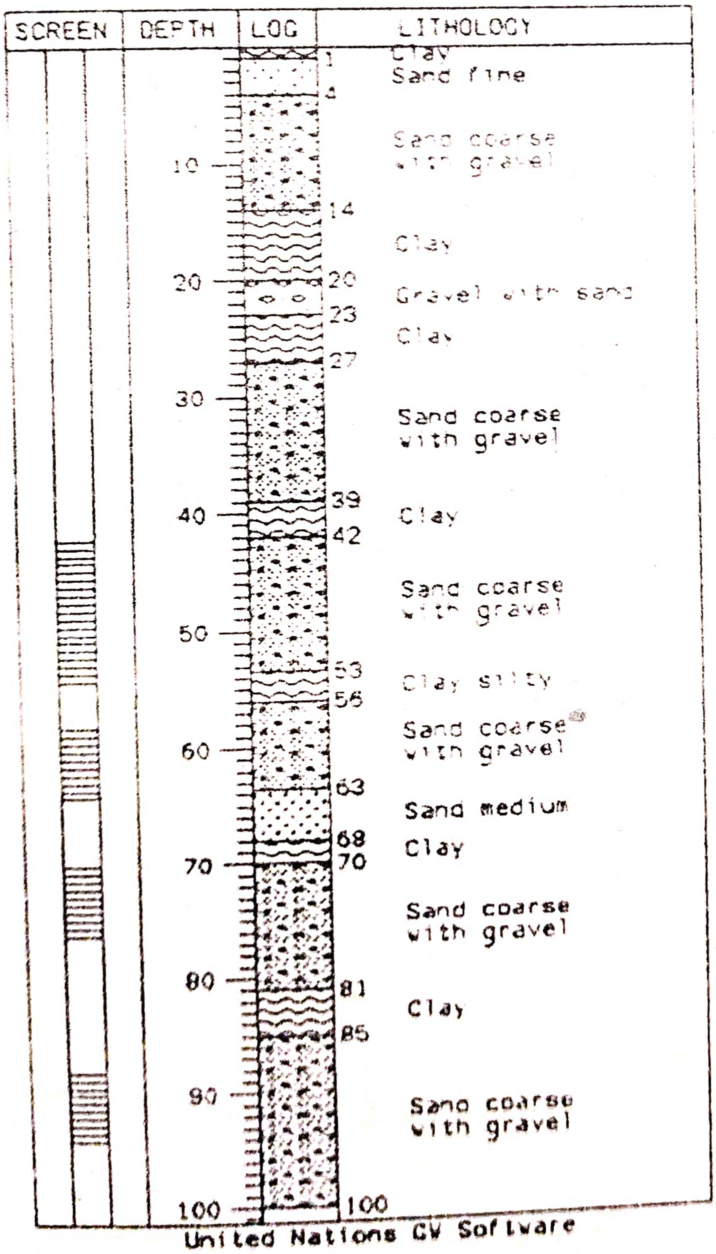
PUMPING TEST

SWL 2 30 m
DWL 9 50 m

B-46: Well Log of JR C-33

Well No NC 1/14	Location SIMRA FACTORY
Elevation 137	X = 299600 Y = 3005300
Method of Drilling RIG	
Drilling Dates 10 2 88 - 18 3 88	
Total Depth 100 00	
Comments Well size 8/6" Screen position 42 - 54, 58 - 64 m 70 - 76, 88 - 94 m Screen type Slotted Drilled under NISSAKU/HULAS STEEL IND	

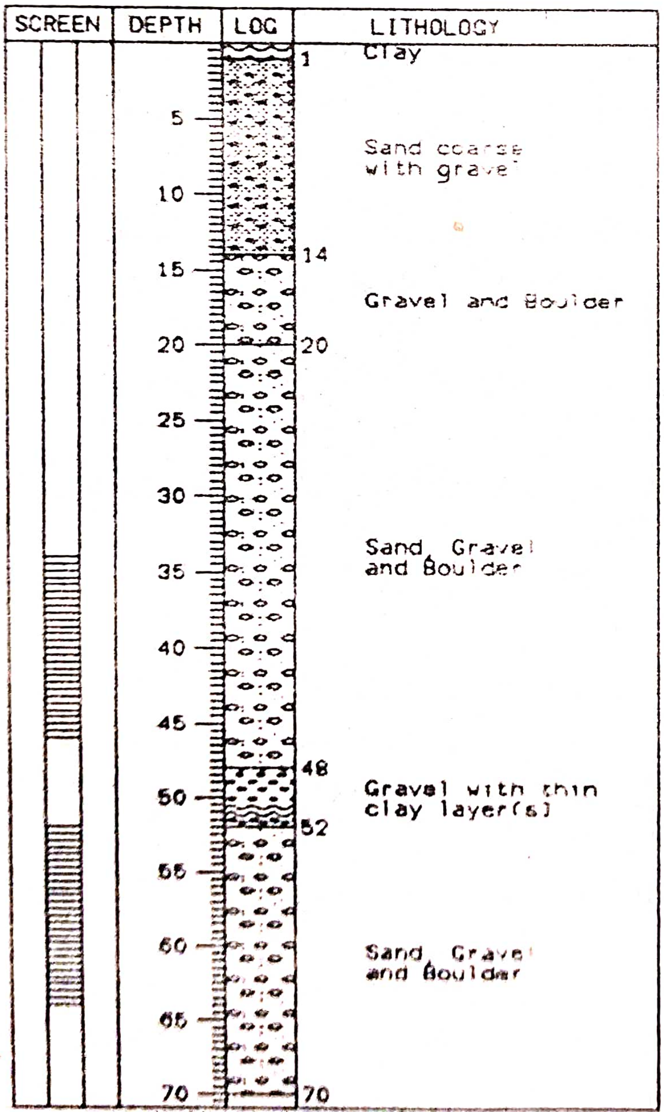
W E L L   L O G



B-47: Well Log of N 1/14

Well No NC 1/9	Location [illegible]
Elevation: 99	X = 302500 Y = 2991900
Method of Drilling: RIG	
Drilling Dates: 16.6.86 - 24.7.86	
Total Depth: 70.00	
Comments: Screen position 34 - 46, 52 - 64 m Screen type: Slotted Drilled under NISSAKU/T.C.F DEV PROJ	

W E L L   L O G



United Nations GW Software

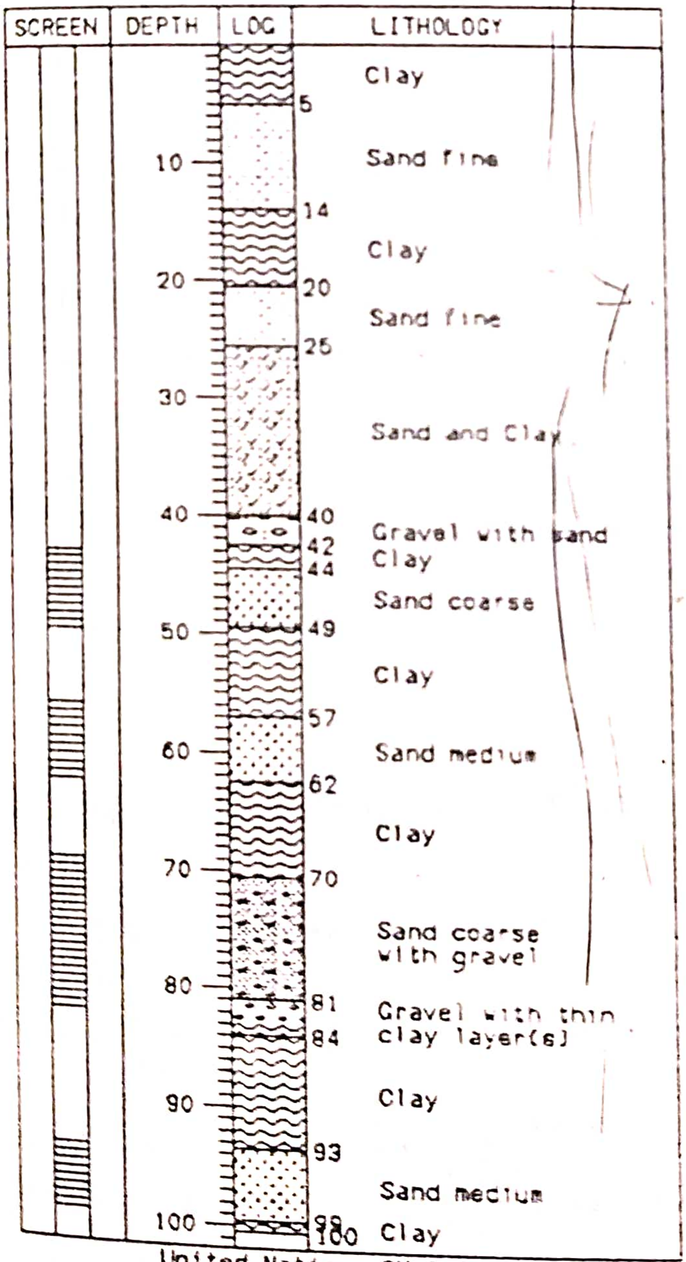
PUMPING TEST

Capacity: 725 L/MIN
SWL: 23.1 M
DWL: 31.55 M

B-48: Well Log of N1/9

Well No NC 1/8	Location PARAWANIPUR
Elevation: 107	X = 29[illegible]000 Y = 2996900
Method of Drilling: RIG	
Drilling Dates : 8.3.86 - 31.3.86	
Total Depth : 100.50	
Comments : Well size: 6/4" Screen position 43.0-49.7,56.0-62.5 m 69.2-82.2,93.7-99.2 m Screen type: Slotted Drilled under NISSAKU/SKIN TANNING IND	

W E L L   L O G



United Nations GW Software

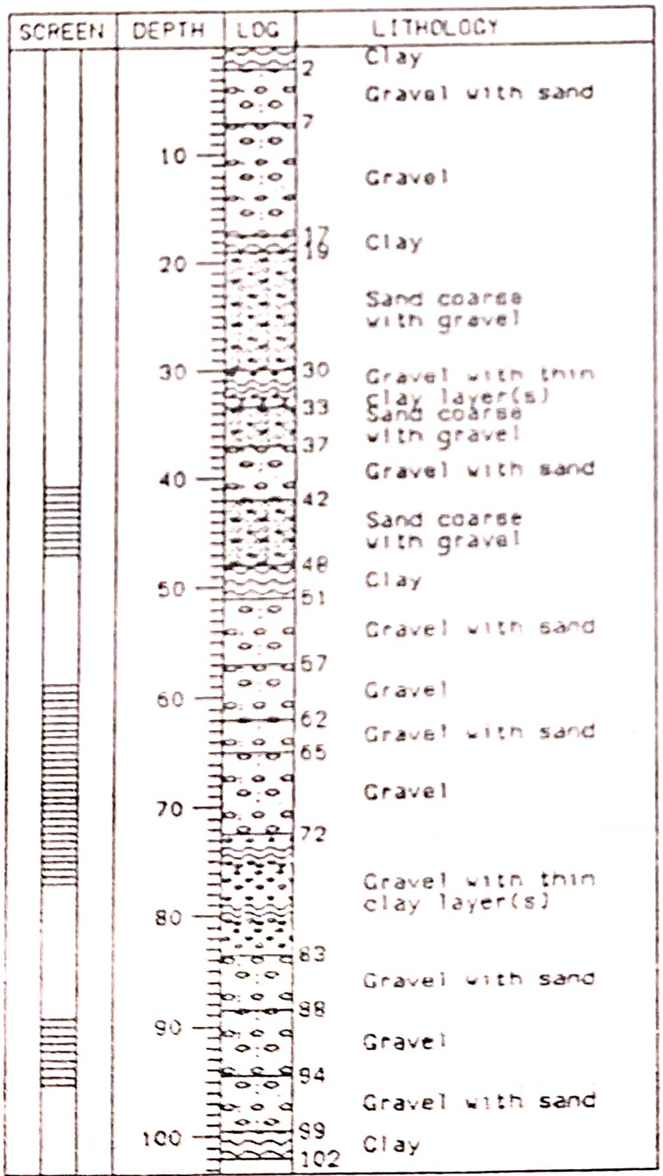
PUMPING TEST

Capacity 611.3 l/min
SWL +1 m (AGL)
DWL -3.14 m

B-49: Well Log of N 1/8

Well No NC 1/6	Location : SIMARA
Elevation : 138	X = 299600 Y = 3007250
Method of Drilling : RIG	
Drilling Dates : 7 6 85 - 9 6 85	
Total Depth : 102 00	
Comments : Well size 6/4" Screen position 40 5-46 7,58 6-76 9 m 89 2-95 2 Screen type Slotted Drilled under NISSAKU/SURYA TOBACCO	

WELL LOG



United Nations GW Software

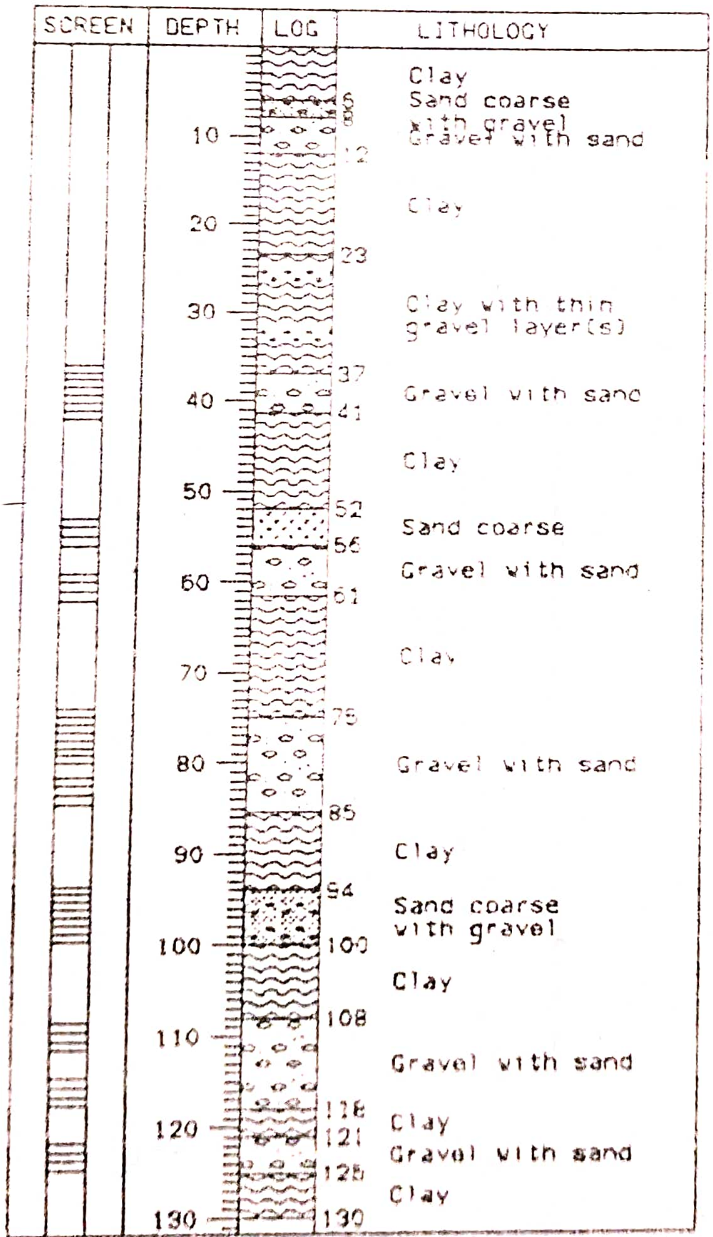
PUMPING TEST

Capacity 851 3 l/min
SWL 0 78 m
DWL 3 13 m

B-50: Well Log of N 1/6

Well No NC 1/1	Location BHARSENI,BARA
Elevation: 95	X = 295500 Y = 2992000
Method of Drilling: RIG	
Drilling Dates: 5 8 84 - 4 10 84	
Total Depth: 130 00	
Comments: Well size 6/4" Screen position 36-42,53-56,59-62,74-80m 81-84,93-99,108-111,114-117,121-124 m Screen type Slotted Drilled under NISSAKU/E TEXTILE IND	

W E L L   L O G

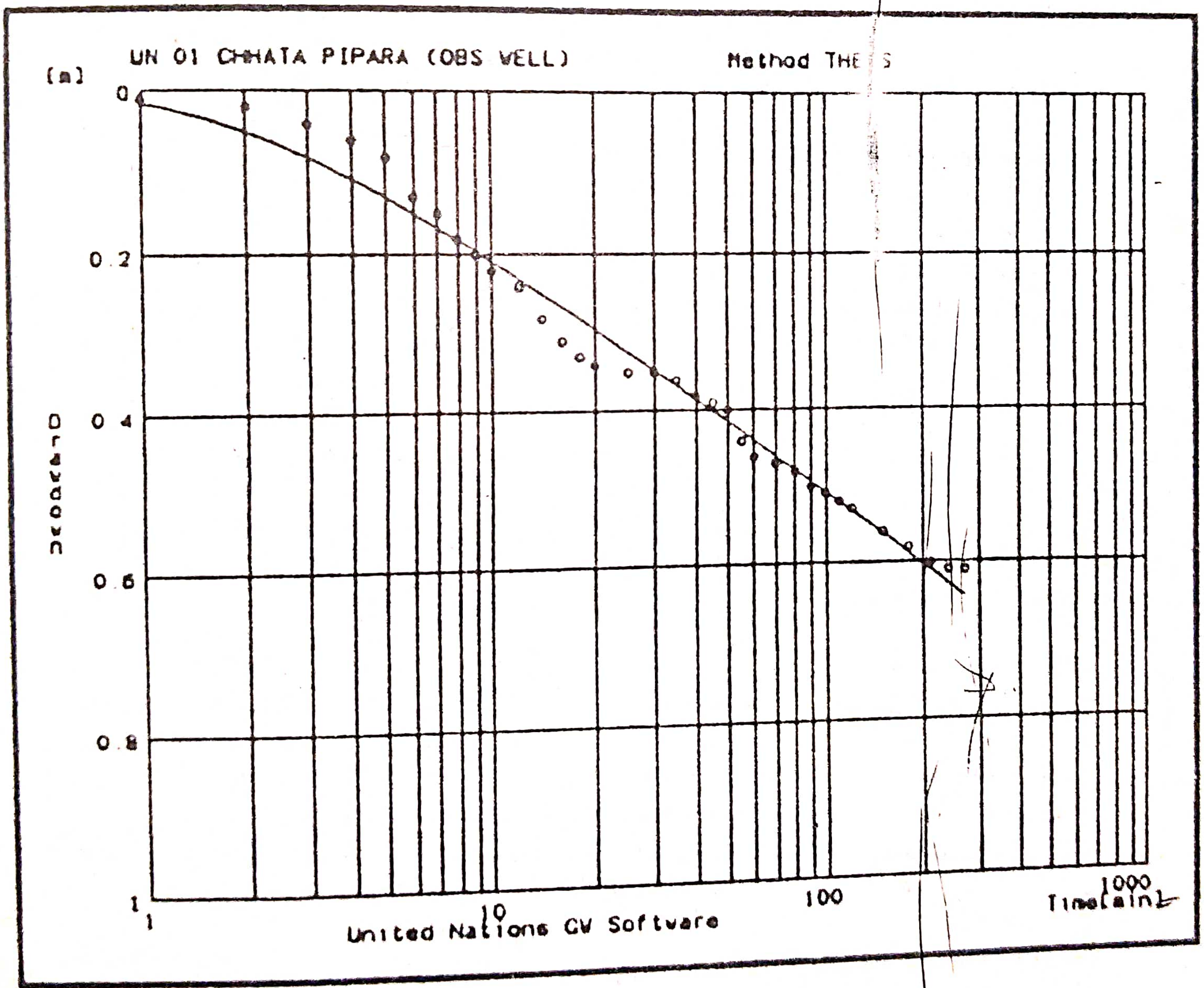


United Nations GW Software

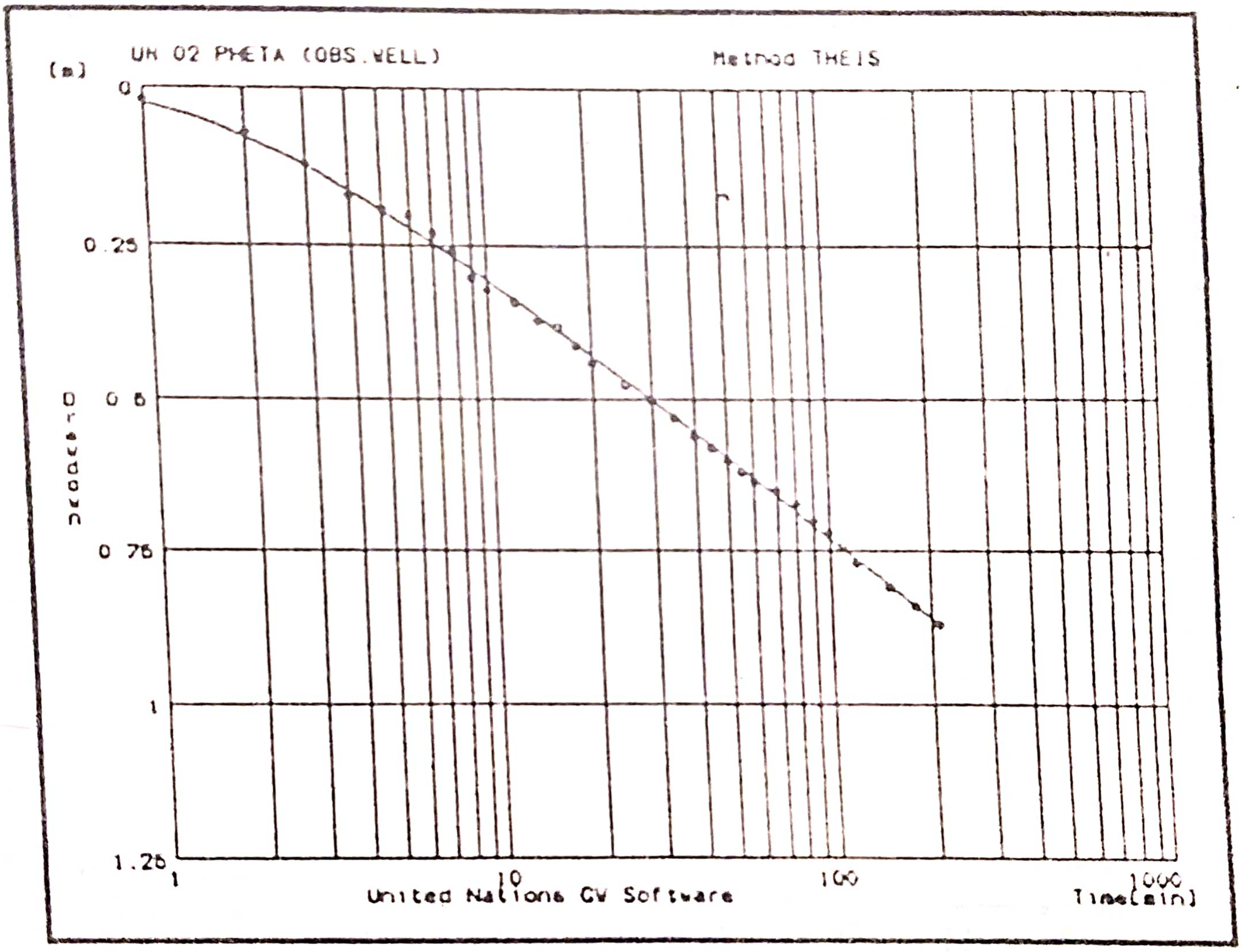
PUMPING TEST

Capacity 989 6 l/min
Transmiss 4298 m2/min
Method Theis
SWL +0.05 m
DWL -0.78 m

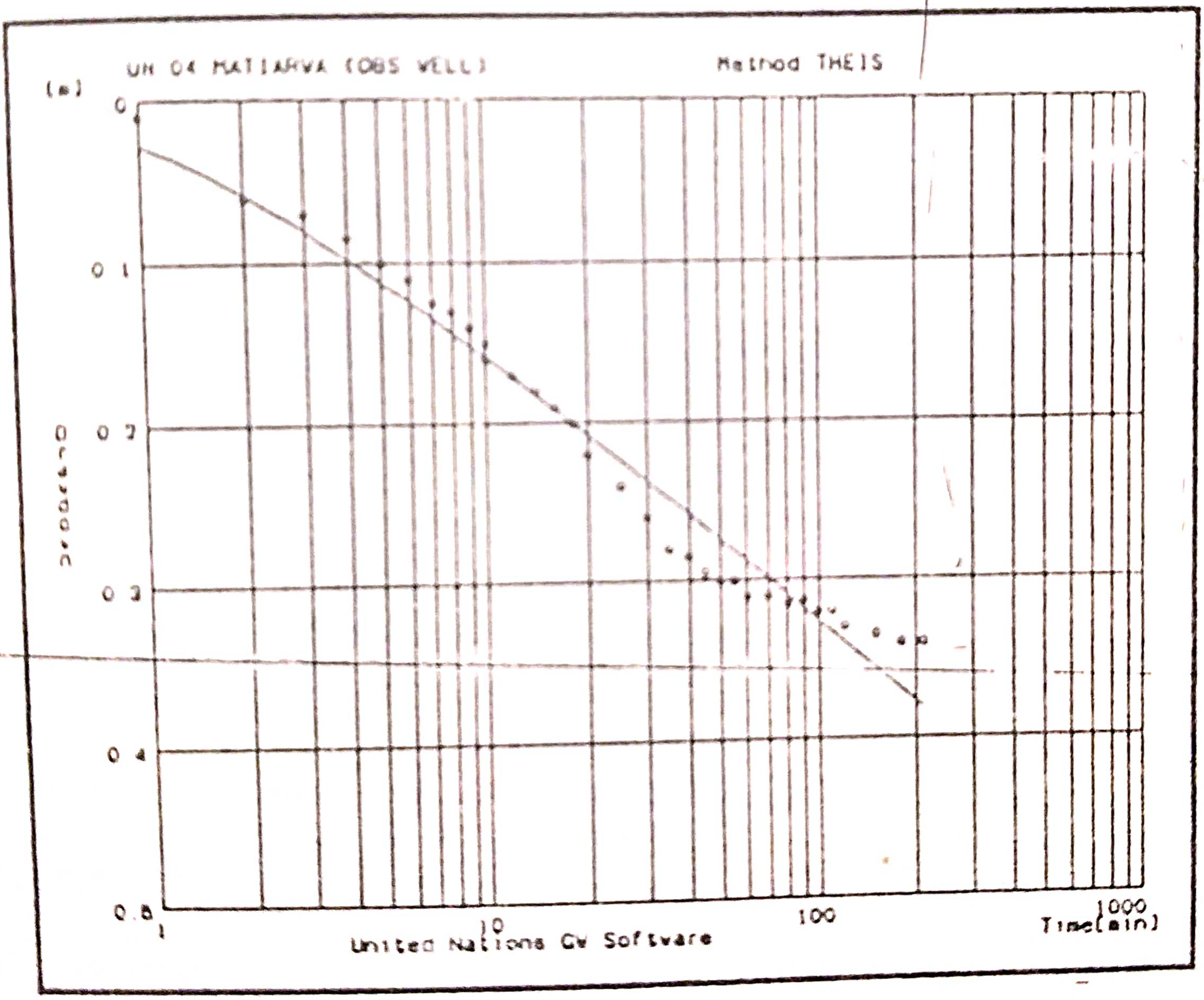
B-51: Well Log of N 1/1



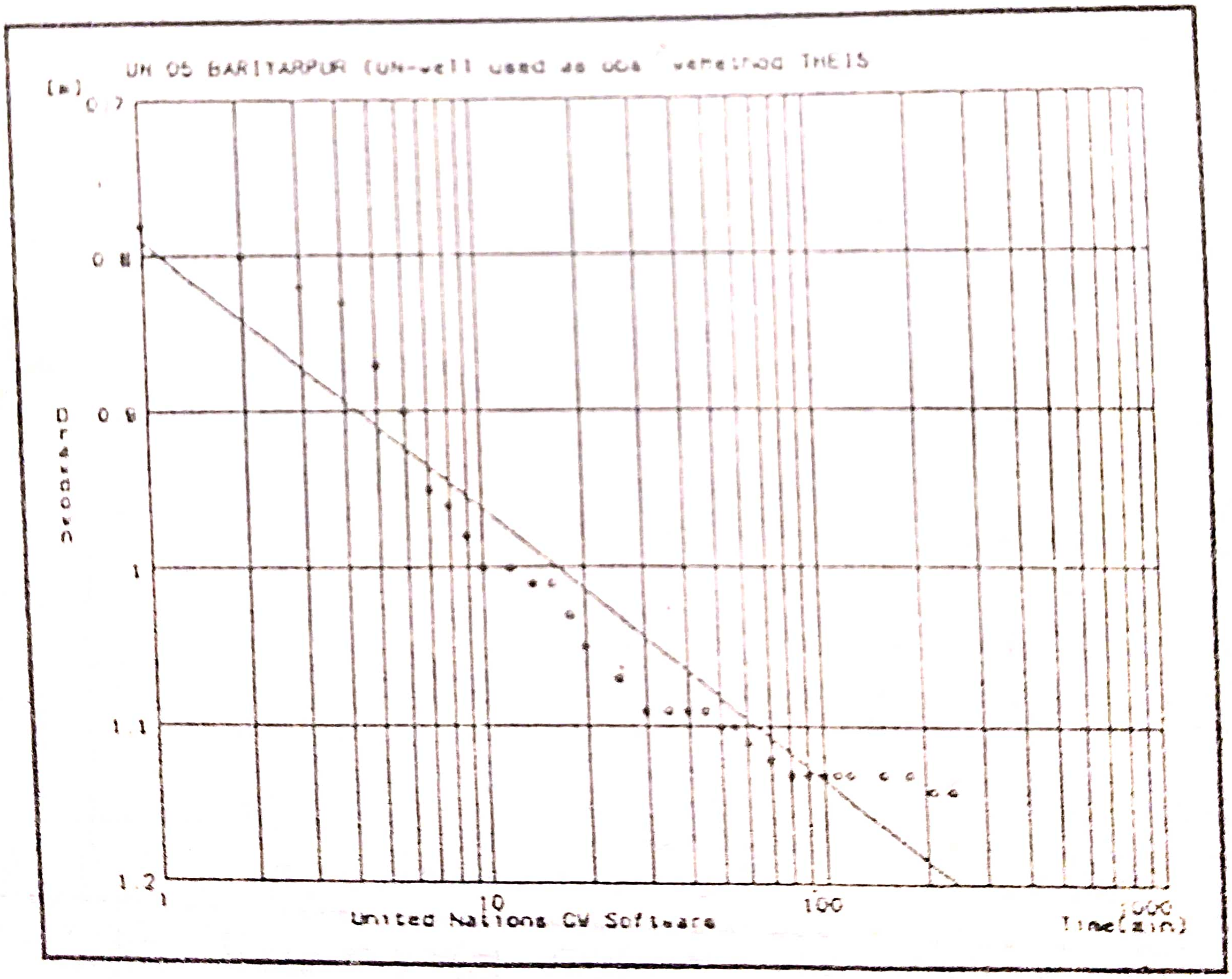
C-1: Pumping Test of UN 01



C-2: Pumping Test of UN 02

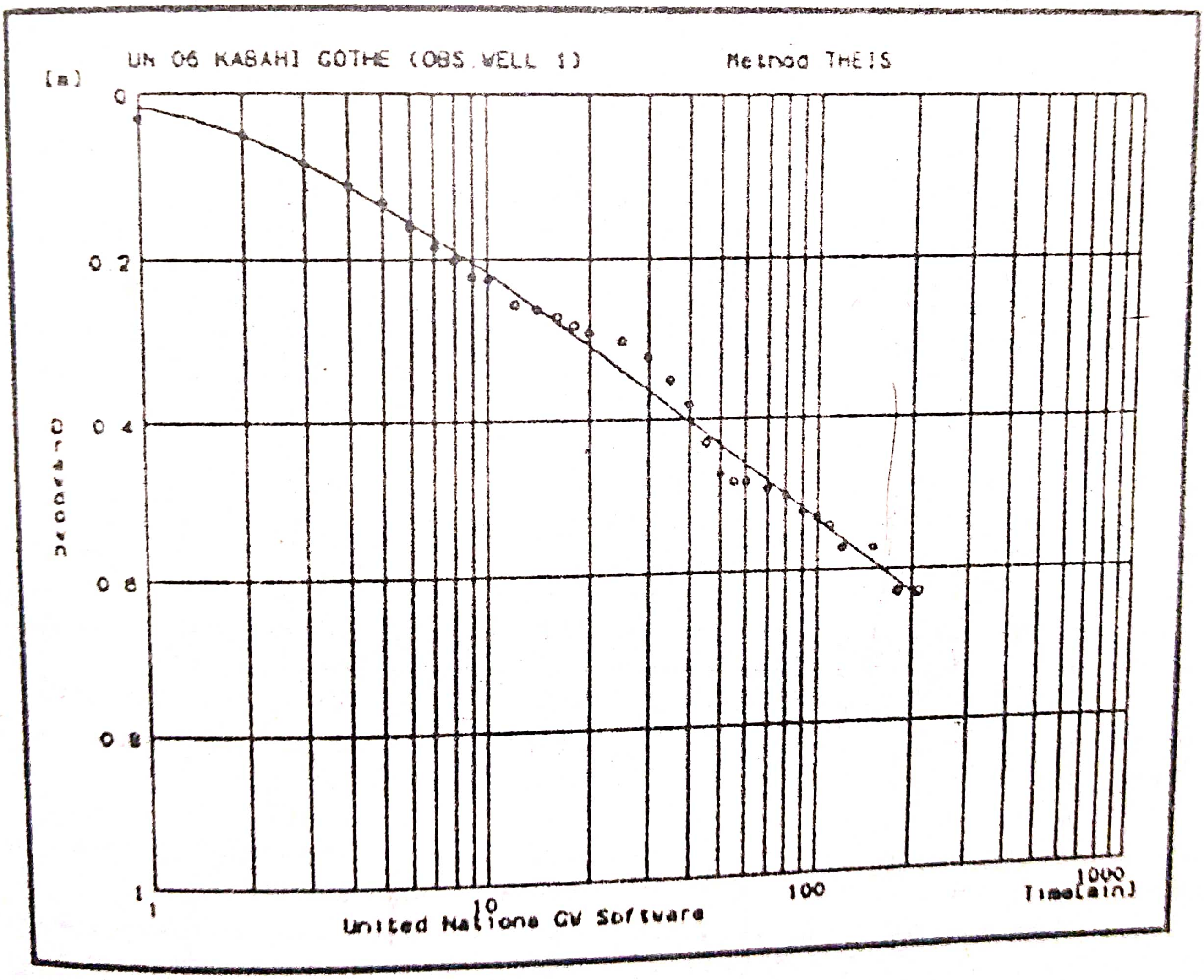


UN 04 MATIARVA (OBS WELL)
Method THEIS
(m)
0
0.1
0.2
0.3
0.4
0.5
Drawdown
1
10
100
1000
Time(min)
United Nations GW Software

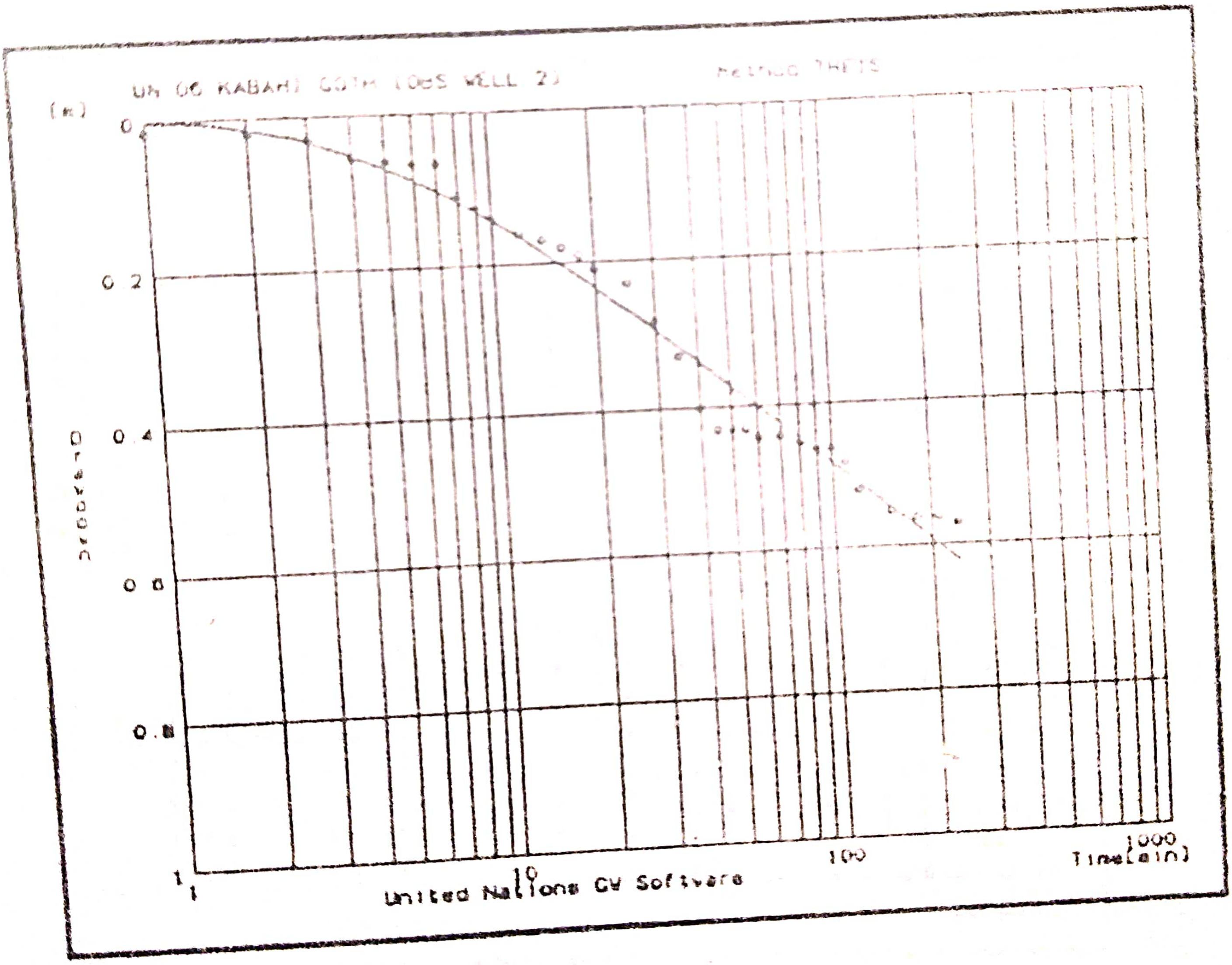


C-4: Pumping Test of UN 05

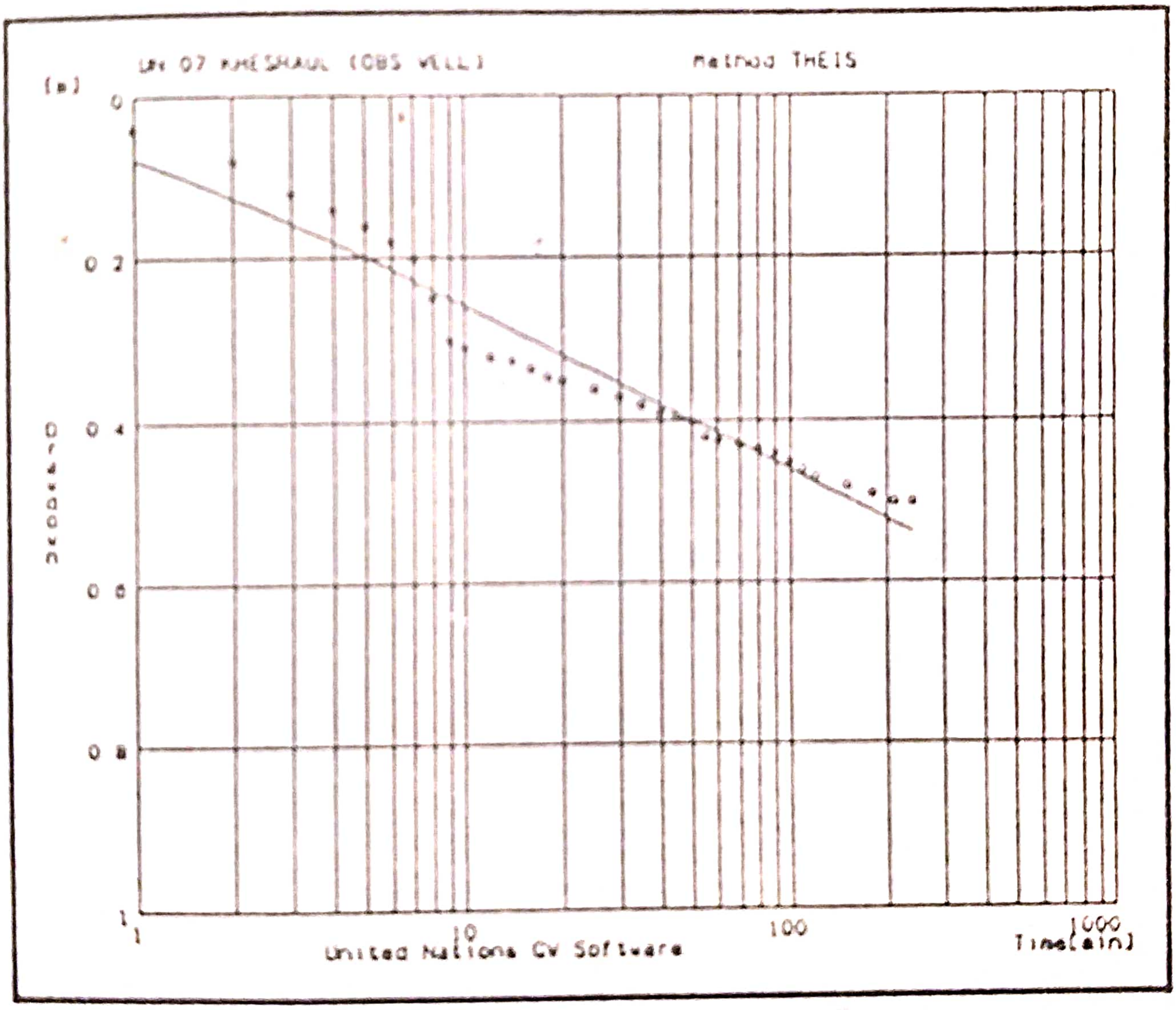
C-3: Pumping Test of UN 04



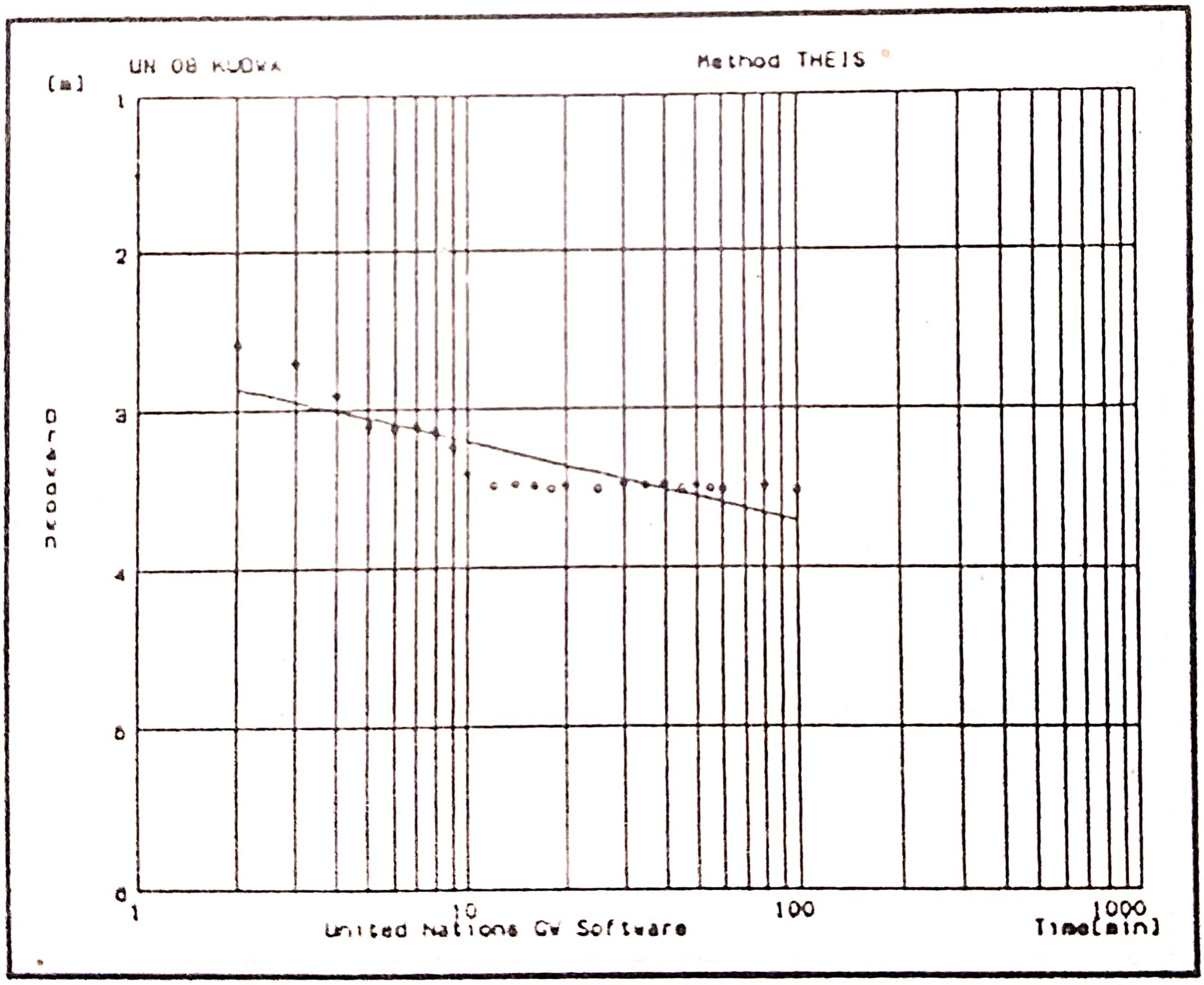
C-5: Pumping Test of UN 06 (obs 1) (obs 2)



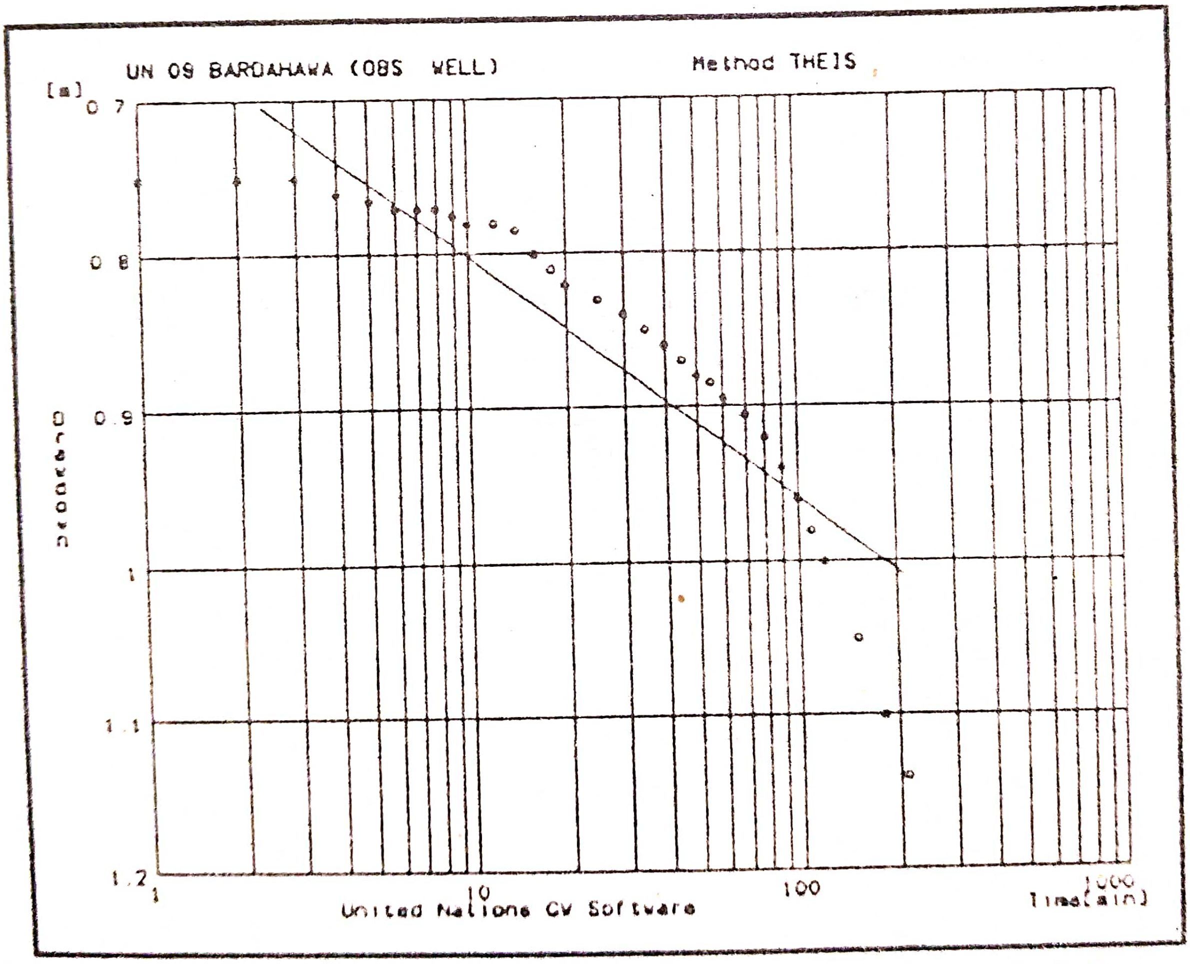
C-6: Pumping Test of UN 06



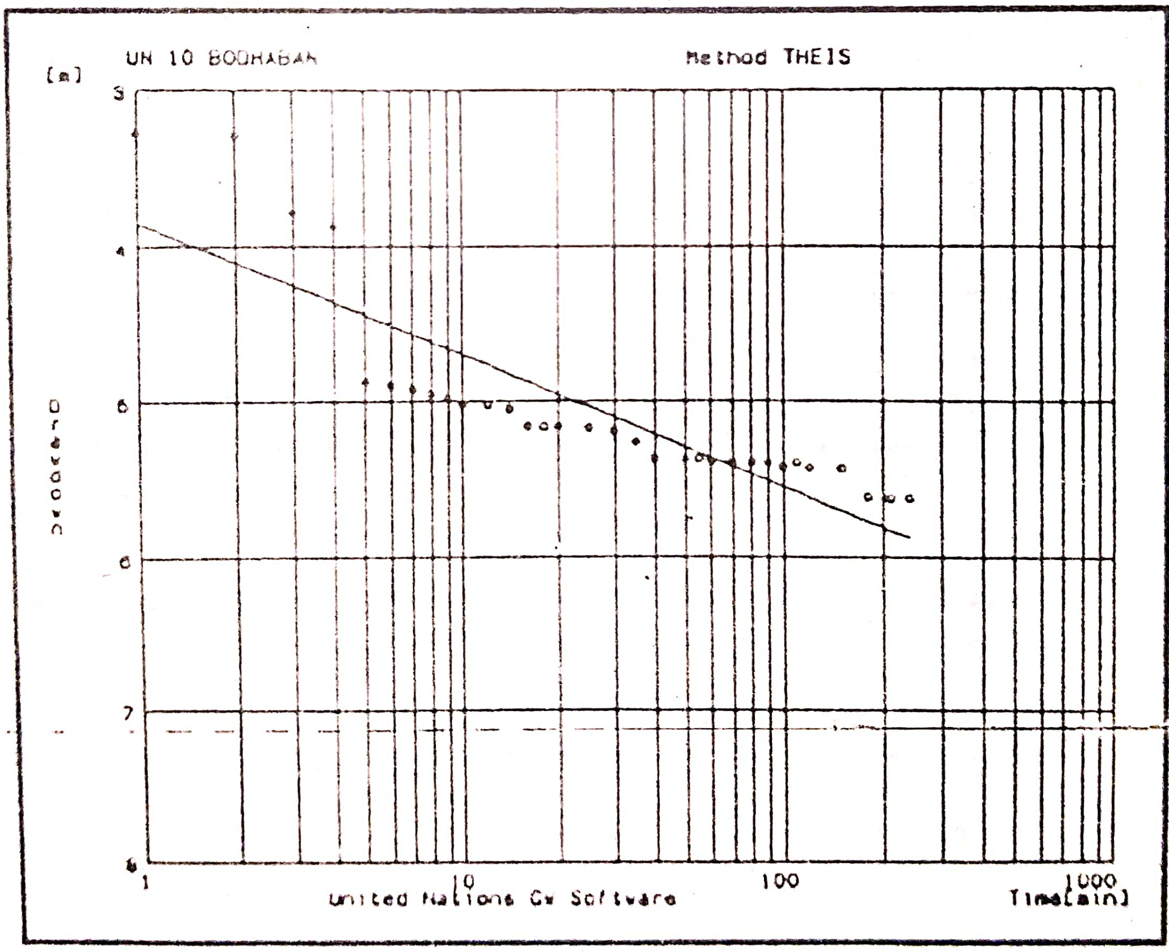
C-7: Pumping Test of UN 07



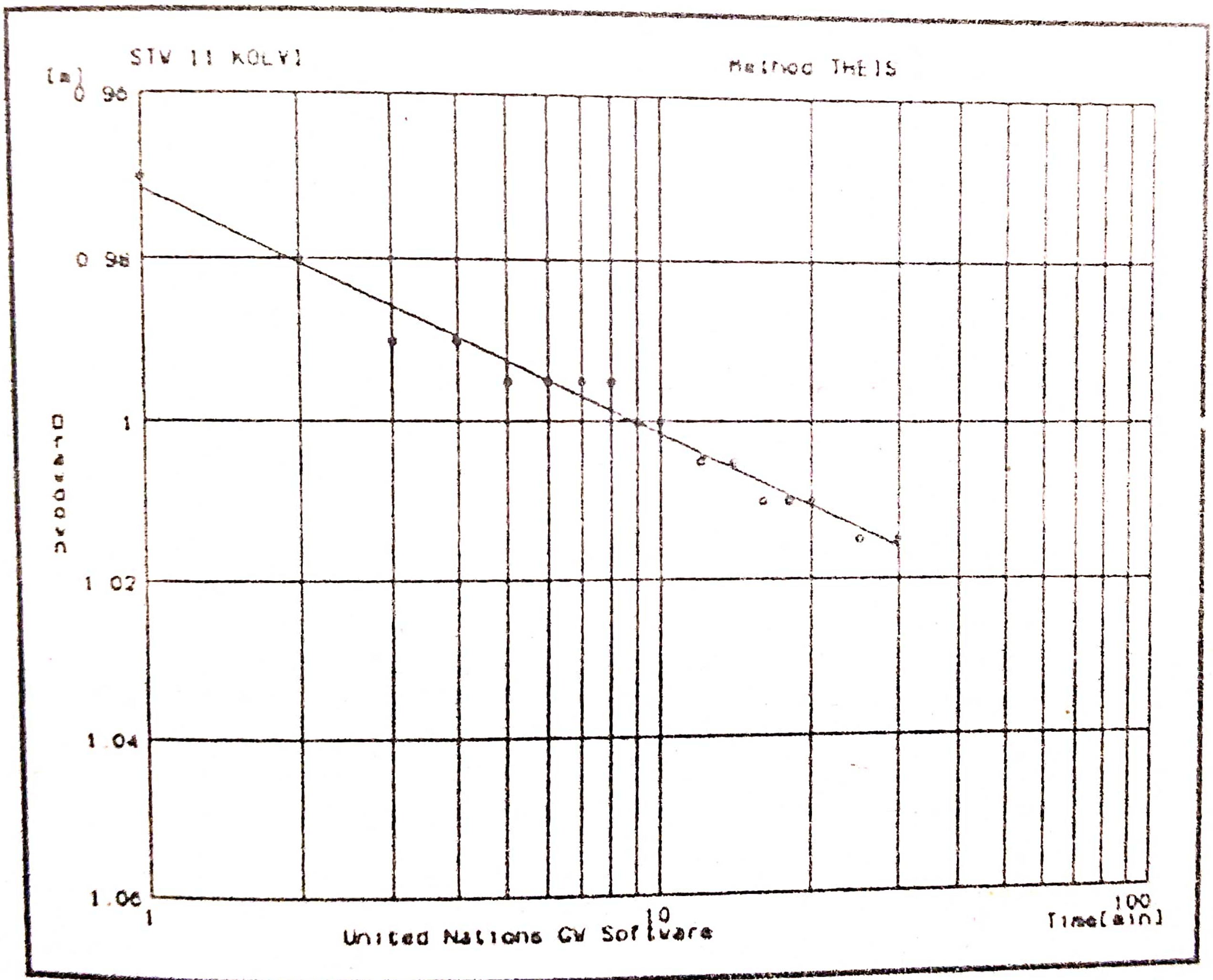
C-8: Pumping Test of UN 06



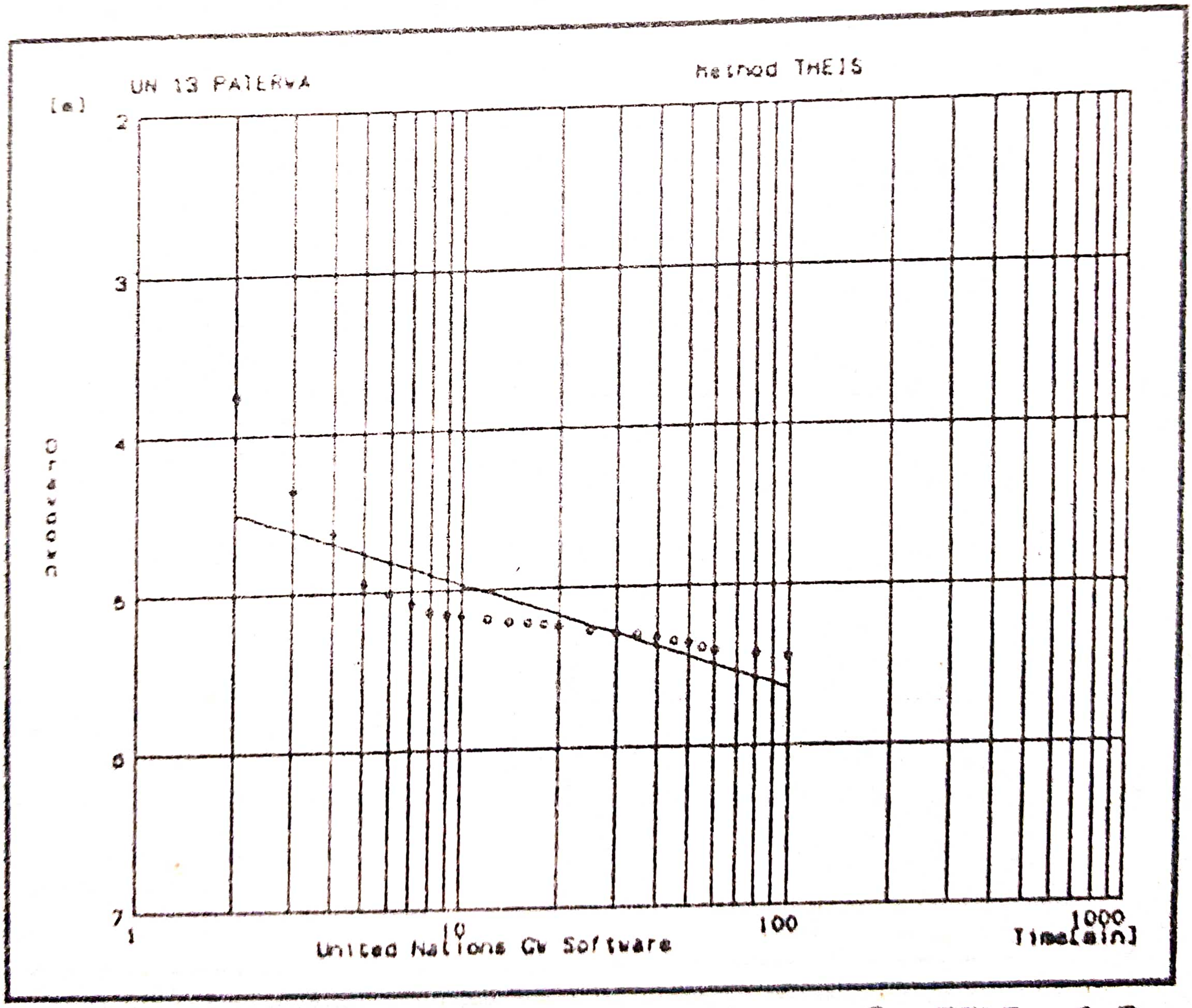
C-9: Pumping Test of UN 09



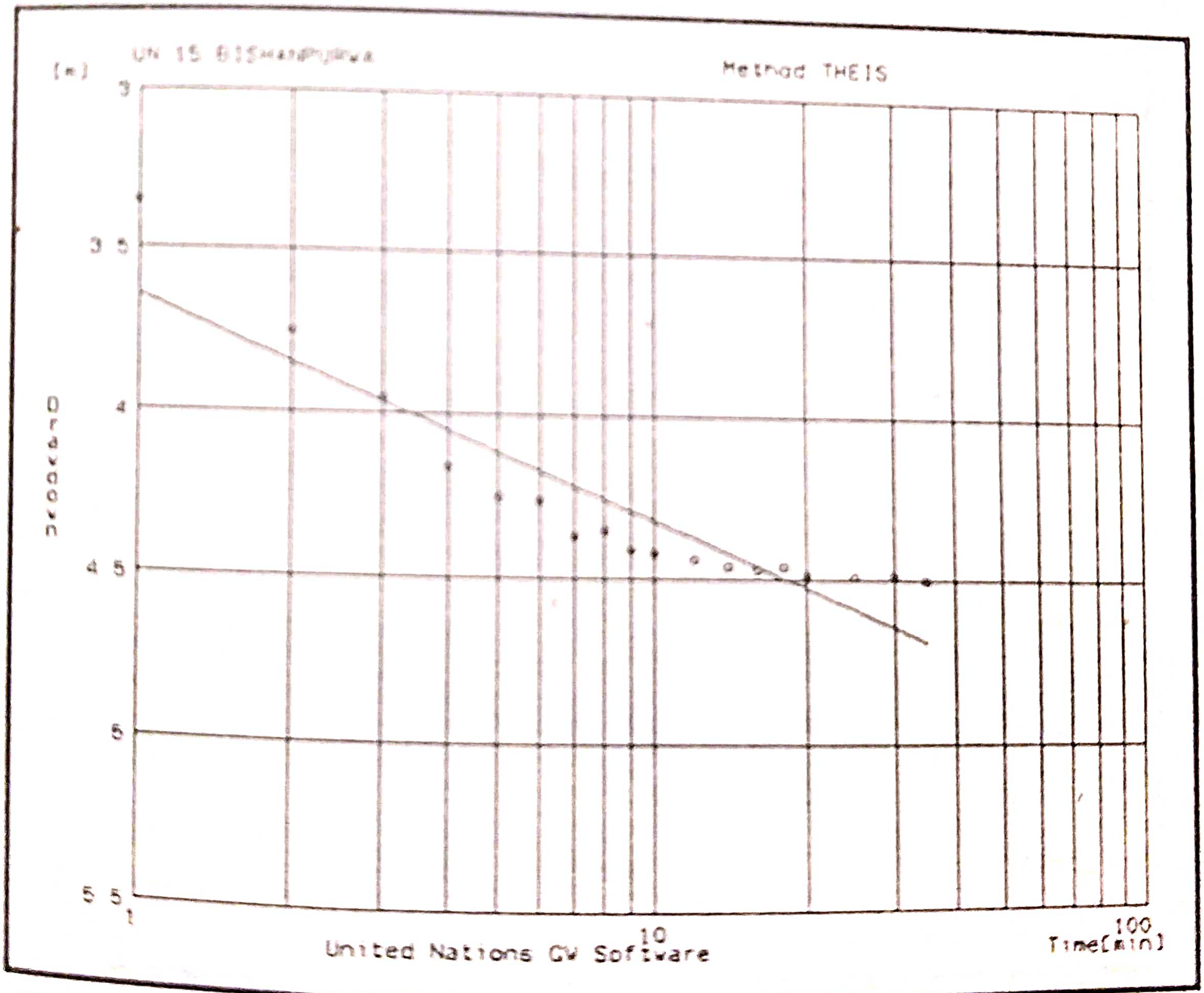
C-10: Pumping Test of UN 10



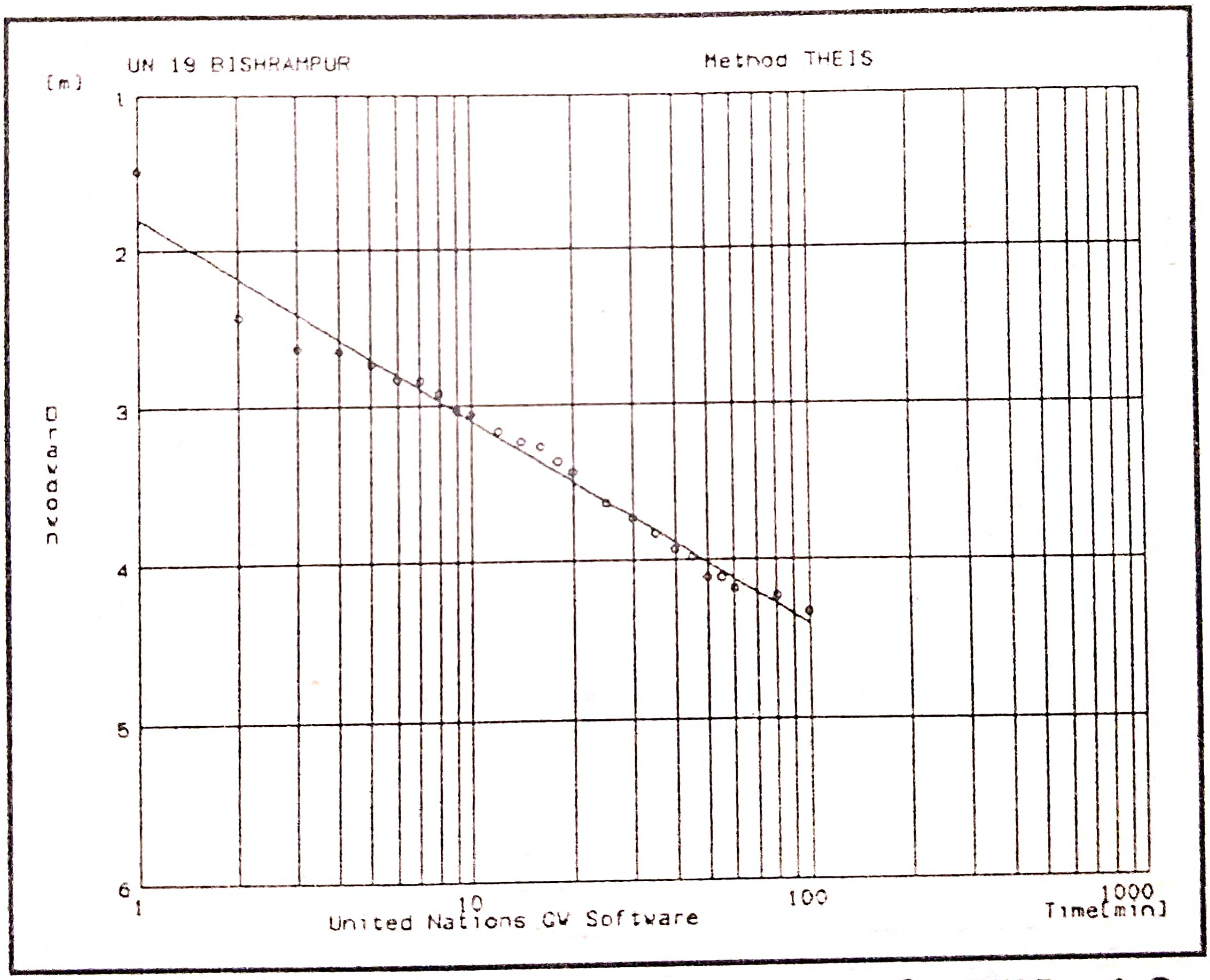
C-11: Pumping Test of UN 11



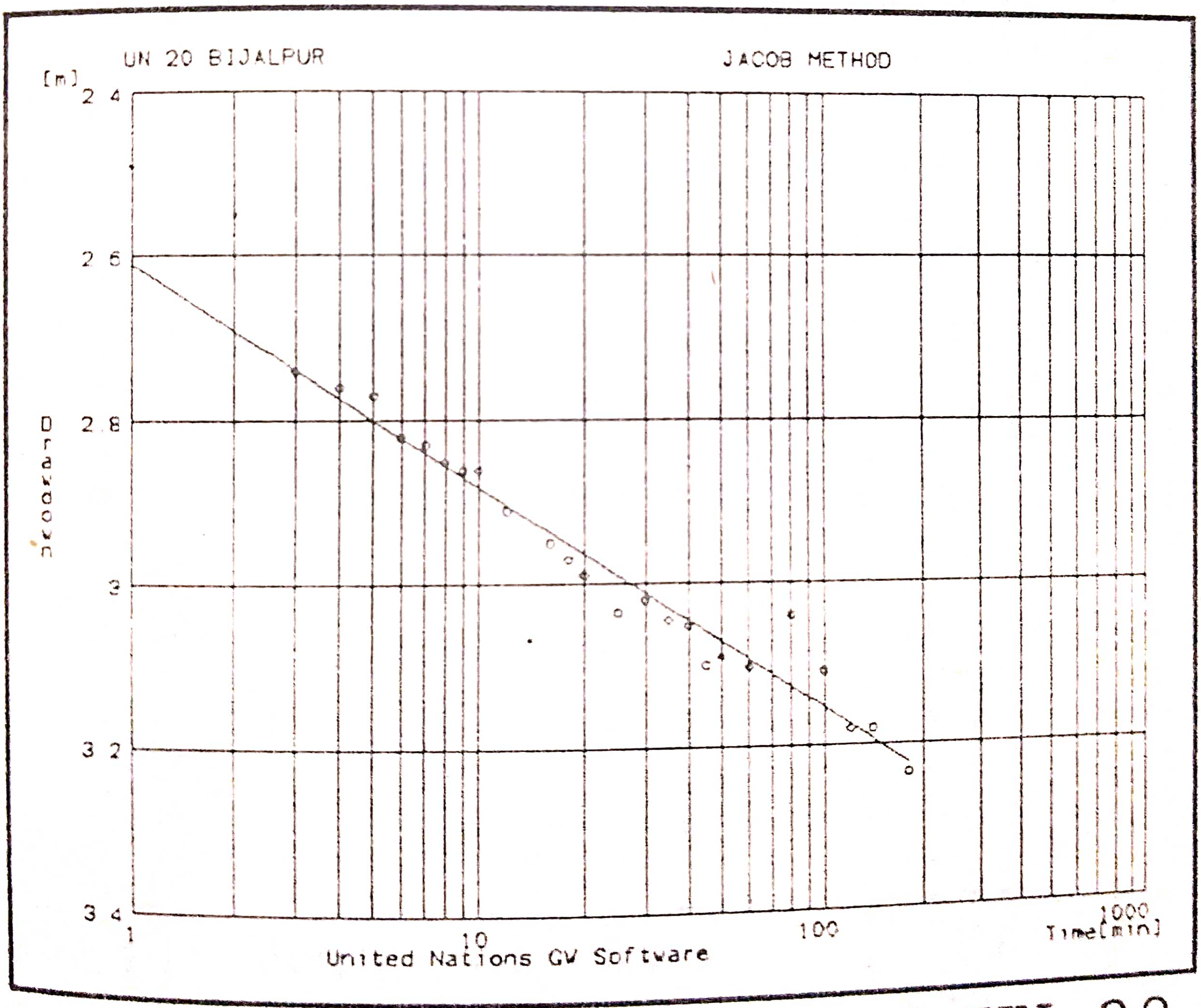
C-12: Pumping Test of UN 13



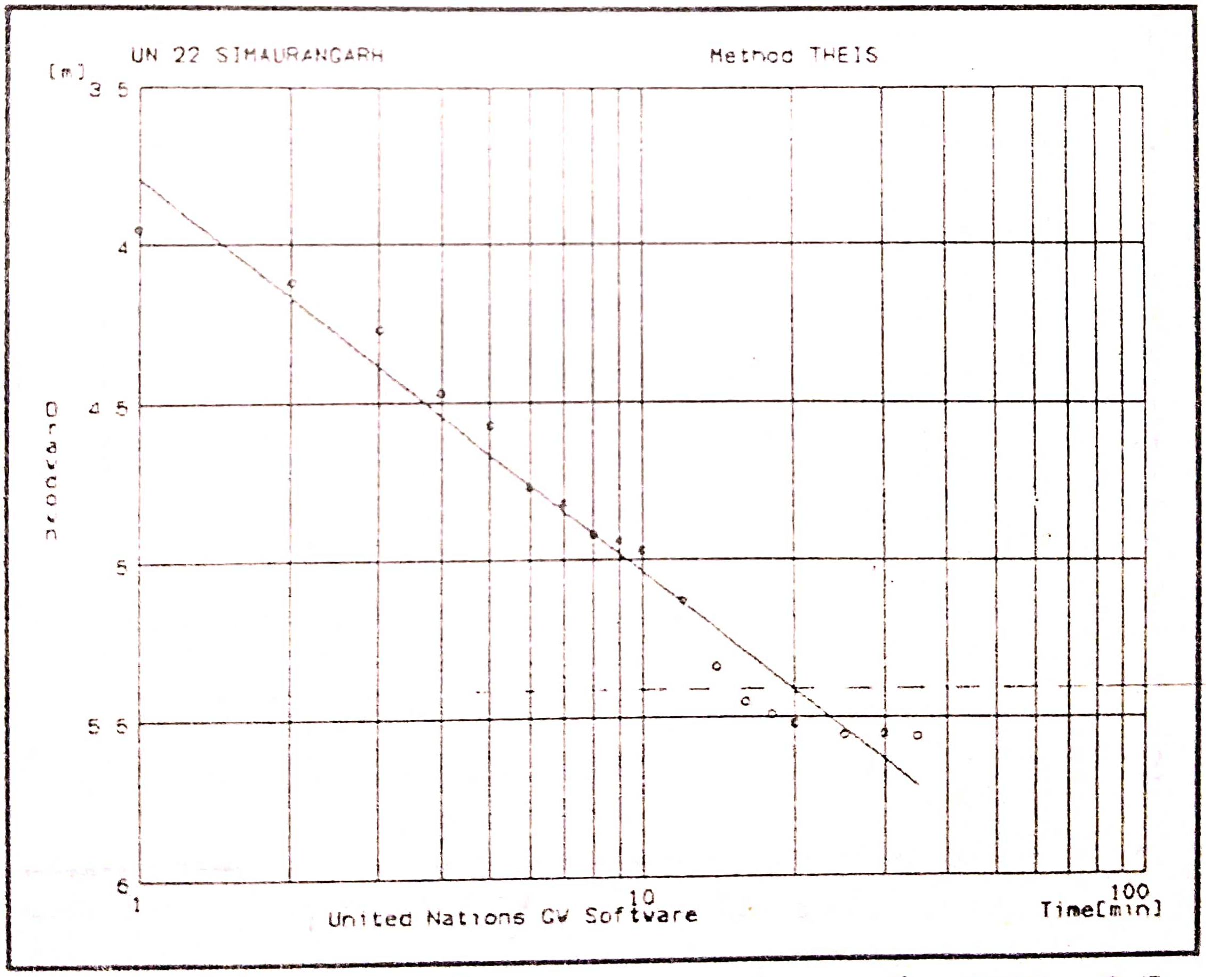
C-13: Pumping Test of UN 15



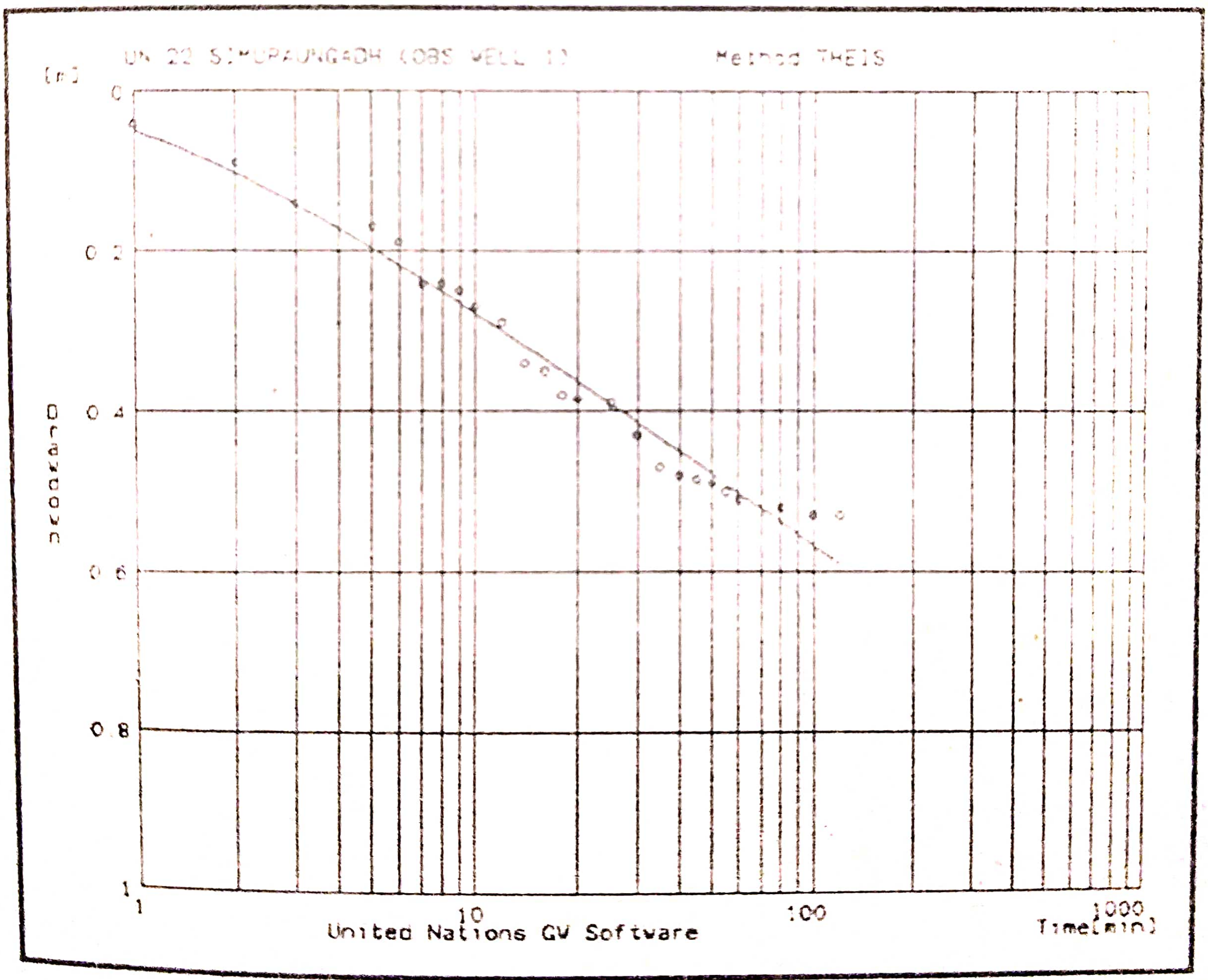
C-14: Pumping Test of UN 19



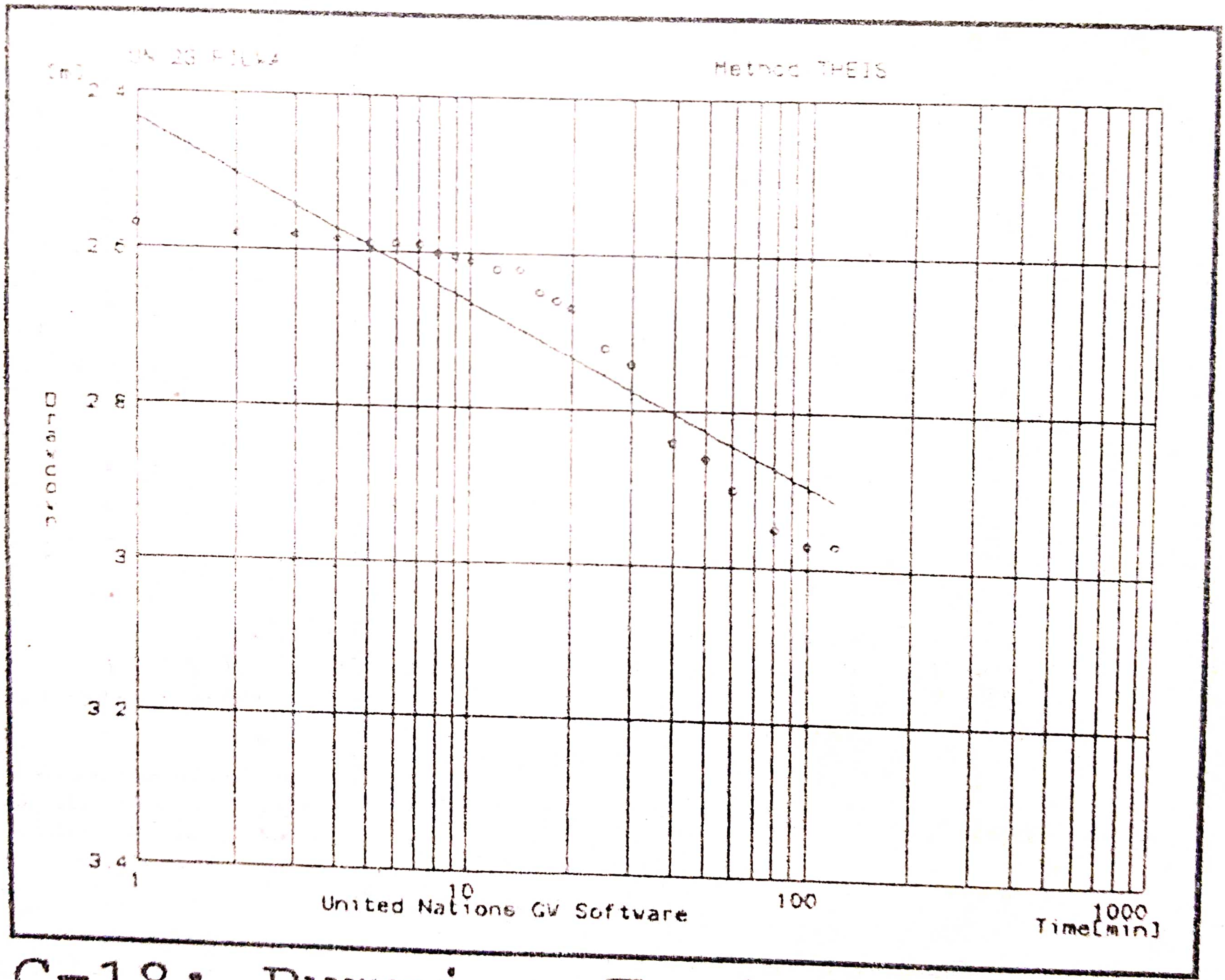
C-15: Pumping Test of UN 20



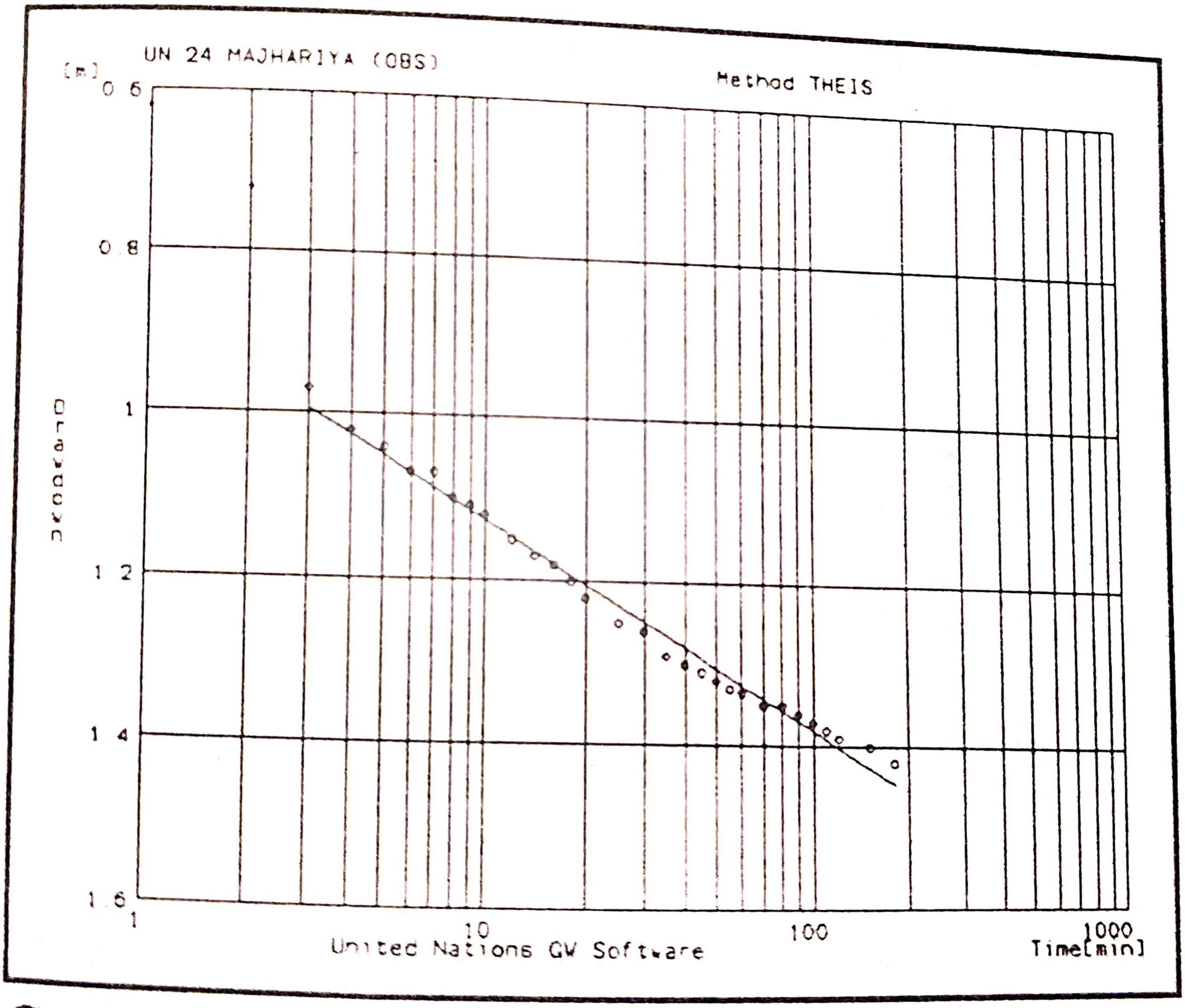
C-16: Pumping Test of UN 22



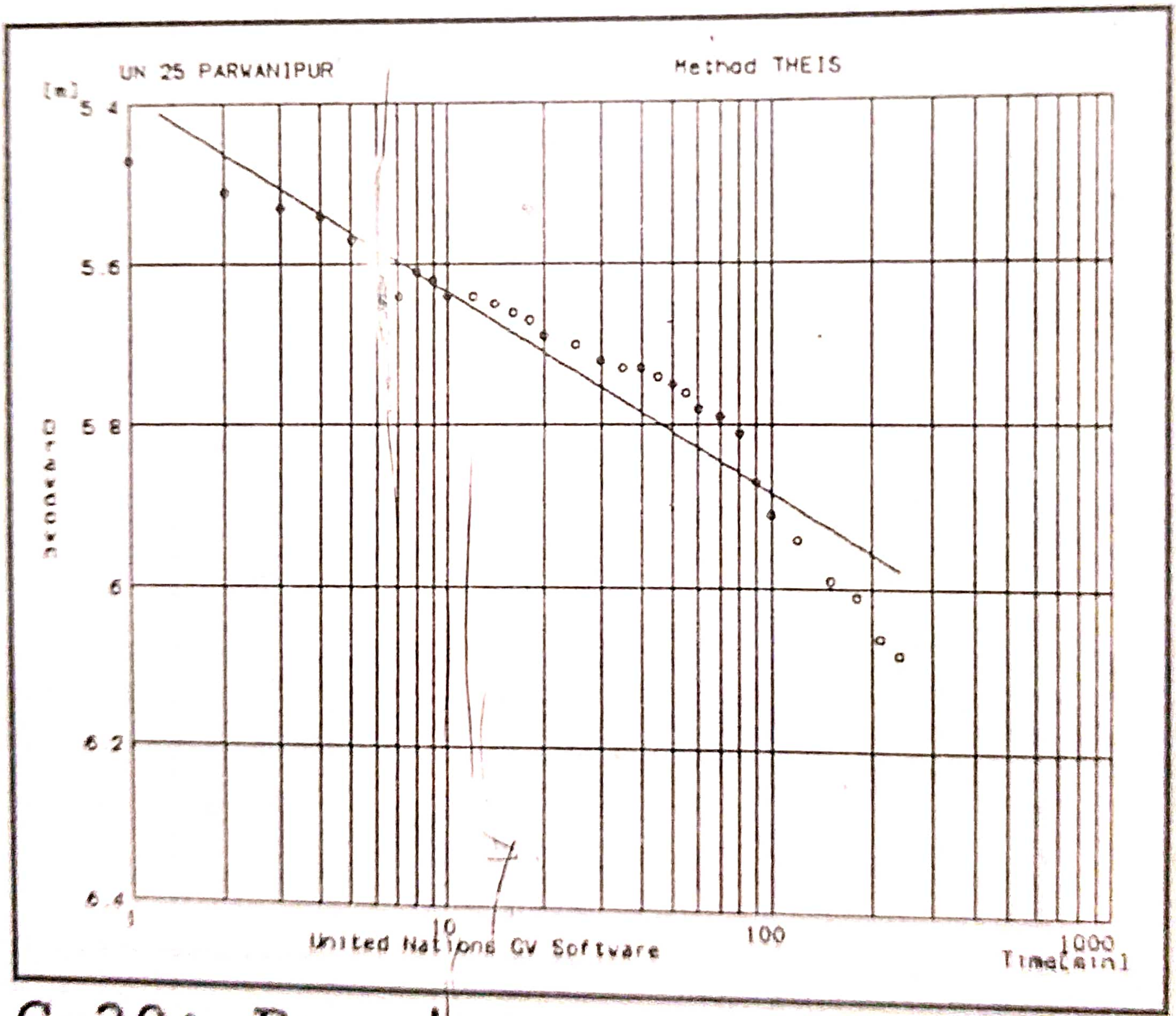
C-17: Pumping Test of UN 22 (obs)



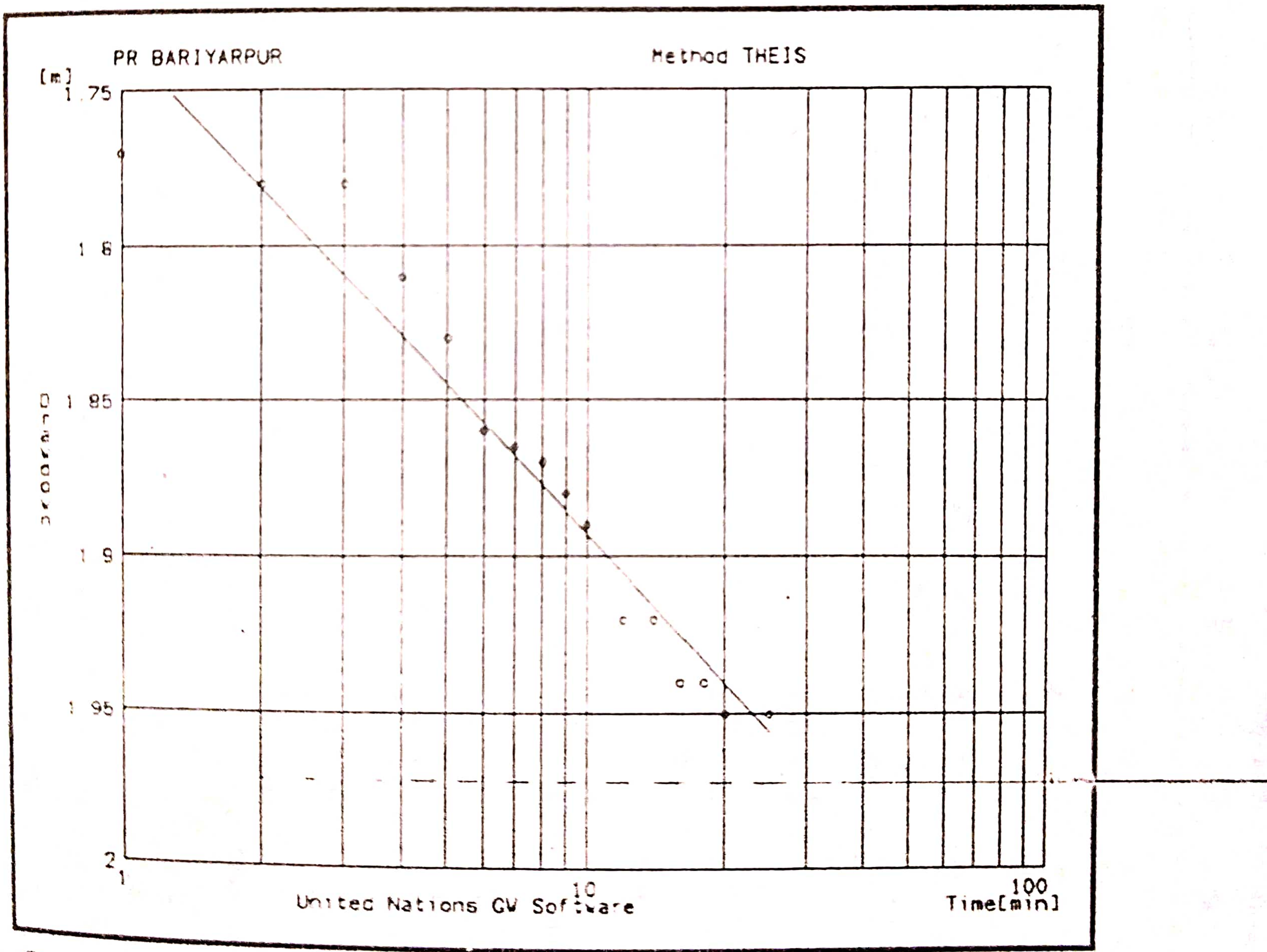
C-18: Pumping Test of UN 23



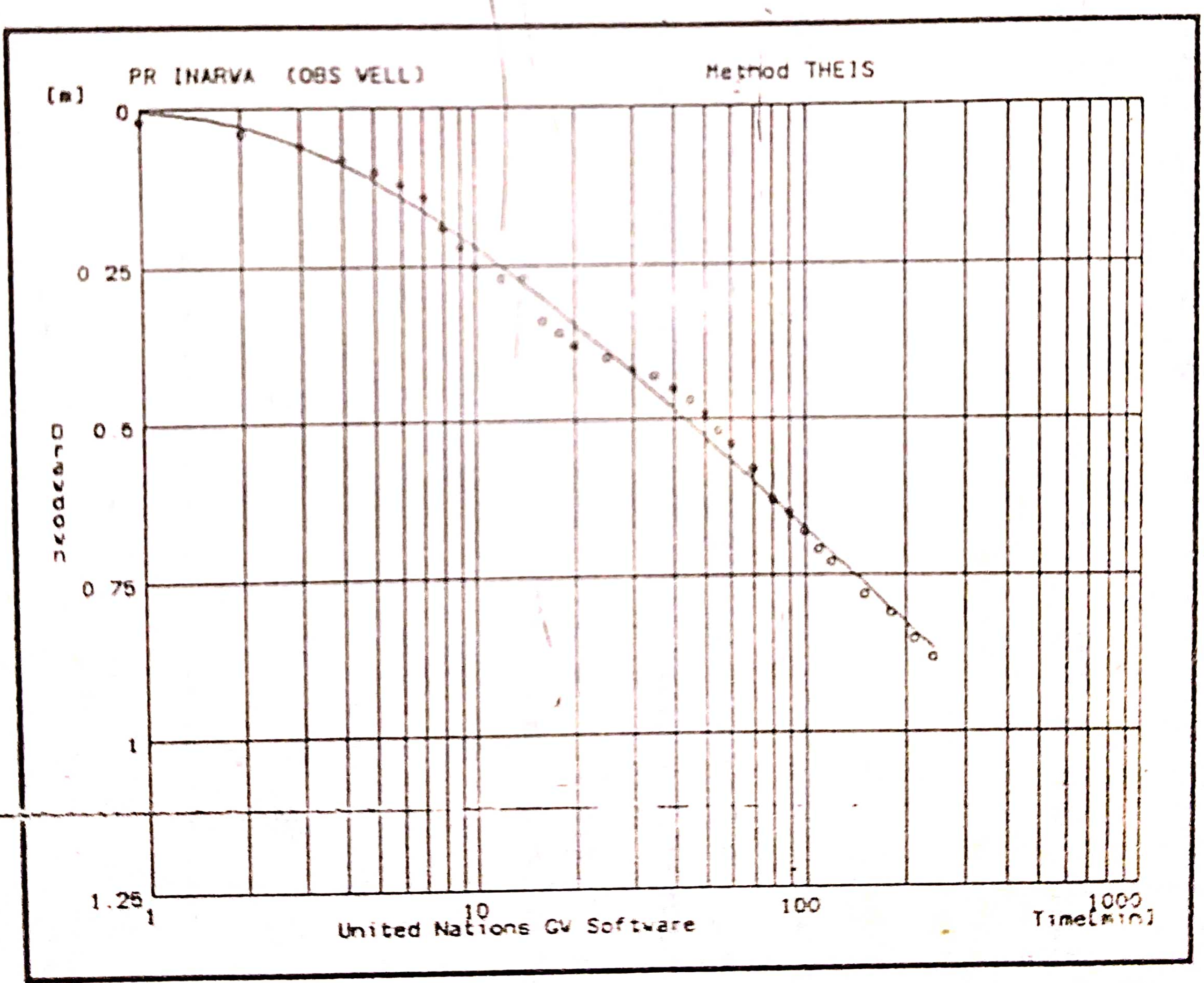
C-19: Pumping Test of UN 24 (obs)



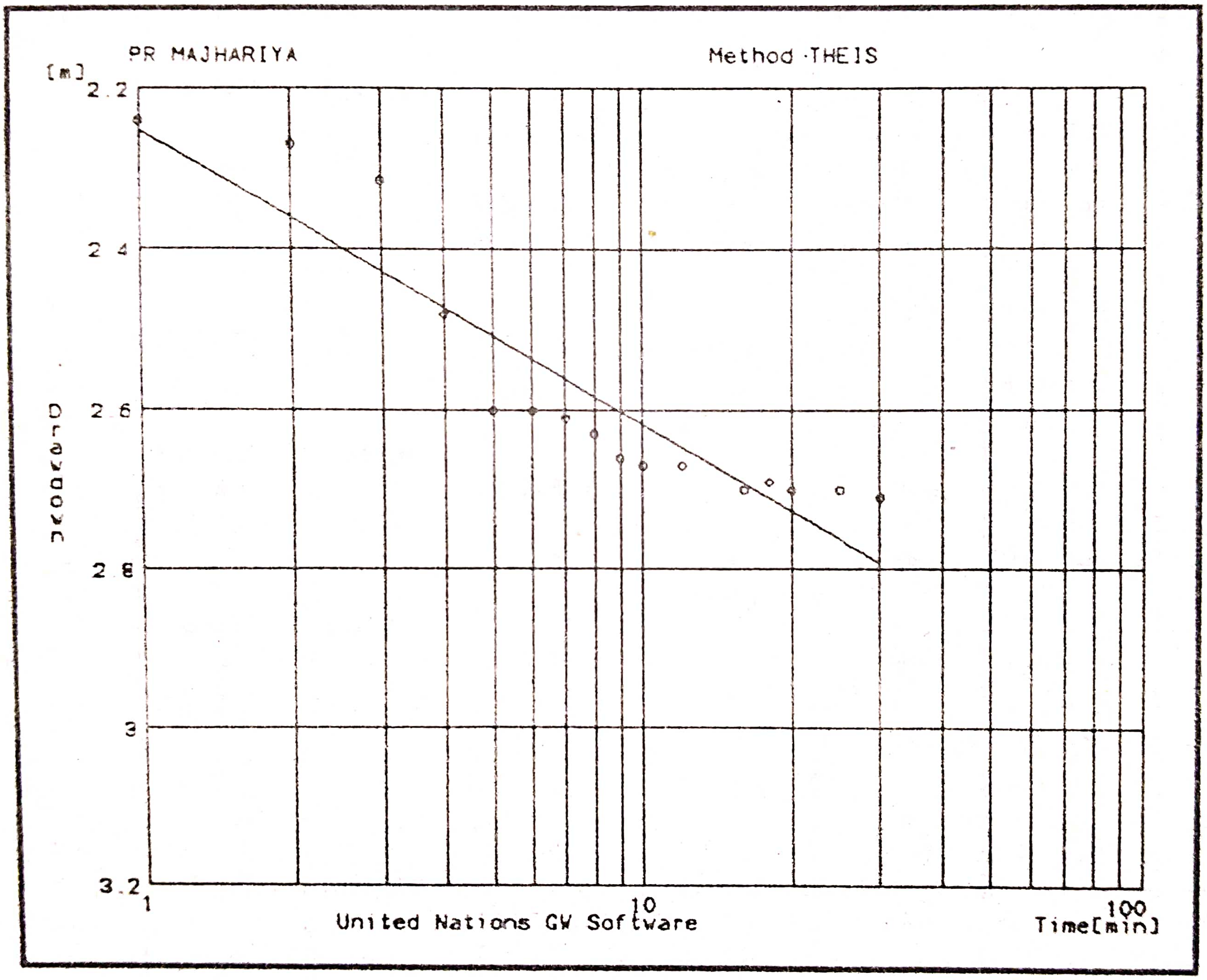
C-20: Pumping Test of UN 25



C-21: Pumping Test of Pr 01



C-22: Pumping Test of Pr 02



C-23: Pumping Test of Pr 03

APPENDIX D

D-1: Monthly Water level Measurement in UN STW in Bara District

UN WELL No	Location	X	Y	Ele(m)	M.P	Year	Water Level Measurements in meters (BGL)											
							Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.	Chhatapira	297050	2999500	99.95	0.65	1990			3.3	1.7	1.7	1.4	1.4	0.9	0.7	0.6	1.0	1.4
						1991	1.6	1.7	1.7	1.8	1.9	2.0	0.4	0.8	0.9	1.1	1.2	1.6
2.	Pheta	297900	2988500	86.64	0.60	1990			2.9	3.8	3.8	3.7	4.0	2.8	2.3	2.2	2.8	3.7
						1991	3.8	3.8	4.2	4.3	4.1	3.9	2.3	1.9	1.9	2.4	2.5	-
3.	Simra	299800	3008100	142.09	0.65	1990		9.8	10.6	10.6	10.3	9.3	9.2	9.2	9.7	9.8	10.1	10.1
						1991	10.3	10.4	10.6	10.6	10.7	10.7	10.1	9.6	-	-	-	-
4.	Matiarwa	299500	2984350	83.66	0.49	1990			1.7	3.8	4.0	4.0	3.9	3.7	3.5	3.0	3.3	3.9
						1991	4.1	4.0	4.3	4.7	4.8	4.8	4.1	3.6	3.6	2.6	2.7	3.4
5.	Bariyarpur	306200	2986450	86.66	0.75	1990			3.8	4.4	4.4	3.9	3.4	3.1	2.5	2.2	3.2	3.7
						1991	3.8	3.9	4.0	4.1	4.2	4.1	3.5	3.4	1.9	2.7	2.8	3.5
6.	Kabahigoth	304600	2978900	79.55	0.40	1990			2.3	2.4	2.6	2.5	2.5	2.1	1.7	1.1	1.5	2.4
							2.5	2.6	2.8	2.8	2.9	3.0	2.5	2.4	1.0	1.3	1.4	1.8
7.	Khesraul	300800	3001000	113.01	0.72	1990			3.4	3.5	3.5	3.1	3.0	1.1	2.0	1.9	2.2	3.0
						1991	3.0	3.1	3.2	3.3	3.4	3.5	2.4	2.4	0.8	2.5	2.7	3.0
8.	Kurwa	311600	2981450	84.46	0.80	1990			4.8	5.1	5.1	4.9	4.6	4.5	3.3	3.2	3.3	4.8
						1991	1.8	4.9	1.9	5.1	5.1	5.1	4.4	4.3	0.7	4.1	4.2	4.5
9.	Bardahawa	307600	3004200	120.63	0.65	1990						1.5	1.4	0.8	0.7	0.7	1.1	1.7
						1991	4.9	1.8	5.0	2.1	2.1	2.2	0.8	0.7	1.5	1.4	1.6	1.8
10.	Badhaban	312600	2997000	120.95	0.7	1990						1.5	1.3	0.8	0.7	0.7	1.1	1.7
						1991	1.0	1.3	1.0	1.0	1.1	0.9	0.5	0.4	0.7	0.4	0.5	0.7
11.	Kolvi	319600	2994500	108.88	0.65	1990			3.3	3.8	3.6	3.2	1.7	1.6	1.5	1.3	1.9	2.1
						1991	2.3	2.4	2.5	2.5	2.6	1.8	1.7	1.6	2.0	1.5	1.7	2.1
12.	Shreenagar	311400	2974700	108.88	0.7	1990			3.5	3.7	3.8	3.7	3.5	3.2	3.0	2.6	2.7	3.1
						1991	3.5	3.4	3.6	3.7	3.8	3.8	3.5	3.5	0.8	2.8	2.9	3.3
13.	Paterwa	318200	2978950	87.13	0.15	1990			3.1	3.5	3.7	3.6	3.6	2.5	1.9	1.9	2.2	2.4
						1991	2.7	3.8	3.8	3.0	3.1	3.1	2.6	2.6	1.3	2.3	2.5	2.8
14.	Nijgarh	320500	3010600	165.5	0.65	1990										16.5	15.3	15.9

15.	Bishanpurwa	316200	2986100	91.25	0.70	1990			3.8	3.8	3.9	3.6	3.5	2.0	1.8	1.6	1.6	2.2	2.6
						1991	3.9	3.4	4.1	4.1	3.7	3.8	3.7	4.3	1.1	2.8	2.9	3.0	
16.	Pathaliya	300500	300900	152.18	0.65	1990						9.7	18.5	18.5	18.4		18.9	19.4	.8
						1991	19.5	19.4	19.5	19.5	17.1	17.2	17.6	17.6	16.3	15.3	15.6	-	
17.	Umjan	313250	2991100	96.42	0.4	1990			1.4	1.5	1.6	0.4	0.4	0.3	0.3	0.4	0.7	1.0	.7
						1991	1.2	1.3	1.3	1.4	1.4	0.9	0.4	0.4	0.7	0.5	0.6	0.9	
18.	Lautan	2930002	9921500	86.29	0.4	1990			2.6	2.3	2.3	2.4	2.8	0.4	0.2	0.4	1.0	1.7	2.6
						1991	1.8	1.9	2.3	2.4	2.7	2.9	0.8	0.1	0.1	0.9	1.0	1.6	
19.	Bishrampur	291050	2986900	79.39	0.65	1990			3.7	2.7	2.6	3.5	4.4	4.2	4.1	2.9	3.2	3.4	1.5
						1991	1.4	4.1	1.6	4.2	4.4	4.4	3.6	3.6	2.9	3.2	3.4	3.6	
20.	Bijalpur	305500	2990900	83.79	0.6	1990			3.9	1.4	1.6	1.6	1.7	1.3	0.4	0.8	1.1	1.3	
						1991	3.5	1.5	4.1	1.7	1.7	1.6	0.7	0.7	2.0	1.0	1.1	1.4	
21.	Surahi	302400	2995200	99.09	1.1	1990				3.9	3.9	2.9	2.3	1.5	1.5	1.6	1.9	2.2	
						1991	2.3	2.3	2.4	2.5	2.7	2.6	1.3	1.3					
22.	Simraungarh	317000	2974600	80.44	0.3	1990				3.1	3.4	3.4	3.3	2.8	2.6	2.0	3.2	3.8	
						1991	3.8	3.9	4.0	4.1	3.1	3.2	3.2	-	-	2.2	2.3	2.8	
23.	Pilwa	307450	3006600	135.59		1990								5.2	5.1	5.1	5.7	5.8	
						1991	3.9	3.9	4.0	4.1	4.1	4.2	-	-	-				
24.	Majhariya	306900	2983500	83.92		1990								2.2	2.0	1.9	2.6	3.1	1.3
						1991	3.2	3.1	3.3	3.5	3.8	3.9	2.4	2.5	2.5	2.7	2.4	3.0	
25.	Parwanipur	297100	2999200	94.18		1990								1.8	1.9	2.1	3.4	3.0	2
						1991	3.1	3.2	3.5	3.6	3.7	3.7	1.8	1.9	1.8	2.6	2.8	3.2	

APPENDIX D

D-2: Monthly Water level Measurement in Dug Well in Bara District

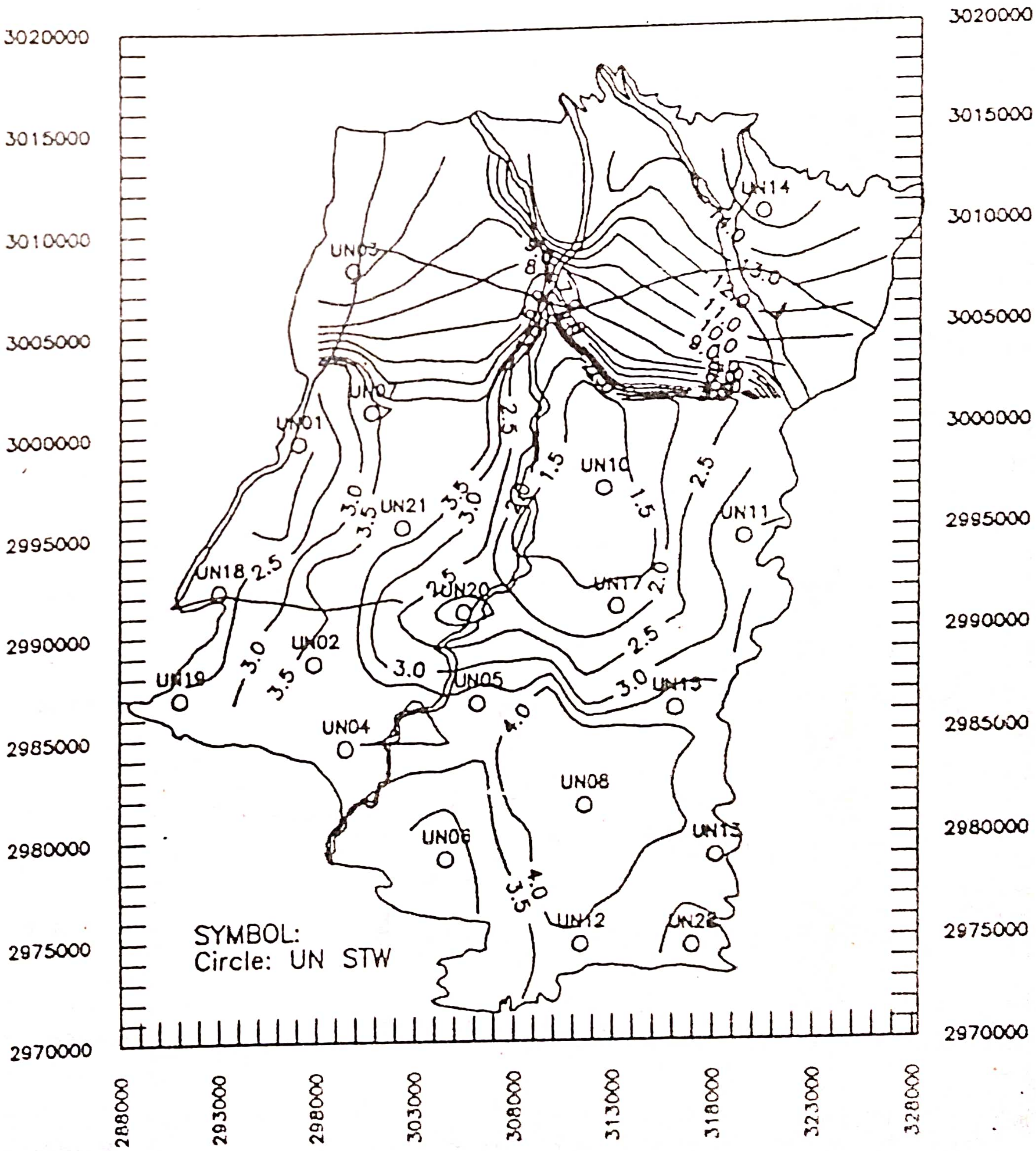
S. No	Village Name	X	Y	M.P. (m)	Year	Water Level Measurments in Meters (BGL)											
						JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	NIZAGARH	322250	3007125	0.9	1987					16.6		17.0					
					1988					16.9		17.0	17.6	13.6	11.0	11.4	12.2
					1989	13.7	15.3	16.1	16.6	17.0	15.2		17.3	16.3	14.7	12.6	14.0
					1990	12.5	15.2	15.3	15.2	16.0	16.0	15.6	15.5	15.3	15.0	15.9	16.2
					1991	17.2	16.6	16.7	16.8	16.8	16.9						
2	SIMARA	299875	3006125	0.47	1987					1.7		3.4					
					1988					0.3		3.7	4.6	3.6	5.9	4.4	4.5
					1989	4.6	4.7	4.8	4.9	5.0	5.5	5.1	5.5	5.5	5.5	10.0	4.4
					1990												
					1991												
3	DUMARBANA	303500	002500	1.3	1987					1.4		1.1					
					1988					1.8		1.6	2.3	0.9	1.6	2.0	2.2
					1989	2.0	2.1	2.2	2.3	2.4	1.5	1.7	1.4	1.4	1.1	1.5	2.1
					1990	1.8	2.2	2.1	3.4	3.7	1.4	1.3	1.2	1.0	0.9	1.1	1.2
					1991	1.4	1.3	1.2	1.3	1.4	1.4						
4	BADAFAKHOLA	306250	003125	0.52	1987					2.0		1.5					
					1988					2.3		1.8	2.4	1.2	2.1	2.2	2.2
					1989	2.2	2.3	2.4	2.3	2.4	2.0	2.2	1.9	1.9	1.7	2.1	2.2
					1990	2.1	2.2	1.9	2.8	3.4	3.3	2.6	2.5	2.3	2.2	2.5	2.7
					1991	2.8	2.8	2.9	3.0	3.1	3.1						
5	BODHABAN	311125	2997625	0.65	1987					0.9		0.8					
					1988					1.0		0.9	1.4	0.1	1.3	1.6	1.8
					1989	1.8	2.1	2.2	2.2	2.3	2.0	1.9	1.5	1.6	1.1	1.5	3.4
					1990	3.3	2.6	1.7	2.4	2.4	1.2	1.0	0.9	0.7	0.5	1.4	2.3
					1991	2.5	2.4	1.9	2.0	2.1	1.9						
6	KOLVI	319625	2995375	1.1	1987					1.6		2.3					
					1988					1.4		1.0	1.5	0.4	1.1	1.4	1.5
					1989	1.6	1.7	1.8	2.0	2.1	2.2	2.2	1.9	1.8	1.4	2.7	2.7
					1990	3.0	3.8	2.9	2.3	2.2	2.2	1.7	1.6	1.5	1.3	1.9	2.4
					1991	2.6	2.6	2.6	2.7	2.7	1.5						
7	KHOPUWA	314875	2989875	1.1	1987					2.8		2.8					
					1988					2.8		2.1	2.6	1.0	2.7	2.8	2.8
					1989	2.9	3.0	3.1	3.2	3.5	3.1	2.9	2.8	2.8	2.8	2.6	3.4
					1990	3.3	3.2	3.5	3.3	3.0	2.8	2.1	2.0	1.9	1.7	1.9	2.1
					1991	2.4	2.4	2.5	2.6	2.7	2.7						
8	BHATTANIA	316750	2982375	0.5	1987					2.9		2.1					
					1988					3.8		2.4	2.7	1.4	1.6	2.4	2.6
					1989	2.6	2.8	2.9	3.0	3.2	2.7	3.7	3.3	3.2	2.9		3.0
					1990	3.4	2.6	2.9	3.3	3.6	3.5	3.1	3.0	2.9	2.1	2.3	2.5
					1991	2.8	2.8	2.9	5.0	5.1	5.2						
9	BASBARIA	308000	2973625	0.6	1987					6.0		1.8					
					1988					2.9		2.4	2.9	1.5	2.3	3.0	3.1
					1989	3.2	2.4	2.5	2.5	2.6	2.4	1.7	1.1	1.3	1.2	2.6	3.0
					1990	3.4	3.1	3.1	3.6	4.6	4.3	4.1	4.0	3.8	3.7	4.1	4.3
					1991	4.4	4.5	4.6	4.7	4.8	4.8						
10	RAMNAGAR	319000	2977750	1.2	1987					2.9		1.5					
					1988					2.9		1.8	2.1	1.5	0.6	1.6	1.7
					1989	0.8	1.0	1.2	1.3	1.4	1.9	2.2	2.0	1.9	2.0	2.6	2.6
					1990	2.7	2.0	2.8	2.9	3.3	1.8	1.6	1.5	1.4	1.2	2.3	2.8
					1991	3.1	3.0	3.1	3.2	3.3	3.3						

S. No	Village Name	X	Y	M.P. (m)	Year	Water Level Measurments in Meters (BGL)											
						JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					1987					4.4		2.7					
					1988					1.7		2.8	3.4	2.3	1.1	2.5	2.6
11	BISANPUR	308625	2975250	1.35	1989	2.7	2.0	3.2	3.3	3.5	2.7	3.3	3.0	2.5	2.9	3.5	4.5
					1990	1.9	2.1	1.7	2.0	2.8	3.1	3.2	3.1	3.0	2.9	3.7	4.2
					1991	2.1	2.1	2.2	2.3	2.3	2.4						
					1987					4.5		4.5					
					1988					4.9		4.5	5.0	2.5	3.8	4.3	4.4
12	BELWATOLE	311125	2977875	0.45	1989	4.5	4.7	4.8	4.9	5.4	4.1	3.6	3.1	3.0	2.9	3.4	2.8
					1990	2.6	3.3	4.0	3.8	4.0	4.2	4.0	3.8	3.5	3.5	4.1	4.5
					1991	4.6	4.6	4.2	4.3	4.3	3.9						
					1987					5.0		3.8					
					1988					4.5		3.4	3.9	2.1	3.3	3.4	3.5
13	CHAPAKAIYA	312500	2982625	0.6	1989	3.6	3.8	3.8	3.9	4.0	3.4	2.4	1.6	1.7	1.5		4.0
					1990	4.2	4.3	4.3	4.8	4.3	4.2	4.1	3.9	3.8	3.6	4.2	4.4
					1991	5.1	5.2	5.2	5.3	5.4	5.4						
					1987					2.9		1.2					
					1988					2.8		1.4	1.9	0.6	1.1	2.0	2.2
14	INARWA	306625	2984875	*	1989	2.7	3.0	3.2	3.0	3.1	3.1	2.8	1.6	1.4	1.4	3.2	
					1990												
					1991												
					1987					3.0		1.5					
					1988					2.5		2.1	2.5	0.9	0.9	1.8	1.7
15	KABAHIGOTH	304875	2977875	0.5	1989	1.6	2.1	2.2	2.2	2.2	3.1	3.9	2.2	2.1	2.0	2.6	2.3
					1990	2.6	2.6	2.7	1.7	2.9	2.9	2.5	2.4	0.5	2.2	3.3	3.6
					1991	3.8	3.9	2.8	3.0	3.1							
					1987					4.7		0.6					
					1988					2.0		1.0	0.9	0.1	0.8	1.8	2.2
16	GANJA BHAWANIPUR	306375	2989625	0.65	1989	2.5	2.3	2.5	2.7	2.7	2.2	1.8	1.3	1.1	1.0		4.4
					1990	3.0	3.7	4.8	4.9	4.3	4.6	4.1	4.0	3.9	3.8	4.5	4.8
					1991	5.0	5.0	5.1	5.2	5.3	5.3						
					1987					3.3		1.2					
					1988					2.5		2.2	2.0	1.1	1.5	2.1	2.3
17	KALAIYA	302500	2992375	1.4	1989	2.7	3.0	3.3	3.4	3.4	3.5	3.6	2.0	1.9	1.6	2.5	2.7
					1990	2.6	1.2	1.3	3.1	3.3	3.2	3.1	3.0	2.9	2.8	3.7	4.4
					1991	4.6	4.6	4.7	4.8	4.9	4.9						
					1987					3.3		1.7					
					1988					2.9		2.4	2.4	0.8	1.3	2.2	3.8
18	INARBARI	298750	2988625	*	1989	3.9	5.2	3.8	4.9	4.9	4.1	4.9	3.9	3.8	3.7	4.5	
					1990												
					1991												
					1987					3.1		1.7					
					1988					3.1		2.3	2.1	0.7	1.4	2.3	2.5
19	MATIARWA	298750	2983250	0.4	1989	2.5	2.6	2.5	2.9	3.0	3.3	3.5	2.2	2.1	1.8	3.5	3.8
					1990	3.9	3.6	2.8	3.2	3.1	4.0	4.2	4.0	3.9	2.5	3.4	3.7
					1991	3.8	3.8	4.0	4.2	4.3	4.3						
					1987							1.2					
					1988					2.8		2.0	1.9	0.5	1.5	2.1	2.5
20	TRIBENI	294875	2991000	0.1	1989	2.4	2.8	2.5	2.6	2.8	3.0	3.0	1.8	1.6	1.5		6.4
					1990	4.0	3.1	3.1	2.9	3.0	3.0	2.9	2.8	1.7	1.7	1.9	2.2
					1991	2.4	2.5	2.6	2.7	2.8	2.8						

S. No	Village Name	X	Y	M.P. (m)	Year	Water Level Measurments in Meters (BGL)											
						JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
					1987					3.1		3.7					
					1988					4.0		2.7	2.6	1.4		6.0	2.6
21	BISHRAMPUR	292125	2986500	0.65	1989	2.2	3.0	2.9	2.9	3.0	5.7	3.7	1.6	1.4	1.4	4.5	2.2
					1990	2.0	2.6	2.5	2.5	2.5	3.0	3.0	2.8	2.8	2.7	3.6	3.7
					1991	4.0	4.1	4.1	4.3	4.3	4.4						
					1987					2.4		2.9					
					1988					3.1		2.8	2.7	2.4	2.8	3.7	4.0
22	RAMPUR	296000	2996125	0.5	1989	3.9	3.9	4.1	4.2	5.2	4.7	4.7	2.5	2.4	2.4	3.4	3.0
					1990	1.5						1.7	1.6	0.5	0.4	1.0	1.4
					1991	1.6	1.6	1.7	1.8	1.9	2.0						
					1987					3.8		3.3					
					1988					3.8		3.4	1.7	1.0	3.2	3.6	3.9
23	JEETPUR	298125	3002875	0.58	1989	4.3	5.0	4.7	4.8	4.8	4.8	4.6	3.3	3.1	3.0	5.2	4.8
					1990	4.9	4.8	5.3	5.5	5.6	5.4	5.0	4.9	4.8	4.6	5.5	5.7
					1991	5.9	5.9	6.0	5.6	5.6	5.7						

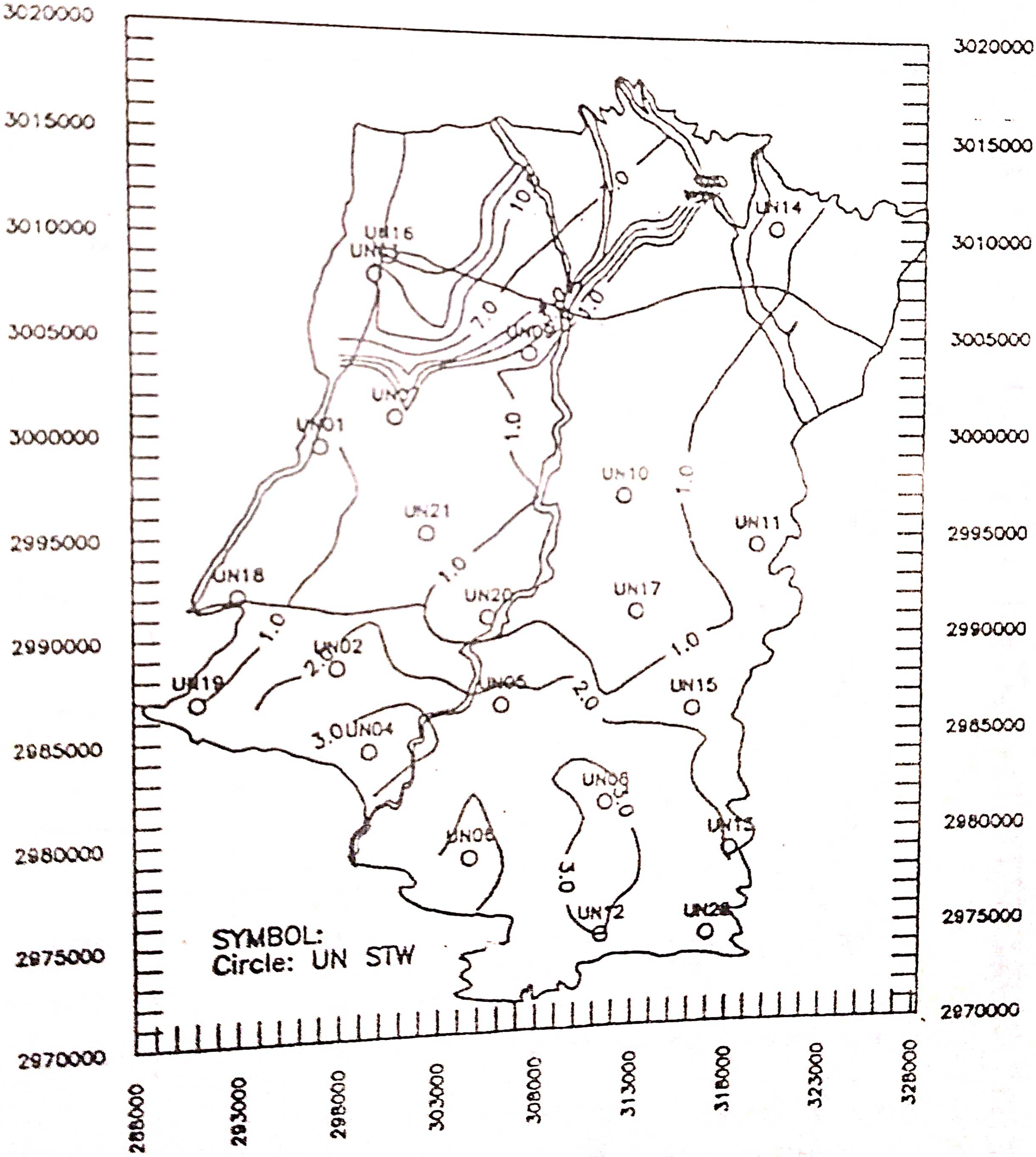
APPENDIX D-3:
Water Level Fluctuation Maps

BARA - DEPTH TO WATER TABLE IN MAY 1990

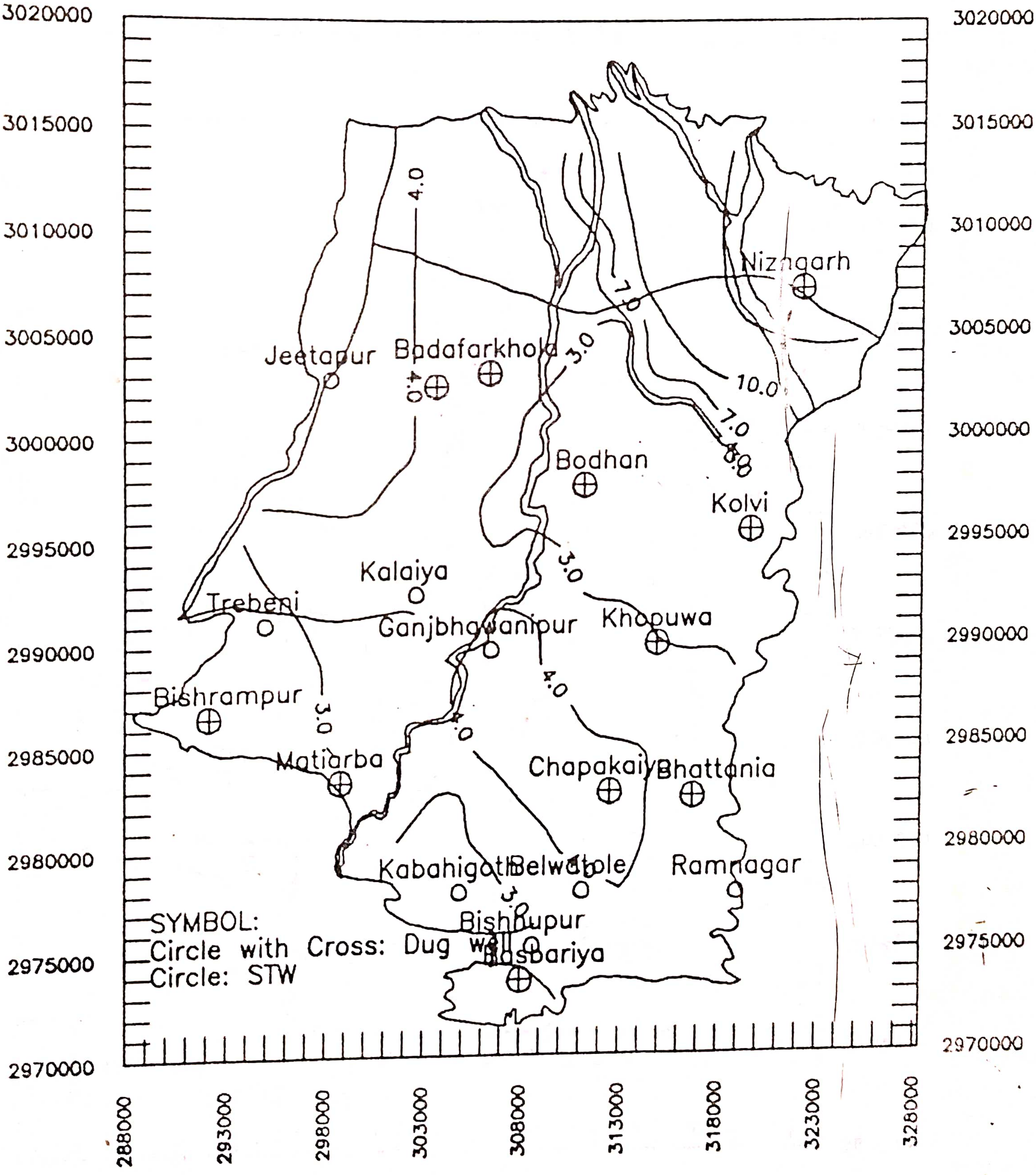


BARA - DEPTH TO WATER TABLE IN SEP 1990

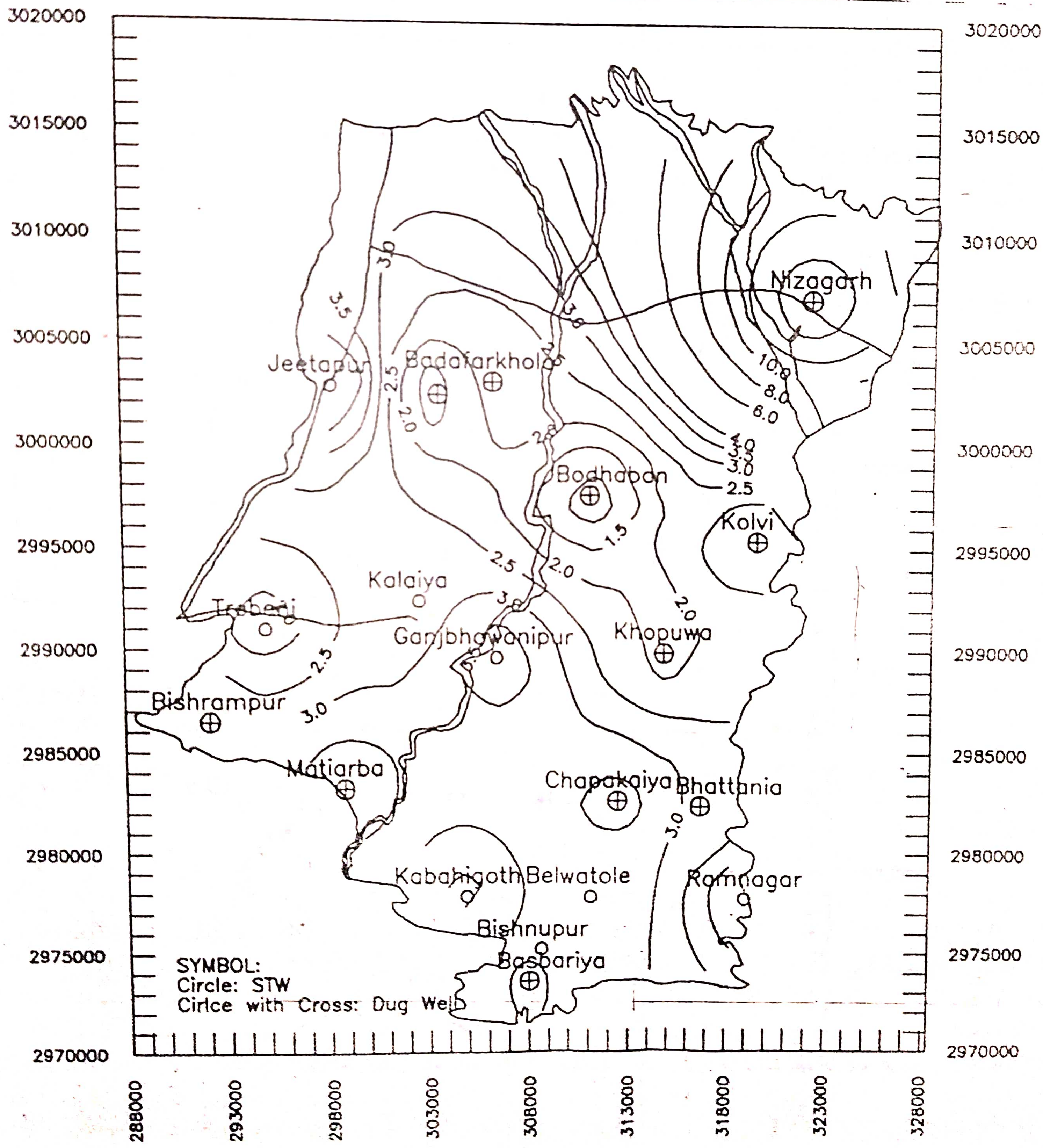
BARA – DEPTH TO WATER TABLE IN SEP 1990



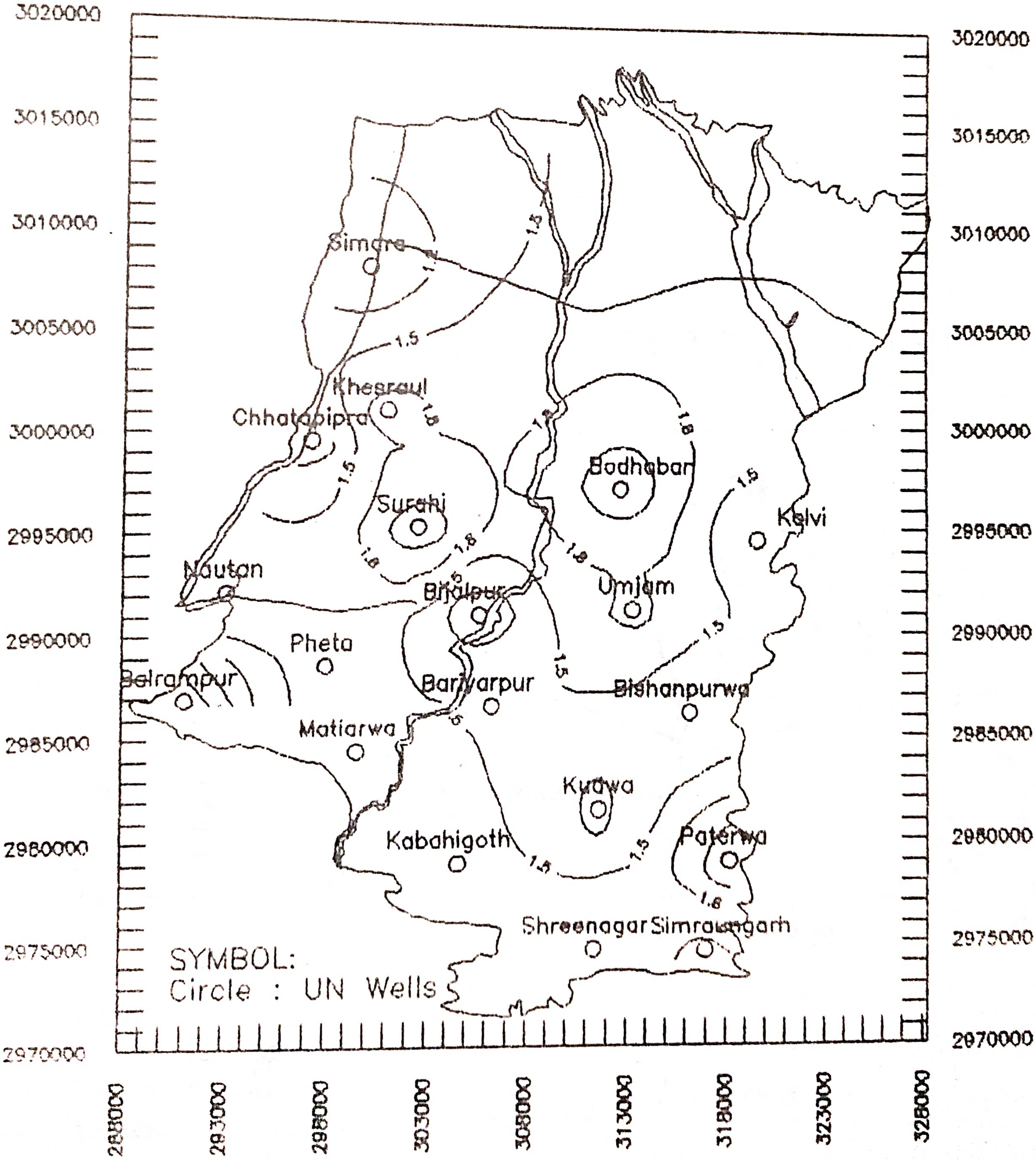
BARA - DEPTH TO WATER TABLE IN MAY 1990



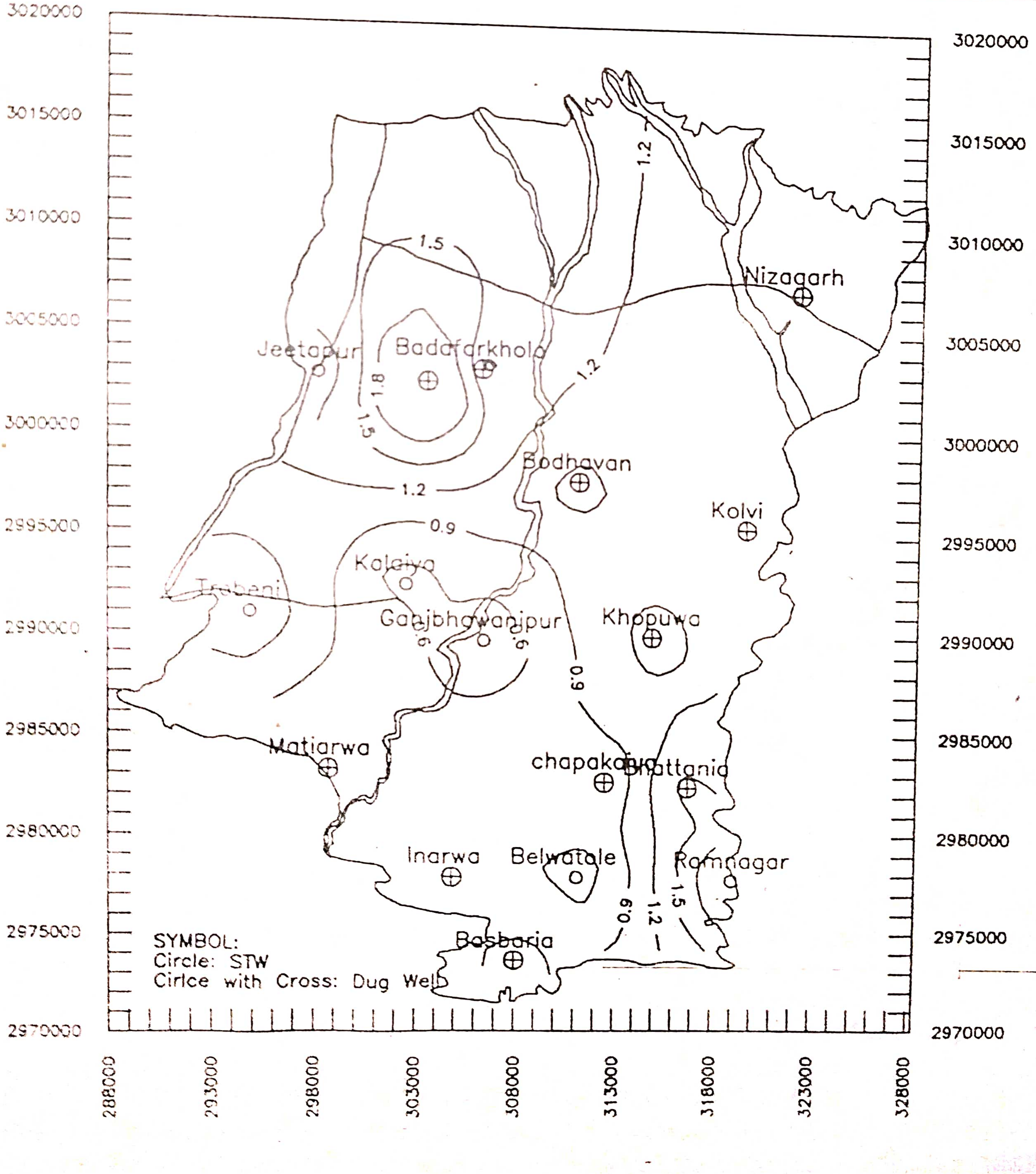
BARA – DEPTH TO WATER TABLE IN SEP 1990



BARA - RISE OF WATER TABLE IN MAY - SEP 1990

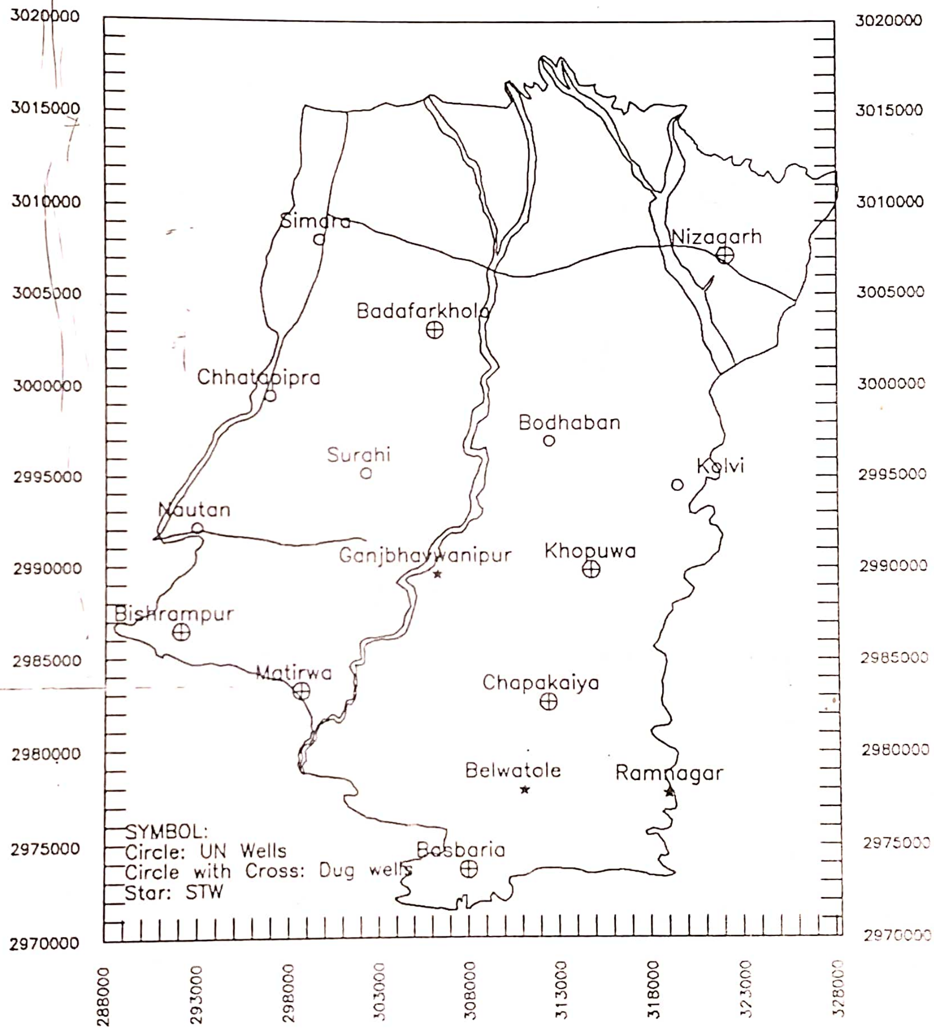


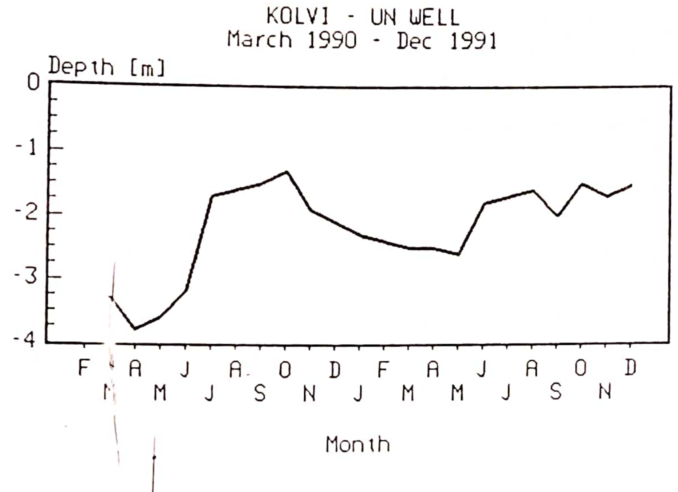
BARA - RISE OF WATER TABLE IN MAY-SEP 1990

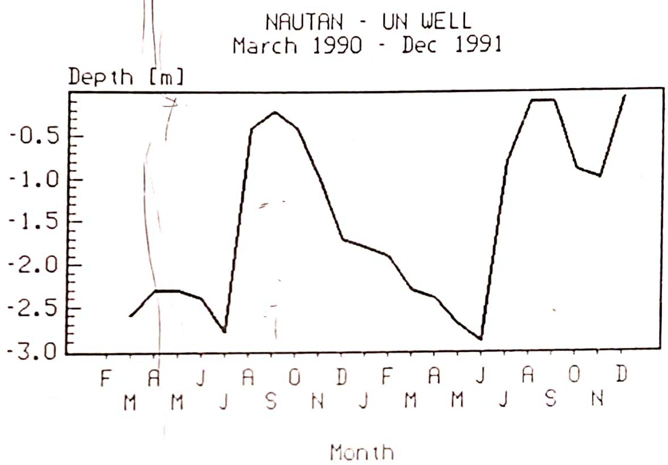


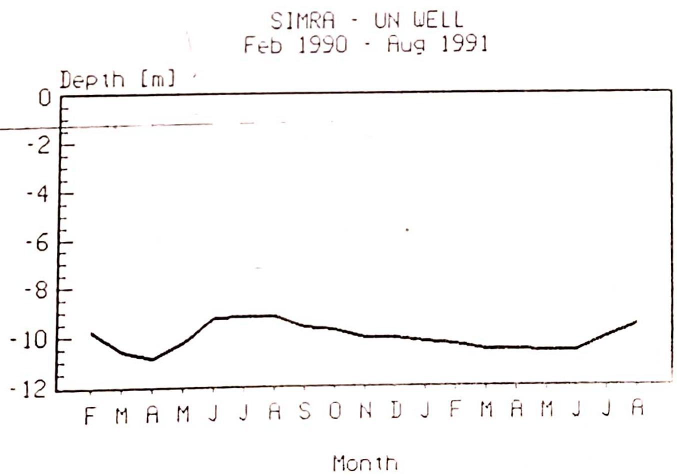
APPENDIX E

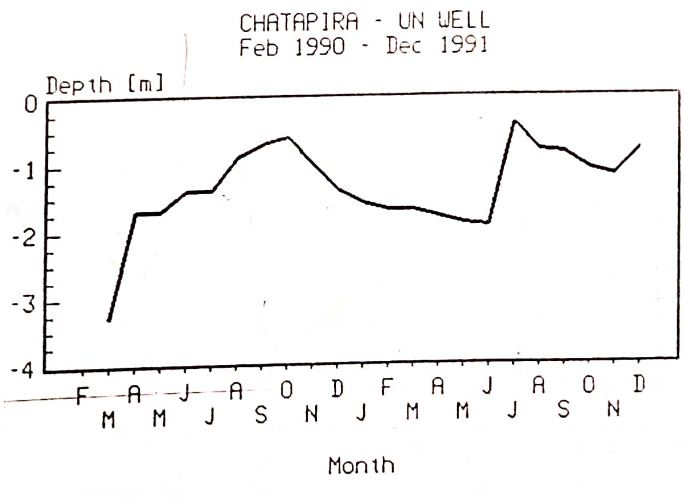
BARA - LOCATION OF SELECTED WELLS FOR HYDROGRAPHS

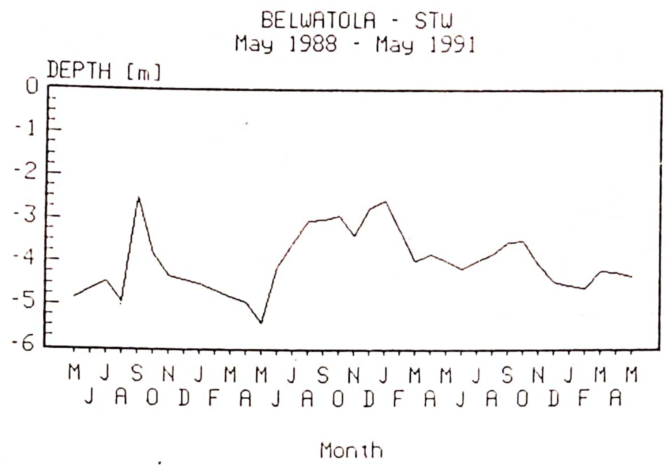


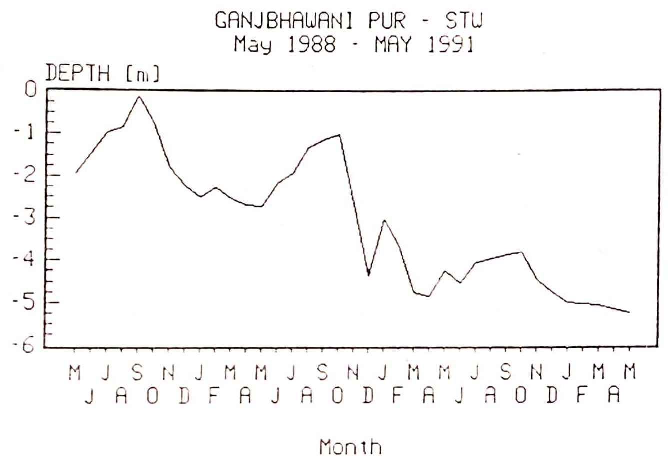

KOLVI - UN WELL
March 1990 - Dec 1991
Depth [m]
0
-1
-2
-3
-4
F A J A O D F A J A O D
M M J S N J M M J S N
Month

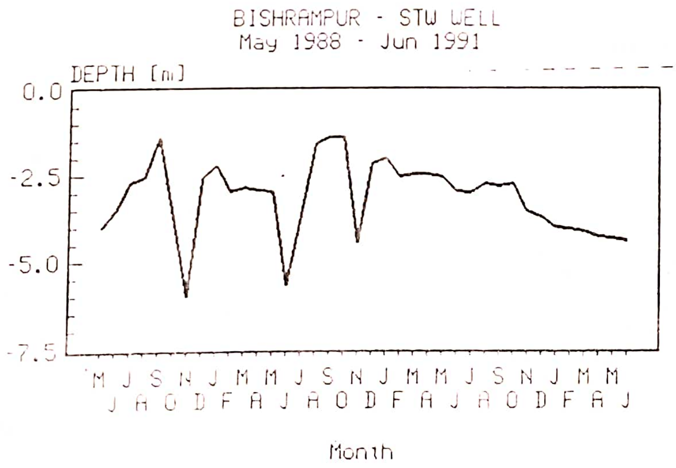

NAUTAN - UN WELL
March 1990 - Dec 1991
Depth [m]
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
F A J A O D F A J A O D
M M J S N J M M J S N
Month

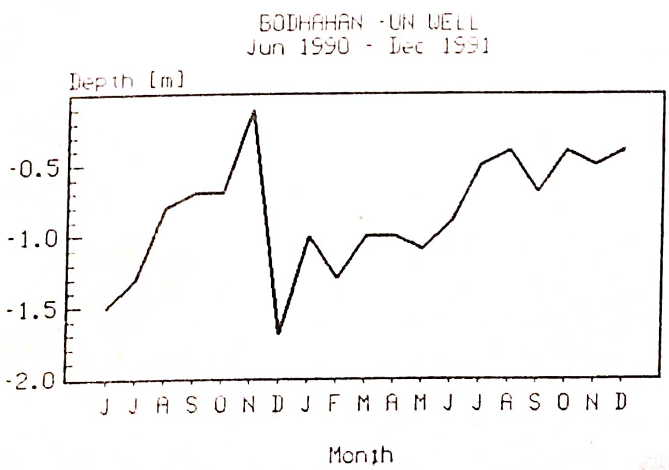

SIMRA - UN WELL
Feb 1990 - Aug 1991
Depth [m]
0
-2
-4
-6
-8
-10
-12
F M A M J J A S O N D J F M A M J J A
Month

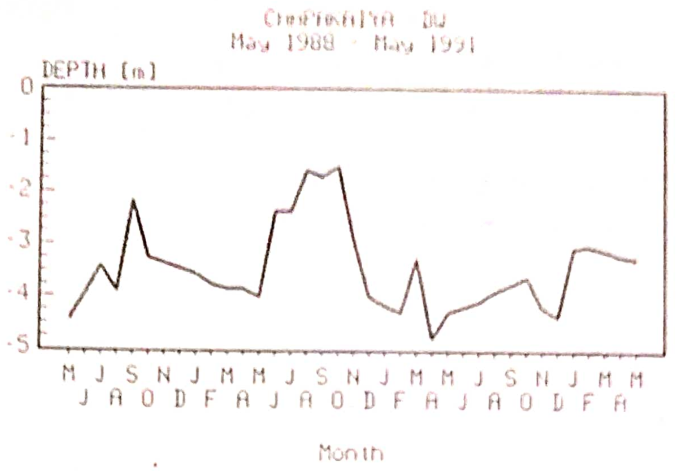

CHATAPIRA - UN WELL
Feb 1990 - Dec 1991
Depth [m]
0
-1
-2
-3
-4
F A J A O D F A J A O D
M M J S N J M M J S N
Month

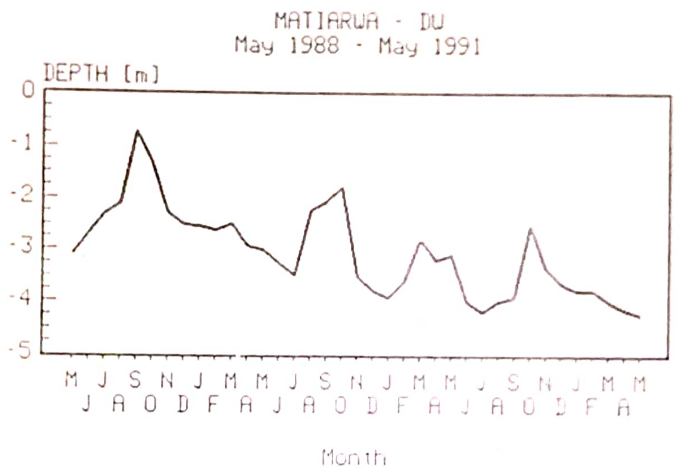

BELWATOLA - STW
May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
-5
-6
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A
Month

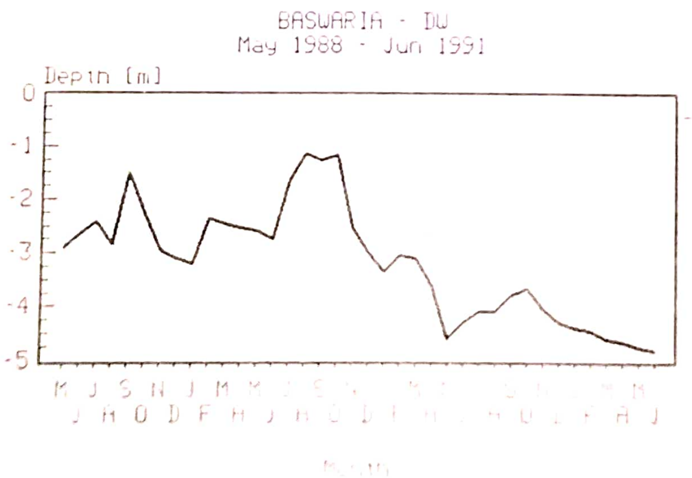

GANJBHAWANI PUR - STW
May 1988 - MAY 1991
DEPTH [m]
0
-1
-2
-3
-4
-5
-6
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A
Month

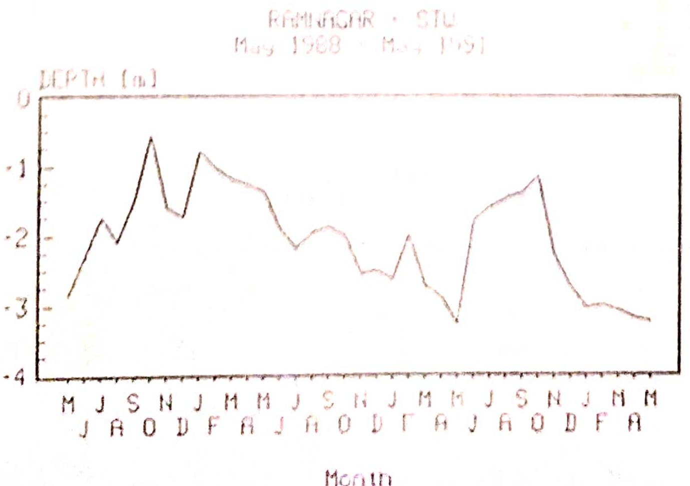

BISHRAMPUR - STW WELL
May 1988 - Jun 1991
DEPTH [m]
0.0
-2.5
-5.0
-7.5
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A J
Month

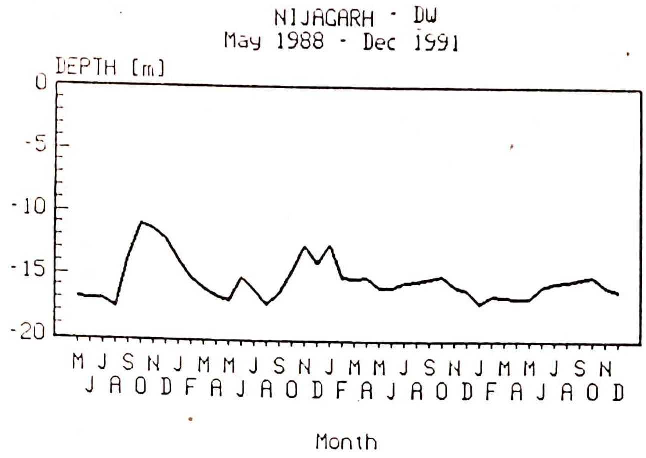

BODHAHAN -UN WELL
Jun 1990 - Dec 1991
Depth [m]
-0.5
-1.0
-1.5
-2.0
J J A S O N D J F M A M J J A S O N D
Month

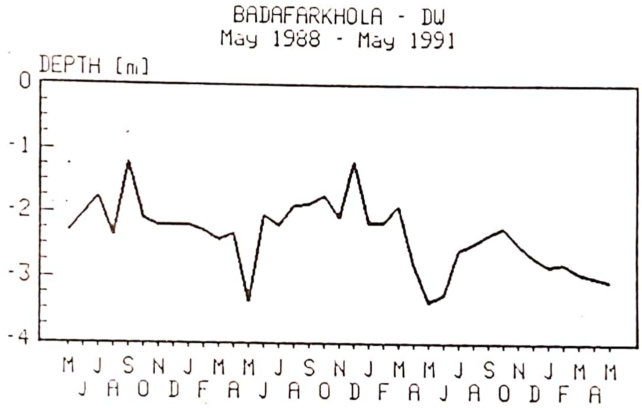

May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
-5
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A
Month

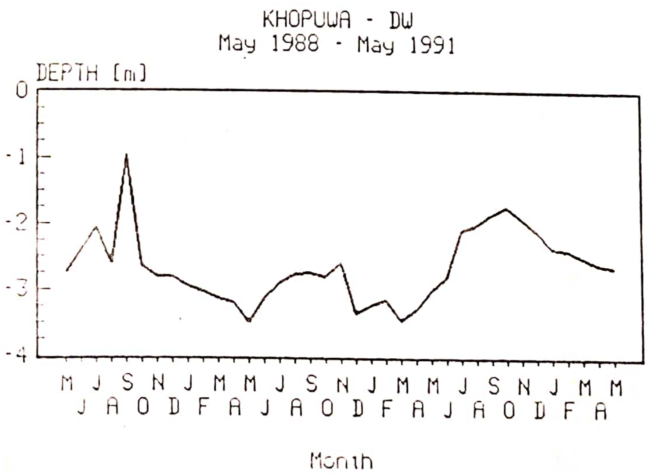

MATIARWA - DW
May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
-5
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A
Month

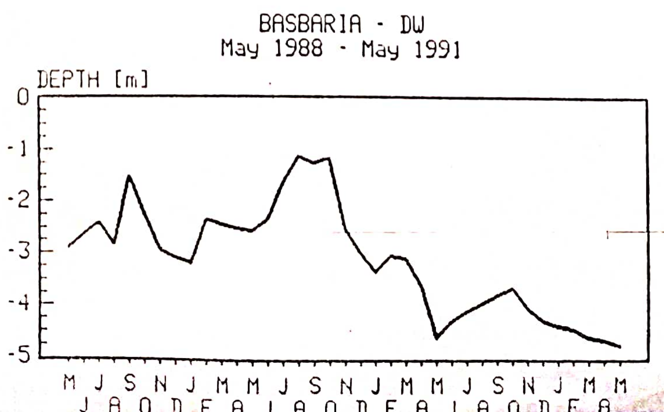

BASWARIA - DW
May 1988 - Jun 1991
Depth [m]
0
-1
-2
-3
-4
-5


RAMNAGAR - STW
May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A


NIJAGARH - DW
May 1988 - Dec 1991
DEPTH [m]
0
-5
-10
-15
-20
M J S N J M M J S N J M M J S N J M M J S N
J A O D F A J A O D F A J A O D F A J A O D
Month


BADAFARKHOLA - DW
May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A


KHOPUWA - DW
May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
M J S N J M M J S N J M M J S N J M M
J A O D F A J A O D F A J A O D F A
Month


BASBARIA - DW
May 1988 - May 1991
DEPTH [m]
0
-1
-2
-3
-4
-5
M J S N J M M J S N J M M J S N J M M