United Nations Development Programme
and His Majesty's Government of Nepal Project

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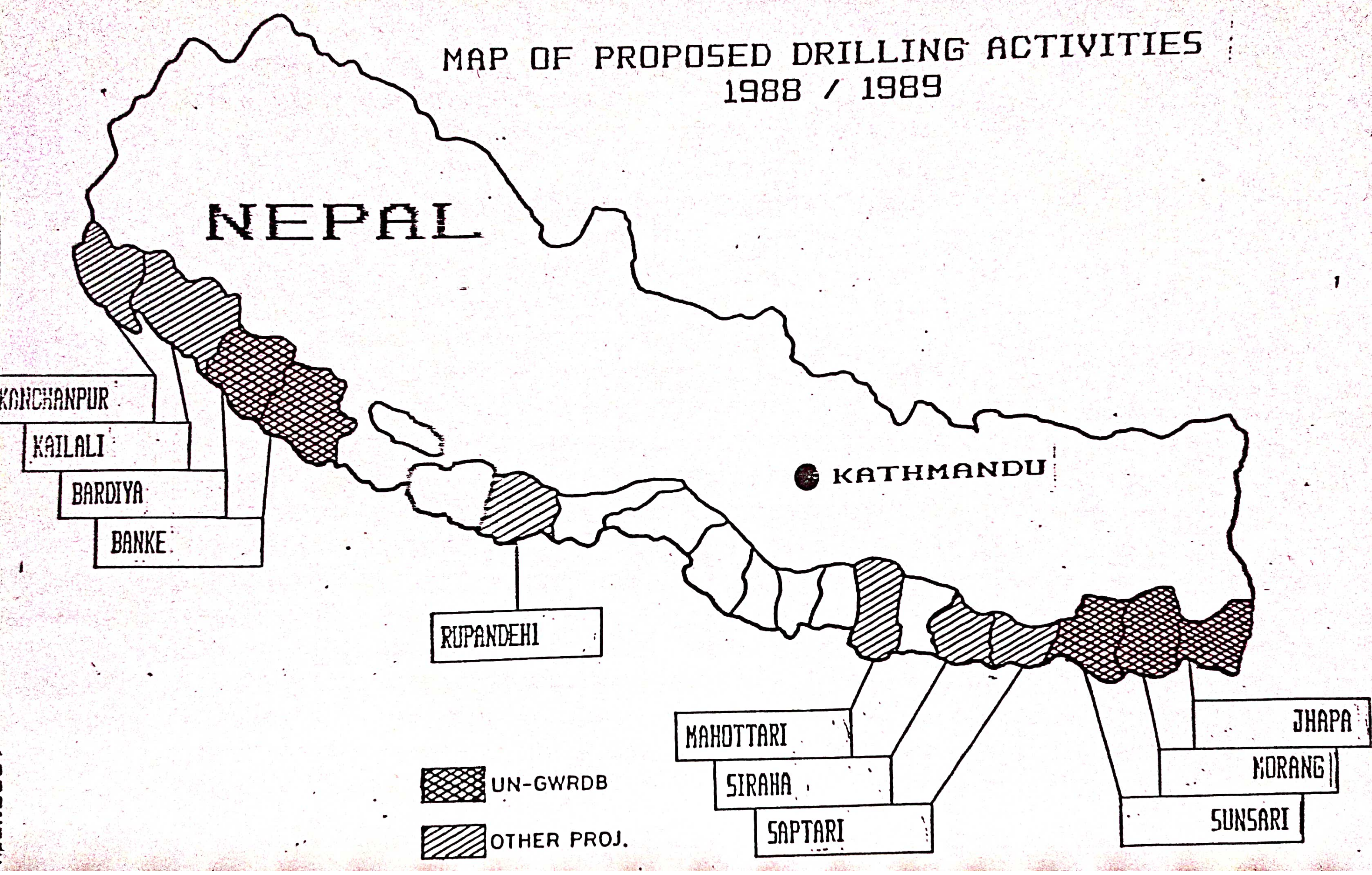
Executing Agency: United Nations Department of Technical Co- operation for Development

Shallow Ground Water Investigations in the Terai

7th MISSION REPORT
(31 May - 18 June 1989)

Author: Dr.J.Karanjac, Chief Consultant
Hydrogeologist & Computer Specialist

Kathmandu, June 1989


MAP OF PROPOSED DRILLING ACTIVITIES
1988 / 1989
NEPAL
KATHMANDU
KANCHANPUR
KAILALI
BARDIYA
BANKE
RUPANDEHI
MAHOTTARI
SIRAHA
SAPTARI
JHAPA
MORANG
SUNSARI
UN-GWRDB
OTHER PROJ.

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APPENDICES

1. INTRODUCTION

1.1. Project Objectives

The project "Shallow Ground Water Investigations in the Terai" is executed by the United Nations Department of Technical Co- operation for Development (UN/DTCD), and the counterpart agency in Nepal is Ground Water Resources Development Board (GWRDB) of the Ministry of Water Resources (Department of Irrigation).The project's immediate objectives are to generate technical information on the occurrence and potential of shallow ground water resources in the Terai, and to enhance the capacity of GWRDB with respect to ground water exploration, assessment, development, interpretation of results, and advanced computer processing of collected data. The project started in June 1987. Its expected termination date is end of 1991.

1.2. Terms of Reference for This Mission

This is the seventh mission of the Chief Consultant in the project NEP/86/025 and is the continuation of the previous missions. The routine work includes (a) supervision of current activities of the project staff and preparing work plans and job activities for the immediate future period, (b) guidance and assistance to the project staff in preparing technical reports, (c) technical reporting, especially interpretation of hydrogeology and development potentials, (d) mathematical modelling. In this particular mission, the terms of reference called for (1) completing and assisting in writing of four technical reports (Sunsari district, Kapilvastu district, Dang valley and Deukhuri valley of Dang district), (2) assisting Associate Expert in preparing the mathematical model of Sunsari district, (3) demonstration of and training of staff in new ground water data application program (well lithology and construction log).

1.3. This Mission Timing, Activities, Outputs

This current mission started on 31 May 1989 and was completed on 18 June 1989. The highlights of the mission are the following:

(a) Reviewing text and graphical appendices of Technical Report No. 7, Kapilvastu District ... Basic Documentation, prepared by Mr. R.S.Uprety.

(b) Rewriting textual part and reviewing graphical appendices of Technical Report No. 8, Dang Valley ... Basic Documentation, Prepared by Mr. R.S. Uprety.

(c) Commenting on and guiding the preparation of Technical Report No. 9, Deukhuri Valley ... Basic Documentation, prepared by Mr. R.S.Uprety with assistance of Mr. Kanzler.

(d) Contributing to textual interpretation of Technical Report No. 10, Sunsari District ... Basic Documentation, prepared by Mr. A.Kanzler, with assistance of Mrs. R.Shrestha.

(e) Updating computer software prepared by the United Nations for ground water interpretation and presentation. Demonstration of computer-processed well logs and lithological cross sections. Preparation of new symbols for lithology.

(f) Guidance to Mr. A.Kanzler in preparation of the mathematical model of Sunsari District.

(g) Work plan for the period through the end of 1989.

1.4. Planning for Remaining Two Missions in 1989

The next two missions of this consultant (one month each) are planned for the period end of August through end of September 1989, and end of October through the end of November 19890. The main activities shall be the following:

(a) Assisting Associate Expert A.Kanzler in finalizing the mathematical model of Sunsari District.

(b) Making the model of Dang valley, with assistance of Mr. Uprety.

(c) Completing the reports on Morang and Rupandehi districts (Basic Documentation).

(d) Preparing for and attending Tripartite Project Review to be held in Kathmandu either in September or in November.

(e) Overall supervision of project activities and guidance to project staff.

2. Evaluation of Work in 1988/89 Drilling Season

2.1. General

Due to developments which were beyond the control of the project or GWRDB (lack of fuel and other supplies), all field activities were suspended at the end of March. Only in June two field teams were sent to Banke and Bardiya districts to run some pumping tests. However, the monitoring work in observation networks continued, with some gaps and missing months, almost in every district of the Terai.

2.2. Progress of Work

The drilling and pumping test activities started in January 1989 with a very ambitious program: 237 shallow wells to drill, and 275 wells to test by pumping. The completion of this program is shown graphically in Appendix 3: 124 wells were drilled and 62 wells tested. The completion of drilling is thus about 52%, and of pumping tests only 22%. However, the situation is different if one considers in which districts the wells have been drilled and tested.

Most of drilling was concentrated in several districts, which might have enough information for reporting in the form of Basic Documentation (Appendices 4 and 5):

Sunsari District: 17 drilled wells (reported in Technical Report 10)

Banke District: 23 drilled wells (to be reported before the end of the year, provided sufficient number of pumping tests is completed)

Bardiya District: 20 drilled wells (to be reported before the end of the year, provided pumping tests become available)

Morang District: 12 drilled wells (will be reported in 1989, since much more information is available from other sources)

Rupandehi District: 21 drilled wells and 13 pumping tests (will be reported by the end of 1989)

Kanchanpur District: 13 drilled wells (reporting shall be delayed since information is not received by the project, and pumping tests were not carried out)

2.3. Backlog of Information and Reporting

There is plenty of information currently available on ground water in the Terai which needs immediate processing. The data are collected from this ongoing UNDP project (124 wells drilled in 1989, 62 pumping tests), from ADBN and GWRDB wells (notably in Morang, Kanchanpur, Kailali), from Japan Red Cross Society (in RupandehiMost of information can be relatively quickly transferred into the computerized format which was prepared by this project. Currently the project has computer programs for interpretation and preparation of the following information:

Well Logs and Lithology ... Appendices 3 in Basic Documentation (BD)
Lithological Cross Sections ... Appendices 4 in BD
Pumping Tests ... Appendices 5 in BD
Transmissivity Map ... Appendix 6 in BD
Hydrographs ... Appendices 10 in BD
Contour Maps (depths to water table, water levels in absolute elevations, etc.) ... Appendices 8,9 in BD

It should be a relatively routine work to compile all available information on lithology, drilling, and testing and prepare a technical report for a particular district.

The government executing agency GWRDB rightly wants all information on deep tube wells transferred into the computer and presented in a form similar to shallow wells, that is Basic Documentation with well construction data, lithology, pumping test results, water levels, etc. There is no doubt that information from many hundreds of wells can be located. This project should offer assistance to GWRDB staff in processing such information and preparing reports. GWRDB management shall have to appoint appropriate staff, or the current UNDP project could be expanded for more UNDP input (primarily manpower).

3. TECHNICAL REPORTS

3.1. Sunsari District ... Basic Documentation. Technical Report No. 10

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

The drilling program which was formulated about a year ago, was completed according to the expectations. Seventeen holes were drilled with the total drilling metrage of 558 m (Appendix 6). The average depth of newly completed wells is 32.8 m. Considering the lithology of shallow ground water system, this depth is probably adequate for the project purpose. Within the upper 33 meters about 56% are composed of permeable formations (sand and gravel). Quite a high presence of gravel is noted (Appendix 8). This makes the Sunsari district favourable for shallow ground water development. Only eight successful pumping tests have been performed. Out of 17 drilled wells, 8 wells were constructed by a drilling rig, and 9 wells by indigenous (manual) methods of drilling ("sludge" method).

In the Sunsari drilling project the local contractor was capable of producing manually-drilled well 41.2 m deep. Yet some wells were very shallow (13.7 m, 16.8 m, 18.3 m).

As a conclusion of the drilling program in Sunsari district the following may be inferred. The drilling of shallow wells should be done with as little as possible bentonite mud. The screens should be best pre-packed with gravel, or alternatively the drilling diameter should be minimum 10 inches to accommodate 4 or 6-in casing and minimum 4-in gravel pack. More attention should be given to well development. Screens with slot opening less than 1.0 mm should not be used. Better supervision of drilling and development activities is needed to produce better wells.

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

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

According to lithology and transmissivity of investigated shallow aquifer, both the lithology and transmissivity are very favourable all over the district. Lithology is dominated by coarse materials (gravels), the transmissivity is high (between 1500 and 4500 m2/day, Appendix 9). (The same conclusion can be safely "extrapolated" to the area near the SAPTA KOSHI River in which information is missing.) One should expect considerable drilling problems with cobbles and boulders all over the area.

Since aquifer percentages and permeabilities are high there is no obvious distinction between so-called deep and shallow aquifers.

From individual points (not absolutely conclusive), two zones may be singled out. The first is a high-transmissivity area in the central-south part, near Satyajhoda and Kushaha, extending toward Biratnagar in Morang. The transmissivity is over 2500 m2/day reaching over 4000 m2/day in Satyajhoda. The second is slightly less favourable zone than the rest in the west-central part, between Inarwa and Bhokraha. Inarwa well is the only location with less than 1000 m2/day transmissivity.

The hydraulic conductivities of shallow aquifer materials in the whole district are about 75 m/day, exceptionally several hundred meters per day (Satyajhoda, over 500 m/day). The values of about 80-100 m/day are characteristic for clean coarse-grained sand with gravel. The values over 100 m/day indicate greater proportion of clean gravel over sand.

The pump testing program in Sunsari district should be continued. There are many wells which lend themselves to testing. Most of hand-pump equipped wells (drilled by ADBN) could be easily tested. If out of 500 shallow drilled wells 20 are tested, the wealth of information and knowledge about the district would be enormously improved.

Sunsari district is well covered with water-level monitoring network (Appendix 7). In the month of May 1989, the network includes 14 project-drilled wells, 9 STWs from ADBN program, and 1 dug well. Tentatively the proposed network for future monitoring shall include 17 "project" drilled shallow wells, plus five wells equipped with hand pump from the old program. The final network in Sunsari district could have about 22 shallow tube wells. Three wells should be drilled near the Sapta Koshi River to the depth of some 20 m, to provide a base for evaluating the connection between shallow aquifer and the river.

In most of the area the levels in May 1988 are deeper than 3.0 m under the land surface. There is a zone in central part of deep water table. The depth to water table in September 1988 is still high, about 2-3 m. This is favourable in the sense that the evaporation process, which in other Terai districts can be responsible for quite a loss of water, is of minor importance in Sunsari.

As expected the general direction of ground water flow is from north to south (Appendix 10). The maps of water level contours are not as accurate as one would desire since land surface elevations of observation wells were not surveyed but taken from topographic map. Yet the general conclusions about the flow pattern shall not be affected by this definite disadvantage.

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

(1) With the average transmissivity of about 2500 m2/day in the northern part (Kalabanjar-Tarahara) and flow gradient of some 0.0025, the total ground water flow across the section of 20 km (Sapta Koshi River - Dhanpuri - Hansphosa) can be about 125,000 m3/day (1447 l/sec). This water comes mostly from recharge from hill sides (Bhabar zone, fan deposits, underflow from hills).

(2) In the southern part, toward India-Nepal border, the transmissivity of 2000 m2/day and flow gradient of some 0.001 produce the total flow over a section of 15 km (Harinagar- Raniganj) equal to 30,000 m3/day (347 l/sec).

(3) Through the whole section of some 33 km (from the point where SAPTA KOSHI river leaves Nepal to Duhabi village), with an average transmissivity of 2500 m2/day and average flow gradient of 0.001, the flow could be as high as 82,500 m3/day (956 l/sec).

There is some 40,000 m3/day unaccounted for. The water that is mostly recharged in the north may (a) evaporate on its way to the south (near the river banks the water table can be closer than 3 m even in May), (b) get lost through direct outflow into the SAPTA KOSHI River (in May, a portion of river flow is base flow, which is ground water contribution), (c) be consumed by shallow tube and dug wells by local farmers.

Although an assessment of shallow aquifer water balance is not attempted in this report, some preliminary evaluation is presented. A parallel study is being currently run by this project in which a mathematical model is under construction and testing (Appendix 11). The model shall provide some answers to the following: (a) recharge from rainfall in the Bhabar Zone and elsewhere, (b) the connection with the Sapta Koshi River in minimum and maximum flow conditions, (c) the importance and magnitude of evapotranspiration process, (d) the correct order of magnitude of hydrogeological parameters, (e) the volume of outflow across the district boundary into India.

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

(1) The district is dominated by the past and present course of the SAPTA KOSHI River and its pied-mont fan. The net effect of wide area occupied by the KOSHI river deposits is that aquifer percentages and permebilities are high and that no obvious distinction can be made between deep and shallow aquifers.

(2) The recharge comes from local infiltration of rainfall everywhere where more or less permeable surface permits.

(3) The Bhabar zone is an important "contributor" in the reported area.

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

(5) The outflow into India across the border is calculated approximately with gradients from Appendices 9/1 and 9/2, and transmissivities from Appendix 6. The volume of water that may be outflowing is about 80,000 m3/day or 29 MCM/year (million cubic meters in one year). This is quite a high percentage of potential annual recharge from infiltrated rainfall. If, conservatively, only 10% of annual rainfall of 2222 mm infiltrate and recharge the shallow aquifer, the volume of recharge over an area of about 900 km2 could be about 200 MCM/year. The difference between this hypothetic recharge of 200 MCM and out-flow into India of about 29 MCM is discharged through evaporation process (dominantly), and the rest is outflowing into the SAPTA KOSHI River (locally very high) or is withdrawn from dug and drilled wells (unknown component at present).

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

(a) Drilling of three wells near the left bank of the river, to the depth of only 10-15 m.

(b) Continuous monitoring of water table in these new wells in one year period. Description and measurement of river stage in the same period at the site of the first upstream well. It is important that the river flood stage is correctly monitored.

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

(d) Correlation of water table in three new wells (recommended at a) with the river level height.

(e) Calculation of the base flow at upstream and downstream station, if established, in the dry season.

Finally, on the basis of the presented information, there appear good prospects of developing shallow ground water resource in almost whole district area, except in the north, at the foot of hills where water table may be too deep and/or large boulders can create drilling problems.

3.2. Kapilvastu District ... Basic Documentation. Technical Report 7

The objective of this report was to present technical information on the occurrence of shallow ground water in Kapilvastu district. It was presented in a form of a basic documentation with some preliminary interpretation.

The drilling program which was formulated about a year ago, was completed according to the expectations. Twenty three holes were drilled with the total drilling metrage of 1131 m (Appendix 12). The average depth of newly completed wells was 50 m. Considering the lithology of shallow ground water system, this depth is probably adequate for the project purpose. Most of wells were not absolutely efficiently developed. It seems that too much bentonite was used, and the screen of only 0.5 mm openings and about 11% open area was found to be inadequate. As a consequence, pumping tests failed in such wells. Out of 23 drilled wells, 22 wells were constructed by a drilling rig, and only one well by indigenous (manual) methods of drilling. Same conclusion applies here as in Sunsari district. The drilling of shallow wells should be done with as little as possible bentonite mud. The screens should be best pre-packed with gravel. More attention should be given to well development. Screens with slot opening less than 1.0 mm should not be used. Better supervision of drilling and development activities is needed to produce better wells.

In the case of Kapilvastu, no one can be satisfied with the results of pumping tests. It is believed that least attention was given to the well development part. The quality of testing must be improved, as well as the accuracy of equipment used.

Moreover, the fact is that in seven project drilled wells pumping test have not been attempted. The explanation appended to field drilling report that depth of water level was unacceptable for centrifugal pumps does not stand since in five wells the depth to water table was at the time of drilling less than 5 m and in two wells the levels rose to within 4 m from the land surface in August 1988. If pumping test results can be trusted, then the distribution of transmissivity can be interpreted in the following way. First, the lithology and permeability of shallow ground water system of Kapilvastu district is not as favourable as in other districts of Terai. There is a dominance of clay and silt sediments over permeable ones, at a ratio of 2 to 1 (Appendix 14). Except the north eastern and north western parts, in which the transmissivity is relatively acceptable (over 300 m2/day), the rest of the area in Kapilvastu Terai is not at all suitable for intensive ground water development. Even individual wells for local water supply of a village demand a minimum transmissivity of at least 300 m2/day. Except in the north-west around Bijgauri and Loharaula, and in the north-east near to Bhalwar and Motipur, nowhere else the transmissivity comes close to that minimum (Appendix 15). Again, one must be cautious not to jump to conclusions since pumping test results are not always reliable.

It is clear that hydraulic conductivity values do not match with the corresponding lithology, which is the consequence of poor well construction (too much drilling mud, unsatisfactory well screens), and poor well development (late development with low- capacity pump, short duration of development, etc.). One of disadvantages of the drilling program is less-than-useful location of drilling sites for present purpose. The wells should have been located nearby an existing ADBN well which would have permitted the second well to act as observation well during pumping tests. Unfortunately, not in one single case this was possible and not one single value of storage coefficient had been produced.

The pump testing program in Kapilvastu district should be continued. There are many wells which lend themselves to testing. If remaining wells are tested after proper development, the wealth of information and knowledge about the district would be enormously improved. Likewise, the project wells which were poorly developed could be redeveloped properly and retested. Otherwise, there is always a possibility to be mislead when attempting to make assessment of ground water system balance, whether analytically or by means of mathematical models.

Kapilvastu district is well covered with water-level monitoring network (Appendix 13). In the month of May 1989, the network includes 26 dug wells and 21 project drilled wells. Tentatively the proposed network for future monitoring shall include only 21 "project" drilled shallow wells. The continuing observation in some other wells will be helpful for comparison, but the number of such wells should be reduced to a maximum of five.

The depths to water table in October 1988 indicate that levels are very close to the land surface almost everywhere excluding a limited area near the hills. The line of wells from Bijgauri in the west to Bharsarwa in the east separates the zone of less than 2 m depth (south) from the zone of more than 2 m (north). In almost one fourth of the district, in the southeast corner, the levels are closer than 1 m to the land surface. Thus the area of potentially very high evaporation loss in the months of high levels covers about four fifths of the district area.

The direction of shallow ground water flow is from north to south (Appendix 16). The gradient of flow in the northern part is mostly about 0.003 or 3 meters per one kilometer. There is a change of gradient from contour line 110 (Bharsarwa). The gradient becomes gradually more gentle, first about 0.0015, and finally 0.0005 near the Nepal-India border in the southern corner. The change of gradient may be an indication of the change of transmissivity, which, then, should be higher in southern compared to northern part. Yet, in the case of Kapilvastu district, the change of gradient is an indication of less water flowing through cross-section in the southern part. Some preliminary evaluation on an assessment of shallow ground water is presented as follows:

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

(2) The Bhabar zone may be an important contributor to recharge of shallow aquifer. With rainfall about 1900 mm/year, and almost 200 km2 of Bhabar in the district, the input into the Bhabar sediments could be very high, 166 MCM (million cubic meters). Yet, due to drilling problems encountered with coarse and hard materials and excessive depth of water, the Bhabar zone appears to be of marginal value for water development in spite of relatively acceptable transmissivity.

(3) The outflow of shallow ground water is mostly across the border into neighboring India. The outflow into India across the border is calculated approximately with gradients from contour maps produced in this report, and with transmissivities from pumping tests. With the length of outflow section is 50 km and average transmissivity of about 90 m2/day (from 150 m2/day near Shivnagar to 30 m2/day in the middle of the section), and gradient of flow of about 0.0008, the volume of water that may be outflowing is about 3,600 m3/day or 1.3 MCM/year (million cubic meters in one year). This is a small fraction of potential annual recharge from infiltrated rainfall. If, conservatively, only 10% of annual rainfall of 1900 mm infiltrate and recharge the shallow aquifer, the volume of recharge over an area of about 1500 km2 could be about 285 MCM/year. The difference between this hypothetic recharge of 285 MCM and outflow into India of about 1.3 MCM is discharged through evaporation process (dominantly), into the Banganga and other rivers and withdrawals from dug and drilled wells (minor component at present).

(4) It may be also considered that land surface is not permeable in the whole area. When thick clay deposits underlie the surface, there is no direct recharge by infiltrated rainfall.

Conservatively one may assume that the total recharge to shallow aquifer in Kapilvastu is about 200 MCM. The outflow into India is a very small fraction of that volume, so that most of ground water must be lost through evaporation process. This is the water that can be salvaged by carefully planned exploitation, provided that the lithology of shallow aquifer (that is its thickness and transmissivity) permit the ground water development by pumping.

On the basis of the presented information, the feasibility of shallow ground water development in the reported area is as shown in Appendix 17. It is difficult to interpret the area in terms of suitability for large-scale development. Nowhere in the district one can suggest even a limited zone that may be suitable for irrigation of a considerable area. The only way to describe the suitability for development is in relative terms. Of course, this interpretation does not go beyond the penetrated depth of, on average, 49 m.

The area in the north, the Bhabar zone, may be locally suitable for individual wells in places where water level is closer to the land surface. The land depressions should be the points of interest. The south-east and south-central parts are relatively more suitable for development, but on limited scale, in places where lithology is more favourable. This may be an area near the Banganga River or its local tributaries. The area in the west and central part may be good for individual wells only, for water supply of villages but not for irrigation.

Considering the water balance, the best development procedure would be to develop shallow ground water from the central area near Gorusinghe down to the India-Nepal state border (Sultanpur-Harnampur-Karmahawa). The development in that area would tend to lower the regional water table and salvage the water from being lost through evaporation. Yet, it is questionable how many wells one needs to drill in a zone of very low transmissivity to accomplish any substantial abstraction. The number of shallow tube wells to develop available water cannot be assessed with the information available. Although more than 200 MCM annually recharge the shallow aquifer, an individual well can hardly pump more than 3-4 l/sec from very low transmissivity. If each well is pumped 120 days in dry season on a 12-hr per day basis, one well can hardly abstract more than about 18,000 m3. Thus the number of wells should be as high as 11,000, which is certainly an extremely high number. In the case of Kapilvastu district this is not the question of availability of water, and the forecast of maximum permissible number of wells, but the question how many wells are required to abstract the water that may be available.

To bring more certainty into the process of planning the shallow ground water development in Kapilvastu district, it is recommended that additional exploration wells are drilled in the central and south-eastern corner, where water levels are close to the land surface. It goes without saying that careful attention should be given to their development and testing, much more than in the present project work.

3.3. Dang Valley ... Basic Documentation

The objective of the report was to present technical information on the occurrence of shallow ground water in Dang valley. It is given in a form of a basic documentation with some preliminary interpretation.

The drilling program which was formulated about a year ago, was completed according to the expectations. Eight wells were completed with the total drilling metrage of 273 m (Appendix 19). The average depth of newly completed wells is 30.0 m. Considering the lithology of shallow ground water system, and especially the depth to water table in static and pumping conditions, this depth is not adequate for the project purpose. All of 8 wells were constructed by drilling rig. In the area such as Dang, where water table is normally deep, except near the river, and where large pebbles, cobbles and boulders can be found at any depth and any place (Appendix 21), any method of drilling will have to surmount obstacles. Manual, or indigenous, method is probably not suitable here, but, likewise a drilling rig may have problems unless it is powerful, well equipped and well maintained. Diverse drill bits should be readily available when needed. An average shallow well in Dang valley, to be used for either monitoring water levels or as a producer, should be between 60 and 70 m deep. The upper permeable layers are in most places dry during a portion of year.

In Dang either electrical submersible pump or vertical turbine pump should be used. To accommodate such a pump, well diameter should be 6 inches.

Mostly because of deep levels and inadequate pumping equipment in only seven UN "project" wells pumping test had been run. However, the information presented in the report is expanded by making an interpretation of earlier pumping tests conducted by GWRDB several years ago.

The pump testing program in Dang valley should be continued. There are some wells which lend themselves to testing in the period when water levels are within suction lift capacity of centrifugal pump, and in others an adequate pump should be employed. If remaining wells are tested, the wealth of information and knowledge about the district would be improved to some extent.

Although, generally, the Dang valley is characterized by high transmissivities of shallow layers, which in places reaches as high as 6,000 m2/day (Appendix 22), several wells did not fit into the picture. One well in the east and two in the west have shown rather poor transmissivities: Pakkoi - 26, Bainsa - 36 and Baibang - 86 m2/day. In Baibang the lithology shows 11 m of gravel. If the lowermost possible hydraulic conductivity of gravel is considered, the well should have produced at least 440 m2/day transmissivity. Likewise, in Bainsa, about 50 m of gravel and sand have shown 36 m2/day and in Pakkoi, 11 m of gravel has produced only 26 m2/day transmissivity. From this, it can be concluded that either the reported lithology or the construction and/or development of wells are not correct. Considering the location of the well, one can suspect that the wells at Pakkoi and Baibang must have been not properly developed. There is also a possibility that drilled-through layers are composed of conglomerates rather than gravel. The wells in central and southern parts which are mostly along the Babai and Guwar rivers have shown higher transmissivities.

Dang valley is well covered with water-level monitoring network (Appendix 20). In the month of February 1989, the network includes 8 project- drilled wells, 10 GWRDB drilled wells and one dug well. It is recommended to continue with the same network, i.e. with 19 wells, on a once-a-month basis.

The hydrogeology of Dang valley can be best described as follows.

(a) The percentage of permeable material (sand, gravel) in the upper 30 or so meters is about 48%. In deeper parts this percentage is either about the same or even higher.

(b) There are several permeable layers, which may be interconnected over a larger distance, but locally they are separated by considerable clay layer (more than 10 m thick).

(c) Water table is generally deep, especially in the northern half of the valley. The deepest water table is close to 30 m. Fluctuations of water levels are generally high, in some places over 20 m. Water table of aquifer at depths 50 to 70 m in some wells in the southeastern part of the valley near the river are deep under the river bed, indicating effective separation between the surface and ground water.

(d) The recharge into the shallow ground water system is from rainfall, and discharge is to the Babai River. The rainfall may contribute the recharge over about 50% of the valley, that is to some 500 km2. With the average annual rainfall of some 1900 mm, and with the percentage of infiltration of 14 (a result of calculation from flow net), the total input into the shallow ground water system could be about 130 MCM per year.

(e) Although one would expect that the outflow of shallow ground water would be normally towards southwest into the Babai river, and although the water level contour maps (Appendix 23) confirm this, in many places along the river line the shallow water table is very deep under the river bed, making, thus, any connection unlikely. Actually, the water level contour maps indicate that the shallow ground water flows directly into the river in the western half of the valley; between Baibang and Bhojpur, while in the eastern half, the flow is parallel with the river course.

(f) The outflow into Babai river from Rangaincha to Bhojpur is calculated from the gradient of ground water flow and transmissivities from pumping tests. The gradient all over the valley is very high, on average 40 m per 5 kilometers, or 0.008. The volume of water that may be outflowing through the section between Baibang and Bhojpur (12 km) could be about 336,000 m3/day, or 122 MCM per year. With westernmost section from Baibang westwards included, the total outflow into the river in the western half of the valley could be as high as 130 MCM. In an average year, in a closed basin such as the Dang, all recharge should be balanced by discharge. Since the evaporation process may have only limited importance, and pumping from wells is at the moment of low significance, the recharge to the system could be at least 130 MCM/year.In other words, the outflow into the Babai River of 130 MCM may be on the conservative side. The ground water system as explained in this report lends itself favourably to extensive ground water exploitation. The potential exists, aquifers are permeable and transmissive. Most of this 130 MCM of water can be abstracted by careful siting of wells, by reversing the gradients and by creating an extended cone of depression. The only constraint seems to be the economics of pumping, considering the depth of water table. One should count with dynamic (pumping) depths of over 40 m in some places. A typical well would be 80 m deep, with screens set in intervals between 30 and 70 m, and pump installed at some 40 or more meters. The well design must be such to permit the installation of 10 l/sec pump, that is the well screen diameter in the upper 40 m must be minimum 6 inches.

On the basis of the presented information, the feasibility of shallow ground water development in the reported area is as follows (Appendix 24):

The best area for shallow ground water development by using centrifugal pump is along the Babai river. In the rest of the valley, water table is beyond the suction lift reach of centrifugal pump. This is not to say that shallow ground water development is not feasible in such areas. On the contrary, notably in the central part where transmissivities are higher than 2000 m2/day, the development potential is very high but other types of pumps should be used, and well diameter should be at least 6 inches. Only in the northwestern part and along the rim of the valley, the development potentials appear to be impaired due to (a) unknown lithology, (b) deep water table, (c) very hard material, (d) rough or "undulating" topography.

It is believed that wells in Dang valley shall be able to pump between 30 and 50 l/sec, from dynamic depths of some 40-50 m. The number of wells, producing on average 150,000 m3/season, which may be sufficient to irrigate about 10 hectares, could be about 900. These are expensive wells, with expensive pumping equipment, but since each can irrigate at least 10 hectares, the expense may be shared by a group of farmers.

Finally, the following is recommended to be done during future investigations:

(i) Complete pumping tests in existing wells. Use adequate pumping equipment.

(ii) Drill additional test holes between Tari Gaon and Amuwapur, Bainsa and Tulsipur, north of Rangaicha, between Asuwar and Kataha to fill the gap.

(iii) Construct several 6" size wells nearby already existing 4" size in the areas where water table is always below 7 m and conduct pumping test using 4-in existing wells as observations wells. Make one well 70 m deep, which would be of typical design for future large-scale exploitation (6-in casing in upper 50 m, 4-in in lower part; well screen 4-in and 6-in; drilling diameter 10-in, gravel pack 2-in) and run a long-term pumping test (3 days minimum).

(iv) Continue monitoring of water levels without interruptions. Use all 19 wells.

(v) Make a mathematical model of the whole valley which will quantify the parameters and processes involved in the present ground water flow environment and offer planning and management alternatives for future intensive ground water development. The network of the model is shown in Appendix 25.

3.4. Deukhuri Valley ... Basic Documentation. Technical Report No. 9

The basic documentation on Deukhuri valley shall be submitted as Technical Report No.9 in early July. This is a small valley which is highly dominated by the Rapti River.

4. ACTIVITIES IN THE PERIOD FROM JUNE THROUGH DECEMBER 1989

4.1. Pumping Tests

To complete the drilling and testing program of 1989 and to have sufficient information for reporting on a district, the following is recommended:

(a) Banke District: complete the planned testing program (30 tests)

(b) Bardiya District: complete the planned testing program (30 tests)

(c) Rupandehi District: compile all available information on shallow wells testing by ADBN, USAID, GWRDB, Bhairawa-Lumbini irrigation project, UNDP project. Run additional tests if the program (31 tests) is not completed.

(d) Morang District: complete the planned testing program (25 tests).

(e) Dang District: follow the recommendations for testing from Technical Report No. 8.

(f) Kapilvastu District: follow the recommendations for testing from Technical Report No. 7.

4.2. Data Base

One of project objectives is to establish a shallow wells computerized data base with about 2000 selected STWs. The activity leading to the establishment of the data base was postponed for reasons explained in Mission Report 6. The additional two computers are not yet received by the project. In addition to technical problems related to the establishment of the data base, as mentioned in Mission Report 6, this consultant may have reservations about the real benefits of a data base, especially if it is prepared by commercial programs, such as dBase IV, Paradox, or any other integrated data base software. Such a data base will not produce dedicated retrievals, e.g. in the form of lithological logs, pumping tests, or hydrographs. On the other hand, the software prepared by this consultant on behalf of the executing agency, DTCD (New York), is not an integrated software for all components and parameters that may describe a well. This subject shall be raised at next project's Tripartite Review, which was originally scheduled for November/December 1989, but which may be held earlier (August/September).

4.3. Reporting

The project contemplates to process the information from the following districts (in listed order):

MORANG (September 1989)
BANKE (September 1989, provided pumping tests are completed)
BARDIYA (October 1989, provided pumping tests are completed)
RUPANDEHI (November 1989, provided support from Bhairawa is given)
Likewise, the following mathematical models can be made:

SUNSARI (September 1989)
DANG valley (October 1989)
MORANG (December 1989)

These targets are in the same time the work plan for office activities by the end of 1989.

4.4. Field Activities

The **drilling activities** which were suspended at the end of March, shall not continue in the coming monsoon period. By November this year, it will be clear whether the program shall continue, which districts shall be given priority in the drilling season of 1990 (December 11989 - May 1990), and whether the portion of the uncompleted work in 1988/89 shall be completed.

Pumping test activities should be given priority, provided fuel becomes available, regardless the weather conditions.

Monitoring of water levels in all districts must continue without gaps, missing wells, or skipped months.

5. CONCLUSIONS AND RECOMMENDATIONS

Drilling. The work plan for 1988/89 was overly ambitious. Without the fuel problems, the implementation would have been very satisfactory. Yet, the drilling campaign produced almost enough information for preparation of reports on shallow aquifer lithology and development potentials in Sunsari, Morang, Rupandehi districts. With additional pumping tests in Banke and Bardiya, these two districts shall also be completed.

Pumping Tests. To repeat the conclusion from previous Mission Report, this activity appears to be low on the list of GWRDB priorities, although it should be the other way around. Banke and Bardiya districts cannot be reported without pumping test results. Likewise, there is no information on eventually conducted pumping tests in Kailali and Kanchanpur districts, which are omitted from the consideration for reporting. Moreover, the pumping test activity in some districts produces unreliable results on account of inadequate equipment (centrifugal pump with limited suction head; well discharge measuring equipment; pump fluctuations during the test) and too short duration. As a matter of routine, each pumping test should continue for a minimum 2 hours, in some cases more.

Monitoring Water Levels. This is a routine procedure which is carried out to an expected level of acceptance. There must be no gaps, especially in May-September period, where even once-a-week measurements are not sufficient.

Levelling Wells. Unfortunately, the work on reporting the districts of Terai cannot wait for local surveyors to produce elevations of land surface at well sites. The contour maps of Sunsari districts were produced by "reading" elevations from topographic maps (accuracy several meters). The Dang, Deukhuri, and Kapilvastu reports contained maps with correct altitudes obtained through a subcontract. The mathematical model of Sunsari district, which is currently under preparation, also will suffer from the lack of accurate elevations, especially of the Sapta Koshi river stage. The reports and models of Morang and Rupandehi will probably be completed without having accurately surveyed elevations. Needless to say, the accuracy of presentation shall be inferior to other districts in which land surface elevations were available.

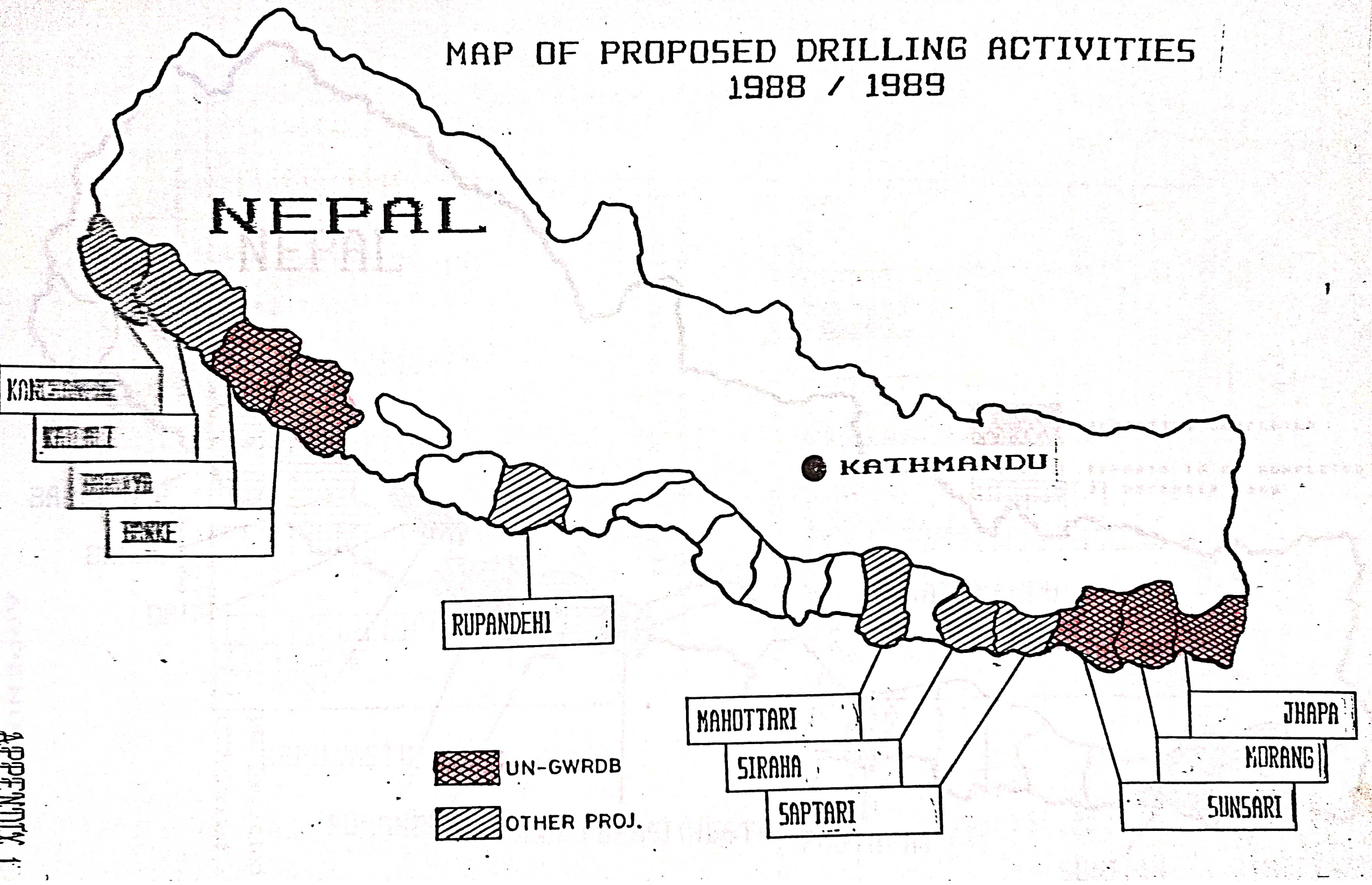
Reporting. As shown in Appendix 2, five districts are covered by Basic Documentation reports (Rautahat, Nawalparasi, Kapilvastu, Dang and Deukhuri, Sunsari). Four more districts are planned to be completed by the end of this year (Morang, Banke, Bardiya, Rupandehi). Eleven districts still remain to complete the field work, process information and report. This will be the job for the remaining two years of the project, i.e. 1990-91.

Computerized Data Bases for STWs and DTWs. Decision should be made as to the real benefits of a data base, its structure, design and components, having in mind the retrieval programs that are currently available, but which cannot fit into a commercial data base software. The alternative is to produce several data bases, which will be object oriented. For example, the well construction and lithology data base, with one of retrievals produced by the computer as shown in Appendix 26. Such an output from the lithological data base can easily be prepared (at a rate of one staff member 10 wells in one day). Each district, or zone, may have its own lithological and well construction data base, one for deep tube well, another for shallow wells. Another example is pumping test data base with pumping test data. Water levels data bases could also be produced independently for each district, and type of aquifer. At some later date, this project may produce software which shall integrate all individual data bases into one. The point is that a data base is of questionable use if application and retrieval programs are not considered at the very beginning of its creation.

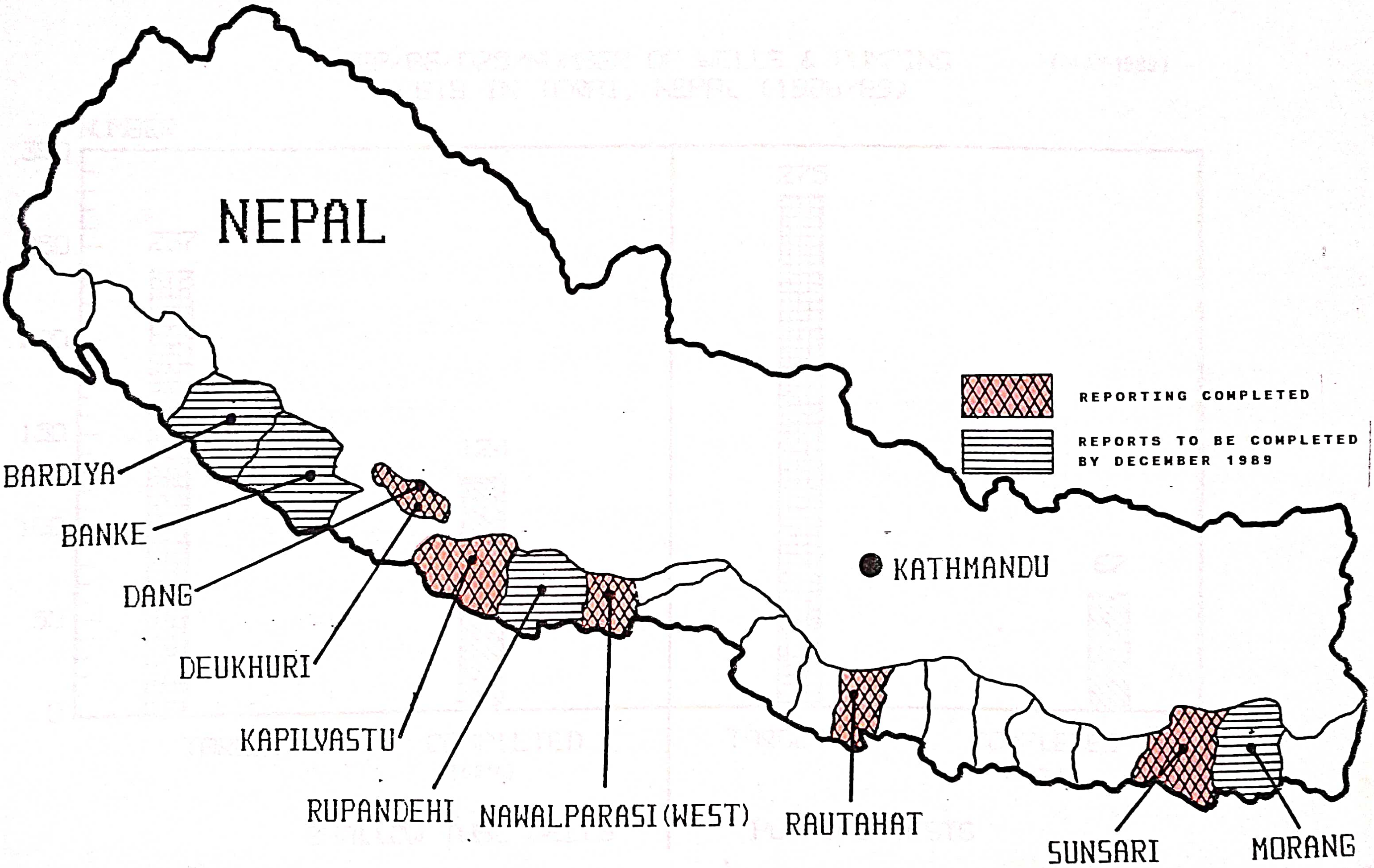
This work on the establishment of dedicated data bases will demand additional manpower, both from GWRDB side and UNDP. This consultant recommends that in addition to one associate expert post, one additional post be established for a consultant hydrogeologist to work one year on the transfer of data, data processing, preparation of reports, modelling, and training to GWRDB staff.

APPENDIX 1

MAP OF PROPOSED DRILLING ACTIVITIES 1988 / 1989

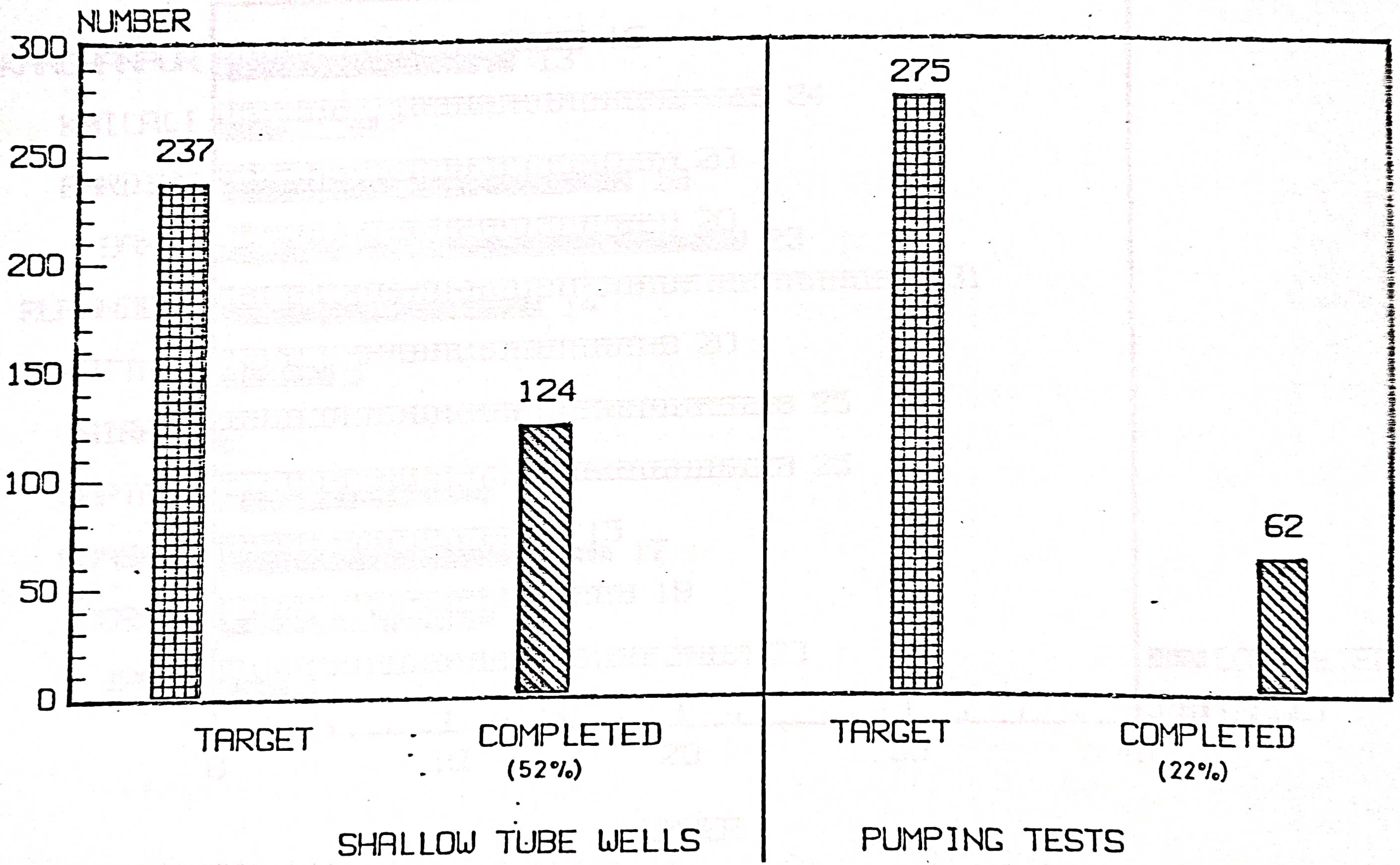


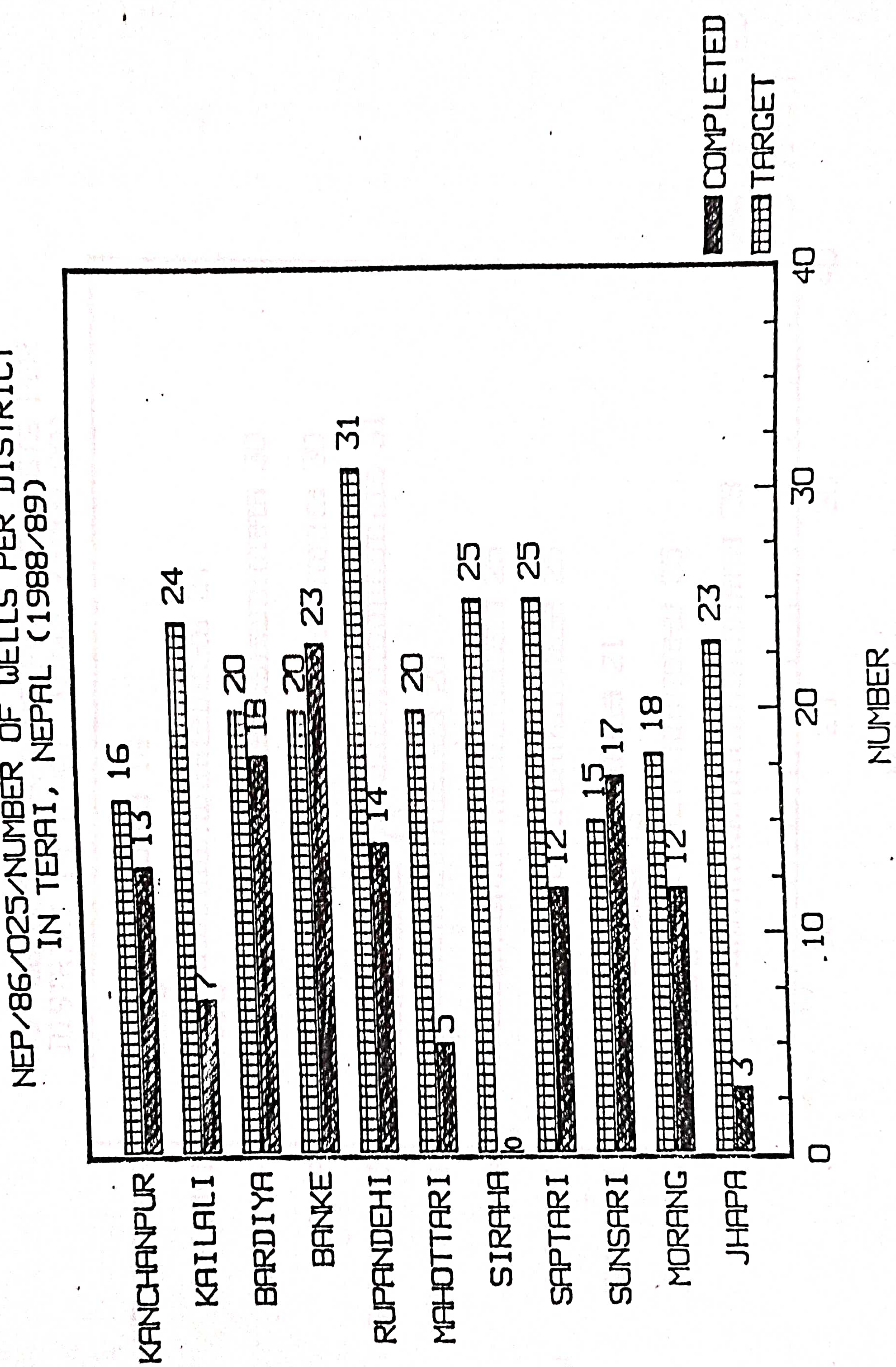
APPENDIX 2


NEPAL
REPORTING COMPLETED
REPORTS TO BE COMPLETED BY DECEMBER 1989
KATHMANDU
BARDIYA
BANKE
DANG
DEUKHURI
KAPILVASTU
RUPANDEHI
NAWALPARASI (WEST)
RAUTAHAT
SUNSARI
MORANG

NEP/86/025/NUMBER OF WELLS & PUMPING TESTS IN TERAI, NEPAL (1988/89)

(MAY 1989)

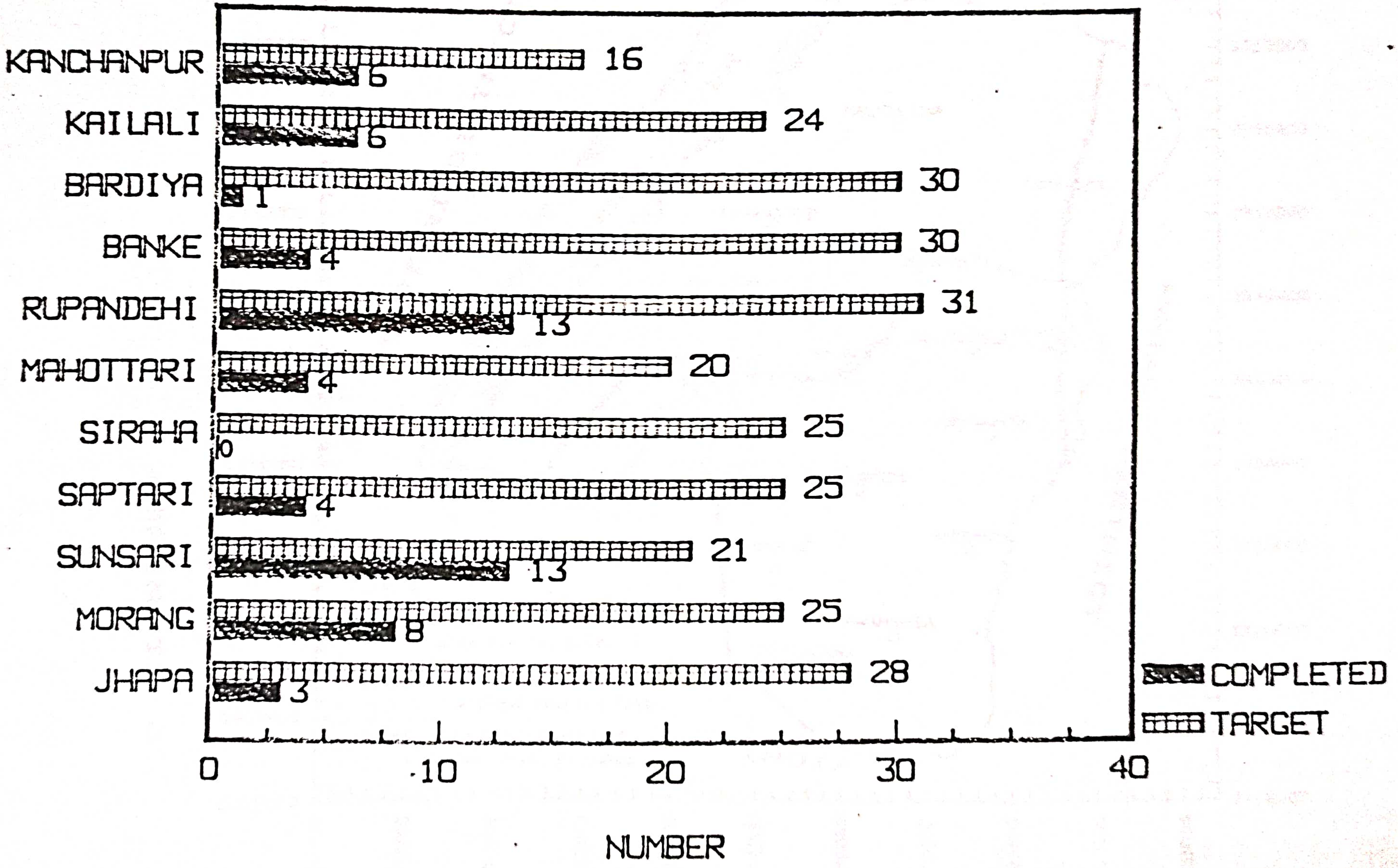



NEP/86/025/NUMBER OF WELLS PER DISTRICT
IN TERAI, NEPAL (1988/89)
KANCHANPUR 16 13
KAILALI 24 7
BARDIYA 20 18
BANKE 20 23
RUPANDEHI 31 14
MAHOTTARI 20 5
SIRAHA 25 0
SAPTARI 25 12
SUNSARI 15 17
MORANG 18 12
JHAPA 23 3
0
10
20
30
40
NUMBER
COMPLETED
TARGET

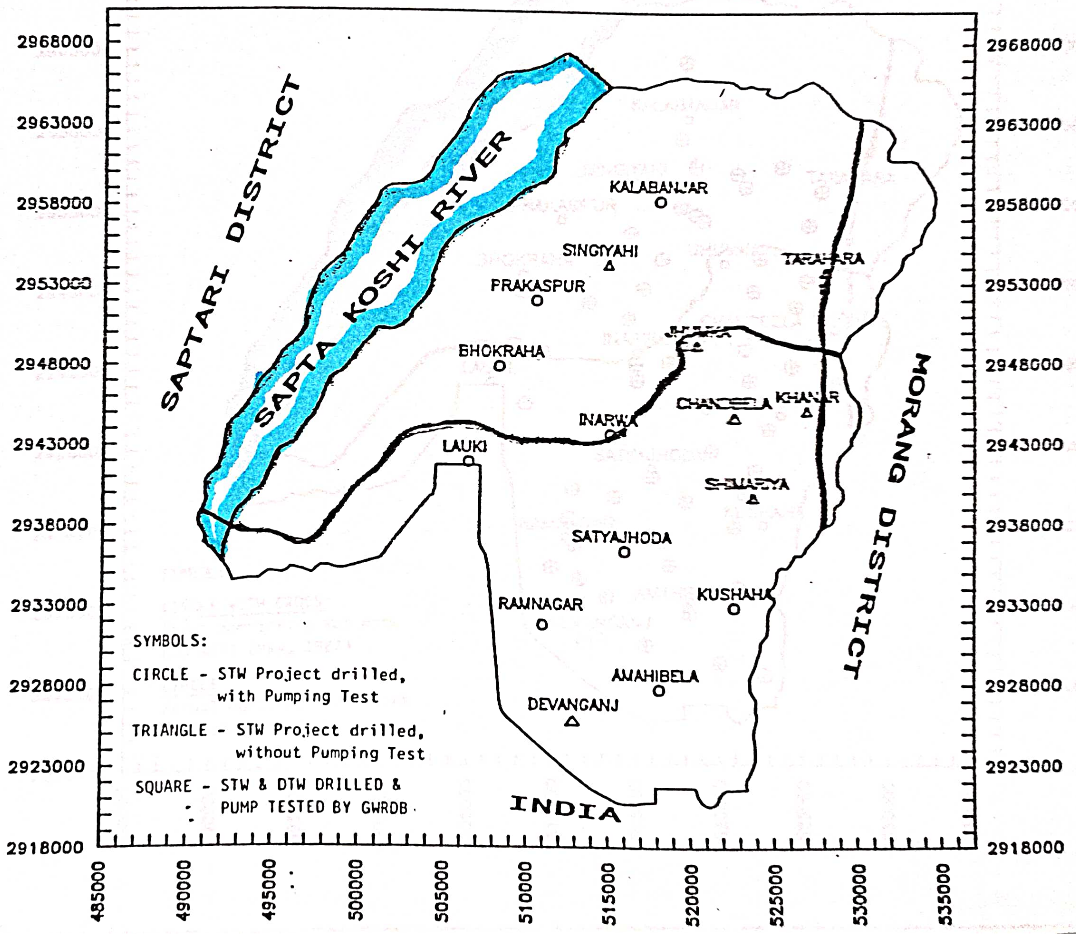
APPENDIX 4

APPENDIX 5

NEP/86/025/NUMBER OF PUMPING TESTS PER DISTRICT IN TERAI, NEPAL (1988/89)

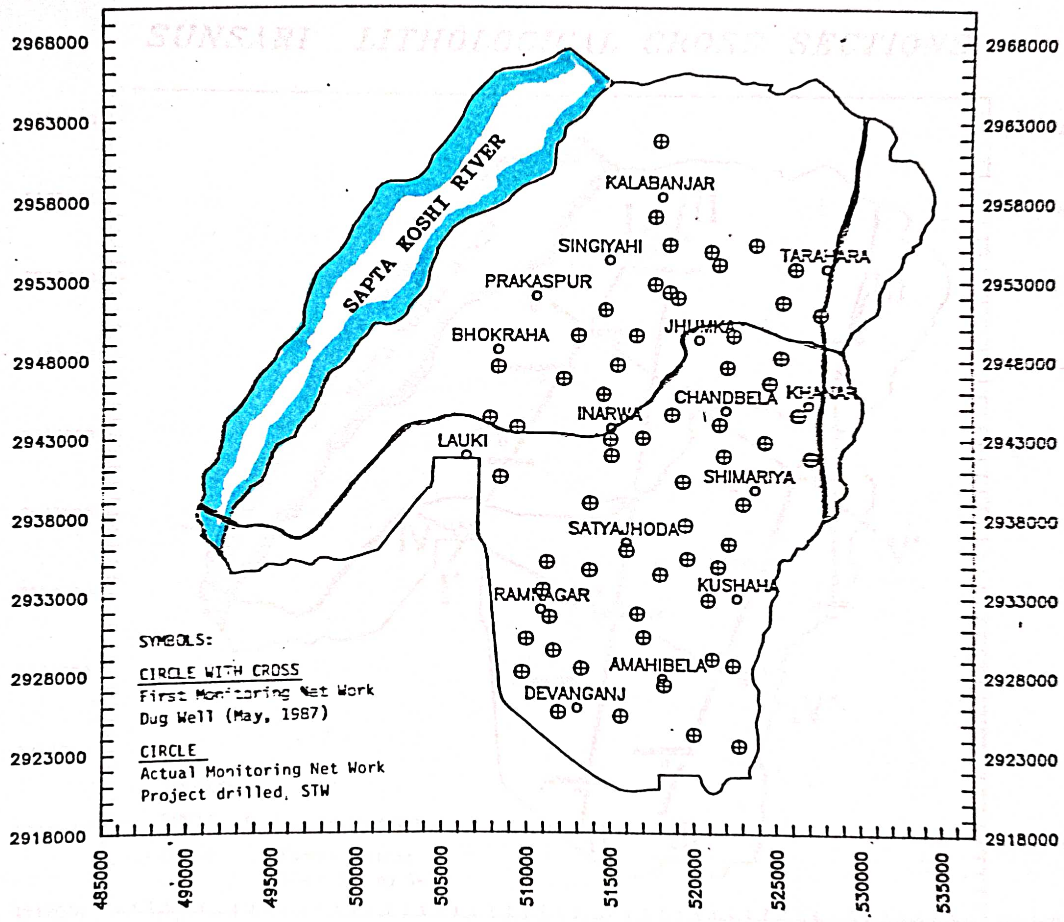


SUNSARI PROJECT WELLS AND PUMPING TESTS

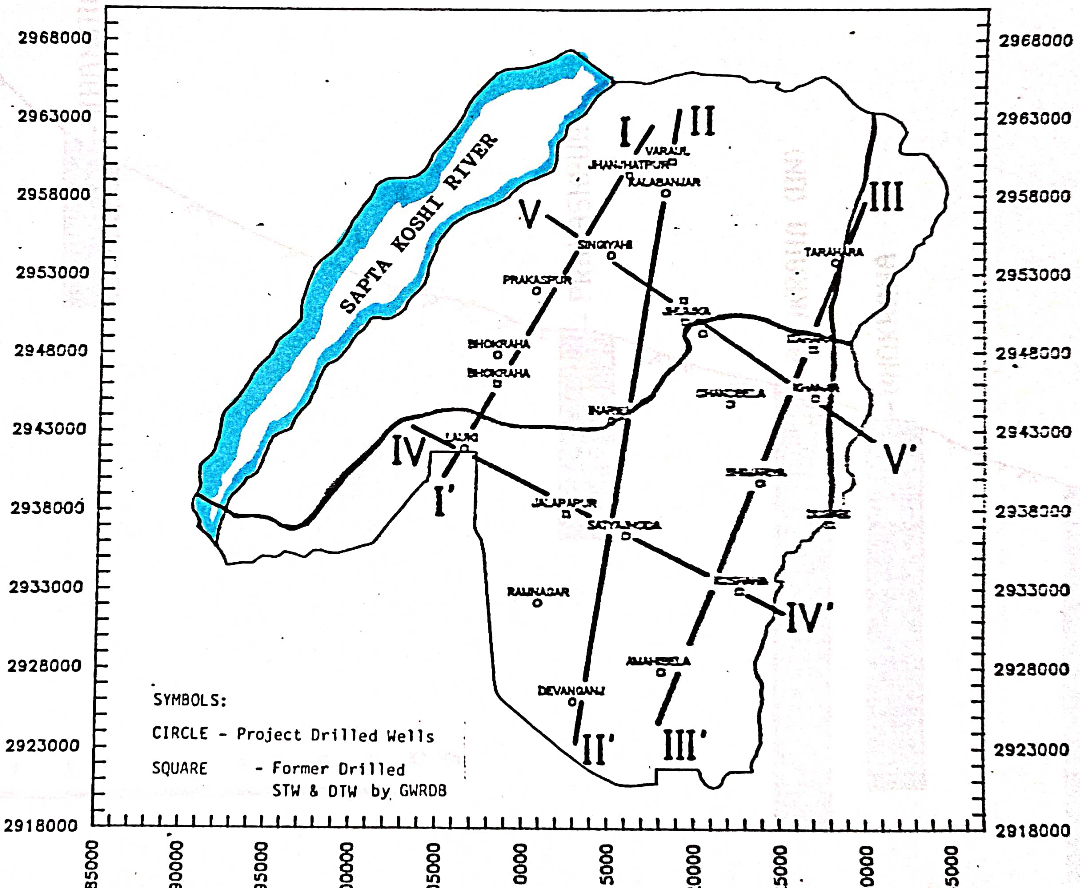


APPENDIX 6

SUNSARI LOCATION MAP FOR MONITORING NETWORK



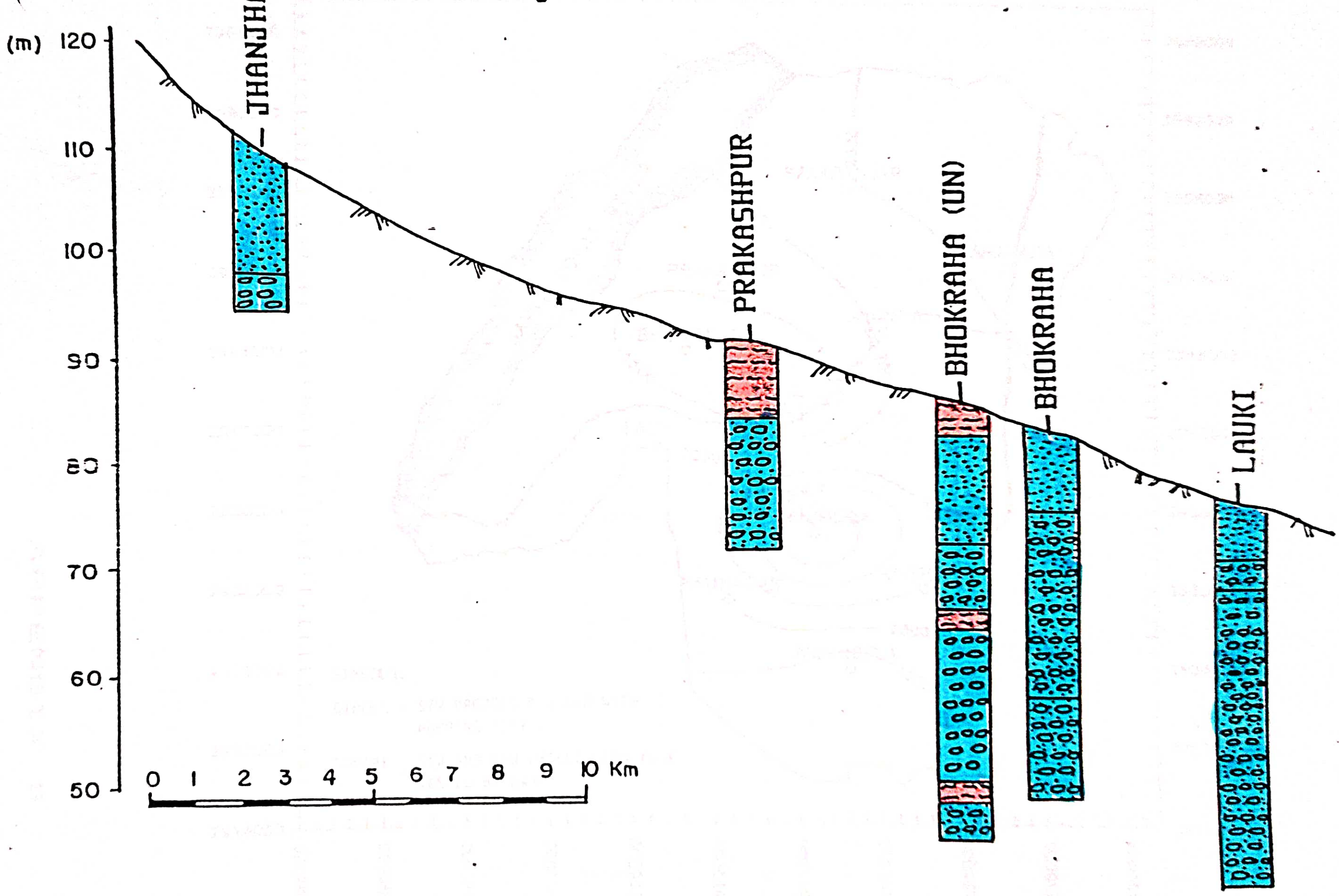
SUNSARI LITHOLOGICAL CROSS SECTIONS



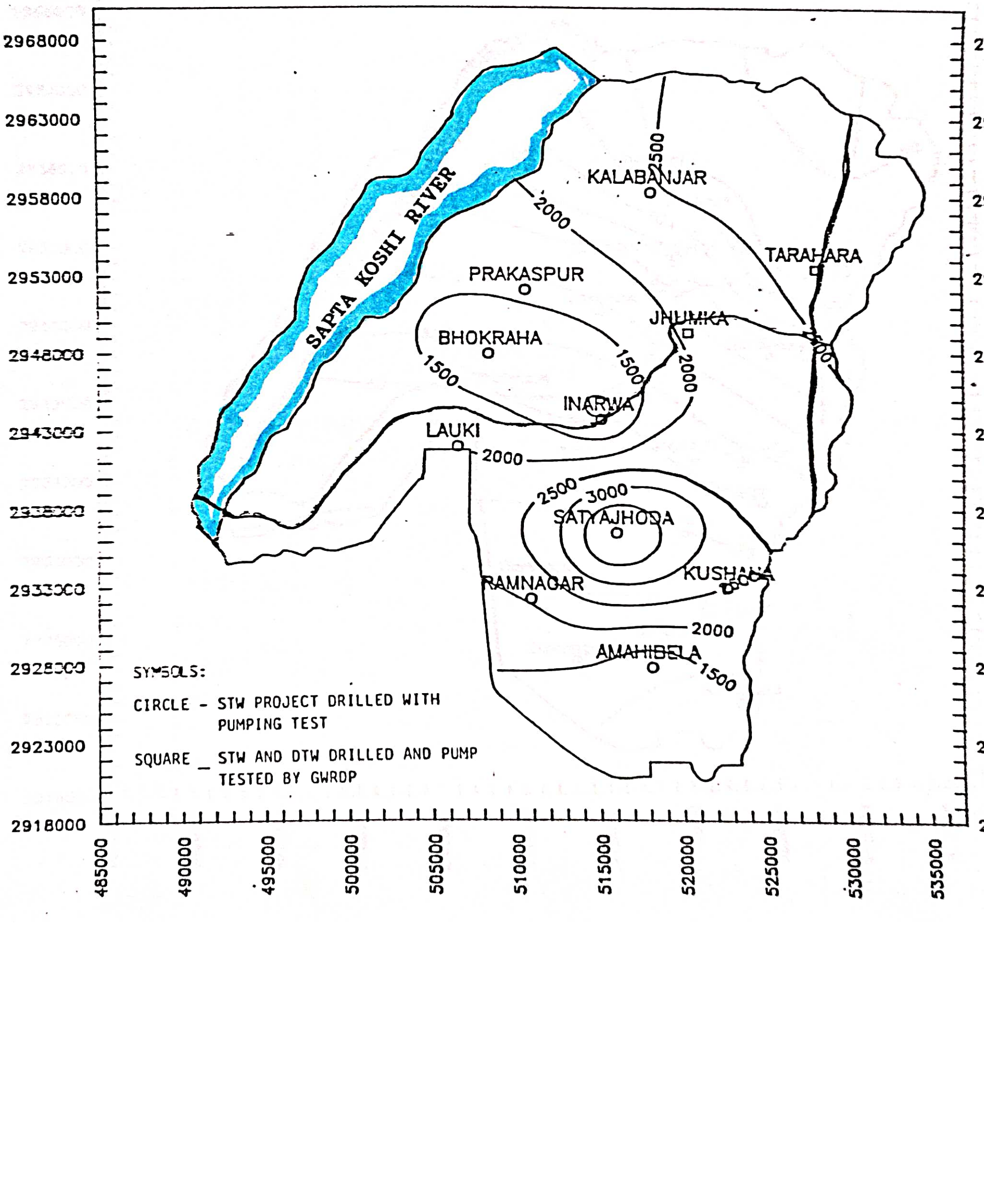
APPENDIX 8/1

APPENDIX 8/2

LITHOLOGICAL CROSS SECTION I - I'

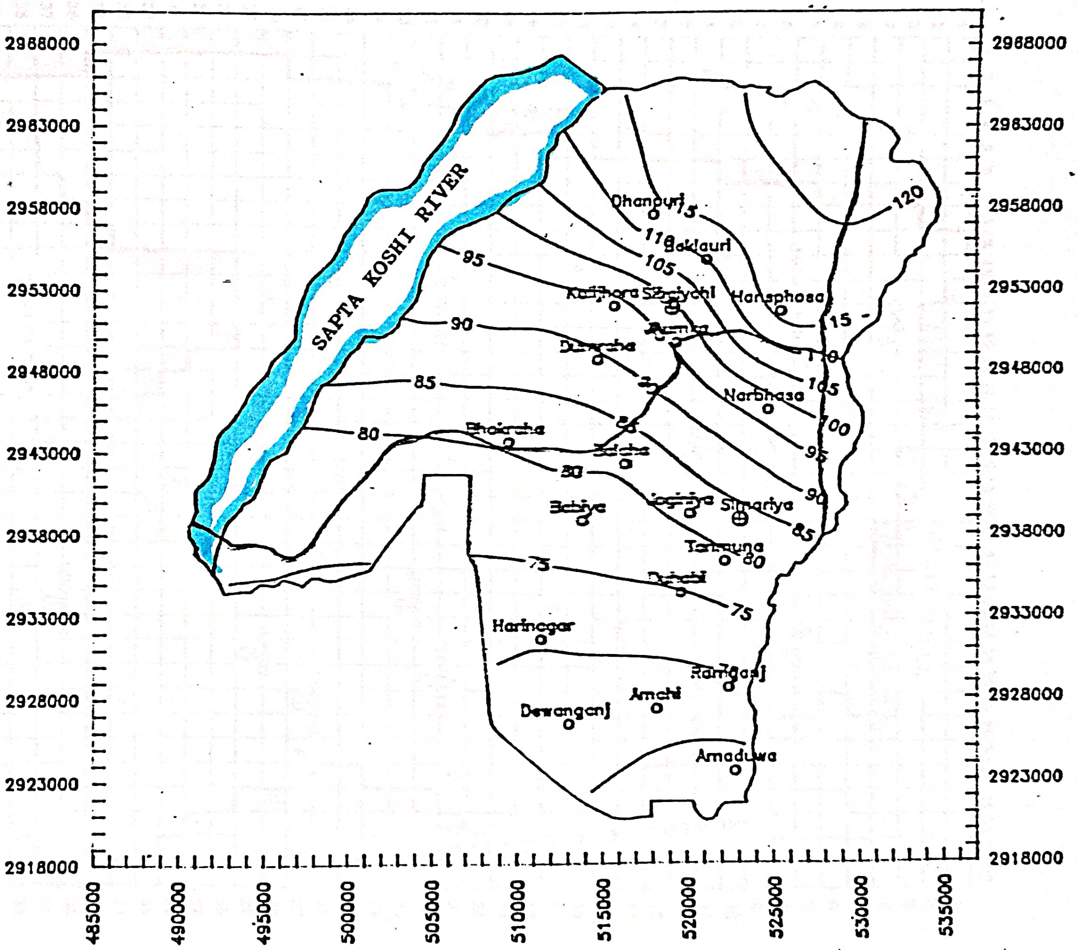


SUNSARI TRANSMISSIVITIES (M2/DAY)



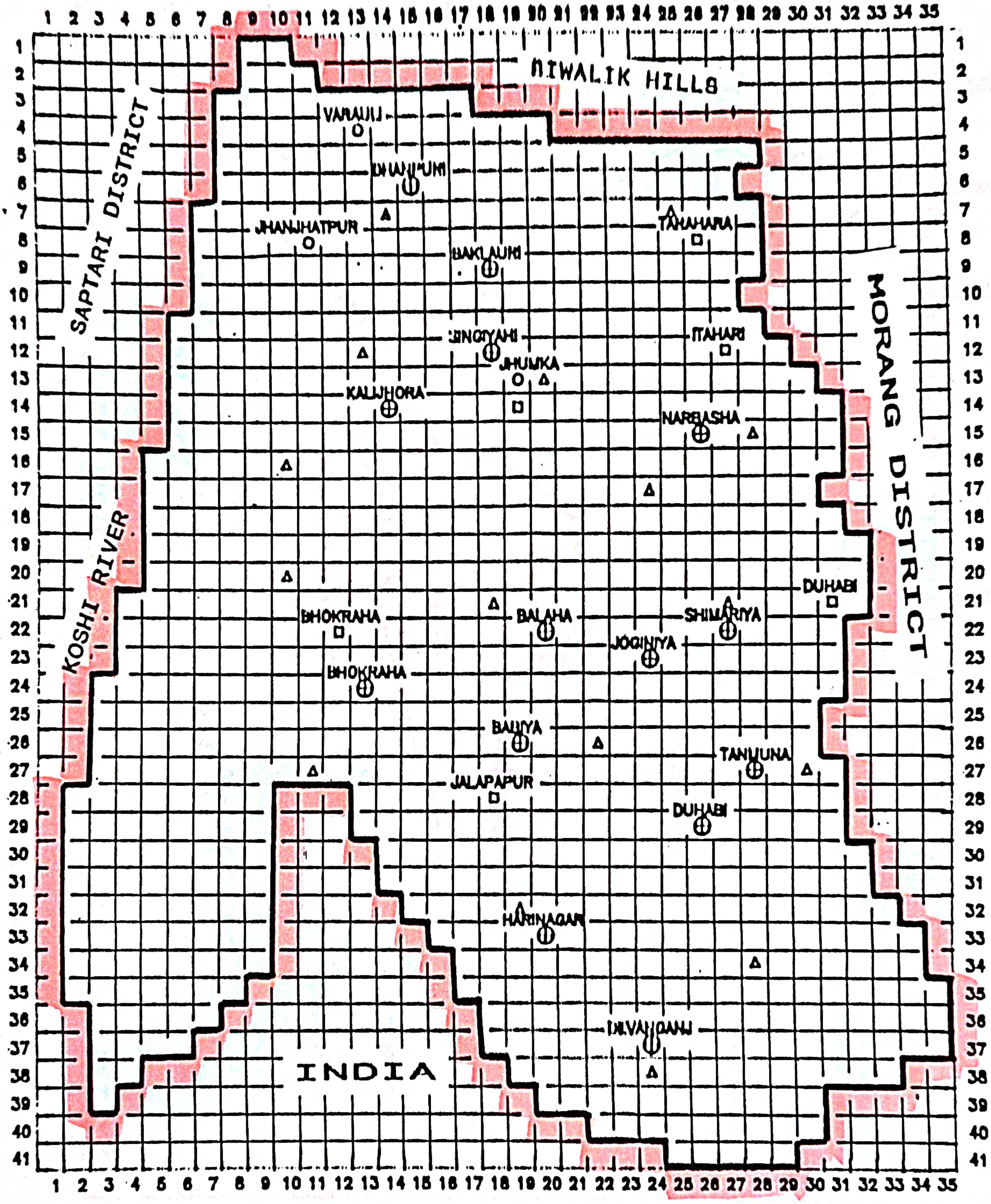
APPENDIX 9

SUNSARI WATER LEVEL CONTOUR MAP SEP 1988



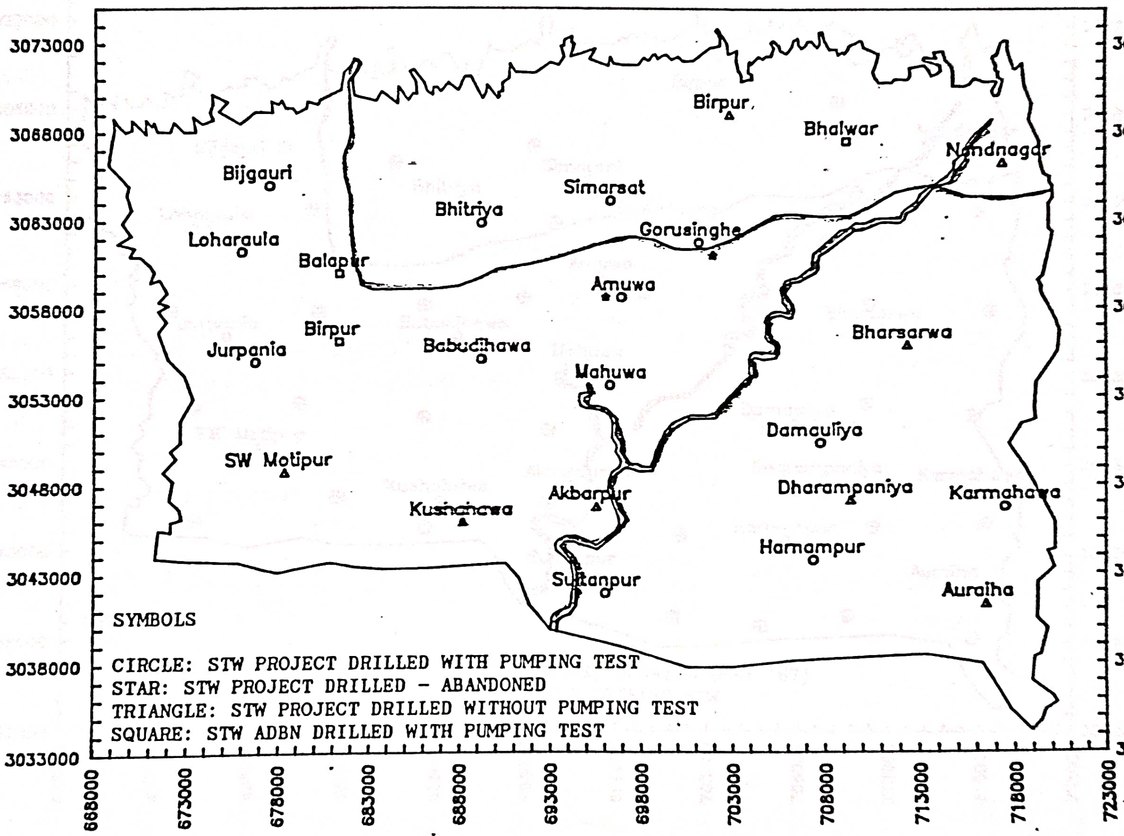
APPENDIX 10

SUNSARI: MATHEMATICAL MODEL NETWORK

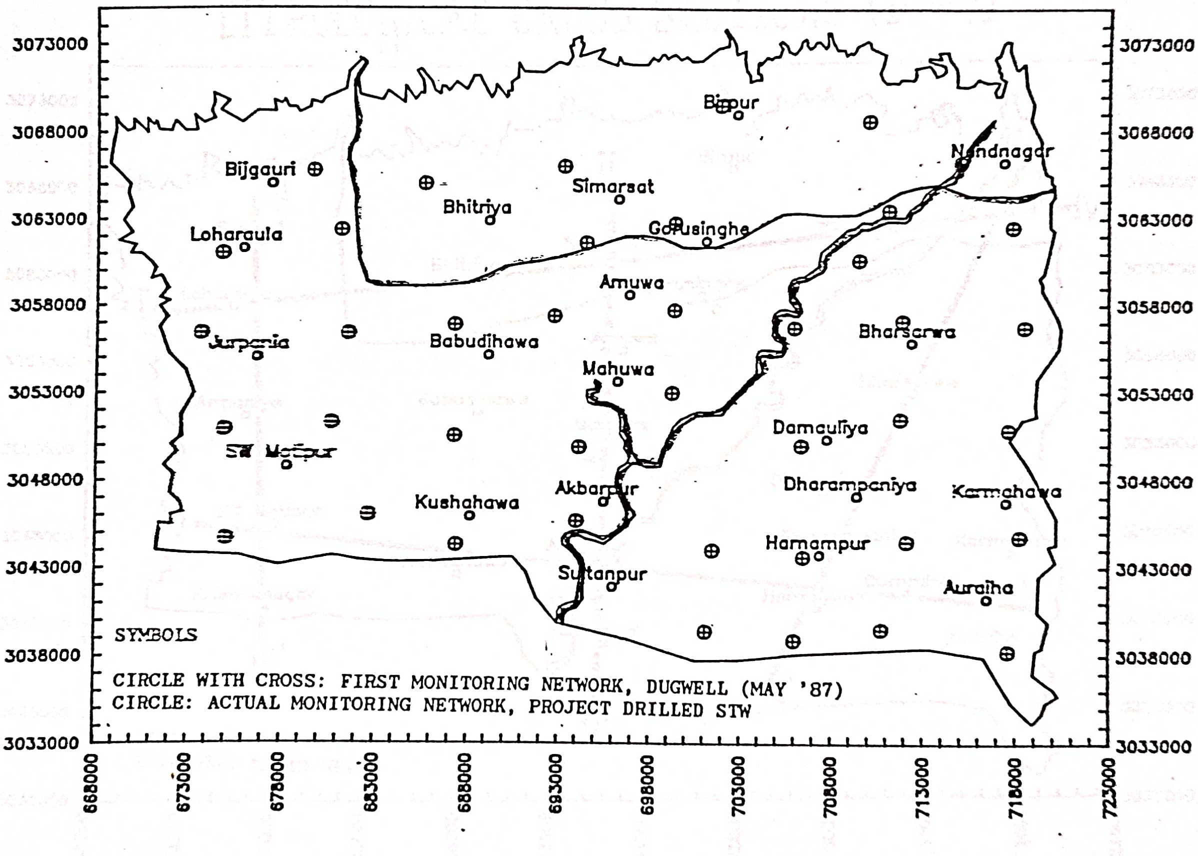


APPENDIX 12

KAPILVASTU TERAI – PROJECT WELLS AND PUMPING TESTS



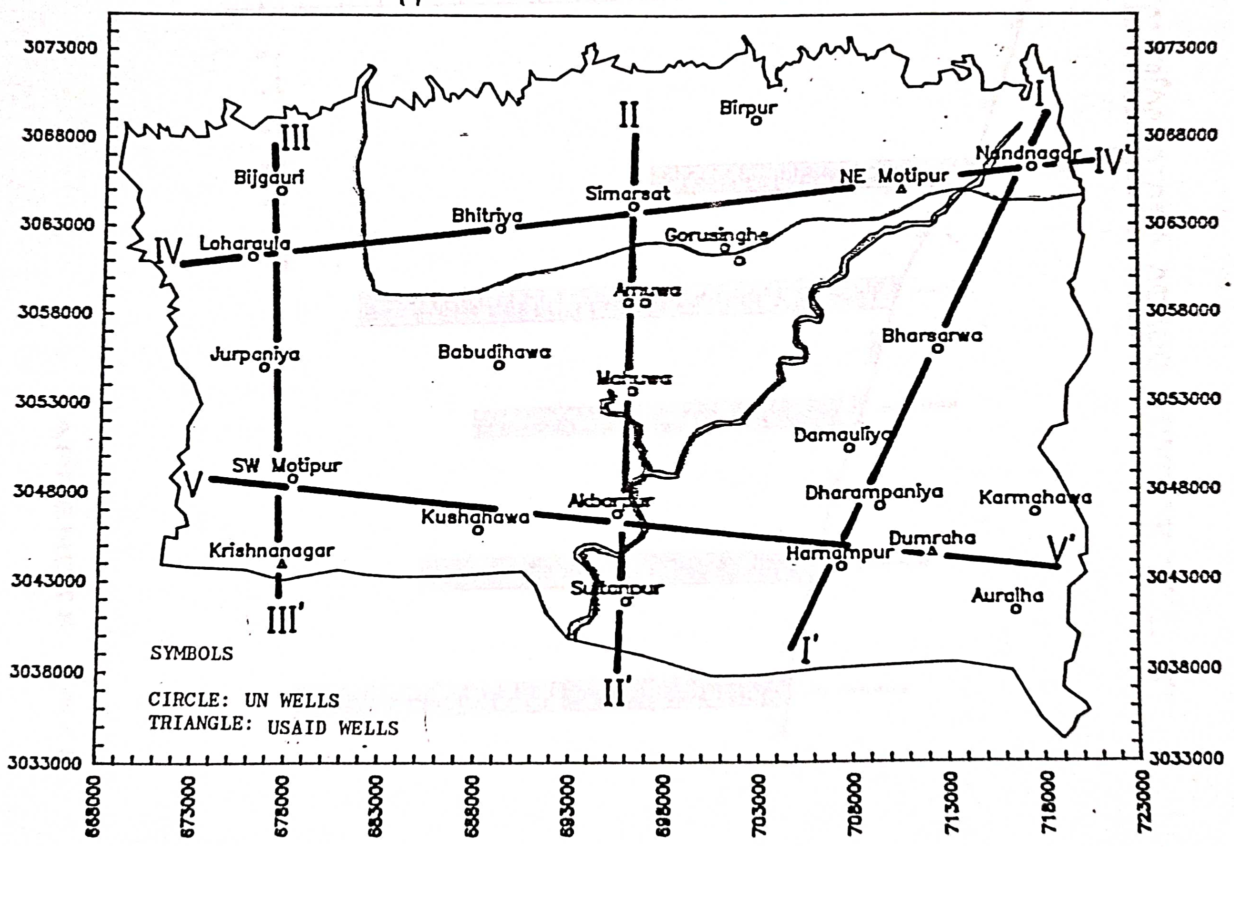
KAPILVASTU TERAI – LOCATION MAP FOR MONITORING NETWORK



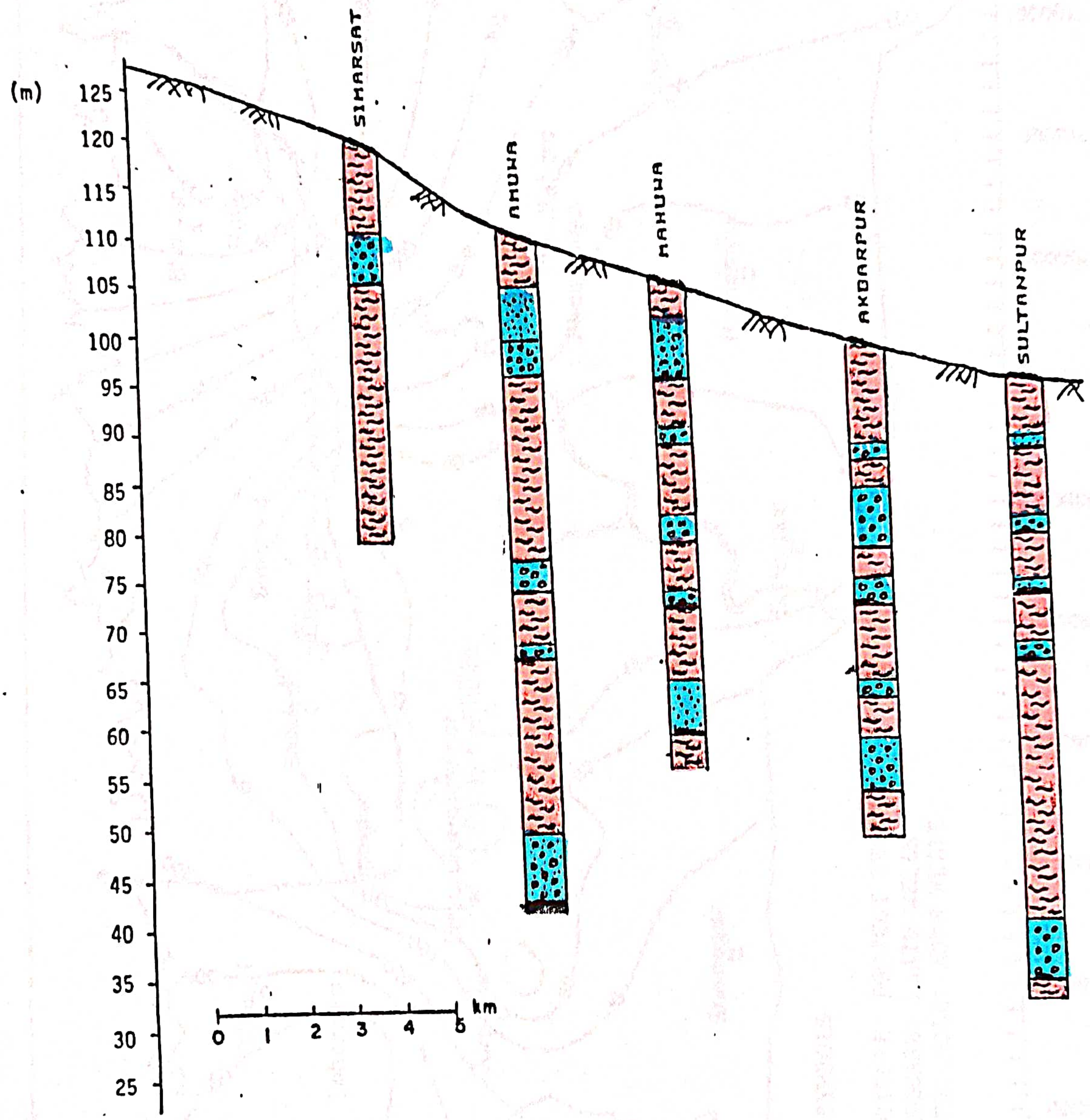
APPENDIX 13

KAPILVASTU - LOCATION OF WELLS

LITHOLOGICAL CROSS SECTIONS (I - V)

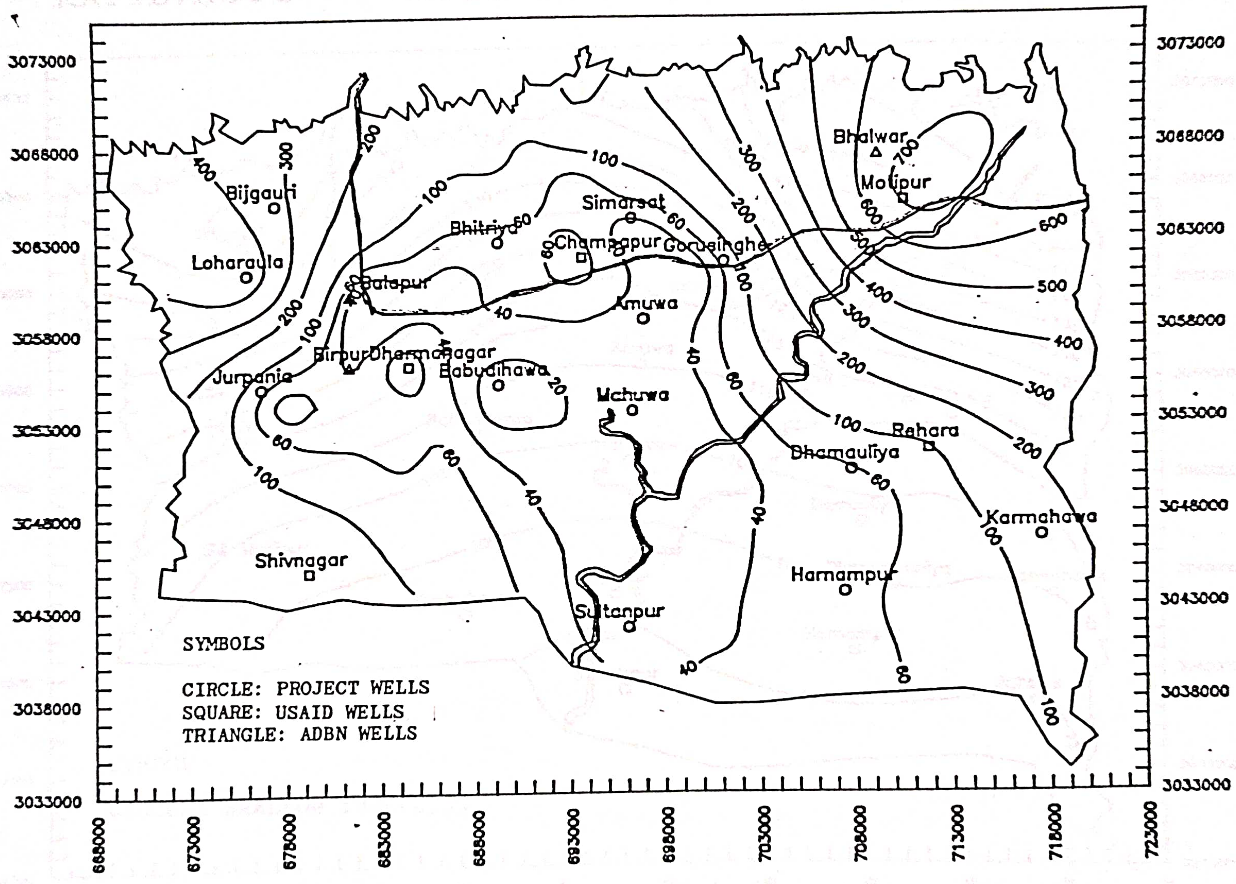


LITHOLOGICAL CROSS SECTION II - II'



APPENDIX 14/2

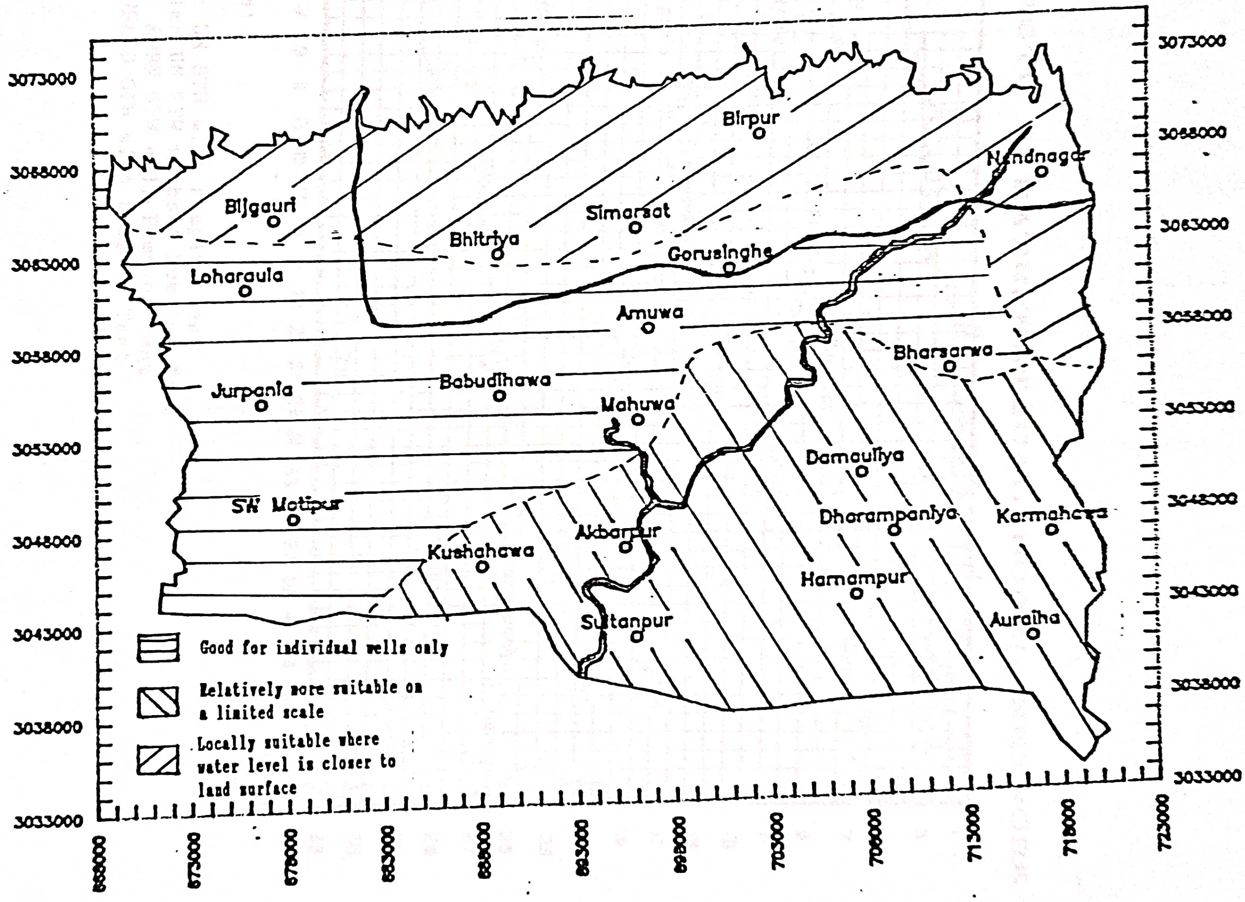
KAPILVASTU TERAI - TRANSMISSIVITIES (M2/DAY)



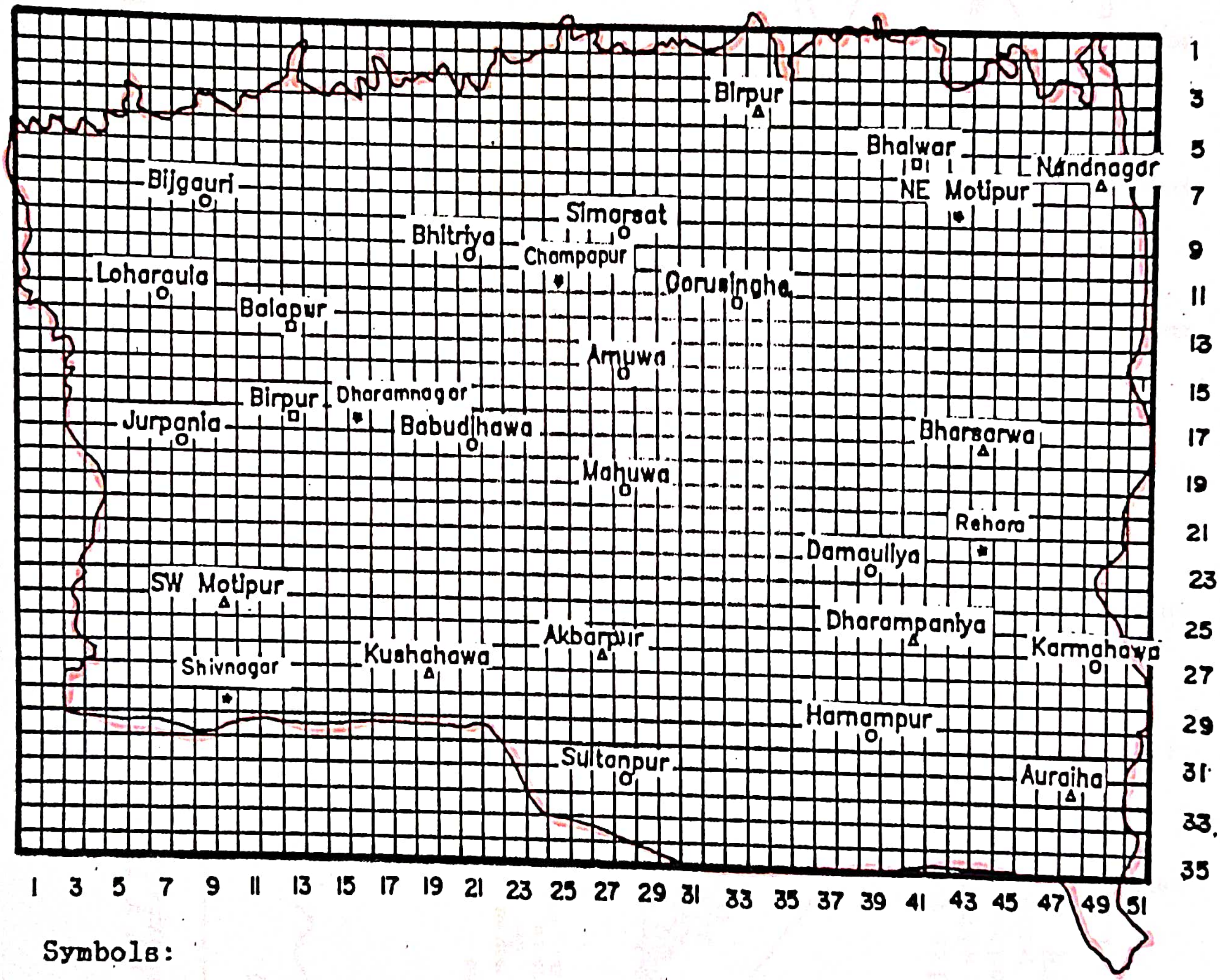
APPENDIX 15

APPENDIX 17

FEASIBILITY FOR SHALLOW GROUNDWATER DEVELOPMENT



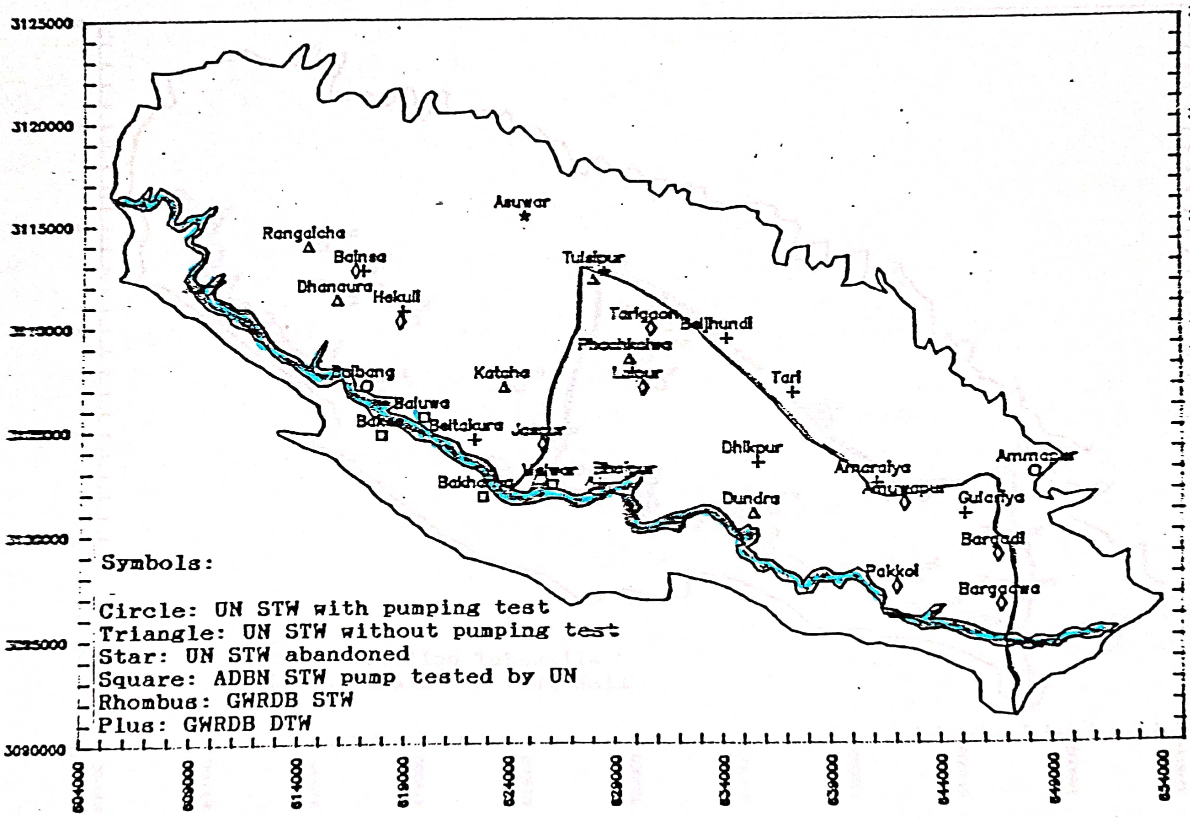
KAPILVASTU – MATHEMATICAL MODEL NETWORK



Symbols:

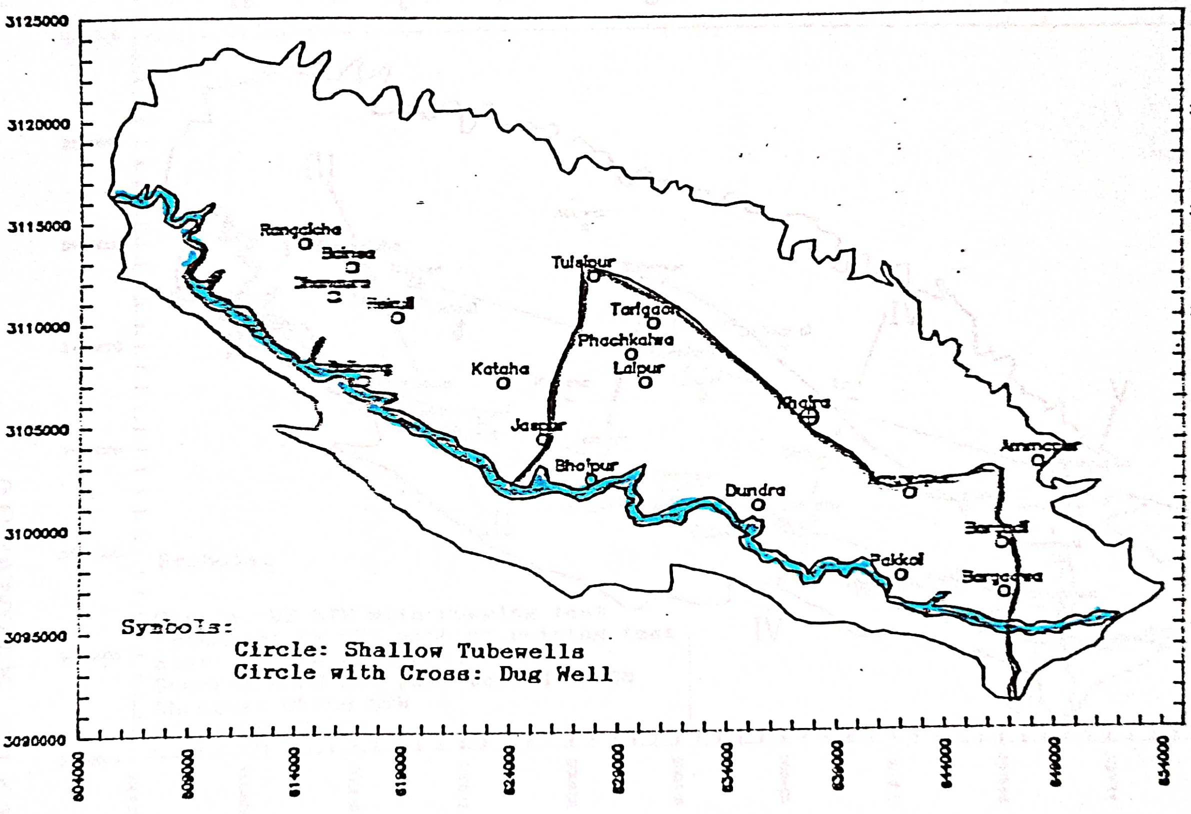
Circle: UN STW with Pumping Test
Triangle: UN STW without Pumping Test
Square: ADBN STW only Pumping Test
Star: USAID STW with Pumping Test

DANG VALLEY - TUBEWELL LOCATION MAP



APPENDIX 19

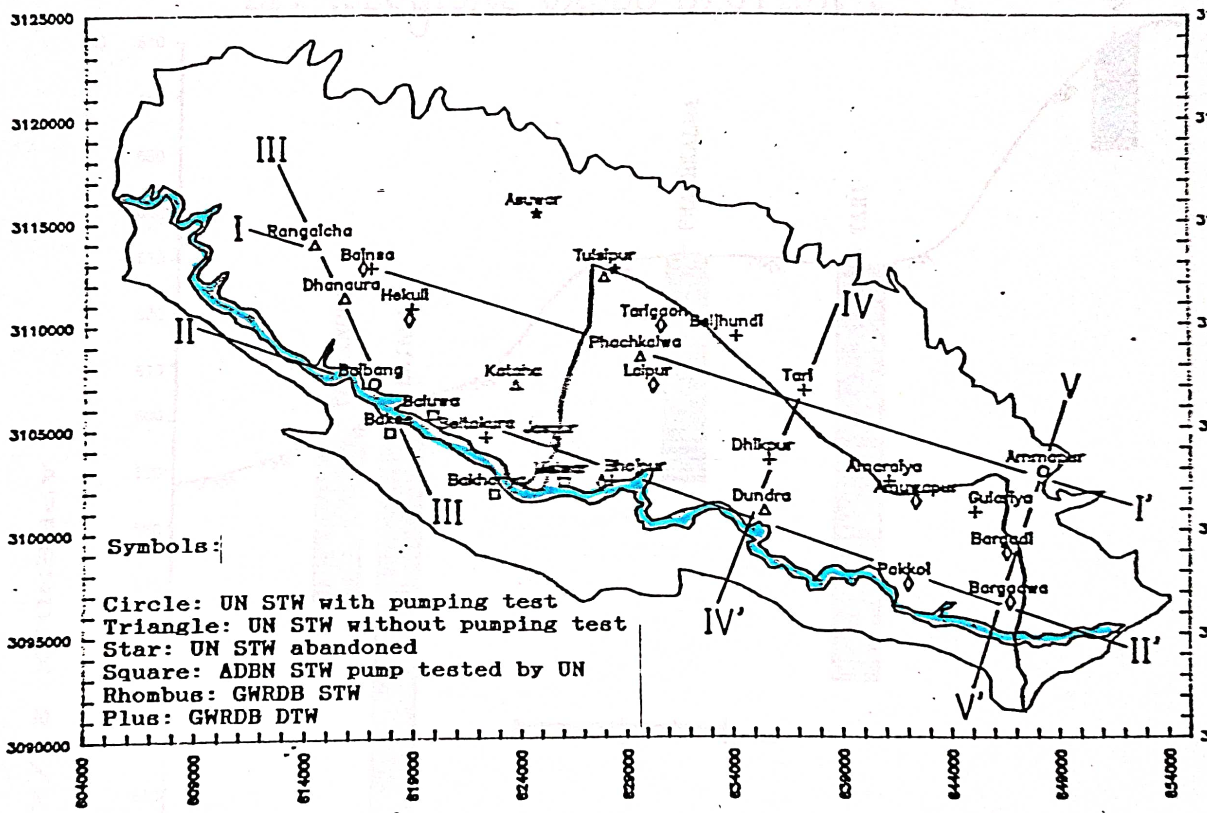
DANG VALLEY - ACTUAL MONITORING NETWORK



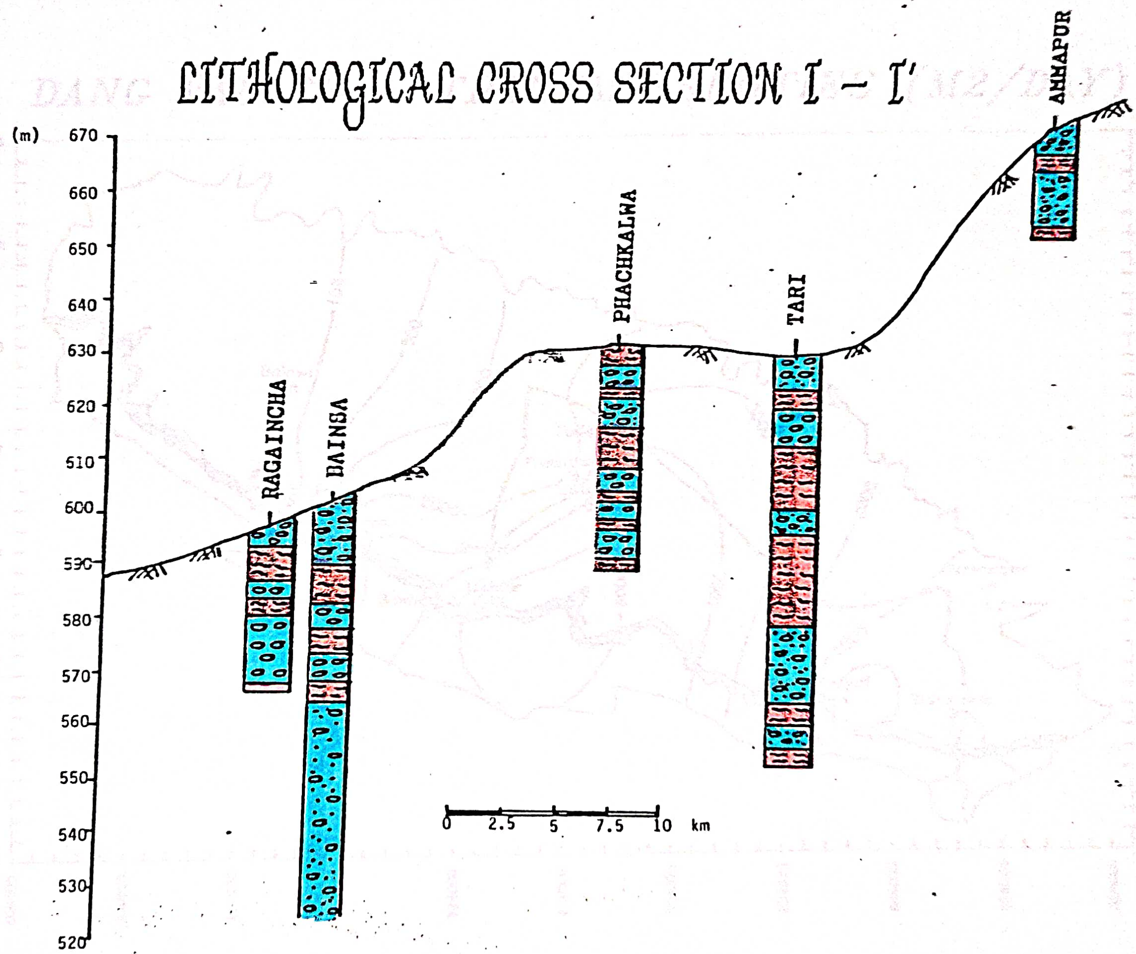
APPENDIX 20

APPENDIX 21/1

DANG VALLEY - LITHOLOGICAL CROSS SECTIONS I - V

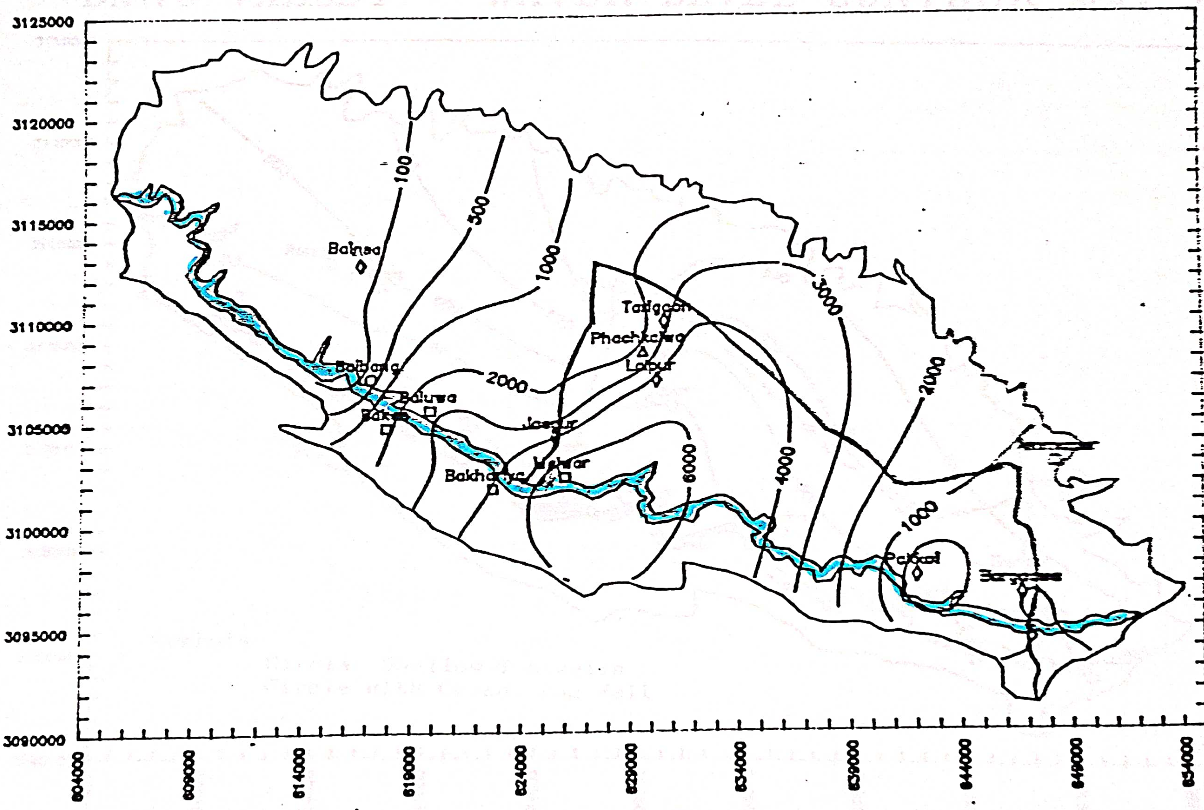


LITHOLOGICAL CROSS SECTION I – I'



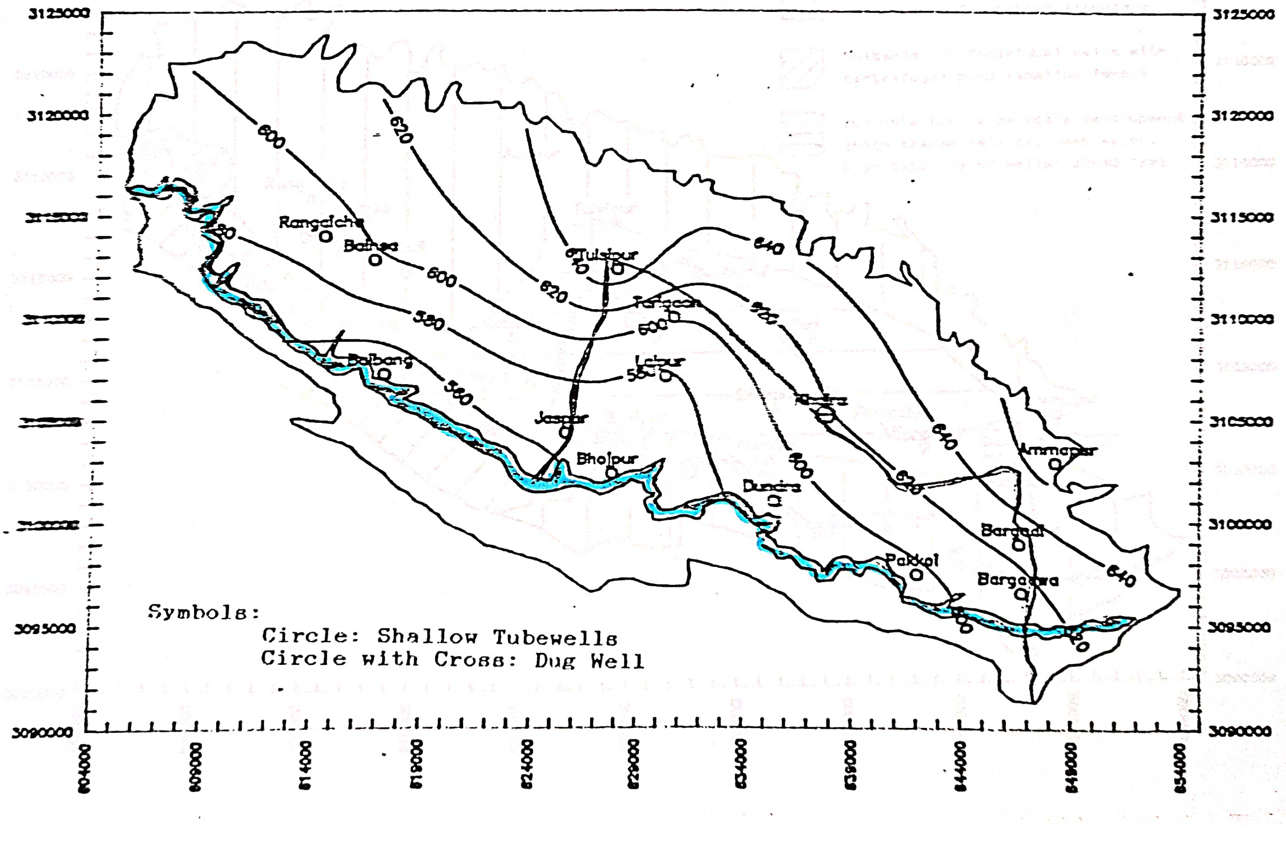
APPENDIX 21/2

DANG VALLEY – TRANSMISSIVITIES (M2/DAY)



APPENDIX 22

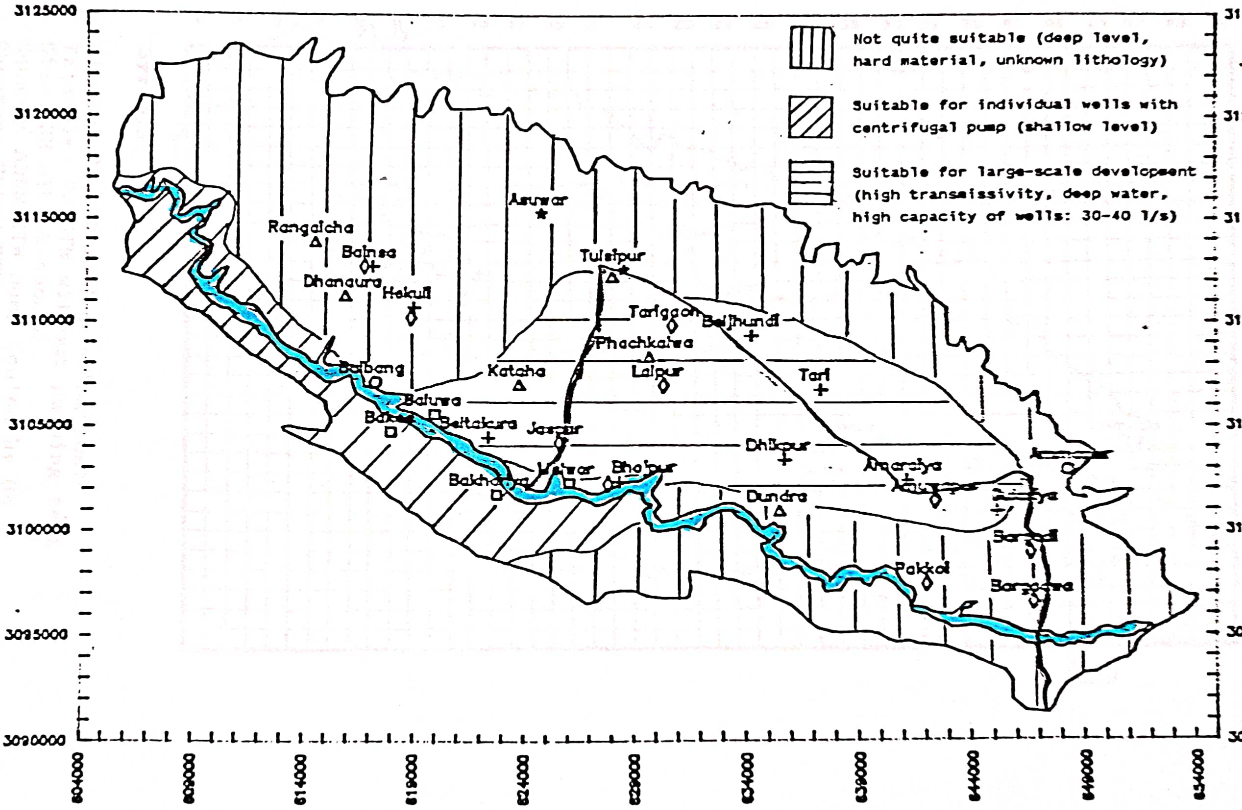
DANG VALLEY - WATER LEVEL CONTOUR MAY 1989



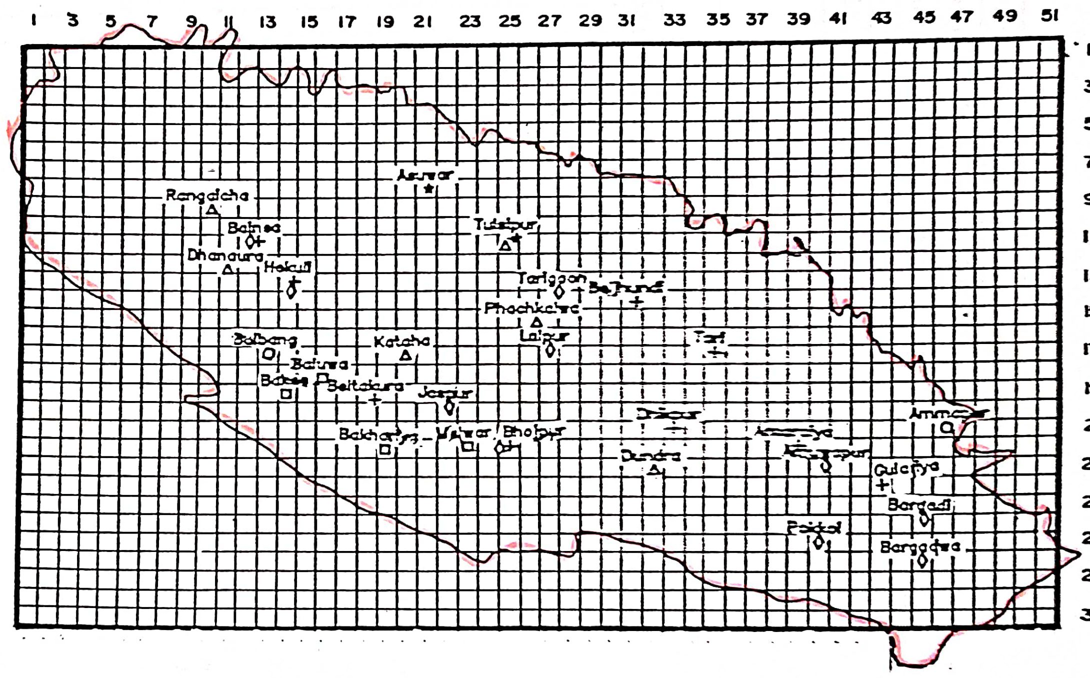
APPENDIX 23

APPENDIX 24

FEASIBILITY FOR GROUND WATER DEVELOPMENT



DANG VALLEY – MATHEMATICAL MODEL NET WORK



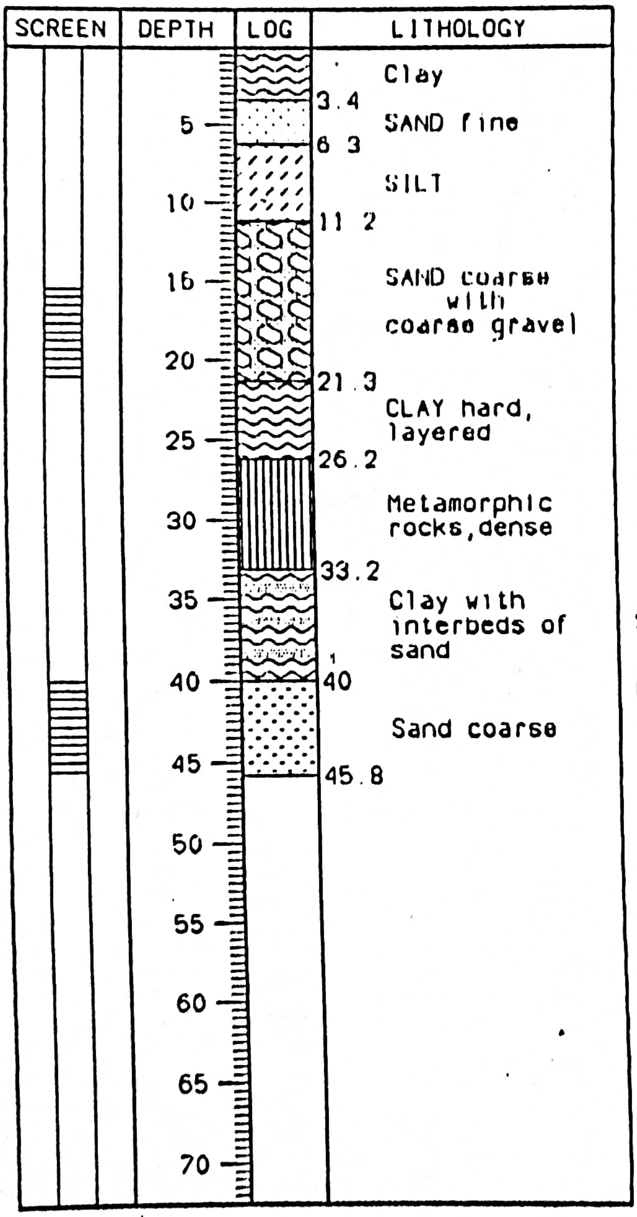
Symbols:

Circle: UN STW with pumping test
Triangle: UN STW without pumping test
Star: UN STW abandoned
Square: ADDN STW pump tested by UN
Rhombus: GWRDB STW
Plus: GWRDB DTW

APPENDIX 25

Well No. Well 1	Location: Kapilvastu
Elevation: 96.68	X = 696500 Y = 3046750
Method of Drilling: ROTARY RIG	
Drilling Dates : 15/3/89-18/3/89	
Total Depth : 45.80	
Comments : Screens at 15.5-21.0 m and 40.0-45.5 m Measuring point +0.5 m above Lans Surf. Screen: Wire wrap with 1.5 mm openings.	

WELL LOG



PUMPING TEST

Date: 22/4/89
Capacity: 5 l/sec
Duration: 60 minutes
Transmissivity: 125 m2/day
Method: THEIS
Storage Coefficient: 0.004
Static Water Level: 3.45 m
Dynamic Water Level: 5.65 m

APPENDIX 2


NEPAL
REPORTING COMPLETED
REPORTS TO BE COMPLETED
BY DECEMBER 1989
KATHMANDU
BARDIYA
BANKE
DANG
DEUKHURI
KAPILVASTU
RUPANDEHI
NAWALPARASI(WEST)
RAUTAHAT
SUNSARI
MORANG