APPENDIX-7 HYDRO-GEOLOGY AND GROUNDWATER DEVELOPMENT

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CHAPTER 1 INTRODUCTION

This APPENDIX-7, HYDRO-GEOLOGY AND GROUNDWATER DVELOPMENT, discusses natural condition that has relation to groundwater, the feature of aquifer and groundwater development plan together with the associated issues. Furthermore this chapter deals with the geological survey and soil test used to investigate what soils are present and how they are distributed under the proposed headworks site. In the compilation of this Appendix, inputs have been received from concerned offices such as Groundwater Resources Development Project (GWRDP) and their Biratnagar Field Office as well as field observations and field surveys together with findings and results from other Appendix.

This Appendix consists of, aside from this Chapter 1 INTRODUCTION, six chapters; namely, CHAPTER 2 PERFORMANCE REVIEW OF GROUNDWATER SECTOR, CHAPTER 3 NUTURAL CONDITION, CHAPTER 4 HYDROGEOLOGY, CHAPTER 5 GROUNDWATER DEVELOPMENT and CHAPTER 6 GEOLOGICAL SURVEY.

CHAPTER 2 PERFORMANCE REVIEW OF GROUNDWATER SECTOR describes the brief review of the groundwater sector in this Country and the organizations concerned as well as lessons learned from previously carried out. The intent of this Study was to gather information on the hydro-geological condition and groundwater development by the tube-well of the Study area and to present these data in a condensed format to plan groundwater development for irrigation.

CHAPTER 3 outlines NATURAL CONDITION, which is composed of Topography, Geology and Hydrology on the Study area. This chapter deals with natural condition around the study area. Topography describes location, landform and relation between surface and river trace. Geology describes the material, the structure of aquifer and the recharge area of groundwater of the study area, and outlines stratigraphy on Terai Plain. Hydrology describes distribution of major rivers and tributary and its relation also. Especially the result of field survey on the river condition for water-way up to Sunsari river from the vortex tube of CMC are reported herein. Submergence Condition in Hydrology describes distribution, damage and system of inundation in the Study area.

CHAPTER 4 HYDROGEOLOGY is composed of Groundwater, Existing Observation Well, Groundwater Quality and Observation Well Drilling. Groundwater describes distribution, movement, recharge system of it and groundwater use. Existing Observation Well describes the existing data of the drilling records and the result of pumping-test on the tube-wells. Groundwater Quality describes the result of the in-site and laboratory tests of the samples collected at the existing observation tube-wells. Pumping-test has been conducted to obtain further detailed information about the hydro-geological contents to plan the groundwater development for irrigation. The details of the pumping-test are reported herein.

CHAPTER 5 GROUNDWATER DEVELOPMENT discusses the feature of aquifer such as hydro-geological contents, the optimum standard design of the tube-well, the estimated construction cost of the tube-well, operation and maintenance system of DTW and the irrigation system plan of groundwater for the Study area.

CHAPTER 6 GEOLOGICAL SURVEY presents the results of detailed studies on the foundation of the proposed headworks site. This chapter is composed of Core boring, Soil Test and geological condition of the foundation. It describes geological structure, the results of standard penetration test, the results of the unconfined compression test and soil test. Finally, this chapter deals with feature of the foundation and to present these data in a condensed format to civil engineering.

CHAPTER 2 PERFOMANANCE REVIEW OF GROUND WATER SECTOR

2.1 Groundwater in Terai Area

The Terai plain is northern most continuation of the Indo-gangetic plain with composition of Recent Alluvium. This unit lies South of the Churia hills (Siwalik) of Nepal. The Terai plain slopes south and nearly flat near the Indo-Nepal border. The elevation varies from 60 meter in the South to about 200 meter in the foothills of Siwalik. The Terai plain is divided into Bhabar zone, middle Terai and Southern Terai.

The Bhabar zone is located in the foothills which is presented by very course alluvial deposits consisting of mainly boulder, cobble and pebbles. The Southern margins are located at a spring line that gives rise to many streams. The middle Terai is an undulating terain with isolated pocket of water logged and marshy conditions towards the southern part of the Bhabar zone. The Southern Terai lies between middle Terai and Indo-Nepal border. The zone is composed of sand, silt and clay. The Bhabar zone being porous helps to recharge the deep aquifer whereas the middle Terai helps to recharge the shallow aquifer. Thus the perennial Koshi River plays a great role as one of the major source of groundwater contributing to the deep as well as shallow aquifers of the Study area.

Annual rainfall is the next major source of groundwater contributing to deep and shallow aquifer through the Bhabar zone and middle Terai. On the basis of these geology and groundwater hydrology of the Terai which is northern continuation of Indo-gangetic basin, it can be considered as high potential area for groundwater from which we can explore and exploit groundwater for multipurpose.

2.2 Related Program/Project

This report is based on the following related project reports of the Study area.

2.2.1 UNDP/HMGN, NEP/86/025 Project, "Shallow Ground Water Investigation in Terai", Technical Report No. 10, Sunsari District, June 1989.

This project was completed in April 1992. This project had drilled 17 shallow tube-wells (STWs), out of which 8 STWs were drilled by rig machine and 9 STWs by manual method ("sluge "). The average drilling depth was 28 meter (shallowest depth 13.7m and deepest 41.2m). Aquifer test were done successfully in 10 STWs only. Out of 17 STWs, 3 STWs fall to the present Study area which helped us to calibrate shallow aquifer system in the present Study area.

2.2.2 HMGN, DOI, GWRDP/GDC, Cambridge, UK, "Reassessment of Groundwater Development Strategy for Irrigation in the Terai", April, 1994.

This project was completed in April 1994. The project studied the groundwater development for irrigation in Terai plain which includes a review of the aquifer systems, aquifer development potential, the methods currently to exploit these aquifers by tube-well irrigation, and the possibility that existing tube-wells may be better designed and constructed at sizes and costs appropriate to Terai irrigator. This report became a much helpful to identify the deep as well as shallow aquifer system for the present Study area.

2.2.3 JICA/HMGN, DOI, "The Mater Plan Study on The Terai Groundwater Resources Evaluation and Development Project for Irrigation", Vol. I-III, March 1995.

This project was completed in March 1995. This project studied the groundwater resources evaluation and development for irrigation in Terai plain.

Jhapa district Eastern Nepal, Mahottari district Central Nepal and Banke district Western Nepal were the study area of the project. In Jhapa district, the project constructed 15 exploratory deep tube-wells (DTWs) (dia.300/150mm) and 5 observation wells (dia.100mm) by machine drill. The average depth was 200m (min. 100m and max. 300m). Aquifer test were done in all 15 DTWs.

Besides these, the project made Geophysical prospecting, bore hole logging, groundwater monitoring, discharge measurement of artesian flow, pumping test, and water quality analysis for the evaluation of groundwater resource in Jhapa district.

The project used existing data for evaluation of groundwater in case of Mahottari and Banke districts. This report was consulted for the shallow and deep aquifer system of Terai and framework study.

2.2.4 ADB/HMGN, DOI, "Community Groundwater Irrigation Sector Project (TA 2589-NEP)" Vol.1-6, October 1997.

It is on-going project. The project is to contribute to the achievement of HMGN's goals of reducing poverty and increasing employment in rural areas by (i) increasing agricultural productivity on a sustainable basis and (ii) improving the income of small farmers.

To achieve these objectives the project will comprise a*) Groundwater Irrigation Development* (involves installation of manually drilled 13,500 group STWs and 1,500 individual STWs) in 300 VDCs from Jhapa district to the East to Chitwan district to the West, *b) Supportive Infrastructure Development* (comprise improvement of rural access village road in the 300 VDCs), *c) Project Management and Groundwater Support Services* (comprise Agricultural extension services in the beneficiary VDCs), and *d) Technology Improvement and Dissemination*.

The pilot area of this project is located at Bharaul VDC in Sunsari District North near the alluvial fan. The result of pilot study was already reported in the Final Report Volume 2 of this project at October 1997. The target VDCs plan in Sunsari District of this project was twenty-one (21) VDCs in 1997 are as follows, but the latest plane has been changed to the fifteen (15) targets VDCs. The original target VDCs are Bharaul, Mahendranagar, Pakashpur, Madhuban, Laukahi, Narsingha, Baklauri, **Basnatpur**, Damraha, Inurwa, **Harinagar, Madhya-Harshahi**, **Ghuski**, **Kaptanganj**, **Sahebgan**j, Amaduwa, Amahibela, Ramganj-Belgachiya, Koiritol, **Babiya**, **Ramnagar VDC (bold face locate at the Study area).**

This project used existing data for evaluation and analysis of groundwater for irrigation by

STW. This report contributed most of the study field of present study area.

2.2.5 IFAD/HMGN, DOI, "Community Shallow Tube well Irrigation Project", December 2000.

This project was terminated in December 2000. This project had looked over five Terai districts; Sarlahi, Rautahat, Siraha, Saptari, and Sunsari Districts. The project was here to contribute to the achievement of HMGN's goals of reducing poverty and increasing employment in rural areas by increasing agricultural productivity and improving the income source of small farmers.

This project prioritized the formation of women's water user group. This project used existing data for evaluation and analysis of groundwater for irrigation by STW. Some data of this report contributed to the present Study area.

2.3 Sector Performance Review and Lessons

The Ground Water Resources Development Project (GWRDP), Field Office, Biratnagar is the main concerned office for the present Study area in the field of groundwater. The GWRDP field office is working in this region since two decades. Construction and management of exploratory and irrigation tube-wells (Deep and Shallow) under different programs, water level measurement, monitoring and evaluation are the major work of this office.

This office looks over Sunsari, Morang and Jhapa Districts of Eastern Development Region of Nepal. The GWRDP, Field Office, Biratnagar (GWRDPB) helped us by providing important hydro-geological (water level, lithology, aquifer test, etc.) data and valuable suggestions concerned with the present study area.

CHAPTER 3 NATURAL CONDITION

3.1 Topography

3.1.1 General

The Study area lies 210 kilometers East-Southeast of Kathmandu, which is located at 26° 24′ N to 26° 30′ N in latitude and 87° 04′ E to 87° 12′ E in longitude. It is situated between 64 meters and 80 meters above sea level. The Study area is rectangular in shape and E-W width varies from 4 to 8 kilometers and N-S axis is about 22 kilometers, which covers 140 square kilometers. The West-Southern borders of the Study area are with India.

The Study area is located at the East bank of the Koshi River in the northern part of the Indo-Gangetic plain. The terrain starts from foothills of the Siwalik range and slopes gently down to South with an inclination of 5 degrees on the average. The terrain of the Study area is formed by alluvium of old and present rivers.

3.1.2 Topography of the Study Area

As ATTACHMENT 1 Figure 3.1.1 shows, there are two main rivers entering the Study area in a direction parallel to the Koshi River. The Sunsari River flowing southwest through the central part of the study area and the Budhi River flowing South along the Eastern border of the Study area. The river trace diverges from the Sunsari River in the central part of the Study area between Jalpapur and Kaptanganj. It is called the Old Sunsari River.

The topography of the study area of high erosion susceptibility is waving in E-W direction. Generally, terrain found within the study area includes gently sloping alluvial surfaces and a nearly level valley floor such as a swamp.

3.1.3 Upland Area

Along the Southern India-border in the East bank of the Old Sunsari River is upland and consists of mainly sand. Topographic relationship to the river terrace indicates that the upland area in Kaptanganj is a part of the flood plain deposits along the big river like Koshi that is called " a natural levee". This upland area may be traced to India-border from up stream along the Old Sunsari River. It is assumed that the upland area was formed as surrounding area was eroded. A part of natural levee that must has dominated between Kaptanganj and Shankarpur which were washed away by streams.

As Figure 3.1.2 in ATTACHMENT 1 shows, this area is located in the high elevation as compared to the Shankarpur canal. In accord with the field observations, the result of an analysis of the topographic map in a scale of 1:10,000, it can be stated that the upland area covers 426 hectare (ha), and about 29 hectare (ha) in the area is agriculturally abandoned land such as a residential land. Therefore 397 hectare (ha) in the upland area is cultivated land where is impossible to irrigate by a watercourse and it is the target of irrigation by another way such as a tube well. According to the field survey, very few shallow tube well seldom distributed in the area and some part of the area is not make use of field for cultivation.

3.1.4 Relationship of Topography and Land Use

The gently sloping alluvial surface in the Study area is used for cultivated land, orchard and residential land. The riverbed of the Old Sunsari River and swamp are used for cultivated land and grazing. There are only a few trees along the residential land that mainly composed of a bamboo grove.

3.2 Geology

3.2.1 General

As Table 3.2.1 shows, the stratigraphic classification and outline of the general geology around the Study area are as follows. Tectonically/Geologically surroundings of the Study area can be divided into four zones: The Alluvial Fomation, Siwalik Group, Takure Formation and Seti Formation. The Alluvial Formation un-conformably overlies Siwalik Group. Siwalik Group is in fault contact with Takure Formation. Also, Takure Formation in fault contact with Seti Formation. (refer to ATTACHMENT 3 Figure 5.1.1)

Table 3.2.1 The Stratigraphic Classification of the Study Area

Quaternary (Recent)	Alluvium	Boulder, Gravel, sand and Silt-Clay	The Study Area, Bhabar Zone (Alluvial Fan)
Mid-Miocene – Pleistocene	Siwalik Group (Churia)	Fine to medium grained arkosic pebbly sandstone, unconsolidated conglomerate. Fine grained, hard gray sandstone inter-bedded with purple colored shale	Siwalik Range (Mountain)
Permo – Corboniferous	Takure Formation	Sandstone, quartzitic sandstone, graphitic coals, chloritic phyllites	(Mountain)
Precambrian	Seti Formation	Gray to greenish gray phyllites, quartzites with minor conglomeratic	(Mountain)

3.2.2 Sedimentary Environment

The summary of the sedimentary environment on the Study area is based largely on *Sharma C.K., 1995 Shallow Aquifers of Nepal*.

The Terai plain was created by tectonic upheaval of himalaya and development of fore deep of Indo-gangetic basin a millon year ago. When Himalaya rose to this final shape a fore deep was created in which Siwalik and older sediment layers sunk in the trough.

Now Siwalik rock lies at a depth of 1.2 to 1.5 km below the Terai alluvium. The alluviums in Nepalese Terai were deposited by sediment derived from nearby mountains. Lithology of top part of the alluvium beds is found to be similar to rocks exposed near mountain.

Furthermore, not all rivers which are at presents flowing through Terai have contributed to the deposition. Only major rivers like the Kosi with antecedent nature had deposited first in the basin. Later on when other rivers came into existence they also started depositing on the top of older material. On the basis of age, the Terai alluvium can be divided into two parts i.e. older and newer alluvium.

3.2.3 Geological Feature of the Study Area

The Study area is underlain by unconsolidated alluvial deposit. This formation is irregular alternating beds of silt, sand and gravel. These deposits grade laterally and vertically into each other. Local boulders are found with a scattered pattern outcrops at a construction site of a road and a bridge. The feature described above suggests that:

- It consists of unconsolidated sedimentary deposits and makes an excellent aquifer.
- The cultivated land involves attention to presence of the high permeable sandy-soil. In the case of Kaptanganj VDC, subsurface geological section is illustrated in Figure 3.2.1.
- Particular attention should be paid to mapping unconsolidated deposit such as sand, gravel and boulder which might behave as zone of seepage from the riverbed, and clay or silt as zone of weakness under at the sides of the irrigation facilities.

3.3 Hydrology

3.3.1 River System

1) Relationship to the Koshi River

The Study area is located at the East bank of the Koshi River that is the biggest river of Nepal. The Koshi River Basin falls in the Tibetan autonomous region of China. Its catchment area is about 25,600 sq. kilometer. The Sunsari River, the Bhudhi River and the Koshi River are parallel to each other and flow in SW-S direction to India. There is no connection between the Koshi River and others directly.

2) River System on the Study Area

The Sunsari River and the Budhi River come from the mountainous area of Northern Terai Plain passing through the permeable zone on the alluvial fan which is called Bhabar zone at foothills of Siwalik Range. These rivers and the rainfall in the rainy-season supply sufficient water for recharge through the permeable zone to the deep and shallow aquifer of the Study area. In contrast to this, these rivers have low discharge of water and the water mostly vanished in dry-season while passing the permeable zone (alluvial fan) and usually come out at spring area. The results of field survey in May 2001 are as follows: (refer to ATTACHMENT 1 Figure 3.3.1)

2.1) The Sunsari River

It starts at edge of Bhabar zone (alluvial fan) and joins with two major tributaries which are called the Kurawa River and the Kakar River in Bhokraha VDC about 1 kilometer North of E-W highway. Before joining to the major tributaries, the Sunsari River is joined with the

Belaha River and the Thalaha River at 13 kilometer North of the Study area in Mahendragah VDC.

The major tributaries, the Kurawa River and the Kakar River, originate from the Siwalik Range (mountain) and pass through Bhabar zone before meeting the Sunsari River. Both of them do not show water between the foot of Siwalik and alluvial fan. Also these tributaries drain from edge of alluvial fan again.

Some seepage points are found in Dumraha VDC which are 4 to 7 kilometer North from Inaruwa. Then it starts as a small tributary and joins the Sunsari River. In the Study area, the Sunsari River meandrous flows towards southwest at Babiya VDC.

2.2) The Budhi River

Many small tributaries of the Budhi River start at the spring line around the edge of Bhahar zone (alluvial fan) and these tributaries form complicated flow like a hexagonal pattern before joining each other at West side of the Study area.

At beside of the Study area, the Budhi River meandered flows South to Indian-border. The Budhi River forks two directions at Babiya VDC and joins again at Rajganj Sinuwari VDC.

2.3) The Old Sunsari River

The Old Sunsari River is a crescent lake and it is old channel of the Sunsari River. The Old Sunsari River was formed as the present landform by raging flood waters when a dike on the head-works collapsed in 1964. There are the head-works in the Sunsari River at downstream of the juncture of it and the Old Sunsari River, and a canal along the Old Sunsari River for irrigation. However that head-works and a canal were destroyed after flooded in it for river control.

A thought behind the origin of the Old Sunsari River is that a big river like Koshi had field the Terai basin very fast. It shows maturely nature in Terai plain by meandering. So the type of river changes the river course during rainy season by flash blood and leaves the older river as ox-bow lakes and swamps that we find in the Old Sunsari River. It was few flooded near the main road at Ramnagah Bhutaha VDC.

3) The Waterway from the Vortex Tube

There are two vortex tubes along CMC, the vortex tube #1 is located at about 500 meters north from the intake gate of Suksena Branch Canal (RD32 on CMC), whereas the vortex tube #2 lies at RD39 on CMC. Both the vortex tubes connected to the tributaries of Sunsari River pass through a canal therefore it may be possible to use these facilities as a waterway up to Sunsari River from CMC. According to information of SMIP that the vortex tube #1 has 3.5 cubic meters per second (m^3/s) and the vortex tube #2 for 5 cubic meters per second (m^3/s) of current capacity.

The Study Team conducted field reconnaissance along the tributaries to clarify necessary civil works for releasing water from both the vortex tubes up to Sunsari River. The field survey is to search failures showing at the riversides, to interpret the boundaries of the environment that might be affected in the case of water releasing from the vortex tube.

Figure 3.3.2 (ATTACHIMENT 1) represents the connection between the vortex tubes and Sunsari River, and location of some remarkable points along the waterway such as a bridge.Typical relation between current capacity and depth of the waterway are shown in Figure 3.3.3 in ATTACHIMENT 1.

Table 3.3.1 The Riverside Condition of the Waterway from the Vortex Tube

Survey Site	Location	Distance (Km)*	Scale (m)			Total (m^3)	Remark
			Width	Length	Height		
-	Vortex Tube #1	0.00	-	-	-	-	
1	Belaha Khola	0.75	1.0	1.0	1.0	1.0	A water station
2		1.50	3.0	12.0	3.0	108.0	Erosion
3		1.82	3.0	3.0	3.0	27.0	-do-
4		2.73	3.0	2.0	8.0	48.0	-do-
5		3.00	3.0	7.0	2.0	42.0	-do-
6		3.70	21.0	3.0	2.0	126.0	-do-
7		4.80	-	9.0	-	-	Bridge
8		5.50	6.0	95.0	4.5	2565.0	Erosion
Sub-total						2916.0	Erosion only
-	Vortex Tube #2	0.00	-	-	-	-	
9	Thalaha Khola	0.22	2.0	30.0	3.0	180.0	Erosion
10		0.74	3.0	30.0	3.0	270.0	-do-
11		1.17	2.0	9.0	2.0	36.0	-do-
12		2.98	3.0	20.0	3.0	180.0	-do-
13		3.43	3.0	6.0	2.0	36.0	-do-
14		3.46	12.0	3.0	2.0	72.0	-do-
15		3.53	6.0	19.0	1.5	171.0	-do-
Sub-total						945	Erosion only
Total						3,861.0	Erosion only

*; Distance from the each vortex tube.

Results of field survey are as follows:

- The Belaha Khola and the Thalaha Khola originate at the seepage line along the edge of alluvial fan in the active flood plains that lies North of the CMC.
- Within the Belaha Khola and Thalaha Khola, 15 remarkable points were identified along the riverside that were shown in Figure 3.3.2 and Table 3.3.1.
- Survey site #1 is a water station for local using by about 28 households. It is located about 1.5 meters above the riverbed that will be always flooded by water releasing from the vortex tube #1 (see Fig. 3.3.2). This water station is a concrete sump with puts in a PVC pipe to the bank of CMC to take drinking water.
- There are in the active flood plane along both the tributaries, therefore no need to care

of civil works to at erosion of the survey site #2 to #15 and a footpath bamboo bridge at the survey site #7 for water release from the vortex tube.

3.3.2 Submergence Condition

As ATTACHMENT 1 Figure 3.3.4 shows, based on the interview of farmers in April to May 2001, there are eight areas of inundation in the Study area. These areas are concentrated in a nearly level valley floor, southern part of the Study area, although few flood areas occur in the north and northeast. These areas are limited in the active flood plains in the Study area.

Inundation of the Study area is characterized by flood type and submergence type. Water flows in flood type from river into downstream pass through the cultivated land and residential land at gently sloping alluvial surfaces during the heavy rain. But it is submergence type and it has piled up over these areas at a nearly level valley floor during heavy rain and after that. These inundation areas are as follows:

1) Babiya VDC

Around Miyatol / gently slope to south / Flood covers about 1 sq. kilometer 1 to 2 days in every rain-season. Flowing from NW to SE, the banks of Shankarpur Canal is eroded and floods with 30cm to 50cm above surface.

2) Babiya VDC

East side of Jalpapur Batartol / along west bank of Bhudhi River / Flood covers about 1 sq. kilometer with 0.5 kilometer width and 2 kilometer long 1 to 2 days in rain-season. The Bhudhi River flooded during heavy rain.

3) Rajganj Sinuwari VDC

Between Sinuwari and Rajganj / a nearly level valley floor / This area is submerged about 3 sq. kilometer with 0.3 meter above surface during 15 to 30 days in rain-season. Flowing from NW.

4) Sahebganji VDC

Between Dhanuktol and Teliyaritol Suritol / a nearly level valley floor / This area is submerged abut 2 sq. kilometer with 1 meter above surface during 7 to 10 days in the rain-season. The Bhudhi River flooded during the heavy rain.

5) Narshimha VDC

Between Narsimha and Jhabatol / a nearly level valley floor / This area is submerged abut 3 sq. kilometer with 1 to 1.5 meter above surface during one week in the rain-season. The Sunsari River flooded during the heavy rain.

6) Narshimha VDC

Soniyahi Miyatol / a nearly level valley floor / This area is submerged abut 5 sq. kilometer with maximum 1 meter above surface during 10 days in the rain-season. The Sunsari River flooded during the heavy rain.

7) Basantapur VDC - Ghuski VDC

Between Suksena to Kabilasa Daksintol / along East bank of the Sunsari River / Flood covers abut 10 sq. kilometer with 0.3 to 1.0 meter above surface muximum 10 days in the rain-season. The Sunsari River flooded during the heavy rain.

8) Kaptanganji VDC

Around Shivaganj Raghunathpur / a nearly level valley floor in poorly drained area along the Sunsari River with Indian-border / This area is submerged about 6 sq. kilometer with maximum 1.5 meter above surface during 15 days in the rain-season. The Sunsari River flooded during the heavy rain.

Intense rainfall, relief and slope form are recognized as factors in inundation system and distribution. Submergence condition is associated with in location of river and conditions of either prolonged or high intensity rainfall especially. Submergence and Flood cannot be prevented or even accurately predicated, but repair the bank along the area which tend to concentrate runoff should reduce the possibility of damage.

CHAPTER 4 HYDROGEOLOGY

4.1 Groundwater

4.1.1 Groundwater Distribution

Groundwater table contour line in above sea level surrounding of the Study area is shown in ATTACHMENT 3 Figure 5.1.1. According to the monitoring records of the existing tube-wells by GWRDP Biratnagar Field Office, groundwater is found widespread, and exists in the relatively shallow subsurface beneath most of the Study area. Groundwater flows approximately Northwest to Southeast along the landform in the Study area.

Groundwater in the Study area is composed of confined aquifer and unconfined aquifer. Confined aquifer exists greater than about 50 meters below the ground surface. As mentioned above, unconfined aquifer is still limited to depth from near the ground surface to 50 meters.

4.1.2 Groundwater Movement

Unconfined aquifer is subjected to fluctuations according to the seasons of the year and local irrigation practices. Also a long term monitoring of groundwater level in the Study area indicates that groundwater table in unconsolidated aquifer varies seasonally, often in response to annual climatic variations. The monitoring record and a graphical interpretation between groundwater level and rainfall is shown in ATTACHMENT 2 Table 4.1.1 – 4.1.16 and Figure 4.1.1 – 4.1.12. The monthly rainfall data observed at Chatra meteorological station that is located at the foothills in a recharge area shows in those figures.

The monthly groundwater level of STW-8 at Dewanganj varies from 1.5 meter to 6.5 meter below the ground surface seasonal that is one of the typical shallow tube-well in the Study area (see Figure 4.1.4). Groundwater level rises from May to August and decreases during September to April. That fluctuation range is about 4 meter.

This condition is almost same as on deep tube-wells, i.e. DTW-10 and DTW-15 that are located at the Study area North and East (see Figure 4.1.11). These tube-wells of the Sunsari district that have been installed screen in both un-confined and confined aquifer.

A design of deep tube well in the Study area is characteristic in that the screen pipes tapped in both unconfined and confined aquifers. This typical system by GWRDP is very important for save the groundwater quantity and to permanent use of it. According to DOI-GWID, in the case of west Terai, actually some of the deep-tube wells tapped in unconfined aquifer only were exhausted for reasons of uncontrolled pumping up.

Existing data of the groundwater level in the Study area was measured once a month only, however it shows relationship between the groundwater level and rainfall. Therefore the Study team selected one typical deep tube well (DTW-16, Madaya Harashahi VDC) and installed an automatic water level recorder (see Figure 4.1.13) for supplementing and conforming existing date. The following result have been obtained:

- Daily groundwater level is shown in Figure 4.1.14. by comparing it with the daily rainfall data of Chatra station and Biratnagar airport (see Table 4.1.17 – 4.1.19). There is relationship between the groundwater level and the rainfall same as existing data. Some peaks of the groundwater level on the graph seem responsive to the rainfall pattern. There is a time delay about one week between a groundwater level peak and a rainfall peak of Chatra station.

- The fluctuation range of the groundwater level of DTW-16 has about 2.5 meter as compared with about 4 meter for a typical shallow tube well STW-18. The fluctuation range of DTW is relatively low.

- Rainfall pattern at DTW-16 in Madaya Harashahi VDC is presumably same as Biratnagar airport because of its location. However there is a time delay the fluctuation of the groundwater level to rainfall peak on the graph. Because both the stations locates at another hydrological basin.

As Figure 4.1.4 in ATTACHMENT 2 shows, the deepest groundwater level recorded in April 1992 and 1994. This fact is in accordance with a result of hydrological analysis by the Study Team that the year 1994 was a drought period during last thirty years. To be more precise, as compared with an average rainfall of 2,213 mm during 1950 to 2000, the rainfall in 1994 is only 1,459 mm.

4.1.3 Groundwater Recharge System

Rainfall, falling in the mountains and Terai Plain, is the principal source of groundwater in the Study area. The Koshi River is major source for groundwater recharge in the Study area too. Rainfall supplies the unconfined aquifer with water passing through Bhabar zone or directly. Also the confined aquifer is recharged by rainfall but it does not come into directly.

As ATTACHMENT 2 Figure 4.1.15 shows, the Koshi River connects to the Sunsari River, the Old Sunsari River and the Bhudhi River with unconfined aquifer. The contour of groundwater table shows that slopes from Northwest to Southeast approximately. The feature described above suggests that the Koshi River supplies both the unconfined and the confined aquifer too.

4.1.4 Groundwater Use

The groundwater is used for drinking and farming purpose in the Study area. The results of investigation on water utilization in the Study area covering 33 villages is summarized in Table 4.1.20 that is the present conditions of the groundwater use.

According to the above result of field research, all households (100%) utilize groundwater for drinking and chores by the shallow tube-well with hand-pump.

About 70 percent of farmers lease a shallow tube-well or an engine-pump for farming and 30 percent of them are owners of it.

Table 4.1.20 Present conditions of groundwater use in the Study area

VDC	Drinking (Shallow tube-well with Hand-pump)	Farming (Shallow tube-well)	
		Owner	Lease
Sahebganj	100 (2/2)	30% (6/20)	70% (14/20)
Kaptanganj	100% (4/4)	25% (1/4)	75% (3/4)
Dewanganji	100% (1/1)	100% (1/1)	-
Ghuski	100% (5/5)	100% (5/5)	-
Ralganj Sinuwari	100% (5/5)	30% (2/7)	70% (5/7)
Madhya Harsahi	100% (3/3)	100% (3/3)	-
Basantapur	100% (1/1)	100% (1/1)	-
Harinagara	100% (3/3)	10% (3/24)	90% (21/24)
Rammnagar Bhutaha	100% (3/3)	20% (43/215)	80% (172/215)
Jalpapur	100% (3/3)	-	100% (3/3)
Narsima	100% (4/4)	25% (1/4)	75% (3/4)
Gautampur	100% (1/1)	50% (50/100)	50% (50/100)
Babiya	100% (2/2)	60% (17/28)	40% (11/28)
Total	100% (33/33)	32% (131/413)	68% (282/413)

Remark: Estimated on basis of interview of 33 villages.

4.2 Existing Observation Well

Seventeen observation shallow tube-wells are drilled in 1989 and a further sixteen observation deep tube-wells have been drilled in 1996 by GWRDP in Sunsari district. The Study team selects 9 shallow tube-wells and 5 deep tube-wells from above wells which have relation to the Study area on hydro-geology. ATTACHMENT 2 Table 4.2.1 and Table 4.2.2 show the result of the pumping test at the existing observation wells. In addition to those tables, pump discharge tests in STW at five representative VDCs of the study area were made. The result of the test is presented in ATTACHMENT 2, Table.4.2.3. The result is found similar to the result of existing pumping test data. Table 4.2.4 summarizes the above data.

Table 4.2.4 Pumping Test Result of the Existing Wells

Test Items	Sallow Tube-well			Deep Tube-Well		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Well Depth (m)	13.7	50.9	30.2	55.48	120	87.30
Screen Lange (m)	2.86	10.00	5.98	8.74	33.24	20.40
Aquifer type	Unconfined			Unconfined and Confined		
SWL (bgl m)	1.01	3.47	2.52	4.13	11.63	6.10
Draw-down (m)	1.01	4.54	2.59	1.62	12.17	4.81
Discharge (l/s)	2.00	24.00	18.19	30.00	39.00	35.16
Specific Capacity (l/s/m)	4.41	23.76	9.58	2.94	18.52	11.93
Transmissivity (m2/d)	900	4300	1920	-	-	-
Storage Coefficient	-	-	-	-	-	-
Total wells	9 wells			5 wells		

SWL: Static Water Level
bgl: below ground level

4.3 Groundwater Quality

2) General

Groundwater quality is analyzed by in-site test and laboratory test both during May and August in 2001. Samples are collected at the existing observation shallow well STW-8 and STW-13, and the deep well DTW-10 and DTW-16. These wells are selected in relation to the known groundwater distribution and flow at North and South in/around the Study area.

Test items are composed of an index to find out water pollution for irrigation use. Laboratory test is conducted in Kathmundu under the control of a specialist of GWRDP Head office. The location of wells, the test items and the guidelines of FAO are listed in ATTACHMENT 2 Figure 4.3.1 and Table 4.3.1-Table 4.3.2, and the result of analysis is shown in ATTACHMENT 2 Table 4.3.3

Groundwater taken from hand-pomp is principal water source for the drinking reached nearly 100 percent of the households in the Study area. Therefore, twenty-one water samples are analyzed with in-site test by the Study Team which are collected from the hand-pump wells in May 2001. The in-site test for the hand-pump wells is the same as above method. The location of samples and the result of in-site test are shown in ATTACHMENT 2, Figure 4.3.2 and Table 4.3.4

Details of laboratory test such as sampling technique, chain of custody of the samples, analysis methodology and result are shown in APPENDIX 10 ATACHMENT.

4.3.2 Result of In-site Test

Results are summarized as Table 4.3.5.

Table 4.3.5 Result of In-site Test

	Hand-pump	Sallow tube-well		Deep tube-well	
	May	May	August	May	August
Temperature (° C)	24.5-29.1	27.2-28.3	27.6-28.4	27.6-27.7	28.4-29.9
PH	5.81-8.43	7.13-7.24	7.40-7.70	7.54-8.01	8.1-8.4
EC (mS/m)	23.21-56.17	10.35-20.81	12.00-40.30	14.91-28.28	10.40-25.70
DO(mg/l)	-	1.24-3.79		1.25-1.80	

EC: Electric Conductivity (18° C)

DO: Dissolved Oxygen

1) Electric Conductivity (EC)

Electric Conductivity (EC) values indicate the soluble ions of different elements and radicals in groundwater. The problem of soil salinity occurs when there is an accumulation of salts in topsoil. These salts can affect the crop production.

The samples range in Electric Conductivity (EC) from 10.35 to 56.17 mS/m in May. While in monsoon season (August), it is 10.40 to 40.30mS/m. According to the EC values prescribed in the FAO recommendation of irrigation water, the groundwater in the Study area is suitable for irrigation without any restriction.

2) pH

High pH of the irrigation water means high alkalinity of the soil. The problem of alkalinity and salinity are interrelated. High pH value of irrigation water affects susceptible crops. The normal range of pH value is 6.5 to 8.4 for irrigation water.

The samples range in pH value from 5.81 to 8.43 in May. While in August, it is 7.4 to 8.1. The samples less than 6.5 in pH value were from hand-pump wells. These aquifer are located at nearby ground-surface. However, in all the samples pH value is with in the desirable level.

3) Dissolved Oxygen

Generally, an amount more than 5 mg/l for Dissolved Oxygen is applied to the limitation for irrigation purpose. The samples range in DO value from 1.24 to 3.79 mg/l. This low value results from a feature of groundwater but not originated in contamination.

4) Colon Bacillus and Total Colonies

All samples were contaminated by many numbers of colon bacillus and total colonies. This fact has not influenced the groundwater for irrigation, but it is harmful for humans depending on the situation. There has not been disease caused by groundwater with hand-pump use in recent years.

High value of contamination of colon bacillus and total colonies in the samples results from some kind of it inhabiting in soil and groundwater naturally. It may be contaminated by life water from the surface around well.

5) Iron(Fe)

As ATTACHMENT 2 Figure 4.3.3 shows, the groundwater contains Fe exists overall the Study area. According to the 33 questionnaires to users of hand-pump, 42 percent of the wells contained Fe in the respondent and the taste of drinking water may be affected adversely by the presence of iron salts which can cause staining as well.

4.3.3 Result of Laboratory Test

According to the results of laboratory test, the groundwater in the Study area is suitable for irrigation use. Results of laboratory test and feature of groundwater in the Study area are as follows (see ATTACHMENT 2 Table 4.3.3).

1) Sodium Adsorption Ratio (SAR)

Excess of sodium in irrigation water relative to calcium and magnesium or relative to total salt content can adversely affect soil structure and reduce the rate which water moves into and through the soil, as well as reducing the soil aeration. SAR value less than 3 is considered as suitable for irrigation without any degree of restriction.

The samples range in SAR value from 0.27 to 0.80 in May. While in August, it is 0.29 to 0.75. All the samples have SAR less than 1 in both season, thereby no problem exists for using the water for irrigation.

2) Trilinear Diagram

As ATTACHMENT 2 Figure 4.3.2 shows, the Trilinear Diagram describes the future of groundwater in the Study area. On the basis of Trilinear diagram, all samples can be classified as 'No Dominant' (Carbon-Hardness) type. These samples are same type in both May and August. Similarly, according to Anion Trilinear diagram, all the samples are found to be 'Bicarbonate' type and on the basis of Cation-Anion diagram all the samples can be categorized into 'Alkaline Earth Weak acid' type in both seasons.

3) Iron(Fe) and Manganese(Mn)

The concentration of iron (Fe) is found with in the tolerance limit (< 5 mg/l) in most of the samples except in STW-8. Concentration of iron in STW-8 coincides with casing pipe becoming rusty extremely.

While manganese (Mn) is found to be in higher concentration (0.2 mg/l) in most of the samples, specially in monsoon season. Both of Fe and Mn values increase in monsoon season.

Because, in the monsoon season, rainfall containing carbon dioxide (CO_2) is discharged into a permeable soil and will dissolve sodium bicarbonate ($Fe(HCO_3)$) into groundwater. It is known to be leach from the soil contain iron oxide such as Fe_3O_4 or Fe_2O_3.

Therefore, high concentration value of Fe and Mn in monsoon season results from the natural soil condition and the groundwater can be used for irrigation purpose.

4) Arsenic (As)

The concentration of arsenic is found to be with in the recommended level (0.01 mg/l) in all the samples in both seasons. According to the laboratory of GWRDP in Kathmundu, there have not been instances of the excessive concentration of As in Terai plain in the past.

4.4 Observation Well Drilling

Accumulated data of the Study area indicate incompetent as basic data on hydro-geological contents such as transmissivity, storage coefficient, drawdown and radius of influence particularly for planning irrigation and well design. These data are indispensable for groundwater condition. Therefore the Study Team felt a need of drilling the observation tube well with the following objectives:

- To obtain the hydro-geological conditions such as the lithological features, hydraulic characteristics of aquifers, groundwater quality and so forth, in the Study Area.
- The works will consist of Pumping Tests (aquifer test) such as well yield, time

drawdown test (constant discharge), step-drawdown test, and recovery tests, inclusive of water sampling.

The drilling site is located at Kaptanganj VDC, just west of the Kaptanganj Police Station (Lattitude:26°24'56"N, Longitude:87°8'36"E and Elevation 68.7m from msl). The location map is presented in Figure 4.4.1, ATTACHMENT 2. Since Kaptanganj is the elevated land in the southern part of the Study area, the gravity-designed canal alignment is not possible to reach here. To meet this point as well, the drilling site is selected at Kaptanganj. The up-landed area covers about 450ha. The Study Team is going to constructed two tube wells, one is major test deep tube well with 10/6" diameter and another one is observation tube well with 4" diameter at distance of 50m. The TOR with detail specification and methodology of the tube well drilling work is enclosed in the Attachment.

4.4.1 Well drilling

The drilling work was started on 28 August 2002 and completed on 16 September 2002. The drilling work was done by Rotary drilling method with Rig Machine PORTADRILL, USA, Duprex Reciproching Pistone type, Mud pump type-Gardener Percall, USA with capacity 500m depth. As per the TOR both wells were drilled up to 120m. The drilling (lithological) log is presented in Table 4.4.1 (a) and Table 4.4.1 (b) of observation and Test well respectively, see ATTACHEMENT 2.

Immediately after the completion of pilot hole drilling, the electrical resistivity logging (long normal, short normal and S.P.) was done for conformation of the drilling log. The electrical resistivity logging data (long normal, short normal and S.P.) of observation well and Test well are presented in the Table 4.4.2 (a) and Table 4.4.2 (b) respectively and the resistivity curve of those two wells are shown in Figure 4.4.2 (a) and Figure 4.4.2 (b) respectively, see ATTACHMENT-2.

On the basis of existing lithological data of the Study area, it is found that there are three aquifer layers (see sec.5.1) in the Study area. From the present data of drilling log and the electric log, it is found that there is presence of all the aquifers and confining layers as mentioned in sec. 5.1. The summary of the aquifer and lithological status found in the Kaptanganj drilling site is presented in Table 4.4.3 below.

Table 4.4.3 Summary of Aquifer and Geological Status of Kaptanganj

Aquifer	Depth in m. (bgl)	Thickness (m)	Geology
Aquifer I (unconfined)	upto 42m	Upper 32m, Lower 3m	Alternative layers of fine to medium Sand and med. to coarse Sand with some fine Gravels
1st Confining layer	42m	2m	Silty Clay
Aquifer II (confined)	44m	12m	Medium to Coarse Sand with Some fine Gravel
2nd Confining layer	56m	5m	Sandy Clay
Aquifer III (confined)	61m	>60m	Alternative layer of fine to medium Sand and Gravel with Coarse Sand
3rd Confining layer			Beyond this depth of study

1) Well Design

Well design was done according to the obtained data of drilling log, electric log and grain size analysis. The figure showing lithology, resistivity curve and well design of the drilling site is presented in Figure 4.4.3 (a) and Figure 4.4.3 (b) of Attachment 2 for observation well and Test well respectively.

As per the approved well design, lowering of the observation tube well was done on 1st September 2002 and test well on 16 September 2002. The gravel size (4-8mm, pea gravel) for gravel packing was used according to TOR. After completion of gravel packing, the well was washed by backwash method.

4.4.2 Pumping Test

The pumping test proceeded after the well development of the tube well by compressor (jetting and surging) and pump as per TOR. The pump was run for 24 hours. The Maximum discharge from the pump (VT Pump, 25HP) was found 30l/s.

1) Step-Drawdown Test

The Step-Drawdown Test was carried on September 25, 2002. As per TOR, the step-drawdown tests were made at three steps increasing and two steps decreasing discharge rates. The increasing discharge was selected at 20l/s, 25l/s and 30l/s and decreasing discharges were fixed at 22l/s and 16l/s, according to the maximum discharge of the tube well. The Step–Drawdown Test data and step-drawdown curve is presented in the Table 4.4.4 (a)-(b) and Figure 4.4.4 (a)-(b) respectively in ATTACHMENT 2.

2) Time-Drawdown Test

The Time-Drawdown Test was done on 23 September 2002. The Time-Drawdown data and Time-Drawdown Curves are presented in Table 4.4.5 (a)-(b) and Figure 4.4.5 (a)-(b) in

ATTACHMENT 2. The pumping test data were analyzed by Jocob's methods. The formulas are presented below:

<u>*Jacob's Analysis:*</u>

$$T=2.3Q/4\pi\Delta s=0.183Q/\Delta s, \qquad S=2.25Tt_o/r^2$$

Where,

T = Transmissitivity in m^2/day
Q = Discharge in m^3/day
Δs **=** Total difference in drawdown in meter
S = Storage coefficient (dimensionless)
t_o = intercept of the straight line to zero drawdown in days
r = distance between centre of pumped well and centre of observation well

The result of time-drawdown test is presented in the Table 4.4.6.

Table 4.4.6 Result of Time-drawdown Test Analysis

Methods	Transmissivity (T) m^2/d	Storage coefficient (S)
Jacob	4312	0.003

3) Recovery Test

The Recovery Test was carried on immediately after the completion of Time-Drawdown Test on 24 September 2002. The Result of Recovery Test data and Curve is presented in the Table 4.4.7 (a)-(b) and Figure 4.4.6 in Attachment 2.

4) Analysis of the Pump Test Results

4.1) Transmissivity (T)

According to the approved well design, the Aquifer II and Aquifer III were tapped for the tube well. Both of them Aquifer II and III are confined type. As per the pumping test result, the maximum discharge and drawdown were found as 30l/s and 0.045m in observation well and 14.71m in test well respectively. The Transmissivity for this location is calculated by using Jocob Method. The formula is given in No.2) of section 4.4.2 above.

4.2) Storage Coefficient (S)

The range of storage coefficient value for confining aquifer is 0.0005-0.005. From the analysis of the pumping test, the Storage Coefficient for the Kaptanganj area is found to be 0.003.

4.3) Radius of Influence (R)

The radius of influence is a function of time of pumping, the capacity of the well and the aquifer characteristics. The radius of influence for the Kaptanganj area was calculated by following formula developed by Jacob (distance-drawdown relationship).

$$\boxed{\mathbf{S=2.25Tt/r_o^2}}$$

where,

S	= Storage Coefficient
T	= Transmissivity in m^2/day
t	= Time since pumping started in days
r_o	= Intercept of extended straight line at zero drawdown in m (Radius of Influence)

The Radius of Influence at Kaptanganj is calculation from the Joacob's distance-drawdown relationship (see Figure 4.4.7 in ATTACHMENT-2). It is found to be 50m.

4.4.3 Water Quality Test

Groundwater quality of the tube well constructed at Kaptanganj, Sunsari was analyzed by in-site test (on Sept.2, 2002) and laboratory test (Sept.5, 2002) both during September 2002. Laboratory test is conducted in laboratory of Nepal Environmental and Scientific Services (p) Ltd. (NESS), Kathmundu.

The results of the water quality test in site and laboratory are summarized in the table 4.4.8 below. The observed value for Iron (0.45 mg/l), Manganese (2.6mg/l) and Arsenic (0.03mg/l) exceed the prescribed limit of WHO guideline values for Drinking Water but still permissible for irrigation according to the recommendation of England. The Standard of England for irrigation recommends are 5.0mg/l as Iron, 0.2mg/l as Manganese and 0.1mg/l as the limit of Arsenic. The Manganese value is also higher than the recommendation of England but this is recommended 10mg/l for use up to 20 years on fine textured soil of pH 6.0 to 8.5.

Table 4.4.8 Summary of Water Quality Test Result in Observation Well (JKPT-1)

S.N.	Parameters	Observed Values	WHO Limits for Drinking Water
	In Laboratory Test		
1	Bicarbonate Alkalinity, (mg/l)	260	-
2	Chloride, (mg/l)	7.92	250
3	Sulfate, (mg/l)	N.D.(<1)	250
4	Orthophosphate, (mg/l)	0.67	-
5	Ammonia, (mg/l)	0.49	1.5
6	Nitrate, (mg/l)	N.D.(<0.05)	50
7	Nitrite, (mg/l)	N.D.(0.01)	3
8	Calcium, (mg/l)	70.54	-
9	Magnesium, (mg/l)	17.01	-
10	Sodium, (mg/l)	5.0	200
11	Potassium, (mg/l)	4.24	-
12	Iron, (mg/l)	0.45	0.3
13	Manganese, (mg/l)	2.6	0.5
14	Arsenic, (mg/l)	0.03	0.01
15	Chemical Oxygen Demand, (mg/l)	4	-
	In Site Test (Sept.2,2002)		
16	Temperature (^{o}C)	28.3	-
17	pH (pH)	7.78	-
18	EC (mS/m)	41.4	-
19	DO (mg/l)	4.81	-
20	Col.(n/100ml)	2	-
21	Total c.(n/10ml)	Non	-
22	ORP(m/V)	-	-

N.D. : Not Detected.

CHAPTER 5 GROUNDWATER DEVELOPMENT

5.1 Aquifer

Aquifer characteristic of the Study area is established from the existing shallow and deep tube-wells data presented in the ATTACHMENT 2 Table 4.2.1 - Table 4.2.2 above. The Hydro-geological Map and Hydro-geological Cross Sections along X-X' and Y-Y' are prepared with reference to those data see ATTACHMENT 3 Figure 5.1.1 – Figure 5.1.3 presented in Attachments.

The maximum drilling depth of deep-tube well in this area is found 120m, while minimum depth is 55.48m and average depth is 87.30m. In case of shallow tube wells, the maximum drilling depth is found 50.9m, while minimum depth is 13.7m and average depth is 30.2m.In this region.

Three major aquifers are identified named as Aquifer I, Aquifer II and Aquifer III. The Aquifer I is unconfined type whereas Aquifer II and Aquifer III are confined type. All the Aquifers are sloping down toward south, nearly parallel to the topography.

5.1.1 Aquifer I unconfined type

The thickness of Aquifer I varies approximately from 40 to 50m. The Aquifer I is classified into two layers by composition namely Upper layer and Lower layer.

1) Upper layer

The thickness of the Upper layer varies from 25 to 35m. This layer is composed of mainly sand. Some lenses of clay layers with thickness of few meters to ten meters are found in this Upper layer (see ATTACHMENT 3 Figure 5.1.3 Hydro-geological Section Y-Y'). A lens of sandy gravel is marked in Dewanganj area, southern part of the Study area (see STW-8 in ATTACHMENT 3 Figure 5.1.3 Hydro-geological Section Y-Y').

Almost all the shallow tube-wells of this region were drilled up to this depth and tapped lower part of this Upper layer aquifer. It is found that the maximum discharge is about 20 l/s.

The transmissivity for this unconfined aquifer is calculated from the Logan's approximation theory. In this region the maximum transmissivity is found 2710m2/day whereas the minimum is 502m2/day and the average is about 1200m2/day. The range of storage coefficient for the unconfined aquifer is considered from 0.05 to 0.3.

2) Lower layer

The Lower layer of the Aquifer I is composed of mainly sandy gravel and its thickness is about 15 to 25m. Most of the deep tube-wells of this region tapped this Lower layer unconfined aquifer also. Then, the first confining layer composed of clay/sticky clay underlies the Aquifer I. Its thickness varies from 1 to 3m.

5.1.2 Aquifer II confined type

This aquifer underlies the first confining layer at a depth of about 55m below ground level. This aquifer is composed of mainly sandy gravel and pebble. The thickness of this aquifer varies from about 4m to 25m. In the Hydro-geological Cross Section Y-Y', it is clearly seen that the Aquifer II is thicker toward the North of the Study area to about 25m and thinning out toward South-West Indo-Nepal border to about 4m.

Almost all the deep tube wells of this region tapped this Aquifer II and it is found that an average discharge is of about 35 l/s. The transmissivity for this confined aquifer is calculated from the Logan's approximation theory. In this region the maximum transmissivity is found 1983m^2/day whereas the minimum is 1590m^2/day (considering the DTW 15 and DTW16 of the Study area) and the average is about 1800m^2/day. The storage coefficient for the confined aquifer is considered as a range from 0.0005 to 0.005. The storage coefficient values are adopted from available reports of this region, published books and test well.

The second confining layer underlies the Aquifer II at a depth of about 55 to 75m below ground level. The composition of this confining layer varies from North to South direction. To the North, the composition of this layer is found sticky clay which changes to silty/sandy clay to the South of this region. The thickness of this layer varies from about 10m to the North to about 20m to the South Indo-Nepal border.

5.1.3 Aquifer III confined type

This aquifer underlies the second confining layer at a depth of 70 to 80m below ground level. The composition of this aquifer is mainly sandy gravel, pebble and boulder. The thickness of this aquifer is about 20 meter that continues throughout the region from North to South but it is thinning out toward South-East (see ATTACHMENT 3 Figure 5.1.2 Hydro-geological Section X-X'). This aquifer is tapped by those deep tube-wells which have more than 60m depth. Since the existing deep tube wells of this area tapped multi-aquifers that are Aquifer I (unconfined), Aquifer II (confined) and Aquifer III (confined), the results of aquifer test have been found similar to Aquifer II. In this case, the transmissivity of Aquifer III is also found similar to Aquifer II.

Below this Aquifer III, the third confining layer underlies at a depth of about 90 to 100m below ground level. The composition of this confining layer is same as second confining layer that is, sticky clay to the North and changing to South as silty and sandy clay. The thickness of this confining layer remains unknown due to lack of deeper lithological data.

5.2 Groundwater Development

Groundwater development analysis of the area is established from the existing 5 deep tube-wells and 9 shallow tube-wells of Sunsari district. Out of those tube-wells, two deep tube-wells (DTW-12 and DTW-16) and four sallow tube-wells (STW-8, STW-9, STW-10 and STW-12) fall in the present Study area. The tube-wells DTW-10, DTW14, DTW15 and STW5 lie nearby the Study area, so their data as well as the test well data are considered here for the hydro-geological calibration.

5.2.1 Standard Design of Tube-well

Standard well design and capacity of the irrigation tube-well for the present Study area are calibrated from the existing shallow and deep tube-well and test well data and test well of this region (see ATTACHMENT 3 Table 5.1.1). With reference to the available data, geological cross sections, aquifer test and hydro-geological data, following specifications are recommended for a standard design of shallow tube well (STW) and deep tube well (DTW).

1) Depth

The well depth for the standard design is fixed from the hydro-geological section presented in ATTACHMENT 3 Figure 5.1.2 and Figure 5.1.3. The STW is designed to tap the unconfined Aquifer I, so the depth is fixed to be 30m. Similarly the DTW is designed to tap confined Aquifer II and Aquifer III, so the designed depth is fixed to be 100m.

2) Diameter

The diameter of shallow tube-well and deep tube-well will be 100mm and 250mm respectively. These diameters are fixed by referring the existing standard tube-well data and availability of the materials e.g. pipes.

3) Screen length

To fix the screen length of STW, it is considered the maximum value 9m (with 12-15% opening area) among the three shallow tube-wells STW5, STW8 and STW10. Similarly in case of deep tube-well the screen length is fixed to be 25m (12-15% opening area) considering the maximum value in DTW-15 and DTW-16.

5.2.2 Hydro-geological Contents

The hydro-geological content for the standard STW and DTW were presented as follows.

1) Transmissivity (T)

The transmissivity is calibrated by using the Logan's Approximation Method and found 1200m^2/d for shallow tube-well design and 1800m^2/d for deep tube-well design.

2) Discharge (Q)

The required discharge is designed to be 14l/s and 40l/s for shallow tube-well and deep tube-well respectively. For these figures, the ADB/CGISP project report and the knowledge of farmers about operation and maintenance of the pumps are considered. According to the hydrogeology of the Study area, the discharge of the deep tube well can be increased to 100l/s and even more than that. For this situation the design of the present standard deep tube well should be changed.

3) Storage Coefficient (S)

A range of storage coefficient is selected as 0.05-0.3 (unconfined aquifer) for shallow tube-well and 0.0005-0.005 (confined aquifer) for deep tube-well. For these values the typical values for confined and unconfined aquifer from available reports, published books and the result of a test well are considered.

4) Drawdown (d)

The drawdown for shallow tube-well is fixed to be 1.5m by considering the lowest static water level of STW-8 in the years 1992 and 1995 and maximum suction capacity of centrifugal pump. In the case of deep tube-well the drawdown is fixed to 3m considering the maximum deep value from the existing data.

5) Operation Time (t)

The operation time for both shallow and deep tube-well is selected to 0.5 day by practice.

6) Radius of Influence (R)

Radius of influence is calculated by using the Jacob Method. Considering the maximum value of storage coefficient (0.3 for unconfined aquifer and 0.005 for confined aquifer), it gives that the radius of influence (R) as 67m for STW and 600m for DTW. If the average storage coefficient (0.175) for STW and (0.003) for DTW is selected, the Radium of Influence R will increase to 88m and 800m for STW and DTW respectively.

5.2.3 Shallow Well

The standard shallow tube well design is established from the available existing hydro-geological data of the Study area considering mainly the data of STW5, STW8, STW10 and hydro-geological cross sections. From those available hydro-geological data, following specifications are made for the standard shallow tube well (STW) design. The schematic drawing of Standard Shallow Tube Well is shown in ATTCHMENT 3 Figure 5.2.1.

1) Well depth - 30m

The maximum depth of shallow tube well in the Study area is found 24.4m in STW5 and minimum depth of shallow tube well is found 16.8m in STW10. But, the hydro-geological cross section Y-Y' shows clay lenses in some areas of the Study area and also from the field survey, it is found that in some places groundwater could not be found up to about 21m depth e.g. Jalpapur area. Moreover, the aim of STW is to tap the Aquifer I of the area. To satisfy the required screen length and discharge, the depth for standard shallow tube well is selected to be 30 meter that will be in safe side.

2) Diameter of well - 100mm

The diameter of shallow tube well is fixed to be 100mm considering the reference of the existing shallow tube wells data of the Study area. This is a standard diameter for irrigation shallow tube well and the pipes (made up of UPVC, PVC as well as Mild Steel) of this diameter is easily available in the local market. There are some manufacturing companies in Nepal which produce UPVC and M.S. pipes.

3) Screen length - 9m

The screen length for the STW design is selected to be 9m by considering the maximum screen length among the STW5, STW8 and STW10. This screen length with 12-15% opening area will be sufficient to meet the required discharge.

4) Transmissivity - 1200m^2/day

The existing transmissivity data (1100m^2/d in STW5, 15000 m^2/d in STW8 and 4300 m^2/d in STW10) seem to be so high for the nature of Aquifer I of this region. So the transmissivity is calculated from the Logan's Approximation Method for unconfined aquifer ($T = 1.2Q/S_m$, where T is transmissivity in m^2/d, Q is discharge in m^3/d and S_m is the maximum drawdown in m) using the available hydro-geological data. From the calculation, the maximum transmissivity value for Aquifer I (unconfined) is found to be 2710m^2/day whereas minimum is 502m^2/day and the average is around 1200m^2/day. The average transmissivity value 1200m2/d is found very close to the transmissivity value mentioned in the ADB/CGISP report (i.e. 1500 m^2/d).

5) Discharge - 14 l/s

Farmers of this region are experienced to control/manage the operation and maintenance of pump having this capacity of discharge. So, the average designed discharge with safe yield is recommended to 14l/s which is accepted with reference to the field practice as well as consideration of the ADB/CGISP project report which is on-going project in 12 Terai districts including Sunsari District. The maximum discharge by centrifugal pump recorded in the Study area was around 20l/s.

6) Storage Coefficient: 0.05-0.3 (for unconfined aquifer)

For the Aquifer I the range of storage coefficient value 0.05-0.3 is considered by consulting the typical value for unconfined aquifer from available reports of the Study area and published books. The average value from the range is found to be 0.175.

7) Drawdown - 1.5m

For shallow tube well design in the Study area, the drawdown is limited to 1.5m. This figure is fixed according to the reference of annual deepest static water level (SWL) in year 1992 and 1995 in STW8. In those years, the SWL went down to 6.5m below ground level (bgl). Since, the maximum suction limit of a centrifugal pump is around 8m, the limit will be the difference between SWL and suction limit of centrifugal pump i.e. 1.5m.

8) Operation Time - 0.5 day (12 hours)

The pump operation time is selected to be 0.5 day according to field practice. It is also considered here the recovery time. Under the similar condition of the unconfined aquifer, the range of recovery time is found from 9-15 hours (referred the recovery test data of EX-13, EX-14 and others, JICA/HMGN/DOI, "The Master Plan Study on the Terai Groundwater Resources Evaluation and Development Project for Irrigation " Jhapa district, March 1995).

9) Radius of Influence - 67m

The radius of influence is calculated by following formula developed by Jocob (distance-drawdown relationship).

$$S=2.25Tt/r_o^2$$

where,

S = Storage Coefficient
T = Transmissivity in m^2/day
t = Time since pumping started in days
r_o = Intercept of extended straight line at zero drawdown in m (Radius of Influence)

Considering, Q=14l/s, T=1200m^2/d, S=0.3(max.), and t=0.5day, the result of the radius of influence is found to be 67m. If, the average storage coefficient (0.175) is considered, the radius of influence will be increased to 88m.

5.2.4 Deep Well

The standard deep tube well design is established from the available existing hydro-geological data of DTW 15 and DTW16 and hydro-geological cross sections. From those available hydro-geological data, the specifications for the standard deep tube well (DTW) design are made as discussed below. The schematic drawing of Standard Deep Tube Well is shown in ATTACHMENT 3 Figure 5.2.2. Moreover, the description of updated data received from the test tube well drilled at Kaptanganj is followed by each headings explained below.

1) Well depth - 100m

The maximum depth of deep tube well in the study area is found to be 120m at DTW15 and minimum depth is found to be 89m at DTW16. These DTWs tapped the Aquifer I, Aquifer II and Aquifer III. At present, the DTWs will tap preferably the Aquifer II and Aquifer III whose maximum depth is 100m (see the hydro-geological cross section Y-Y'). So the well depth is fixed to be 100 meter which will satisfy the required screen length as well as the required discharge in safe side.

This Study constructed two deep tube wells at Kaptanganj. One is test deep tube well and another one is observation deep tube well. The well depth (lowering depth) of both tube wells are 100m. The wells were drilled up to 120m for lithological confirmation. At this depth, all the hydrogeological contents (requirements) are satisfied for this area. So, this depth is recommended to consider as the designed depth for DTW in this area.

2) Diameter of well - 250/150mm

The diameter of deep tube well is fixed with reference to the existing deep tube wells data of the Study area. This is a standard diameter for irrigation deep tube well and the pipes (made up of UPVC/mild steel) of these diameters are easily available through local suppliers.

The diameters of the tube wells drilled at Kaptanganj were 10"/6" for test well and 4" for the observation well. In both tube wells, UPVC pipes were used. This diameter for the DTW is recommended as standard diameter which satisfies the hydrogeological contents and availability of materials (pipe, pumps etc) and manageable to water user groups.

3) Screen length - 25m

The screen length for the DTW design is selected to be 25m by considering the maximum screen length among the DTW-15 and DTW16. This screen length with 12-15% opening area will be sufficient to meet the required discharge.

In the test and observation wells drilled at Kaptanganj, 30m UPVC slotted screen with 12% opening area were installed. Considering entrance velocity and required discharge, this length of the screen is found sufficient.

4) Transmissivity - 1800m^2/day

According to the nature of the Aquifer II and Aquifer III of this region, the existing transmissivity data of DTWs show a very high value. So, the transmissivity is calculated from the Logan's Approximation Method for confined aquifer ($T = 1.6\ Q/S_m$ where, T is transmissivity in m^2/d, Q is discharge in m^3/d, and S_m is maximum drawdown in m) using the available hydro-geological data. It is also marked that the existing deep wells tapped multi-aquifer from Aquifer I to Aquifer III which will show a very general value of transmissitity. From the calculation, the maximum transmissivity value has been found to be 1983m^2/day whereas minimum is 502m^2/day and average is found to be around 1800m^2/day.

The tube well drilled at the Kaptanganj to be tapped two confined aquifers, Aquifer II and Aquifer III. The transmissivity was calculated by Jacob methods. The formula for the method is presented in No.2 of section 4.4.2 above. From the calculation, the Transmissivity (T) was found to be T = 4312m^2 /day. This Transmmivity value calculated for the Kaptanganj area is found higher than the average Transmissivity calculated for other parts of the Study area. So, to be in safe side the Transmissivity T=1800m^2 /day is recommended as the average T value for the Study area.

5) Discharge - 40 l/s (standard)

Farmers are well familiar to the pumps having this capacity of discharge and can control/manage the operation and maintenance of the pump. So, the designed discharge of 40l/s is selected with reference to these field practice as well as consideration of the ADB/CGISP project report which is on-going project in 12 Terai districts including Susari.

Discharge measured in the test deep tube well installed at the Kaptanganj was found to be 30l/s (the pump capacity was low). It is found that within a limit of drawdown the required discharge (40l/s) is available in this area. So Q=40l/s can be considered as standard discharge of this area.

According to the hydrogeology of the Study area, the discharge of the deep tube well can be increased to 100l/s and even more than that. For this situation the design of the present standard deep tube well needs to be changed.

6) Storage Coefficient: 0.0005-0.005 (for confined aquifer)

The range of storage coefficient value 0.0005-0.005 is considered by consulting the typical value for confined aquifer from available reports of the Study area and published books. The average value from the range is found 0.003.

By analysis of the pumping test data of Kaptanganj area the Storage Coefficient is found to be 0.003. This value is similar to the other parts of the Study area. Therefore S=0.003 is considered as the average value for this Study area.

7) Drawdown - 3m

For deep tube well design in the Study area, the drawdown is limited to 3m. This figure is fixed according to the annual deepest static water level (SWL) in DTW15 and DTW16. The maximum SWL in those tube wells were 2.5 meter below ground level and by rounding it is considered as 3m in safe side.

After completion of Time-Drawdown Pumping Test work in the test tube well constructed at Kaptanganj, the drawdown was found to be 0.045m in observation well and the Static Water Level was 2.8m (BGL). Although the drawdown in Kaptanganj area is found to be low, the drawdown is recommended to be 3m considering the field practice and safe side.

8) Operation Time - 0.5 day (12 hours)

The pump operation time is selected to be 0.5 day according to field practice. It is also considered here the recovery time. Under the similar condition of the confined aquifer, the range of recovery time is found from 9-15 hours (referred the recovery test data of Ob-5, EX-15 and others, JICA/HMGN/DOI, "The Master Plan Study on the Terai Groundwater Resources Evaluation and Development Project for Irrigation " Jhapa district, March 1995).

The recovery time in the test tube well drilled at Kaptanganj was found to be 3min. The Kaptangaj area lies at Southernmost part of the Study area and the soil in this area is mostly sandy. So considering this recovery time as well as the field practice, the standard operation time is considered to be 0.5 day (12 hours).

9) Radius of Influence

The Radius of Influence is calculated by following formula developed by Jocob Method (distance-drawdown relationship).

$$\mathbf{S=2.25Tt/r_o^2}$$

where,

S = Storage Coefficient

T = Transmissivity in m^2/day
t = Time since pumping started in days
r_o = Intercept of extended straight line at zero drawdown in m

Considering Q=40l/s, T=1800m^2/d, S=0.005(max.) for confining aquifer, and t=0.5day, the result of the radius of influence is found to be 600m. If, the average storage coefficient (0.003) is considered, the radius of influence will be increased to 800m.

From the analysis of pump test results of test deep tube well at Kaptanganj, it is found that Q=30l/s, T=4312m^2/d, S=0.003 for confining aquifer and t=0.5day. The Radius of Influence for Kaptanganj is calculated from the Jacob's Distance-Drawdown Relationship (see Figure 4.4.7 in ATTACHEMENT-2). It is found to be 50m.

5.3 Cost Estimation of STW and DTW

5.3.1 Cost Estimation of STW

Cost of standard STW for the Study area drilled by rig machine up to 30m depth considering the specifications described in 5.2.1 above is found to be NRs.128,000.00. It includes the diesel pump. Similarly, the cost estimation of standard STW for the Study area drilled by manual method (sludge method) is found to be NRs. 63,300.00. It also includes diesel pump (see Table 5.3.1 below and for economic analysis see ATACHMENT 3 Table 5.3.3). The inflation rate is considered up to 2001/02 in the estimated costs.

According to the field practices the life of machine drilled and manually drilled STW is considered to be 10 years and 5 years respectively. The difference is due to better well development and gravel packing in case of machine drilled STW which will not be practiced in case of manually drilled STW.

Table 5.3.1 Cost Estimation of STW

S. No.	Descriptions	Machine drilled cost for 30m depth (Rs.)	Manually drilled cost for 30m depth (Rs.)
A.	**Construction Cost**		
1	Drilling, Installation, Development aquifer test (Diameter:100mm)	68,000.00*	10,400.00
2	Material Cost (4"PVC casing pipe, 4" PV screen pipe, M.S. top casing pipe and sockets)	33,000.00*	25,900.00
B.	**Pump (Diesel) Cost** 7HP, 14l/s discharge	27,000.00	27,000.00
	Total capital cost (Rs.)	**128,000.00**	**63,300.00**

*The figure includes additional contractors overhead and taxes 27.5% (15% overhead,10% VAT & 2.5% local tax).

It will be better to mention here that in some places of the Study area (nearby the Baba Paper Factory, Sunsari), it was found that the farmers have installed local made electrical centrifugal pumps in their STWs. They used 7.5 HP motor (3 phase line) for the pump. The average cost for the pump is NRs. 32,000.00. The average cost for 10m distance electric line (440 volt) is around NRs.14,000.00 and about NRs. 54,000.000 for pump house. In average the total cost for electric system (10m distance) with pump house for STW is around NRs. 100,000.00. At present, HMG is providing 50% subsidy in electricity consumption used for irrigation.

5.3.2 Cost Estimation of DTW

Cost of standard DTW for the Study area drilled by rig machine up to 100m depth considering the specifications described in 5.2.2 above is found to be NRs.3,265,000.00. The cost estimation includes electricity system, electric submersible pump and pump house and distribution system (see Table 5.3.2 below and for economic analysis see ATTACHMENT 3 Table 5.3.3). The inflation rate is considered up to 2001/02 in the estimated costs.

Table 5.3.2 Cost Estimation of DTW

S. No.	Descriptions	Machine drilled cost for 100m depth (Rs.)*
A.	**Construction Cost**	
1.	Drilling, Installation, Development aquifer test, well sealing (Diameter:250mm/150mm)	692,000.00
2.	Material Cost (250mm M.S. casing pipe for housing, 150mm M.S. screen pipe for production, 150mm M.S. slotted pipe for production)	183,000.00
	Sub Total (Rs.)	**875,000.00**
B.	**Electricity System (for 1Km)** 50% for 11KV main line, 45% for 50KVA transformer, 5% for service line	500,000.00
C.	**Submersible Pump (Electric) Cost** 40-45l/s discharge, 30-40m head	450,000.00
D.	**Pump House**	140,000.00
	Total capital cost (NRs)	**1,965,000.00**
E.	**Distribution System** 1500m UPVC pipe line laying 15 nos. of alpha/alpha outlet valve M.S. pipe fittings 2 nos. of surge riser	1,300,000.00
	Grand Total (NRs)	**32,65,000.00**

*The figures include additional contractors overhead and taxes 27.5%
(15% overhead, 10% VAT & 2.5% local tax).

The materials for the construction of tube wells (casing pipe and screen pipes) are made of mild steel. The electricity system consists of 11KV main line extension up to 1Km including all materials needed, 50KVA transformer and installation charges. The designed submersible pump will have 40-45l/s discharge and 30-40m head. Distribution system consists of installation of 1500m UPVC pipe line distribution, 15 alpha/alpha outlet valve, 2 surge risers and M.S. pipe fittings.

At this time the electric line distribution is available only up to Harinagar VDC. The distance from Harinagara Bazar to the planned pump irrigation area Kaptanganj is about 9

Km. According to the Nepal Electricity Authority, Sunsari District will take few years to reach the electricity distribution line up to Kaptanganj (planned deep tube well construction area). The electric poles were already erected up to Kaptanganj VDC.

5.4 Operation and Maintenance System

The Study team visited the existing Deep Tube Well Irrigation System and Shallow Tube Well Irrigation System in Sunsari and Morang Districts. Those visited tube well irrigation systems were constructed under GWRDP, Biratnagar. With reference to the field practice, the recommended standard O & M system is presented in the Figure 5.4.1 and Figure 5.4.2 for STW and DTW respectively. The O & M systems adopted by the WUG of DTW and STW irrigation systems in Sunsari and Morang districts are described below.

5.4.1 O & M System of STW

1) Operation System

The WUG members operate the centrifugal pump (diesel) themselves. They do not have separate pump operator. All the members are trained by GWRDP, field office, Biratnagar. Each and every time, after operation of the pump, the water user himself will fill up the diesel tank of the pump to full tank. So they do not need to pay any amount to the WUG.

2) Maintenance System

Whenever the pump needed to be maintained, the maintenance cost will be estimated and the charge will be share by each member of the water user group.

3) Operation and Maintenance Cost

The annual operation and maintenance cost for machine drilled STW is found to be NRs.11870.00. The total present value (PV) cost of machine drilled STW is found to be NRs.200,881.00 (calculated by considering 10 years of life). Then the calculated water cost is found to be NRs.2.59/m^3. In the same way, the annual operation and maintenance cost for manually drilled STW is found to be NRs.9282.00 and total PV is found to be NRs.98,478.00 (considering 5 years of life). Then the water cost is found to be NRs.2.06/m^3 (see table 5.3.3 in Attachement-3 for detail).

5.4.2 O & M System of DTW

1) Operation System

Members of WUG of the DTW irrigation system are trained by the GWRDP-Birartnagar for pump operation and maintenance system. The WUG members are paying NRs.10.00/ unit for the operation of the pump to the chairman (or responsible executive member) of the WUG. The chairman (or responsible executive member) of the WUG will pay the electric bill each month from the collected money. The remaining fund will be allocated for pump operator and maintenance, after clearance of electric bill every month. At present, HMGN providing 50% subsidy in the electric bill to the farmers for irrigation purpose.

2) Maintenance System

The WUGs are charging NRs. 50.00/year to each users of the WUG. The maintenance of the pump unit (including distribution systems) will be made from those collected money.

3) Operation and Maintenance Cost

The annual operation and maintenance cost for DTW is found to be NRs.141,600.00. The total present value (PV) cost of DTW is found to be NRs.3,345,516.00 (calculated by considering 20 years of life for DTW and 10 years for pump). Then the calculated water cost is found to be NRs.2.73/m^3 (see table 5.3.3 Attachement-3 for detail).

Figure 5.4.1 Standard O & M System of DTW

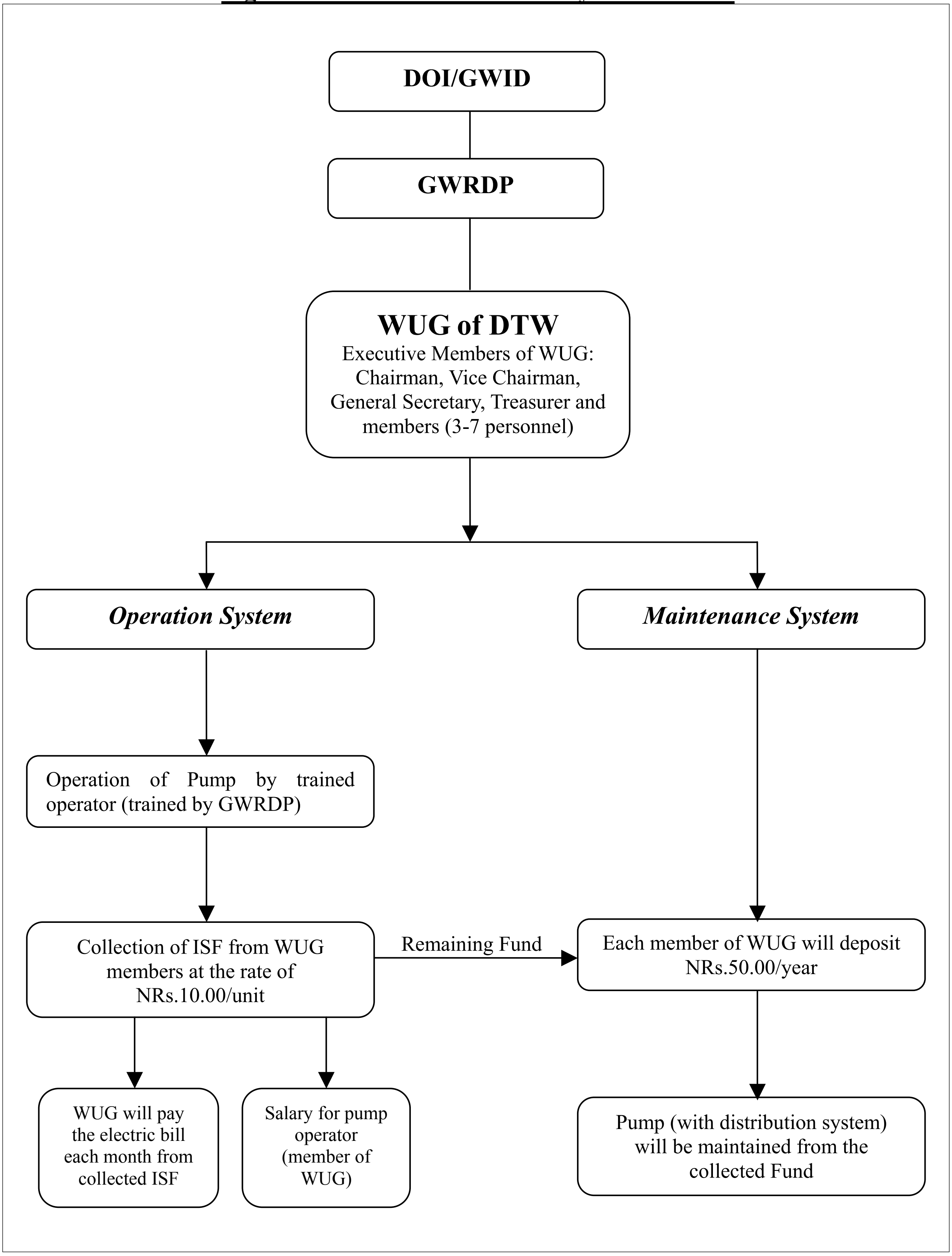
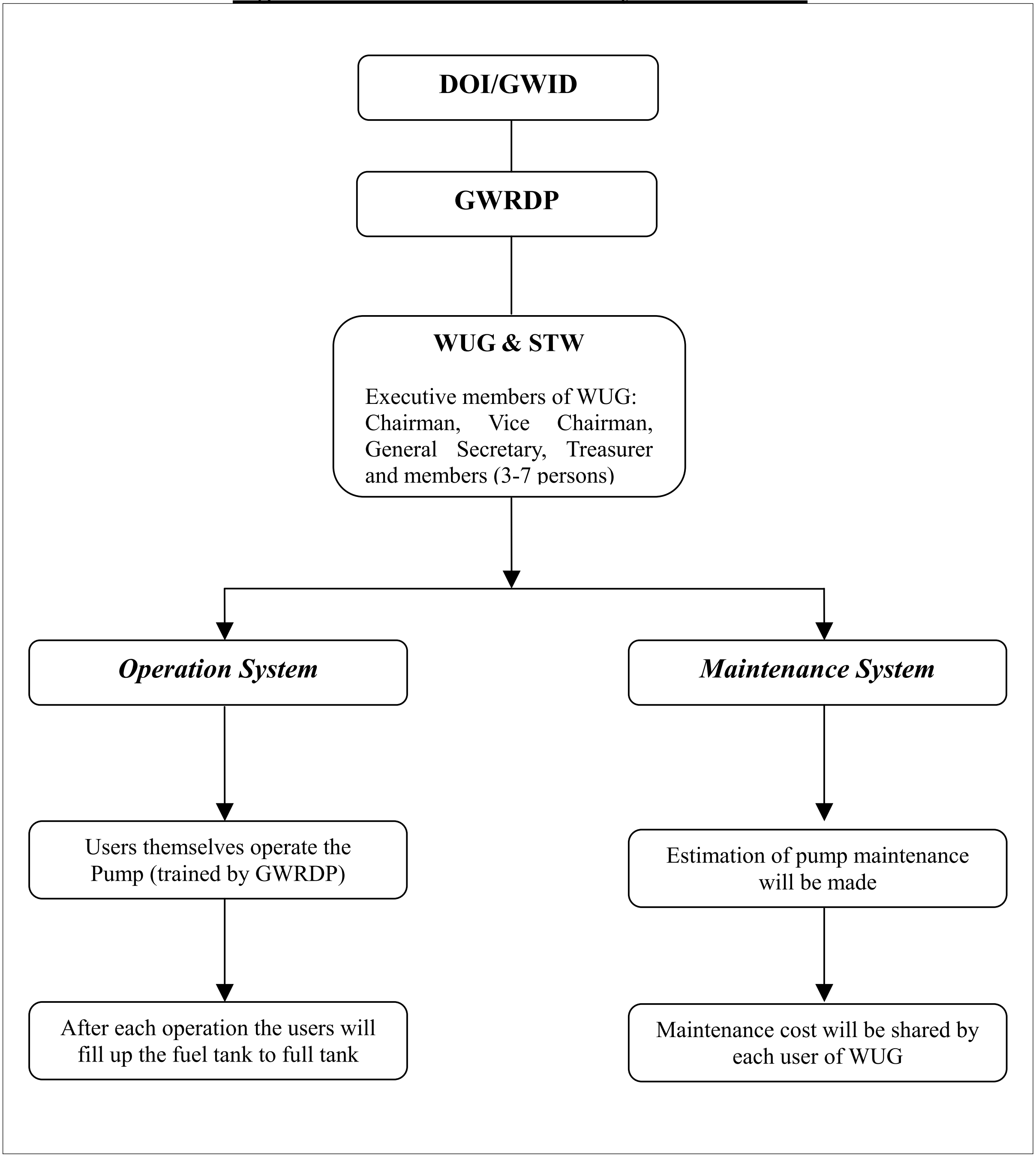


Figure 5.4.2 Standard O & M System of STW



5.5 Irrigation System Plan of Groundwater

Irrigation System Plan of Groundwater is basically depends upon the safe yield capacity of tube well and pump efficiency. With reference to those analyzed data, irrigation capacity by tube well, distribution system and density of tube well distribution will be planned.

5.5.1 Standard well design and distribution of STW for Safe Yield

The result of hydrogeological analysis of the Study area shows that the Study area is feasible for construction of shallow as well as deep tube well. With reference to the field practice and hydrogeological analysis of the available data of the Study area, the standard well design is recommended as specified below for construction of shallow tube well (STW) which will provide maximum safe yield.

Recommended Standard well design of STW specification is given by;

Items	*Recommended value for safe yield*
Well depth	30m
Diameter	100mm
Screen length	9m
opening area of screen	more than 12%

The tube well constructed as per the recommended well design will provide the hydrogeological contents as explained below.

Hydrogeological contents	*Calculated values*	*Remarks*
Discharge (Q)	14 l/s	Irrigation capacity is 2.5-4 ha
Drawdown (s)	1.5m	
Transmissivity (T)	1200m2/d	
Storage Coeficient (S)	0.05-0.3 (0.175 avg.)	for unconfined aquifer

1) Distribution of Tube Well

Considering those calculated hydrogeological contents and S=0.05-0.3 and operation time t=0.5 days, the Radius of Influence is found to be 67m. If the average storage coefficient (S) i.e. 0.175 is considered, the Radius of Influence will be 88m. That means, the distance between tube well to tube well should be 170m (i.e. two times of radius) apart for safe yield.

5.5.2 Standard Well Design and Distribution of DTW for Safe Yield

In the same way, considering the hydrogeological analysis of the available data for DTW of the Study area, the standard well design having following specification is recommend for construction of deep tube well (DTW) which will provide the maximum safe yield.

Recommended Standard Well Design of DTW Specification is given by;

Items	*Recommended values for Safe yield*
Well depth	100m
Diameter	250mm
Screen length	25m
Opening area of screen	more than 12%

The test deep tube well constructed by this Study at Kaptanganj considered the well design as specified as above. The hydrogeological results obtained from the test deep tube well are presented below.

Hydrogeological contents	*Calibrated values*	*Remarks*
Discharge (Q)	30l/s	Irrigation capacity is 40ha
Drawdown (s)	0.045m (obs. well)	
Transmissivity (T)	4312m2/d	
Storage Coefficient (S)	0.003	

1) Distribution of Tube well

As considering the calibrated hydrogeology of the Kaptanganj, the Radius of Influence is found to be 50m only. The designed command area of a DTW will cover 40ha area which will have a circle of about 350m radius (see Table 5.1.1 in ATTACHMENT-3). Therefore, although the radius of influence for Kaptanganj is 50m, the distance between deep tube well to deep tube well is recomended to be about 700m (double of radius 350m) apart for safe yield.

5.5.3 Standard Pump Design for Maximum Discharge with Safe Yield

1) STW

With reference to the field practice and considering the ADB/CGISP project report, the centrifugal suction pump (diesel) with 5.5-7HP is recommended as standard pump for the Study area for safe yield. The pump consumes 1.25-1.50 liter of fuel per hour and discharge ranges from 14-20 l/s. Alternatively, electric centrifugal suction pump also can be recommended for the electrified area.

The cost details of the pump and STW are described in the section 5.3 above. The O & M system adopting by WUG is discussed in section 5.4.

2) DTW

Submersible pump (electric) with 40-45l/s discharge capacity and 30-40m head is recommended as standard pump for deep tube well for the Study area. As for bigger discharge 100 l/s, submersible pump with bigger Horse Power (HP) at least 80HP will be needed. In this situation, the well design should be modified accordingly.

The cost details of the pump and DTW are mentioned in section 5.3 and the O& M system using by the WUG of the study area is explained in section 5.4 above.

5.5.4 Standard and Maximum Distribution Systems

As per the calibrated data and field practice, the designed discharge of a deep tube well is 40 l/s and irrigation capacity by one DTW is about 40 ha. With reference to field practice and consultation with GWRDP, an arrangement of the Standard Distribution System for DTW is designed which will irrigate about 40ha of land. It will consist of 1500m buried UPVC pipe alignment with 15 alpha-alpha outlet valves (it can be varied according to field arrangement). Two number of surge risers will be installed for pressure release in the UPVC pipe line distribution. The layout diagram of distribution system is shown in Figure 5.5.1.

As for 100l/s discharge design, the irrigation capacity of the tube well will be about 100 ha. In this situation the distribution of buried UPVC pipes and outlets will be increased accordingly.

5.5.5 DTW Distribution Plan in Kaptanganj

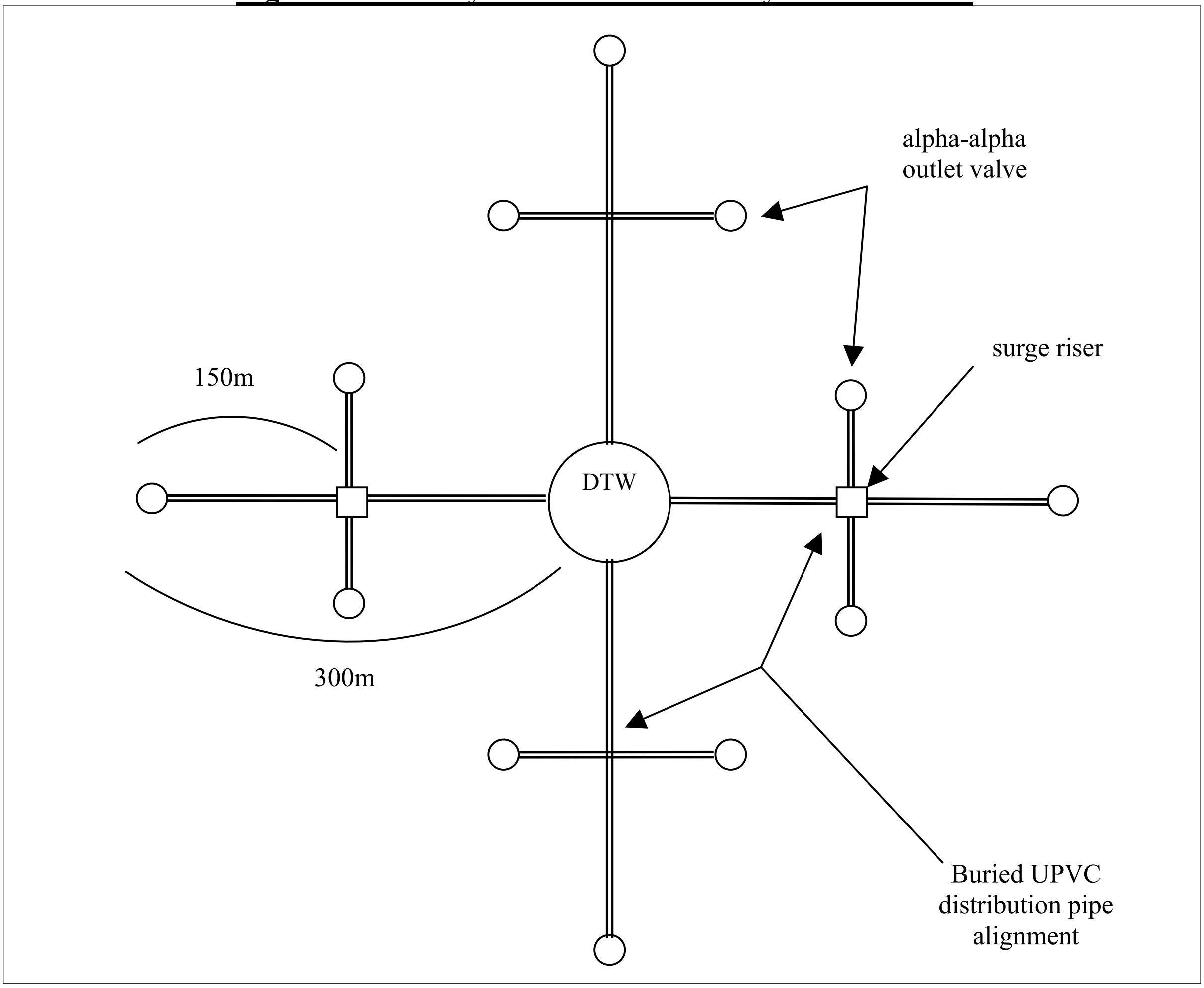
Topography of the Study area shows that the Kaptanganj lies at an up-landed area.

Therefore it is found that the surface irrigation can not reach to this area. The up-landed area of Kaptanganj covers about 450ha and the net irrigable area in the up-landed area is about 400ha. In these areas, it is planned to provide irrigation by STW as the short/mid term development and thereafter by DTW having bigger capacity such as 60-100l/s. The irrigation capacity of tube well is presented in the Table 5.5.1 below and Figure 5.5.2 in ATTACHIMENT.

Table 5.5.1: Irrigation Capacity of Tube well

Tube well Type	Discharge (l/s)	Capacity (ha)	No. of wells for 400ha	Remarks
STW	14	2.5	160	without dist. system
DTW	40	40	10	with dist. system
	100	100	4	with dist. system

Figure 5.5.1 Layout of Distribution System for DTW



CHAPTER 6 GEOLOGICAL SURVEY

6.1 Work Specification

6.1.1 Objectives of Works

The Study team carried out a core boring in order to confirm the geological structure and the bearing capacity of the prospective construction sites of the headworks. The intent of this survey was to gather information on the structure of the foundation, the physical condition of the soil at the headworks site and to present these data in a condensed format to planners for the design.

6.1.2 Contents of Works

The contents of works are as follows:

- Two (2) core borings at the proposed headworks (one each at right and left sides of the headworks), inclusive of Sampling.
- Standard Penetration Test (SPT) for a total of sixty (60) times
- Unconfined Compression Test for a total of four (4) samples
- Soil Test (index properties) for a total of thirty (30) samples

6.1.3 Location of Works

As shown in Figure 6.1.1 - Figure 6.1.3, the boring points are located at the proposed headworks site about 600meter downstream along the Sunsari River from the E-W highway bridge. In considerations of the relationship of geology to the headworks, a core boring for the right bank (boring name is JB-1) was selected at 77meters downstream from the centerline of the proposed headworks site where was the centerline of initial plan. The other side a core boring for the left bank (boring name is JB-2) was selected at 27meters upstream from the proposed centerline for reason of the surface condition at that time.

6.2 Core Boring

The core boring conducted according to standard **IS-5313-1980**. The holes drilled by fluid-circulating direct rotary with diesel engine and the surface casing pipe installed to control sloughing and to ensure good condition to make the core sampling and Standard Penetration Test (SPT). The samples collected for geological inspection, soil test and unconfined compression test with minimum drilling diameter of 66 millimeter. The boring logs are illustrated in Figure 6.1.4 in ATTACHIMENT.

Engineers of the study team observed the boring core at the in-site and the result of it was recoded with following a criterion. However particular attention should be paid to record on the boring core probably disturbed by drilling works. A criterion of the in-site inspection for the boring core is shown in Table 6.1.1.

Table 6.1.1 Relationship of Soil, Relative Density and N Value

Clay *		Sand *	
Relative Density	N Value**	Relative Density	N Value**
Very soft	0 – 3	Very loose	0 - 6
Soft	3 – 6		
Medium	6 – 12	Loose	6 - 15
Stiff	12 – 23	Medium	15 - 45
Very stiff	23 – 45	Dense	45 - 75
Hard	45 <	Very dense	75 <

*; by Terzaghi. **; N value in Nepal standard (follow ASTM D1586)

6.2.1 Core Boring at the Right Bank (JB-1)

1) Soil Classification

Core boring JB-1 was drilled up to 20 meters below surface during the period July 16–July 30 2002. The geological feature of boring sites is summarized in Table 6.1.2.

Table 6.1.2 Geological Feature of JB-1 (Right Bank)

Depth (m)	Soil classification*	Color	Density	Remarks
0.00 – 2.30	Sandy-silt	Brown	Medium	Bank foundation level,
2.30 – 3.80	Silty-sand (vf.)	Grayish brown	Loose	Mica are found
3.80 – 4.30	Silt	Gray	Medium	Column core
4.30 – 5.00	vf.-f. sand	Right brown	Loose	Containing many quartz
5.00 – 6.00	f. sand	Dark brown - gray	Loose	
6.00 – 7.00	f.-m. sand, silty	Yellowish brown	Loose	
7.00 – 8.00	Sandy-silt	Right brown	Medium	
8.00 – 10.0	f.-m.-c. sand	Gray	Medium	Containing many quartz
10.0 – 11.0	Sandy-silt	Gray	Stiff (sandy)	
11.0 – 12.0	f. sand	Gray	Medium	
12.0 – 13.0	f.-m. sand	Gray	Medium	
13.0 – 15.0	c. sand	Gary	Medium	Well sorted
15.0 – 16.0	Gravel	Right gray	-	Max. 66mm<
16.0 – 20.0	Sandy-gravel	Right gray	-	

*: (vf.)very fine, (f.)fine, (m.)medium, (c.)coarse in grain size.

2) Stratigraphic Classification

The boring site is underlain by silt, sand, and gravel of fluvial origin. The layer is divided into two stratigraphic members of the Quaternary. The upper layer is presumably unconformity overlying the lower layer. Both the layer is well layered with graded bedding.

The upper layer is divided into sand, and alternating beds of silt and sand in ascending order, and total thickness is 10 meters. The alternating beds are about 8 meters thick and it composed mainly of very fine to medium-grained sand with occasional thin beds of silt. The bed below consists fine to course-grained sand, which is about 2 meters thick. This layer is characterized by the abundance in mica, quartz, and feldspar etc.

The lower layer is divided into silt, sand, and gravel in ascending order, the every unit being conformable to each other and total thickness exceeds 10 meters. The silt bed is 1 meter thick with occasional thin beds of dark gray clay. The bed below consists fine to course-grained sorted sand, which is about 4 meters thick. Further the underlying sand and gravel beds are mainly consists of pebble with fine to medium sand matrix. The total thickness exceeds 5 meters. The gravel are composed of mudstone, sandstone, chert, limestone and granite, it reach a maximum diameter of more than 70 millimeters.

3) Groundwater Distribution

Groundwater level in the core boring JB-1 remains constant at 1.5 meters below surface with depth. The level agrees with that of the Sunsari river water level.

6.2.2 Core Boring at the Left Bank (JB-2)

1) Soil Classification

Core boring JB-2 was drilled up to 40 meters below surface during the period Aug. 1–Aug. 26 2002. The geological feature of boring sites is summarized in Table 6.1.3.

Table 6.1.3 Geological Feature of JB-2 (Left Bank)

Depth (m)	Soil classification*	Color	Density	Remarks
0.00 – 0.75	Silty-sand (vf.)	Brown	Loose	
0.75 – 2.28	Sandy-silt	Brown	Stiff	Bank foundation level, column core max 10cm
2.28 – 3.20	vf. Sand	Right brown	Medium	Column core
3.20 – 3.82	f.-m. sand	Gray	Medium	Mica are found, very loose
3.82 – 5.20	Silt/vf. Sand (Alt.)	Dark gray- gray	Stiff / Loose	Clay max 5cm, irregularity
5.20 – 6.00	f. sand	Gray	Loose	
6.00 – 7.00	f.-m.-c. sand silty	Gray	Medium	River bed foundation level, Contain pebble
7.00 – 8.00	f.-m. sand silty	Gray	Loose	
8.00 – 9.00	f.-m. sand	Gray	Medium	Well sorted, contain pebble 5mm <
9.00 – 11.0	f.-m. sand silty	Gray	Medium	
11.0 – 12.0	m.-c. sand	Gray	Medium	Mica are found
12.0 – 13.0	c. sand	Gray	Medium	
13.0 – 14.0	c. sand with gravel	Right brown	Medium	Few pebble
14.0 – 15.2	c.-vc. Sand	Right brown	Medium	Iron sheet pile foundation level
15.2 – 17.0	f.-m. sand gravely	Right brown	Medium	Few pebble
17.0 – 18.0	m.-c. sand with gravely	Gray	-	Pebble 20%
18.0 – 19.0	Sandy-gravel	Gray	-	Few pebble
19.0 – 21.0	Gravel	Gray	-	Max. 60mm<
21.0 – 22.5	f.-m. sand with gravel	Gray	-	Sorted mainly quartz
22.5 – 24.5	Pebble with boulder	Gray	-	With sandy matrix
24.5 – 35.0	Gravel with sand	Gray	-	
35.0 – 37.0	f.-m. sand	Gray	-	
37.0 – 40.0	Gravel with sand	Gray	-	Drilling water was leaking

*: (vf.)very fine, (f.)fine, (m.)medium, (c.)coarse in grain size.

2) Stratigraphic Classification

The boring site is underlain by silt, sand, and gravel of fluvial origin. The layer is divided into two stratigraphic members of the Quaternary. The upper layer is presumably unconformity overlying the lower layer. Both the layer is well layered with graded bedding.

There is the continuity in the layer between JB-1 at downstream of right bank and JB-2 at left bank upstream of proposed centerline. Stratigraphic classification for JB-2 is entirely identical with JB-1.

The upper layer is divided into sand, and alternating beds of silt and sand in ascending order, and total thickness is 10 meters. The alternating beds are about 8 meters thick and it composed mainly of very fine to medium-grained sand with occasional thin beds of silt. The bed below consists fine to course-grained sand, which is about 2 meters thick. This layer is characterized by the abundance in mica, quartz, and feldspar etc.

The lower layer is divided into silty-sand, sand, and gravel in ascending order, the every unit being conformable to each other and total thickness exceeds 30 meters. The silty-sand beds are made up mainly of fine to course-grained sand and contain silt. This bed probably corresponds to the silt bed in the lower layer at JB-1. The bed below consists of fine to course-grained sorted sand and contains few pebbles in the base with about 6 meters thick. This bed thins downstream JB-1 from JB-2. Further the underling sand and gravel beds are mainly consists of pebble with fine to course-grained sand matrix, but contains some intercalated sand and cobbles. It may contain boulders. The total thickness of the layer exceeds 23 meters. The gravel layer is composed of sandstone, chert, schist, hornfels, quartzite and granite.

3) Groundwater Distribution

Groundwater level in the core boring JB-2 varies from at 1.5 meters to 2.0 meters below surface. The level agrees with that of the Sunsari river water level.

6.3 Structure of the Foundation

6.3.1 Stratigraphic Classification

If classified by the size of grain, the unconsolidated deposits in much of the proposed headworks site can be divided into two layers in ascending order are the lower layer and the upper layer. The upper layer can be divided into the alternating beds (U1) of sand and silt, and sand bed (U2). The lower layer can be divided into three beds in ascending order are gravel (L3), sand (L2), and silty bed (L1). Those beds are well layered each other in both the upper layer and the lower layer.

To sum up the above description;

Stratigraphic Classification of the Proposed Headworks Site

The upper layer

Alternating beds (silt and very fine to medium-grained sand) -------/8 meters **(U1)**
Fine to course-grained sand --------------------------------/2 meters **(U2)**

~~~~~~~~~~~~~ unconformity ~~~~~~~~~~~~~~

The lower layer

Silt (occasional thin beds of clay) to silty sand (fine to medium-grained) ----/1 meter **(L1)**
Fine to course-grained sorted sand ---------------------------/4-6 meters **(L2)**
Sand and gravel beds (pebble – boulder with sandy matrix) -----/23 meters more **(L3)**

6.3.2 The underlying beds at the foundation level

The foundation structure at the proposed headworks site is illustrated in Figure 6.3.1 and Figure 6.3.2 on the typical section of headworks. The section along the Sunsari River is shown in Figure 6.3.3.

There are tree foundation levels for the proposed headworks site. The bank foundation level (a intake bed level) is located at about 2 meters below surface in both the banks of Sunsari River where the intake lining. The riverbed foundation level (a pile cap level) is located at 6 to 7 meters below surface in the Sunsari River bed where the concrete floor of the headworks. The sheet pile foundation level is located at between 7 to 15meters below surface where the iron sheet piles. The geological conditions on each the foundation levels are summarized as follows:

- The sandy-silt layer underlying at the bank foundation level (a intake bed level) in depth around 2 meters below surface. The bed consists mainly silt with interbedded very fine-grained to fine-grained sand. The bed can be classified medium to stiff density based upon the in-site inspection criterion for clay layer. (See Table 6.1.1) The column core was about 10 centimeter in maximum length.
- The beds consists fine to course-grained sand and partly contained few pebles,
~~~~~~~~~~~~~

which are about 2 meters thick at depth from 6 to 8 meters below surface for the riverbed foundation level (a pile cap level). These beds are related to the iron sheet pile cap level or/and the concrete floor of the headworks at the riverbed of the Sunsari River. The bed can be classified loose to medium in density based upon the in-site inspection criterion for sandy soil.

- The bed consists mainly fine to course-grained sorted sand and occasionally contained few pebbles, which is about 7 meters thick at depth of 8 to 15 meters below surface along the iron sheet pile level. The bed can be classified loose to medium in density based upon the in-site inspection criterion for sandy soil.

6.4 Soil Condition

6.4.1 Standard Penetration Test (SPT)

1) Test Method

The SPT test method has been standardized by **ASTM D-1586 (IS 2131-1963)** as "Standard Method for Penetration Test and Split-Barrel Sampling of soils" and is commonly called the standard penetration test. This test consist of:

- Driving the standard Split-Barrel Sampler (of standard dimension) a distance of 460mm (18") into the soil at the bottom of the boring.
- Counting the number of blows to drive the tube the last 305mm (12") to obtain the N (SPT) number (value).
- Using a 63.5kg (140 lb) driving mass falling free from a height of 760mm (30").

2) Test Result

The results of SPT are illustrated in Figure 6.1.4 (ATTACHIMENT). The relationship between ***N*** values and the layers are as follows:

2.1) The upper layer

Alternating beds (**U1**; silt and very fine to medium-grained sand) were recorded to range from 9 to 16 for 306 millimeters with an average of about 13.

Fine to medium-grained sand beds (**U2**) were recorded to range from 27 to 35 for 306 millimeters with an average of about 31.

2.2) The lower layer

The silt bed (**L1**; occasional thin beds of clay) was only recorded 17 for 306 millimeters with an average of about 17.

Fine to course-grained sorted sand beds (**L2**) ware recorded to range from 18 to 62 for 306 millimeters with an average of about 34.

Sand and gravel beds (**L3**; pebble and fine to medium sand) were dense and hard with ***N*** values from 39 to over 50 and rebounded, and an average of about over 50. However it should be emphasized that the beds consist mainly pebbles.

6.4.2 Unconfined Compression Test

1) Test Method

The unconfined compression test method is followed on standard **ASTM D-2166-85**.

2) Test Samples

Total four (4) samples were selected for the unconfined compression test from the boring core samples and a test pit at the Sunsari River bed. Two spare samples were taken from a test pit for reason of boring core condition. All samples were tested for the bank foundation level layer because other foundation level is underlined by unconsolidated sand beds which unformed a cylindrical shape sample. The relationship of samples to layers is as follows:

Sample	Soil	Depth (m)	Location	Cylindrical Sample
1	Vf.-f.sand (U1)	5.0	JB-1 boring core	Unformed
2	Sandy-silt (U1)	1.7	JB-2 boring core	Casting
3	Sandy-silt	1.5	Test pit	Unformed
4	Sandy-silt	1.5	Test pit	Unformed

3) Test Result

The only Sample #2 is formed a cylindrical shape for a test sample for reasons of soil conditions. The unconfined compression test results are shown in table 6.4.1. Unconfined compression strange (q_u) of alternating beds (**U1;** silt and very fine to medium-grained sand) is 27.5 kN/m^2 at depth of 1.7m from the surface.

In case of alluvial clay-soil Unconfined compression strange (q_u) is related to N value, by

$$q_u = 2.5N.$$

N value of alternating beds (**U1**) was recorded to range from 9 to 16 with an average of about 13. According to above relationship Unconfined compression strange (q_u) of alternating beds (**U1**) may be in the range of 22.5 to 40 kN/m^2 with an average of 32.5 kN/m^2.

Table 6.4.1 The Unconfined Compression Test Results for the Bank Foundation Level

Sample	Soil	Depth (m)	Unconfined Compression Strange (q_u)
1	Vf.-f.sand (**U1**)	1.5	-
2	Sandy-silt (**U1**)	1.7	27.5 kN/m^2
3	Sandy-silt (**U1**)	1.5	-
4	Sandy-silt (**U1**)	1.5	-
Max.			27.5 kN/m^2
Min.			27.5 kN/m^2
Ave.			27.5 kN/m^2

6.4.3 Soil Test

1) Test Method

The soil physical test was conducted following the standards.

- **ASTM D-854-83** as "Density Test"
- **ASTM D-2216-92 or D-4643-93** as "Water Contents"
- **ASTM D-442-63 (1972)** or/and **D-1140-54 (1992)** as "Grain-size"
- **IS-2720** as "Liquid Limit and Plastic Limit"

2) Test Sample

Twenty-eight (28) samples are collected at an interval of every one (1) meter below the surface in the core boring JB-1 and JB-2 by split-barrel sampler of SPT. Some of beds loose and it could be not taken for a sample such as a sorted sand bed. Therefore two (2) samples were taken at a test pit. Total thirty (30) samples were tested for soil condition on the underlying beds at the proposed headworks site. The samples composed of U1, U2, L1, L2, and intercalated thin sand bed in L3.

3) Test Result

The soil physical test results for the underlying beds at the proposal headworks site are shown in Table 6.4.2. And the results are summarized as follows:

3.1) Density Test

- Density of **U1** ranges between 2.59 and 2.67 g/cm^3 with an average of 2.64 g/cm^3 on 20 samples.
- Density of **U2** ranges between 2.62 and 2.64 g/cm^3 with an average of 2.63 g/cm^3 on 3 samples.
- Density of **L1** is 2.64 g/cm^3 on a sample.
- Density of **L2** ranges between 2.60 and 2.63 g/cm^3 with an average of 2.61 g/cm^3 on 4 samples.
- Density of **L3** is 2.56 g/cm^3 on 2 samples.

3.2) Water Content

- Water Content of **U1** ranges between 14.3 and 21.6 % with an average of about 18 % on 15 samples.
- Water Content of **U2** is 13.8 % on a sample.

- The results of **L1**, **L2** and **L3** are excluded for reasons of sample conditions.

3.3) Grain-Size (Soil Texture)

The samples were divided into four (4) grain-size (soil texture) which ML, SM, SP and SW of the Soil Textural Class Definitions of Design Manuals for Irrigation Projects in Nepal, 1990 (hereafter DM). Soil classification of each layers are as follows:

- Grain-Size of **U1** is divided into 4 groups which ML (6 samples), SM (7), SP (5) and SW (2).
- Grain-Size of **U2** is divided into 3 groups which SM (1 sample), SP (1) and SW (1).
- Grain-Size of **L1** is classified into SW (1 sample).
- Grain-Size of **L2** is classified into SP (1 sample).
- Grain-Size of **L3** is classified into SW (1 sample).

The typical names of above group symbols are as follows:

- **ML**: Silts and Clays. Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts, with slight plasticity.
- **SM**: Sanda more than half of coarse fraction is smaller than no.4 sieve size. Silty sands, sand-silt mixtures.
- **SP**: Sanda more than half of coarse fraction is smaller than no.4 sieve size. Poorly graded sands, gravelly sands, little or no fines.
- **SW**: Sanda more than half of coarse fraction is smaller than no.4 sieve size. Well-graded sands, gravelly sands, little or no fines.

3.4) Liquid Limit

- The samples range of **U1** in liquid limit from 22.3 to 34.60 % with an average of 27.1 % on 16 samples.
- Liquid Limit of **U2** is 25.9 % on a sample.

3.5) Plastic Limit

- The samples range of **U1** in plastic limit from 24.6 to 28.9 % with an average of 25.6 % on 8 samples.

Table 6.4.2 Results of Soil Physical Test

No	Boring Core	Depth (m)	Layer	Density ρ_s(g/cm^3)	Water Contents W_n (%)	Grain-size	W_L (%)	W_P (%)
1	JB-1	1.00	U1	2.62	20.00	SM	30.50	24.60
2		1.75		2.59	19.00	ML	28.60	25.80
3		2.00		2.59	17.00	SM	24.00	-
4		3.00		2.67	15.00	SP	22.30	-
5		3.75		2.60	21.60	SP	24.80	-
6		4.00		2.62	18.50	SM	22.80	-
7		5.00		2.62	19.48	ML	31.30	26.00
8		7.00		2.67	Exclude	SP	-	-
9		8.00		2.63	-do-	SP	-	-
10		10.00	U2	2.63	13.80	SM	25.90	-
11	JB-2	1.00	U1	2.65	15.90	SM	24.60	-
12		1.75		2.66	15.40	ML	30.20	25.10
13		2.00		2.67	14.30	SM	26.10	-
14		3.00		2.64	17.00	SM	25.20	-
15		4.00		2.67	19.20	ML	29.80	25.20
16		5.00		2.67	18.30	SM	28.50	24.60
17		6.00		2.63	Exclude	SW	23.10	-
18		7.00		2.64	-do-	SW	-	-
19		8.00		2.64	-do-	SP	-	-
20		9.00	U2	2.64	-do-	SW	-	-
21		10.00		2.62	-do-	SP	-	-
22		11.00	L1	2.64	-do-	SW	-	-
23		12.00	L2	2.62	-do-	SP	-	-
24		13.00		2.63	-do-	SP	-	-
25		14.00		2.60	-do-	SP	-	-
26		15.00		2.60	-do-	SP	-	-
27		19.00	L3	2.56	-do-	SW	-	-
28		22.00		2.56	-do-	SW	-	-
29	T.P.	1.50	U1	2.67	20.15	ML	34.60	28.90
30		1.50		2.65	18.35	ML	27.90	24.90

T.P.: Test pit. **Grain-size**: Follow the "Design Manuals for Irrigation Projects in Nepal – M.4 Soils and Land Use" MWRDI (1990).

6.5 Geological Condition at the Headworks Site

The relationship of geology at the headworks site to soil physical conditions is described in Table 6.4.3. The bank foundation level and the riverbed foundation level are located at **U1** where the intake liming level and the concrete floor level of the head-works. The sheet pile foundation level is located at from **U1** to **L2** where the iron sheet piles levels.

Table 6.4.3 Relationship between the Foundation and Soil Condition.

Layer	**Depth (m)**	**N Value** Max.-Min. /Ave.	q_u **(kN/cm²)** (Samples)	ρ_s**(g/cm³)** Max.-Min. /Ave. (Samples)	W_n **(%)** Max.-Min. /Ave. (Samples)	**Grain-Size** (Samples)	W_L **(%)** Max.-Min. /Ave. (Samples)	W_p**(%)** Max.-Min. /Ave. (Samples)
U1	0.0–8.0	9-16 /13	27.5	2.59-2.67 /2.64 (20)	14.3-21.6 /18 (15)	ML, SM SP, SW	22.3-34.6 /27.1 (16)	24.6-28.9 /25.6 (8)
U2	8.0-10.0	27-35 /31	-	2.62-2.64 /2.63 (3)	13.8 (1)	SM SP, SW	25.9 (1)	-
L1	10.0-11.0	17/17	-	2.64 (1)	-	SW	-	-
L2	11.0-17.0	18-62 /34	-	2.60-2.63 /2.61 (4)	-	SP	-	-
L3	17.0-	39-50< /50<	-	2.56 /2.56 (2)	-	SW	-	-

Note: Number shows "Maximum - Minimum/Average". Unconfined compression strange (**q_u**), Density of soil (**ρ_s**), Water contents (**W_n**), Soil Texture **(Grain-size)**, Liquid Limit (**W_L**), Plastic Limit (**W_p**).

ATTACHMENT 1

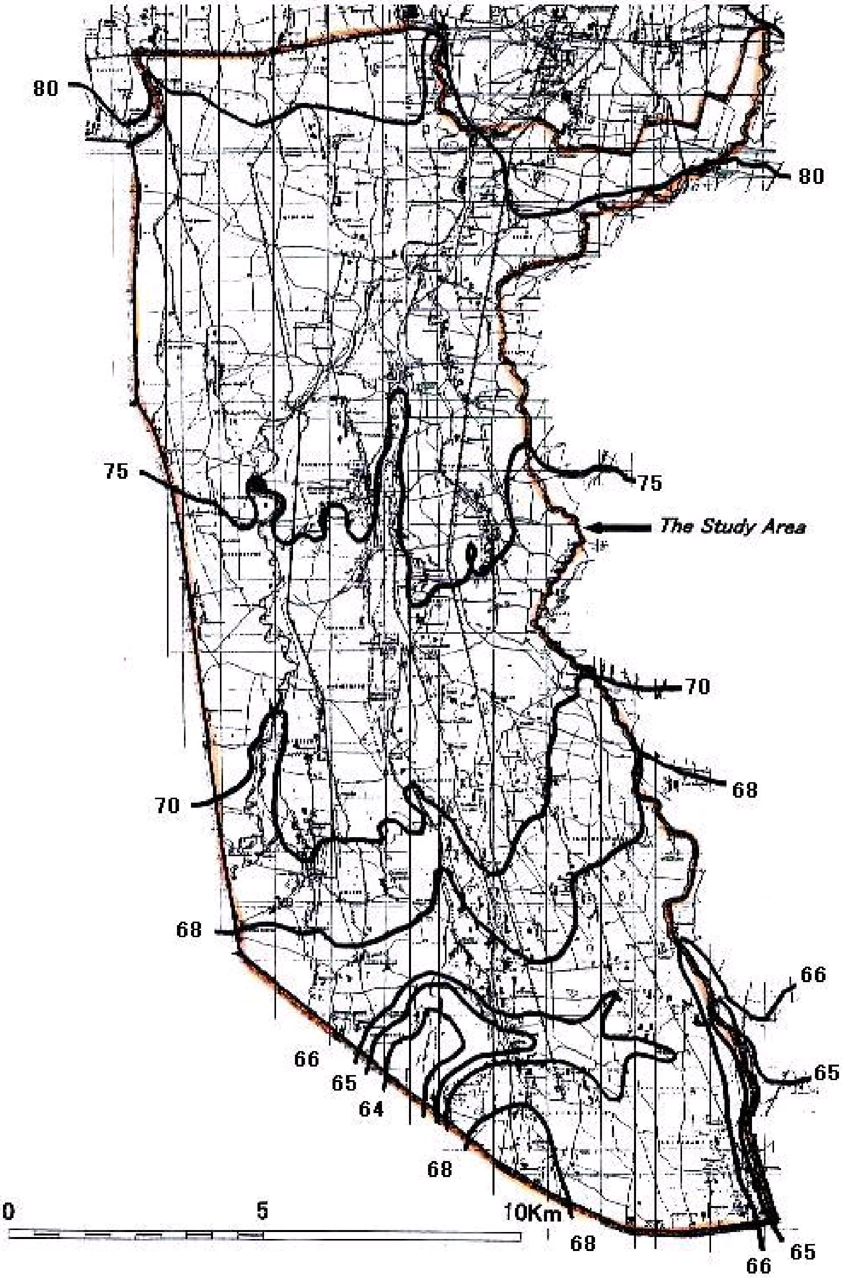


Figure 3.1.1 Topography of the Study Area

ATTACHMENT 1

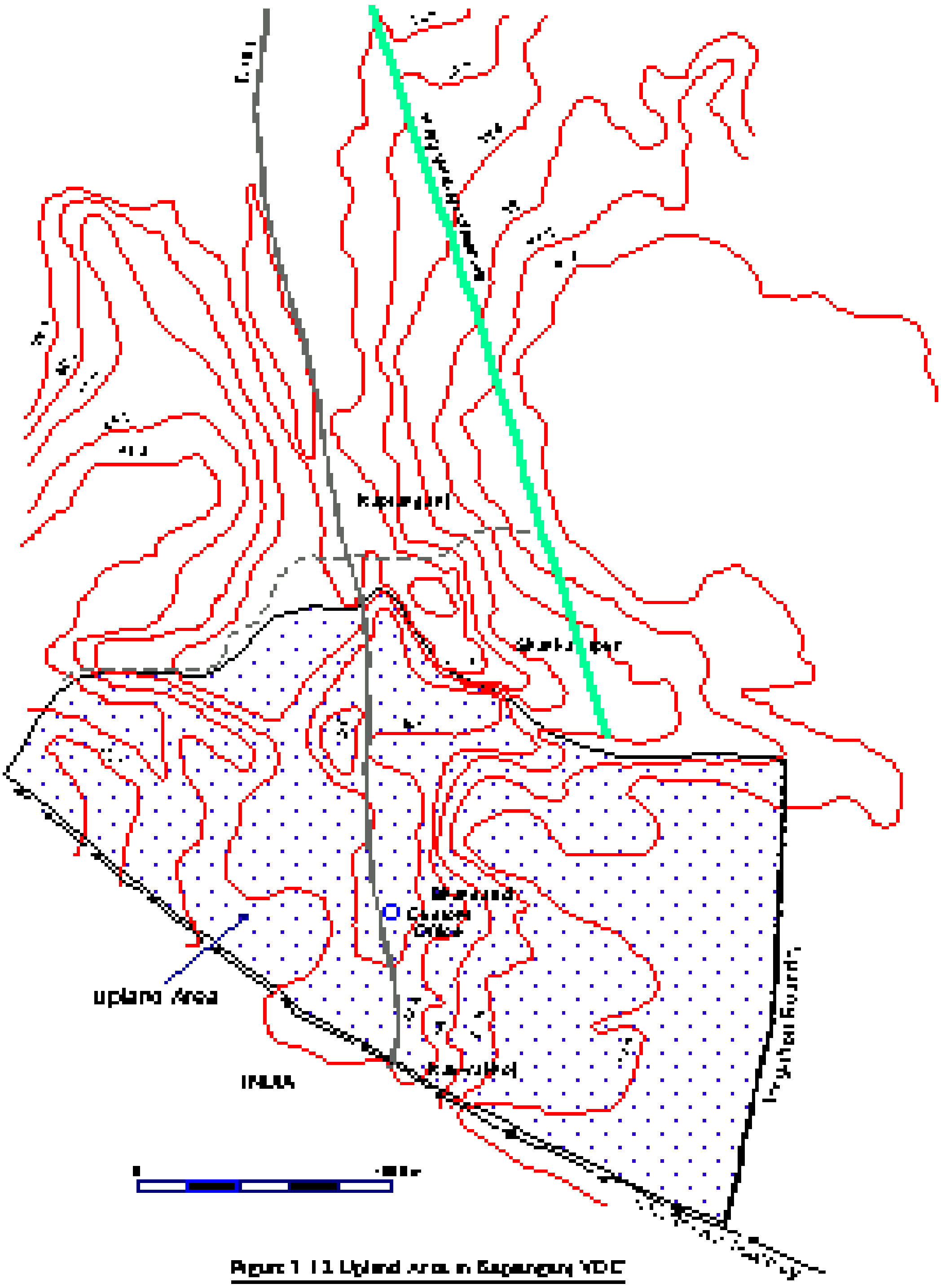


Figure 3.1.2 Upland Area in Kaptanganj VDC

ATTACHMENT 1

Subsurface Geological Section at Kaptanganj VDC

Location :Bhansatol
Test Pit :for Test well drilling works

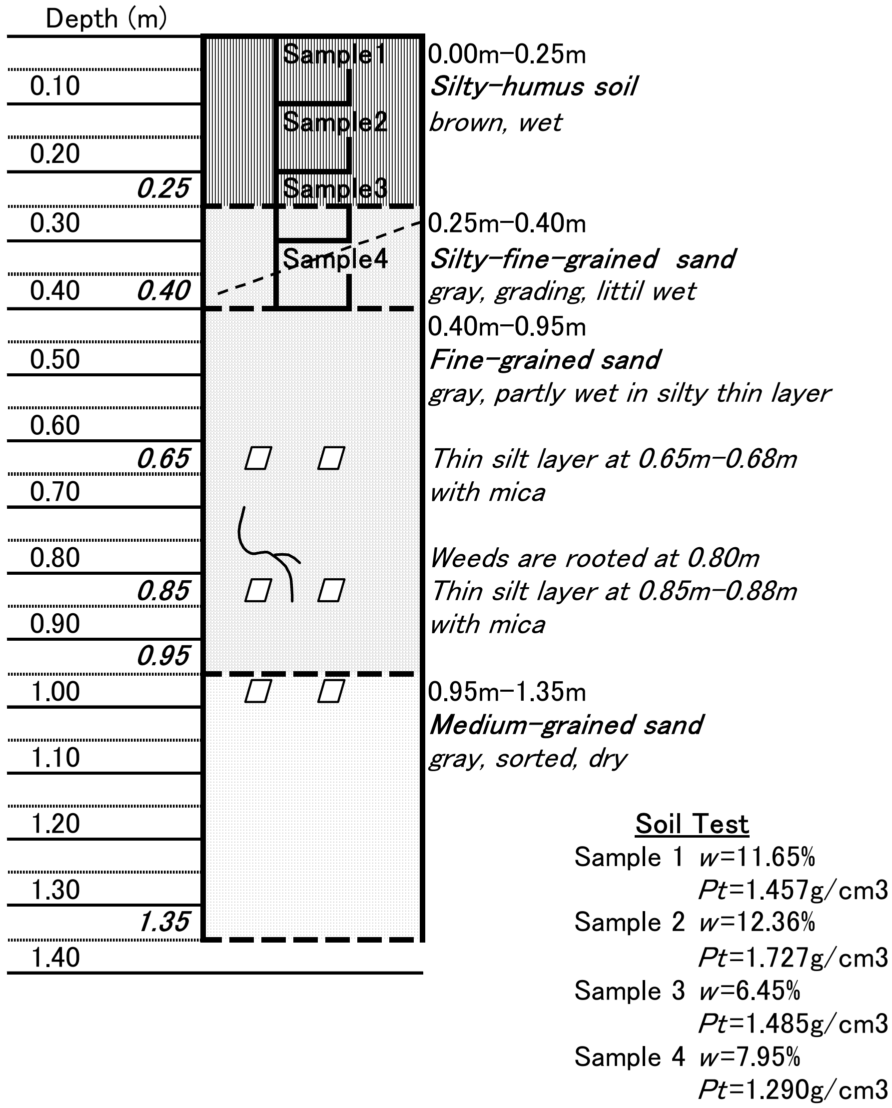


Figure 3.2.1 Subsurface Geological Section at Kaptanganj VDC

ATTACHMENT 1

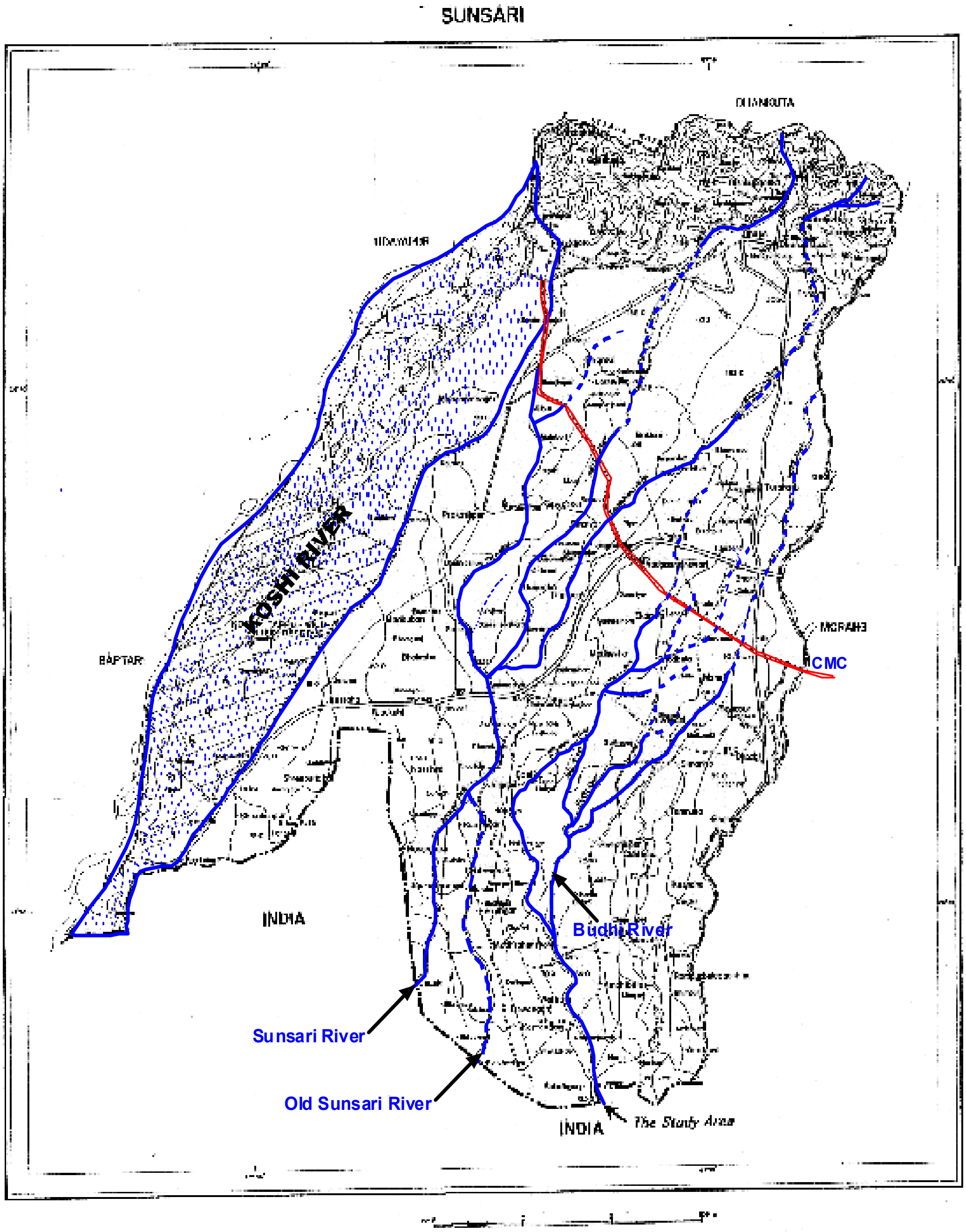
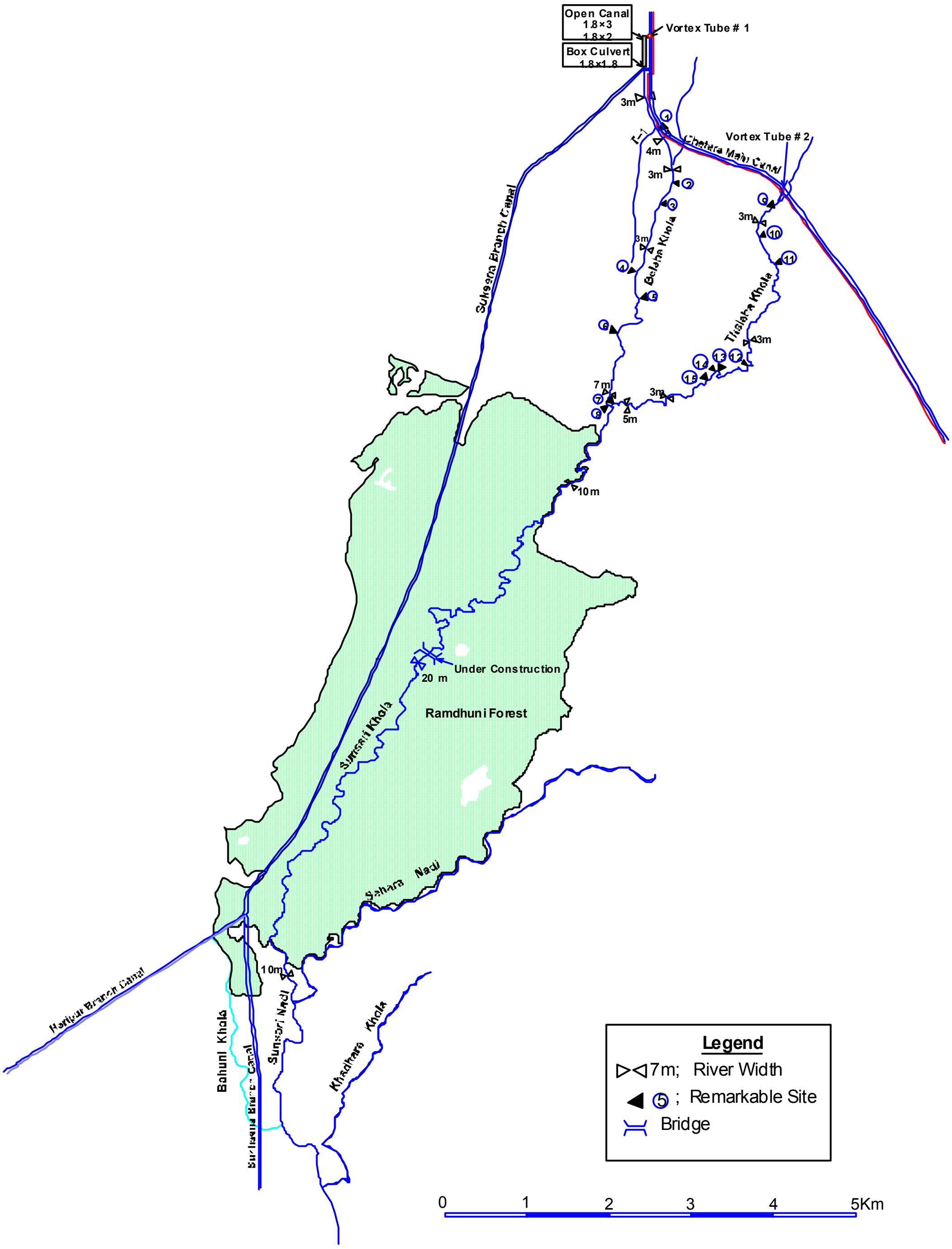


Figure 3.3.1 River System in the Study Area

Figure 3.3.1 River System in the Study Area

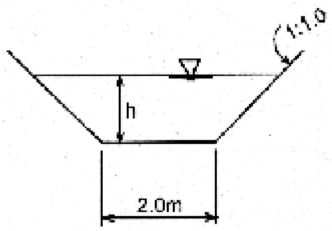
ATTACHMENT 1



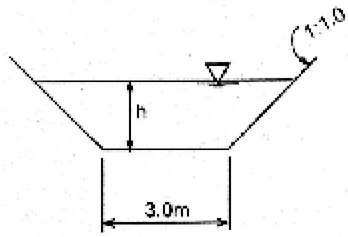
3.3.2 The riverside condition of the water from the vortex tube upto Sunsari River

Figure 3.3.2 The River Condition From Vortex Tube up to Sunsari River

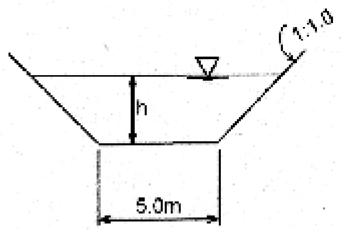
ATTACHMENT 1



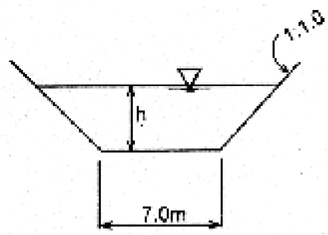
Depth h(m)	Current Q(m^3/s)
0.7	1.0
1.3	3.0
1.6	5.0
1.9	7.0



Depth h(m)	Current Q(m^3/s)
0.5	1.0
1.0	3.0
1.4	5.0
1.7	7.0



Depth h(m)	Current Q(m^3/s)
0.4	1.0
0.8	3.0
1.0	5.0
1.3	7.0



Depth h(m)	Current Q(m^3/s)
0.3	1.0
0.6	3.0
0.9	5.0
1.1	7.0

Figure 3.3.3 Relation Between Current Capacity and Depth of the Water Way

Figure 3.3.3 Relationship between Currant Capacity and Depth of the Watter Way

ATTACHMENT 1

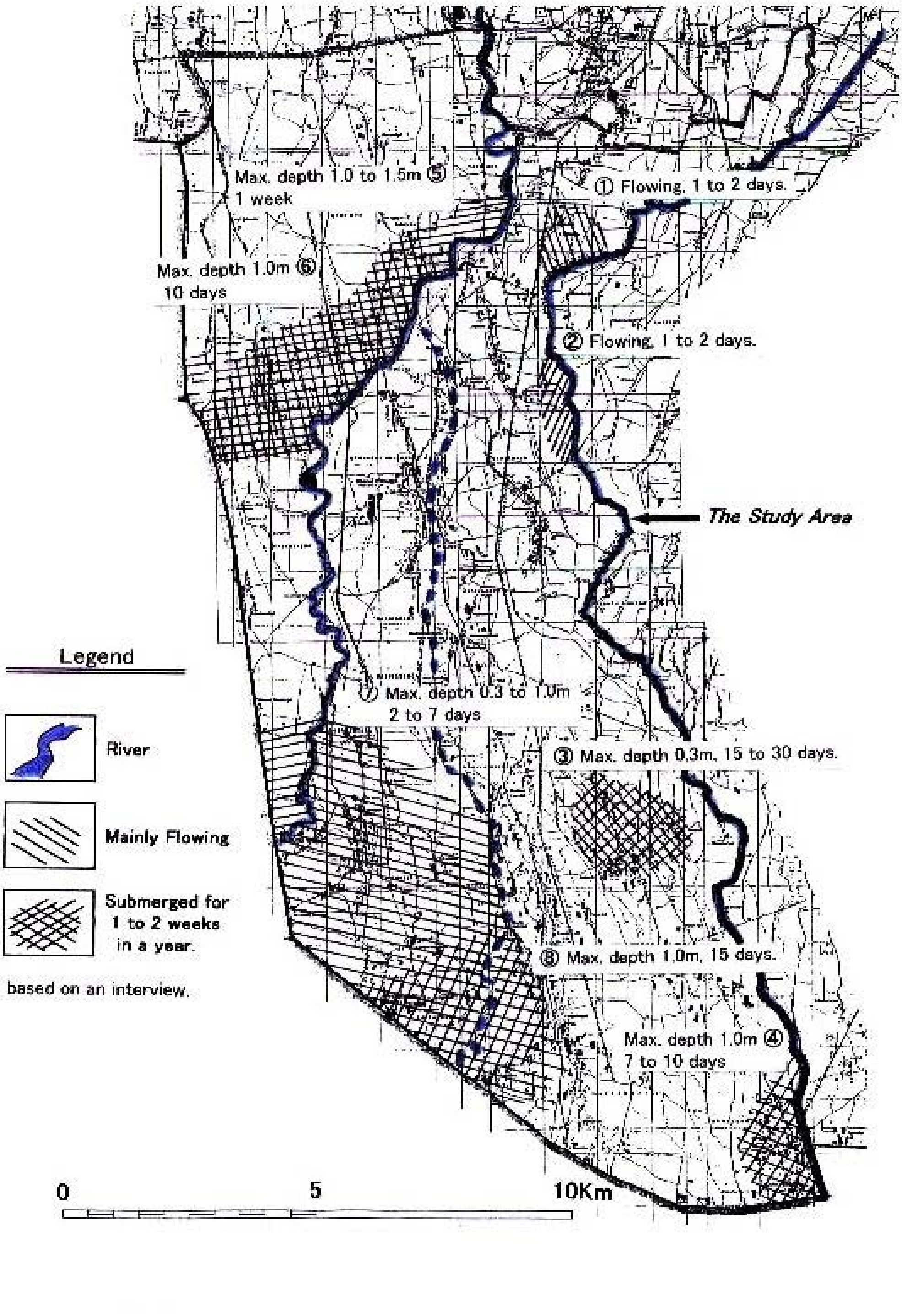


Figure 3.3.4 Distribution Map of the Submergence Area

ATTACHMENT 2

Table 4.1.1 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1990												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya	2.02	2.12	2.57	**2.97**	2.04	2.63	0.85	0.36	0.73	1.10	1.49	2.16	**2.97**	0.36	
STW-5	Amahi Belha	2.90	3.00	3.06	**3.17**	3.11	3.10	1.94	1.05	1.75	2.58	2.30	2.73	**3.17**	1.05	
STW-7	Bhokraha	2.88	2.99	3.03	3.07	**3.36**	3.21	2.77	1.57	1.88	1.93	2.98	2.98	**3.36**	1.57	
STW-8	Dewanganj	3.02	3.15	3.27	3.44	**3.53**	3.32	2.01	1.29	1.96	2.02	2.61	3.04	**3.53**	1.29	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ	1.29	1.36	1.43	1.50	**1.69**	1.25	0.95	0.21	0.41	0.35	1.05	1.34	**1.69**	0.21	in the study area
STW-13	Inaruwa	4.02	3.86	3.90	4.15	**4.48**	4.10	3.08	1.81	2.16	2.19	2.74	3.79	**4.48**	1.81	

Table 4.1.2 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1991												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya	2.36	2.64	2.83	3.30	**3.56**					0.67	1.84	2.07	**3.56**	0.67	
STW-5	Amahi Belha	2.58	3.15	3.25	3.25	**3.77**					2.04	2.26	2.77	**3.77**	2.04	
STW-7	Bhokraha	3.13	3.27	3.77	4.93	**4.99**					1.36	1.68	2.33	**4.99**	1.36	
STW-8	Dewanganj	3.22	3.64	3.80	3.97	**4.37**					2.27	2.62	3.04	**4.37**	2.27	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ	1.18	1.28	1.40	2.66	**2.95**						1.23	1.61	**2.95**	1.18	in the study area
STW-13	Inaruwa	**4.06**	4.03									2.43	2.47	**4.06**	2.43	

Table 4.1.3 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1992												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya															
STW-5	Amahi Belha	4.02	4.80	5.10	**5.55**	3.63	2.40			1.10	1.32	1.80	2.80	**5.55**	1.10	
STW-7	Bhokraha	2.40	2.85	2.86	**4.60**	3.52				1.54	1.72	2.40	2.80	**4.60**	1.54	
STW-8	Dewanganj	5.19	5.74	5.99	**6.49**	6.40	3.58			1.93	2.15	2.60	3.18	**6.49**	1.93	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa	5.28												**5.28**	5.28	

Table 4.1.4 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1993												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya	4.68	4.48	4.86	4.98	5.10	**5.18**	1.91	4.63	4.48	4.16	4.70	4.86	**5.18**	1.91	
STW-5	Amahi Belha	2.20	3.35	3.50	3.75	3.95	3.90		0.70		1.27	3.09	**4.13**	**4.13**	0.70	
STW-7	Bhokraha	3.32	3.45	3.55	3.65	3.80	**3.89**	3.64		3.12	3.24	3.33	3.46	**3.89**	3.12	
STW-8	Dewanganj	4.35	4.58	4.63	4.76	4.91	**4.96**	4.75	4.44	4.34	4.47	4.94	4.72	**4.96**	4.34	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa	5.90	**6.01**	5.19	5.18	5.23	5.18	4.76	4.44	4.29	4.37	4.42	4.48	**6.01**	4.29	

Table 4.1.5 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1994												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya	5.20	5.14	5.65	5.69	**5.80**			4.06	5.53	4.63	4.88	5.06	**5.80**	4.06	
STW-5	Amahi Belha	5.07			5.89	**5.97**								**5.97**	5.07	
STW-7	Bhokraha	3.72	3.96	4.14	4.32	**4.42**			3.60	3.30	3.40	3.62	3.84	**4.42**	3.30	
STW-8	Dewanganj	4.95	5.19	5.42	5.60	**5.65**			4.85	4.49	4.60	4.83	5.07	**5.65**	4.49	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa	4.69	4.85	5.08	5.25	**5.34**			4.76	4.43	4.49	4.65	4.80	**5.34**	4.43	

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Table 4.1.6 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1995												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya															
STW-5	Amahi Belha	4.02	4.80	5.10	**5.55**	3.63	2.40			1.10	1.32	1.80	2.80	**5.55**	1.10	
STW-7	Bhokraha	2.40	2.85	2.86	**4.60**	3.52				1.45	1.72	2.40	2.80	**4.60**	1.45	
STW-8	Dewanganj	5.19	5.74	5.99	**6.49**	6.40	3.58			1.93	2.15	2.60	3.18	**6.49**	1.93	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa	5.28												**5.28**	5.28	

Table 4.1.7 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1996												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya								1.05	1.40	1.47	**1.77**		**1.77**	1.05	
STW-5	Amahi Belha	3.10	3.50	3.65		**4.35**	3.85		1.11	0.85	1.22	2.05	2.35	**4.35**	0.85	
STW-7	Bhokraha	3.25	3.45	3.75	**4.45**	**4.45**	4.24		1.45	1.60	1.65	2.24	2.55	**4.45**	1.45	
STW-8	Dewanganj	3.48	3.73	4.13	**4.98**	**4.98**	4.38		1.36	1.38	1.43		2.76	**4.98**	1.36	in the study area
STW-9	Laukahi-Ⅰ								**0.30**	0.08				**0.30**	0.08	
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa				5.48	**5.98**	4.68		1.93	1.38	1.88	2.33	3.43	**5.98**	1.38	

Table 4.1.8 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1997												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya															
STW-5	Amahi Belha	2.67	2.46	2.61	3.03	3.04	3.16	1.60	**3.71**	0.89	1.30	2.07	3.00	**3.71**	0.89	
STW-7	Bhokraha	2.87	3.02	3.07	3.24	3.33	3.43	1.91	1.61	1.76	**3.45**	2.10	1.15	**3.45**	1.15	
STW-8	Dewanganj	3.15	3.44	3.61	3.79	3.72	3.76	2.30	2.00	2.17	2.08	2.77	**3.85**	**3.85**	2.00	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa	3.88	3.93	**4.23**					1.34	1.52	2.00	3.45	2.85	**4.23**	1.34	

Table4.1.9 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1998												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya															
STW-5	Amahi Belha	1.90	1.85	2.70	2.80	2.90	2.05	**3.10**	2.70	1.13	1.23	1.43		**3.10**	1.13	
STW-7	Bhokraha	2.64	4.55	5.52	6.35	4.65	6.75	**6.90**	6.62	5.37	5.48	5.69		**6.90**	2.64	
STW-8	Dewanganj	2.98	3.85	4.70	3.80	**5.60**	4.30	5.35	5.10	3.75	3.85	4.03		**5.60**	2.98	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa	4.15	6.20	**6.45**	5.50	6.25	5.60	2.80	2.38	2.27	2.34	2.52		**6.45**	2.27	

Table4.1.10 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		1999												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya															
STW-5	Amahi Belha	2.72												**2.72**	2.72	
STW-7	Bhokraha	6.05												**6.05**	6.05	
STW-8	Dewanganj	3.31												**3.31**	3.31	in the study area
STW-9	Laukahi-Ⅰ															
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa															

Table 4.1.11 Depth to Groundwater Tablel of the Shallow Tubewell (Monthly)

Tubewell		2000												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
STW-4	Simariya			2.70	2.74	2.80	2.85	2.81	2.74	2.76	2.83	2.89	**2.93**	**2.93**	2.70	
STW-5	Amahi Belha			2.72	2.78	2.85	2.91	2.89	2.80	2.83	2.89	2.93	**2.96**	**2.96**	2.72	
STW-7	Bhokraha			5.51	5.57	5.65	5.72	5.70	5.61	5.63	5.66	5.73	**5.80**	**5.80**	5.51	
STW-8	Dewanganj			4.72	4.77	4.85	4.93	4.91	4.94	4.99	5.03	5.09	**5.14**	**5.14**	4.72	in the study area
STW-9	Laukahi-Ⅰ											1.58	**1.66**	**1.66**	1.58	
STW-12	Laukahi-Ⅱ															in the study area
STW-13	Inaruwa			4.45	6.51	6.60	6.67	6.65	6.57	6.58	6.64	6.72	**6.78**	**6.78**	4.45	

ATTACHMENT 2

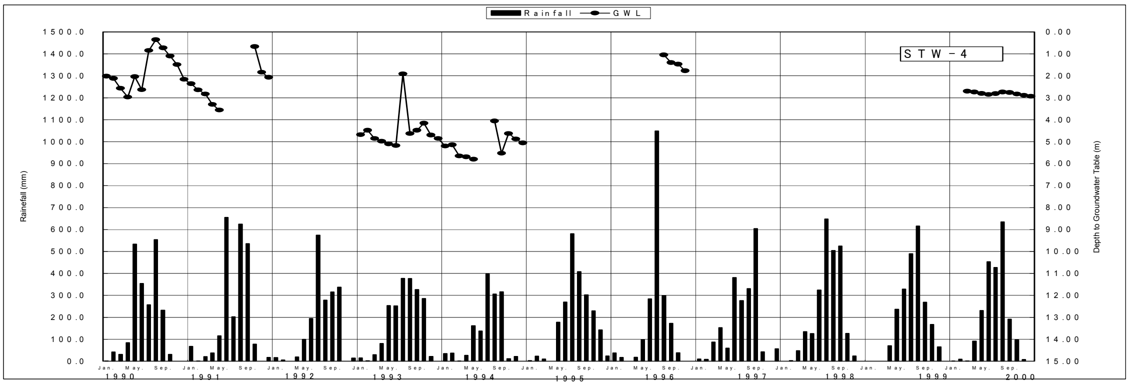

Figure 4.1.1 Depth to Groundwater Table of the Shallow Tube-well (STW-4)

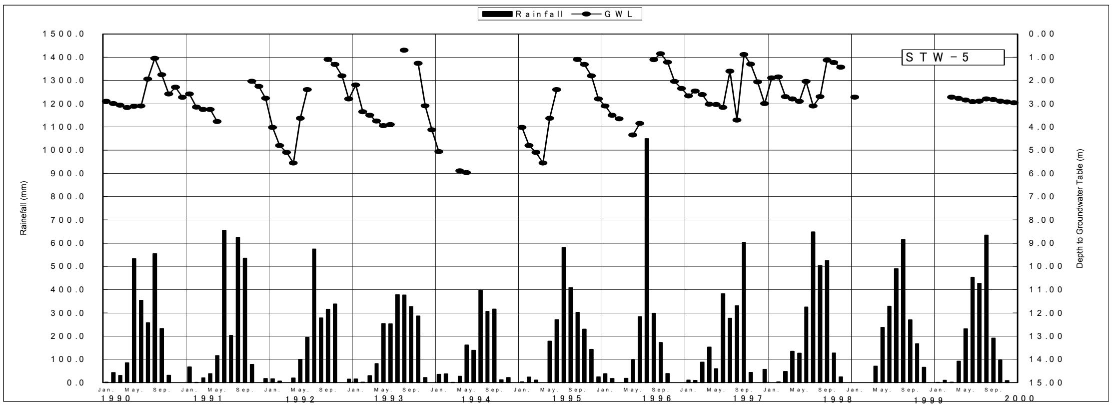

Figure 4.1.2 Depth to Groundwater Table of the Shallow Tube-well (STW-5)

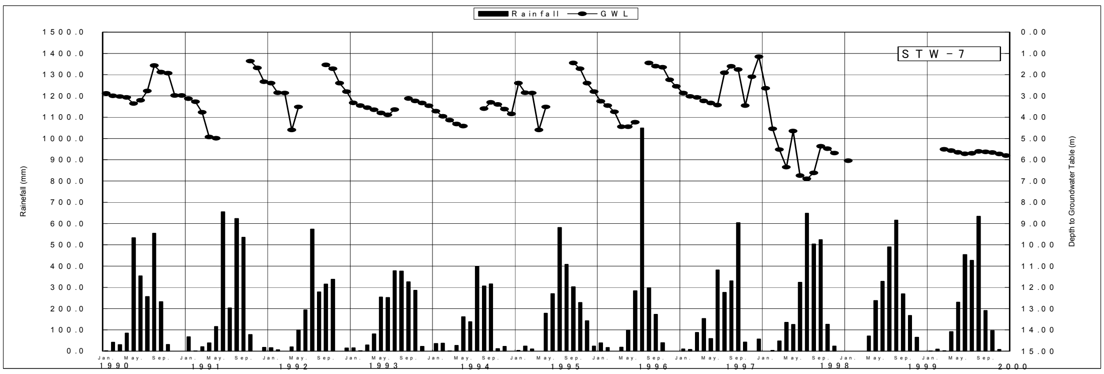

Figure 4.1.3 Depth to Groundwater Table of the Shallow Tube-well (STW-7)

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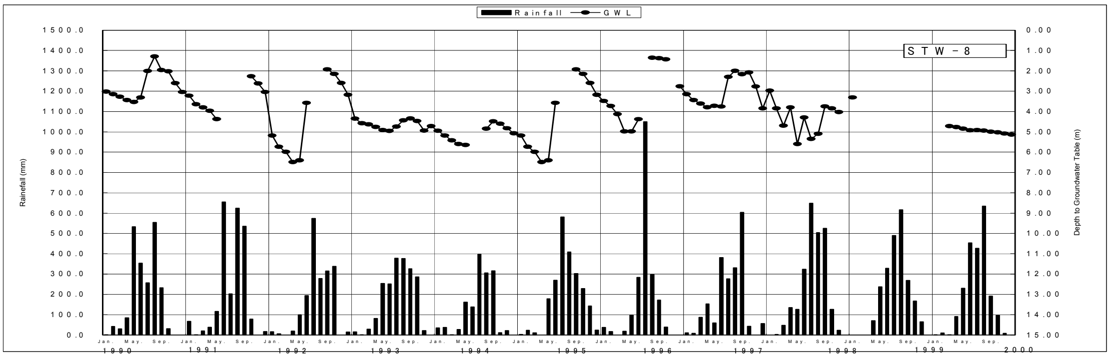

Figure 4.1.4 Depth to Groundwater Table of the Shallow Tube-well (STW-8)

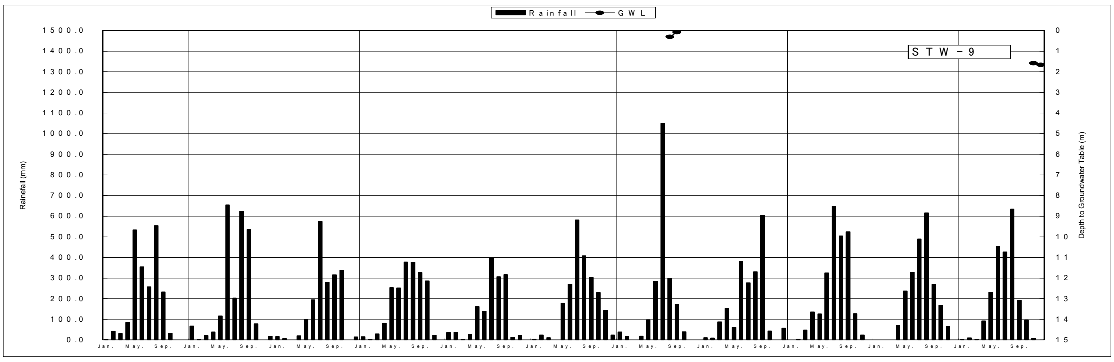

Figure 4.1.5 Depth to Groundwater Table of the Shallow Tube-well (STW-9)

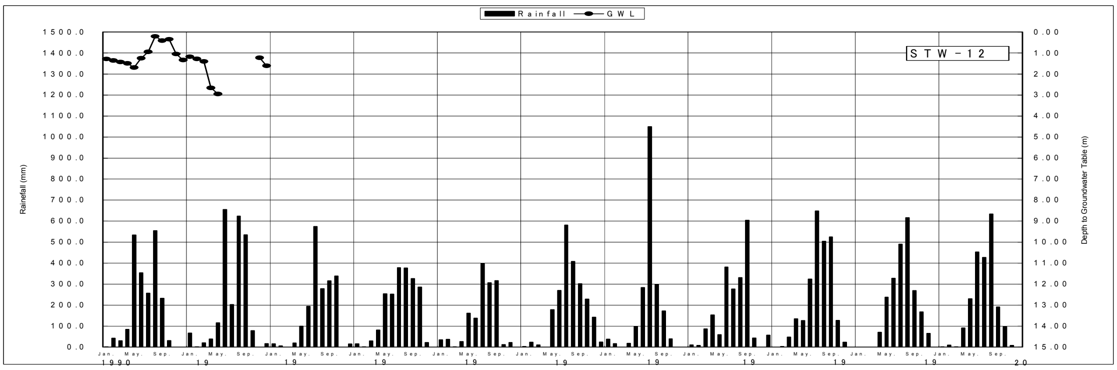

Figure 4.1.6 Depth to Groundwater Table of the Shallow Tube-well (STW-12)

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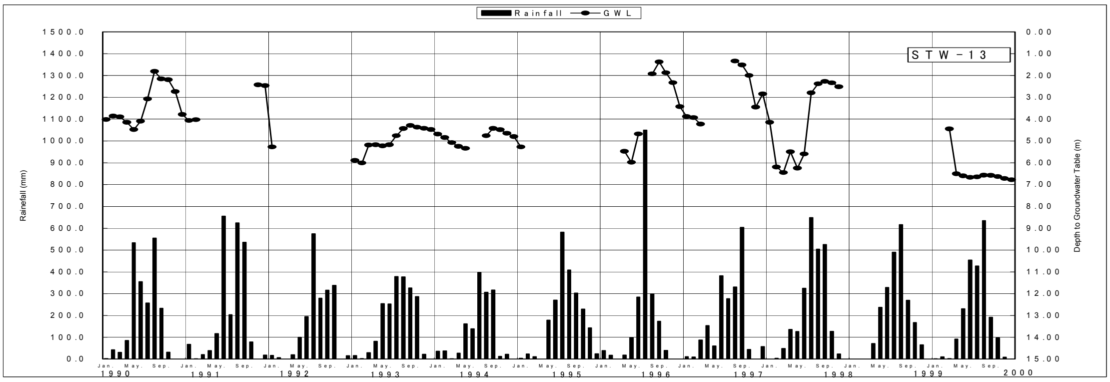

Figure 4.1.7 Depth to Groundwater Table of the Shallow Tube-well (STW-13)

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Table 4.1.12 Depth to Groundwater Table of the Deep Tubewell (Monthly)

Tubewell		1996												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
DTW-1	Laksmipur						12.47		11.70	9.95	9.23	9.05	10.75	12.47	9.05	
DTW-2	Baklauri	10.35	10.65	11.10		11.52	11.20		6.95	8.45	8.30	8.55	8.75	11.52	6.95	
DTW-10	Balaha Jhora	3.33	4.31	4.36		5.30			2.15	1.45	1.85	2.53	4.35	5.30	1.45	
DTW-15	Amduwa	2.19	2.49	2.89		3.79	2.64		1.25	0.90	1.45	2.36	2.30	3.79	0.90	
DTW-16	Madhya Harsah	3.30	3.45	3.90		4.65	4.05							4.65	3.30	in the study area

Table 4.1.13 Depth to Groundwater Table of the Deep Tubewell (Monthly)

Tubewell		1997												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
DTW-1	Laksmipur	9.87	10.16	10.60	11.04	11.46	11.88	10.29	9.89					11.88	9.87	
DTW-2	Baklauri	9.95	10.07					8.55	8.14	8.30	8.65	9.51	8.95	10.07	8.14	
DTW-10	Balaha Jhora	4.82	4.93	5.07	5.27	5.60	5.95	3.39	2.99	3.17	8.05	3.89	3.90	8.05	2.99	
DTW-15	Amduwa	2.56	2.43	2.67	2.83	2.94	3.06	1.50	0.78	0.98	1.41	5.10	4.30	5.10	0.78	
DTW-16	Madhya Harsahi															in the study area

Table 4.1.14 Depth to Groundwater Table of the Deep Tubewell (Monthly)

Tubewell		1998												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
DTW-1	Laksmipur															
DTW-2	Baklauri	8.60	9.50	8.47	7.52	8.25	8.50	9.55	9.19	8.65	8.79	8.99	9.12	9.55	7.52	
DTW-10	Balaha Jhora	4.85	4.80	4.90	4.30	6.15	5.30	2.75	2.35	1.70	1.80	1.99	4.86	6.15	1.70	
DTW-15	Amduwa	6.10	6.10	6.24		4.55	6.45	5.60	5.23	1.33	1.42	1.61	2.64	6.45	1.33	
DTW-16	Madhya Harsahi															in the study area

Table 4.1.15 Depth to Groundwater Table of the Deep Tubewell (Monthly)

Tubewell		1999												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
DTW-1	Laksmipur															
DTW-2	Baklauri															
DTW-10	Balaha Jhora		5.11	5.28	5.31	5.36	5.38	5.42	5.36	5.32	5.25	5.20	5.15	5.42	5.11	
DTW-15	Amduwa		2.91	3.02	3.06	3.10	3.13	3.16	3.12	3.07	3.02	3.00	2.98	3.16	2.91	
DTW-16	Madhya Harsahi															in the study area

Table 4.1.16 Depth to Groundwater Table of the Deep Tubewell (Monthly)

Tubewell		2000												Max.	Min.	Remarks
No.	Name	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.			
DTW-1	Laksmipur															
DTW-2	Baklauri															
DTW-10	Balaha Jhora	5.13	5.09	5.34	5.38	5.42	5.46	5.43		3.91	3.96	4.00	4.05	5.46	3.91	
DTW-15	Amduwa	2.95	2.90											2.95	2.90	
DTW-16	Madhya Harsahi															in the study area

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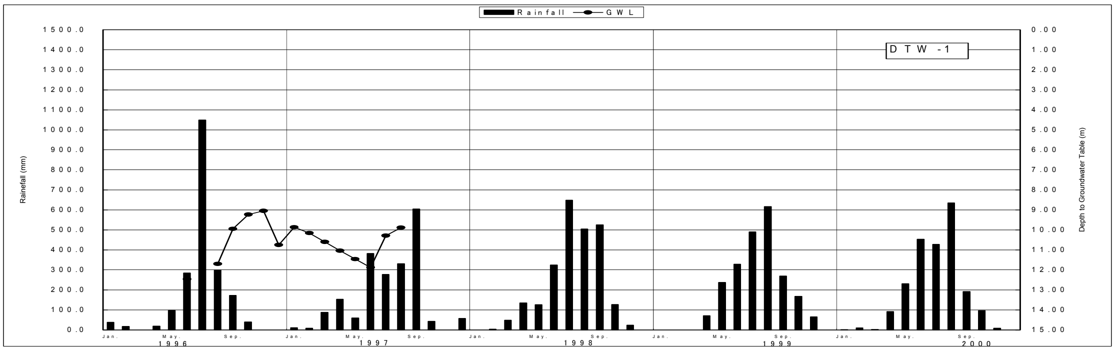

Figure 4.1.8 Depth to Groundwater Table of the Deep Tube-well (DTW-1)

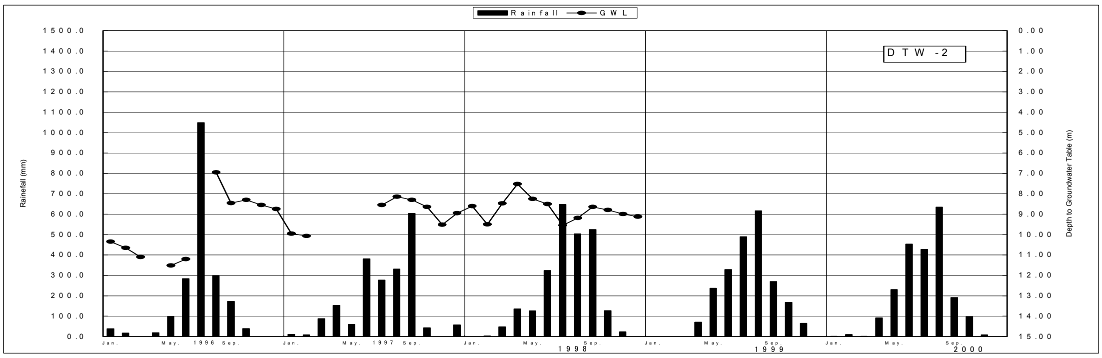

Figure 4.1.9 Depth to Groundwater Table of the Deep Tube-well (DTW-2)

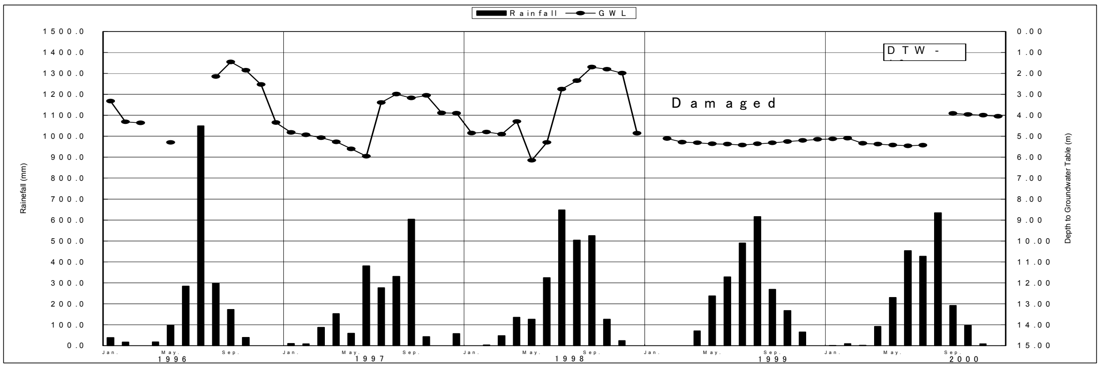

Figure 4.1.10 Depth to Groundwater Table of the Deep Tube-well (DTW-10)

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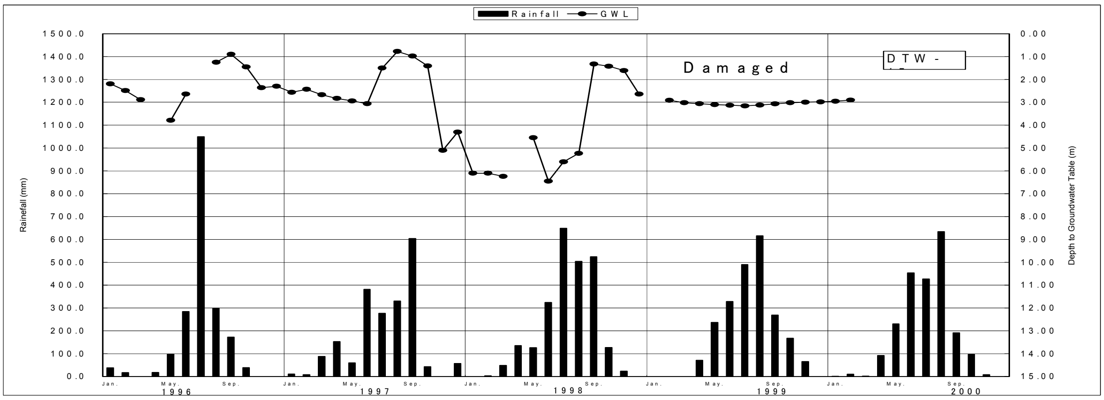

Figure 4.1.11 Depth to Groundwater Table of the Deep Tube-well (DTW-15)

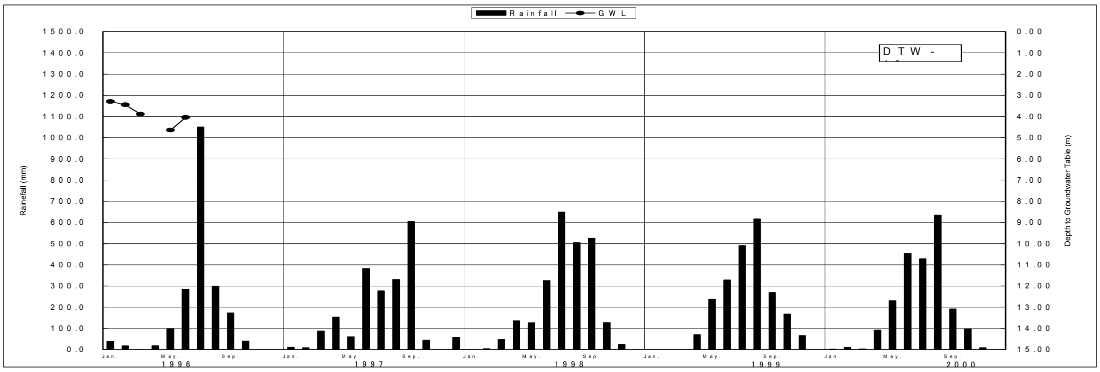

Figure 4.1.12 Depth to Groundwater Table of the Deep Tube-well (DTW-16)

ATTACHEMENT 2

Structure of the Installation Well for the Automatic Water Level Recorder at DTW-16, Madya Harsahi

9:30 a.m. May 16 2001

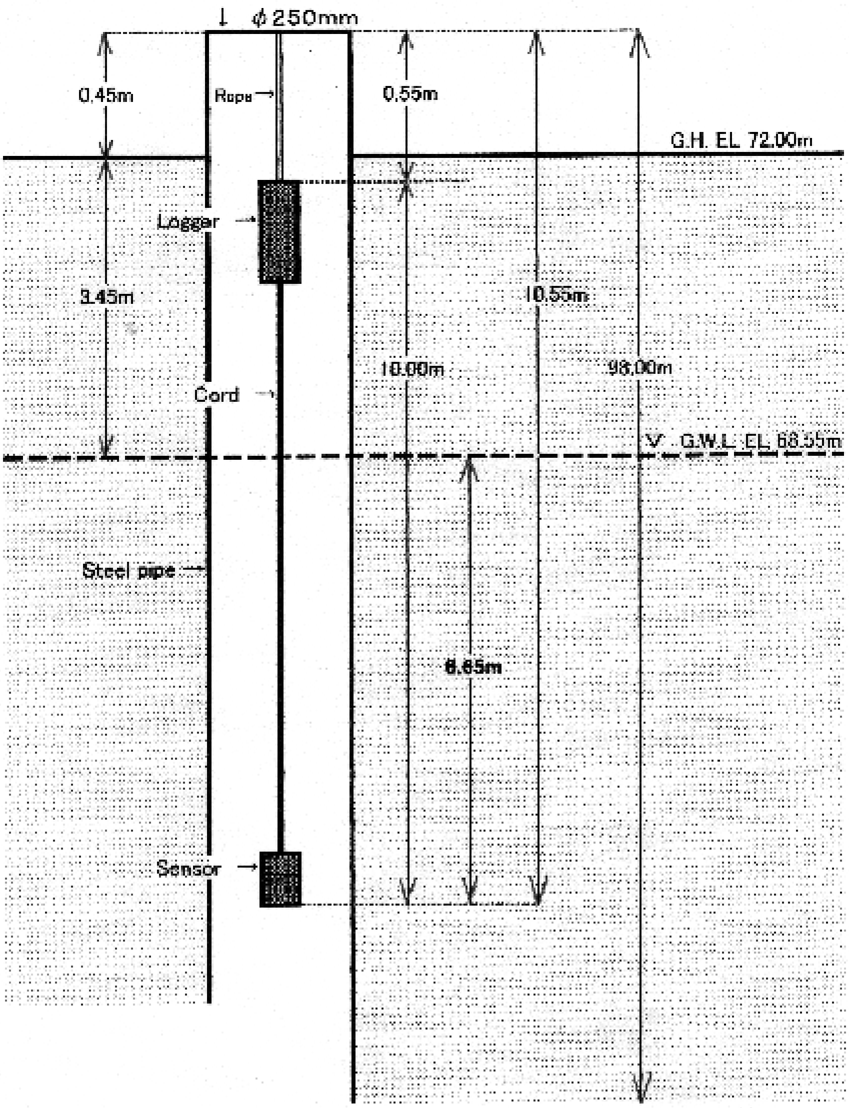

Figure 4.1.13 The Installation Well Structure of Automatic Water Level Recorder

Figure 4.1.13 The Installation Well Structure of Automatic Water Level Recorder

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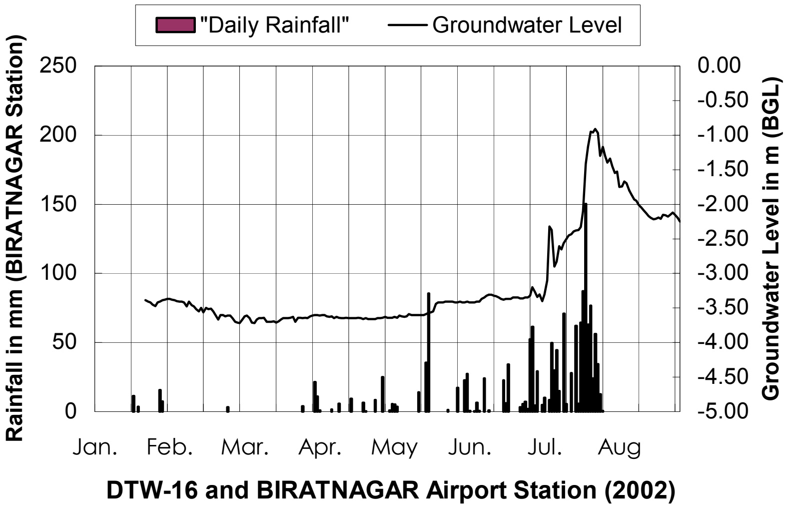

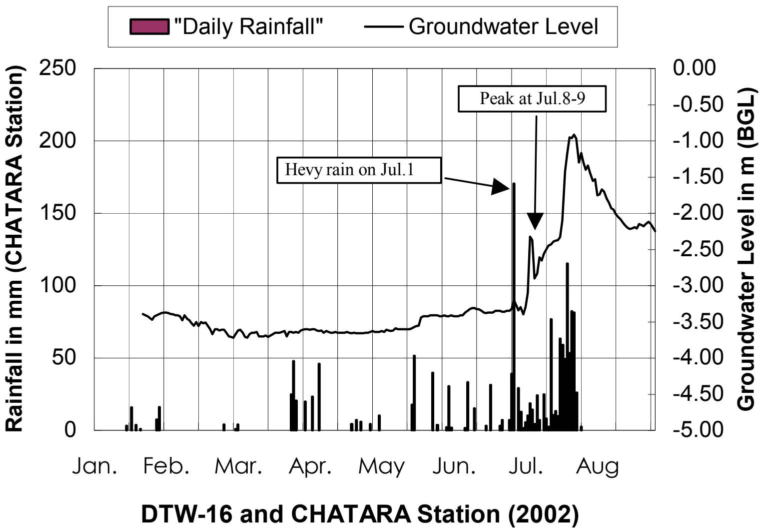

Figure 4.1.14 The Relationship of Groundwater Level to Daily Rainfall (2002)

ATTACHEMENT 2

Table 4.1.17 Depth to Groundwater Table in DTW-16 (Daily)

Unit ; m (BGL)

	2002							
Date	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
1		-3.37	-3.71*	-3.61	-3.63	-3.41	-3.20	-1.40
2		-3.38	-3.72*	-3.60	-3.64	-3.42	-3.27	-1.34
3		-3.39	-3.67*	-3.60	-3.64	-3.42	-3.34	-1.45
4		-3.40	-3.62	-3.61	-3.64	-3.41	-3.30	-1.55
5		-3.41	-3.61	-3.60	-3.63	-3.42	-3.40	-1.53
6		-3.41	-3.65*	-3.60	-3.64	-3.42	-3.30	-1.75
7		-3.42	-3.71*	-3.62	-3.61	-3.42	-3.10	-1.74
8		-3.48*	-3.72*	-3.63	-3.62	-3.41	-2.32	-1.67
9		-3.41	-3.67	-3.62	-3.63	-3.41	-2.37	-1.70
10		-3.46*	-3.65	-3.65	-3.62	-3.37	-2.83	-1.80
11		-3.48*	-3.65*	-3.63	-3.59	-3.35	-2.69	-1.86
12		-3.52*	-3.64	-3.64	-3.60	-3.32	-2.65	-1.93
13		-3.55*	-3.70*	-3.65	-3.60	-3.31	-2.56	-1.95
14		-3.50*	-3.70*	-3.65	-3.60	-3.31	-2.56	
15		-3.56*	-3.70*	-3.64	-3.60	-3.32	-2.50	
16		-3.50	-3.69	-3.65	-3.60	-3.33	-2.45	
17		-3.52*	-3.71*	-3.65	-3.60	-3.35	-2.83	
18		-3.51*	-3.69	-3.65	-3.59	-3.37	-2.39	
19		-3.55*	-3.67	-3.65	-3.57	-3.38	-2.38	
20		-3.60*	-3.65	-3.64	-3.56	-3.37	-2.37	
21		-3.67*	-3.65	-3.65	-3.55	-3.37	-2.33	
22	-3.39	-3.60	-3.65	-3.66	-3.44	-3.37	-2.10	
23	-3.41	-3.60	-3.64	-3.65	-3.42	-3.35	-1.42	
24	-3.42	-3.62	-3.63	-3.66	-3.42	-3.35	-1.17	
25	-3.45*	-3.61	-3.70*	-3.66	-3.42	-3.35	-1.95	
26	-3.47*	-3.61*	-3.64	-3.66	-3.41	-3.36	-1.96	
27	-3.42	-3.65*	-3.64	-3.66	-3.41	-3.36	-1.91	
28	-3.41	-3.70*	-3.65	-3.65	-3.41	-3.35	-1.97	
29	-3.39	-	-3.64	-3.65	-3.41	-3.35	-1.30	
30	-3.38	-	-3.65	-3.64	-3.42	-3.32	-1.17	
31	-3.37	-	-3.62	-	-3.42	-	-1.30	
Max.	-3.37	-3.37	-3.61	-3.60	-3.41	-3.31	-1.17	-1.34
Min.	-3.47	-3.70	-3.72	-3.66	-3.64	-3.42	-3.40	-1.95
Ave.	-3.41	-3.52	-3.67	-3.64	-3.55	-3.37	-2.40	-1.67

*The nearby STW is in operation.

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Table 4.1.18 Daily Rainfall at CHATARA Station (2002)

DAILY RAINFLL IN mm.

STATION : CHATARA
INDEX No. : 1316
ESTD. DATE : Sep. 1972

LAT : 26ª 49'
LONG : 87ª 10'
ELEV : 0183 M.

2002

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	170.5	NA	NA	NA	NA	NA
2	0	0	0	19.8	0	2.2	T	NA	NA	NA	NA	NA
3	0	0	1.0	0	0	30.3	29.2	NA	NA	NA	NA	NA
4	0	0	3.9	0	10.4	1.8	12.7	NA	NA	NA	NA	NA
5	0	0	0	23.3	0	0	1.4	NA	NA	NA	NA	NA
6	0	0	0	0	0	0	5.6	NA	NA	NA	NA	NA
7	0	0	0	0	0	0	10.3	NA	NA	NA	NA	NA
8	0	0	0	45.9	0	0	18.5	NA	NA	NA	NA	NA
9	0	0	0	0	0	0	14.3	NA	NA	NA	NA	NA
10	0	0	0	T	0	1.5	4.2	NA	NA	NA	NA	NA
11	0	T	0	0	0	33.3	24.2	NA	NA	NA	NA	NA
12	0	0	0	0	0	0	7.1	NA	NA	NA	NA	NA
13	0	0	0	0	0	T	T	NA	NA	NA	NA	NA
14	0	0	0	0	0	15.3	25.0	NA	NA	NA	NA	NA
15	3.2	0	0	0	0	0	8.0	NA	NA	NA	NA	NA
16	0	0	0	0	0	0	2.5	NA	NA	NA	NA	NA
17	15.8	0	0	0	0	0	76.8	NA	NA	NA	NA	NA
18	0	0	0	0	17.6	0	10.7	NA	NA	NA	NA	NA
19	3.7	0	0	0	51.5	3.2	13.2	NA	NA	NA	NA	NA
20	0	0	0	0	0	0	9.9	NA	NA	NA	NA	NA
21	1.0	0	0	0	0	31.3	63.4	NA	NA	NA	NA	NA
22	0	0	0	4.3	0	0	59.0	NA	NA	NA	NA	NA
23	0	0	0	0	0	0	49.0	NA	NA	NA	NA	NA
24	0	0	0	7.2	0	0	115.2	NA	NA	NA	NA	NA
25	0	T	T	0	0	3.0	53.5	NA	NA	NA	NA	NA
26	0	3.9	0	5.9	0	7.0	82.3	NA	NA	NA	NA	NA
27	0	0	24.7	0	39.9	0	81.5	NA	NA	NA	NA	NA
28	7.5	0	47.9	0	0	0	26.2	NA	NA	NA	NA	NA
29	16.3		20.5	0	3.6	7.0	T	NA	NA	NA	NA	NA
30	0		0	4.3	0	39.2	2.5	NA	NA	NA	NA	NA
31	0		0		0			NA	NA	NA	NA	NA
Total	47.5	3.9	98.0	110.7	123.0	175.1	976.7	-	-	-	-	-

	Jan	Feb	Mar	Apr	May	Jun	Jul
Max in 24 Hr	16.3	3.9	47.9	45.9	51.5	39.2	170.5
Date	29	26	28	8	19	30	1
# >= 1.0	6	1	5	7	5	12	27
O 1-9.9	4	1	2	4	1	7	8
F 10-24.9	2	0	2	2	2	1	7
D 25-49.9	0	0	1	1	1	4	4
A 50-99.9	0	0	0	0	1	0	6
Y >=100	0	0	0	0	0	0	2

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Table 4.1.19 Daily Rainfall at BIRATNAGAR Airport (2002)

DAILY RAINFLL IN mm.

STATION : BIRATNAGAR AIRPORT — LAT : 26ª 29'
INDEX No. : 1319 — LONG : 87ª 16'
ESTD. DATE : Jul. 1968 — ELEV : 0072 M.

2002

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	61.6	NA	NA	NA	NA	NA
2	0	0	0	21.5	0	0	4.4	NA	NA	NA	NA	NA
3	0	0	0	11.0	1.0	22.8	29.2	NA	NA	NA	NA	NA
4	0	0	0	1.1	5.6	27.4		NA	NA	NA	NA	NA
5	0	0	0	0	5.3	0.7	4.8	NA	NA	NA	NA	NA
6	0	0	0	0	3.6	T	10.0	NA	NA	NA	NA	NA
7	0	0	0	0	0	0.3		NA	NA	NA	NA	NA
8	0	0	0	0	0	6.6	8.6	NA	NA	NA	NA	NA
9	0	0	0	1.6	0	0.8	49.8	NA	NA	NA	NA	NA
10	0	0	0	0	0	0	29.8	NA	NA	NA	NA	NA
11	0	0	0	0	0	24.0	44.5	NA	NA	NA	NA	NA
12	0	0	0	5.8	0	0	15.0	NA	NA	NA	NA	NA
13	0	0	0	0	0	1.0		NA	NA	NA	NA	NA
14	0	0	0	0	0	0	71.0	NA	NA	NA	NA	NA
15	0	0	0	0	13.9	0	5.4	NA	NA	NA	NA	NA
16	0	0	0	0	0	0		NA	NA	NA	NA	NA
17	11.4	0	0	9.5	0	0	28.0	NA	NA	NA	NA	NA
18	0	0	0	0	35.5	0	0.1	NA	NA	NA	NA	NA
19	3.7	0	0	0	85.5	22.7	62.2	NA	NA	NA	NA	NA
20	0	0	0	0	0	6.1	5.7	NA	NA	NA	NA	NA
21	0	0	0	0	0	34.0	64.5	NA	NA	NA	NA	NA
22	0	0	0	6.5	0	0	87.0	NA	NA	NA	NA	NA
23	0	0	0	0.2	0	T	150.3	NA	NA	NA	NA	NA
24	0	0	0	0	T	0	63.0	NA	NA	NA	NA	NA
25	0	3.2	0	0	T	T	76.8	NA	NA	NA	NA	NA
26	0	0	0	0	0	3.1	24.0	NA	NA	NA	NA	NA
27	0	0	0	8.5	1.2	5.4	56.4	NA	NA	NA	NA	NA
28	15.7	0	4.0	0	0	7.3	34.4	NA	NA	NA	NA	NA
29	7.6		0	0	0	2.0	12.8	NA	NA	NA	NA	NA
30	0		0	25.1	0	52.4	0.8	NA	NA	NA	NA	NA
31	0		0		17.2			NA	NA	NA	NA	NA
Total	38.4	3.2	4.0	90.8	168.8	216.6	1000.1	-	-	-	-	-

	Jan	Feb	Mar	Apr	May	Jun	Jul
Max in 24 Hr	15.7	3.2	4.0	25.1	85.5	52.4	150.3
Date	28	25	28	30	19	30	23
# >= 1.0	4	1	1	9	9	13	24
O 1-9.9	2	1	1	6	5	7	5
F 10-24.9	2	0	0	2	2	3	4
D 25-49.9	0	0	0	1	1	2	6
A 50-99.9	0	0	0	0	1	1	8
Y >=100	0	0	0	0	0	0	1

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Figure 4.1.15 Groundwater Recharge System

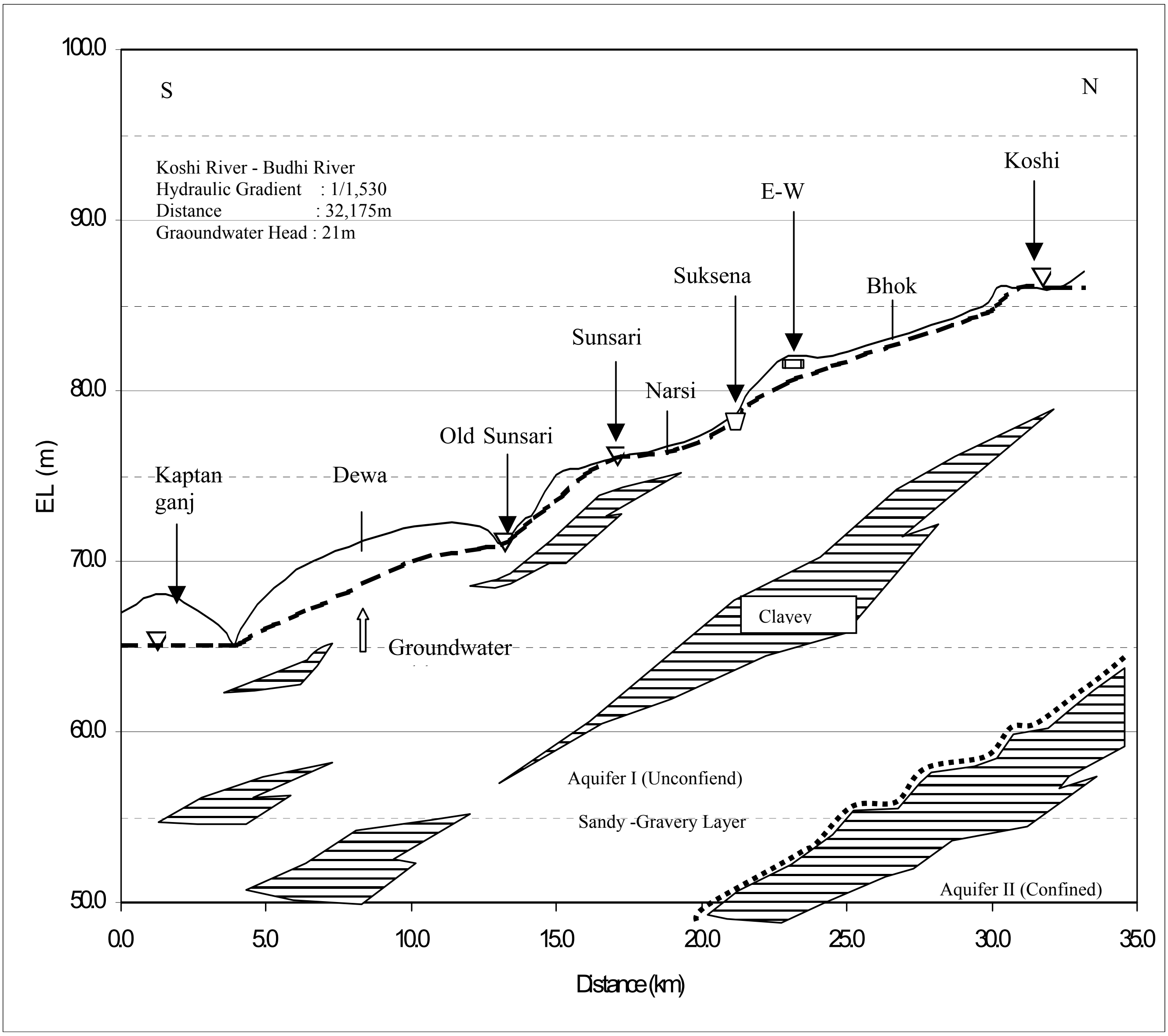

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Table 4.2.1 Pumping Test Result of the Existing Observation Shallow Tube Well

Well Name	Depth (m)	Screen Depth & Lenge (m)	Aquifer	SWL (bgl m)	Drawdown (m)	Discharge (l/s)	Q (m3/d)	Specific Capacity (l/s/m)	Y.F. (l/s/m/m)	Transmissivity (m2/d)	Logan`s Trans. (m2/d)	Storage Coefficient S	Pumping Test Date
STW-4 Simariya	41.2	15.2-19.2 4.00	Ⅰ	-	-	-	-	-	-	-	-	-	No Test Data
STW-5 Amahibela	24.4	8.7-17.8 9.10	Ⅰ	3.11	1.92	18.50	1598.40	9.64	1.06	1100	1099	-	12/2/89
STW-7 Bokraha	41.8	33.5-39.5 6.00	Ⅰ	2.51	3.27	20.00	1728.00	6.12	1.02	1200	698	-	26/12/88
STW-8 Dewanganji	18.3	11.7-17.8 6.10	Ⅰ	3.03	1.01	24.00	2073.60	23.76	3.90	(15000)	2710	-	23/12/88
STW-9 Laukai Ⅰ	13.7	5.6-9.1 3.50	Ⅰ	1.14	3.00	20.00	1728.00	6.67	1.91	2400	760	-	25/12/88
STW-10 Satyajhora	16.8	8.7-14.8 6.10	Ⅰ	2.58	2.90	20.00	1728.00	6.90	1.13	4300	787	-	28/12/88
STW-12 Lauki Ⅱ	36.9	13.7-14.5,19.5-28.7 10.00	Ⅰ	1.01	4.54	20.00	1728.00	4.41	0.44	1600	502	-	10/1/89
STW-13 Inarwa	50.9	16.3-19.4,31.6-37.7 6.20	Ⅰ	3.47	1.50	21.00	1814.40	14.00	2.26	900	1597	-	12/1/89
DTW-12 Jalparur	27.5	- 2.86	Ⅰ	3.28	-	2.00	172.80	-	-	-	-	-	1977/78
Max.	50.9	10.00		3.47	4.54	24.00	2073.60	23.76	3.90	4300.00	2710.00	-	
Min.	13.7	2.86	Ⅰ	1.01	1.01	2.00	172.80	4.41	0.44	900.00	502.00	-	
Ave.	30.2	5.98		2.52	2.59	18.19	1571.40	9.58	1.67	1916.67	1164.71	-	

Source ; Shallow Groundwater Investigation in Terai, Sunsari. (UNDP, GWRDP,Jun. 1989)

Table 4.2.2 Pumping Test Result of the Existing Observation Deep Tube Well

Well Name	Depth (m)	Screen Depth & Lenge (m)	Aquifer	SWL (bgl m)	Drawdown (m)	Discharge (l/s)	Q (m3/d)	Specific Capacity (l/s/m)	Y.F. (l/s/m/m)	Transmissivity (m2/d)	Logan`s Trans. (m2/d)	Storage Coefficient S	Pumping Test Date
DTW-2 Baklouri	102.13	41-44.2,48.7-60.9,80.7-99 33.24	Ⅰ, Ⅱ,Ⅲ	11.63	1.62	30.00	2592.00	18.52	0.56	-	2112	-	1992/93
DTW-9 Jhunka	55.48	42-44.5,48.7-54.7 8.74	Ⅰ, Ⅱ	5.00	5.70	39.00	3369.60	6.84	0.78	162757	780	-	1977/78
DTW-10 Balahajhora	69.89	52.2-67.5 12.50	Ⅱ	5.57	12.17	35.79	3092.26	2.94	0.24	627000	335	-	1978/79
DTW-15 Amuduba	120.00	26.52-34,51-59,106-116 25.50	Ⅰ, Ⅱ,Ⅲ	4.13	2.51	35.00	3024.00	13.94	0.55	2400	1590	-	1994/95
DTW-16 Madhyaharsia	89.00	31.5-39.5,50-52,73-85 22.00	Ⅰ, Ⅱ,Ⅲ	4.15	2.07	36.00	3110.40	17.39	0.79	4300	1983	-	1994/95
Max.	120.00	33.24		11.63	12.17	39.00	3369.60	18.52	0.79	627000.00	2112.00	-	
Min.	55.48	8.74	Ⅰ Ⅱ Ⅲ	4.13	1.62	30.00	2592.00	2.94	0.24	2400.00	335.00	-	
Ave.	87.30	20.40		6.10	4.81	35.16	3037.65	11.93	0.58	199114.25	1360.00	-	

Source ; Investigation Deep Tubewell in Terai, Sunsari. (GWRDP-Biratnagar ,Sep. 1996)

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Table 4.2.3 Result of Pump Running Test of STW

Location	Pump	STW			Pump Running Test		
		Depth (m)	Establish	Operating Time (h/Y)	Quantity (l)	Running Time (s)	Discharge (l/s)
RAMNAGAR BHUTAHA VDC Ward #1 Nathunitol	Centrifugal Pump 5.5hp 4”	15	1999	500hr/Y Dec. – Feb. 0.67ha/6hr	147	6.7	21.9
					147	6.6	22.2
HARINAGARA VDC Ward #5 Kumaltol	Centrifugal Pump 5.5hp 4”	27	1993	1500hr/Y 1200hr/(Dec.-Feb.)	147	7.3	20.1
					147	7.8	18.8
MADHYA HARASAHI VDC Ward #3 Madhya Harasahi	Centrifugal Pump 7hp 4”	14	1999	25hr/Y/ 3.35ha for Wheat	147	6.2	23.7
					147	6.3	23.3
DEWANGANJ VDC Ward #9 Yadavtol	Centrifugal Pump 5.5hp 3”	18	1998	1500hr/(Dec.-Feb.) for Wheat, Vegetable	147	10.7	13.7
					147	10.8	13.6
KAPTANGANJ VDC Ward #4 Shankarpur	Centrifugal Pump 5.5hp 4”	15	1996	1200hr/(Dec.-Feb.) for Wheat, Vegetable	147	Pump trouble	
					147	-	-
Max.	**4” (100mm)**	-	-	-	147	6.2	23.7
Min.		-	-	-	147	7.8	18.8
Ave.		-	-	-	**147**	**6.8**	**21.6**
Max.	**3” (75mm)**	-	-	-	147	10.7	13.7
Min.		-	-	-	147	10.8	13.6
Ave.		-	-	-	**147**	**10.75**	**13.65**

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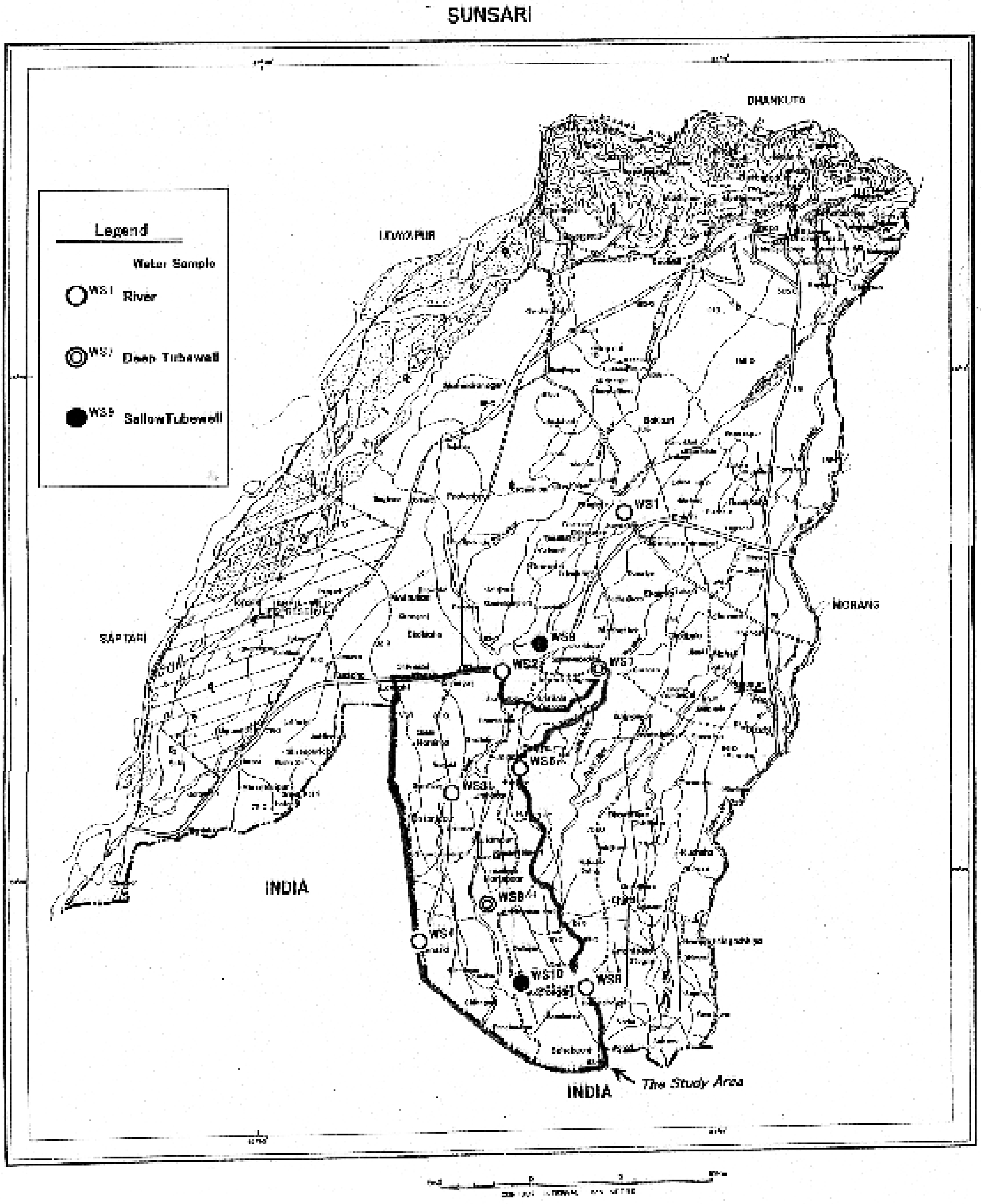

Figure 4.3.1 Location Map of Water Quality Test Sample

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Table 4.3.1 Water Quality Test Items

Test	Test Item	Note
In-site test	**Water temperature** [°C]	
	pH : Hydrogen ion concentration [pH]	
	EC : Electric conductivity [mS/cm]	
	DO : Dissolved Oxygen [mg/l]	
	Colon bacillus colony number [n/100ml]	Coliform group
Laboratory test	Nutrient salty materials : **(NO3, NO2, NH4, PO4)** [mg/l]	
	Sediment **(Carbon, Nitrogen)** [mg/l]	
	Soluble ion **(Ca, Mg, K, Na, Cl, SO4, HCO3)** [mg/l, meq/l]	**Trilliner Plotting SAR**
	BOD : Biochemical Oxygen Demand [mg/l]	
	DOC : Dissolved Organic Carbon [mg/l]	substitute **KMnO4**
	As : Arsenic [mg/l]	
	Fe : Iron [mg/l]	with HN3(5ml/l)
	Mn : Manganese [mg/l]	with HN3(5ml/l)

Table 4.3.2 Guidelines for Interpretation of water quality for irrigation

Potential Irrigation Problem	Units	Degree of restriction on use		
		None	Slightly Moderate	Severe
Salinity (affects crop water availability)				
EC or	dS/m	< 0.75	0.75 – 0.3	> 3.0
TDS	mg/l	< 450	450 – 2000	> 2000
Infiltration (affects infiltration rate of water into the soil, evaluate using EC and SAR together				
SAR = 0.30	–	> 0.7	0.7 – 0.2	< 0.2
SAR = 3.60	–	> 1.2	1.2 – 0.3	< 0.3
SAR = 6.12	–	> 1.9	1.9 – 0.5	< 0.5
SAR = 12.20	–	> 2.9	2.9 – 1.3	< 1.3
SAR = 20.40	–	> 5.0	5.0 – 2.9	< 2.9
Specific ion toxicity (affects sensitive crops)				
Sodium (Na): Surface Irrigation	SAR	< 3.0	3.0 – 9.0	> 9.0
Sprinkler Irrigation	mg/l	< 69.0	> 69.0	
Chloride (Cl): Surface Irrigation	mg/l	< 141.8	141.8 – 354.6	> 354.6
Sprinkler Irrigation	mg/l	< 106.4	> 106.4	
Boron (B)	mg/l	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous effects (affects susceptible crops)				
Nitrate–Nitrogen (NO_3–N)	mg/l	< 5.0	5.0 – 30.0	> 30.0
Bicarbonate (HCO_3)	mg/l	< 91.5	91.5 – 537.0	> 537.0
pH	–	Normal Range (6.5–8.4)		

Source: Water quality for agriculture, FAO Irrigation and Drainage Paper 29, Rev.1, FAO Rome, 1985
EC = Electrical Conductivity, TDS = Total Dissolved Solids, SAR = Sodium Absorption Ratio,
meq = milliequivalent, dS/m = desi Simen/meter

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Table 4.3.3 Result of Water Quality Test of the Existing Observation Wells

Sample			In-site-test							Remarks
No.	Name	Mon.	Temp.[°C] t	pH[pH]	EC [mS/m]λ18	DO [mg/l]	Col. [n/100ml]	Total c. [n/10ml]	ORP [m/V]	
7	DTW 10	May	27.7	8.01	14.91	1.80	32	a lot	+ 249	Deep tubewell
		Aug.	28.4	8.46	10.40	0.04	3	few	-	
8	DTW 16	May	27.6	7.54	28.28	1.25	21	a lot	+ 209	Deep tubewell
		Aug.	29.9	8.10	25.70	0.08	non	non	-	
9	STW 13	May	28.3	7.24	10.35	3.79	36	a lot	+ 219	Shallow tubewell
		Aug.	28.4	7.70	12.00	0.02	non	non	-	
10	STW 8	May	27.2	7.13	20.81	1.24	a lot	a lot	+ 233	Shallow tubewell
		Aug.	27.6	7.40	40.30	0.27	non	non	-	
WHO			-	7.5 - 8.5	-	-	-	-	-	Desirable Level (Tap Water)
FAO			-	-	-	-	-	-	-	

Sample			Laboratory test: Nutrient salty materials [mg/l]				Soluble ion [mg/l]												Remarks
No.	Name	Mon.	NO_3^-	NO_2^-	NH_4^-	PO_4^-	Ca^+	Mg^+	K^+	Na^+	Cl^-	SO_4^-	HCO_3^-	BOD [mg/l]	$KMnO_4^+$ [mg/l]	As [mg/l]	Fe [mg/l]	Mn [mg/l]	
7	DTW 10	May	0.02	0.04	0.10	<0.01	10.00	7.00	7.10	13.50	9.30	<1	100.0	2.1	2.6	<0.01	<0.01	0.08	
		Aug.	0.19	0.10	0.11	0.05	11.00	5.00	6.70	11.50	7.40	<1	105.0	2.0	6.7	<0.01	0.41	0.08	Deep tubewell
8	DTW 16	May	0.03	0.01	0.41	<0.01	40.00	16.00	5.30	8.00	9.30	<1	212.0	2.0	2.7	<0.01	<0.01	<0.01	
		Aug.	0.21	<0.01	<0.01	0.15	49.00	14.00	6.87	8.95	5.60	<1	238.0	1.9	6.9	<0.01	1.07	0.24	Deep tubewell
9	STW 13	May	0.88	0.51	1.42	<0.01	8.00	6.00	8.80	6.60	9.30	4.00	61.0	2.1	2.7	<0.01	0.01	0.01	
		Aug.	0.17	0.02	1.61	0.03	10.00	3.00	10.10	6.96	9.30	3.00	61.0	1.8	10.1	<0.01	2.85	0.34	Shallow tubewell
10	STW 8	May	0.48	<0.01	0.55	0.11	46.00	24.00	9.90	13.70	18.60	<1	281.0	1.5	1.7	<0.01	<0.01	<0.01	
		Aug.	0.30	<0.01	0.40	0.08	52.00	26.00	22.20	13.70	20.50	1.00	286.0	1.7	22.2	<0.01	8.38	0.74	Shallow tubewell
WHO			(50)	(3)	-	-	75.00	30.00	-	(200.0)	200.0	200.0	-	-	-	(0.01)	0.10	0.10	(Tap Water)
FAO			-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.00	0.20	

Sampling ; May and August 2001.

In-site-test [MODEL : D-24T, HORIBA, Ltd.]
Temp. : Water temperature [°C]
pH : Hydrogen ion concentration [pH]
EC : Electric conductivity [mS/m]
[$\lambda_{18} = \lambda t\{ 1+\alpha(18-t) \}$
***λ** t ; test value, **t** ; Water temperature*
α = 0.02
DO : Dissolved Oxygen [mg/l]
Col. : Colon bacillus colony number [n ; Coliform group
Total c. : Total colonies [n/10ml] ; extra item
ORP : Oxidation-Reduction Potential [m/V]
[=E+206-0.7(t-25)] E; test value, t; W. temperature

Laboratory test [GWRDP-Kathmandu]
Nutrient salty materials : **(NO3, NO2, NH4, PO4)** [mg/l]
Sediment **(Carbon, Nitrogen)** [mg/l] ; Trilliner Plotting, SAR
Soluble ion **(Ca, Mg, K, Na, Cl, SO4, HCO3)** [mg/l]
BOD : Biochemical Oxygen Demand [mg/l]
KMnO4 has substituted **DOC** : Dissolved Organic Carbon [mg/l]
As : Arsenic [mg/l]
Fe : Iron [mg/l]; treat a sample with HN3 [5ml/l] in site.
Mn : Manganes ; treat a sample with HN3 [5ml/l] in site.

WHO ; International Standards for Drinking Water Quality (1995).
FAO ; Recommended maximum concentrations of trace in irrigation water (1985).
* Coliform Bacteria
1. Coliform bacteria should not be present in 100ml of any two consecutive sample of drinking water;
2. No sample should contain more than 10 coliform becteria per 100ml;
3. Throughout any year, 95 percent samples should not contain any coliform bacteria in 100ml;
4. No 100 sample should contain E. coli;

Condition of Tubewell

Sample No.	Name	G.W.L. [bglm	Screen depth [m]	Pipe	Constructed in ...
7	)TW-1(	5.20	52.2 - 67.5	steel	29/10/1978
8	)TW-1(	3.40	-39.5, 50.0-52.0, 73.0-8	steel	16/11/1994
9	STW-1	4.10	33.35 - 39.63	steel	15/11/1988
10	STW-8	3.74	11.74 - 17.84	steel	20/11/1988

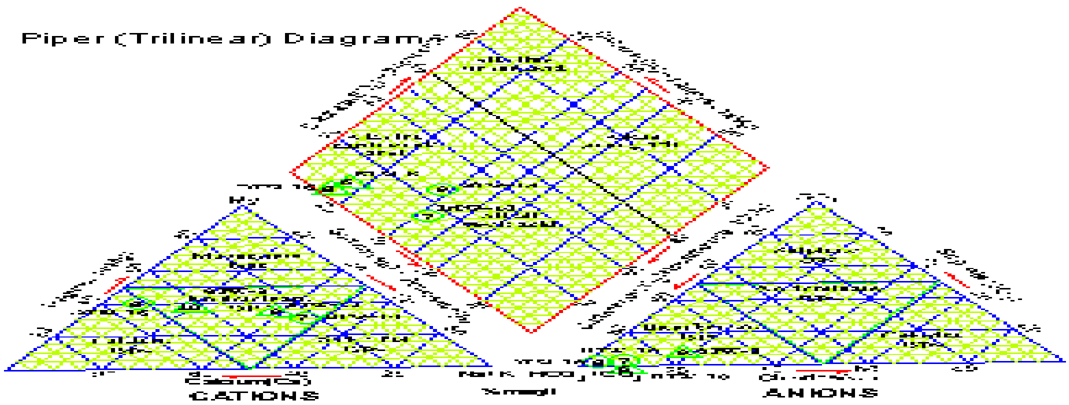

Figure 4.3.2 Trilinear Diagram of Water Samples

ATTACHMENT 2

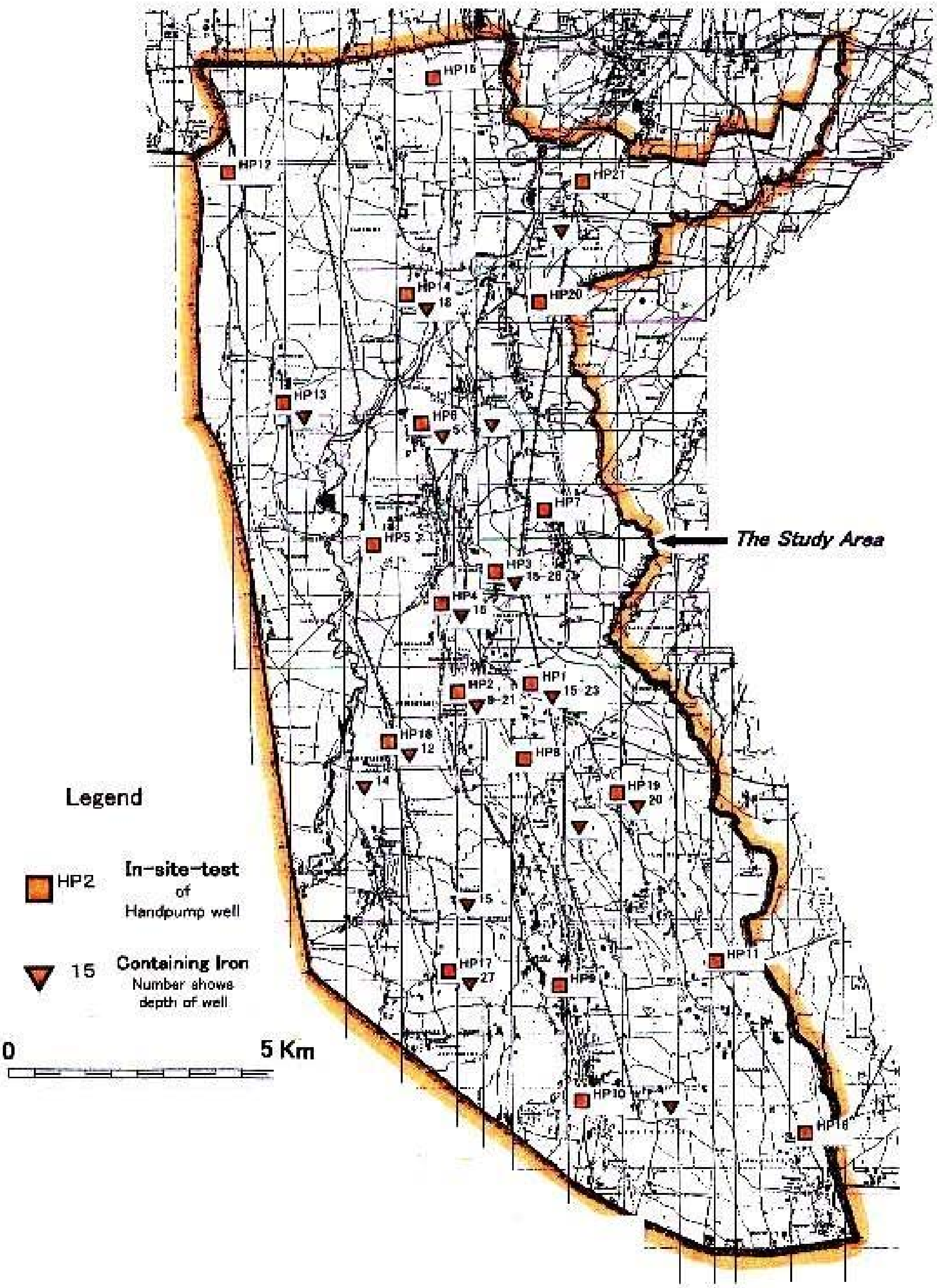

Figure 4.3.3 Location Map of Water Quality In-site Test

ATTACHMENT 2

Table 4.3.4 Result of Water Quality Test of the Hundpump Wells (May 2001)

Sample			Well			In-site-test								Remarks
No.	Location		Total depth	Screen depth	Material	Temp. [°C]	pH [pH]	EC [mS/m] λ18	Col. [n/100ml]	Total c. [n/10ml]	ORP [mV]	Color	Odor	
	VDC	Village	[m]	[m]	Casing / Screen									
1	HA	Harinagara	15.0	13.2 to 15.0	galvanizing / PVC (1.8m)	28.10	6.24	27.77	a lot	14	+246	clear	odorless	UNICEF, 12/03/1993. 18 wells/village. ..contains iron.
2	HA	Harinagara	9.0	-	-	27.70	7.18	28.37	a lot	8	+211	clear	odorless	constructed in 1998. ..chenged to red after 2-3 hr.
3	HA	Khadahitol	15.0	12.0 to 13.8	galvanizing(3m)/PVC(1.8m)	25.50	6.83	33.24	Nil	1	+209	clear	odorless	Water color chenged to red after 4-5 hr.
4	RB	Teliyari	7.5	-	steel / bamboo	27.00	8.43	56.17	a lot	8	+226	light yellow	odorless	constructed in 13/05/2001. ..cheng to red after 6-8 hr.
5	RB	Chamrari	7.5	-	steel / bamboo	27.60	7.25	-	a lot	6	+230	clear	odorless	
6	RB	Chaprahi	5.0	-	-	28.40	6.96	-	a lot	1		light yellow	odorless	constructed in 1999. Containing iron above 5m.
7	GA	Gautampur	4.5	-	-	24.50	6.89	38.80	Nil	8	+212	clear	odorless	constructed in 1996.
8	MA	Tatmatol	4.5	3.0 to 4.5	galvanizing / PVC (1.5m)	25.50	7.02	-	14	19	+227	light yellow	odorless	constructed in 16/10/2000
9	DE	Dewanganji	9.0	7.5 to 9.0	galvanizing / PVC (1.5m)	25.80	6.92	46.08	-	-	+235	light yellow	odorless	constructed in 2001
10	KA	Shankarpur	4.5	3.0 to 4.5	galvanizing / PVC (1.5m)	25.00	6.11	28.12	-	-	+231	clear	odorless	constructed in 1995 by the Government.
11	RS	Khairatol	4.5	3.0 to 4.5	galvanizing / PVC (1.5m)	25.60	5.99	-	-	-	+263	light yellow	odorless	constructed in 1998. Very few water above 17m.
12	NS	Ulti Jhagarahi	5.0	3.5 to 5.0	galvanizing / PVC (1.5m)	27.20	5.81	-	-	-	+271	light yellow	odorless	constructed in 1995.
13	NS	Soniyahi Myatol	13.5	11.7 to 13.5	galvanizing(3m)/PVC(1.8m)	27.70	7.25	55.05	-	-	+219	light yellow	odorless	constructed in 1994, UNICEF.
14	NS	Kalichok	18.0	16.2 to 18.0	galvanizing(1.5m)/PVC(1.8m	29.10	7.32	44.42	-	-	+234	clear	odorless	1988. Containing iron above 18m.
15	NS	Janatachoc Jirat	4.5	3.0 to 4.5	galvanizing / PVC (1.5m)	26.90	7.47	-	-	-	+231	clear	odorless	constructed in 1995.
16	SA	Dhauktol	10.0	5.0 to 10.0	galvanizing(5m)/PVC(5m)	26.20	6.69	-	-	-	+240	light yellow	odorless	constructed in 1995.
17	GH	Kobilasa Daksintol	27.5	22.5 to 27.5	galvanizing(5m)/PVC(5m)	26.10	7.30	-	-	-	+227	clear	odorless	1990, UNICEF. Below 24m is water. Containing iron(15
18	BA	Sukhsena	12.0	7.0 to 12.0	galvanizing(5m)/PVC(5m)	27.40	7.29	37.76	-	-	+207	clear	odorless	2000, Containing iron.
19	RS	Sinuwari	20.0	15.0 to 20.0	galvanizing(5m)/PVC(5m)	27.30	7.03	-	-	-	+236	clear	odorless	Mar. 2001. Containing iron.
20	JA	Chaudharitol	18.0	13.0 to 18.0	galvanizing(5m)/PVC(5m)	27.70	6.71	-	-	-	+230	clear	odorless	constructed in 2000.
21	BA	Telitol	9.0	4.0 to 9.0	galvanizing(4m)/PVC(5m)	25.80	6.43	23.21	-	-	+267	clear	odorless	constructed in 1994.
WHO						-	6.5 - 9.2	-	*	*	-			

In-site-test ; 14/05/2001-21/05/2001

WHO ; International Standards for Drinking Water Quality (1995).
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3. Throughout any year, 95 percent samples should not contain any coliform bacteria in 1
4. No 100 sample should contain E. coli;

In-Site-Test [MODEL : D-24T, HORIBA, Ltd.]
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α = 0.02
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Col. : Colon bacillus colony number [n/100ml] ; Coliform group
Total c. : Total colonies [n/10ml]
ORP : Oxidation-Reduction Potential [mV]
[=E+206-0.7(t-25)] , ***E*** *; test value,* ***t*** *; Water temperature*

VDC ; Village Development Committee
SA ; SAHEBGANJI
KA ; KAPTANGANJI
DE ; DEWANGANJI
GH ; GHUSKI
RS ; RAJGANJI SINUWARI
MA ; MADHAYA HARSAHI
BA ; BASANTAPUR
HA ; HARINAGARA
RB ; RAMNAGAR BHUTAHA
JA ; JALPAPUR
NA ; NARSIMHA
GA ; GAUTAMPUR
BB ; BABIYA

ATTACHMENT-2

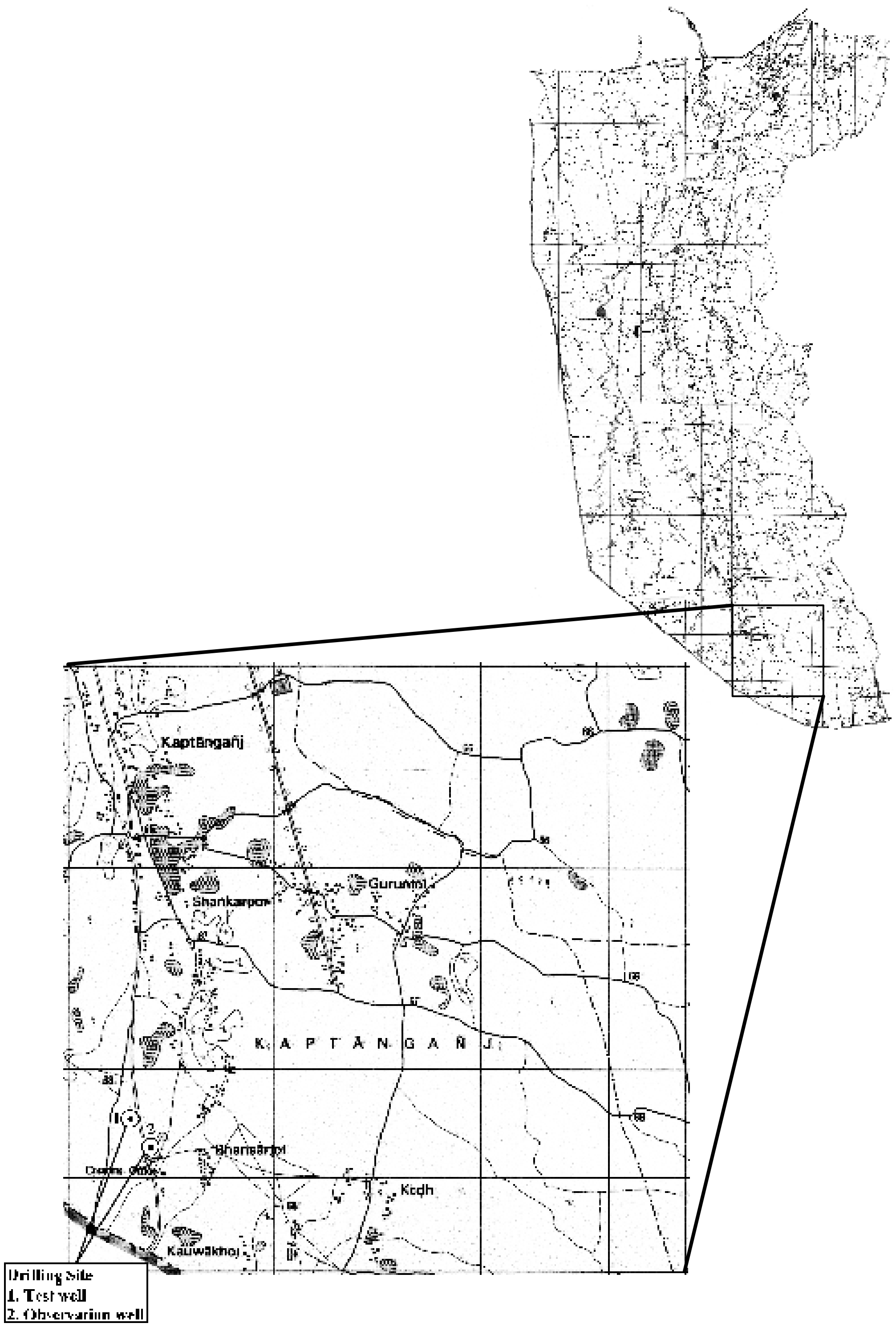

Figure 4.4.1 Drilling Site Location Map

Figure 4.4.1 Location Map of Drilling Site