HYDROGEOLOGICAL STUDY IN MID-WESTERN PART

DEUKHARI DUN VALLEY
Of
SATBARIA REGION
DANG DISTRICT MID WESTERN NEPAL

A Dissertation submitted to the

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In Partial Fulfillment of the Requirement for the Award of Degree of

Master of Science in Geology

By

Uttam Raj Singh

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CENTRAL DEPARTMENT OF GEOLOGY

Kirtipur, Kathmandu

NEPAL

RECOMMENDATION

This is to certify that MR Uttam Raj Singh has completed this dissertation work entitled **"HYDROGEOLOGICAL STUDDY IN MID- WESTERN PART OF SATABARIA REGION, DANG DISTRICT WESTERN NEPAL"** as a partial fulfillment of the requirements of the requirements of M.Sc. degree in Geology under my supervision. To my knowledge this work has not been submitted for any other degree.

………………………………..

Dr Suresh Das Shrestha

(Supervisor)
Associate Professor,

Central Department of Geology
Tribhuvan University
Kathmandu, Nepal

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF GEOLOGY

KIRTIPUR, KATHMANDU

NEPAL

CERTIFICATE OF APPROVAL

On the recommendation of Dr. Suresh Das Shrestha this dissertation work of Mr. Uttam Raj singh is approved for the examination and is submitted to the Tribhuvan University in partial fulfillment of the requirements of M.Sc. degree in Geology.

………………………………

Head of the Department

Central Department of Geology

Tribhuvan University

TRIBHUVAN UNIVERSITY

CENTRAL DEPARTMENT OF GEOLOGY

KIRTIPUR, KATHMANDU

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BOARD OF THE EXAMINERS

Recommended by: ……………………………. `
Dr. Suresh Das Shrestha (Supervisor)

Approved by: ……………………………..
Dr. L.P Paudel (Head of the Department)

Examined by: ……………………………
Internal Examiner

Examined by: …………………………….
External Examiner

Date:

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Uttam Raj Singh

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ABBREVATIONS

AD	Anno Domini
amsl	above mean sea level
AWWA	American Water work Association
bgl	below ground level
CBS	Central Bureau of Statistics
DMG	Department of Mines and Geology
DTW	Deep Tube Well
DW	Dug well
EC	Electrical Conductivity
ENPHO	Environmental and Public Health Organization
Fig	Figure
GWIP	Ground Water Irrigation Project
GWRDP	Ground Water Resource Development Project
HMG/N	His Majesty Government/Nepal
km	Kilometer
km^2	Square kilometer
l/sm	litre per second meter
m	meter
m-amsl	meter above mean sea level
m-bgl	meter below ground level
MBT	Maim Boundary Thrust
MCT	Main Central Thrust
MFT	Main Frontal Thrust
mg/l	milligram per liter
mm	millimeter
NASC	National Arsenic Steering Committee
NWSC	Nepal Water Supply Corporation
Ppb	Parts per billion
STW	Shallow Tube Well
SWL	Static Water Level
TU	Tribhuvan University
UNDP	United Nation Development Programme
WHO	World Health Organization

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CHAPTER 1

INTRODUCTION

1.1 Background

Due to uneven distribution of rainfall both in time and space, the surface water resources are unevenly distributed. This has resulted in increased emphasis on development of groundwater resources. The simultaneous development of groundwater, especially through dug wells and shallow tube wells, will lower water table, provide vertical drainage and thus can prevent water-logging and salinaization.

On the other hand, continuous increased withdrawals from a groundwater reservoir in excess of replenish able recharge may result in regular lowering of water table. In such a situation, a serious problem is created resulting in drying of shallow wells and increase in pumping head for deeper wells and tube wells. This has led to emphasis on planned and optimal development of water resources. An appropriate strategy will be to develop water resources with planning based on conjunctive use of surface water and groundwater.

The 'National Water Policy' adopted by the Government of Nepal, regards water as one of the most crucial elements in developmental planning. Regarding groundwater, it recommends that

- ❖ There should be a periodical reassessment of the groundwater potential on a scientific basis, taking into consideration the quality of the water available and economic viability of its extraction.
- ❖ Exploitation of groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of over-exploitation of groundwater need to be effectively prevented. Groundwater recharge projects should be developed and implemented for improving both the quality and availability of groundwater resource.

- Integrated and coordinated development of surface water and groundwater resources and their conjunctive use should be envisaged right from the project planning stage and should form an essential part of the exploitation of groundwater resources.

Nepal is very rich in water related resource and is abundant for year round irrigation and industry. Studies carried out so far have shown that a total of 726,000ha in Terai is feasible for the STW irrigation development and 305,000ha for marginal potential. Similarly 190,000ha have good potential for DTW irrigation development.

The utilizable water resources of Nepal are estimated to be 8800 MCM out of which 756MCM is extracted for Irrigation and Industrial use whereas 297MCM is extracted for drinking purpose. With this use the unused is expected to be 7746MCM.

The underground reservoir or the aquifers can be used as a storage and distribution system analogous to the surface reservoir and distribution system. The storage capacity of the underground reservoir or the aquifer can be used by withdrawing water during the dry period and replenishing during the subsequent wet period. The groundwater use is progressively increasing due to increase in tube well irrigation, industrial use and municipal use resulting in annual increase of extraction. When total extraction increases compared to recharge of the aquifer, the water level decreases, adverse salt balance will increase and other environmental issues will crop up. Hence it is very important that a balance should be maintained before these effects are seen.

The groundwater potential is not the same everywhere. Depending upon the history of the deposition of the sediments and other related factors, the groundwater potential is feasible in one place and is unfeasible in other place. Hence, scientific study is to be carried out to understand the sediment history and aquifer settings of the project area. Hydro geological studies have to be conducted to assess the groundwater potential in the area.

Agriculture is the main sector of Nepal's economy. It provides employment for more than 80% of the active workforce and contributes to about 38% to total GDP. Although agriculture is major sector, its performance is low as measured in per capita GDP mainly due to widespread poverty. Most of poor populace are dependent on agriculture and live in rural areas. The agriculture sector continues to be major focus for Government plans and policies in addressing the country's poverty concerns, and irrigation remains the main investment tool in enhancing agricultural production.

The Hydro geological study in Satbaria region (North of Rapti river and south of Mahendra highway) mid-western part of the Deukhury Dun valley, Dang District, Mid western Nepal was carried out to meet the requirement of the partial fulfillment for the final year of the master's degree of science in Geology prescribed by the syllabus of the Central Department of Geology, Tribhuvan University, kirtipur, Kathmandu. The Dissertation consists of six chapters describing.

1. Introduction to the study area and previous work.
2. Methodology,
3. Geology of the area.
4. Hydrogeology of the study area
5. Data analysis, discussion and results
6. Conclusion and recommendations.

The study was concerned on the hydro geological condition and ground water potential of the shallow aquifers for irrigation purpose in the study area. The thesis is mainly based on the interpretation of the existing and collected data from the wells of the study area.

1.2 Objectives

The following are the main objectives of the study:

1. To understand the sediment distribution of the study area
2. To understand the groundwater condition of the study area.
3. To understand the irrigation potential of the study area.

1.3 Location and Accessibility

The study area (Satabaria) lies in the southern central part of the Dang District, Rapti zone of Nepal. Satbaria VDC is located at 4km west of Lamahi. The east west highway (Mahendra Rajmarg) Passes through Satabaria (Fig: 1.1). The total area Deukhuri Valley is about 700km^2 (GWRDP/UN, Technical Report, 1989). The study area covers about 15km^2 areas, which is about 1.5km wide in north south direction, and 10km long in east west direction. Satabaria, Uchanimbu, Gidhinia, Janakpur Phacakpur are the main villages of the study area. East west Mahendra Highway passes through the northern part and graveled cart track as well as foot trails are scattered throughout the study area.

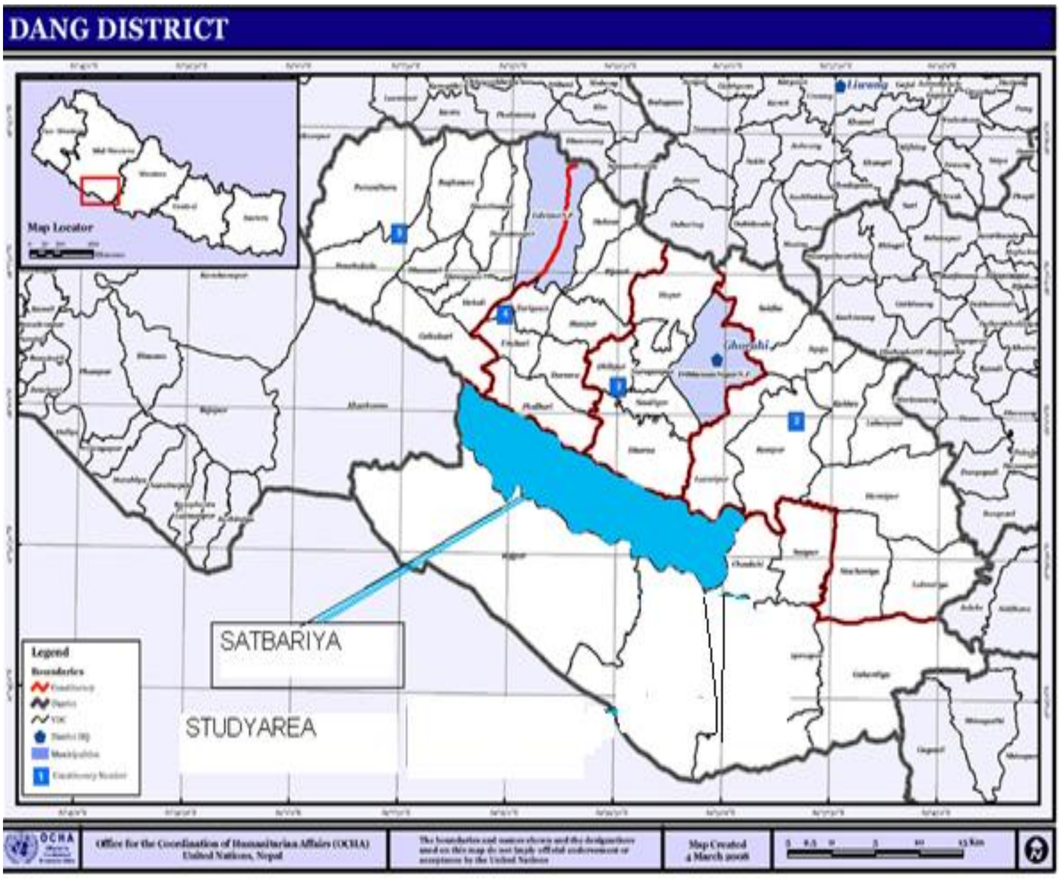

Fig. 1.1 Location map of the study area

1.4 Topography and Drainage

Photo 1: Part of Rapti River in the study area

Physiographically, the study area lies in the Dun Valley of Nepal encompassed by the Siwallik. Siwallik hills with altitude of 800 to 860m are situated in the northern side, where as on the southern side the Siwalik hill have the altitude of 400 to 700m. The Siwalik represents very young and immature topography with steep escarpment on the southern and northern hills. The area is flat flood plain of the east west flowing Rapti River (Photo 1.1). The main perennial river (Rapti River) passes from east to west through the southern part of Satabaria. The main tributaries of the Rapti River In the study area are Arjun Khola, Bhaukahava Khola which flows towards south (Fig: 1.2).The drainage system of the study area shows the dendrite drainage pattern. The channel morphology of the Rapti River shows the braided type of river channel pattern because there are more channels with small stable islands. The average discharge of the Rapti River measured at Bhalubang (Inlet) and Amile (outlet) points of the valley are 93 and 122 m^3/sec respectively. Highest flow normally occurs between July and August (GWRDP/UNDP, Technical Report, 1989)

1.5 Climate and Vegetation

The climate of Deukhury Valley is sub-tropical type having average annual precipitation of approximately 1700mm.The average annual temperature is 20^0C and the mean monthly temperature ranges from13^0C in January to 27^0C in May. The temperature is recorded at the metrological station Ghorahi on the north of the study area. The temperature and rainfall data has been shown on the table of Appendix: A. Average maximum and minimum temperatures of the study area are 39.9^0C and 6.1^0C from 2005 to 2011 AD respectively.

The average Precipitation of the area has been shown on the table of Appendix: B. The mean annual rainfall during the year of 2005 to 2011, measured at Ghorahi Dang is 619.15 mm. More than 85% of the total annual rainfall occurs during the monsoon season from June to September. Deukhury Valley has humid and sub-tropical type of climate. Sal, Sissau, Mango, Guava and Banana are the major types of vegetations within the valley. Dense green forest of Sal tree and other shrubs can be seen on the northern and southern part of siwalik hill.

1.6 Soil

The composition of the soil depends on the composition of the parent rocks of the adjacent areas. Rapti River and its tributaries may have transported alluvial deposits like sand, mud, and gravel, from the adjacent Siwalik and Lesser Himalayan terrains. The soils in the area are mostly alluvium and outwash deposits from the hill slopes. In the northwestern and northeastern parts of the area, red soils are exposed with badland topography. In the central part, the soils are yellowish and gray clays with humus. In the upper layer, topsoil thickness ranges from 3 to 10m. It is coarser towards northern and southern foothills and fine towards the center of the valley.

1.7 Agriculture

The area covers about 90% agricultural land. Alluvial plains, river terraces and alluvial fans are the main agricultural land of the area. The land is divided into two categories, low land (Khet) and upland (Bari). Generally, the area reveals the mix cropping pattern. The major crops of the area are paddy, maize, wheat, potato, oilseeds etc. Other crops such as millet, barley are also planted. Vegetables like Cauliflower, Cabbage, Tomato, Ladyfinger, Radish and fruits like Mango, Banana, Lychee, and Guava are also grown. Besides the production of mentioned crops, people adopt livestock for fertilizer and income generation.

1.8 Irrigation

Substantial water is required for irrigation and hence many farmers depend on both surface and groundwater pumped from irrigation wells. Many among of them are still depending on rainfall for crop plantation. Surface irrigation systems are inadequate and these systems are only operated during the monsoon seasons when the sufficient rainfall occurs. Ground water irrigation system is being extensively used for the last two decades.

So, shallow and deep tube wells as well as dug wells have been constructed in large scale. GWRDP has supported the farmers to install deep tube wells, shallow tube wells and dug wells for the irrigation. Electric motor as well as diesel pump is used for the extraction of groundwater in the area

1.9 Population and Socio-economic condition

The total population of the Dang District is 552,583 (CBS, Statistical Pocket Book, 2011 and the estimated population of the study area is about 25,000. Ethnically, Tharu (Chaudharies) are dominant cast groups. Other castes like Yadav, Bramhans Chhetri are situated as minority.The economy of the area is primarily agriculture. About 80% people of the area depend upon the agriculture. Paddy, wheat, maize, and mustard are the main crops. Remaining about 20% people engage in industry, trading, teaching and private as well as government jobs.

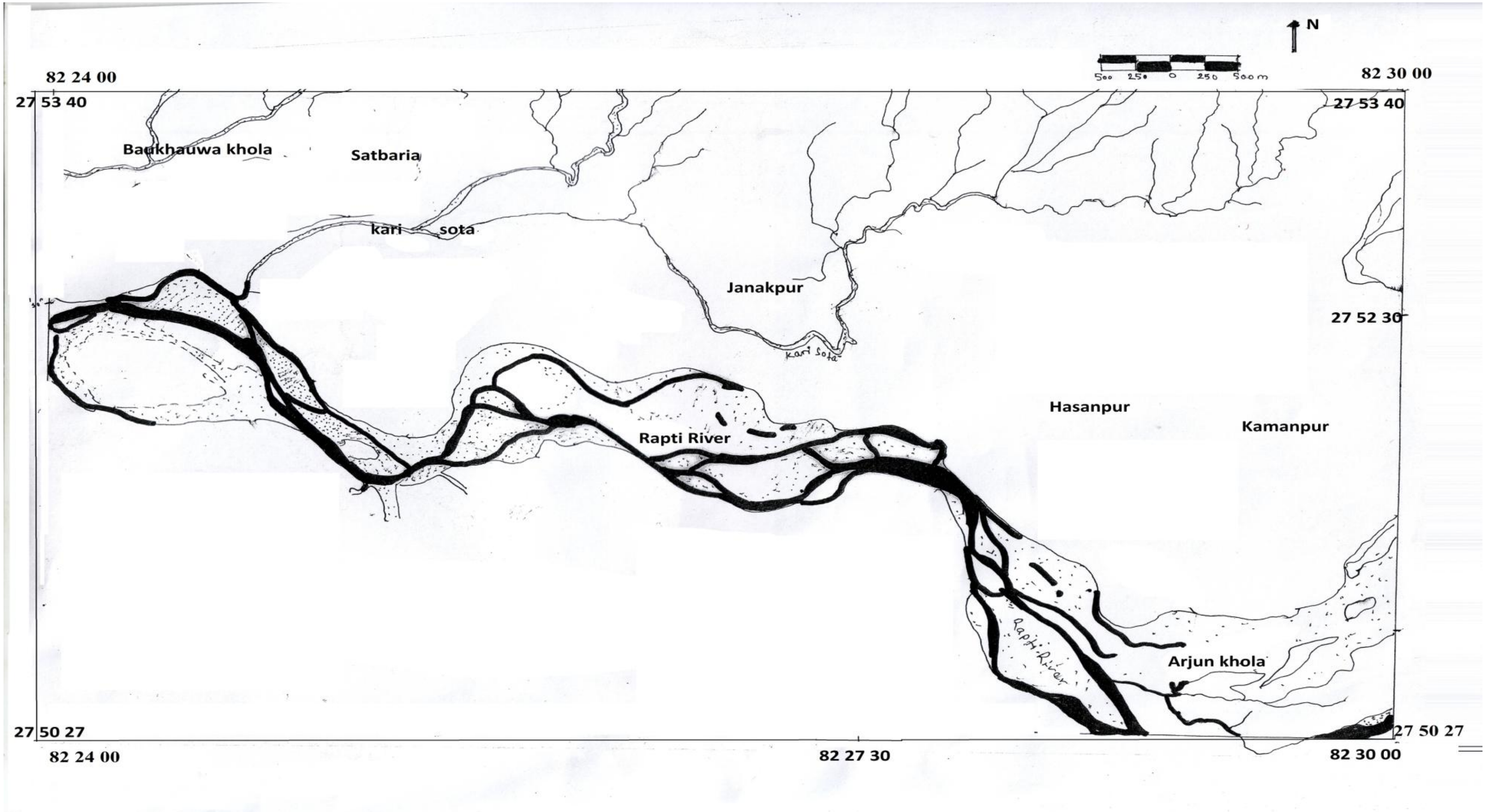

Figure: 1.2 Drainage Map of the Study Area

1.10 Previous Works

Detailed study on geology or hydrogeology has not been done in the study area. Previous works related to geology and hydrogeology is given as following:

- Sharma, C.K (1979) discussed in general the groundwater condition of the valley.
- Corvinus, G (1995) studied the Quaternary stratigraphy of the intermountain Dun Valley of Dang, k
- GWRDB/UNDP (1986), carried out the shallow groundwater investigation in Deukhuri Valley.
- GWIP (Ground Water Irrigation project, Chitawan), 2010, has studied Enviromental impact Evaluation of STW in Satabaria and Gadhava VDC.
- Adhikary, P.C, Sharma, R.H and Thapa, H (Unpublished) studied the lithostratigraphical framework for Pleistocene geological mapping of the Deukhuri Dun.They divided the loose surfacial deposits in the valley into nine stratigraphical unitsnamely from older to younger are Lamahi Formation, Kakrahawa Formation, SatbariyaFormation, Kolahi Formation, Banghushri Formation, Bhalubang Formation, JharauniFormation, of the Pleistocene age and Gobardiha Gravel and Rapti Flood Plain of Holocene age.
- GWRDB established in 1969 under the Ministry of Water Resource, Nepal has drilled more than 800 deep tube wells (Investigation and Production) in Terai and Dun Valley since 1969. Out of which 1 deep tube wells and about 40 shallow tube wells are located in the study area.
- GWRDP has investigated groundwater condition in the valley and has drilled and monitored deep as well as shallow tubewells. For the purpose of investigation, lithologs, resistivity logs, and self-potential (SP) logs of the individual tube wells have been taken.
- NASC and ENPHO (2003) have published the state of arsenic in Nepal in which, arsenic
- Concentration in the ground water of the Dang District is also mentioned.
- Piya, Birendra (1993) has studied Hydrogeological condition in parts of Dang valley, Western Nepal

- Pokhrel Mahesh (2004) has studied hydrogeological condition in western part of Deukhkhury Dun valley Dang distric Western Nepal.

CHAPTER 2

METHODOLOGY

The methodology applied to prepare present hydro geological study work was divided into following parts:

1. Collection and review of the existing data and information
2. Field survey
3. Data processing and interpretation.

2.1 Collections and Review of Existing Data and Information

The available literature, reports, maps, and relevant well data related to present study were collected. Well logs, pumping test data, monthly well observation data were collected from the Ground Water Resource Development Project field office, Lamahi Dang and the Groundwater Resource Development Board, Babarmahal, Katmandu. The meteorological data like monthly temperature record and rainfall record of the area were collected from the Department of Hydrology and Meteorology, Central Office Babarmahal, Katmandu. Topographical map of the study area and Geological map of the Western Nepal were purchased from the Survey Department of Nepal, Minbhaba, Kathmandu. The collected literatures, reports, and well litho logs were thoroughly reviewed. Interpretation of hydrogeological condition of the study area was made on the basis of litho logs and pumping test data of the wells.

2.2 Field Survey

Based on review of existing literature, reports and data, field survey and well inventory were designed and questionnaire/field format (Appendix: J) was developed. By following the questionnaire and format, the survey was conducted. Fieldwork was carried out for about two weeks to collect geological as well as hydro geological information of the study area. During the field survey, the data collected from secondary sources were verified and additional new data were collected. Field survey was carried out in the study area for two weeks in May. During the field visit, well inventory locations were performed. Additional geological and hydro geological data and relevant information were also gathered during the field visit. Locations of the wells were plotted on the toposheet of 1:25,000 in the field (Fig: 2.1) with their respective symbols.

2.2.1 Data collection

Photo: 2 static water level (SWL) measurements of Shallow tube wells

During the field visit six dugwells and twenty-five tubewells were surveyed from one to six wards of the Satabaria VDC to collect the information such as well type, depth, water level, screen position, and date of construction of the wells. Static water levels of the wells were measured by water level indicator. Other information such as discharge depth, command area for irrigation, litholog of wells were taken from relevant farmers. Topographic positions like latitude, longitude and altitude were noted by using Geographic Positioning System (GPS). The altitude of the particular location for the analytical purpose was taken from the toposheet of that area, and values already given in the well documents provided by the GWRDP.

2.3 Data processing and Interpretation

Many types of data were included for the study and the accuracy of these data affect the reliability of the computed result. The data used in the study were: well discharge, pumping test data during the well construction, monthly water table monitoring data of the wells and the vertical lithologs of the wells. Temperature record, rainfall record of the area and discharge record of the Rapti River were also included.

Aquifer thickness was measured from the lithologs and water level elevation from the mean sea level. Specific Capacities (Sp.Cp) were calculated from the discharge and drawdown data of the pumping test wells by using the following relationship (Todd, 2001). Specific Capacity (Sp.Cp) =Discharge/Total drawdown.

Various maps like location map, drainage map, geological map, lithological cross-sections, hydrogeological maps and other relevant figures were prepared. These maps and figures were prepared manually. Interpretation and analysis were made based on the hydrogeology, reports and data, maps, and figures, as well as from field experience.

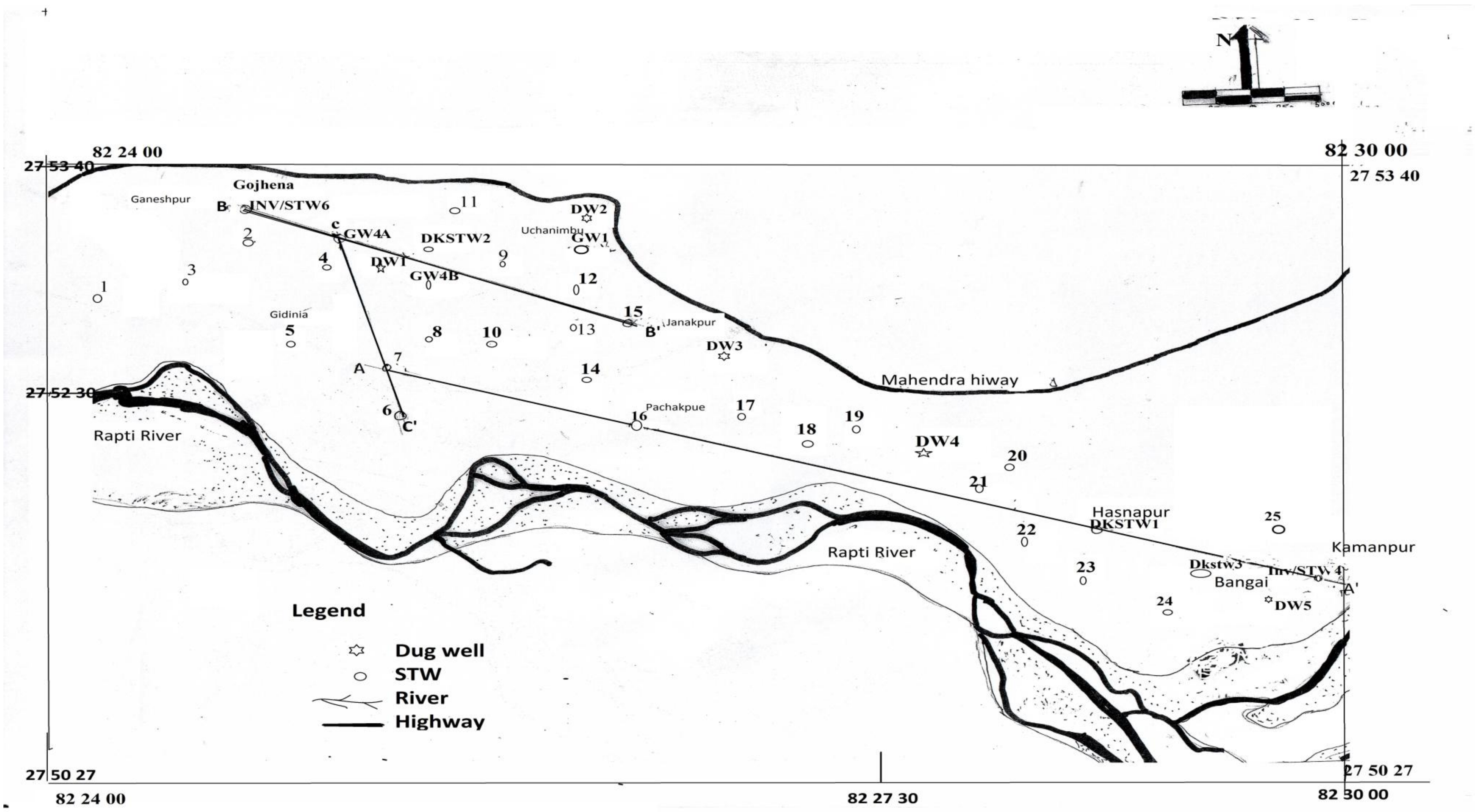

Figure 2.1 Well Location in the study area

CHAPTER 3

GEOLOGY

3.1 Geological setting of Nepal

The 800km long Nepal Himalaya lies in between the Karakoram Himalaya in the west and the Sikkim-Bhutan Himalaya in the east. The Nepal Himalaya has unique geological setting and exhibits numerous folds, faults, thrusts, nappe and klippe structures.

Ganser (1964) divided Nepal Himalaya into four tectonic zones from south to north as the Sub Himalaya (Siwaliks), the Lesser Himalaya, the Higher Himalaya and the Tibetan – Tethys Himalaya. Later on many scholars including Upreti (1999), proposed five tectonic zones – adding the Indo-Gangetic Plain in the southern most part (Fig. 3.1).

3.1.1 Tibetan Tethys Himalaya

The Tibetan Tethys Himalaya lying at the northern part of the mid-Western Nepal is made up of sedimentary rocks of Paleozoic to Cenozoic age. A fault zone, which stretches along the Indus and Tsangpo river, represents the northern border of the Himalayas, referred toas Indus-Tsangpo Suture zone (ITS), which signifies the collision trace of the subcontinent with Eurasia (Kizaki, 1994). The Tibetan Tethys Himalaya is characterized by fossiliferous sediment rich in brachiopods, corals and bryozoans.

3.1.2 Higher Himalayas

This zone lies north of MCT and south of the South Tibetan Detatchment System (STDS) which separates the Tibetan Tethis Zone from it. This succession mainly consists of crystalline rocks of high grade metamorphism like gneisses and schists with index minerals of kyanite, sillimanite etc. Some granitic bodies are also intruded with in this zone. The age of this zone is Precambrian.

3.1.3 Lesser Himalayas

The lesser Himalayan Zone lies in between the Main Central Thrust (MCT) in the north and Main Boundry Thrust (MBT) in the south. The lesser Himalayas of Nepal include both physiographic division of Midland and the Mahabharat Zone and are characterized by verities of rocks such as slates, phyllites, schist, gneisses Quartzite,marbles dolomite, limestone etc. The Lesser Himalayan sediments of Precambrian to early-Paleozoic age are barren in fossil except for a few occurrences of stromatolities, while the Gondwana sediments of the Paleozoictoearly Tertiary age have abundant fossils (Kizaki, 1994).

3.1.4 Sub- Himalayas (The Siwaliks)

This zone is bounded by HFT in the south and Main Boundary Thrust (MBT) in the north. It basically consists of rocks of fluvial origin belonging to the Neogene age. It is divided into three formations namely: Lower Siwalik, Middle Siwalik and Upper Siwalik. The Lower Siwalik consists of variegated mudstone with interbedding of sandstones, the Middle Siwalik comprises medium grained salt and pepper textured sandstone interbedding with mudstone and the Upper Siwalik consist conglomerate and boulder beds. The mid-Miocen to Pleistocen aged Siwalik rock sequence is coursing upward and is rich for both flora and fauna fossils.

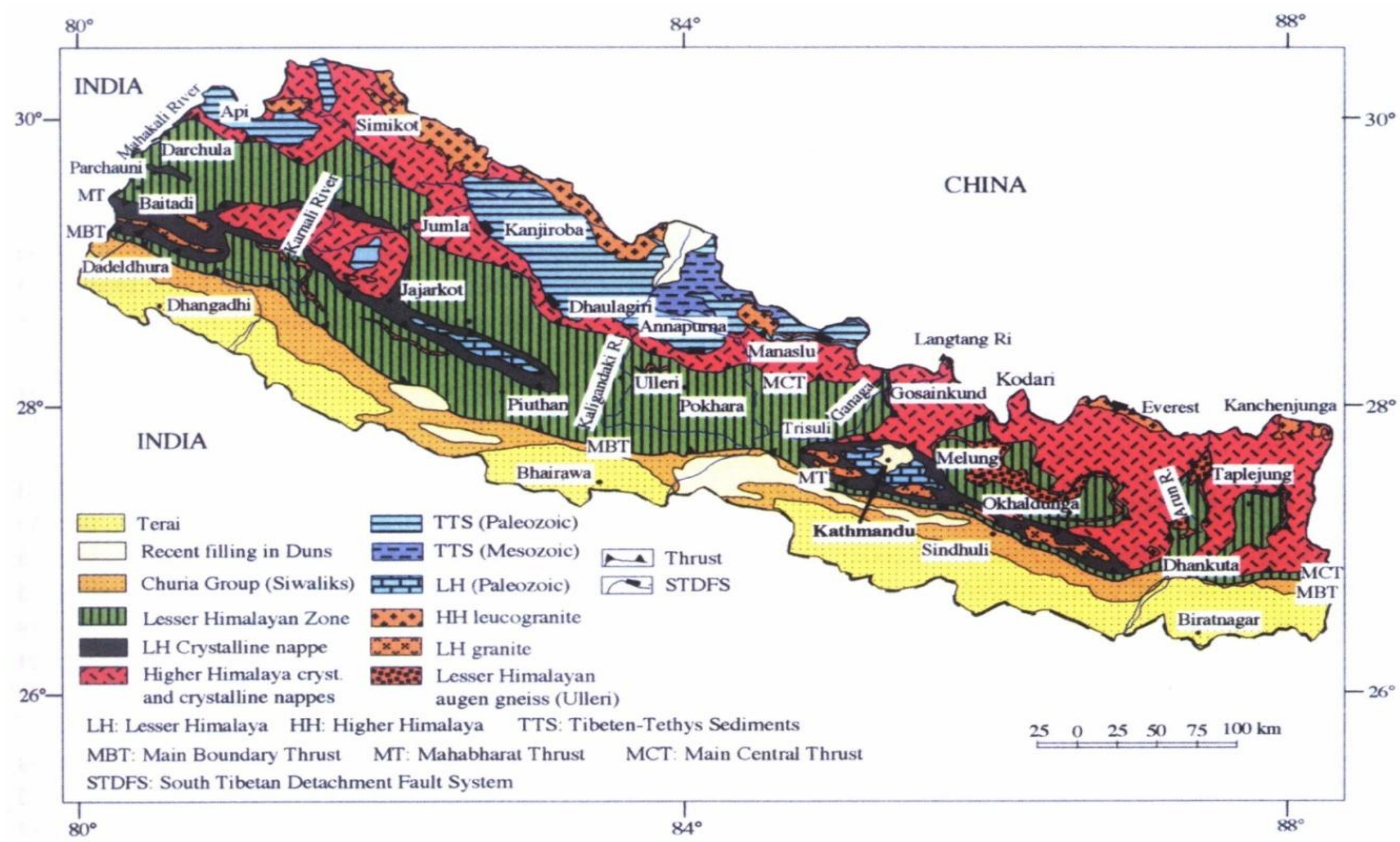

Figure 3.1

Fig 3.1 Geological Map of Nepal (after Upreti, 1999)

3.1.5 Terai Plain

The Terai plain lies in the southern part of Nepal demarcated from the Siwalik in the north by Main Frontal Thrust (MFT). It is the northernmost continuation Gangatic alluvial plain. The Terai plain is extended from east to west except at Chitwan and Koilabas area of Dang district and has occupied17% of the total area of Nepal (Sharma, 1990)

The underlying unconsolidated alluvial deposits consist of intercalated beds of silt, clay, sand, gravel boulder etc. The finer sediments are distributed relatively towards south. So the facies change can be well delineated from north to south. Terai plain has further sub divided into three parallel zones from north to south as follows (Sharma, 1990)

a. Bhaver zone
b. Marshy Zone
c. Southern Terai

a. Bhaver zone

The Bhabar Zone lies in the base of foothills delineated by the Main Frontal Thrust (MFT) in the north and spring line in the south. It is about 12km wide and mainly composed of boulder, cobbles and pebbles of rocks of Churia hills or Mahabharat range deposited by the present rivers (Sharma, 1990).

b. Marshy Zone

The Marshy zone is found to the south of Bhabhar zone where two different lithological units (Bhaver zone and Middle Terai) meet or interfinger. The Marshy Zone is also known as middle Terai and is about 14km wide. The area is swampy and possesses ponds and pools. The spring lines are also marked in the northern part of the area .The Marshy zone is not everywhere in the Terai of Nepal

c. Southern Terai

The southern Terai of Nepal lies in between the middle in the north and Indo-Nepal boarder in south. It is about 6km wide and is composed of sediments like clay, silt and sand.

3.2 Physiography and Geology of the study area

Churia group rocks are faulted, folded and thrusted to the south over the recent alluvium of the Terai zone .Central Churia Thrust (CCT) has developed resulting in the repetition of the formations Thrust propagated broad asymmetrical folds have given rise to many wide valleys in the Churia zone of Nepal called Dun valley which are generally filled with recent alluvial sediments (Basyal, 1998). The dun valley is 5-30km wide and has 200 to 300m altitude.

Physiographically, the study area lies within the dun valley (Fig 3.2) where the Siwalik hills are situated on the northern and southern ends. The rocks of upper Siwalik are exposed on the southern part and rocks of the lower and middle Siwalik are exposed on the the northern part of the valley (DMG, 1983).

Dun valley in the Himalaya consists of thick sequences of the clastic sediments. Deukhury Valley also comprises thick clastic alluvial deposits of Pleistocene to Quaternary age and is being accumulated to the present days. Loose, surface deposit in the Deukhury Dun Valley is characterized by old debris flow, mudflow, weathered and recent alluvial deposits. The Rapti River which is flowing from east to west in the study area originate from the Lesser Himalayas is the main source of sediment discharge (Adhikary et. Al, unpublished)

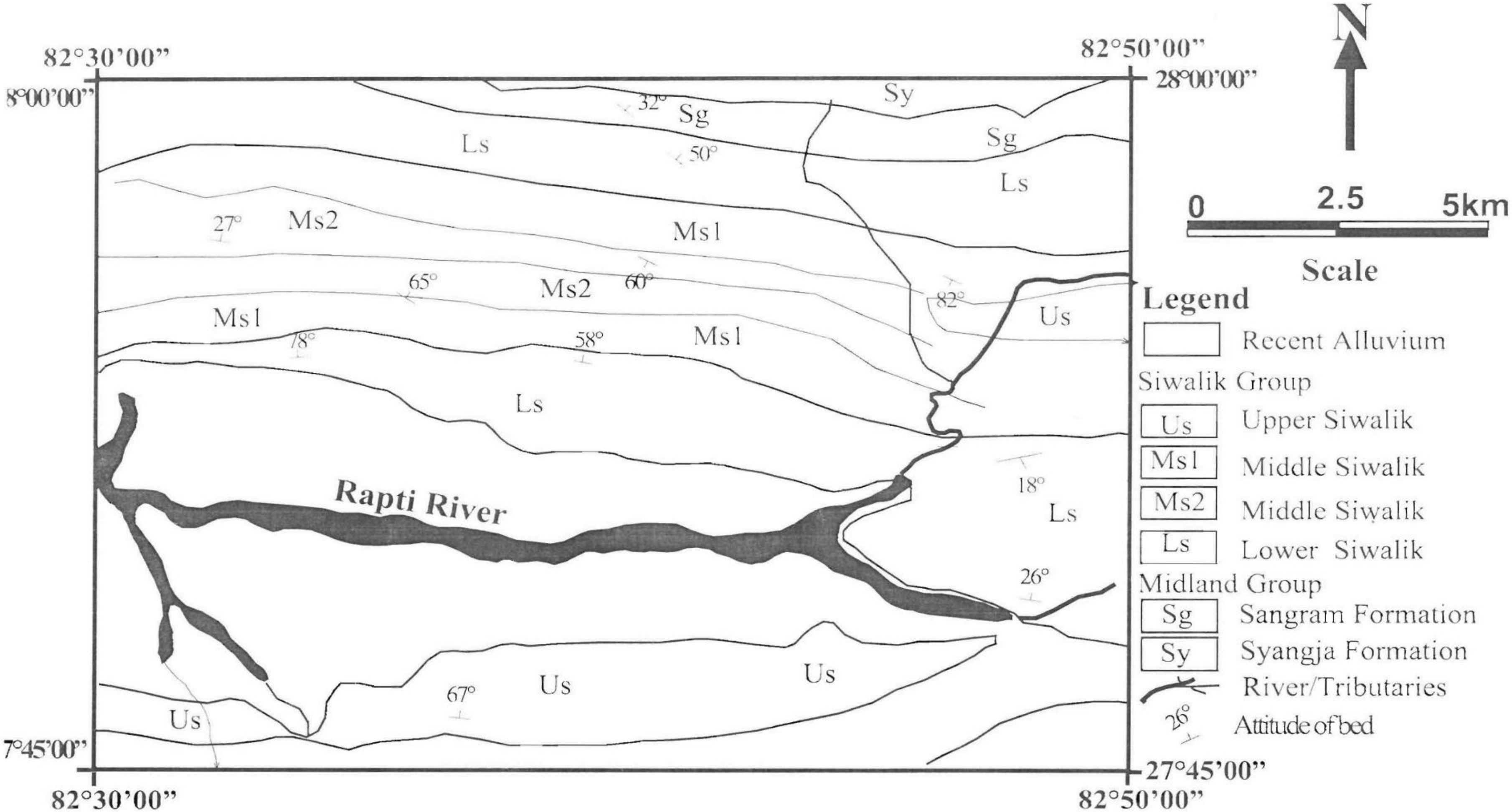

Fig 3.2 Geological Map of the adjacent Part of the Study Area

(Source: DMG, Geological Map of Western Central Nepal)

CHAPTER 4

HYDROGEOLOGY

4.1 Subsurface Geology of the study area

According to the past studies the subsurface geology of the study area is dominated by the alluvial deposits which are fine to coarse grained. The clay beds are intercalated with the fine sand. As the area is located near to the siwalik hill the deposition of siwalik formation are also predominant. 10 to 15m thick finer sediments like clay and silt including topsoil is the dominant on the upper part; the relatively coarser sediments like sand and clay with gravel compose the second horizon, which is about 15 to 30m thick(Pokharel 2004). Coarser sediments like gravel and coarse sand are dominated below 50m-bgl. The subsurface lithology is composed of clastic sediments like gravel, and sand with intercalation of clay. There is no uniform distribution of sediments in the underlying alluvial deposits and the sequence shows sharp changes in lithology from place to place. Generally, the upper part is dominated by finer sediments like clay and topsoil upto 10m-bgl, the middle part is comprised by the thick layer of intercalation of clay, sand, and gravel in between 10 and 20m-bgl and the lower zone is also the layer of coarser sediment like gravel and coarse sand below 20m-bgl. in the study area there consists of mostly alluvial deposit of Rapti River(GWIP, 2010).

The debris due to erosion and land flow form Churia hill has contributed greatly to the formation of the soil in the upland part. In the low land alluvial deposit of Rapti River are dominant. The upper 15 meters of earth strata suggests a hard layer of conglomerate measuring a meter in thickness throughout the region. Cobble deposit near the surface was also observed, indicating the border point of upland and lowland area. Type of soil in the study area is mainly silt mixed with some percentage of fine sand and fine loamy texture. Cobble and clay layers can be found only in the lower level in the strata.

4.2 Aquifer system

Saturated rock or soil units that have sufficient hydraulic conductivity to supply water for a well or spring are aquifers. Aquifers transmit water from recharge areas to discharge areas, such as springs, lakes, and rivers. Typical aquifers are gravel, sand, sandstone, limestone, and fractured igneous and metamorphic rock.

The study area covers only Satbaria region of the Deukhuri Valley through which a high dischargeable Rapti River flows. Deukhuri Valley is a Dun Valley and consists of coarse sediments similar to Bhabar zone in northern part of the Terai. One of the sources of sediments deposition is from the Rapti River and its tributaries. The average grain size of river-deposited sediments vary considerably; flood plain deposits consist of extremely fine clay to coarse gravel in the center of the valley, where as coarse gravel or sand is more typical of alluvial fan deposits on the northernmost and southernmost part of the valley.

The Rapti River is active for the sediment deposition and frequently changes its course. Therefore it is difficult to predict the aquifer setting of the valley without the detailed study of the drainage system and subsurface lithology upto deeper depth of the whole valley. With the limited lithologs of the deep tubewells as well as shallow tubewells there are two-layered aquifers at different depth. Hence previous reports on that area shows that there are two types of aquifers system such as Unconfined and Confined Aquifer

An unconfined aquifer is under the pressure exerted by the overlying water and atmospheric pressure. The level of water in an unconfined aquifer changes during the period of draught and monsoon. Wells drilled into an unconfined aquifer are called water-table wells (Todd, 2001). The aquifers bounded above and below by confining beds and filled with water are called as confined aquifers. The water level in a well supplied by a confined aquifer will stand at some height above the top of the aquifer. Water that flows out of the well is called flowing artesian wells. Confined aquifer occurs where ground water is under the sufficient pressure by overlying relatively impermeable strata, which is greater than atmospheric pressure (Todd, 2001).

CHAPTER 5

DATA ANALYSIS, RESULT, INTERPRETATION, AND DISCUSSION

5.1 Lithological Interpretation Based on Well Lithologs

Geology of the adjacent portion of the study area has been traced from the geological map of the mid-Western Nepal published by DMG/HMG, Nepal. Subsurface geology of the study area has been assumed on the basis of well geologic logs, analysis of river channel, morphology from topographical map, resistivity logs of the wells, and verification during field visit. For the purpose, two litho logical cross-sections in the study area from west to east profiling on the northern and southern part were prepared and described. Similarly one profile along north to south was plotted. The profiles are shown in fig: 5.1, Fig: 5.2 and Fig: 5.3. Based on these cross-sections, subsurface sediments distributions are as follows. The northern profile sketched (B-B') shows that in general subsurface formation consist of clay, sand and gravel layers. The upper 1- 3 meters are composed of top soil consisting organic debris. After that clay layer of 5-6 meter are found which are mainly sandy clay and below that gravel layers mixed with sand (An aquifer) are found. Generally two major gravel layers (an aquifer) exist in the area which is the main source of water in that area. The trend of lithology is similar in the case of southern part also (Fig: 5.1, Profile A-A'.).

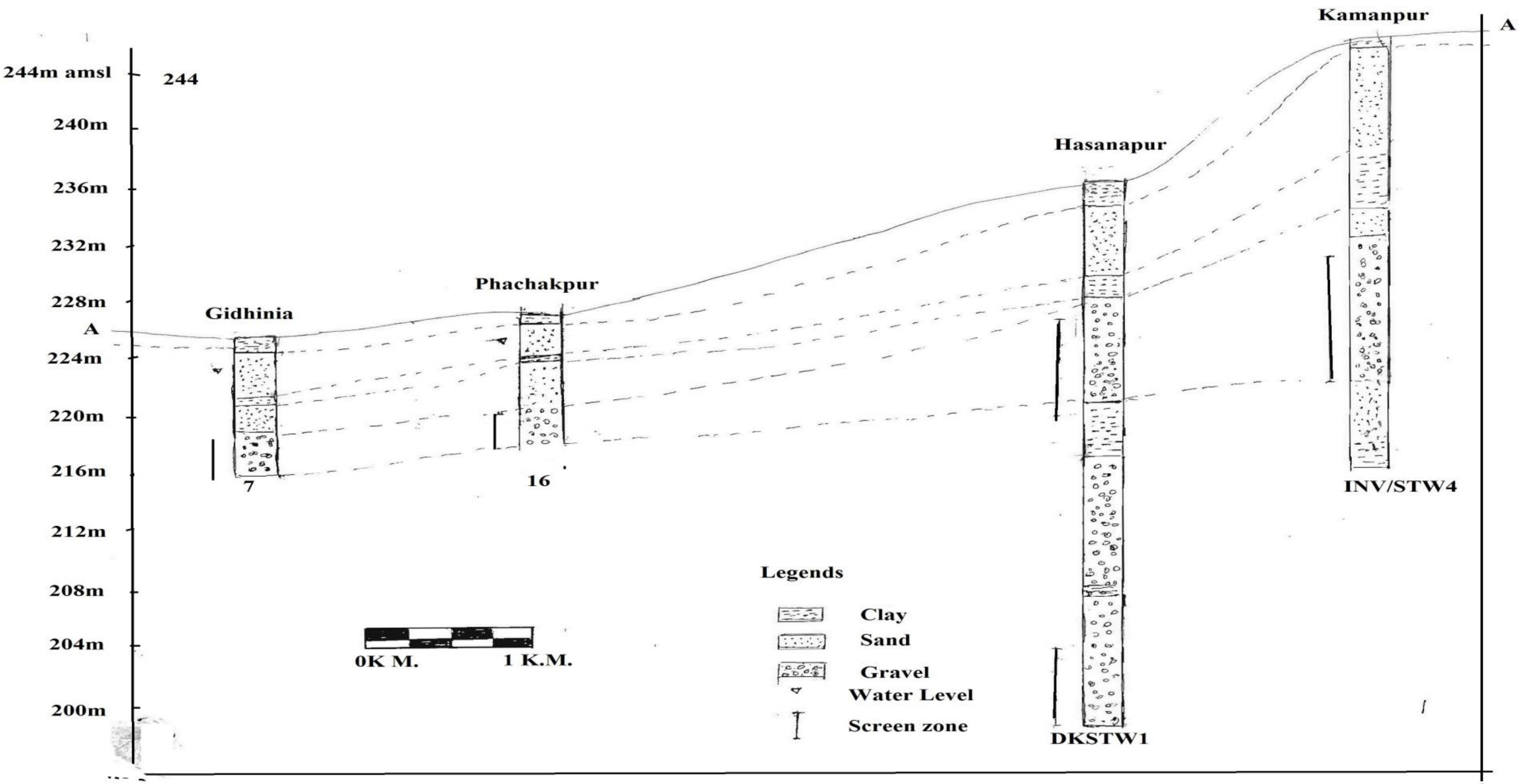

Fig: 5.1 Lithological Cross-section along the line A-A'

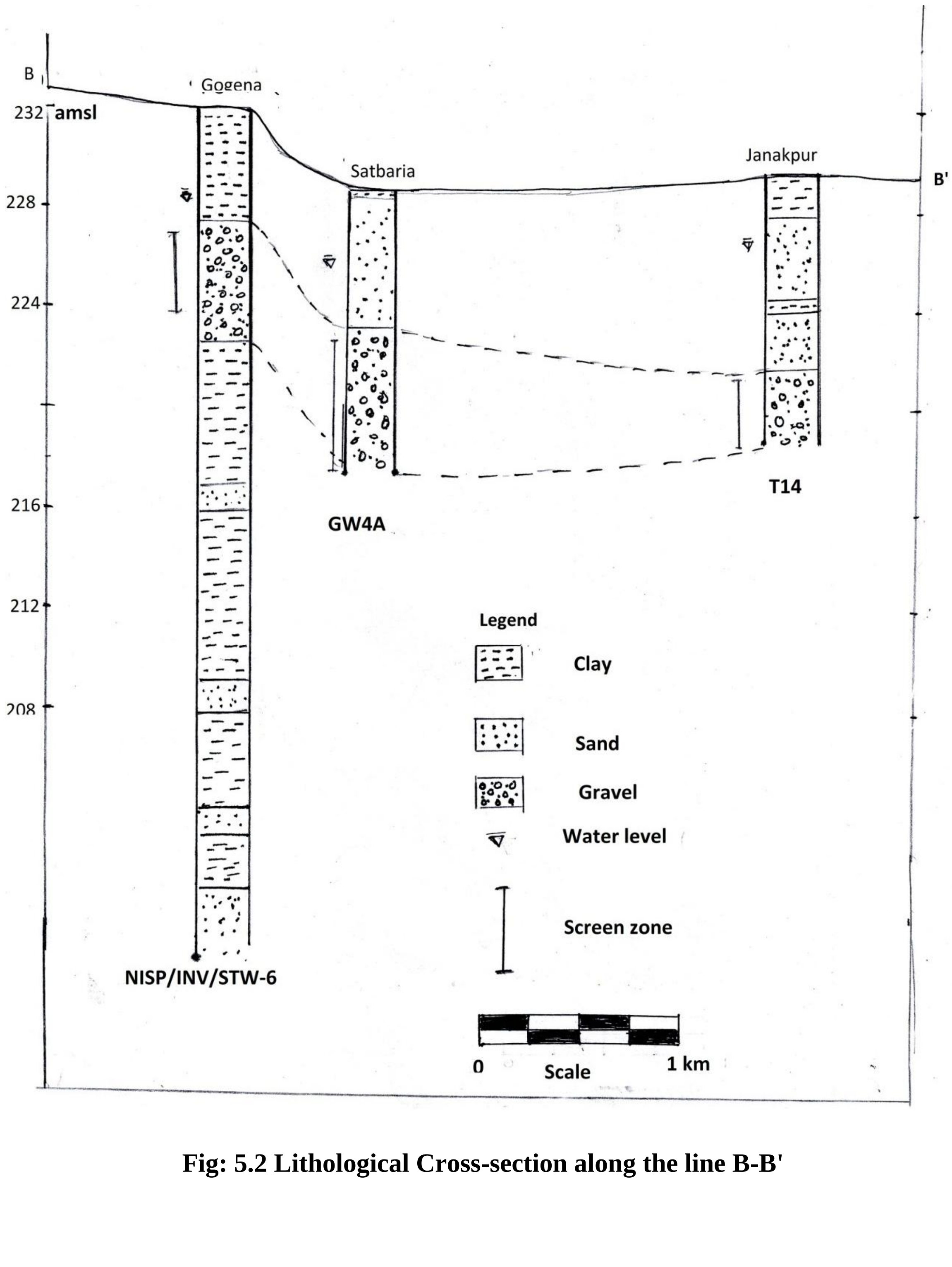

Fig: 5.2 Lithological Cross-section along the line B-B'

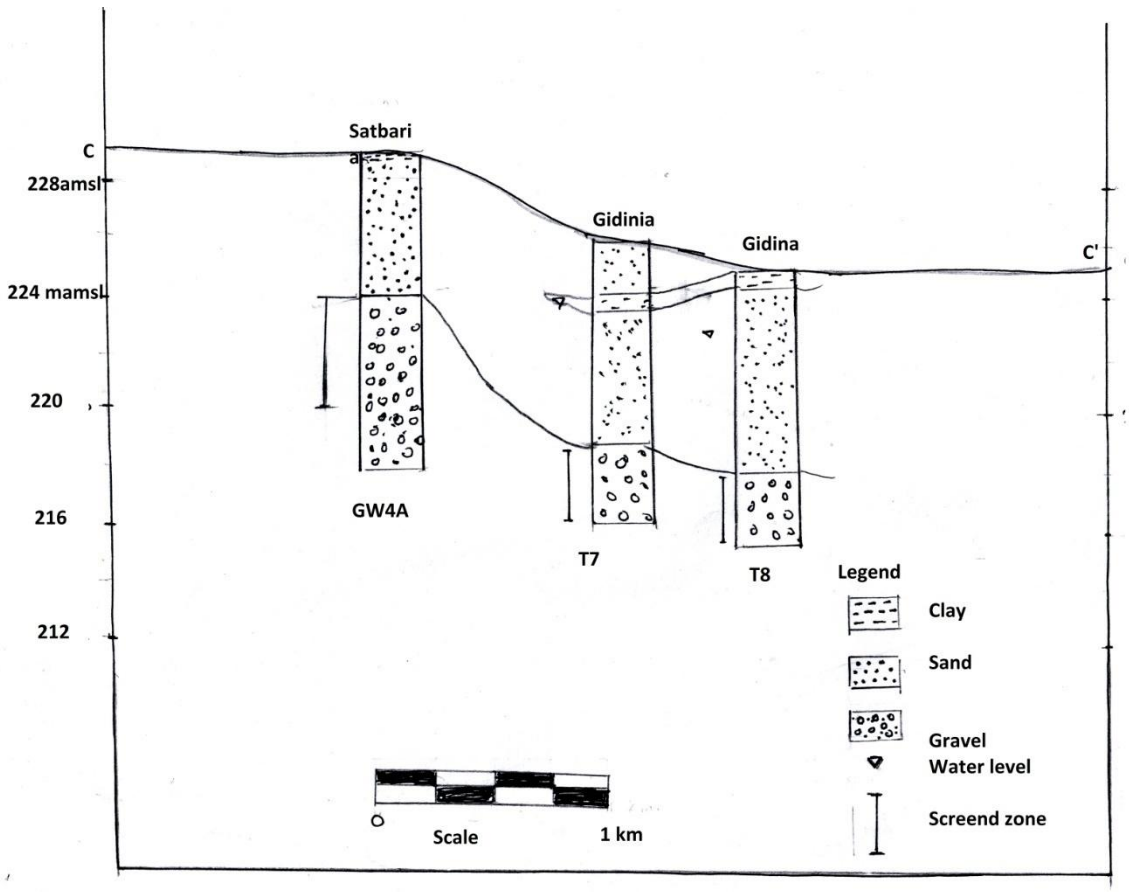

Fig: 5.3 Lithological Cross-section along the line C-C'

However in the southern part the formation materials are finer in comparison to the northern part. The northern profile shows a deposition of Siwalik material where as to the southern part alluvial deposits are dominated. The subsurface lithology is composed of clastic sediments like gravel, and sand with intercalation of clay. There is no uniform distribution of sediments in the underlying alluvial deposits and the sequence shows sharp changes in lithology from place to place. The profile sketched along north to south (C-C') Shows that the subsurface lithology of the area in these profiles are not uniform type. Generally, the upper part is dominated by finer sediments like clay and topsoil up to 2m and the middle part is comprised by the thick layer of intercalation of clay, sand, and gravel in between 10 and 20m-bgl and the lower zone is also the layer of coarser sediment like gravel and coarse sand below. The screens are placed in this sandy and gravel layers.

5.2 Lithological interpretation based on well resistivity data

The ability of geologic materials to resist an electrical current depends upon three factors: the amount of open space between particles (porosity), the degree of interconnection between these opens space and, the volume and conductivity of water in the pores. Thus the resistivity decreases as decrease in porosity, hydraulic conductivity, water content, and water salinity. Clay and shale have low resistance, and dry sand and gravel have higher resistance than saturated sand and gravel. Typical resistivity values for common materials are presented on the table below (Table: 3.1)

Table 5.1 Resistivity value for the common materials

Lithology	Resistivity Range (Ωm)
Sand and Gravel	$1*10^{2}$-$1*10^{3}$
Sand	$1*10^{0}$-$1*10^{3}$
Clay	$8*10^{1}$-$1*10^{2}$
Top soil	$2*10^{2}$-$1*10^{3}$
Ground water	$2*10^{1}$-$8*10^{1}$
Sea water	$3*10^{-1}$

Source: H. Ando

GWRDB carried out about 50 electrical resistivity logs of the deep and shallow tube well to determine depth and thickness of the aquifer zone in the Deukhuri valley. The resistivity values for different formations are attributed on the table (Table: 3.2)

Table 5.2 Resistivity values for the different formations on the study area

Lithology	Resistivity Range(Ωm)
Clay (Unsaturated)	<10
Clay With sand and silt (Unsaturated)	10-15
Gravel and sand (saturated)	15-20
Gravel and boulders (saturated)	20-30

Source: GWRDP/Lamahi

The resistivity log of shallow tubewells at kamanpur(eastern part of the study area) the study show that first 3meter has Resistnace value ranging from 11 – 24Ωm, 3- 15meter has 3-9 Ωm , 15-23 meter has 19 Ωm and 23- 29 meter 5-10 Ωm. This indicates that the middle layer of the tubewell has coarser material of gravel and sand indicating the presence of aquifer. The electrical resistivity show that the clay, sand and gravel layers are intercalated and the deposition resemble the flow of river in that area which has deposited the material during the course of its flow at that time. A resistivity data obtained in the north western part of the study area at Gojheni show that at some places a huge clay deposition in the past have occurred. A total of 64 meter drilled well except at the depthin between 5-8 meter(10-15 Ωm,) rest have only the resistant value < 4 Ωm, This shows that either there could be thick deposit of Siwalick or clay layer deposition by the flowing river in ancient time

5.3 Distribution of Aquifer in the study area

The study area comprises alluvial fan, alluvial deposits and river terraces. The northern peripheries consist of fan deposits whereas the southern part (along Rapti River) of the area comprises alluvial deposits and river terraces. The grain sizes are not uniform; they are poor to well sort. There are thick to thin layers of impervious clay horizons. Thin sticky clay layer and clay mixes with other sediments are not considered as the demarcated layers of the confined aquifers.

Considering this, the study area shows that there are unconfined aquifers within 15m-bgl. Shallow tube wells and dug wells are tapped within the unconfined aquifers. Deep drilled log (up to the depth of 75meters) at Satabaria, Well no. GW4b show that the aquifer within 25 m-bgl to be of semi unconfined in nature where as the aquifers below that depth seems to be of confined in nature. The horizon is dominated by gravel with sand, silt and clay. The upper and lower layers of that horizon are clay with sand and clay with gravel. In the shallow tubewell the screen positions are within 5 to 15 m-bgl. There is one deep drilled log on the western part of the study area at Gogena (Drilled up to the depth of 64 m well no NISP/INVSTW 6) which shows the upper 4.5m (from 4.5.-9 meter) consist of gravel rest of all are clay and clay with fine sand indicating that within the depth of 64 m no aquifer are available but shallow aquifer of 4.5 meter is available that is being used by the people to have water for their requirement. A deep well in the central and the eastern part of the study area at Satbaria and Kamanpur respectively shows that shallow tube wells and dugwells are completely tapped within unconfined aquifer zone. The screen position and litho logs of wells show the unconfined aquifers are scattered up to 15m-bgl. Sandy gravel layers are within the 5 to 15m-bgl on the middle and western side, whereas those layers are below 20mbgl on the eastern side of the area. Generally, multi-layered unconfined to semiconfined aquifers are situated on the study area, of which, first aquifer is situated within 15mbgl where as second aquifer are situated within 45- 60mbgl.

5.4 Hydrogeological Condition

Lithological cross-sections, hydrological maps map were prepared, which reflects the hydrogeological features of the study area. The aquifer encountered within the study area comprises unconsolidated sediments like sand, gravel that are generally phreatic and unconfined in nature. Lithological section was prepared based on the generalized lithologs. West to east lithological section showed the variation in depth of aquifer layers below ground level at different locations. Finer sediments are predominant at upper sections upto 25m-bgl. Based on screening position of the deep tube well, it comprises single to multi-layered aquifer horizons. Commonly first aquifer lies in 225m-amsl to 210m-amsl. The length of the screen varies from place to place. The aquifer horizons are thicker on the eastern side than the western side. The type of wells in the study area are made as per the nature of the aquifer and at the same time the economic value have also made people to construct the type of well particularly in the case of dug and shallow well. Hence in general there are three types of wells that are being constructed.

5.4.1 Dugwells

Static water level (SWL) was measured during the well inventory survey in the premonsoon (May 2010), (Table: 5.1). The ground elevation of the dugwell location varies from 228m. above mean sea level(amsl) to 245m-amsl. The depth of the dugwells varies from 8 to 10m bgl and diameter of the well varies from 1.53m to 0.85m. The static water level in May (premonsoon) ranged from 3.6m-bgl to 5.1-bgl on different locations. The maximum elevation of SWL was on the northeastern side and minimum elevation was on the bank of the Rapti River of the area. From monthly well observation data2010, (Appendix:D) In the post monsoon period, the maximum water level depth at Banghusari,DW4 was (4.3m-bgl) and minimum at Satbaria, Dw1 (0.5m-bgl). The maximum static water level difference at UcchanimbuDW2 was 5m and minimum at BanbhusariDW4 was 2.45m. The static water level variation from Ucchanimbu (7.6m) Banbhusari (6.75) and in Satbaria it is 4.85. Hence it shows that in case of dugwell the water level dreaceses from east to west (Banghusari eastern side of the study area 6.7m and Satbaria western side of the study area 4.85). Whereas going from north to south the water level increases from south (Banghusar and Satbaria southern part of the study area 6.7 and 4.50) to north (Ucchanimbu northern side of the study area 7.6m). Precipitation hydrographs of the of the year 2010 and 2011 (Appendix: C) show the maximum rainfall occurred on the month July and August whereas minimum rainfall occurred on the months before April and after October in the year 2010, The rainfall data is attached in Appendix: B. Water level hydrograph of the year 2010 (Appendix: E) show the maximum depth of water level was on the months May/June in the year 2010.

Photo: 3 Dug well in the study area

5.4.2 Shallow Tubewell

On the eastern side the SWL at Kamanpur area varied from 8.25m-bgl to 12.00m-bgl in the year 2010 (Appendix: D). Similarly at Satabaria the SWL varies from1.85m bgl to 3.6m bgl. The hydrographs of the well show the maximum of water level depth below ground level is on May/June and minimum SWL on August/September in the year 2010. Precipitation hydrograph and water level hydrographs show the maximum water level depth occurred during the monsoon period also. The relationship shows the delay time for the infiltration of rainwater to raise the water level. The records from the shallow tubewell data shows that the transmissivity of the area 700m^2/day at Satbaria and 4608m^2/day at Hasnapur where as the Sp. Capacity at Hasanapur (DKSTW1) 4.77 l/sm and Gogena (INV/STW6) 1.45 l/sm, indicating that the potentiality increases towards south eastern part of the area. The average discharge on the shallow wells ranges from 7 – 10 lit/sec. The discharge increases towards the west and southern part of the study area.

Table 5.3: Well Inventory survey data of STW and Dug wells in the study area

Well no	Location	Depth (m)	G.L.	May-10		Screen lenth (m)	Discharge (l/s)
				STW bgl(m)	STW amsl(m)		
Dw1	Satabaria	9	228	3.6	224.4		
Dw2	Uchanimbu	10	235	3.9	231.1		
Dw3	Janakpur	8	234	4.1	229.9		
Dw4	Banagushari	8	240	4.8	235.2		
Dw5	Bangai	7.5	244	5.1	238.9		
Dw6	Kamanpur	8	245	5.2	239.8		
T1	Dhanpurwa	9.5	227	2.3	224.7	2.5	8
T2	Gojhena	9.5	233	3.1	229.9	2	7
T3	Gidhinia	8.5	228	2.4	225.6	2.5	9
T4	Satabaria	10	228	3	225	3	9
T5	Gidhinia	8	225	2.1	222.9	2	
T6	Gidhinia	9.5	225	2.3	222.7	2.5	9
T7	Gidhinia	10	226	2.2	223.8	3	10

T8	Gidhinia	10.5	226	2.4	223.6	2.5	
T9	Satabaria	11	228	3.1	224.9	3	10
T10	Khallotol	8	228	2.9	225.1	2	
T11	Bichka	12	232	3.3	228.7	2.5	9
T12	Uchanimbu	12	230	3.4	226.6	3	7
T13	Janakpur	9	229	2.7	226.3	2.5	8
T14	Khallotol	8	229	2.3	226.7	2	11
T15	Janakpur	11	230	3.2	226.8	3	8
T16	Phackpur	9	227	2.3	224.7	3	12
T17	Janakpur	9	236	3.5	232.5	1.5	7
T18	Janakpur	10	232	3.1	228.9	2	
T19	Banghusari	8	232	2.9	229.1	1.5	
T20	Banghusari	12	235	3.9	231.1	3	9
T21	Banghusari	10	232	3	229	1.5	
T22	Hasanapur	11	232	3.2	228.8	3	10
T23	Hasanapur	10	233	2.8	230.2	2.5	11
T24	Bangai	13	236	3.7	232.3	2	10
T25	Bangai	11	241	3.9	237.1	2.5	

5.5 Water Quality

According to the reports regarding the quality of water the shallow aquifer have good quality of water for all purpose like domestic, irrigation and other industrial use. The water quality of the study area is tabulated as below and analysis for chemical and physical parameters for water quality was obtained from earlier studies which are tabulated in Table 5.2.

Table 5.4: Water quality of Satbariya VDC

S No	Parameter	Unit	Satbariya
1	Appearance		Clear
2	Color	^{0}Hazen	7.1
3	Turbidity	NTU	5.2
4	EC	µS/sec	253.9
5	pH		7.21
6	TH	Mg/l	328
7	CaH	Mg/l	257
8	MgH	Mg/l	74
9	TDS	Mg/l	300
10	Cl^{-}	Mg/l	5
11	SO_4^{2-}	Mg/l	33
12	Fe^{3+}	Mg/l	0.1
13	TA	Mg/l	171
14	HCO_3	Mg/l	170
15	Arsenic concentration	Mg/l	<10ppb

Source: GWIP/Chitwan

TH= Total Hardness as $CaCO_3$, CaH= Calcium Hardness as CaCO3, MgH=Magnesieum Hardness, TDS=Total Dissolved Solids, pH= Hydrogen Ion Concentration, Cl-=Chlorine ion concentration, SO4^{2-}-= Sulphate ion concentration Fe3+= Iron ion in ferric form, CO3= Carbonate, HCO3=Bicarbonate, TA= Total Alkalinity, EC= Electrical Conductance (WHO, 1984).

In general, almost all the parameters were less than the value prescribed by the WHO for the drinking purpose, except the values of iron. Naturally, ground water has more iron than the surface water, but this should be within the desirable limit. Iron was more concentrated on the northern part than the southern part, whereas remaining almost other parameters were less concentrated on the northern part than the southern part. Water of the area was satisfactory for the drinking use.

5.6 Irrigation Potentiality in the Study Area

The potentiality of ground water is estimated on the basis of water level and discharge of the existing tube wells. As the water level in the area is within the suction limit of centrifugal pump and the discharge obtained is around 7- 10 lit/sec with average command area of 2.5 ha indicating that the STW are very potential for the exploration of ground water for any use particularly for irrigation. The construction of STW is increasing but till date there is no depletion of water level and at the same time the depletion in the discharge of water has not been observed. The potential area for the ground water is shown in the Map 5.4 below. The trend of tube well construction in the study area is shown in the Table 5.3. As observed the water level, Transmisivity and well discharge increases towards the south eastern part of the area. The Transmissivity at the North West part is only 700 m^2 /day where as the Transmissivity at the south eastern part is high 4600m^2 /day at Hasnapur indicating that the potentiality increases towards south eastern part of the area although all most all the study area is potential for the shallow ground water exploration.

Satbariya VDC is majorly inhabited by people of Tharu community. In addition to them there are people from Bahun, Chhetri, Magars etc. It includes ancient Tharu people with migrants from nearby hilly district like Dang, Pyuthan, Arghakhanchi, Salyan and Rolpa. Due to the potentiality of STW irrigation, ground water irrigation system is implemented and consequently positive impacts have been experienced by local community and the living condition of the people increased considerably. Previously, un-irrigated farm used to support farmers for only 3-5 months. But now with development of STW, farmers can not only sustain their family needs but also are selling their surplus product to local market. It has been found that in an average farmer has sold over 10-15 quintals of rice and same is the case with vegetables. After development of STW irrigation, an opportunity to sell the surplus of product has been created. It is found that each farmer is capable of earning 15,000 to 20,000 rupees by selling paddy only. Their annual income has been increased up to 10 times by selling cash crops and surplus of food crops.

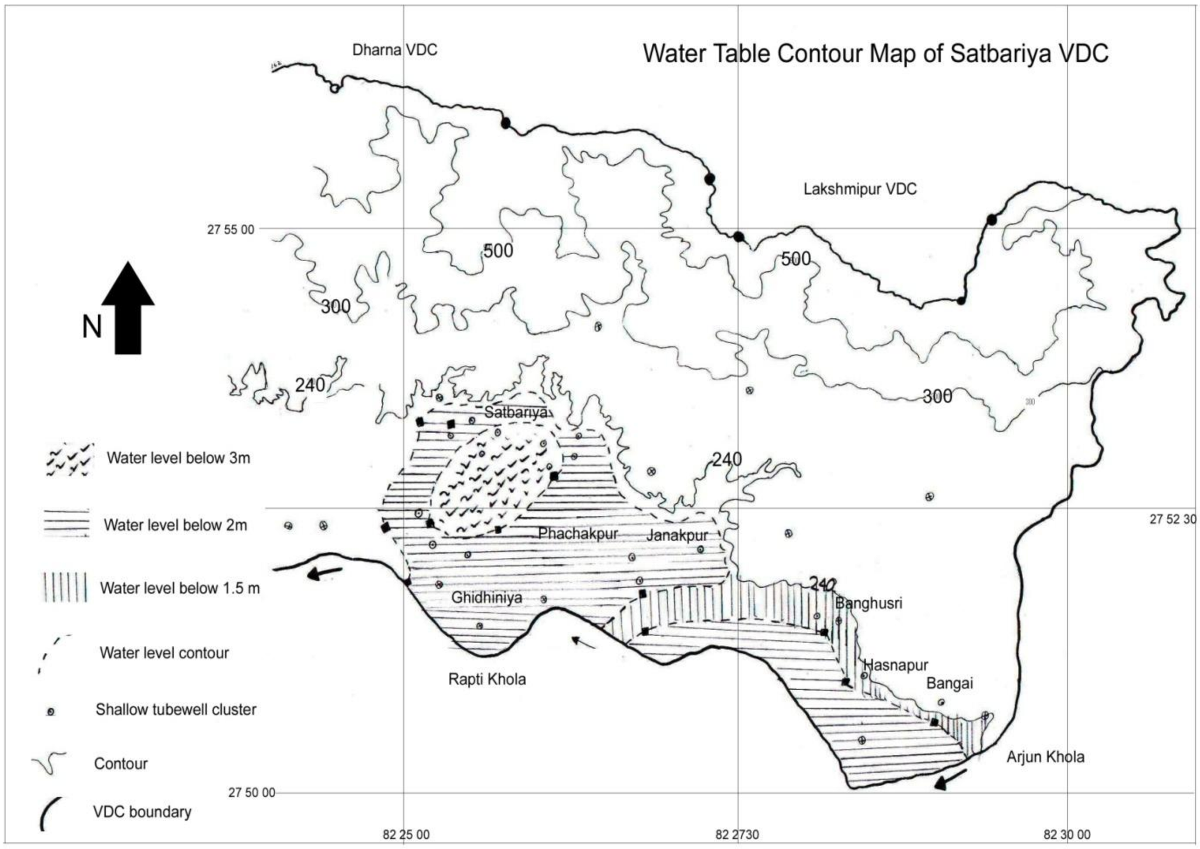

Fig: 5.4 Water Table Counter Map of study area

Source GWIP (2010)

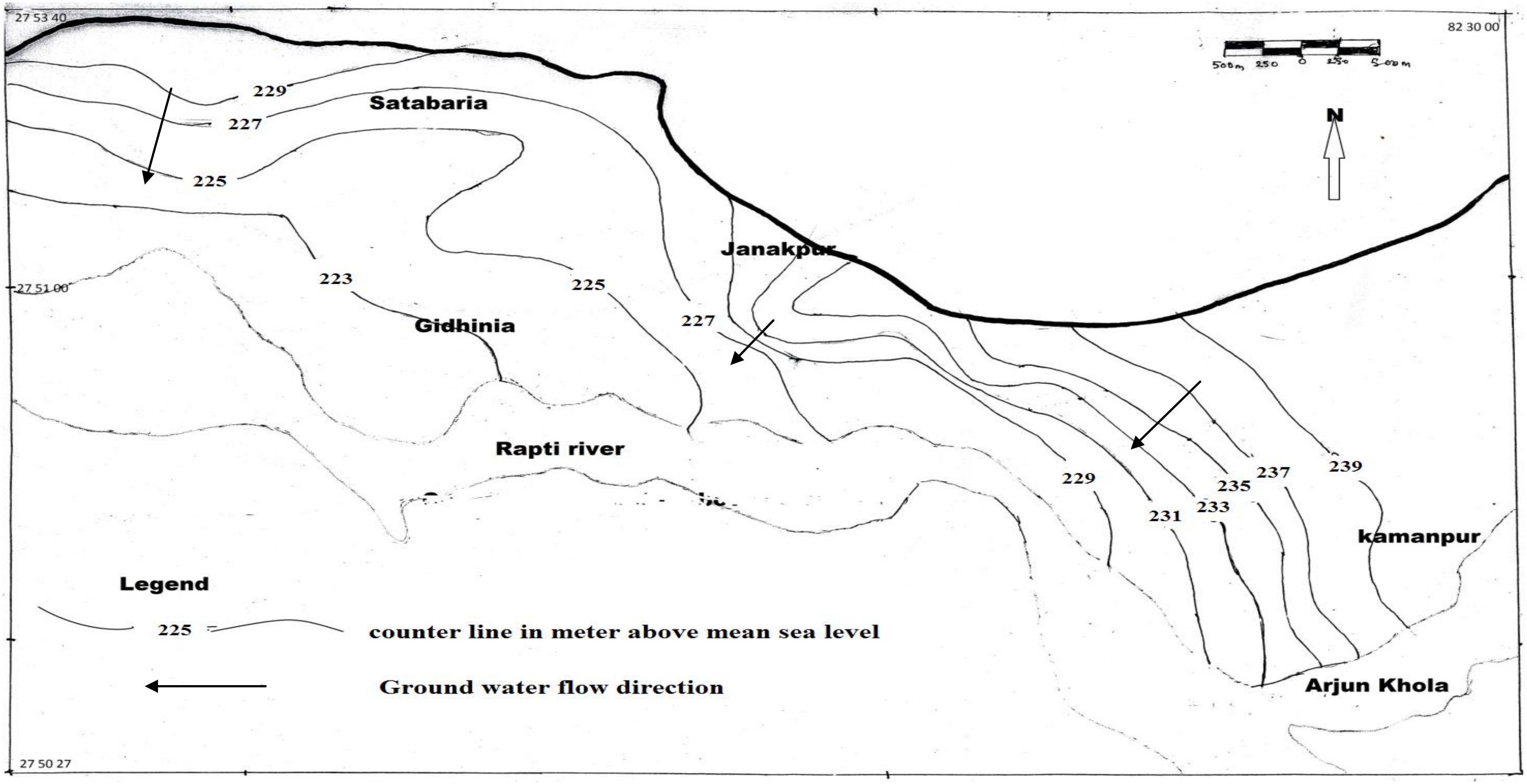

Figure 5.5 Water table map of study area from data of May 2010

Table 5.5: G.W. development in the study area

Year	HH	Population	No of TW	Irrigated land(ha)
60-61	44	450	20	50
62-63	151	1360	20	60
63-64	602	5171	80	207
64-65	345	1949	55	146
65-66	1026	5865	120	317
66-67	1457	7601	200	516
67-68	512	4668	81	202.5
68-69			112	280

Source: GWRDP/Lamahi

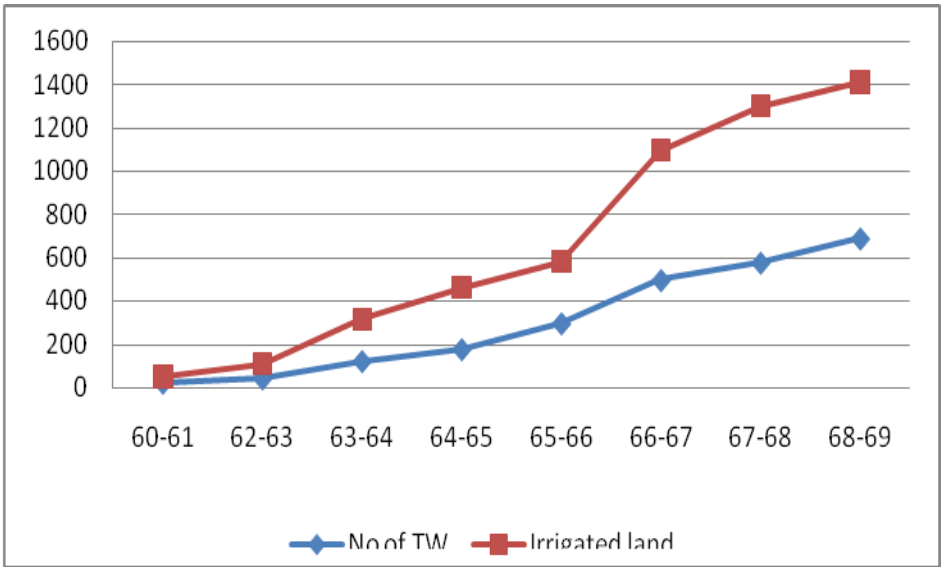

Fig 5.6: Trend of STW construction & increase of irrigated land (ha)

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

A comparative hydrogeological as well as water quality studies were carried out in the study area. In the course of this study systematic data collection, fieldwork and table work were accomplished.

The lithologs of the deep as well as shallow tubewells shows the lithology rapidly changes over small distance, which may be due to their fluvial or the recent alluvial sedimentation. The upper strata of the area is dominated by finer sediments like clay, silt and fine sand on the northern part and fine to coarse sediment distribution on the southern part.

There consist both confined and unconfined aquifers. Unconfined aquifers are within the shallow depth and confined aquifers are at the great depth. The aquifers are tapped within the gravel and sand with the intercalation of silt and clay.

The maximum water table fluctuation was noticed at Uchanimbu(DW2), northern part of the area. Based on water level elevation flow direction is mainly from north east to south west towards the Rapti River.

Well parameters are comparatively better on the east southern part than the north western part; therefore shallow aquifer is better on the east southern part as compared with the north western part. The ground water quality is almost similar through the area. Almost all the parameters are within the WHO permissible limit for the drinking purpose. Water from the shallow aquifer can be used both for drinking and irrigation purpose. Considering the nature of aquifer, socioeconomic condition and other well parameter it is concluded that shallow tubewell irrigation schemes are potential in the study area.

6.2 Recommendation

As this study was carried out is as a partial fulfillment of the requirement for the final year of Master's Degree in Geology (Natural Recourse Stream). The data, methodology and the time were limited in the study. Complete hydro geological condition couldn't be carried out from such type of study due to these limitations.

Detailed geological as well as hydrogeological study should be carried out in the whole of the area to know the detailed hydrogeological condition. A detail study should be carried to know the limit of ground water exploration in the area so that there could be taken a prevention measure before any natural disorder. In general northern part has recharge zone and so to preserve ground water natural vegetation of northern part has to be protected. Drinking water quality should be regularly monitored to fulfill the growing water demand, because the area is being urbanized and the groundwater is the main source for the purpose.

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Appendix: A- Monthly Temperature (^{o} C) Data at Ghorahi Dang

Year	2006		2007		2008		2009		2010		2011	
month	Max	Min	Max	min	Max	Min	Max	Min	Max	Min	Max	Min
January	22.7	5.9	20.9	5.1	20.3	6.4	23.2	7.2	22.1	6.1	20.6	5.2
February	26.8	12.2	22.0	9.2	22.0	7.3	26.4	9.3	24.1	8.5	24.5	8.9
March	28.3	13.0	26.4	12.8	29.1	13.8	30.5	13.0	31.7	15.2	29.9	13.6
April	32.6	17.8	32.9	18.9	33.2	17.5	34.7	18.7	36.7	20.1	33.3	17.8
May	32.2	21.5	33.3	20.6	34.6	20.9	33.0	20.5	34.6	20.7	33.4	21.4
June	31.7	22.7	32.5	23.1	29.9	22.4	33.7	22.3	34.6	23.3	31.7	22.7
July	30.5	23.6	29.1	23.1	29.4	22.8	31.5	23.6	30.8	23.3	30.9	23.4
August	30.9	23.0	30.5	22.8	30.0	22.6	30.4	23.0	30.6	23.1	31.3	23.1
September	30.2	21.6	30.2	21.8	30.2	21.0	30.4	21.6	30.0	21.5	30.9	22.1
October	29.1	16.9	28.8	17.1	28.7	15.8	29.1	16.0	29.9	17.7	30.0	17.2
November	25.2	11.2	25.2	10.3	26.1	11.6	25.7	11.3	26.1	12.9	25.7	12.7
December	22.7	7.5	21.7	6.4	23.1	8.3	22.3	7.2	22.7	6.2	22.7	7.3

Source: Department of Hydrology and Metrology, HMG, Nepal

Appendix: B- Monthly Rainfall Data at Ghorahi, Dang

Month	Precipitation						
	2005	2006	2007	2008	2009	2010	2011
Jan	45.1	0	0	8.2	0.0	0.0	5.8
Feb	28.1	0	76.7	11.5	5.3	24.9	12.4
Mar	5.2	32.6	59.0	1.6	0.2	0.9	5.8
Apr	17.4	44.2	12.0	63.8	1.0	52.4	5.8
May	103.4	116.0	89.1	52.6	269.2	73.6	135.5
Jun	110.1	157.0	272.0	429.6	107.2	297.0	234.8
July	416.7	403.5	645.9	422.3	249.4	430.6	384.8
Aug	448.5	293.9	417.7	521.0	617.7	380.1	249.5
Sep	229.8	191.3	183.6	191.8	130.7	273.5	371.1
Oct	152.8	8.2	23.5	16.8	170.5	35.8	9.4
Nov	0	0	0	0.6	0	0.0	0.0
Dec	0	19.6	0	0	0	0.0	0.0

Source: Department of Hydrology and Metrology, HMG, Nepal

Appendix: C- precipitation Hydrograph in the year 2010 and 2011

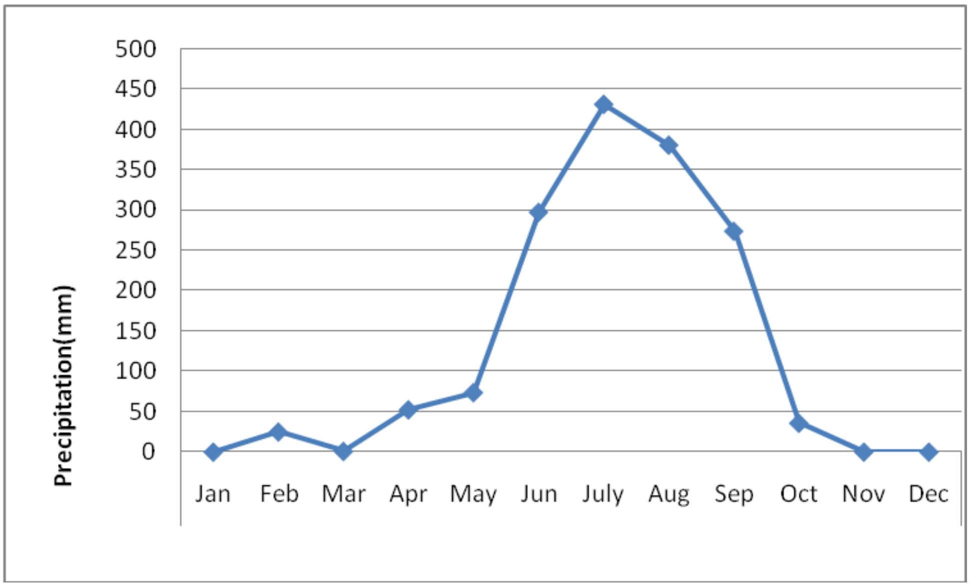


Chart: 1 Precipitation Hydrograph 2010

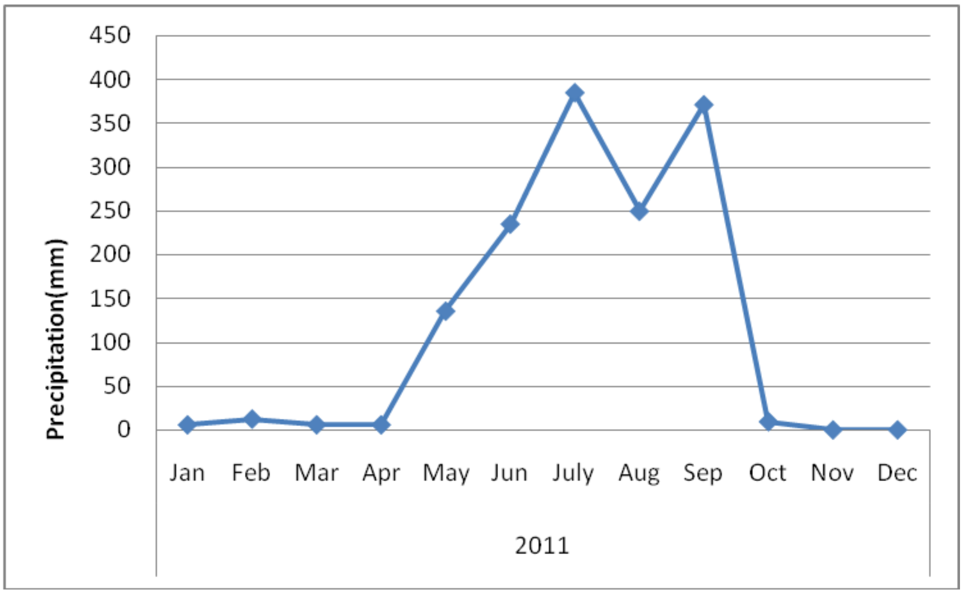


Chart: 2 Precipitation Hydrograph 2011

Appendix: D- Monthly Static water Level measurement in STW and DW of the study area

Well Observation Record in the year 2010

Location & well no.	G.L. amsl	Static water level (m) in year 2010																							
		Jan	Jan	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Jun	Jul	Jul	Aug	Aug	Sep	Sep	Oct	Oct	Nov	Nov	Dec	Dec	Remarks
		bgl	amsl	bgl	bgl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	ams	bgl	amsl	
Bengasari D4W	240	5.9	234.2	6.1	234.0	6.3	233.7	6.6	233.4	6.8	233.3	7.0	233.1	5.7	234.4	4.3	235.7	4.5	235.6	5.1	235.0	5.3	234.8	5.6	234.5	D.W.
Uchanimbu DW2	235	5.0	230.1	5.8	229.3	6.4	228.6	6.5	228.5	7.6	227.4	7.9	227.1	5.5	229.5	4.6	230.4	5.4	229.7	5.4	229.6	5.5	229.6	4.7	230.4	D.W
Satabaria DW1	228	3.7	224.4	3.9	224.2	4.2	223.9	4.4	223.6	4.9	223.2	5.0	223.1	1.7	226.3	0.9	227.2	1.5	226.5	2.4	225.7	2.4	225.6	3.4	224.7	D.W
Gidhinia	226	4.7	221.3	5.3	220.7	5.9	220.1	6.5	219.5	7.1	218.9	7.7	218.3	4.8	221.2	5.0	221.0	5.2	220.9	5.4	220.6	5.7	220.4	6.0	220.1	S.T.W.
Satabaria Gw4A	228	2.9	225.1	3.2	224.8	3.3	224.7	3.5	224.5	3.6	224.4	3.9	224.1	2.2	225.8	1.9	226.2	2.2	225.8	2.3	225.7	2.4	225.6	2.5	225.5	S.T.W
Gojenil NV/STW6	233	2.3	230.8	2.6	230.5	2.8	230.3	3.0	230.0	3.2	229.9	3.5	229.6	1.2	231.9	0.8	232.2	1.2	231.9	1.6	231.5	1.9	231.1	2.0	231.1	S.T.W.
Kamanpur INV/STW4	245	10.4	234.7	10.9	234.1	11.3	233.8	11.5	233.5	11.7	233.3	12.0	233.0	8.8	236.3	8.3	236.8	8.5	236.6	8.8	236.2	11.1	233.9	11.6	233.4	S.T.W

* Measured From the topo sheet

Source: GWRDP/Kathmandu

Well Observation Record in the year 2011

		Static water level (m) in year 2011																								
Location & well no.	G.L. amls*	Jan	Jan	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Jun	Jul	Jul	Aug	Aug	Sep	Sep	Oct	Oct	Nov	Nov	Dec	Dec	Remarks
		bgl	amsl	bgl	bgl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	ams	bgl	amsl	
BengasariDW4	240	5.9	245.6	6.1	246.1	6.3	246.3	6.6	246.6	6.8	246.8	7.0	247.0	5.7	245.7	4.3	244.3	4.5	244.5	5.1	245.1	5.3	245.3	5.6	245.6	D.W.
UchanimbDW2	235	5.0	240.0	5.8	240.8	6.4	241.4	6.5	241.5	7.6	242.6	6.9	241.9	5.6	240.5	2.6	237.6	5.3	240.3	5.4	240.4	5.5	240.5	4.7	239.7	D.W
SatabariaDW1	228	3.7	231.7	4.0	232.0	4.2	232.2	4.4	232.4	4.9	232.9	5.0	233.0	1.7	229.7	0.5	228.5	1.5	229.5	2.4	230.4	2.4	230.4	3.4	231.4	D.W
Gidhinia	226	4.7	230.7	5.3	231.3	5.9	231.9	6.5	232.5	7.1	233.1	7.7	233.7	4.8	230.8	5.0	231.0	5.2	231.2	5.4	231.4	5.7	231.7	6.0	232.0	S.T.W.
SatabariaGW4A	228	2.9	230.9	3.2	231.2	3.3	231.3	3.5	231.5	3.6	231.6	3.9	231.9	2.2	230.2	1.9	229.9	2.2	230.2	2.3	230.3	2.4	230.4	2.5	230.5	S.T.W
Gojenil Inv/STW6		2.3		2.6		2.8		3.0		3.2		3.5		1.2		0.8		1.2		1.6		1.9		2.0		S.T.W.
Kamanpu INV/STW4	245	10.4	255.4	10.9	255.9	11.3	256.3	11.5	256.5	11.7	256.7	12.0	257.0	8.8	253.8	8.3	253.3	8.5	253.5	8.8	253.8	11.1	256.1	11.6	256.6	S.T.w

* Measured From the topo sheet

Source: GWRDP/Kathmandu

Well Observation Record in the year 2012

		Static water level (m) in year 2012																				
Location & well no.	G.L.	Jan	Jan	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Jun	Jul	Jul	Aug	Aug	Sep	Sep	Oct	Oct	Remarks
	amsl*	bgl	amsl	bgl	bgl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	bgl	amsl	
BengasariDW4	240	5.9	245.6	6.1	246.1	6.3	246.3	6.6	246.6	6.8	246.8	7.0	247.0	5.7	245.7	4.3	244.3	4.5	244.5	5.1	245.1	D.W.
UchanimbuDW2	235	5.0	240.0	5.8	240.8	6.4	241.4	6.5	241.5	7.6	242.6	6.9	241.9	5.6	240.5	2.6	237.6	5.3	240.3	5.4	240.4	D.W
DW1	228	3.7	231.7	4.0	232.0	4.2	232.2	4.4	232.4	4.9	232.9	5.0	233.0	1.7	229.7	0.5	228.5	1.5	229.5	2.4	230.4	D.W
Gidhinia	226	4.7	230.7	5.3	231.3	5.9	231.9	6.5	232.5	7.1	233.1	7.7	233.7	4.8	230.8	5.0	231.0	5.2	231.2	5.4	231.4	S.T.W.
Satabaria sw4A	228	2.9	230.9	3.2	231.2	3.3	231.3	3.5	231.5	3.6	231.6	3.9	231.9	2.2	230.2	1.9	229.9	2.2	230.2	2.3	230.3	S.T.W
Gojeni INV/SW6		2.3		2.6		2.8		3.0		3.2		3.5		1.2		0.8		1.2		1.6		
Kamanpur INV/STW4	245	10.4	255.4	10.9	255.9	11.3	256.3	11.5	256.5	11.7	256.7	12.0	257.0	8.8	253.8	8.3	253.3	8.5	253.5	8.8	253.8	S.T.w

* Measured From the topo sheet

Source: GWRDP/Kathmandu

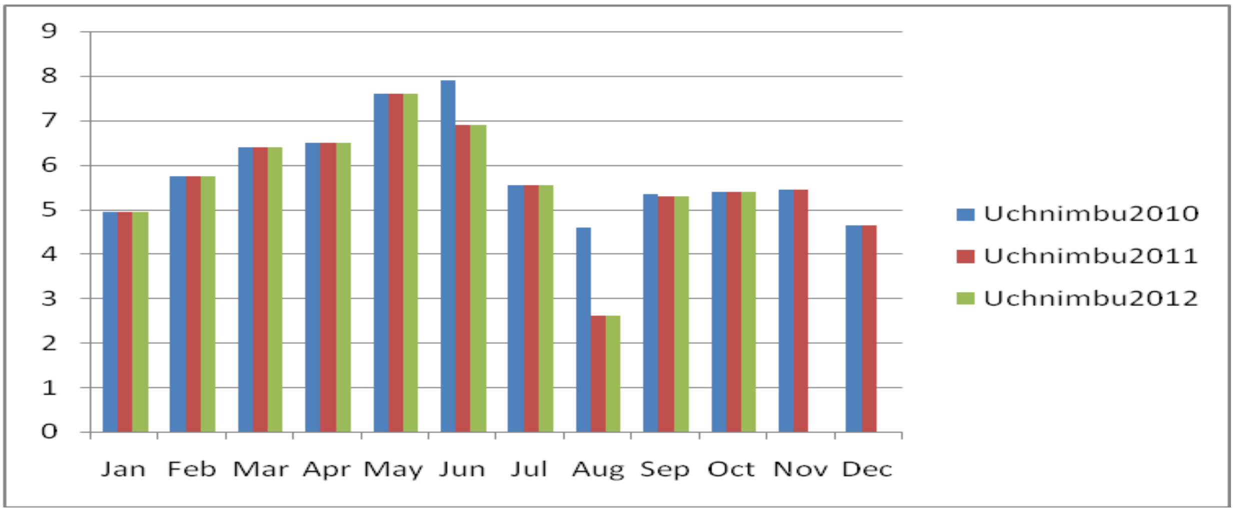


Chart: 1 Monthly W.L. (bgl) Measurement of D.W. at Uchnimbu in 2010, 11, 12

DW2	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Uchnimbu2010	4.95	5.75	6.4	6.50	7.60	7.9	5.55	4.6	5.35	5.4	5.45	4.65
Uchnimbu2011	4.95	5.75	6.4	6.50	7.60	6.9	5.55	2.6	5.3	5.4	5.45	4.65
Uchnimbu2012	4.95	5.75	6.4	6.50	7.60	6.9	5.5	2.6	5.3	5.4		

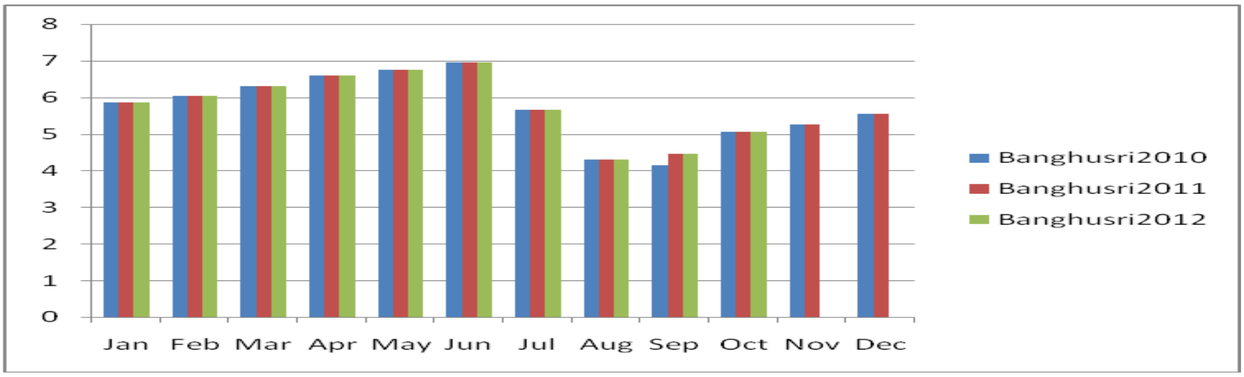


Chart: 2 Monthly W.L. (bgl) Measurement of D.W. at Banghusari in 2010, 11, 12

DW4	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Banghusri2010	5.85	6.05	6.30	6.6	6.75	6.95	5.65	4.3	4.15	5.05	5.25	5.55
Banghusri2011	5.85	6.05	6.30	6.6	6.75	6.95	5.65	4.3	4.45	5.05	5.25	5.55
Banghusri2012	5.85	6.05	6.30	6.6	6.75	6.95	5.65	4.3	4.45	5.05		

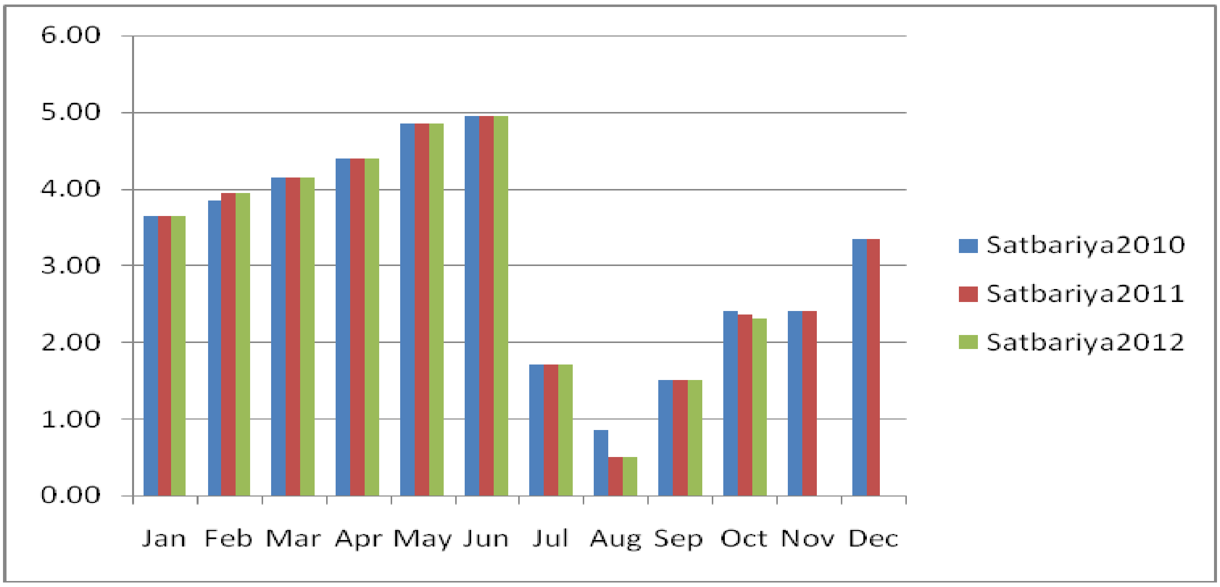
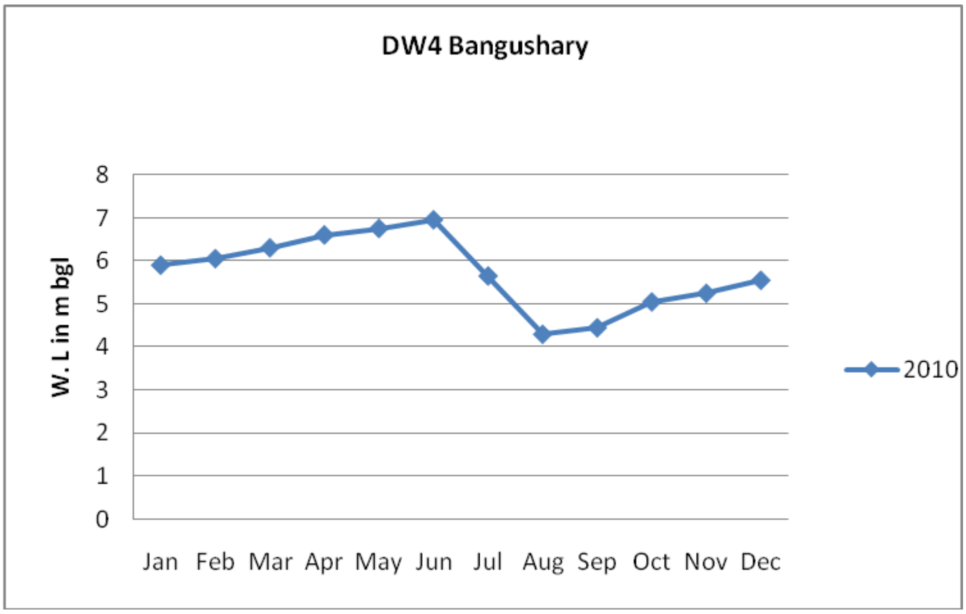
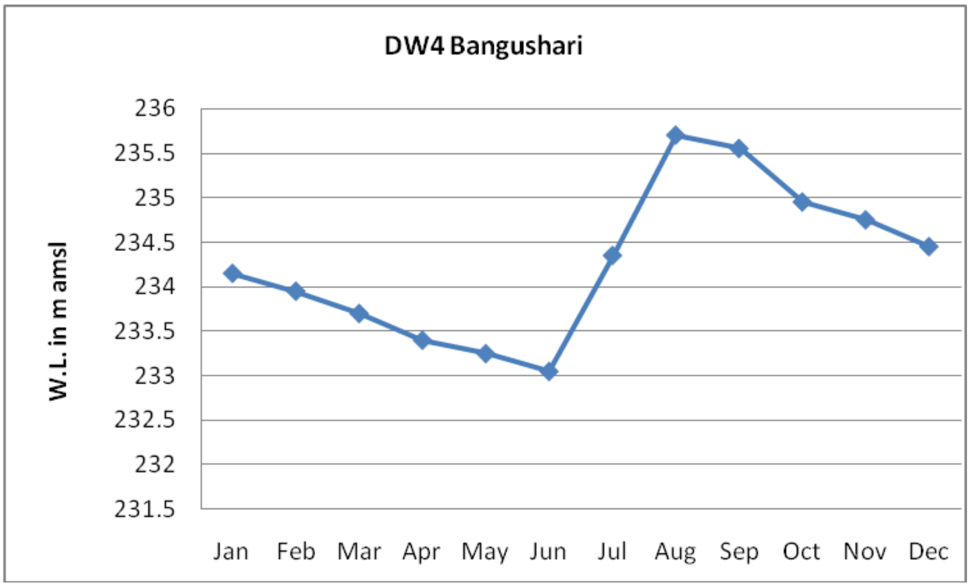


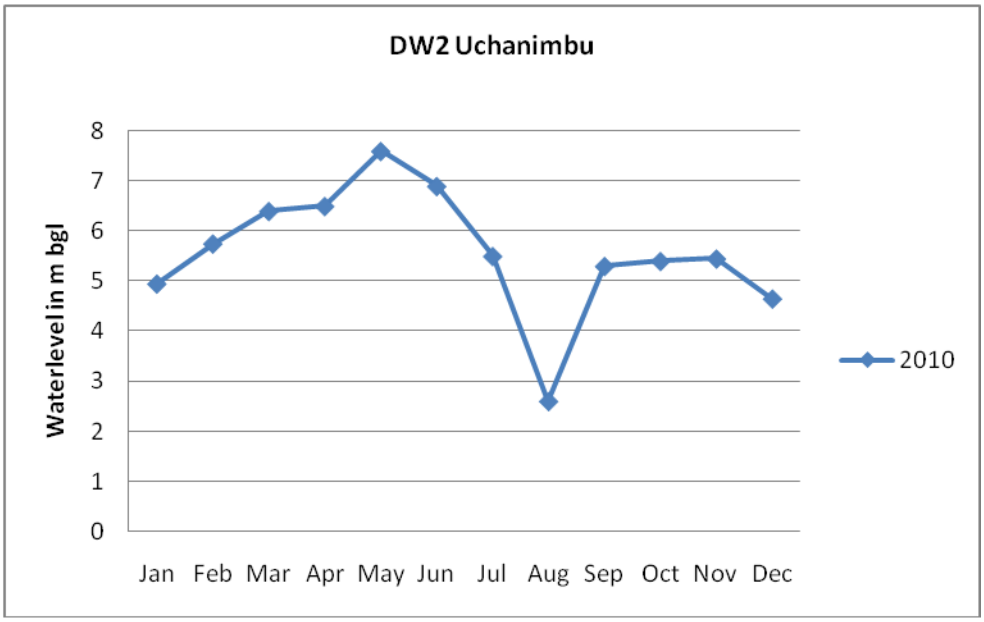
Chart: 3 Monthly W.L.(bgl)Measurement of D.W. at Satabaria in 2010, 11, 12

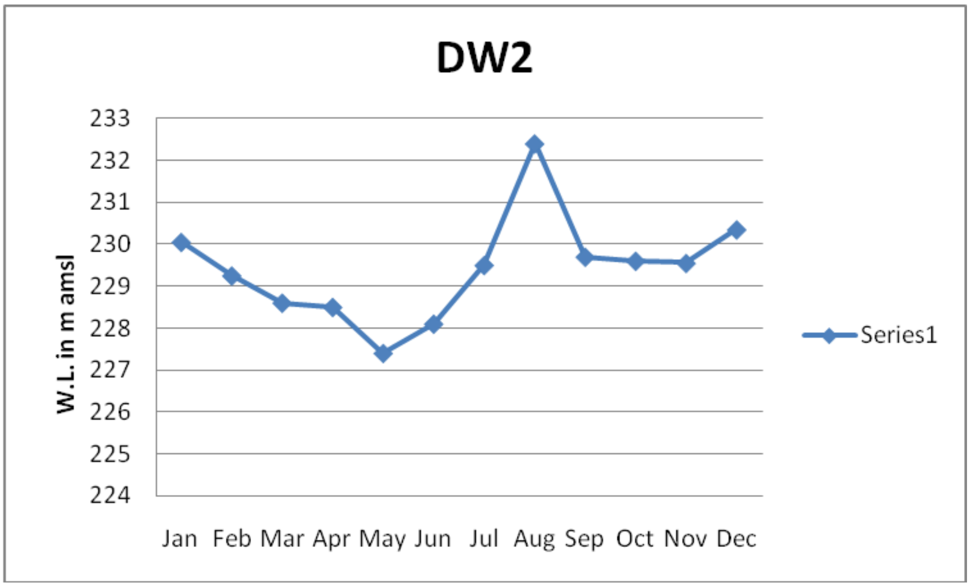
DW1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Satbariya2010	3.65	3.85	4.15	4.4	4.85	4.95	1.70	0.85	1.50	2.4	2.4	3.35
Satbariya2011	3.65	3.95	4.15	4.4	4.85	4.95	1.70	0.5	1.50	2.35	2.4	3.35
Satbariya2012	3.65	3.95	4.15	4.4	4.85	4.95	1.70	0.5	1.50	2.3		

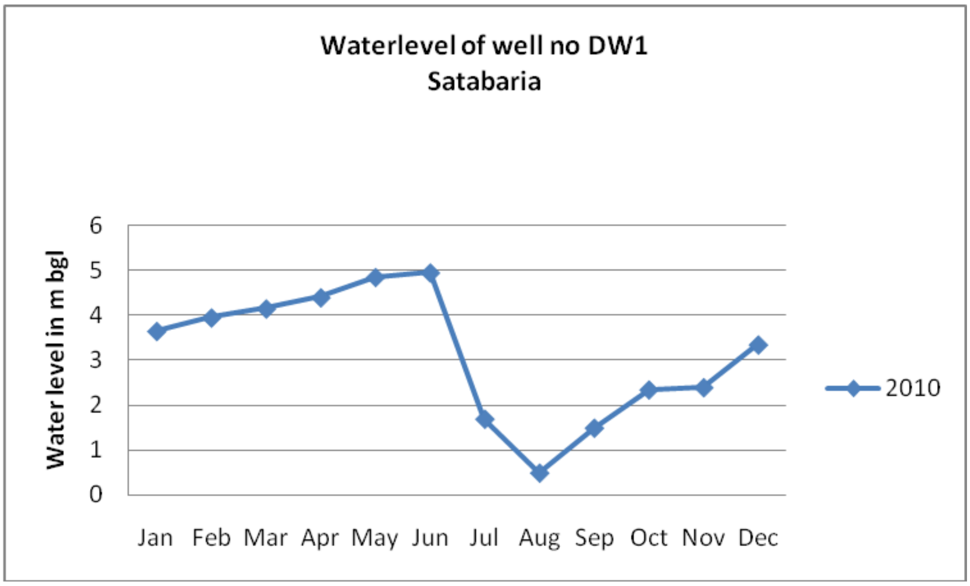
Appendix: E- Water level Hydrograph of Shallow and dug wells 2010



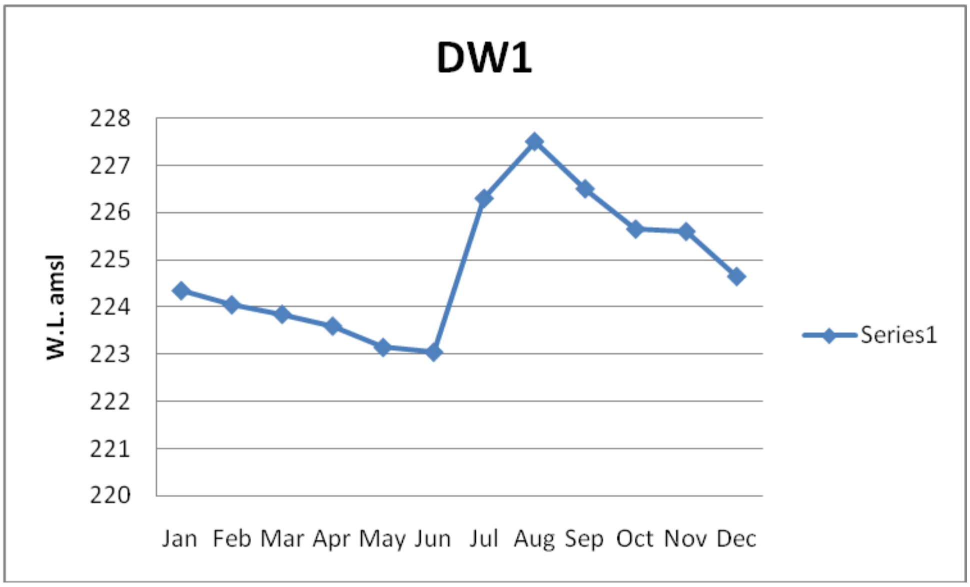


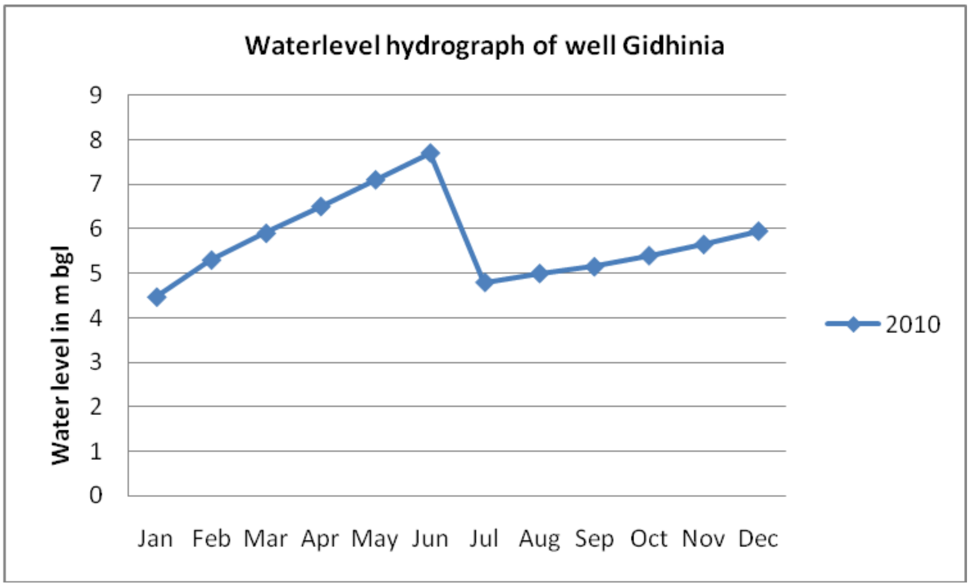

DW2 Uchanimbu
Waterlevel in m bgl
0
1
2
3
4
5
6
7
8
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010

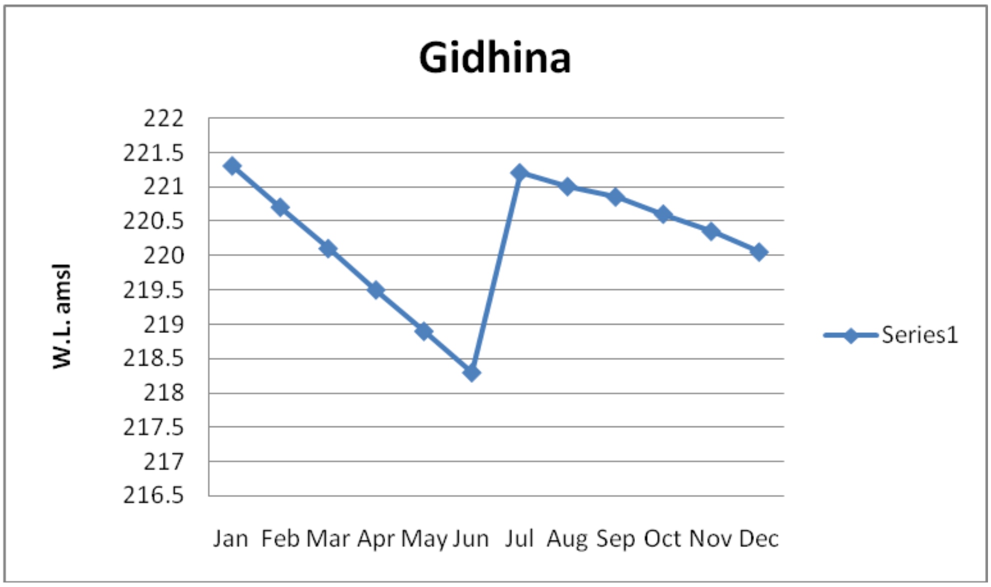

DW2
W.L. in m amsl
224
225
226
227
228
229
230
231
232
233
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Series1

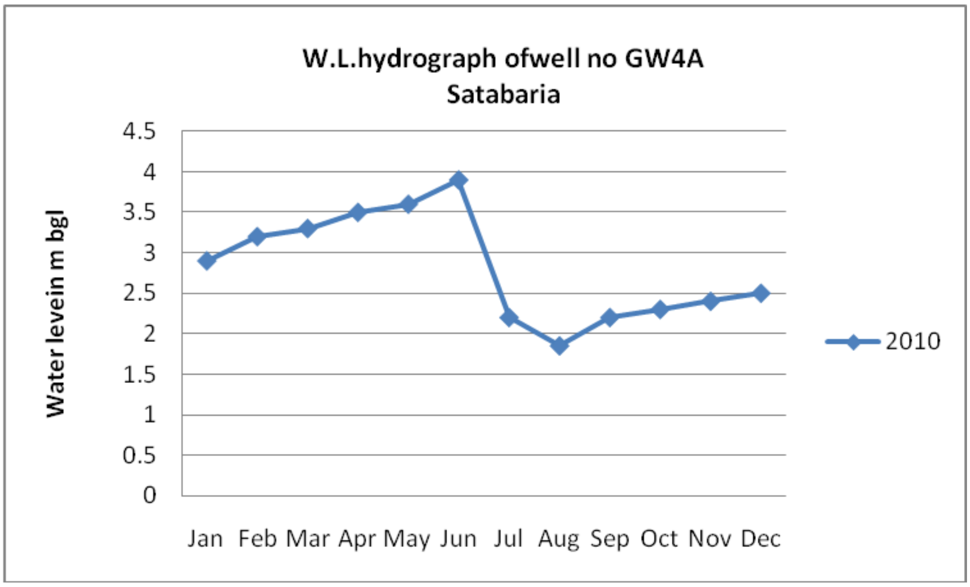

Waterlevel of well no DW1
Satabaria
Water level in m bgl
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2010

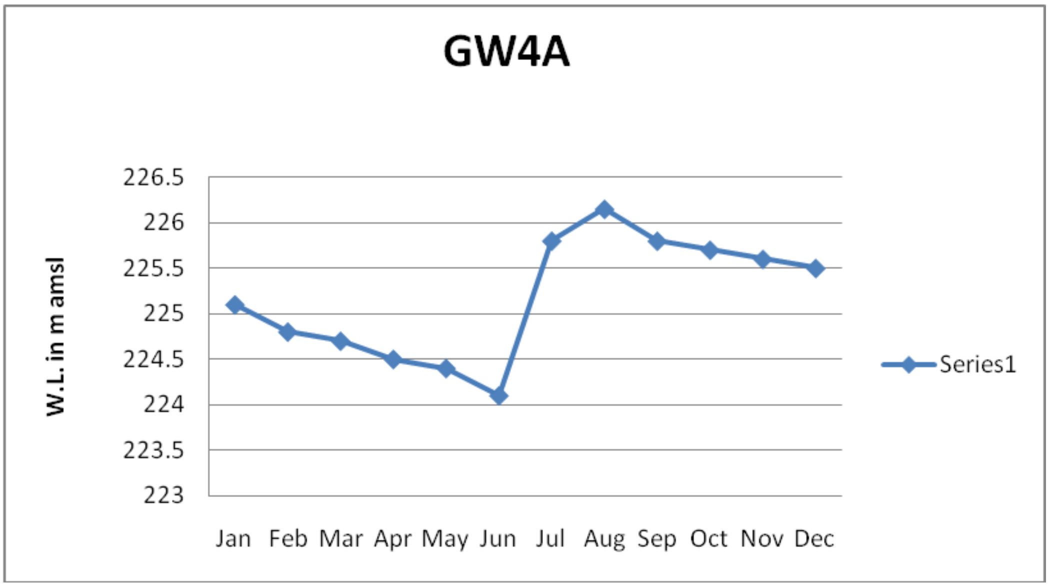
Appendix: D

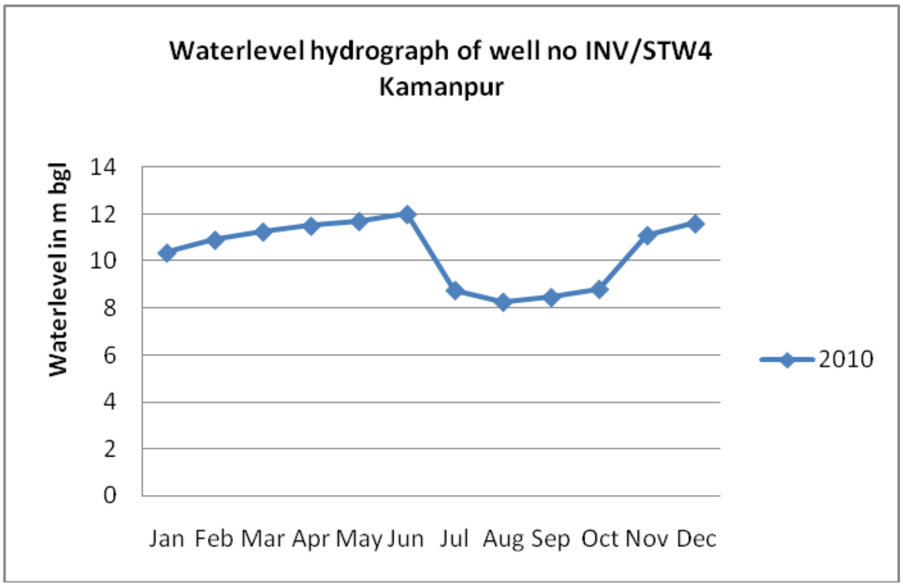

DW1
W.L. amsl
228
227
226
225
224
223
222
221
220
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Series1

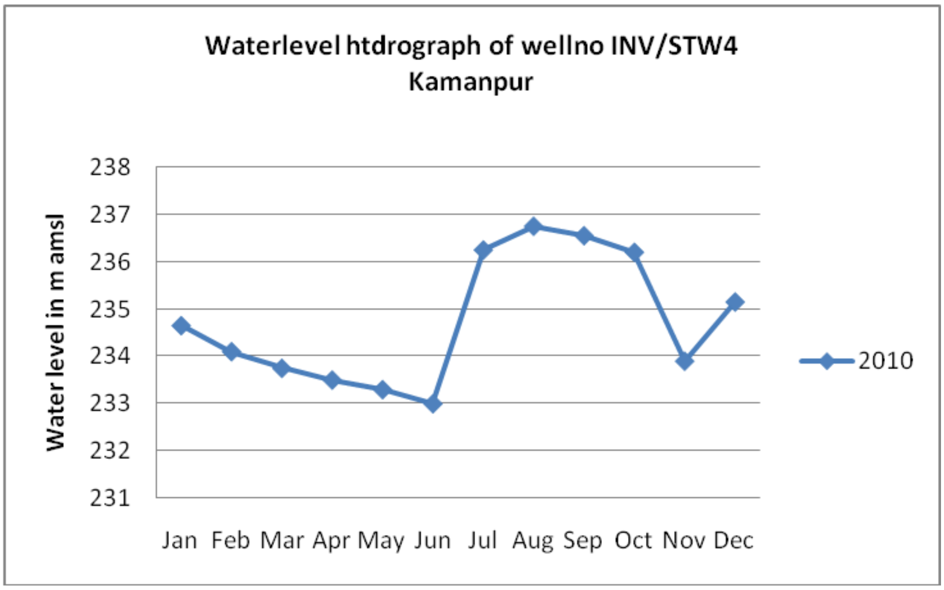

Waterlevel hydrograph of well Gidhinia
Water level in m bgl
9
8
7
6
5
4
3
2
1
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010

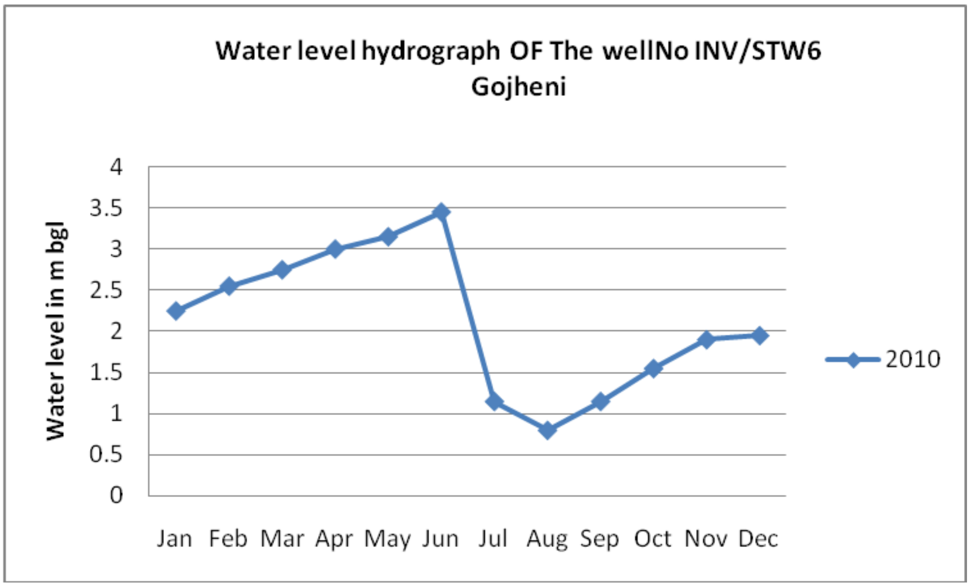

Gidhina
W.L. amsl
222
221.5
221
220.5
220
219.5
219
218.5
218
217.5
217
216.5
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Series1

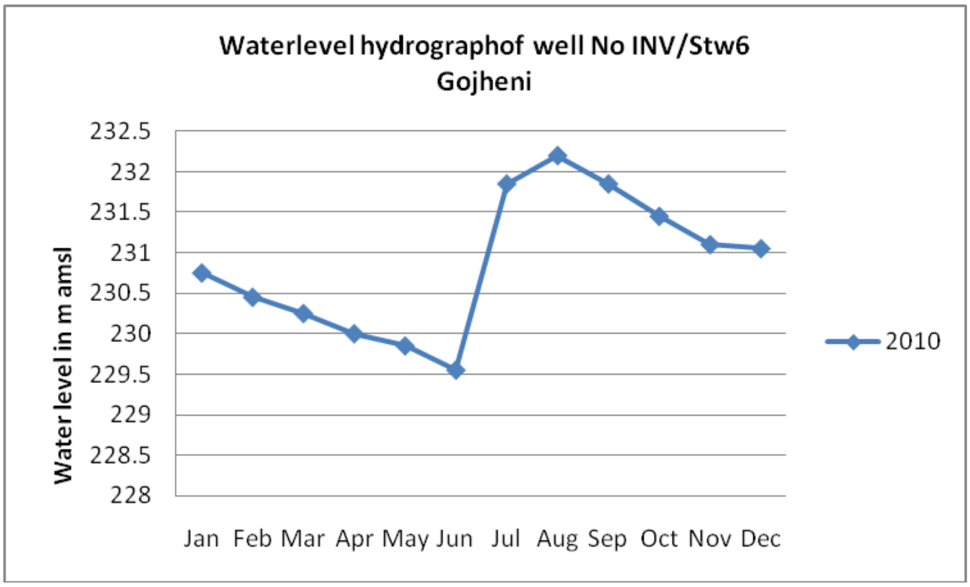

W.L.hydrograph ofwell no GW4A
Satabaria
Water levein m bgl
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010


GW4A
W.L. in m amsl
226.5
226
225.5
225
224.5
224
223.5
223
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Series1


Waterlevel hydrograph of well no INV/STW4
Kamanpur
Waterlevel in m bgl
14
12
10
8
6
4
2
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010


Waterlevel htdrograph of wellno INV/STW4
Kamanpur
Water level in m amsl
238
237
236
235
234
233
232
231
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010


Water level hydrograph OF The wellNo INV/STW6
Gojheni
Water level in m bgl
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010


Waterlevel hydrographof well No INV/Stw6
Gojheni
Water level in m amsl
232.5
232
231.5
231
230.5
230
229.5
229
228.5
228
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010

Appendix: F-Data Summary of Shallow and Deep Tubewells

Location	Well No.	Drilling date	G.L. (m)	Depth	Q ($l\ s^{-1}$)	SWL (m)	Total Drawdown (m)	T (m^2/d	Sp. Capacity l/ sm	Screen Position (m)	Remark
Hasanapur	DKSTW1	1988	235.36	38.1	23	1.95	4.86	4610	4.73	9.5-15.9 32-37.7	STW
Uchanibu	GW1	1985	234.8	74.7		2.5				41-45.9, 49.5-55.2	DTW
Satabaria	GW4a	1987	228.29	11						5.5-11	STW
Satabaria	GW4b	1987	227.69	75		0				46.6-57.7	DTW
Satabaaria	DKSTW2(ADBN)	1988	229			4.21		700			
Bangai	DKSTW3(ADBN)	1988	239			3.78		1217			STW
Gojena	INV/STW6	2055	230	9	7.66	2.82	5.25		1.45	4.5-9	STW

Source: GWRP/ Lamahi

Appendix:G

Lithological log of the shallow tubewell

Well No: NISP/INV/W-6 | Well Depth:22.37m
Location: Gojhena | Drilling Started: 2055-1-18
Drilling Depth: 65.7m | Drilling completed:
Screen

Lithological Description

Depth(m)	Thickness(m)	Lithology
0-0.5.0	0.5	Top soil
0.5-.5.0	4.0	Clay
4.5-9.0	4.5	Thick to medium gravel with fine sand
9.0-21.0	12.0	Clay
21.0-23.0	2.0	Clay mixed with fine gravel
23.0-26.0	3.0	Clay
26.0-29.0	3.0	Clay mixed with few gravel
29.0-65.7	36.7	Clay

Source: GWRP/Lamahi

Lithological log of the shallow tubewell

Well No: Gw 4 a

Well Depth: 11m

Location: Satabaria

Drilling Started: 02/87-4/04/87

Drilling Depth: 11m

Drilling completed:

Screen position: 5.5-11m

Lithological Description

Depth(m)	Thickness(m)	Lithology
0-0.9	0.9	Topsoil
0.9-4.6	4.5	sand
4.6-11.0	10.54	Gravel

Source: Gwrp –UNDP Nep/86/025

Lithological log of the shallow tubewell

Well No: GW4b

Well Depth: 57.7m

Location: Satabaria

Drilling Started: 08/04/87

Drilling Depth: 77m

Drilling completed:

Screen Position: 46.6-57.7m

Lithological Description

Depth(m)	Thickness(m)	Lithology
0-0.3	0.3	Topsoil
00.3-7.6	7.3	Gravel and sand
7.6-13.1	5.5	Clay
13.1-20.7	7.6	Clay and gravel
20.7-23.5	2.8	Gravel and pebble
23.5-25.6	2.1	Clay
25.6-29.9	4.3	Gravel and sand
29.9-44.2	14.3	Clay and gravel
44.2-65.2	21	Gravel and sand
65.2-76.2	11.0	Clay and gravel

Source: Gwrp –UNDP Nep/86/025

Lithological log of the shallow tubewell

Well No: GW1

Well Depth: 55.2

Location: Unchanimbu

Drilling Started: 08/04/87

Drilling Depth: 74.7

Drilling completed:

Screen position: 41-45.9m, 49.7-55.2m

Lithological Description

Depth(m)	Thickness(m)	Lithology
0-5.8	5.8	Clay silty
5.8-10.4	4.6	Clay and Gravel
10.4-41.1	30.7	Clay silty
41.1-47.5	6.4	Gravel and sand
47.5-60.0	12.5	Clay silty
60.0-63.4	3.4	Gravel
63.4-67.4	4	Clay silty
67.4-73.2	5.8	gravel
73.2-74.7	1.5	Clay

Source: Gwrp –UNDP Nep/86/025

Lithological log of the shallow tubewell

Well No: DKSTW 1 Well Depth: 37.7

Location: Hasanapur Drilling Started: 08/04/88

Drilling Depth: 38.1 Drilling completed:

Screen position: 9.5-15.9m, 32-37.7m

Lithological Description

Depth(m)	Thickness(m)	Lithology
0-1.8	1.8	Clay
1.8-6.7	4.9	Sand and gravel
6.7-8.2	1.5	Clay silty
8.2-14.3	6.1	Gravel and sandl
14.3-20.1	5.8	Clay sandy
20.1-38.1	18	Grave and sand

Source: Gwrp –UNDP Nep/86/025

Lithological log of the shallow tubewell

Well No: NISP/INV/STW-4 Well Depth: 29.9

Location: Kamanpur Drilling Started:

Drilling Depth: 30m Drilling completed:

screen Position: 16.0-24.0m

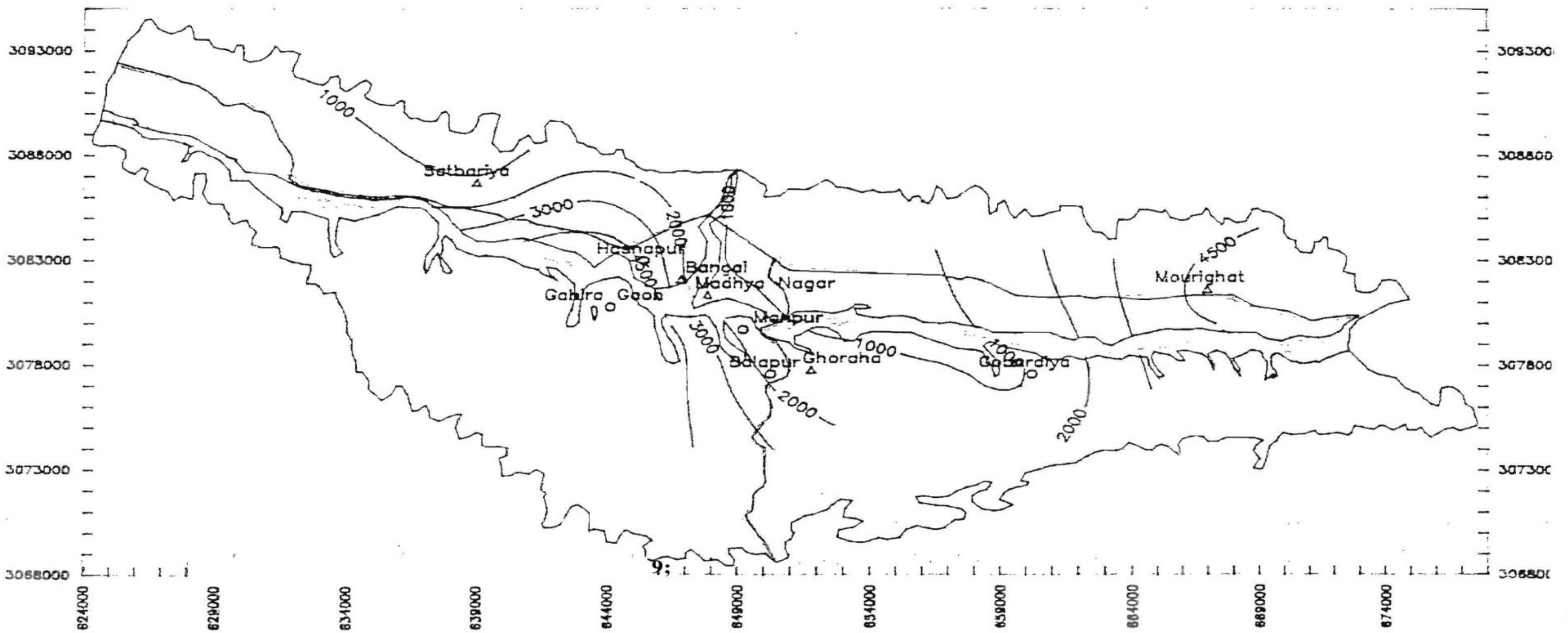
Lithological Description

Depth(m)	Thickness(m)	Lithology
0-0.85	0.85	Topsoil
0.85-1.0	0.15	Silty clay
1-3.25	2.25	Sand and few fine to medium gravel
3.25-8.0	4.75	Clay mixed with few fine to medium gravel
8.0-12.0	4.0	Yellow sticky clay
12.0-14.0	2.0	Clay mixed with few fine to medium gravel
14.0-20.0	6.0	Coarse sand with fine to edium grave
20.0-24.0	4.0	Fine to medium gravel mixed sand
24.0-25.5	1.5	Sand
25.5-28.0	2.5	Sand mixed with gravel
28.0-29.95	1.95	Yellowish clay

Source: GWRP/Lamahi

Appendix: H

Deukhuri valley: Transmissivity(m^2/day)



Source: GWRDP/UNDP; Technical report no9; 1998

Appendix: I

Water Quality standard of WHO, FAO and USA

(WHO International for Drinking Water Quality)

Parameters	Unit	Desirable Limit	Permissible Limit
Color	Hazen	5	50
Turbidity	mg/l	5	25
Total Dissolved Solids(TDS)	mg/l	500	1500
PH	mg/l	7-8.5	6.5-9.5
Mineral Oil	mg/l	0.01	0.3
Phenol	mg/l	0.001	0.002
Total Hardness	mg/l	100	500
Calcium	mg/l	75	200
Chloride	mg/l	200	600
Copper	mg/l	0.05	1.5
Iron	mg/l	0.1	1
Magnesium	mg/l	30	150
Sulfate	mg/l	200	400
Zinc	mg/l	5	15
Ammonia	mg/l	0.05	
Arsenic	mg/l		0.05
cadium	mg/l		0.01
Sydenide	mg/l		0.05
Lead	mg/l		0.1
Mercury	mg/l		0.001

Appendix: J

Field Format for well inventory survey

Sample station: ___

Name of FARMER:

Location obtained from GPS:

X:

Y:

Z:

Number of tube-well they use:

Amount of land they irrigate per tube well

Amount of land remain un-irrigated:

Fuel they use to drive pump:

Major Crop they produce

Cash crops	Food Crops

Number of farmer sharing same tubewell:

Water extraction rate:______________ LPS

Duration:

Time

Distribution Scheme:

Canal: ___________________ (Cemented/earthen/Pipe)

Satisfied with existing system:_____________ (Yes/No)

No=>Resaons____

____

____

Spacing between two adjacent tubewell: _____ m

Depth of tubewell: ______

Does the tube supply water throughout the year: Yes/No

No=> Months: __________ to ________

Duration: _______________________ Months

Change in water level experienced: Yes/No

Yes=> _________ meter or Feet

Since:__________ AD

Change in water quality experienced: Yes/No

Yes =>odor

Color

Turbidity

Other

Since:________ AD

Construction Analysis:

Pipe

Diameter: ________ inch

Thickness:_________mm

Depth: ___________ meter

Type: ___________ (GI/PPR…)

Net

Spacing:_______

Material:_______

Type:______

Other material used for construction1

Specifications1

Specifications2

Other material used for construction2

Specifications1

Specifications2

Power Consumption for electric feed pump: ______kW/hr

Fuel consumption for diesel/petrol feed pump:_____ L/hr

Drying of local Pond nearby: Yes/No

Decrease in river water level: Yes/No

Adverse Impacts experienced by farmers:

S.No	Problem	Remark (Low/medium/high)

स्यालो ट्यूबवेलकालागि सम्भाव्यताअध्ययन

प्रश्नावली

अन्तर्वार्ता लिनेको नाम: अन्तर्वार्ता लिएको मिति:

१. उत्तरदाताको विवरण:

नाम: लिङ्ग: जात: धर्म:

जिल्ला:   गा.वि.स./न.पा.:   गाउँ/टोल:

२. घरपरिवारका सदस्यको शैक्षिक योग्यता:

योग्यता/	अशिक्षित		अनौपचारिक		१-५ कक्षा		६-८ कक्षा		९-१० कक्षा		११-१२ कक्षा		>१२ कक्षा	
उमेर (वर्ष)	म.	पु.	म.	पु.	म.	पु.	म.	पु.	म.	पु.	म.	पु.	म.	पु.
<५														
६-१०														
११-२०														
२१-३०														
३१-४०														
>४०														

३. घरपरिवारको आम्दानीकामूख्यतीन स्रोतहरु के के हुन् ?

1...

2...

3...

४. वर्षमाकतिबाली लगाउनुहुन्छ ?

1.१ बाली   २ बाली   ३ बाली

५. बालीनालीको उत्पादनसंग सम्बन्धीतप्रश्नहरुः

			धान	**मकै**	**गहुँ**	**मुसुरो**	....	....	....	....	....
बालीलगाउने समय											
बालीभित्र्याउने समय											
बीउ											
मूल्य											
परिमाण											
म्ल											
प्रकार											
मूल्य											
परिमाण											
कीटनाशक औषधी											
औषधीको नाम		मूल्य									
		परिमाण									
		मूल्य									
		परिमाण									

६. नजिकको बजार कुनहो ? ....

७. कति टाढा छ ?...

८. उत्पादितअन्न वेचविखनगर्न सुविधा छ की छैन ?

1. छ 2. छैन

९. धेरै भएको अन्नकहाँ सञ्चय गरेर राख्नुहुन्छ ?

1. घरमा
2. कोल्ड स्टोरमा
3. अन्य (खुलाउनुहोस्) ....

१०. यदि धेरै भएको अन्न घरमा नै राख्नुहुन्छ भने कति सम्मअन्न सञ्चय गरेर राख्न सक्नुहुन्छ ?

....

११. हालको सिंचाईको मूख्य स्रोत के हो ?

1. आकाशे पानी
2. नहर सिँचाई
3. इनार
4. बोरिङ्ग

१२. अन्य (खुलाउनुहोस्) हालको सिंचाईको स्रोतले कतिमहीना सिंचाई गर्न पुग्छ ?

....

१३. वर्षैभरी सिंचाई सुविधाउपलब्धभएमातपाईं के गर्नुहुन्छ ?

1. यही स्रोत नै पऱ्याप्त छ
2. लगाईराखेको बालीबाट धेरै उत्पादन लिन्छु
3. नयाँबाली लगाउँछु

१४. अन्य (खुलाउनुहोस्) यदिनयाँबाली लगाउनुहुन्छ वालगाईराखेको वाली प्रणाली परिवर्तन गर्नुहुन्छ भने कुनकुनबालीलाई प्राथमिकता दिनुहुन्छ ?

1. ....
2. ....