Journal of Nepal Hydrogeological Association (JNHA), Vol (1), 43-56 (2024)
ISSN: 3059-9725 (Online)

RESEARCH ARTICLE

Hydrogeological studies in the Western part of Banke District, Nepal (Province 5)

***Dipika Shah[1], Dinesh Pathak[1], Nir Shakya[1], Ramesh Gautam[1] and Surrendra Raj Shrestha[1]**

[1]Central Department of Geology, Tribhuvan University, Kathmandu, Nepal

**Corresponding author: id.dipikashah@gmail.com*

(Submission Date: 29 July 2024; Accepted Date: 5 September 2024)

ABSTRACT

Study of subsurface geology, aquifer system, thickness of hydro stratigraphic units, potential area based on transmissivity and yield, flow direction of groundwater of the western part of Banke District was carried out covering the area of 616.15 km². Lithological, hydrogeological and meteorological data maps, lithologs, static water level, precipitation, transmissivity, yield, springs etc. were carried out during desk study and field work. The study area consists of alluvial deposits of Pleistocene to Recent age derived from the Siwalik Hills and the mountains to the north and deposited by the Rapti River. Lithologically, the study area consists of clay, silt, sand and gravel. The cobbles, pebbles and somewhat boulders are also present. Geologically, the study area is located in Indo Gangetic Plain. The Indo Gangetic Plain is divided into Bhabar Zone and Terai Plain. Further the Terai Plain is divided into Middle Terai and Southern Terai. The Bhabar Zone is estimated of an area 68.83 km². Aquifers in the study area are confined types. The springs were found in the northern flat of the study area. Where the observed springs formed a line called spring line which is the southern boundary of Bhabar Zone and the base of Siwalik is northern boundary. The flow direction of ground water over the study area is towards the north.

Key word: ***Hydrogeology, Hydro stratigraphy, Transmissivity, Yield, Springs***

INTRODUCTION

Banke District, a part of Province No. 5, is one of the seventy seven districts of Nepal. It is located in Mid-western, Nepal with Nepalgunj as its district headquarter and lies between Longitude 81º 30' 0" to 81º 48' 30" and Latitude 28º 19' 0" and 27º 57' 0". There are three main cities in the Banke District: Nepalgunj, Kohalpur and Khajura Bajaar. The Hydrogeological study of western part of Banke District was carried out to know about the area of Bhabar Zone, Sub surface geology, Aquifer system, flow direction and potential area. The Rapti Nadi is the major river and its tributaries Amarai Khola, Amila Nala, Beha Nala, Chyama Khola, Dudawa Khola, Dondra Nala, Itahawa Nala, Jethan Nala, Jethi Nala, Kiran Nala, Man Khola, Murgiha Nala, Pendari Nala and Rohini Nala. The Stream network formed by these streams has an average density of one stream every 10 Km² in Banke (Gautam, 2005). The study area covers 616.15km² area and the population is 3,52,816 (CBS, 2017). Geologically, the study area is Indo Gangetic Plain. The Indo Gangetic Plain is divided into Bhabar Zone and Terai Zone. Further the Terai Zone is divided into Middle Terai and Southern Terai. The Bhabar Zone consists of coarser deposits such as gravel, cobble, and pebble. The Terai Zone consists of sand, gravel and high proportion of silt and clay. The study area is underlain by Churia group, Terrace deposits and Alluvium. The Alluvium

can be subdivided into three groups, Northern Alluium in the Bhabar Zone, Central Alluvium in the undulating plain and Gangetic Alluvium Plain in the southern strip (JICA, 1995). A spring line is usually seen to separate the northern Bhabar Zone from the southern Terai plain (Dhital, 2015). The outcrop area of Bhabar Zone is estimated at 120 km² in Banke area (Tillson, 1985), and is a principal recharge area for the ground water reservoir of the Banke Terai. The location map of the study area is shown in Fig. 1.

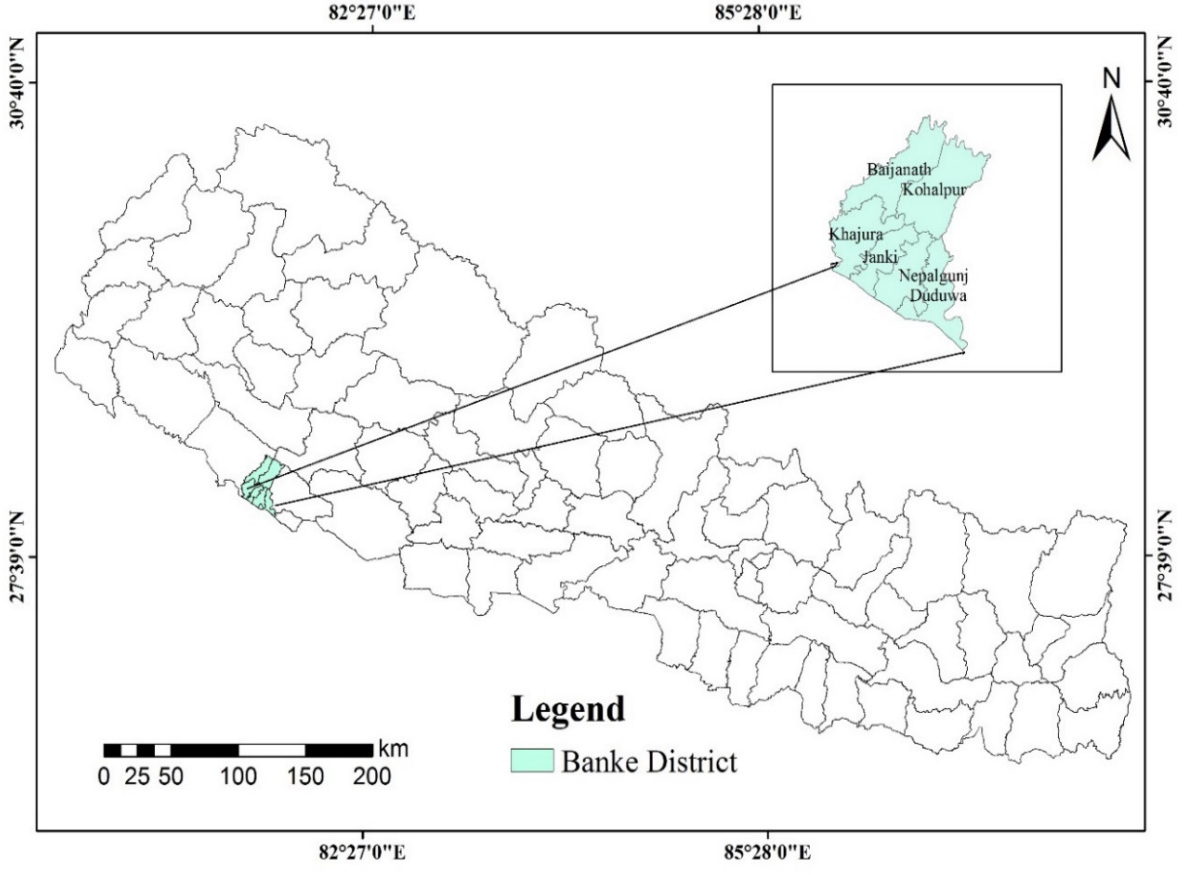

Fig. 1: Location map of Banke District of the study area.

Altogether seventy-four deep tube wells are located in the study area. The well at Chisapani is flowing. The well drilled up to depth 64 to 195.12 m which were constructed at Karkado, Nepalgunj, and K-Gaun, Sitapur-3 of Banke District. The location of deep tube well is shown in Fig. 2.

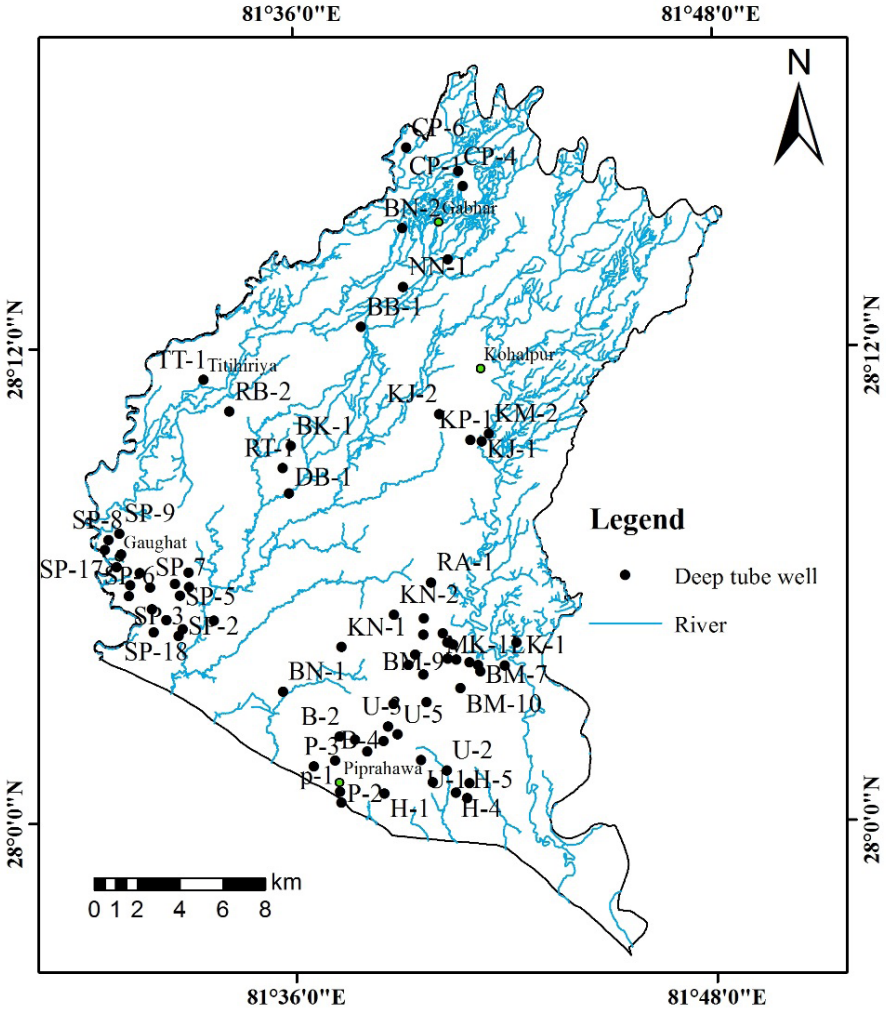

Fig. 2: Location of Deep Tube Well of the study area.

METHODOLOGY

The research is based partly on primary data and partly on secondary data. Collection of previous literature, topographical maps, geological maps, lithological data hydrogeological and meteorological data related to the study area was carried out during desk study. Hydrogeological database of the study area has been prepared in GIS and potential zones for groundwater exploitation have been delineated. Field investigation was carried out for collecting the detailed information on hydrogeological condition of the area. The GPS was used to obtain the coordinates of the observation points and topographical maps (1:25,000) were used as base map in the field. Altogether eight springs was observed during the field study. The observed springs are S1, S2, S3, S4, S5, S6, S7 and S8. The springs are contact spring. After joining all the spring, there observed a line called spring line in ArcGIS and finally the Bhabar Zone is delineated from the spring line. Total Seventy-four deep tube wells are located in the study area. The data obtained from the

pumping test was analyzed and different thematic layers of transmissivity and yield was prepared in the ArcGIS in order to delineate potential zones, flow movement of groundwater using static water level above mean sea level, geological map from observed lithological data and springs. Again, six section lines were drawn in ArcGIS and cross sections were plotted in Rockwork software in order to know hydrogeological conditions and hydro stratigraphical units with confined aquifers and confining layers. And finally, the fence diagram was drawn in order to know 3-D distribution of hydro stratigraphic units in the study area. The thickness maps of aquifer horizons are prepared in ArcGIS.

RESULTS AND DISCUSSION

Delineation of Bhabar Zone (Spring Inventory)

The springs are located at the elevation of 174 meter to 194 meter. Mostly the springs are found in forest area. Based on the deposits, the springs are located in alluvium deposits of rivers. The observed springs are tabulated below (Table 1).

Table 1: Location of springs in the study area.

S.N	Spring	Location	Elevation (m)	Deposit type	Spring type
1	S1	Geruwa khola ,Mehadewa Village	182	Alluvial deposit	Contact spring
2	S2	Rohini khola, Pipaltakur Village	191	Alluvial deposit	Contact spring
3	S3	Duduwa khola, Nayabasti Village	174	Alluvial deposit	Contact spring
4	S4	Duduwa khola, Ranighat Village	190	Alluvial deposit	Contact spring
5	S5	Itahawa Nala, Jumalibasti Village	194	Alluvial deposit	Contact spring
6	S6	Jethi Nala, Thakuritol Village	208	Alluvial deposit	Contact spring
7	S7	Jethi Nala, Daillichar Village	211	Alluvial deposit	Contact spring
8	S8	ManKhola, Jumalibasti Village	200	Alluvial deposit	Contact spring

All the spring observed in field (Table 1), formed a line called spring line which separates the Babar Zone from Terai Plain. The northern part consists of very coarse grain materials and southern part consists of fine grain materials. There exist lateral facies variation changes in the succession. Due to this lateral change of facies, there exist back pressuring of groundwater because of low permeability in southern part (Sah, 2015) and the spring is formed. The spring line also arises due to topographic gradient. Most of the river coming from the hills pass through the permeable zone of north and are found recharging aquifer in the northern part. Rivers which have few cusecs of water mostly vanish in summer while passing through the permeable zone and usually appear after the spring line (Sharma, 1981). The springs observed during field are contact spring. The map is prepared below (Fig. 3) on the basis of observed spring. For the Bhabar Zone delineation, the southern boundary is represented by spring line where as the southern boundary of Siwalik is considered as northern boundary. The area of Bhabar Zone is estimated at nearly 68.83 km^2.

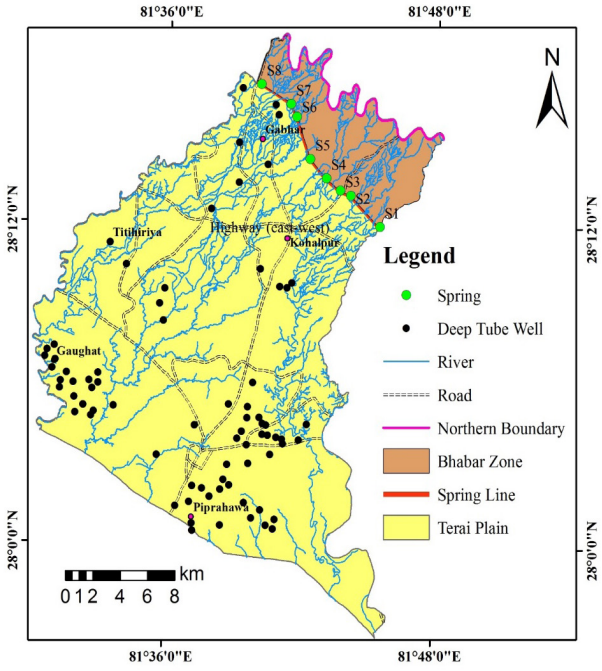

Fig. 3: Delineation of Bhabar Zone on the basis of spring line of the study area.

Groundwater movement and direction

The map (Fig. 4) based upon water level from msl that shows that general flow is towards southern part of the study area. There are two divides, one flow from the upper region north to south-west and another to south-east to the nearby river. It is due to controlled by topography.

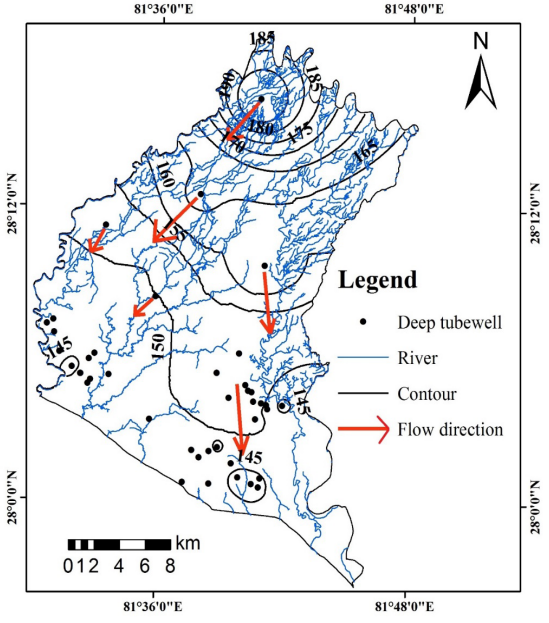

Fig. 4: Water level map above msl with flow direction (contour interval 5 m).

Hydrogeology and hydro stratigraphy of the study area

Sub-surface study was explained on the basis of lithologs of deep tube wells carried out in the study area. The lithologs up to depth 130 were taken for the study. These lithologs vividly gives the picture of sub surface hydrogeology. In modeling regional flow systems, aquifers and confining beds are defined using the concept of the hydro stratigraphic units (Maxey, 1964). Hydro stratigraphic units comprise geologic units of similar hydro geologic properties. Based on the lithologic descriptions contained in the water well records, a hydro stratigraphic model of the aquifer system was developed (Pathak, 2002). Altogether six lithological cross section were drawn (Fig. 5). The cross section is used to describe the subsurface hydrogeology, lithological variations and hydro stratigraphic units. It determines rather changing trend of sub surface sedimentation and flow region of ground water. The top soil is clay.

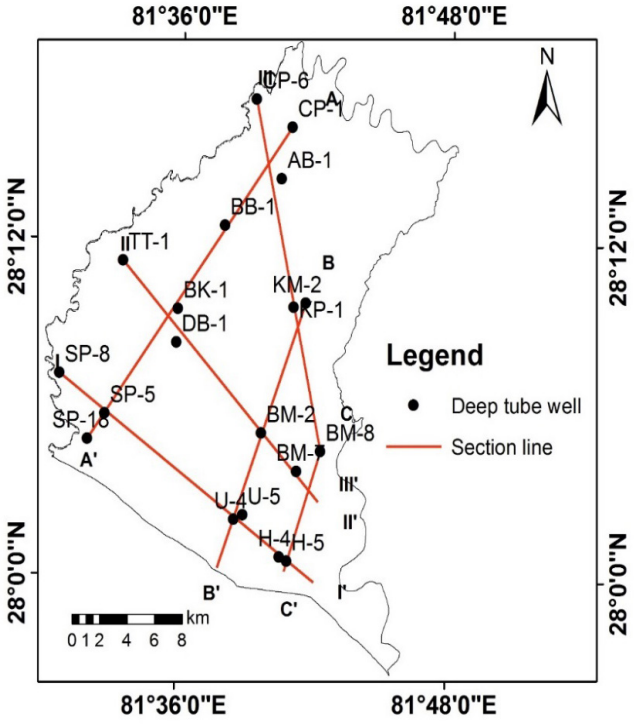

Fig. 5: Cross section lines in the study area.

Cross section A - A' along N-S direction

Cross section A-A' (Fig. 6) runs along north to south direction and includes the well located at Chisapani, Bankatwa, Budhanipur, Sitapur. Surface elevation of well varies from 193 to 144 m above mean sea level. This area consists of four confined aquifer which consists of gravel and some portion of sand in northern part as aquifer materials and in southern parts sand and some portion of gravel as aquifer materials. The aquifer are bounded both side by confining layer making confined. The fining southward succession is seen along the profile. The hydro stratigraphic units along this section are shown in Fig. 7.

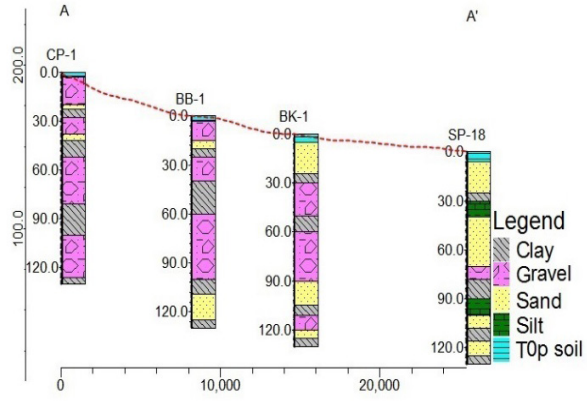

Fig. 6: Cross section along A-A' profile.

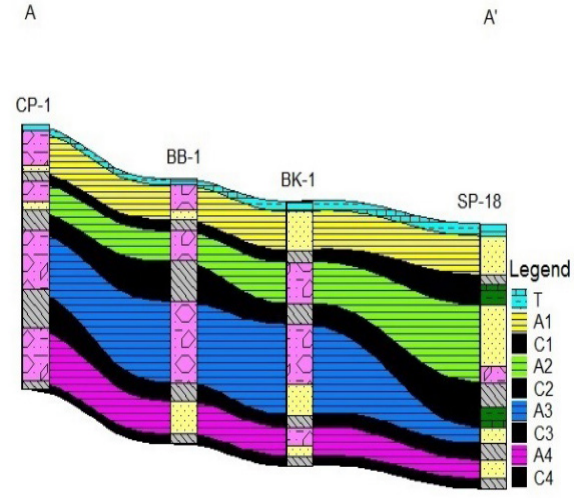

Fig. 7: Hydro stratigraphic units along A-A' profile.

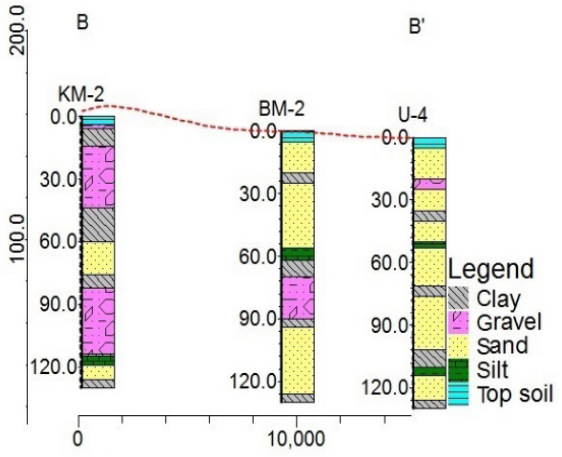

Fig. 8: Cross section along B-B' profile.

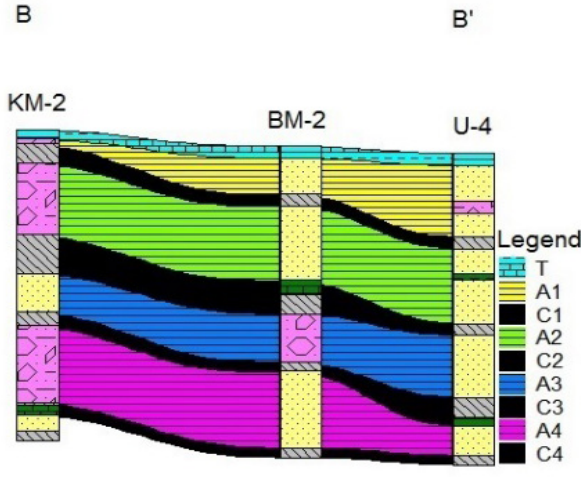

Fig. 9: Hydro stratigraphic units along B-B' profile.

Cross section B - B' along N-S direction

Cross section B-B' (Fig. 8) runs along north to south direction and includes the well located at Kohalpur, Mannpur, Banghusara, Basudevpur, Lodhegaon, Udaypur. Surface elevation of well varies from 159 to 149 m above mean sea level. The gravel and sand are the aquifer materials. More or less fining southward succession is seen along this section. The aerially extension of hydro stratigraphic unit were shown in Fig. 9.

Cross section C - C' along N-S direction

Cross section C-C' (Fig. 10) runs along north to south direction and includes the well located at Padampur, Kamdi, Dhittapurwa-111, Hirminya. Surface elevation of well varies from 151 to 145 m above mean sea level. The northern part consists of coarse sand and gravel whereas the southern part consists of fine sand and some gravels. Lenses of clay and silt are dominant at along this section. The aerial distribution of hydro stratigraphic units was shown in Fig. 11.

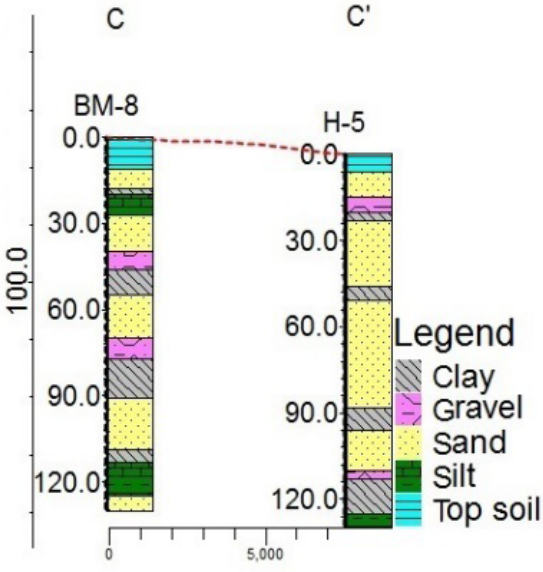

Fig. 10: Cross section along C-C' profile.

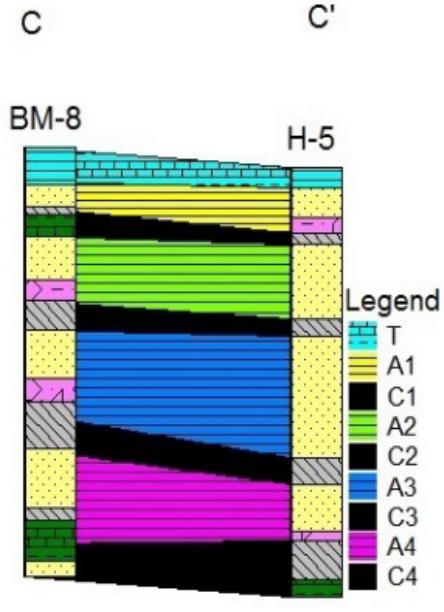

Fig. 11: Hydro stratigraphic units along C-C' profile.

Cross section I - I' along W-E direction

Cross section I-I' (Fig. 12) runs along west to east direction and includes the well located at Sitapur, Udaypur and Hirminya VDC. Surface elevation of wells ranges from 147 to 149 m above mean sea level. The section comprises of fine sand, silt and clay beds and also some amount of gravel. The silt and clay beds are dominant along this section line. The grain size distribution of aquifer material is almost same. The aerial distribution of hydro stratigraphic units is shown in Fig. 13.

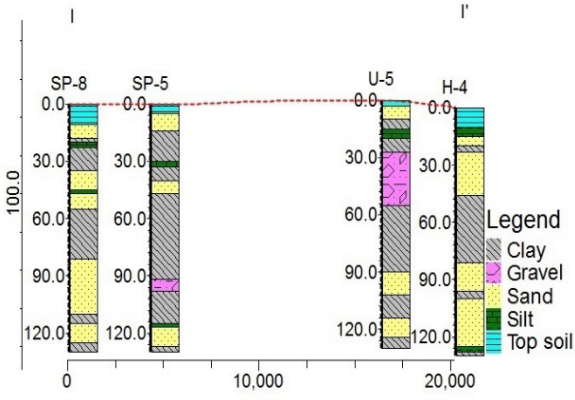

Fig. 12: Cross section along I-I' profile.

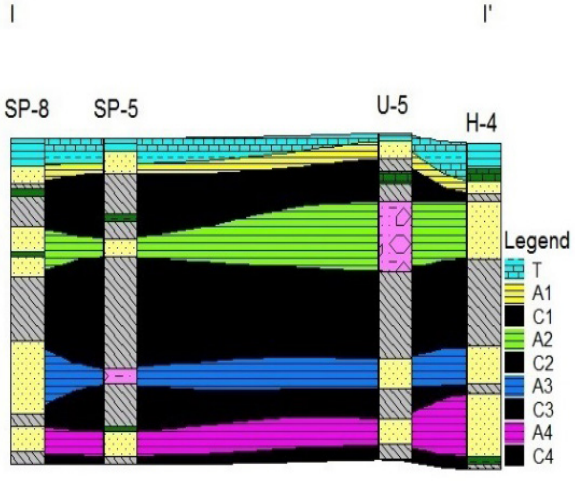

Fig. 13: Hydro stratigraphic units along I-I' profile.

Cross section II - II' along W-E direction

Cross section II-II' (Fig. 14) runs along west to east direction and includes the well located at Titaraiya, D-gaun, Sahapurwa and Basudevpur. Surface elevation of wells ranges from 149 to 154 m above mean sea level. The section comprises of fine sand, silt and Coarse sand and gravel. The silt and clay beds are dominant along this section line. The grain

size distribution of aquifer material is more or less same. The aerial distribution of hydro stratigraphic units was shown in Fig. 15.

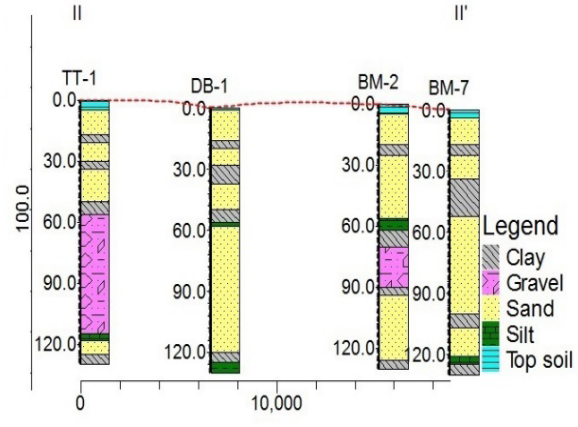

Fig. 14: Cross section along II-II' profile.

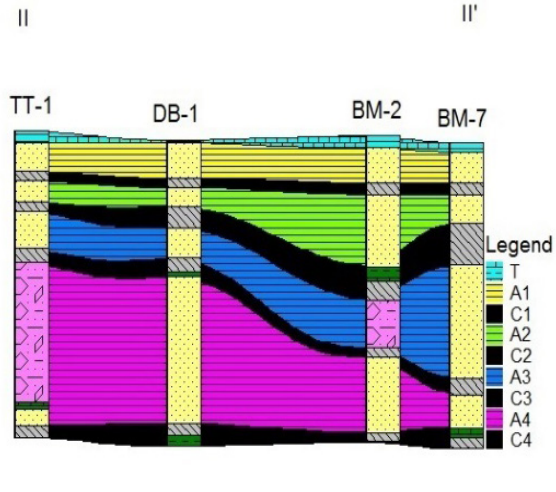

Fig. 15: Hydrostratigraphic units along II-II' profile.

Cross section III - III' along N-S direction

Cross section III-III' (Fig. 16) runs along north to south direction and includes the well located at Chisapani, Baniyabhar, Kohalpur Pipari, Basudevpur. Surface elevation of well varies from 184 to 151 m above mean sea level. Southward gradually fining of material is seen in the section. The section line is continued from almost northern part to middle of Southern part. The northern part consists of coarse sand and gravel whereas the southern part consists of finer sand little amount of coarser sand and gravel. Lenses of clay and silt were dominant at Southern part. The aerial distribution of hydro stratigraphic units was shown in Fig. 17.

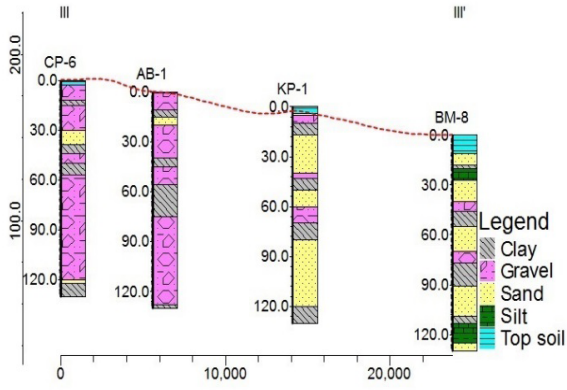

Fig. 16: Cross section along III-III' profile.

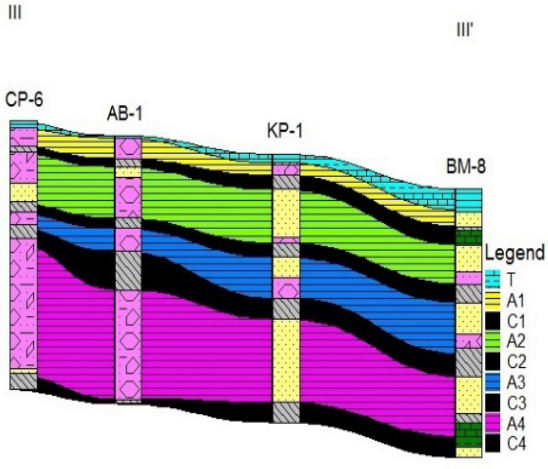

Fig. 17: : Hydro stratigraphic units along III-III' profile.

Fence diagram

It is 3- dimensional representation of lithology of selected area from lithologs of deep tube wells. It defines the hydro stratigraphy of the area. Around 16 wells with depth 130 occupying the study area were taken and the hydro-stratigraphic units were defined as 'C' confining layer and 'A' as aquifer. The different aquifers were given the name A1, A2, A3 and A4– confined aquifer. The

study area exists of four aquifers up to depth 130 m. The confined and unconfined aquifer exists all over the area. There was no well drilled in the Bhabar Zone so no well was taken during the section. The section lines (Fig. 18) and the distribution of hydro stratigraphic units overall study area is shown on the fence diagram (Fig. 19). The stratigraphic units give the information of flow system and distribution of aquifer all over the area. The confining layer (C) separates the aquifers. In these ways the different aquifers are distributed in the study area. The thickness of hydro stratigraphic units (A1, A2, A3 and A4) ranges from 2 to 30 m, 7 to 32 m, 6 to 48 m and 9 to 69 m. The thickness varies because sediments of fluviatile origin and with shifting nature of stream channels.

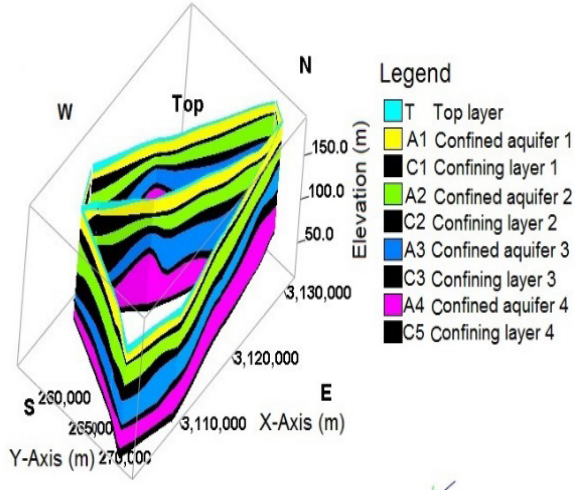

Fig. 19: Fence diagram showing various hydro stratigraphic units in the study area.

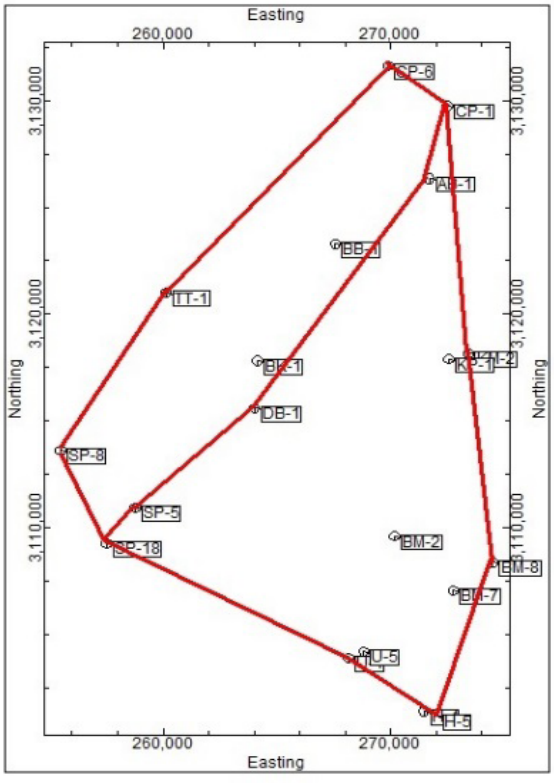

Fig. 18: Section lines to prepare the fence diagram.

Aquifer thickness of hydrostratigraphic units (A1, A2, A3 and A4)

a. Confined aquifer (A1): The aquifer thickness ranges between the 2-11.3 m (Fig. 20).

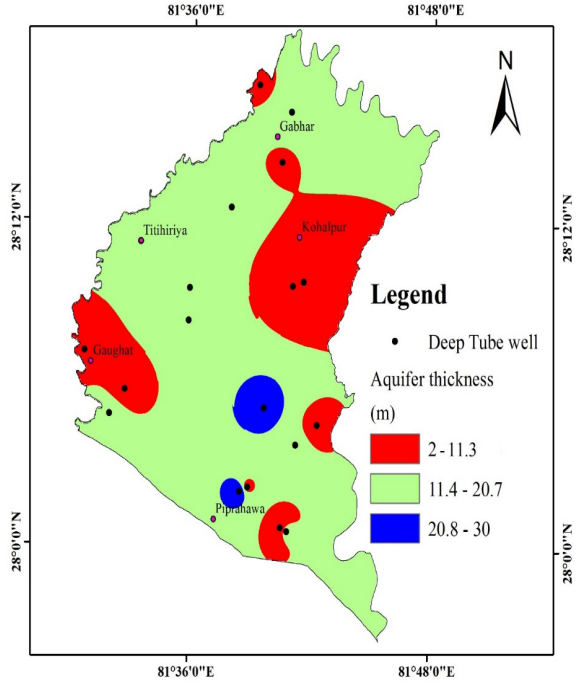

Fig. 20: Thickness map representing confined aquifer A1 of the study area.

b. Confined aquifer (A2): The aquifer thickness range between the 7-15.3 m (Fig. 21).

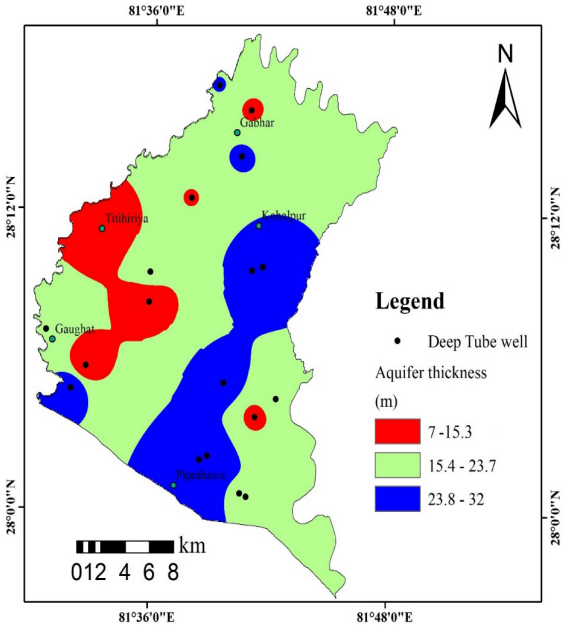

Fig. 21: Thickness map representing confined aquifer A2 of the study area.

c. Confined aquifer (A3): The aquifer thickness ranges between the 6-20 m (Fig. 22).

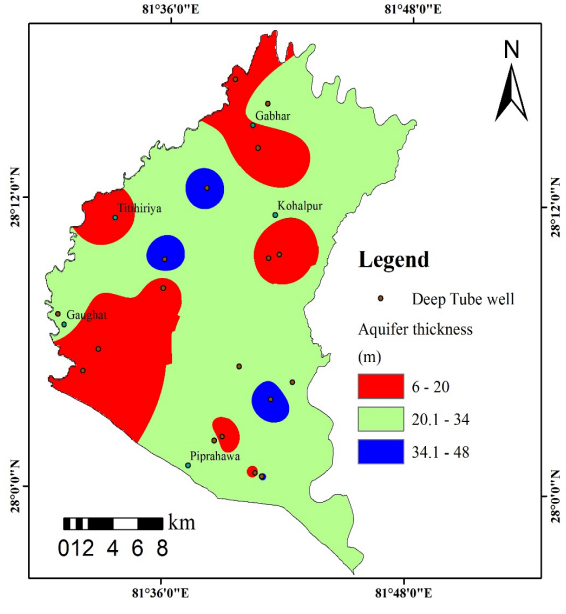

Fig. 22: Thickness map representing confined aquifer A3 of the study area.

d. d. Confined aquifer (A4): The aquifer thickness range between the 9-29 m (Fig. 23).

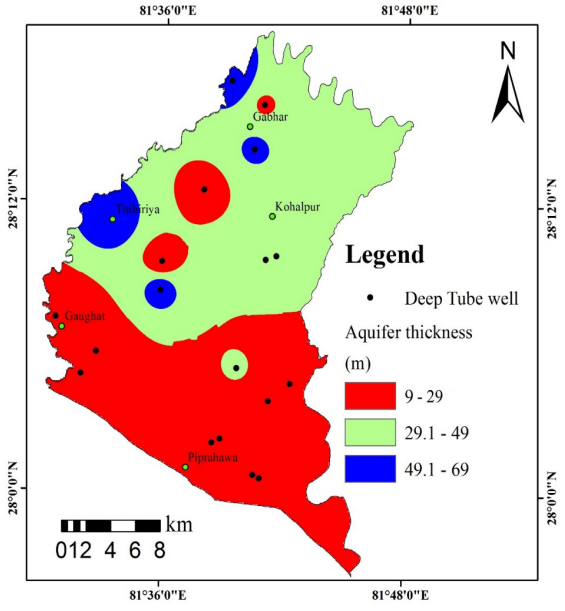

Fig. 23: Thickness map representing confined aquifer A4 of the study area.

Ground water potentiality

Quantitative interpretation of groundwater reservoirs is possible only when the values of hydraulic constants of aquifers are known. (Kumar, 2009) described that to access groundwater potential in any area, it is essential to know the aquifer parameters. They are influence by porosity, grain size, sorting and packing of aquifer materials. The transmissivity and yield data were available so that the analysis was done through these data.

The potential zone of the study area is prepared on the basis of transmissivity (Fig. 24) and yield (Fig. 25). Firstly, the raster map of transmissivity and yield were prepared and reclassify it and given a rank and weight (Table 2) and then the weighted sum were done and finally the potential map was prepared and the potential area were classified as low, medium and high (Fig. 26). Overall, the study area is potential for ground water exploration. Areas of fine-grained sediments have poor water

production like silt and coarse-grained sediments have higher potential like sand and gravel. It is because of coarser aquifer materials with high permeability and porosity. Overall, the study shows the ground water condition of deep aquifer meets to fulfill the water demand.

Table 2: Rank and weight given to transmissivity and yield.

Parameter	Rank	Weight
Transmissivity	1	50 %
	2	
	3	
Yield	1	50 %
	2	
	3	

Potential Zone on the basis of transmissivity and yield

Zone A (Low potential zone): The area covers L-Gaon, Phutaha, Kataliya, Banghusara, Amarahawa, Molahpurwa, Lolinpurwa, Sahapurwa, Jodhapurwa, Puraini, Birta, Hirminya, Parsanpur, Lodhegaon, Lalapurwa, Tankapaseri, Bhawaniyapur, Balegaon, Khajura and Ranjha.

Zone B (Medium potential zone): The area covers K-Gaon, L-Gaon, A-Gaon, Gaughat, Phutaha, Padampur, Naharpurwa, Loharanpurwa, Suryapur, Udaypur, Piparhawa, Babugaon, Kariyatipurwa, Bankatwa, Mahalpurwa, Belvhar, Baniyabhar, Lalapurwa, Jharkatti, Thakurpur, Gautambasti, Tithariya, Karkado, Karelokhola, Naubasta and Pitamari.

Zone C (High potential zone): The area covers Gaughat, L-Gaon, Dhittapur-1, Dhittapur-11, Dhittapur-111, Piparhawa, D-gaon, Raniyapur, Pipari, Mannapur, Gabar, Baniyabhar, Jhandahawa and Budhanipur.

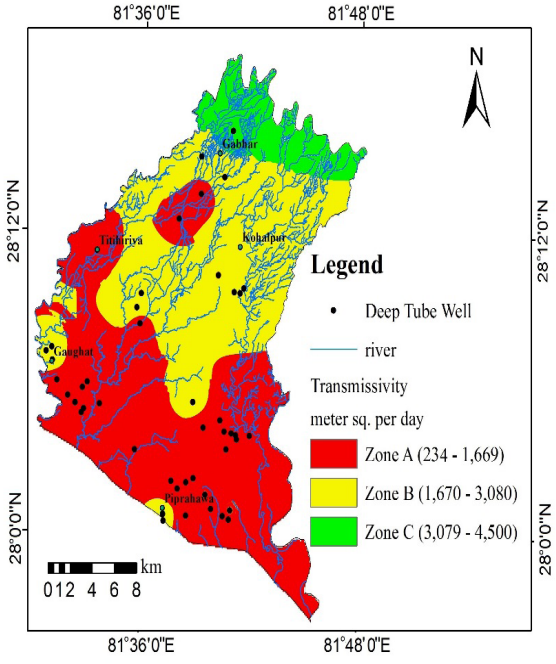

Fig. 24: Ground Water Potentiality Zone on the basis of Transmissivity (m²/day).

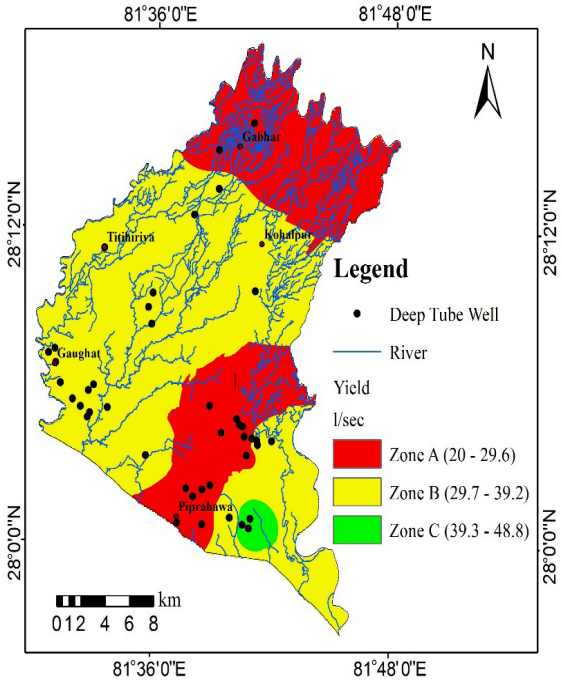

Fig. 25: Ground Water Potentiality Zone on the basis of yield (l/sec).

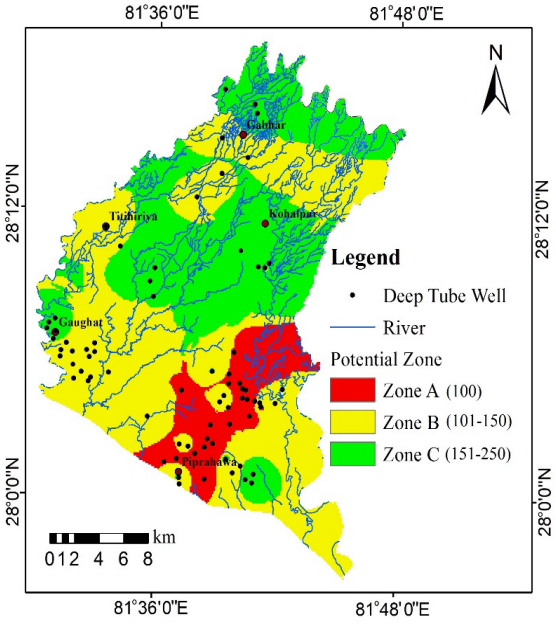

Fig. 26: Final potential zone of the study area on the basis of transmissivity and yield.

CONCLUSION

The Indo-Gangetic plain is divided into Bhabar Zone and Terai Plain. The Terai Plain is divided into Middle Terai and Southern Terai. The Bhabar Zone consists of coarser sediments like pebble, cobble, boulder, gravel whereas the Terai Plain consists of finer sediments like clay, silt, sand and some amount of gravel.

The Bhabar Zone is estimated of an area 68.83 km^2. The northern boundary of Bhabar Zone is base of Siwalik Range and southern boundary is spring line. The springs are contact type.

The ground water flows from north to south direction. There are two flow divides from north to south-east and north to south-west. Aquifers (Hydro stratigraphic units – A1, A2, A3 and A4) in the study area are confined types. The well of Chisapani is flowing well.

The three potential zones were divided on the basis of results obtained by yield and Transmissivity, Zone A as a low potential area, Zone B yield as a medium potential area and Zone C as a high potential area. The Zone A covers the area at covers L-gaon, Phutaha, Kataliya, Banghusara, Amarahawa, Molahpurwa, Lolinpurwa, Sahapurwa, Jodhapurwa, Puraini, Birta, Hirminya, Parsanpur, Lodhegaon, Lalapurwa, Tankapaseri, Bhawaniyapur, Balegaon, Khajura and Ranjha, Zone B covers at K-gaon, L-gaon, A-gaon, Gaughat, Phutaha, Padampur, Naharpurwa, Loharanpurwa, Suryapur, Udaypur, Piparhawa, Babugaon, Kariyatipurwa, Banktwa, Mahalpurwa, Belvhar, Baniyabhar, Lalapurwa, Jharkatti, Thakurpur, Gautambasti, Tithariya, Karkado, Karelokhola, Naubasta and Pitamari. Similarly, the Zone C covers at Gaughat, L-gaon, Dhittapur-1, Dhittapur-11, Dhittapur-111, Piparhawa, D-gaon, Raniyapur, Pipari, Mannapur, Gabar, Baniyabhar, Jhandahawa and Budhanipur.

RECOMMENDATION

a. At the periphery of study area, due to lack of enough data the result obtained may not be reliable to use for practical purpose. But it will serve for academic purposes. Detail study is recommended in this area.

b. The more detail study is needed for delineation of Bhabar Zone. The Bhabar Zone should be preserved because ground water recharge is high in this zone.

AUTHOR CONTRIBUTION

First, all the authors have made the study concept and design. Miss Rosni BC and Miss Dipika Shah started field works around four weeks to collect field data. Dr. Dinesh Pathak, Mr. Surrendra Raj Shrestha, Mr. Nir Shakya and Mr. Ramesh Gautam have analyzed, interpreted and finalize the data to bring the conclusion. The first draft was written by Dipika Shah and finally, all authors contributed to making final version of manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interests.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available from the corresponding authors, upon reasonable request.

REFERENCES

Central Bureau of Statistics (CBS), 2017. National Population and Housing Census 2011, Nepal. Government of Nepal, National Planning Commission Secretariat, (200-203).

Dhital, M.R., 2015. Geology of Nepal Himalaya: Regional perspective of the classical collided orogen. Springer International publishing, Switzerland. p. 498.

Gautam, B., 2005. Hydrogeological study in south-western part of the Banke District, Western Nepal. M.Sc Thesis, Central Department of Geology, Institute of Science and Technology, Tribhuvan University, Nepal.

JICA, 1995. The Master Plan on the Terai Groundwater Resources. Repot of Sanyu Consultants Incorporation, 2, (9-12).

Kumar, C.P., 2009. Aquifer Parameter Estimation, National Institute of Hydrology,

Roorkee, India, Education, Technology, Business. p. 2.

Maxey, G.B., 1964. Hydro stratigraphic units. Journal of Hydrogeology, 2, (124-129).

Pathak, D., 2002. Basement structure, hydrogeology and groundwater: flow model of Nara Basin, southwest Japan. PhD thesis, Osaka City University, Japan.p.129.

Sah, R.B., 2015. Stratigraphy of Nepal. Stratigraphic Association of Nepal (SAN), 10, (6-8).

Sharma, C.K., 1981. Ground Water Resources of Nepal. Published by Mani Ram Sharma, Bishalnagar, Nepal. (62-64).

Tillson, D., 1985. Hydrogeological Technical Assistance to the Agricultural Development Bank of Nepal. ADP-UNDP report.