

Assessment of groundwater conditions in Bilkhawthlir Rural Development Block, Kolasib district, Mizoram, India

F. Lalbiakmawia*, Shiva Kumar

Public Health Engineering Department, Aizawl 796001, Mizoram, India
Professor, Department of Geology, Mizoram University, Tanhril 796004, Mizoram, India

Corresponding author: fbm.geo@gmail.com

The present study deals with the assessment of groundwater conditions both in terms of prospect and quality in the northern part of Mizoram, India. Advent of scientific techniques for identifying groundwater prospective areas and analyzing its quality enables us to save time and money. The study makes use of geo-spatial technology to identify the potential locations for groundwater availability. Important spatial aspects which are responsible for the presence of groundwater within the area were identified. Accordingly, three thematic layers, viz. geomorphology, lithology, geological structures like faults and lineaments were generated. These thematic layers were then combined to form the hydrogeomorphic units which are the aquifers. Different classes of the aquifers determine the groundwater condition in terms of prospect for development. Groundwater samples were collected from 28 locations during the field survey to determine the quality. The major parameters namely pH, total dissolved solids, total hardness, iron, chloride, nitrate, calcium, manganese, magnesium and alkalinity of the samples were analyzed. Spatial interpolation technique through inverse distance weighted (IDW) approach has been used in the present study for generating spatial distribution of the groundwater quality. The final maps show the groundwater conditions of the area in terms of prospect and quality. The final output can be utilized for exploration, development and management of groundwater resources.

Keywords: GIS, Groundwater, Remote Sensing, Bilkhawthlir block.

INTRODUCTION

Groundwater is one of the most important natural resources and the largest reachable source of fresh water which is being utilized for supplying the ever-increasing demand owing to urbanization and growth of population (Sharma and Kujur, 2012; Neelakantan and Yuvaraj, 2012; Kumar, 2013; Choudhary *et al.*, 1996). Hence, finding groundwater potential areas, monitoring and conserving groundwater has become highly necessary in recent times (Rokade *et al.*, 2004; Kumar and Kumar, 2011).

The geology of the Mizoram comprises ridges with steep slopes and narrow intervening valleys, faulting in many areas have also produced steep fault scarps (GSI, 2011). Hence, most of the rain water available is lost as

surface runoff. The age-old method of fetching water from springs is still prevalent within the state whereas the springs which are the main sources of water also get depleted during the post monsoon period (Central Groundwater Board, 2007). Bilkhawthlir block of Kolasib district also experienced acute shortage of water. Therefore, groundwater prospective areas have to be identified so as to adopt proper measures for its development.

Few efforts were made to study groundwater prospect zones within the state of Mizoram using geospatial technology. These include mapping of groundwater potential zones in Serchhip district (Lalbiakmawia and Lalruatkima, 2014), mapping of groundwater potential zones in Aizawl district (Lalbiakmawia, 2015), groundwater prospects studies of Kolasib district (Lalbiakmawia, 2015), and groundwater potential zones mapping of Ma-

mit district (Lalbiakmawia, 2015).

Spatial technology like application of Remote Sensing and GIS techniques allow swift and cost effective survey and for management of natural resources (Nagaraju *et al.*, 2014). Hence, these techniques have wide-range applications in the field of geo-sciences including groundwater prospecting (Jeganathan and Chauniyal, 2002; Anirudh, 2013). Interpretation of satellite data in combination with adequate ground truth information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characteristics that may serve as indicators of the presence of groundwater (Raju *et al.*, 2013).

Therefore, many researchers have utilized these techniques successfully in groundwater studies (Gustafsson, 1993; Saraf and Jain, 1994; Krishnamurthy and Srinivas 1995, Krishnamurthy *et al.*, 2000). The same techniques have been proved to be of immense value not only in the field of hydrogeology but also in water resources development as well (Saraf and Choudhury, 1999; Sharma and Kujur, 2012). The main purpose of the present study is to make use of geo-spatial layers in delineating groundwater prospective areas and assess the quality in Bilkhawthlir block, so as to create vital database for future development and management of groundwater.

Study area

Bilkhawthlir block is located in the northern part of Mizoram between 24°08.535' to 24°31.435' N Latitudes and 92°31.786' to 92°53.887' E Longitudes. It is bounded

to the north and west by Assam state, on the south by North Thingdawl Rural Development block and on the east by Aizawl district (Figure 1). The total geographical area of the block is approximately 516 sq km and it falls in the Survey of India toposheet nos. 83 D/11, 83 D/12, 83 D/14, 83 D/15 and 83 D/16. The study area enjoys a moderate climate owing to its tropical location. It is neither very hot nor too cold throughout the year. The average annual rainfall is 2745.66 mm (Lalzarliana, 2016).

MATERIALS AND METHODS

Groundwater prospecting

Data used

Indian Remote Sensing Satellite (LISS III) data having spatial resolution of 23.5 m and Cartosat-I stereo-paired data having spatial resolution of 2.5 m were used as the main data. Survey of India (SOI) topographical maps and various ancillary data were also referred in the study. For groundwater quality, samples were collected from the field and analyzed in the laboratory.

Thematic layers

Thematic layers generated using remote sensing data like geomorphology, geology and lineaments can be integrated in a Geographic Information System (GIS) environment and can be utilize for delineating groundwater potential zones (Chaudary *et al.*, 1996; Kumar and Kumar,

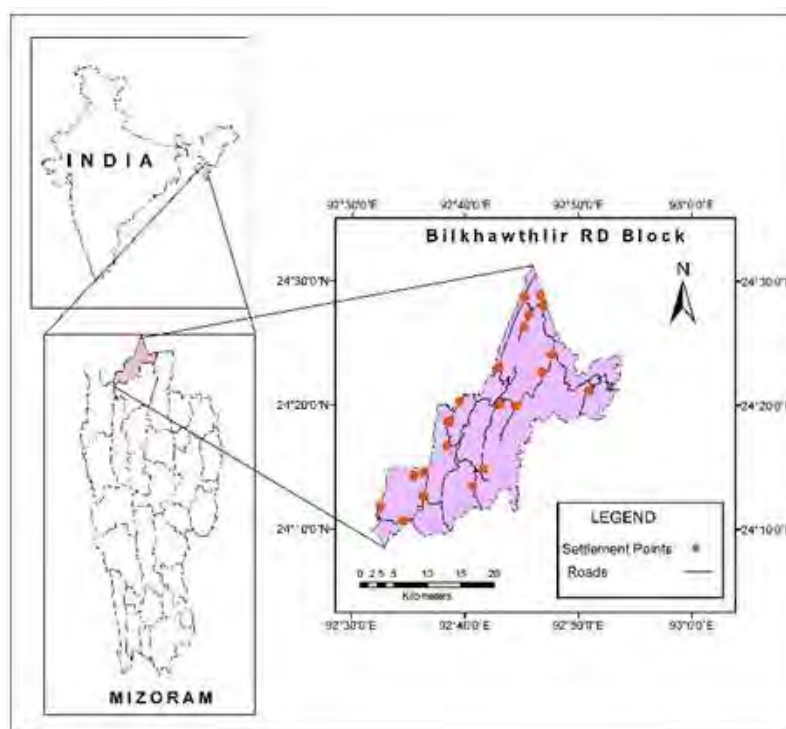


Figure 1: Location map of the study area.

2011). The present study utilized three thematic layers to identify groundwater potential zones of the study area.

Geomorphology

Geomorphology is one of the most important features in evaluating the groundwater potential and prospect. It can also be utilized in managing groundwater resources (Kumar and Kumar 2011; Valliammai *et al.*, 2013, Raju *et al.*, 2013; Ghayoumian *et al.*, 2007). The study area comprises geomorphic units like intermontane valley, alluvial plain, fractured valley, less dissected structural hill, moderately dissected structural hill and highly dissected structural hill.

All the geomorphic units occurring in the study area are mapped as polygon features. While demarcating the geomorphic units, toposheets were consulted to comprehend the relief variations and other topographic features. (RGNDWM, 2008). Geomorphological map of the study area is shown in Figure 2.

Lithology

Detailed knowledge of lithology is an important factor in groundwater exploration and in particular, the features to be considered are geological boundaries, porosity, etc. (CGWB, 2000; Al-Bakri1 and Al-Jahmany, 2013). All the rock formations occurring in the study area are mapped as a layer. Existing geological and literature are consulted which helps in knowing general geological setting of the area and different rocks types that occur in the area (RGNDWM, 2008).

Lithology of Mizoram comprises great flysch facies of rocks made up of monotonous sequences of shale and sandstone (La Touche, 1891). The study area lies over rocks of Lower Bhuban, Middle Bhuban, Upper Bhuban and Bokabil formations of Surma Group of Tertiary age. Recent unconsolidated sedimentary materials are also found in the low lying areas. Lower Bhuban and Upper Bhuban formations comprises mainly of arenaceous rocks while Middle Bhuban and Bokabil formations consist mainly of argillaceous rocks (GSI, 2011).

Geological structure

Lineaments like faults, fractures and joints can be delineated and analysed using remote sensing data (Kanungo *et al.*, 1995). They are the most obvious structural features that are important from the groundwater point of view (Bhatnagar and Goyal, 2012). The geological structures occurring in the area are treated as conduits for the movement of groundwater and provide potential for groundwater recharge (CGWB, 2000; Sankar, 2002; Sharma and Kujur, 2012). It was observed that the rocks exposed within the study area were traversed by several faults and fractures of varying magnitude and length (MIRSAC, 2006). The geological structures are

mapped as line features. The geological map of the study area is given in Figure 3.

Groundwater quality assessment

Water samples were collected from 28 locations and were tested for their chemical properties. The characteristics of the water were subsequently evaluated using the Indian Drinking Water Standards as per BIS Guideline. The major parameters namely pH, iron, alkalinity, total dissolved solids, total hardness, calcium, chloride, nitrate, manganese and magnesium of the samples were analyzed (Table 1).

Table 1: Weightages of parameters.

Parameter	Range	Weight
pH	<6.5	3
	6.5-8.5	1
	>8.5	3
Iron (mg/l)	<0.3	1
	0.3-1.0	2
Alkalinity (mg/l)	<200	1
	200-600	2
Total dissolved solids (mg/l)	0-500	1
	500-2000	2
Total hardness (mg/l)	0-300	2
	300-600	2
Calcium (mg/l)	<75	1
	75-200	2
Chloride (mg/l)	<250	1
Nitrate (mg/l)	<45	1
Manganese (mg/l)	<0.1	1
	0.1-0.3	2
Magnesium (mg/l)	<30	1
	30-100	2

Geospatial technology has been utilized effectively by several researchers. These include Application of GIS for groundwater quality mapping of Tiruppur block, Tamil Nadu, India (Ganesh Babu and Sashikkumar, 2013), Spatial analysis of groundwater quality for Virudhunagar district, Tamil Nadu, India using GIS (Karthikeyan *et al.*, 2013), Application of geo-spatial technologies for groundwater quality mapping of Aizawl district, Mizoram, India (Lalbiakmawia and Vanthangliana, 2015) Application of geo-spatial technology for groundwater quality mapping of Mamit district, Mizoram, India (Lalbiakmawia, 2015).

Spatial interpolation technique through Inverse Distance Weighted (IDW) approach has been used for generating spatial distribution of the groundwater quality. The spatial variation maps of major groundwater quality parameters were prepared as thematic layers following BIS guideline. This guideline categorized each groundwater parameters as Desirable, Permissible and Non-

potable classes (RGNDWM, 2011). All the spatial variation maps/layers were integrated and the final groundwater quality map was then generated.

RESULTS

Groundwater prospecting

In order to delineate the aquifers, the lithological, geomorphological and structural maps are subjected to overlay analysis by superimposing the layers one over the other in GIS environment. The information present in the layers as the attribute data is also subjected to analysis. During the process of integration, the geomorphic units and rock types are made co-terminus by adjusting the boundaries. As a result of the integration, the areas having unique lithology, landform and structure are delineated. There by the primary porosity and permeability of the rock formations and the secondary porosity and permeability developed due to structural deformation and geomorphic process / landform genesis are taken in to account. These integrated lithological-structural-geomorphic units are considered as aquifers. The line features are annotated with different colours as indicated in the classification systems.

The different types of aquifers identified within the study area are unconsolidated sediments represented by alluvial and flood plains, Permeable Rocks which are the semi-consolidated sediments having primary porosity and permeability, and Fractured Rocks which generally acts as conduits for movement of groundwater (RGNDWM, 2008).

The lithological, geomorphological and structural layers are subjected to overlay analysis by superimposing the layers one over the other in GIS environment in order to delineate the aquifers. Subsequently, different types of aquifers were identified depending on the various combinations of the geological materials. The different types of aquifers were classified into 12 categories based on their geomorphic classes and lithological units. This classification is done in accordance to their assumed or expected importance based on the apriori knowledge of the experts (Neelakantan and Yuvaraj, 2012; Krishna Murthy and Renuka Prasad, 2014). The final output is groundwater potential map along with an expressive legend. The map legend shows the geomorphic units, rock types, aquifer materials and groundwater prospect classes.

Groundwater quality assessment

All the layers were individually divided into appropriate classes and weightage value is assigned for each class based on their influence on the quality of groundwater. This process is done in such a manner that less weightage represents better influence whereas and more

weightage represent poorer influence towards the groundwater quality. The assignment of weightage values for the different categories within a parameter is done in accordance to their assumed or expected importance in inducing different classes of the groundwater quality.

The spatial and the attribute database generated are integrated for the generation of spatial variation layers of major water quality parameters. Based on these spatial variation layers of major water quality parameters, an integrated groundwater quality map was prepared using GIS technique.

Results for the major parameters are as follows:

pH

pH is one of the important parameters of water which determines the acidic and alkaline nature of water. The pH value of water ranged between 5.50 and 8.80. The pH values of the samples were classified into two classes. As per BIS guideline, majority of the area falls within desirable limit (6.5-8.5). Few areas were below 6.5 and above 8.5. The spatial variation map for pH was prepared and presented in Figure 5.

Iron

Iron concentration was classified in to three ranges (<0.3 mg/l, 0.3-1.0 mg/l and >1.0 mg/l) by BIS guideline. The study area falls into desirable and permissible classes. The spatial variation map for iron is presented in Figure 6.

Alkalinity

Alkalinity was classified in to three ranges (<200 mg/l, 200-600 mg/l and >600mg/l) by BIS guideline. The study area has only two categories, viz. desirable and permissible classes. The spatial variation map for calcium has been presented in Figure 7.

Total dissolved solids (TDS)

The Total Dissolved Solids (TDS) of water is classified in to three ranges (0-500 mg/l, 500-2000 mg/l and >2000 mg/l) by BIS guideline. The present study area has only two categories which are desirable and permissible classes. The spatial variation map for TDS was prepared based on these ranges and presented in Figure 8.

Total hardness

The total hardness is classified in to three ranges (0-300 mg/l, 300-600 mg/l and >600 mg/l) by BIS guideline. The entire study area falls in desirable class in terms of total hardness. Spatial variation map for total hardness has been delineated and presented in Figure 9.

Figure 2: Geomorphological map of the study area.

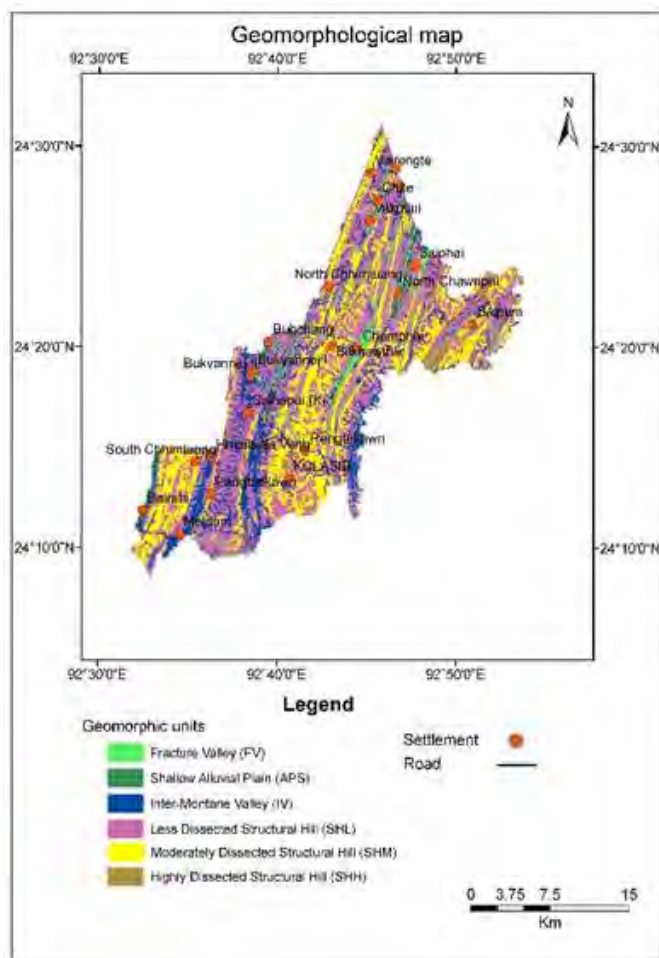


Figure 3: Geological map of the study area.

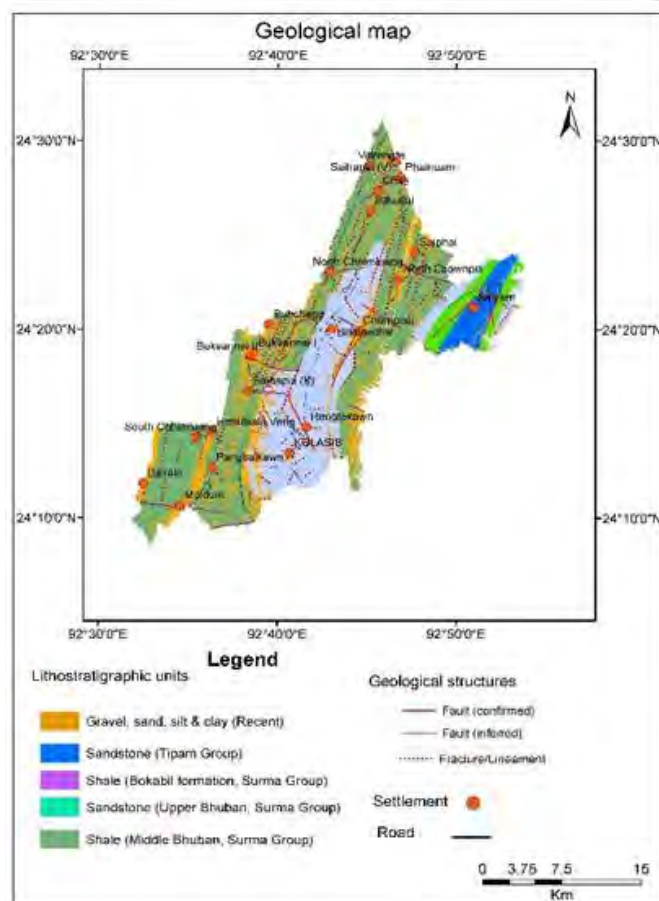


Figure 4: Map of the groundwater prospect map.

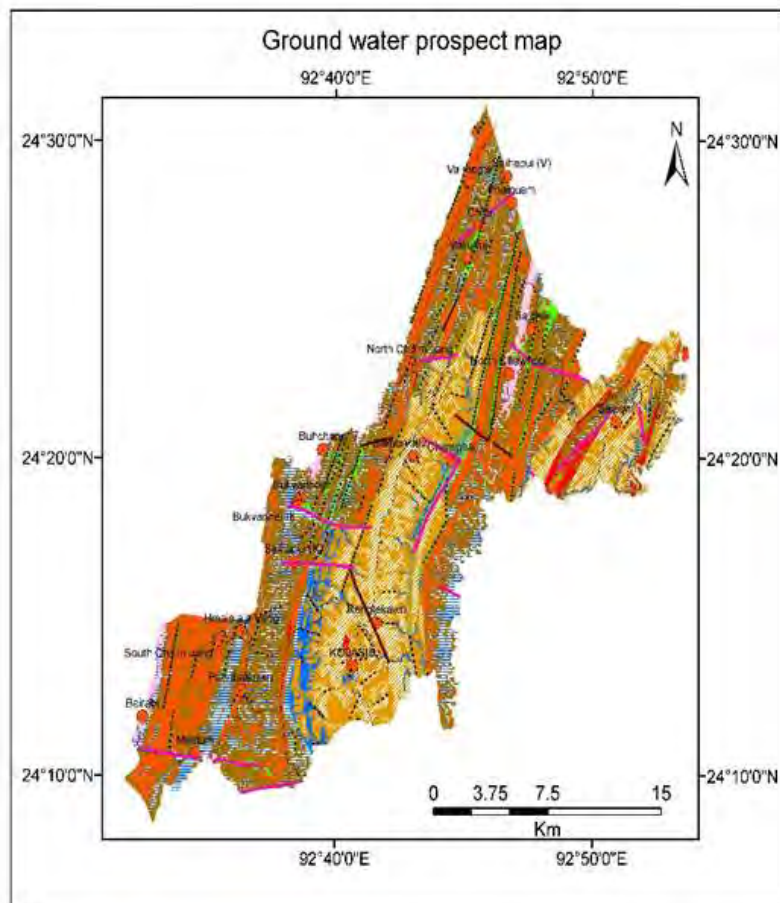


Figure 5: Groundwater prospect map.

GROUND WATER PROSPECT MAP LEGEND OF THE STUDY AREA				
COLOUR CODE	GEOMORPHIC UNITS	ROCK TYPES	AQUIFER MATERIALS	PROSPECT CLASSES
	Alluvial Plain -Shallow	Alluvium-Sand&Silt dominant, underlain by Sandstone	Loose sediment, Permeable rock	Very good prospect
	Alluvial Plain -Shallow	Alluvium-Sand&Silt dominant, underlain by Shale	Loose sediments	Very good prospect
	Fracture Valley	Alluvium-Sand&Silt dominant, underlain by Sandstone	Loose sediment, Permeable rock, Fractured rock	Very good prospect
	Fracture Valley	Alluvium-Sand&Silt dominant, underlain by Shale	Loose sediment, Fractured rock	Very good prospect
	Intermontane Valley	Colluvium-Clay&Silt dominant, underlain by Sandstone	Loose sediment, Permeable rock	Very good prospect
	Intermontane Valley	Colluvium-Clay&Silt dominant, underlain by Shale	Loose sediment	Very good prospect
	Less dissected structural hill	Sandstone	Permeable rock, Fractured rock	Good prospect
	Less dissected structural hill	Shale	Fractured rock	Moderate prospect
	Moderately dissected structural hill	Sandstone	Permeable rock, Fractured rock	Good prospect
	Moderately dissected structural hill	Shale	Fractured rock	Poor prospect
	Highly dissected structural hill	Sandstone	Permeable rock, Fractured rock	Poor prospect
	Highly dissected structural hill	Shale	Fractured rock	Poor prospect
Habitation Road Fault (confirmed) Fault (inferred) Fracture/Lineament				

Figure 6: Spatial variation map of iron.

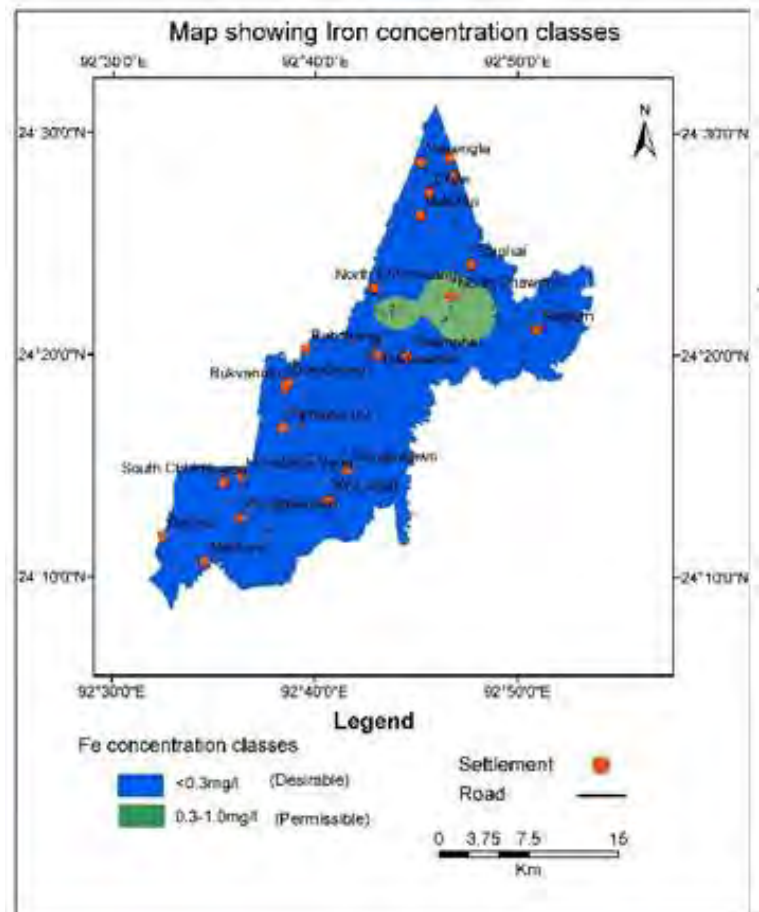


Figure 7: Spatial variation map of alkalinity.

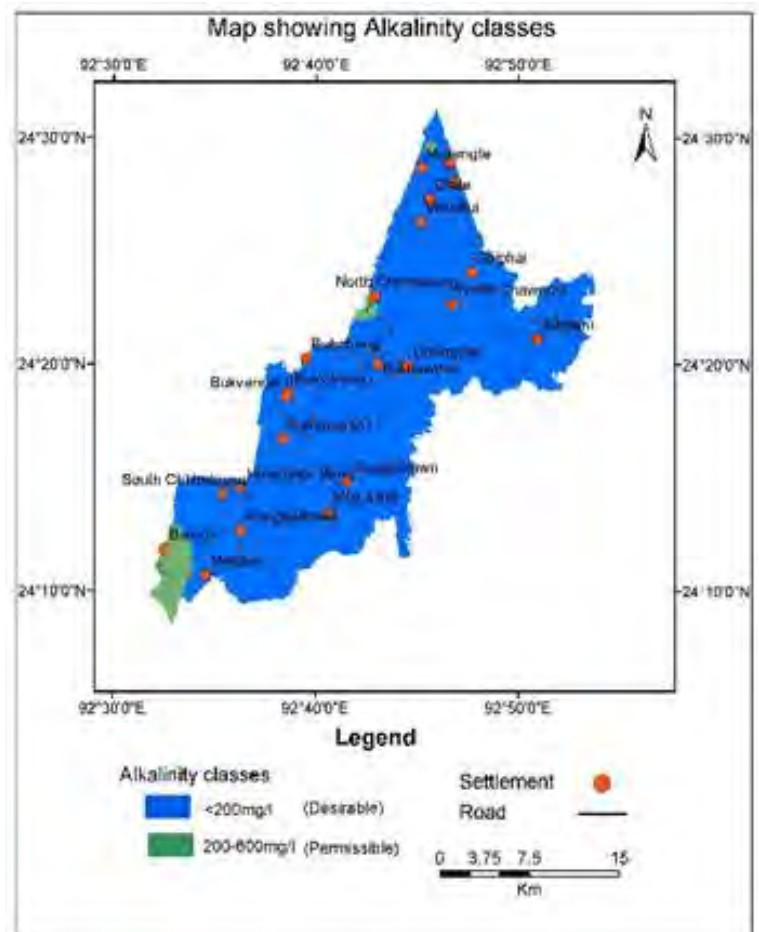


Figure 8: Spatial variation map of TDS.

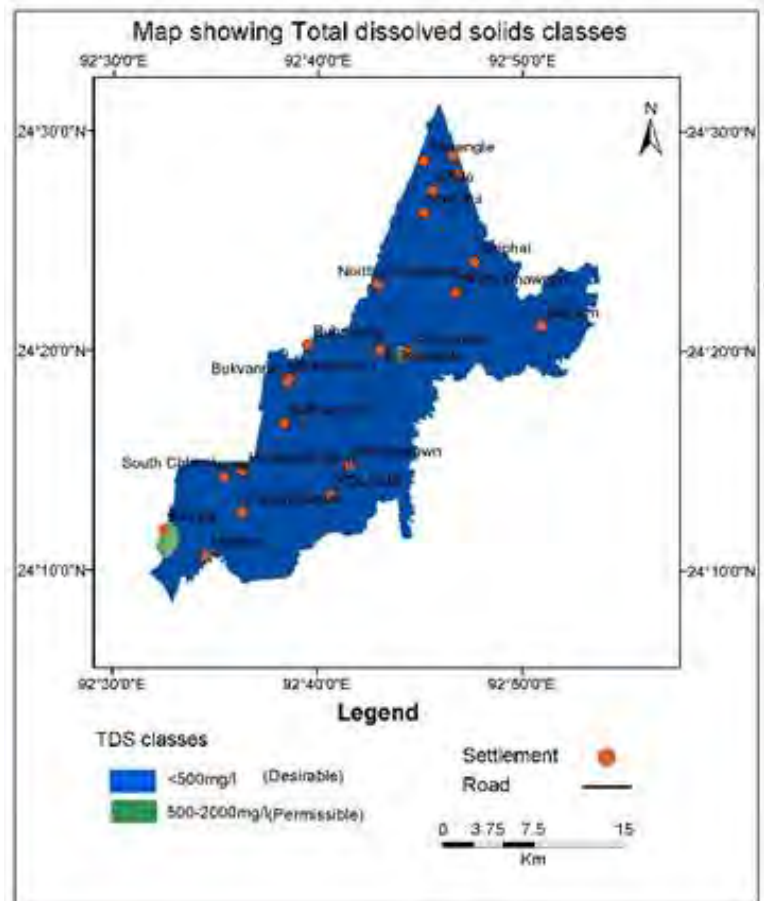


Figure 9: Spatial variation map of total hardness.

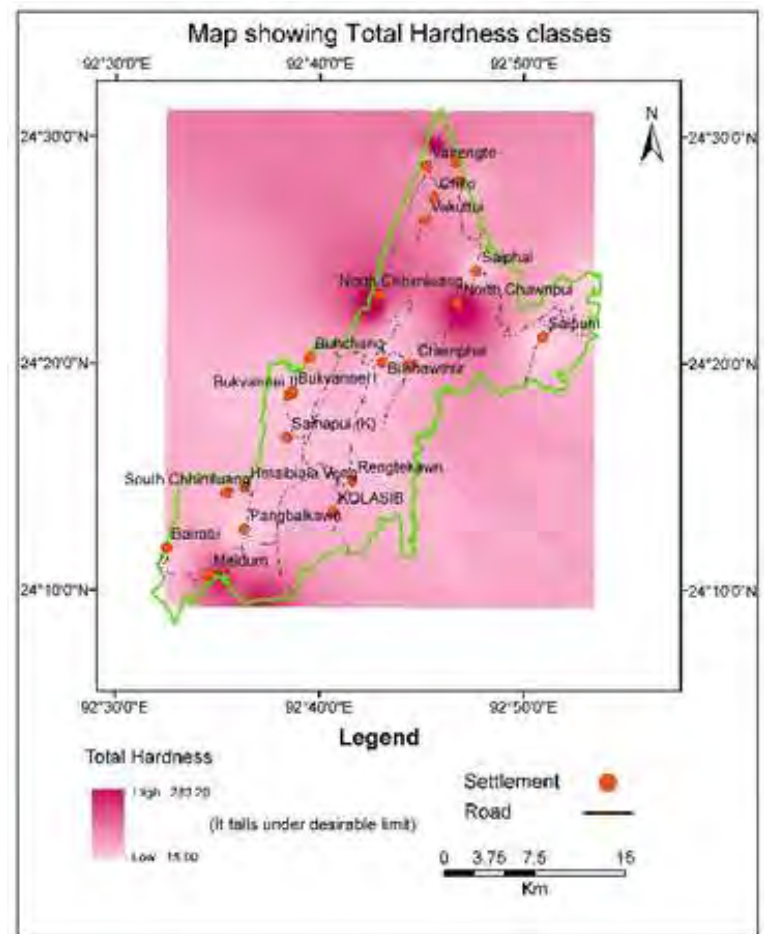


Figure 10: Spatial variation map of calcium.

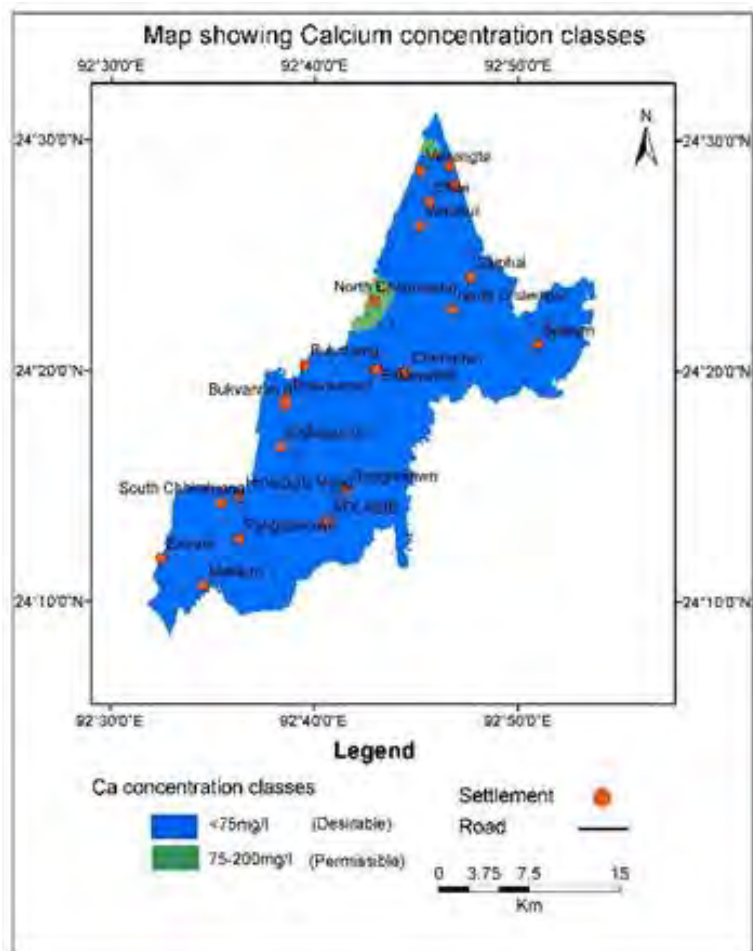


Figure 11: Spatial variation map of chlorides.

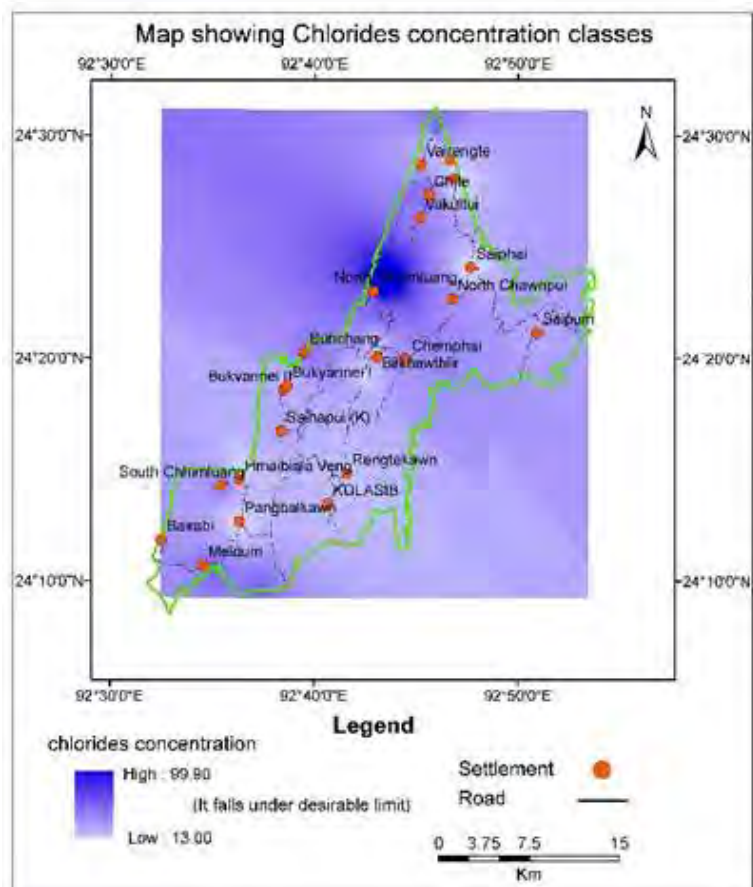


Figure 12: Spatial variation map of nitrates.

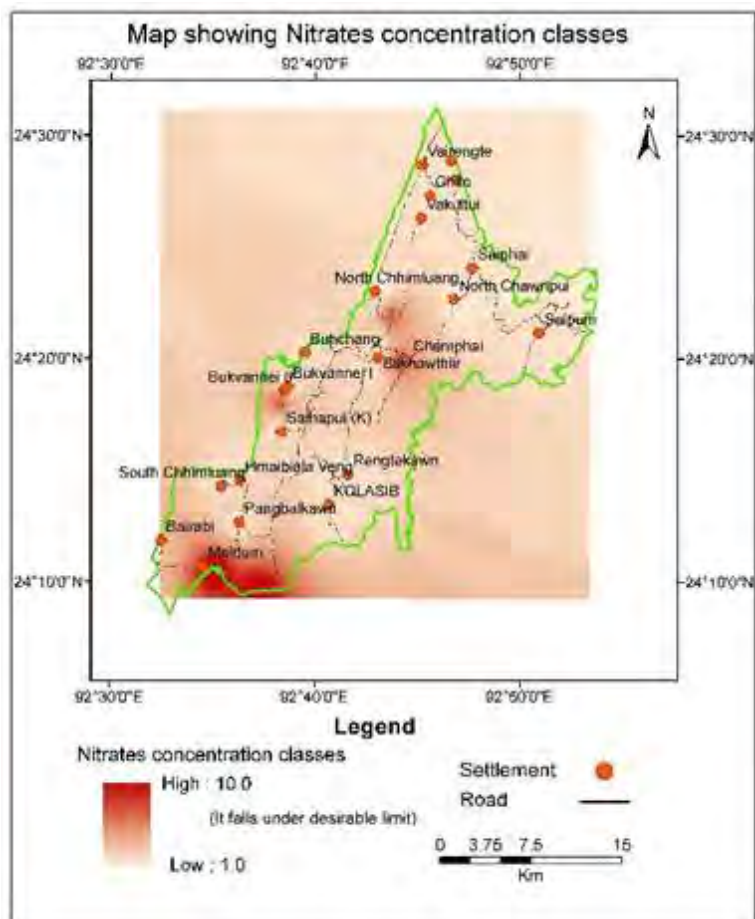


Figure 13: Spatial variation map of manganese.

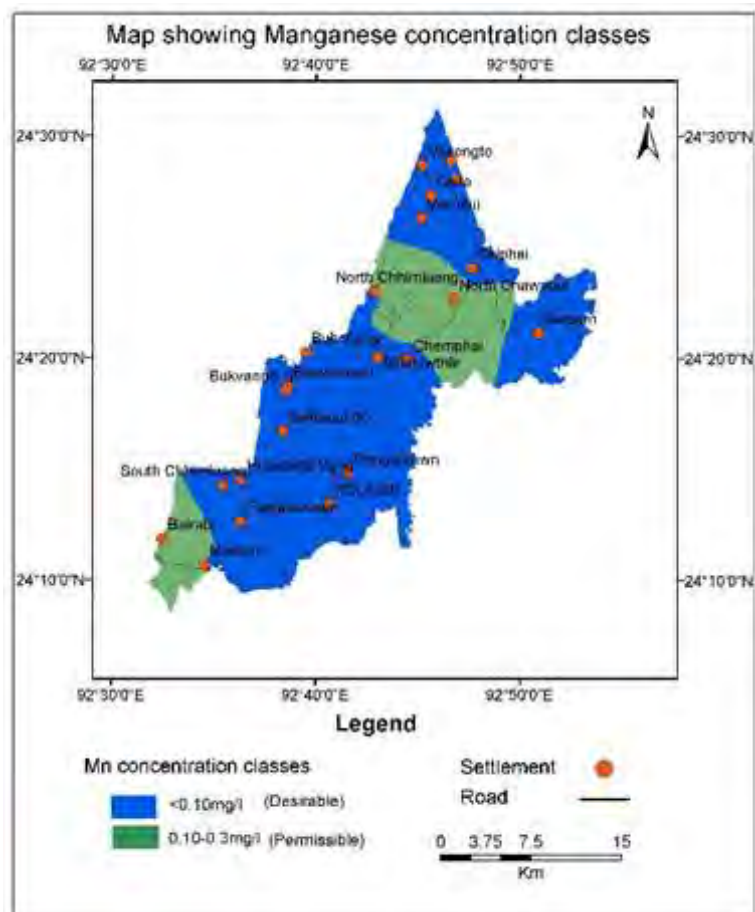


Figure 14: Spatial variation map of magnesium.

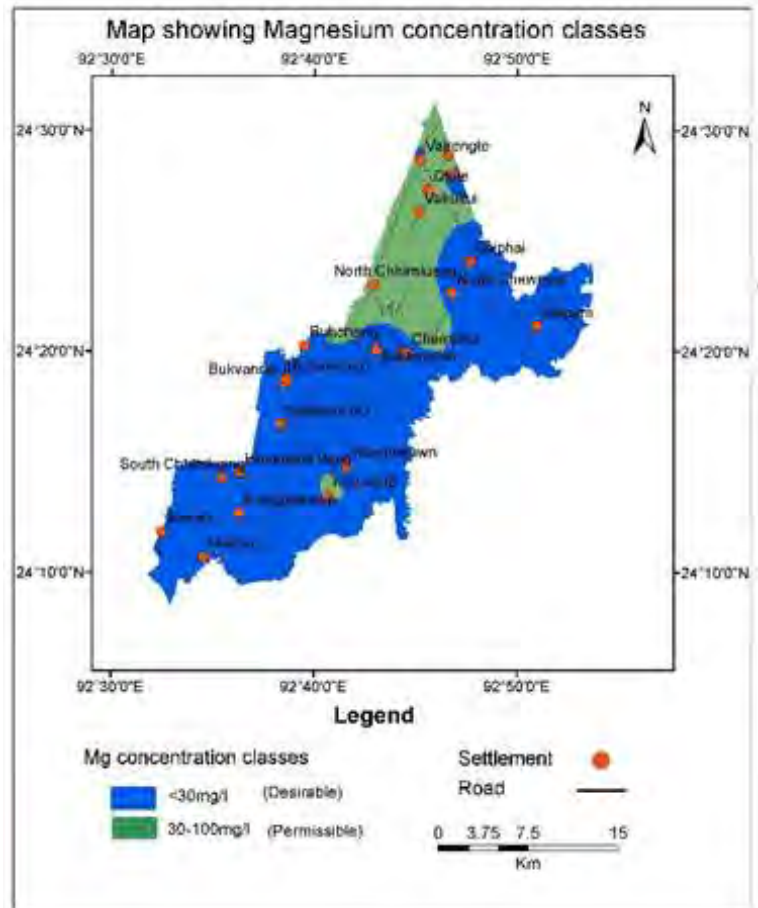
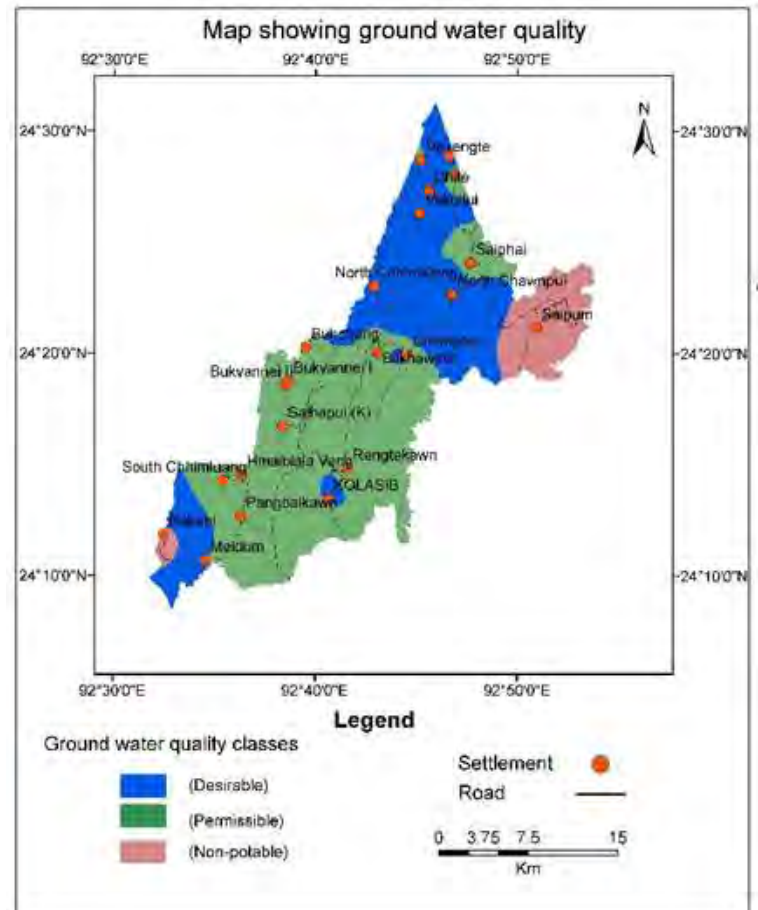


Figure 15: Ground water quality map of the study area.



Calcium

Calcium concentration was classified in to three ranges (<75 mg/l, 75-200 mg/l and >200 mg/l) by BIS guideline. The study area has only two categories, viz. desirable and permissible classes. The spatial variation map for calcium has been presented in Figure 10.

Chlorides

Chlorides was classified in to three ranges (0-250 mg/l, 250-1000 mg/l and >1000 mg/l) by BIS guideline. The entire area has only the desirable class. The spatial variation map for chlorides has been presented in Figure 11.

Nitrate

Nitrate was classified in to three ranges (<45 mg/l, 45-100 mg/l and >100 mg/l) by BIS guideline. The study area has only desirable class. The spatial variation map for Nitrate is presented in 12.

Manganese

Manganese concentration was classified in to three ranges (<0.1 mg/l, 0.1-0.3 mg/l and >0.30mg/l) by BIS guideline. The study area has only two categories, viz. desirable and permissible classes. The spatial variation map for calcium has been presented in Figure 13.

Magnesium

Magnesium concentration was classified in to three ranges (<30 mg/l, 30-100 mg/l and >100 mg/l) by BIS guideline. The study area has only two categories, viz. desirable and permissible classes. The spatial variation map for calcium has been presented in Figure 14.

DISCUSSION

The present study has proven that geo-environmental factors like geomorphology, lithology and geological structure are directly associated with the occurrence of groundwater, and form vital parameters for selecting suitable areas for groundwater exploitation. The study also shows that remote sensing and GIS techniques can be utilized as vital tools in delineating groundwater potential zones.

The final map prepared through the present study shows detailed idea about groundwater potentiality of the area. This, can therefore, forms an important database for developmental activities, and also for identifying critical areas for implementing ground development and management programme. The groundwater quality map helps us to know the existing groundwater condition of the study area. The calculation of groundwater quality zones can be used for groundwater exploration, development and management programme.

The main alarming chemical characteristic of the water quality is pH value at few places. It can be concluded that the quality of groundwater need to be monitored on regular basis with the growing population and urbanization. Geo-spatial technology has been proven to be useful tools for mapping groundwater quality. The groundwater quality map prepared through this study will be useful for planning future groundwater developmental programme.

REFERENCES

- Anirudh, B. (2013). Remote sensing & Geographical information system based study for groundwater prospecting in hard rock terrain. *International Journal of Remote Sensing & Geoscience*, 2(1), 53.
- Bhatnagar, D., Goyal, S. (2012). Groundwater potential zones mapping through Multi-criteria analysis, a case study of sub Watershed of Katni river basin. *International Journal of Remote Sensing & Geoscience*, 1(1), 22-26.
- CGWB (2007). *Manual on Artificial Recharge of Groundwater*. Central Groundwater Board, Ministry of Water Resources, p. 13.
- Choudhary, B.S., Kumar, M., Roy, A.K., Ruhel, D.S. (1996). Application of remote sensing and Geographic Information Systems in groundwater investigations in Sohna block, Gurgaon district, Haryana (India). *International Archive of Photogrammetry and remote Sensing*, 39(B6), 21.
- Ganesh Babu, O., Sashikkumar, M.C. (2013). Application of GIS for groundwater quality mapping of Tiruppur block, Tamil Nadu. *International Journal of Remote Sensing & Geoscience*, 2(5), 18-25.
- Ghayoumian, J., Saravi, M.M., Feiznia, S., Nouri, B., Malekian, A. (2007). Application of GIS techniques to determine areas most suitable for artificial groundwater recharge in a coastal aquifer in southern Iran. *Journal of Asian Earth Sciences*, 30(20), 364-374.
- GSI (2011). Geology and mineral resources of Manipur, Mizoram, Nagaland and Tripura. *Geological Survey of India Miscellaneous Publication No. 30 Part IV*, 1 (2), 36-39.
- Gustafsson, P. (1993). High resolution satellite data and GIS as a tool for assessment of groundwater potential of semi-arid area. In *IXth Thematic Conference on Geologic Remote Sensing*. 8-11 February 1993 at Pasadena, California, USA.
- Kanungo, D.P., Sarkar, S., Mehotra, G.S. (1995). Statistical analysis and tectonic interpretation of the remotely sensed lineament fabric data associated with the North Almora thrust, Garhwal Himalaya, India. *Journal of the Indian Society of Remote Sensing*, 23(4), 201-210.
- Krishnamurthy, J., Srinivas, G. (1995). Role of geological and geomorphological factors in groundwater exploration: A study using IRS-LISS-II data. *International*

- Journal of Remote Sensing*, 16, 2595–2618.
- Krishnamurthy, J., Mani, A., Jayaraman, V., Manivel, M. (2000). Groundwater resources development in hard rock terrain – an approach using remote sensing and GIS techniques. *International Journal of Applied Earth Observation and Geoinformation*, 2(34), 204–215.
- Krishnamurthy, B.N., Renuka Prasad, T.J. (2014). Identification of groundwater potential zones using GIS technique in South Bangalore metropolitan region of Karnataka, India. *International Journal of Geology, Earth & Environmental Sciences* 4(3), 9–22.
- Kumar, B., Kumar, U. (2011). Groundwater recharge zonation mapping and modeling using Geomatics techniques. *International Journal of Environmental Sciences* 1(7), 1671.
- Kumar, C.P. (2013). Assessment and strategies for development potential of deeper confined aquifers in India. *Asian Academic Research Journal of Multidisciplinary* 1 (8), 247–258.
- Lalbiakmawia, F. (2015). Application of remote sensing and GIS techniques for groundwater potential zones mapping in Aizawl district, Mizoram, India. *International Journal of Engineering Sciences & Research Technology*, 4 (1), 292–299.
- Lalbiakmawia, F. (2015). Application of geo-spatial technology for groundwater quality mapping of Mamit district, Mizoram, India. *International Journal of Engineering Sciences & Management Research*, 2, 31–38.
- Lalbiakmawia, F., Lalruatkima, R. (2014). Application of geospatial technology for mapping of groundwater potential zones in Serchhip district, Mizoram, India. *International Journal of Geology, Earth & Environmental Sciences*, 4 (3), 278–288.
- Lalbiakmawia, F., and Vanthangliana, V. (2015). Application of geo-spatial technologies for groundwater quality mapping of Aizawl district, Mizoram, India. *Science Vision* 15(3), 115–123.
- Lalzarliana, C. (2015). *Rainfall Records of Mizoram*. Directorate of Agriculture, Government of Mizoram, p. 1.
- La Touche, T.H.D. (1891). *Records of the Geological Survey of India*. Geological Survey of India (GSI), 24(2).
- MIRSAC (2006). *Natural Resources Mapping of Lawngtlai district, Mizoram using Remote Sensing and GIS, A project report*. Mizoram State Remote Sensing Centre, S&T, Planning Department, Government of Mizoram, p. 28.
- Nagaraju, D., Siddalingamurthy, S., Sumithra, S. (2014). Groundwater prospectus studies of Tattekere watershed, Mysore district, Karnataka, India using Remote Sensing and GIS. *International Journal of Remote Sensing & Geoscience*, 3(1), 6–10.
- Neelakantan, R., Yuvaraj, S. (2012). Evaluation of groundwater using geospatial data – A case study from Salem taluk, Tamil Nadu, India. *International Journal of Remote Sensing & Geoscience*, 1(2), 7.
- Raju, G.S., Babul, K.R., Siva Kumar, K.N., Kumar P.L.K. (2013). Application of remote sensing data for identification of groundwater potential zones in and around Kadapa area, Andhra Pradesh, India. *International Journal of Remote Sensing & Geoscience*, 2(1), 58.
- Sankar, K. (2002). Evaluation of groundwater potential zones using remote sensing data in Upper Vaigai river basin, Tamil Nadu, India. *Journal of Indian Society of Remote Sensing*, 30(30), 119–129.
- Saraf, A. K., Jain, S. K. (1994). Integrated use of remote sensing and GIS methods for groundwater exploration in parts of Lalitpur District, U.P. India. *International Conference on Hydrology and Water Resources*. 20–22 December, 1993 at New Delhi, India.
- Saraf, A. K., Choudhury, P.R. (1998). Integrated remote sensing and GIS for groundwater exploration and identification of artificial recharge sites. *International Journal of Remote Sensing*, 19(10), 825–841.
- Sharma, M.P., Kujur, A. (2012). Application of Remote Sensing and GIS for groundwater recharge zone in and around Gola Block, Ramgargh district, Jharkhand, India. *International Journal of Scientific and Research Publications*, 2 (2), 1.
- Valliammai, A., Balathanduytham, K., Tamilmani, D., Mayilswami, C. (2013). Identification of potential recharge zone of the selected watershed using Remote Sensing and GIS. *International Journal of Scientific & Engineering Research*, 4(8), 611.