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Delineating Ground Water Potential Zones in Khatra Block, Bankura District, West Bengal using MCE, RS and GIS Techniques

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Abstract: *Groundwater is considered to be one of the most valuable natural resources that support human civilization. It is an immensely important and dependable source of water supply in all climatic regions over the world. Due to population explosion and improper management, the resource is depleting drastically and is accomplished by extensive withdrawal of groundwater. Groundwater is in demand in hard rock areas where surface water supply is inadequate. Owing to this geoscientists are employing various techniques to explore the potential zone amongst which Multi-Criteria Evaluation (MCE) technique seems to be more precise. Remote sensing and Geographic Information System (GIS) has proved to be effective tools in delineating and developing potential zone by modeling terrain features specially in hard rock arid regions. The present study area, the Khatra Block, Bankura district is located on the eastern slope of Chotonagpur Plateau, and is mapped on 73 I/12, 73 J/13 and 73 I/16, and falls between $22^0 50' 30'' N$ to $23^0 12' 30''$ N latitude and $86^0 45' 0'' E$ to $86^0 56' 0''$ E longitude covering an area of 447km^2. In present study IRS Resourcesat LISS-4 with 5.8m spatial resolution digital data, CARTOSAT-1 digital elevation model, CartoDEM with 2.5m spatial resolution, data along with other data sets like Survey of India toposheets, GSI Map were used to generate various thematic maps, viz., geomorphology, geology, lineament density, drainage density and slope. The raster maps of these parameters were assigned to their respective theme weight and class rank. The individual theme weight was multiplied by its respective class rank and then all the raster thematic layers were summed up in a linear combination equation in Arc GIS Raster Calculator module. Likewise, the weighted layers were statistically modeled to get the areal extent of groundwater prospects with respect to each thematic layer. Based on this integrated approach, the groundwater availability in the study area was classified into five Categories, viz. very good, good, moderate, poor and very poor. The outcomes reveal that the modeling assessment method proposed in this study is an effective tool for deciphering groundwater potential zones for proper development and management of groundwater resources in hard rock terrains.*

Keywords: *Ground Water Potential zone, Multi Criteria Evaluation, Remote Sensing & GIS, Khatra Block.*

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I. Introduction

In arid and semi-arid regions across the globe, water scarcity is a major problem, and due to deficit rainfall, tremendous pressure is brought on ground water. During the past few decades , the available resource is in decline. India too is heading towards a fresh water crisis. In many parts of the world, groundwater is the largest only fresh water resource which provides a risk buffer to sustain critical water demands during continued dry periods (Assaf and Saadeh 2008). Over the years, the use of groundwater has increased and this has led to a water stress situation owing to unscientific exploitation of this natural resource. A cost and time-effective technique for proper evaluation of this natural resource and its management are of prime importance in the present scenario. Large volume of data from different sources is required to run a groundwater development programme. This can only be done through an integrated remote sensing and GIS study that provides an appropriate platform for convergent analysis of huge volume of multi-disciplinary data and making decision for this. The occurrence and movement of groundwater in a watershed of a hard rock terrain are mainly controlled by secondary porosity caused by fracturing of the underlying rocks (Srivastava and Bhattacharya 2006). Delineating the potential groundwater zones using remote sensing and GIS is an effective tool. Remote sensing not only provides a wide-range scale of the space-time distribution of observations, but also saves time and money (Murthy, 2000; Leblanc et al., 2003; Tweed et al., 2007). In addition it is widely used to characterize the earth surface (such as lineaments, drainage patterns and lithology). Geoscientists are adopting various techniques to target groundwater. High resolution satellite images are being increasingly used in groundwater exploration because of their usefulness in delineating different ground features, that serve as direct indicators of presence of ground water (Krishanmurthy, *et al*., 1996; Das *et al*., 1997; Ravindran and

Jayaram, 1997; Pratap, *et al*., 2000; Sankar, 2002; Bahuguna, *et al*. 2003; Jagadeeswara Rao, *et al.*, 2004; Ratnakar Dhakate, *et al.,* 2008). Indirect analysis of some directly observable terrain features like geological structures, geomorphology and their hydrologic characteristics using remote sensing are also being to find out this natural resource (Jaiswal *et al*., 2003; Basudeo Rai, *et al.,* 2005; Lokesha, *et al.,* 2005; Kumar et al. 2007 and Sreedevi et al. 2005; Samuel Corgne, *et al.*, 2010; Harinarayana et al 2000; Muralidhar et al 2000). Nag 2005 has used the lineament density and hydrogeomorphology-based approach in delineating groundwater potential zones. Saraf and Choudhary (1998), Jasrotia et al.(2007) and Chenini et al. (2010) have used remote sensing and GIS in delineating artificial recharge sites. Geomorphology and lineaments are very essential in groundwater prospecting. Many researchers like Kamal and Midorikawa (2004), Gustavsson et al. (2006) and Singh et al. (2007) have used satellite imagery in identifying geomorphic features and lineaments, applying various techniques that are helpful in groundwater studies. In addition, because of the unpredictable nature of the south-west monsoon in India, the availability of surface water cannot be ensured in the right quantity at the required time. Hence, the majority of the irrigated area in the Khatra Block of Bankura District is being cultivated with the help of groundwater acquired from dugwells and tubewells. However, the unrestricted excessive pumping of groundwater has resulted in lowering of groundwater levels in some parts of the study area. Dugwells and hand pumps also become inoperative every year during the dry period, thereby aggravating the water problem in the study area. Consequently, the objective of the present study was to delineate groundwater potential zone in Khatra Block of Bankura District, West Bengal by considering suitable thematic layers that have direct or indirect regulator over groundwater occurrence using Geoinformatics technology.

STUDY AREA

The study area, Khatra Block I and Khatra II, is situated in the Western part of Bankura district and falls between $22^0 50' 30''$N to $23^0 12' 30''$ N latitude and $86^0 45' 0''$E to $86^0 56' 0''$ E longitude covering an area of 447.km^2 . The area has been mapped on Survey of India toposheet nos. 73 I/12, 73 I/16, 73J/13 (Fig.1). The study area located 35 km from away from Bankura District town of West Bengal, India. The area is underlain by hard rock granites. The study area is located in semi-arid climatic zone. Average annual rainfall in the area is 132 cm, while maximum precipitation occurs during June–September with the onset of southwest monsoon. The temperature ranges from 22°C to 44°C. May is the hottest month with temperatures exceeding 40°C, and January is the coldest month with temperature going down sometimes to below 12°C. The area is characterized by the existence of almost gentle undulating sub-dendritic drainage pattern and seasonal flow. Kangsabati River runs west to east in the southern part of study area with several other streams & channels. Due to rapid urbanization and non-availability of any perennial river, the area is facing water scarcity problem. In the study area, the main source of irrigation is groundwater as the area remains rain deficit most of the year. The area is mainly composed of granites of Archaean age and Precambrians which include various types and grades of granite-gneisses, mica-schists and hornblende-schists as the major rock types that cover the study area (Fig.1.)

II. Data Base And Methodology

Indian Remote Sensing Satellite (IRS Resourcesat LISS-4) data was used in the present study. The survey of India topsheets 73 I/12, 73 I/16, 73 J/13 with a scale of 1:50,000 were used as a source of ancillary information. The imagery has been interpreted visually to identify different hydro-geomorphologic units and standard characteristic image interpretation elements like tone, texture, shape, size, pattern, and association have also been taken into consideration. Geology map was prepared with the help of Geological Survey of India existing map (1:250,000). The slope and drainage map was prepared from Cartosat-1 DEM data in ArcGIS Spatial Analyst module. The drainage density map was prepared using the line density analysis tool in ArcGIS. The most widely used software for the automatic lineament extraction is the LINE module of the PCI Geomatica. (Hung et al. 2005). Lineaments were extracted from Cartosat-1 DEM of the study area. Lineament density map was prepared by using ArcGIS. The thematic layers that are in vector format are converted into raster format and loaded in to GIS environment. Weights were assigned to individual themes *(Wt)* and for each features within the theme, ranks were given (Wi) based on the knowledge upon their significance to groundwater. By multiplying theme weight (Wt) with feature rank (Wi), factor scores were derived for each features. Likewise scores were derived for all the themes. Subsequently themes were converted into raster format thus each pixel contains factor scores with respect to their potentiality to groundwater derived for all the themes. Subsequently themes were converted into raster format thus each pixel contains Finally, all the thematic layers were integrated and the total factor scores for each pixel were calculated through raster calculation process in Spatial analyst extension of ArcGIS 10.Based on the derived scores, the final integrated map was classified into five categories of groundwater prospect zones as (i) Very good (ii) Good (iii) Moderate (iv) Poor and (v) Very Poor.

Cartosat-1 DEM of 30m resolution was used for lineaments analysis and Resourcesat-1 (LISS-IV) for hydrogeomorphological studies for groundwater development works. Lineaments can play a major role in identifying suitable sites for artificial recharge of groundwater because they reflect rock structures through which water can percolate and travel up to several kilometers (Krishnamurthy et al, 2000). A systematic integration of geology, geomorphology, lineament, slope, drainage data with follow-up of hydrogeological investigation provides rapid and cost-effective method for delineation of groundwater potential zones. Nowadays, digital technique is used to integrate various data to delineate not only groundwater potential zone but also to solve other problems related to groundwater. These various data are prepared in the form of a thematic map using geographical information system (GIS) software (ARC GIS .10) tool. These thematic maps are then integrated using "Spatial Analyst" too of Arc GIS.10. The "Spatial Analyst" tool with mathematical and Boolean operators is then used to develop a model depending on the objective of problem at hand, such as delineation of groundwater potential zones. The type and number of themes used for the assessment of groundwater resources by Geoinformatics techniques varies considerably from one study to another. In most studies, local experience has been used for assigning weights to different thematic layers and their features. Every year in summer most surface water sources dry up, causing serious water shortages for both domestic and irrigation purposes.

Geology

The area comprises of most diversified rock types belonging to Precambrian sediment & meta sediments (Table – 1; Figure 1). Precambrians include various types and grades of mica schists and gnesisses, hornblende· schists, amphibolites. Most of the area is covered with mica schist followed by basic rocks. Geologically, the area is mostly dominated by granite gnesiss of Archean age basically the extended part of chotonagpur plateau. For the present study, geological map was prepared from the existing geological map by Geological Survey of India .The Granite-gneiss rocks are wide spread over the study area covering about 260 km^2 (58%) and Schist/metasediments covering 180 Km^2(40.26%) and quartzites are limited in few parts. Granite gneiss covering mostly northern part of the study area with southwestern and eastern fringe. Mica schist covering central portion of the study area. Hornblende schist also present in the south western part of the study area covering 6km^2.Usually, massive unfractured lithologic units in basement setting has little influence on groundwater avail-ability except in cases with secondary porosity through the development of weathered overburden and fractured bed-rock units, which form potential groundwater zones. The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability. The study area contains Granite gneiss & mica schist as major geological structure Hence on the basis of the presence and nature of the weathered regolith units and fracture systems, appropriate weights are assigned to the different rock units in the study area. The weightage has given in terms of increasing groundwater potentiality is in the order of granite gneisses to hornblende schist & mica schist.

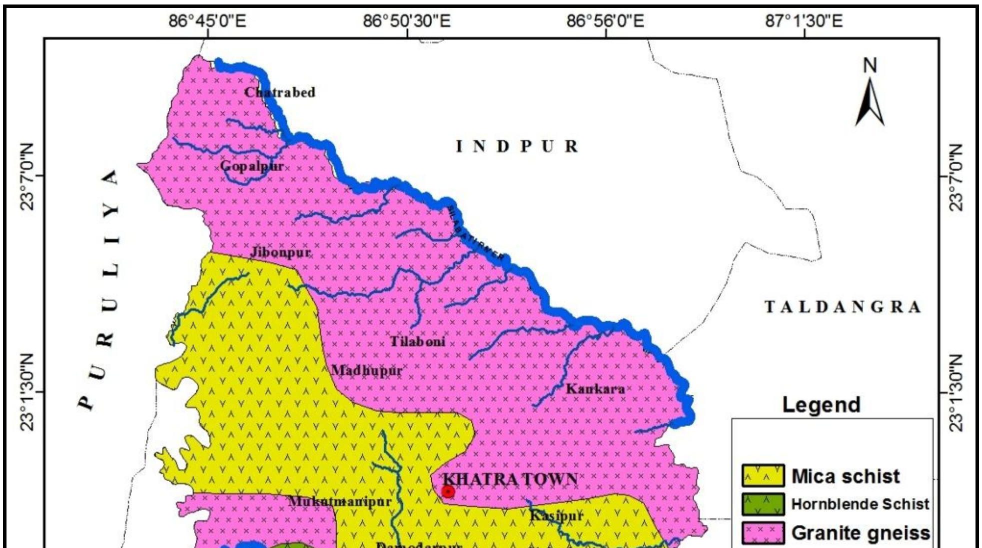

Figure – 1. Geological Map of the Study area.

Table 1: Geological units and their groundwater prospects.

Sl.No	Rock Types	Rock characteristics	Area in Km^2	Area in%	Ground Water Prospects
1	Mica Schist	Highly fractured weathered form	180	40.26	Good
2	Hornblende Schist	Fractured weathered form	6	1.36	Moderate to Good
3	Granite Gneiss	Massive occasionally traverse by joint	260	58	Moderate to Poor

Geomorphology:

The geomorphology of a hard rock terrain is highly influenced by the lithology and structures of the underlying formations. Geomorphology of an area constitutes the most important features in evaluating the groundwater potential and prospect (Kumar et al. 2008). The area is characterized by a dominant rocky undulating terrain and a number of erosional and depositional hydro geomorphic features, which are manifested by hills, uplands and undulating surfaces. Owing to its synoptic, multispectral repetitive coverage of the terrain, remote-sensing studies provide an opportunity for better observation and more systematic analysis of various hydrogeomorphic units/landforms/lineaments, features (Horton 1945; Kumar and Srivastava 1991; Sharma and Jugran 1992; Chatterjee and Bhattacharya1995; Tiwari and Rai 1996). The different hydrogeomorphological units are shown in Figure-2.

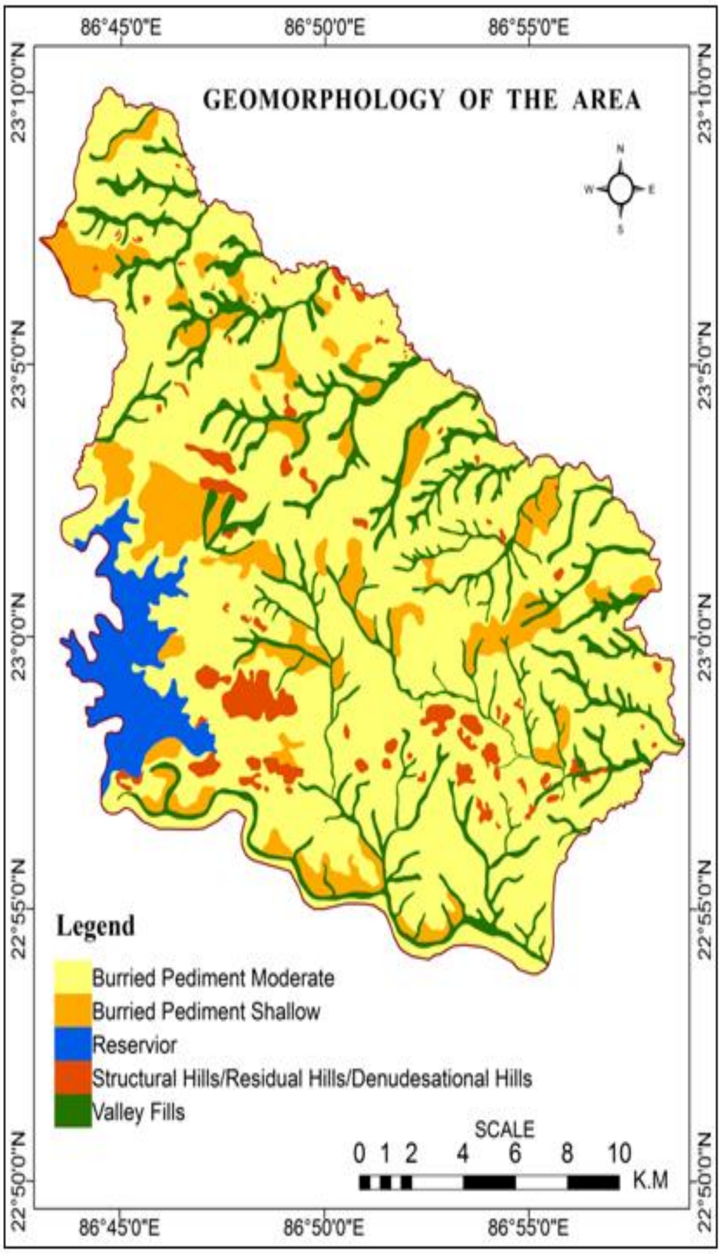

Figure – 2. Geomorphological map of the study area.

Structural hills/ Residual Hills/ Denudesanional Hills

Structural hills : In the study area, the structural hills are in the linear as well as in the arc shapes and exhibited by many definite trend lines and mostly act as runoff zones. Linear ridges are characterized by massive structure and high resistance to erosion. They also act as runoff zone and have very poor potential for groundwater. This unit covers 17sq.km in the study area and occupies 4 % of the study area .This unit is structurally controlled by numerous joints, fractures and lineaments which facilitate some infiltration and mostly act as runoff zones. From the satellite imagery and height verification of DEM data, the structural hills are interpreted by dark green tonal variation and by thick vegetation. The recharge is poor and restricted mainly along the joints, fractures, and faults. Therefore, groundwater occurrence is limited only along the joints, fractures and fault planes.

Residual hills : These are described as isolated hills. Residual hills are scattered in the southwestern part of the study area. In the imagery they exhibit dark greenish color in false color composite. The exposures of granite Gneisses occur as residual hills restricted to some area. The residual hills are more resistant formation from differential erosion and weathering. This unit occurs as isolated patches and found at lower altitudes. In spite of their isolated occurrence, their continuity in a linear or curvilinear manner gives indication that they are structurally controlled. The residual hills have geomorphic expression in the form of inselbergs, tors, linear and curvilinear ridges, exfoliated domes with partially debris cover at the foot slope (Tripathy et al. 1996). Due to steep slope most of the rain water is washed off immediately without much infiltration and hence the groundwater prospect in this unit is very poor.

Denudational hills: These are the hill ranges. These are formed due to differential erosion and weathering. These occupy the central and northern part of the study area at very few places. They appear as dark green greyish in color in the satellite imagery .These hills are covered with big boulders and sparse vegetation in contrast to structural hills. This landform, in general, act as high runoff zone, due to its moderate to steep slope (5 to 20 degree). The groundwater prospect in this zone is also described as very poor.

Pediment:

Pediments consist of very low weathered zone. A flat and smooth surface of buried pediment consists of shallow overburden of weathered derivative material. as the term suggests, is a feature usually formed at the foot of a mountain. Pediments (Figure 2) occur as gently undulating plains with moderate slope dotted with outcrops of gneisses with thin layers of soil. The pediment is a terrestrial erosional foot slope surface inclined at a low angle and lacking significant relief in all three dimensions. It usually meets the hill slope at an angular neck line, and may be covered by transported material. Pediments have been classified into two types a)Burried Pediment Moderate b) Burried Pediment Shallow.

***Burried Pediment Moderate*:**

A nearly flat and smooth surface of buried pediment consists of moderately thick overburden of weathered derivative material Spreading over large area. The moderate buried pediment is a major hydrogeomorphic unit in the study area. This unit is moderately weathered with a thickness various from 5 – 20 m, gently sloping, very deep, clayey to fine loamy soils and is well distributed throughout the region of the study area. This unit is interpreted by light red color to moderate red color in the satellite imagery. Mostly, this unit is found to have a well distributed drainage pattern in the study area. This unit occupies the topographically low-lying area and associated mostly with lineaments. This unit covers 310 sq.km in the study area and occupies 69.35 % of the study area. Groundwater prospects in this unit are considered as moderate to good. Though, higher yields may be expected from this hydrogeomorphological unit as it is associated with Lineaments. The different geomorphic units, their characteristic features and groundwater potentiality are shown in Table – 2.

***Burried Pediment Shallow*:**

Nearly flat to gently sloping topography, shallow to moderately deep, loamy soils followed by regolith zone, very shallow to shallow coarse-textured soil with occasional weathered outcrops of country rocks, wastelands with or without scrub, shallow to moderately deep, loamy skeletal soil, single crop area. This unit is characterized by low weathering thickness of the materials up to 5m. The low moisture content of this unit makes a medium grey tone on the imagery. This unit has a thick soil zone and sparse vegetation. This unit covers 55.17sq.km in the study area and occupies 10.2 % of the study area. Groundwater availability is supposed to be poor to moderate. However, the gentle slope adjacent to the stream course has moderate potential zones. The area covered by this hydrogeomorphological unit can be used for development of groundwater resource in terms of shallow wells (Subba Rao et al, 2001).

Valley Fills:

Valley fills are generally unconsolidated alluvial materials consisting of sand, silt, gravels and pebbles deposited along the floor of a stream valley. Depending upon the parent rock, the valley fills deposits vary in composition and texture (Agarwal and Garg, 2000). Normally, they are covered coarse gravel to sandy and clayey soils. Valley fills are linear depressions present in between the hill ranges and occupy the lowest reaches in topography, commonly filled with pebbles, cobbles, gravel, sand, silt, and other detrital material. The drainage pattern over the valley fills is parallel to sub-parallel indicating that the drainage is by and large controlled by the lineaments. They exhibit dark reddish tone and medium texture in the satellite imagery, which indicates high moisture content due to intensive cultivation. These valleys are developed along the fractures shallow to deep; fine loamy to clayey soils with moderately deep to deep, fine-textured moderately well-drained soils; moderate limitation of wetness single crop mainly terrace cultivation. This unit covers 65.11 sq.km in the study area and occupies 14.56 % of the study area .Groundwater prospects in valley fills are good to excellent because of the topographical location at the bottom of the hill and geological composition consisting of highly porous materials. Valley fills also act as good to excellent subsurface water potential (Murthy and Rao, 1999).

Table 2: Different hydrogeomorphological units, their characteristics, area covered and groundwater prospects.

Hydrogeomorphological units	Description/ Characteristics	Area Km^2	Association	Groundwater prospects
Valley fills	Accumulation zone of colluvial materials derived from surrounding uplands; shallow to deep; fine loamy to clayey soils. Moderately deep to deep, fine textured moderately well drained soils. Moderate limitation of wetness	65.11	Stream course	Good to Very Good
Buried pediment (moderate)	Gently sloping topography; very deep, clayey to fine loamy soils. Moderately deep to deep, fine textured loamy skeletal to coarse loamy soil. Single crop area with marginal	310	Agricultural land	Good
Buried pediment (shallow)	Nearly flat to gently sloping topography, shallow to moderately deep. Very shallow to shallow coarse textured soil with occasional weathered outcrops of country rocks. Wastelands with or without scrub. Shallow to moderately deep	55.17	Hill and stream course	Moderate to poor
Rocky outcrop (Structural Hills/Residual Hills/ Denudation Hills)	Broad uplands of considerable elevation, steeply sloping on all sides. Very shallow, coarse loamy soil on moderately steep to very steep hill slopes	17	Hill and stream course	Poor to Very Poor

Slope:

Slope is one of the factors controlling the infiltration of groundwater into subsurface; hence an indicator for the suitability for groundwater prospect. In the gentle slope area the surface runoff is slow allowing more time for rainwater to percolate, whereas high slope area facilitate high runoff allowing less residence time for rainwater hence comparatively less infiltration. For the generation of slope, the digital elevation model (DEM) Cartosat -1 (30m) resolution is used & developed by ArcGIS Spatial Analysis tools. Slope of the area varies from 0^0 to 35^0. On the basis of the slope, the study area can be divided into five slope classes. The area with 0^0 to 1^0 slope falls in the 'Very good' category due to the nearly flat terrain and relatively high infiltration rate.. The area with 1^0–3^0 slope is considered as 'good' for groundwater storage due to slightly undulating topography with some run-off. Entire central portion and the southern portion (67% of the total area) fall under this category. The area with a slope of 3^0–6^0 causes relatively high run-off and low infiltration, and hence is categorized as 'moderate'. The fourth (6^0-12^0) category is considered as 'poor' due to higher slope and run-off. The areas having a slope 12^0-35^0 are considered as 'very poor' due to higher slope and runoff. These areas are hilly with rocky out crop having steep slope, where amount of infiltration negligible but run off is maximum (Table-3 ; Figure 3).

Table 3: Slope values and their groundwater prospects.

Sl. No.	Altitudinal Zones	Area in km^2	Area in %	Associated land use/ land cover	Ground Water Prospects
1	0^0 -1^0	188	42	Agricultural land	Very Good
2	1^0 -3^0	192	43	Agricultural land with Sparse Vegetation	Good
3	3^0 -6^0	54	12	Scrub land with Sparse Agriculture	Moderate
4	6^0 -12^0	11	2.42	Barren Rocky land	Poor
5	12^0 -35^0	3	0.7	Hilly areas with exposed rocks	Very Poor

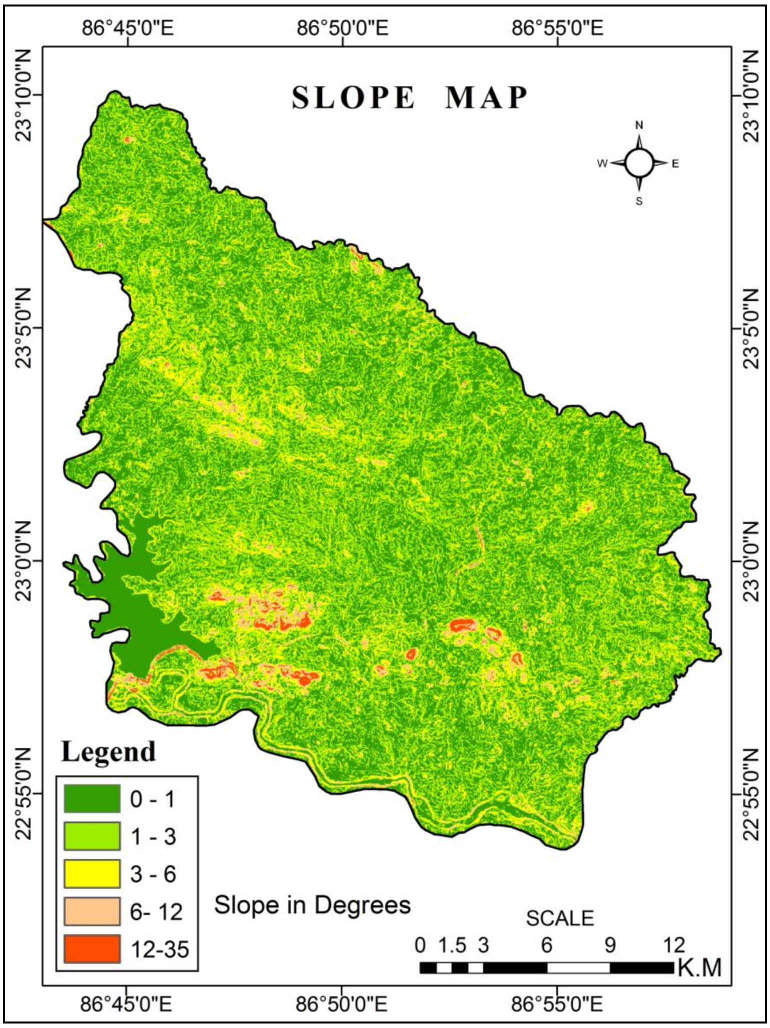

Figure – 4. Slope map of the study area.

Drainage Network:

Drainage network analysis is important for geo-hydrological studies. Drainage pattern reflects the characteristic of surface as well as subsurface formation. "The study area is well drained by" a number of rivers. Kangshabati is the main river flows southern part of the study area originates from hills of Chotonagpur Plataue. A number of rivers run almost parallel to one another in north-west to south-east direction in the study area. Silabati flows northern part of study area. The streams present in the study area have been ordered using Horton's law of stream order and streams up to 5th order have been demarcated. Drainage map of the study area reveals only 2 types of drainage patterns viz. dendritic, parallel to sub parallel. The high resolution Digital Elevation Model of 30m resolution Cartosat-1has been used to extract drainage pattern of the study area. Here we have used “Spatial Analysis” tool of Arc GIS. 10 to develop stream orders . The stream flow pattern is mostly controlled by its lithology in the study area. The entire Kangsabati river basin is composed of two different rocks of different geological period. The western part is composed of relatively older rock mica-schist of Precambrian period while the eastern part is composed of pliestocene laterite formation, strong structural control is observed due to presence of hard base of granite and gneiss in the area.

Drainage Density:

Drainage density is defined as the closeness of spacing of stream channels. It is a measure of the total length of the stream segment of all orders per unit area. The drainage density is an inverse function of permeability. The less permeable a rock is, the less the infiltration of rainfall, which conversely tends to be concentrated in surface runoff. In the present study, since the drainage density can indirectly indicate the groundwater potential of an area due to its relation to surface run-off and permeability, it was considered as one of the indicators of groundwater occurrence. Drainage density (in terms of km/km^2) indicates the nature of surface material. More the drainage density, higher would be runoff. Thus, the drainage density characterizes the runoff in the area or in other words, the quantum of relative rainwater that could have infiltrated. Hence lesser the drainage density higher is the probability of recharge or potential groundwater zone. The study area has been grouped into five classes. These classes have been assigned to 'very low(<1km/km^2), 'low' (1-2 km/km^2), 'moderate' (2-3 km/km^2), and 'high' (3-4 km/km^2) respectively 'very high' drainage density (4-5 km/km^2) (Table – 4; Figure 5). Low network of drainage course indicates presence of highly resistant and permeable rock, while a high drainage course indicates highly weak and impermeable rocks (Karanth 1999). A higher ranking was attributed to low drainage density zones and a lower ranking to a high drainage density zone.

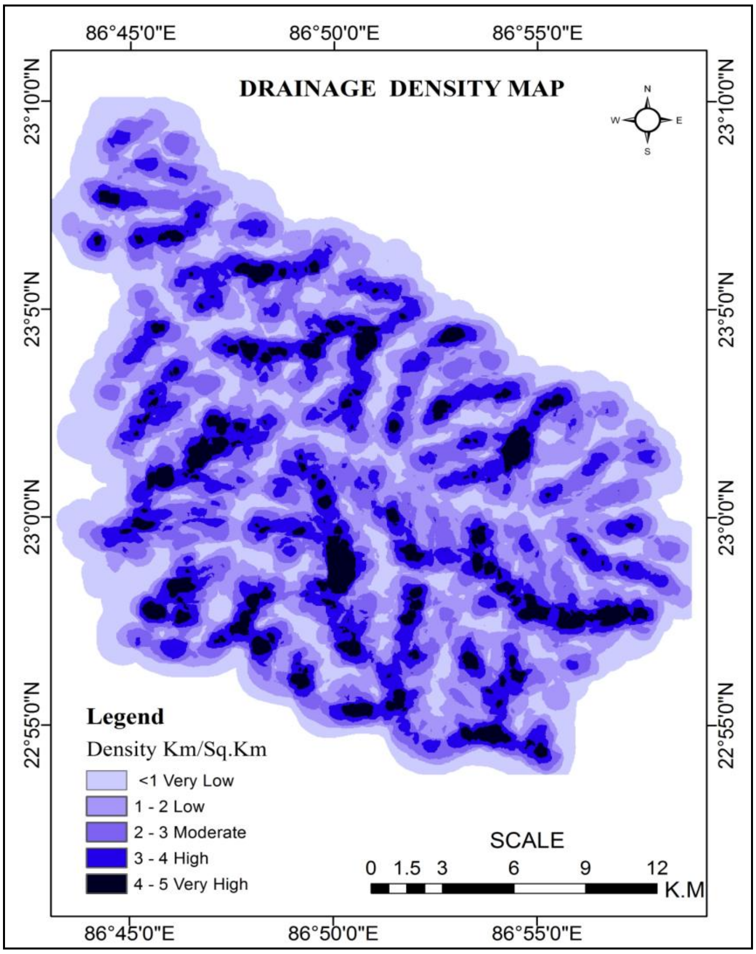

Figure – 5. Drainage density map of the study area.

Table 4: Drainage density and their groundwater prospects.

Sl.No	Drainage Density Km/Km^2	Area in km^2	Area in %	Ground Water Prospects
1	< 1	105	23	Very Good
2	1 -2	121	27	Good
3	2 -3	109	24.32	Moderate
4	3 – 4	80.61	18	Poor
5	4 – 5	31.29	7	Very Poor

Lineament Study:

Geologic lineament mapping is considered as a very important issue for the problem solving in engineering, especially in Geo-hydrological research. The regional study and automated extraction of linear features such as faults, joints, folds, dikes, crustal fracturing, and lithological contacts from remotely sensed imagery has been the subject of extensive research over several decade. The groundwater abundance in hard rocks depends not only on rock types but also on the intensity of the tectonic activity.

The storativity of a hard rock aquifer is of a very complex nature as the rock itself is impervious, and the occurrence and movement of the groundwater are restricted to interconnected fracture systems. Faults are often revealed as linear or curvilinear traces on satellite images. These image lines of different contrast are commonly referred to as lineaments and may extend from a few meters to tens of kilometres in length. Lineament mapping was used long before this work in other geological applications and the first usage of the term lineament in geology is probably from a paper by Hobbs (1904, 1912), defined lineaments as significant lines of landscape caused by joints and faults, revealing the architecture of the rock basement. This was later used by O' Leary et al. (1976) as a basis for developed definitions. Lineaments have been defined as extended mappable linear or curvilinear features of a surface whose parts align in straight or nearly straight relationships that may be the expression of folds, fractures or faults in the subsurface. Studies revealed a close relationship between lineaments and groundwater flow and yield (Mabee et al., 1994; Magowe and Carr, 1999; Fernandez and Rudolph, 2001). Therefore, mapping of lineaments closely related to groundwater occurrence and yield is essential to groundwater surveys, development and management. Lineament density of an area can indirectly reveal the groundwater potential, since the presence of lineaments usually denotes a permeable zone. Areas with high lineament density are good for groundwater potential zones. Lineaments give a clue to movement and storage of groundwater and therefore are important guides for groundwater exploration. In hard rock terrain lineaments and fractures act as master conduits in movement and storage of groundwater (Ramasamy, et.al. 2005, Subash Chandra, et.al., 2010). On contrary to above, if lineament density is high then higher will be the rate of infiltration whereas low density leads to more runoff (Kumar, et al., 1999). The remote-sensing data, which offer synoptic view of large area, helps in understanding and mapping the lineaments both on regional and local scale. The lineament analysis of the area from remotely sensed data provides important information on subsurface fractures that may control the movement and storage of groundwater. Automatic (or digital) extraction*:* various computer-aided methods for lineament extraction have been proposed. Most methods are based on edge filtering techniques such as START, Canny, and EDISON algorithm. The most widely used software for the automatic lineament extraction is the LINE module of the PCI Geomatica. (Hung et al. 2005) .We have used here automatic lineament extraction process. Various optimal edge detectors from the domain of image processing are the algorithms by Canny and the EDISON algorithm were applied on the remotely sensed image, in order to obtain the most suitable edge map. Here Lineaments were extracted from CARTOSAT DEM data of 30m resolution and finally developed by Arc GIS.10 (Figure 6). In the study area, there are 462 lineaments have been mapped through analysis of satellite data. They are generally varying in length from minimum 0.0422 to maximum 3.12 km. Length Measurement is also very much significant, since a fracture with a greater length affects the groundwater flow in a more dominant way than those of smaller length. . Mapping of lineaments is very useful in hard rock terrains, where the storage and movement of groundwater are very much influenced by these linear features. In the study area, major lineaments are surface manifestation of some structural features in the bedrock as fracture and joints developed due to tectonic stress and strain, derived automatically from digital elevation data model (DEM). In the study area Joints may develop in more than one set and with varying frequency in exposures.Three sets of joints/fractures are commonly present in area .ESE–WNW/E–W trending joints conforming with the regional trend to the axial plane foliation of F1 phase folding. The orientation of the lineaments is analysed by constructing rose diagrams. This analysis is very important for the trend of faults throughout the study area.

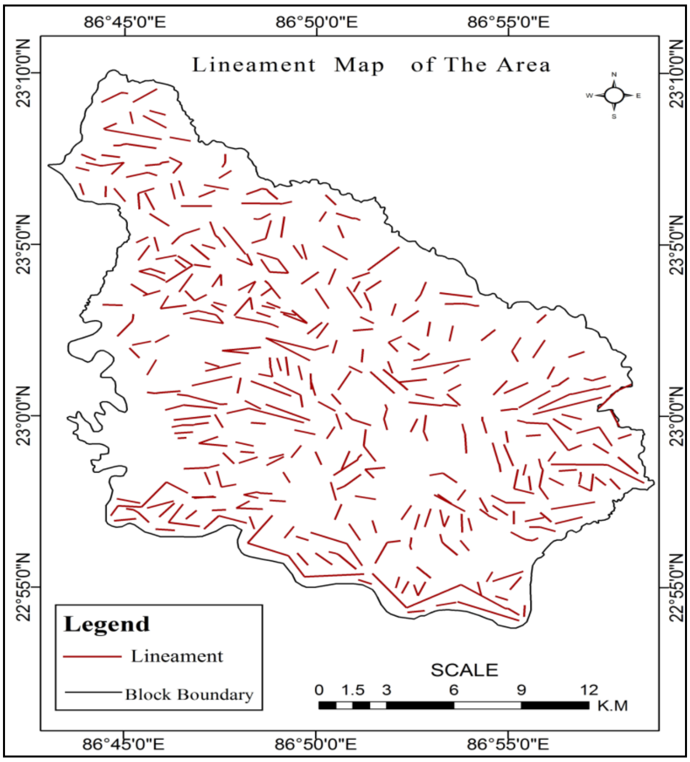

Figure – 6. Lineament map of the study area.

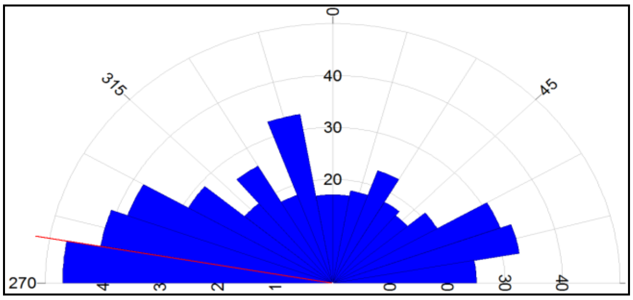

Figure – 7. Rose diagram showing orientation of the lineaments of the study area.

The study area shows that regionally there are bimodal oriented structural trends. The main class is NW and SE strike, while other having NE and SW strike. The uniformity of fracture orientation becomes an additional indication for the hydrogeologic regime. The major directions of the lineament have been plotted in a rose diagram. It has been observed that the majority of the lineaments arc oriented in NW–SE (100–280) direction. Maximum long length lineaments have been observed in the southern (Western and eastern) part of the study area (Figure 7).

Lineament Density:

The purpose of the fracture density analysis is to calculate frequency of the fractures per unit area. With this analysis a map has been produced showing concentrations of the lineaments over the study area. Lineament density of an area indirectly reveals the groundwater potential of that area since the presence of lineaments usually denotes a permeable zone. Areas with higher lineament density are good for groundwater development. Lineament density is the total length of all the lineaments present in the basin/watershed divided by the total study area. Lineament density map was prepared by dividing the study area into 1 km/1 km grid in Arc GIS Line Density calculation platform. The lineament intersection of the study area indicates high and very high intersection in the same areas where there is very high density of lineaments. The zones of high lineament intersection over the study area are feasible zones for groundwater potential evaluation. The highest value of lineament density, 1.431–2.245 km/km^2, is found to be present in southwestern and eastern parts as well as upper central part of the study area. On the basis of lineament density, the area was divided into five different (very high, high, moderate, low, very low) zones. Since groundwater potential is directly proportional to lineament density, hence, high rank was assigned to high lineament density zones and low rank to low lineament density zones (Table – 5; Figure 8).

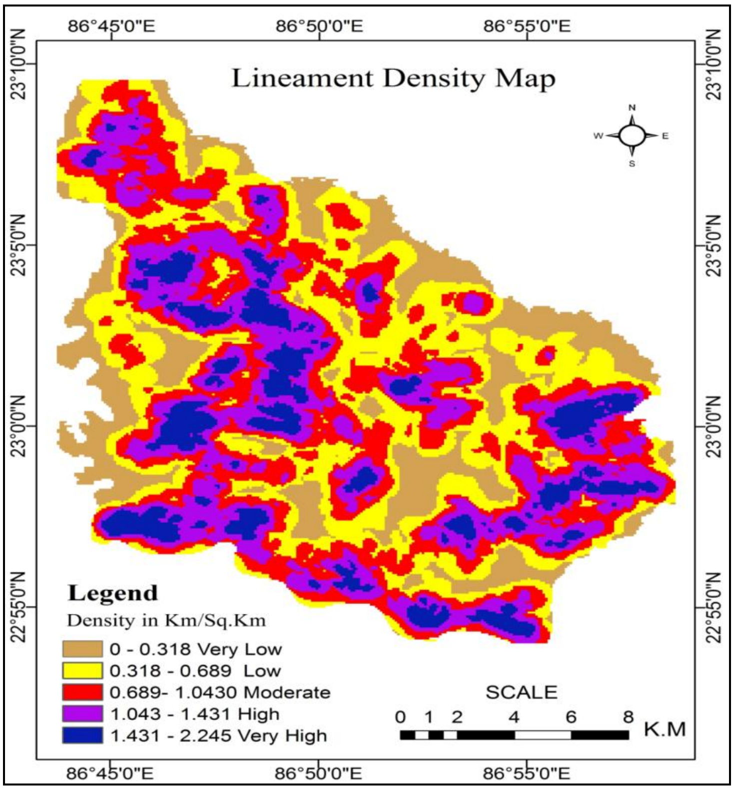

Figure – 8. Lineament density map of the study area.

Table 5: Lineament Density and their groundwater prospects.

Sl.No	Lineament Density Km/Km^2	Area in km^2	Area in %	Ground Water Prospects
1	1.431-2.245	44	10	Very Good
2	1.043-1.431	94	21	Good
3	0.689-1.043	112	25	Moderate
4	0.318-0.689	116	26	Poor
5	<0.318	81	18	Very Poor

III. Results And Discussions

The integration of various thematic maps describing favorable groundwater zones into a single groundwater potential map has been carried out through the application of Arc GIS10. Satellite imageries, topographical maps and conventional data have been utilized to prepare the thematic layers of hydrogeomorphology, lineament density and slope maps of the area. The various thematic layers are assigned proper weightage through MIF technique and then integrated in the GIS environment to prepare the groundwater potential zone map of the study area. The results of the present study can serve as guidelines for planning future artificial recharge projects in the study area in order to ensure sustainable groundwater utilization. The information on geology, geomorphology, lineaments, slope and drainage density was gathered from Cartosat DEM data, GSI map, LISS-IV and Survey of India (SOI) toposheets of scale 1:50,000. In addition, GIS platform was used for the integration of various thematic layers. The composite map generated was further classified according to the spatial variation of the groundwater potential. The spatial variation of the potential indicates that groundwater occurrence is controlled by geology, structures, slope and drainage density. The groundwater potential zones are obtained by overlaying all the thematic maps in terms of weighted overlay method using the spatial analysis tool in ArcGIS 10. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters. The weights and rank have been taken considering the works carried out by researchers such as (Krishnamurthty et al 1996, Saraf & Choudhary 1998).

Table 6: Different thematic layers, their groundwater prospects and their weights and ranks.

Thematic Layers	**Weight (W_i)**	**Features**	**Ground water Prospects**	**Rank (R_i)**
Hydrogeomorphology	40	Valley Fills	Very Good	16
		Buried Pediment moderate	Good	12
		Buried Pediment Shallow	Moderate to Poor	8
		Structural hills/ Denudation hills/ Residual hills	Poor to Very Poor	4
Lineament Density	20	1.43-2.24 Km/Km^2	Very Good	8
		1.04-1.43 Km/Km^2	Good	6
		0.68-1.043 Km/Km^2	Moderate	4
		0.3-0.6 Km/Km^2	Poor	1.4
		<.31 Km/Km^2	Very Poor	0.6
Slope	20	$0^0 – 1^0$	Very Good	8
		$1^0 – 3^0$	Good	6
		$3^0 – 6^0$	Moderate	4
		$6^0 – 12^0$	Poor	1.4
		$12^0 – 35^0$	Very Poor	0.6
Drainage Density	10	0 -1 Km/Km^2	Very Good	4
		1 -2 Km/Km^2	Good	3
		2-3 Km/Km^2	Moderate	2
		3-4 Km/Km^2	Poor	0.7
		4-5 Km/Km^2	Very Poor	0.3
Geology	10	Mica Schist	Good	5
		Hornblende Schist	Moderate to Good	3
		Granite Gneiss	Moderate to Poor	2

All the thematic maps are converted into raster format and superimposed by weighted overlay method (rank and weight wise thematic maps and integrated with one another through Arc GIS environment. For assigning the weight, the slope and geomorphology were assigned higher weight, whereas the lineament density and drainage density were assigned lower weight. After assigning weights to different parameters, individual ranks are given for sub variable. In this process, the different GIS layers such as lineament density, geomorphology, and slope and drainage density have been analyzed carefully and ranks are assigned to their sub variable (Butler et al., 2002, Asadi et al., 2007, Yammani, 2007). The maximum value is given to the feature with highest groundwater potentiality and the minimum given to the lowest potential feature. The landforms such as valley fills, buried pediment moderate are given higher rank and lower value is assigned for structural hilly areas. As far as slope is concerned, the highest rank value is assigned for gentle slope and low rank value is assigned to higher slope. The higher rank factors are assigned to low drainage density because the low drainage density factor favors more infiltration than surface runoff. Lower value followed by higher drainage density. Among the various lineament density classes the very high lineament density category is assigned higher rank value as this category has greater chance for groundwater infiltration. Lower value is assigned for very low lineament density. In Geology high rank is assigned for Mica Schist and low value is assigned for areas underlined by Granitic gneiss.

The groundwater potential zones for the study area were generated through the integration of various thematic maps viz., Hydrogeomorphology, slope, Geology, Drainage Density, lineament Density, using remote sensing and GIS techniques. The demarcation of groundwater potential zones for the study area was made by grouping of the interpreted layers through weighted multi influencing factor and finally assigned different potential zones. Groundwater potential map indicates that low lying area of sand, silt and clay with nearly level slope and very low drainage density has very good potentiality and development and valley fills associated with lineaments is highly promising area for groundwater extraction. The structural hills, denudational hills and residual hills are considered as poor to very poor groundwater potential zone. However, these land landforms act as run-off zones because of their steep slope. Lineaments particularly joints, fractures and their intersection enhances the potential of hydrogeomorphic units. Thus the generated groundwater potential map serves as a base line for future exploration. The hydro-geomorphological units Valley Fills, are most favourable zones for groundwater exploration & development in the study. Hence, these areas are marked as good to very good favourable zones. In case of Buried Pediment with (moderate, shallow) region have been identified as a good to moderate favourable zone and the region of denudational with low lineament density has been identified as the least favourable zone for groundwater exploration & development in the study. A glance at reveals that the southern part of the study area have excellent groundwater potential as compared extreme northern part of the study area.

Weight assignment and Geoinformatics-based modeling

Suitable weights were assigned to the seven themes and their individual features after understanding their hydrogeological importance in causing groundwater occurrence in the study area). The Thematic layers are integrated in the GIS environment to generate groundwater potential index (GWPI). The GWPI is computed by using the weighted linear combination method as follows: (Malczewski, 1999).

All the thematic maps of these parameters were assigned respective theme weight and their class rank. The individual theme weight was multiplied by its respective class rank and then all the thematic layers were converted to raster format and reclassified with individual preference (R_i), aggregated in a linear combination equation in ArcMap GIS Raster Calculator format.

The equation used for analysis

$$\mathbf{GWPI} = \sum \mathbf{W_i} \times \mathbf{R_i}$$

Where W_i = Map weight

R_i = Ranking for the each layer

GWPI= Grond Water Potential Index

GWPI= $W_{Geom} \times R_{Geom} + W_{Slope} \times R_{Slope} + W_{lineament\ Density} \times R_{lineament\ Density} + W_{Drainage\ Density} \times R_{Drainage\ Density} + W_{Geology} \times R_{Geology}$

The final cumulative map generated by applying the above equation, Very Good to Good, moderate, moderate to poor, and poor to very poor. About 3% of the total area falls under the 'very poor' zone, 9% falls under 'poor' zone, 31% falls under 'moderate' groundwater potential zone, and 40% of the study area falls under 'good' zone,17% of the area falls under 'very good' zone. The groundwater potential map demonstrates that the excellent groundwater potential zone is concentrated in the south –western ,central northern region of the study area due to the distribution of valley fills ,high lineament density making fractured network, and low drainage density. Finally, the cumulative effect of the weighted multi influencing factors through overlay analysis in Arc GIS platform revealed the mapping of groundwater potential zones in the study area (Figure 9). The targeting groundwater potential zones are grouped into five different potential zones: very good, good, moderate, poor, very poor. Analysis of the groundwater potential zones shows that the very good groundwater potential zones constitute 17% of the total block area. Good groundwater potential zones occupy approximately 40%, and the

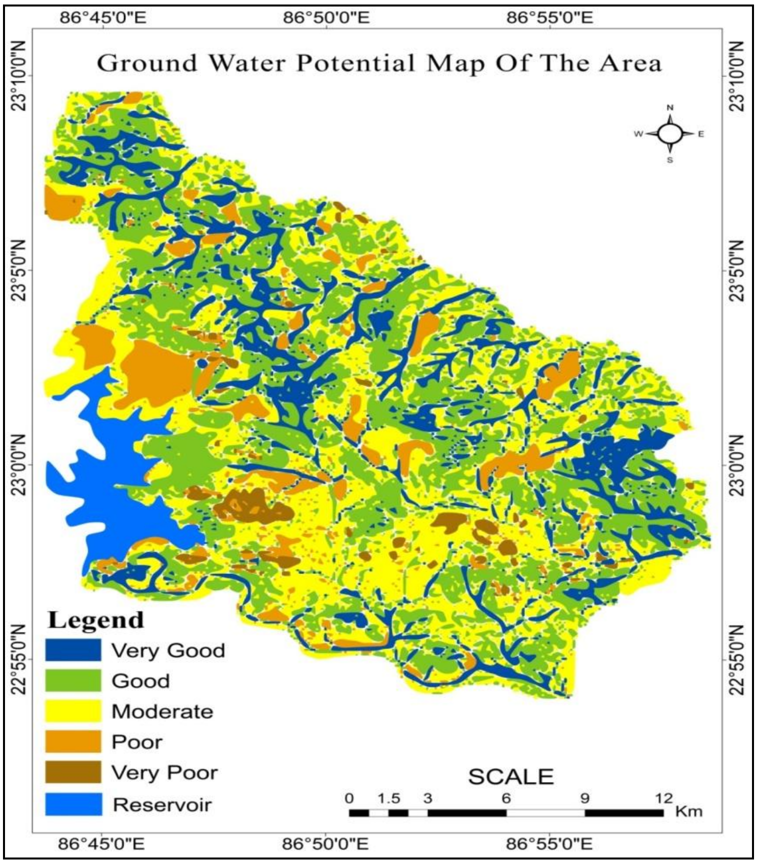

Figure – 9. Map showing Groundwater Potential Zone of the study area.

moderate potential zones occupy about 31%of the total block. Poor potential zones occupy nearly 9% and very poor zone covering 3% of the study area (Figure – 10; Table – 7).

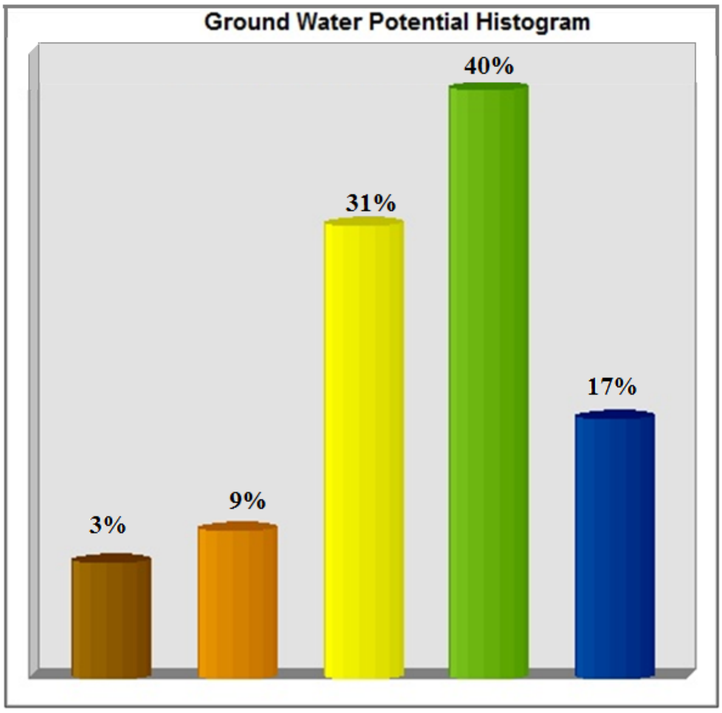

Figure – 10. Histogram showing Groundwater Potentiality of the study area.

Table 7. Different category of Groundwater Potential Zones and their respective area coverage with areal percentage.

Sr. No	Potential zones	Area (Km^2)	Area (%)
1	Very Good	76	17
2	Good	179	40
3	Moderate	138	31
4	Poor	41	9
5	Very Poor	13	3

IV. Conclusion

Geographical information system and remote sensing has proved to be powerful and cost effective method for determining groundwater potential in parts of Bankura District of West Bengal. The study reveals that integration of five thematic maps such as drainage density, slope, geology, geomorphology, lineament density gives first-hand information to local authorities and planners about the areas suitable for groundwater exploration and management**.** This study helps to conduct groundwater exploration mapping faster and more efficiently at the same time. This technology is not viewed as replacement for traditional method, but rather as a complement for detailed hydrogeological mapping, especially for well site. The study concludes that the remote sensing and GIS are a potentially useful tool in delineation of groundwater potential zones in any area. Satellite imageries, topographical maps and conventional data were used to prepare the thematic layers of lineament density, slope and hydrogeomorphology. The geomorphologic units such as valley fill and buried pediment are prospective zones for groundwater exploration and development in the study area. Presence of lineaments in the area enhances the potential of these units .The various thematic layers are assigned proper weightage through MCE technique and then integrated in the GIS environment to prepare the groundwater potential zone map of the study area. In order to demarcate the groundwater potential zones within each thematic layer, an innovative statistical modeling was done using Arc GIS 10. The results reveal that the area falls in four groundwater potential zones ranging from very poor to very good. The poor zone is indicative of the least favourable region for groundwater prospecting, while the good to very good zone indicates the most favourable region. The results obtained can be used for sustainable management of groundwater resources in the area in terms of artificial recharge. Concerned decision makers can formulate an efficient groundwater utilization plan for the study area so as to ensure long-term sustainability.

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