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GROUND WATER POTENTIAL ASSESSMENT USING GEOINFOMATICS OF HIRIYUR TALUK, CHITRADURGA DISTRICT, KARNATAKA

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Abstract

Remote sensing technique integrated with GIS is found to be very effective tool for identification of potential zones for groundwater exploration. Hydro geomorphological mapping coupled with hydrogeological investigations and structure/lineaments have been proved to be effective to locate groundwater potential zones. Identifying a good site for groundwater exploration in a rugged terrain is a challenging task. In hard rocks, groundwater occurs in secondary porosity developed due to weathering, fracturing, faulting, etc., which is highly variable within a short distance. In such situations topographic, hydrogeological and geomorphological features provide useful clues for the selection of suitable site for groundwater exploration and hence integration with GIS and Remote sensing technique can be a most promising method. Remote sensing and Geographical Information System is currently used in the project to analysis the drainage basin and for identification of ground water potential zones on integration of various thematic maps. Based on the available information and the geophysical investigations it is concluded that Stream order of basin indicates that the basin is sixth order basin with dendritic type of drainage pattern with homogeneous nature and the number of streams usually decreases as the stream order increases. The result of aerial aspect shows the texture of drainage is moderate. The ground water potential zones in the study area are classified into poor to medium, medium, medium to high and high respectively. The good potential zones are confined to in and around the lower stream order. Various artificial ground water recharging structures have been provided near 2nd and 3rd stream order for augmentation of water resources in the study area.

Keywords: *GIS, Thematic Maps, Land Use Land Cover, Artificial Recharge, Dendritic Type.*

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1.0 INTRODUCTION

Groundwater plays a vital role in the rapidly expanding Urban, industrial, and agricultural water requirements, in the study area. Therefore, the quantification of the current rate of groundwater recharge is a necessity for the efficient and sustainable groundwater resource management. Groundwater recharge is generally considered as that amount of water, which contributes to the temporary or permanent increase of groundwater resources. From the mechanism of groundwater recharge, it is quite obvious that the highest percentage of water is of meteoric origin. Other sources such as juvenile water of volcanic, magmatic and cosmic origins contribute little to the ground water recharge. Hence there is a need to undertake detailed study considering all the parameters related to groundwater occurrence. The reconnaissance survey helps in demarcating the region for detailed investigation. However, the detailed investigation earned out through preparation and integration of different thematic maps using remotely sensed data and followed by field survey such as geophysical and hydrogeological investigations is found to be appropriate method for groundwater prospective zones mapping.

The factors which control the ground water occurrence include rock type, landforms and soil type, recharge characteristic of soils/overburden material etc., in crystalline hard rock integrated terrain analysis for identifying suitable site for groundwater planning & development studies. The development of remote sensing technology, the resources mapping, monitoring and management have become much simpler. Remote Sensing technique has emerged as one of the powerful tool by providing synoptic view, repetitive coverage, and capability to study inaccessible area at relatively low cost and less time when compared to the conventional techniques. The information generated through remote sensing techniques on landforms, Geology, land use/cover, etc., integrating the same provides an evidence about groundwater occurrence. Thus the remote sensing based groundwater prospects zone map prepared for an area serves as basic information for further development through hydrogeological & geophysical methods to locate the favourable sites.

1.1 Geoinfomatics

A computer system known as a GIS is used to gather, store, analyze, and present information on the location of the earth's surface. Any information that contains a location can be used by GIS. There are numerous ways to provide the location, including using latitude and longitude, an address, or a zip code. Data on population, population density, area, and solid waste generation may be included in the system. It contains information about the locations of streams, various types of soil and vegetation, factories, farms, and schools as well as information about storm drains, highways, and electricity lines. The satellite based remote sensing data and Geographic Information System (G1S) are being efficiently utilized to demarcate the various groundwater controlling parameters as well as groundwater prospective zones. It can be noted that both remote sensing and geographical information system technique provides not only the qualitative information about the condition of the water resources in a particular area, but also helps to narrow down the target area for further detailed study. GIS technique was used to generate layers like drainage and springs, geology, contour, slopes and Digital Elevation Model (DEM), essential for watershed management (Bhavana Umrikar, 2015).

2.0 BACKGROUND AND STUDY AREA

The study area lies in the coordinates of 76° 26′ 00″ E to 76° 54′ 00″ E longitudes and 13° 36′ 00″ N to 14° 18′ 00″ N latitudes. The study area falls under semi-arid climatic zone of Chitradurga district. The highest elevation is 1107 m and lowest is 551 m and the total study area covers an area of 1705 sq. km. The average rainfall is 550mm. The area is overlaid by Gneissic terrain. Topographically area is of

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undulating terrain with sparse vegetation. The study area is well connected by rails and roads. The below Fig. 1 shows the chosen study areas, which comes under Chitradurga District, Karnataka. Characteristics like contour characterization, groundwater quality, and thematic maps created with remote sensing and geographic information system techniques, as well as the techniques used to outline artificial groundwater recharging structures, are identified for possible evaluation.

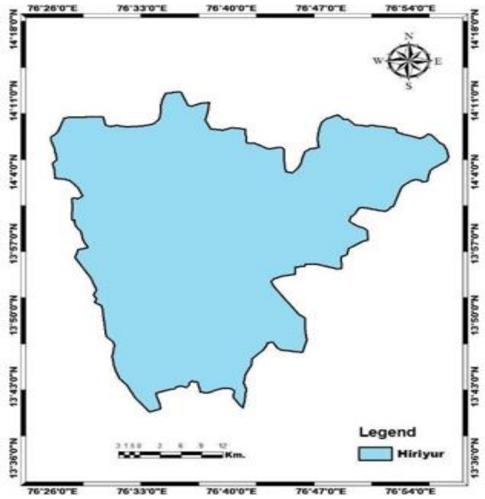

Fig 1: Location map of the study area

3.0 METHODOLOGY

The steps for carrying out an air quality risk assessment are shown in Fig. 2, and the information is described in more depth below.

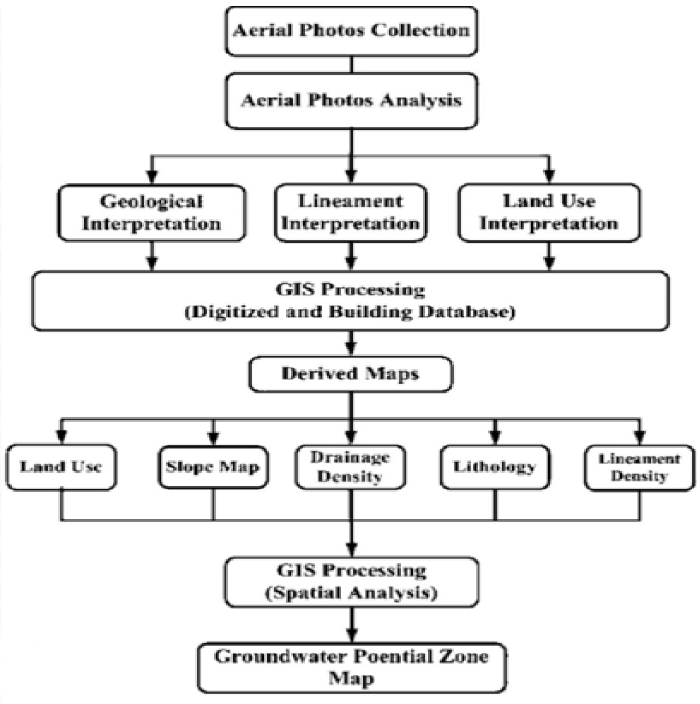

Fig 2: Flow chart showing the methodology adopted

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The study area is demarcated using Toposheets and Satellite imageries. The available information on various parameters is collected from various governmental agencies. The qualitative and quantitative geomorphic analysis is done. The results are correlated with the other hydrological parameters to draw conclusions. The Land use/Land cover for the study area has been demarcated for various types of classes using satellite imageries of IRS - 1C and 1D LISS III and PAN merged data. The Geological map is updated by incorporating structural and lineament information extracted from Satellite imageries. Multiple thematic layers are integrated using GIS to generate groundwater potential zone map.

4.0 RESULTS AND DISCUSSIONS

4.1 Hydrogeological Studies

DEM MAP - Survey of India topographic map (1:50,000), SRTM (Shuttle Radar Topographic Mission 90 m), the drainage network from SRTM DEM was extracted in Fig. 3, using the Arc Hydro toolset in ArcGIS10.2.

Fig 3: SRTM DEM map of the study area

STREAM FLOW DIRECTION MAP - Flow direction is important in hydrologic modeling to determine where a landscape drains, it is necessary to determine the direction of flow for each cell in the landscape. Flow direction was calculated for each pixel using the filled DEM, i.e. the direction in which water will flow out of the pixel to one of the eight surrounding pixels. Arc Hydro in ArcGIS, allows water from a given cell to flow into only one adjacent cell, along the direction of steepest descent encoded from 1 to 128 in different directions (Fig. 4). These techniques are found relevant for the extraction of river basin and its drainage networks (Chaitanya et al., 2015).

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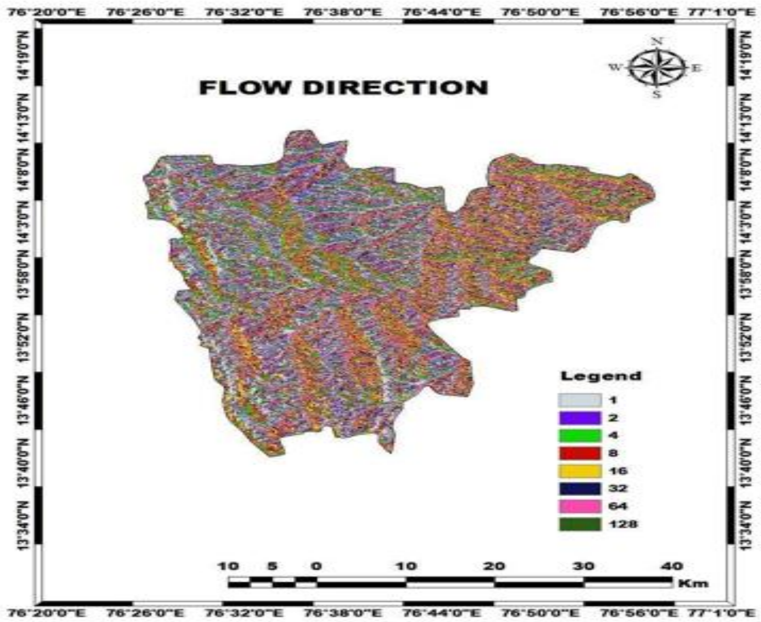
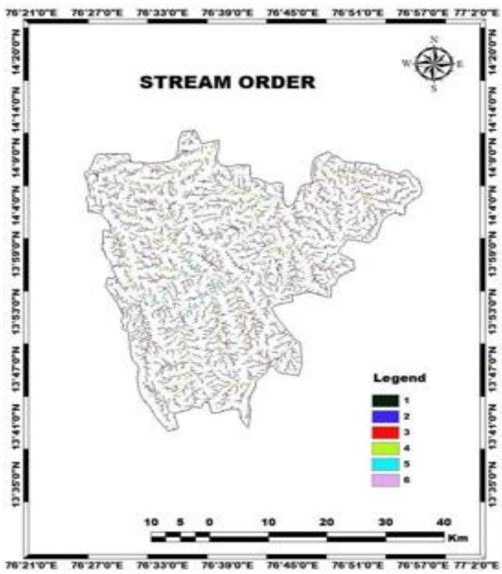


Fig 4: Stream flow direction map of the study area

STREAM ORDER MAP - The designation of stream orders is the first step in drainage basin analysis. It is based on a hierarchic ranking of streams shown in Fig. 5. Stream order or classification of streams is a useful indicator of stream size, discharge and drainage area (Strahler, 1957). Strahler's methodof stream ordering is used for all stream related calculations (Sumantra sarathi biwas, 2016). The extracted drainage network was classified according to Strahler's system of classification and it reveals that the terrain exhibits dendritic to sub-dendritic drainage pattern. Hiriyur is a sixth order basin, it is observed that decrease in stream frequency as the stream order increases. The length of stream segments is maximum for first order stream and decreases as the stream order increases (Ramu et al., 2013).



STREAM ORDER	NO. OF STREAMS
1ST ORDER	2213
2ND ORDER	911
3RD ORDER	509
4TH ORDER	313
5TH ORDER	11
6TH ORDER	1
TOTAL STREAMS	3645

Fig 5: Stream order map of the study area

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SLOPE - Slope is the rate of change of elevation, is also a significant factor in identifying the ground water potential zone. Increased slope results in high runoff and erosion of surface soil. Gentle and nearly level surface allows the water to flow slowly and provide adequate time to infiltrate into the soil. The study area is largely a flat terrain except in the south eastern region, which is a hilly terrain with moderately steep slope. Slope in the study area is differentiated into four classes *Viz*., Gentle, Moderate, Moderately steep and nearly level shown in Fig. 6. High slope will produce more runoff with lesser infiltration, and it will have a poor groundwater prospects contrasted with low slope region. The highest weight has been assigned to gentle slope to nearly level region and low weight to steep slope.

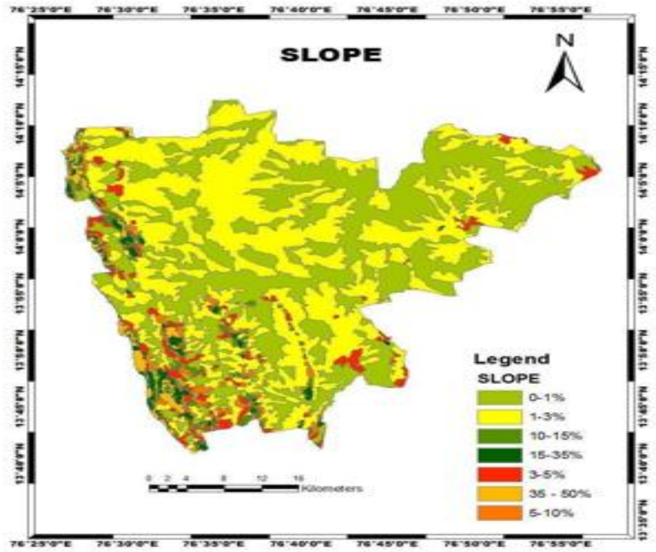

Fig 6: Slope map of the study area

LAND USE LAND COVERS - The land use land cover study area has been attempted in order to identify and map the various types of land use/land cover classes in the area. The classification system was developed by Remote sensing Agency (NRSA, 2012). Land use refers to man's activities and various uses which are carried on land "Land cover refers" to "Natural vegetation, Water bodies, rock / soil, artificial cover and other resulted due to land transformation.

The following are the different Land use/Land cover classes of the study area shown in Fig. 7. Built up land (town, village), crop land, fallow land, agriculture plantation, dense forest, fair dense forest, scrub forest, dense grass land forest plantation, land with scrub, barren rock, mining, waterlogged area, Industrial area, lakes/tank.

1. **Cropland**: These are the areas with standing crop as on the date of Satellite overpass cropped areas appear in bright red to red in color with varying shape and size in a contiguous to non- contiguous pattern.
2. **Scrub Forest**: These are the forest areas which are generally seen at the fringes of dense forest cover and settlements, where there is biotic and abiotic interference. Most times they are located closer to habitations.
3. **Water Bodies:** This category comprises areas with surface water in the form of ponds, lakes, tanks and reservoirs. Land use plays a significant role in the development of groundwater resource. Nature of surface material and land use pattern controls infiltration and runoff. The rate of

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infiltration is directly proportional to the crown density of forest cover, i.e. if the surface is covered by dense forest, the infiltration will be more, and the runoff will be less.

4. **Barren Rocky/Stony Waste:** These are rock exposures of varying lithology often barren and devoid of soil and vegetation cover.

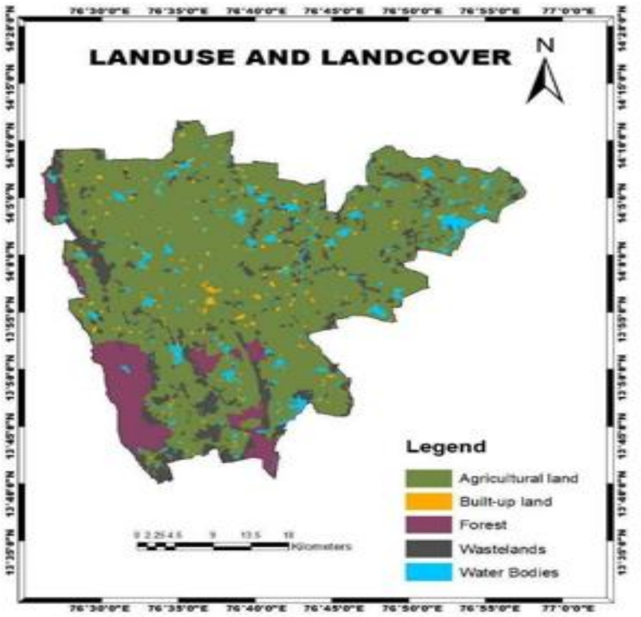

Fig 7: Land use and land cover of the study area

GEOMORPHOLOGY - 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. In other words, at a given location, the occurrence of ground water depends on the storage capacity and the rate of transmission. The framework in which the ground water occurs is as varied as that of rock types, as intricate as their structural deformation and geomorphic history, and as complex as that of the balance among the Lithological, structural and geomorphic parameters.

A detailed hydrogeological investigation of river basin needs a thorough understanding of the drainage basin morphology which enlight on Lithology, Structural controls, Relative runoff, Recharge, Erosional aspects and stage of development of a basin (Karuppannan et al., 2015). They are considered as three dimensional homogenous entities with respect to hydrogeological properties and the recharge condition. The ground water prospects are expected to be uniform in a hydro geomorphic unit. The hydro geomorphological map, as shown in Fig. 8.

In order to delineate the aquifers, the lithological, geomorphological and structural map overlays are subjected to overlay analysis by superimposing the layers one over the other in the GIS environment. During the process of integration, the geomorphic units and rock types are made coterminous by adjusting the boundaries. As a result of the integration, the areas having unique lithology, landform and structure are delineated. These integrated lithological structural geomorphic units are treated as homogenous areas with respect to hydrogeological properties.

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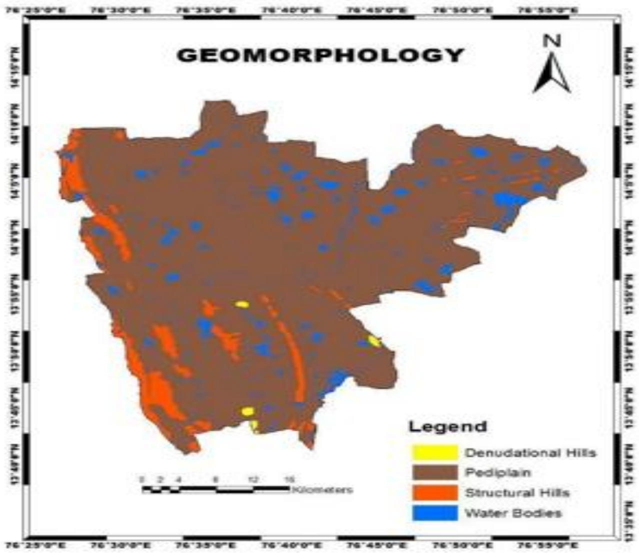

Fig 8: Geomorphology of the study area

GEOLOGY - Lithology is an important aspect in predicting groundwater potential zone. A map weight of 7 has been assigned for the geology theme. Extraction of geological information from satellite data depends on the identification of different patterns on an image resulting from the spectral arrangement of different tones and textures. The watershed comprises of heterogeneous, anisotropic crystalline rocks. The rock types of the study area in Fig. 9 are highly fractured, folded and jointed due to tectonic activities. The intrusions are dolerite dykes and pegmatites. Gneisses, Schist, Granite are the major litho units of the area. Based on the behaviour of a litho unit for groundwater the weights have been assigned.

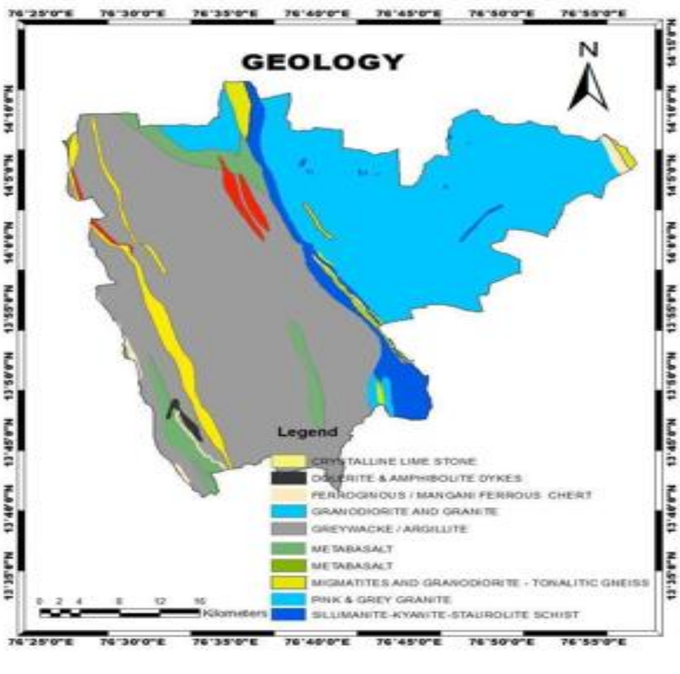

Fig 9: Geology of the study area

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DRAINAGE – The surface water network through which it travels to an outlet are referred to as a drainage system. The flow of water through a drainage system is only a subset of what is commonly referred to as the hydrologic cycle, which also includes precipitation, evapotranspiration, and groundwater flow. Other common terms for a drainage basin are watershed, basin, catchment, or contributing area. This area is normally defined as the total area flowing to a given outlet or pour point area upon which water falls. A pour point is the point at which water flows out of an area. This is usually the lowest point along the boundary of the drainage basin. The boundary between two basins is referred to as a drainage divide or watershed boundary shown in Fig. 10.

Fig 10: Geology of the study area

4.2 Integration of Thematic layers using GIS and Recharging techniques

The integration of various thematic maps describing favourable groundwater zones can be brought out as a single groundwater potential zone map with the application of GIS. The various thematic maps as described above have been converted into raster form to achieve considerable accuracy. Various thematic maps are reclassified on the basis of weightage assigned and brought into the 'Raster Calculator' function of Spatial Analysist tool for integration. The occurrence and movement of groundwater in an area is controlled by various factors. The influence of all factors need not be the same in an area. Therefore, each parameter is assigned a weight depending on its influence on the movement and storage of groundwater.

After assigning the weights to the themes and features, all the themes were converted to raster format using 'Spatial analyst', extension of Arc GIS software and also for final analysis. In this method, the total weights of the final integrated map were derived as the product of the weights assigned to the different layers according to their suitability. Further, different units of each theme were assigned knowledge-based hierarchy of ranking from 1 to 5. On the basis of their significance with reference to groundwater prospects, where 1 denotes poor prospects and 5 denotes excellent prospect of groundwater.

The thematic maps such as Geology, Lineament, Geomorphology, Landuse / landcover, Drainage density, Soil, Geology and Rainfall provides certain clues for the occurrence of groundwater. In order to get all this information unified, it is essential to integrate these data with appropriate factor. Although, it is possible to superimpose this information manually, however it is time consuming and

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the error component is slightly high. Therefore, this information is integrated through the application of GIS.

A simple arithmetical model has been adopted to integrate various thematic maps by averaging the weightage. The final groundwater potential zone map has been generated by integrating all the thematic layers and the map is categorized into three zones, *Viz*., Good, Moderate and Poor zones of groundwater potential. The groundwater potential zone map reveals that the poor zones for groundwater are confined to south eastern and a small patch over northern region and moderate zones occupy majority of the study area this is followed by good potential groundwater zones which are seen along the streams and water bodies.

VALIDATION OF THE MAP - The available yield data is used to validate the results for groundwater potential zones. Higher yield in an observation well indicate that the groundwater potential is good in that region and vice versa. The yield data is classified into three categories based on equal interval method i.e., Good (> 61 lpm), Moderate (31-60 lpm) and Poor (< 30 lpm).

Table 1: Relative weight of thematic layers and their corresponding classes

Feature	Weights	Classes	Ranks	Feature Scores
Geology	7	Granite	2	14
		Greywacke/Argillite	2	14
		Migmatic Gneiss	2	14
		Staurolite Schist	3	21
LULC	5	Agricultural. Land	4	20
		Forest	3	15
		Waste land	1	5
		Built up	2	10
		Water bodies	5	25
Slope	8	Nearly level	5	40
		Very Gentle	5	40
		Gentle	2	16
		Moderate	2	16
		Strong	1	8
		Moderately steep slope	1	8
Drainage density	7	0.1-0.7	1	7
		0.8-1.3	1	7
		1.4-1.9	3	21
		2.0-2.8	4	28
Geomorphology	10	Denudational hill	1	10
		Pedi plane	5	50
		Structural Hill	2	20
		Water bodies	5	50

GROUND WATER POTENTIONAL ZONES - Hydro geomorphological studies coupled with hydrogeological and structural lineament have proved to be very effective tool to discern ground water potential zones in the watershed. The occurrence and movement of groundwater are controlled mainly by porosity and permeability of the surface and underlying geology. Surface hydrological features like topography, drainage density, water bodies, etc., play an important role in groundwater replenishment combining different hydrogeological themes objectively and analyse those systematically for demarcating the potential zone (Fig. 11).

In order to demarcate the groundwater potential zones using GIS for the study area the following thematic maps were used. Geology, Slope, Soil, Land use, land covers Rainfall Hydro- geomorphology, and Groundwater level.

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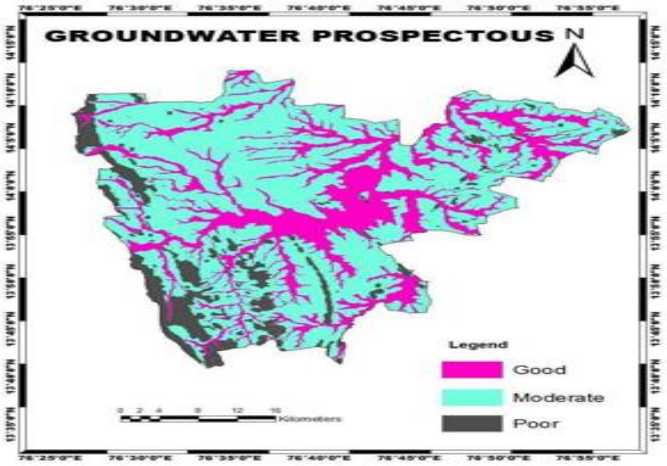

Fig 11: Groundwater potential zone map of the study area

4.3 Artificial groundwater recharging techniques

Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. Although the primary objective of this technology is to preserve or enhance groundwater resources and artificial recharge has been used for many other beneficial purposes. Some of these purposes include conservation or disposal of floodwaters, control of saltwater intrusion, storage of water to reduce pumping and piping costs, temporary regulation of groundwater abstraction, and water quality improvement by removal of suspended solids by filtration through the ground or by dilution by mixing with naturally-occurring groundwater's. Artificial recharge also has application in wastewater disposal, waste treatment, secondary oil recovery, prevention of land subsidence, storage of freshwater within saline aquifers, crop development, and stream flow augmentation. Some of the recharge techniques for groundwater improvement can be adopted in selected area of Fig. 12, such as spreading within channel, spreading stream water through a network of ditches and furrows, check dams, percolation tanks, vertical shafts, lateral shafts and injection wells.

Fig 12: Provision of artificial recharging techniques of the study area

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5.0 CONCLUSIONS

Remote sensing and Geographical Information System helps the researchers to analysis the drainage basin easily and helps for identification of ground water potential zones on integration of various maps. Based on the available information and the geophysical investigations it is concluded that Stream order of basin indicates that the basin is sixth order basin with dendritic type of drainage pattern with homogeneous nature and the number of streams usually decreases as the stream order increases. The result of aerial aspect shows the texture of drainage cis moderate as a result the ground water potential zones in the study area is observed from poor to medium, good near highest stream order. Various artificial ground water recharging structures have been provided near 2nd and 3rd stream order for augmentation of water resources.

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