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Remote Sensing and Geographical Information System (GIS) based Groundwater Potential Zone Mapping in Parts of Dakshina Kannada District.

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Abstract: The groundwater potential zone mapping using modern techniques are essential for the proper identification of this renewable natural resource. In the present paper, an attempt has been made to identify the groundwater potential zones in and around Mangalore taluk of Dakshina Kannada, Karnataka using Remote Sensing and GIS Techniques. Based on the topographical maps and satellite images, various thematic maps like lineament, lithology, geomorphology, drainage pattern, drainage frequency, slope and land use/land cover have been generated. The multidated and multispectral remotely sensed data, when analysed using various image processing techniques, have provided useful information on geological structures like lineaments, faults, joints and folds. The non-spatial data like rain fall, water table fluctuation, census reports, water supply and water consumption, and finally these were integrated with the spatial data in a GIS environment to identify the ground water potential zones. The geological structures especially the linear or curvilinear features (lineaments) play a significant role in controlling the movement of ground water and these structures were identified with the help of directional and non-directional filtering techniques. The information derived from the study can be used for successful identification of suitable locations for extraction of water for drinking and irrigation purposes as well as for the proper management of the watersheds in a sustainable manner.

Keywords: *Groundwater Mapping, Remote Sensing & GIS, Dakshina Kannada, Karnataka*

Introduction:

Rapid urbanization, industrialization and expansion of irrigation increase the demand for water. Surface water is inadequate to meet the demand. Thus pressure on the ground water is increasing. Ground water is a dynamic and replenishable natural resource but in hard rock terrain availability of ground water is of limited extent. Exploration and utilization of ground water especially in hard rock terrains, requires thorough understanding of geology, geomorphology and lineaments of an area, which directly or indirectly control the terrain characteristics. A variety of techniques such as geophysical, geoelectrical etc. can provide information on ground water potential but they are time consuming and expensive. The concept of integrated remote sensing and GIS has proved to be an efficient tool in groundwater studies (Krishnamurthy et al., 1996, Ravindran et al., 1997, Murthy 2000, Girish Gopinath and Seralathan 2004, Lokesha et al., 2005, Khan et al., 2006). Remote sensing provides multispectral, multitemporal and multisensor data of the earth's surface (Lillesand and Kiefer, 2000). Remote sensing data helps in the generation of spatial information on land use/cover, lineaments, geomorphology, geology and drainage characteristics of the terrain, where as GIS is the decision making tool helps in processing, analyzing, integrating and quantifying spatial data sets towards preparing the groundwater potential zone map.

Scope of the Study:

Mangalore is the main port city of Karnataka having major and minor industries. Netravathi and Gurpur are the two major rivers which serve as the sources of water supply for both drinking and industrial purposes. The area is getting more than 3500 mm annual rainfall. During summer the surface water resources are inadequate to fulfill the water demand. Hence, there is a need for the groundwater potentiality mapping to delineate the potential groundwater zones. In the present study an attempt has been made for delineating the ground water potential zones, through an integrated approach of RS and GIS

Study Area:

The study area is bound in the east by the midlands and the Western Ghats, and in the west by the Arabian Sea and it extends from Thalapady (12° 45' and 13° 00' N) in the south to Surathkal (74° 45' and 75° 00' E) in the north (Fig:1). Most of the geomorphic units in the study area are reclaimed and used for residential and plantation purposes. The topography of the study area is undulating plain with a lateritic cap covering most of the area. Geologically, the area mainly comprises of gneisses of the Archean age as basement rock. Alluvium deposits are another major formation occurring along the coast and river courses. The climate of the region is marked by heavy precipitatation (>4000mm), high humidity and oppressive weather condition in summer. Southwest monsoon months are the coolest and April-May are the hottest months of the year

Materials and Methodology:

The different steps followed in order to demarcate the ground water potential zone maps are discussed below (Fig: 2).

Data Used:

The Survey of India (SOI) Topographical map 48 L/13 of scale 1:50,000, IRS-P6 LISS-III of 2006 (Path 97 and Row 64), Geology Map of Dakshina Kannada, and other nonspatial data like rain fall, water table fluctuation, census reports, water supply and water consumption etc. were used in the present study.

Data Processing:

Satellite data processing and analysis was done using ERDAS Imagine software. In the preprocessing phase, both geometric rectification and radiometric normalization were performed. Initially the image was rectified with reference to the SOI topographical map. Various Image processing techniques like image enhancement, filtering, stretching, band rationing, and classification were employed to make the satellite data more interpretable. Finally the thematic layers such as land use/cover, hydrogeomorphology and lineament maps were prepared. For both land use/cover map and hydrogeomorphology map, hybrid classification (involves both supervised and unsupervised classification) was carried out and accuracy achieved was more than 87%. DEM was used for lineament extraction and geomorphologic mapping. Extensive fieldwork was carried out along with hand held GPS for ground checks and verifications of the interpreted features at various stages.

Spatial Database Building:

In this stage, all the appropriate data were brought (from stage 2 and existing relevant data) together into a GIS database. Basically, all the available spatial data were assembled in the digital form, and properly registered to make sure the spatial component overlap correctly. Digitizing of existing data and the relevant processing such as transformation and conversion between raster to vector, griding, buffer analysis, interpolation were also conducted. Finally the layers such as geology, drainage, drainage frequency, contour, slope, DEM, hydrogeomorphology, land use/cover maps were generated.

Spatial Data Analysis:

In this stage various analyses such as table analysis, classification, polygon classification and weight calculation were performed. Polygons in each of the thematic layers were categorised depending on the recharge characteristics and suitable weightages were assigned.

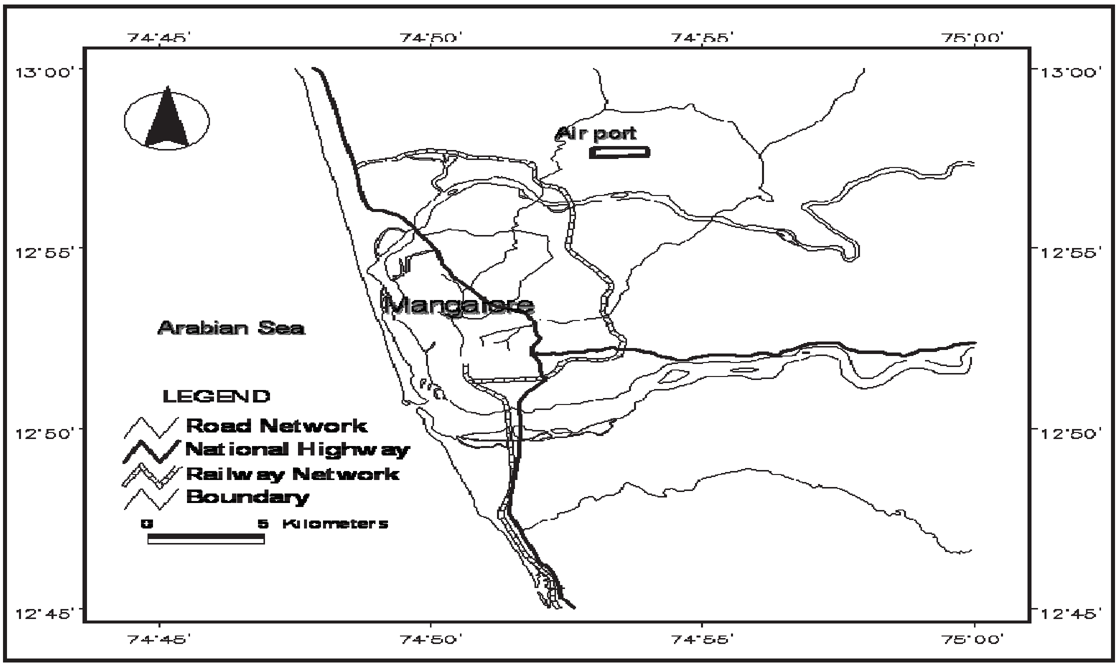

Figure 1: *Map of the Study Area*

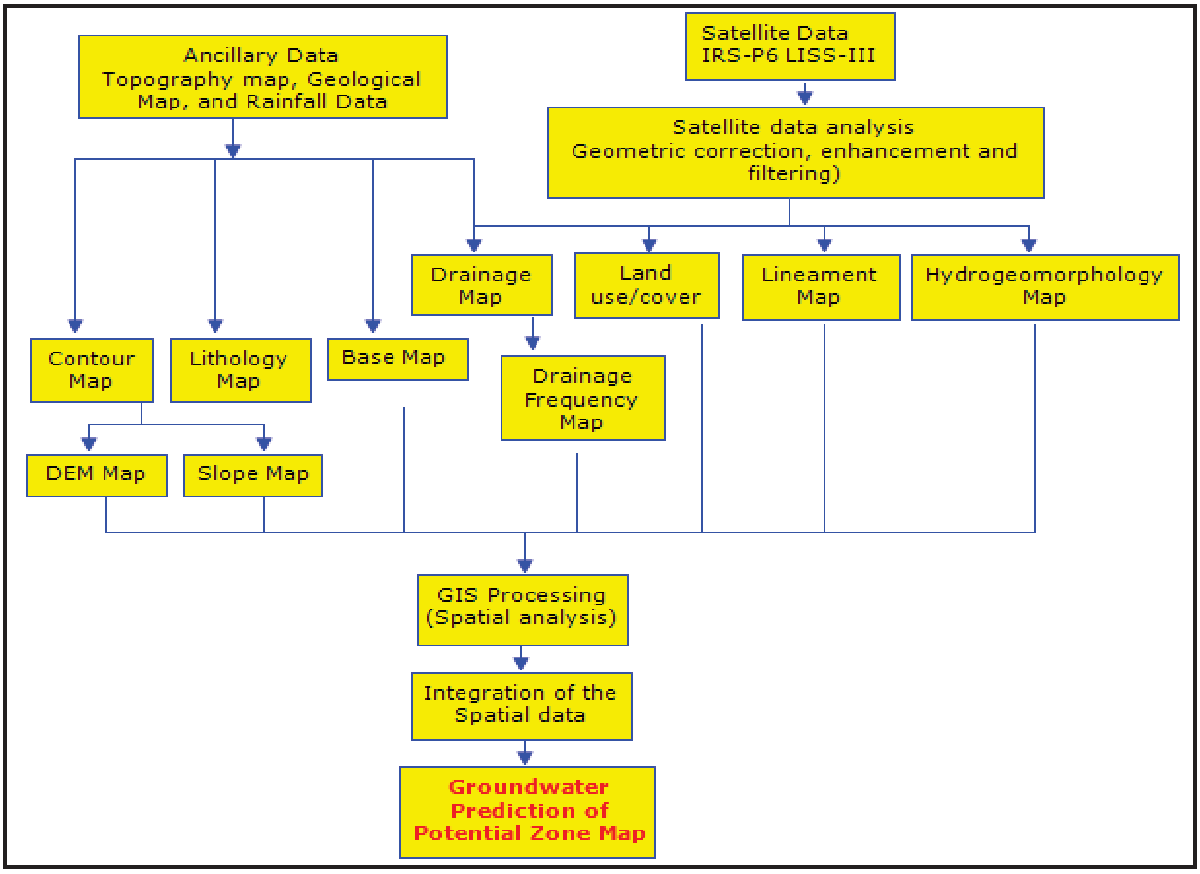

Figure 2: *Flow Chart Showing the Methodology Adopted for this Study*

Data Integration:

Finally thematic layers were converted into grid through GIS (Arc / Info grid environment) with related item weightage and then integrated and analysed, using weighted aggregation method (ESRI 1996). The grids in the integrated layer were grouped into different ground water potential zones by a suitable logical reasoning and conditioning as very good, good, moderate to good, moderate and poor.

Results and Discussions:

Lineaments are hydrologically very important and are interpreted as fault, fracture, joint and linear geological formation, the straight course of streams and vegetation alignment; lineaments provide the pathways for ground water movement (Subba Rao and Prathap Reddy, 1999, Srivastava et al., 2000). These serve as conduit for ground water movement as a result secondary porosity may increase. Intersections of lineaments are also most probable sites of ground water accumulation even in hilly regions (Surabuddin Mondal et al., 2008, Shankar, 2002). Lineaments of the study area shows two sets of prominent trends, i.e. NNW-SSE to NW-SE and NNE-SSW to NE-SW. Most of the lineaments are fracture (Fig: 3).

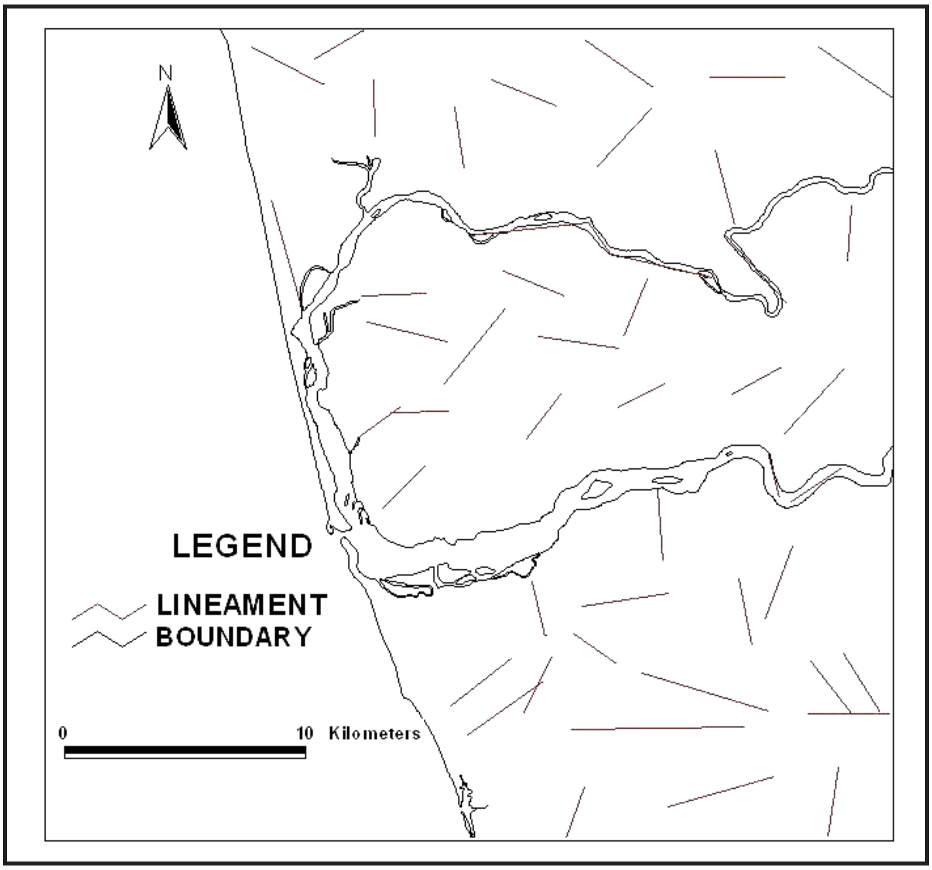

Figure 3: *Lineament Map of the Study Area*

Digital Elevation Model (DEM) and Slope:

DEM is the simplest form of digital representation of topography. Here DEM is in TIN structure, in this model, the points are joined in a network of triangles with each point representing a vertex of a triangle. Each vertex of a triangle represents three values, viz. X, Y and Z, the Z-value is an attribute for point data, e.g. elevation, dug well data, etc and they can precisely model discontinues in the surface with break lines. Examples of break lines are streams, ridges, and roadways, where the surface slope changes sharply. A raster Digital Elevation Model contains sufficient information for delineating drainage basins, extracting stream network and is key to the study and analysis of landforms, land utilization (land use/cover) slope is defined as the loss or gain in altitude per unit horizontal distance in a direction. It is in degree of value between 0^o and 90^o.Slope plays a key role in the ground water occurrence as infiltration is inversely related to slope (Saraf and Chaudhary, l998) i.e. more gentle the slope is, infiltration would be more and runoff would be less and vice-versa. The north, west, central and south central parts of the area have high slope gradient of more than 25 degrees. On the contrary the northwest and southwest, and along the alluvial plain the slope is moderate to gentle (Fig-4 & 5).

Drainage:

The number of streams per unit area is the drainage frequency. Drainage patterns of an area are very important in terms of its ground water potentiality. It is the source of surface water and is controlled by factors like lithology, structure, relief, and slope, intensity of precipitation, runoff, infiltration and vegetation. Ground water prospects are found to be poor in the area with high drainage frequency as high runoff and low infiltration. Similarly, low drainage frequency corresponding to areas characterized by high infiltration rates (Schumm 1956 and Karanth 1987). In the study area the drainage pattern is mainly dendritic and subdendritic on small scales, on large scale rectangular and parallel patterns are also observed. High drainage frequency is seen in central part to east and southeast, and in the north parts of the study area (Fig: 6&7). Presence of high drainage frequency indicates a high degree of dissection in the dissected pediment, which comprise ridge and hills possessing high relief. Low drainage frequency is because of low relief, gravely laterites, coastal and alluvial plains and unmantled pediments.

Lithology:

Alluvium and coastal deposits of Quaternary age comprising of sand, silt, clay, kankar, gravel and boulders are confined to strip along the coast and river courses are highly favorable zones of ground water. On the contrary the major lithological formations exposed in the area include migmatitic gneiss and granites. Archean age covering major part of this area as basement rocks. Dolerites and amphibolite dykes occurs as intrusive rock masses in the east and northeast, patches of charnockites occur in the south eastern part of the area which are relatively acting as poor potential zones because of their massive nature and insignificant primary porosity (Fig:8). There are many outcrops of laterite with patches of duricrusts (the laterite which is hard to very hard and most having vermicular and also exhibit nodular and concretionary structure) along the coastal zone. The laterites have a very extensive development and they form low flat topped ridges, hillocks and undulating plains. At some places these lateritic formations occur above the tertiary sediments and the gneisses. Thickness of Lateritic formation varies from place to place and ranges from 5m to 60m. These are acting moderate to poor ground water potential zones. Mangalore beds are another younger sedimentary rocks exposed as patches in some places. If the bed is confined by hard rock at lower depth is good ground water potential. It consists pebbles, cobble assembles and thickness ranges from 5 to 6 m. There exists the lens shaped clay which in turn is covered by friable, unconsolidated sand which is about 5m.thick.

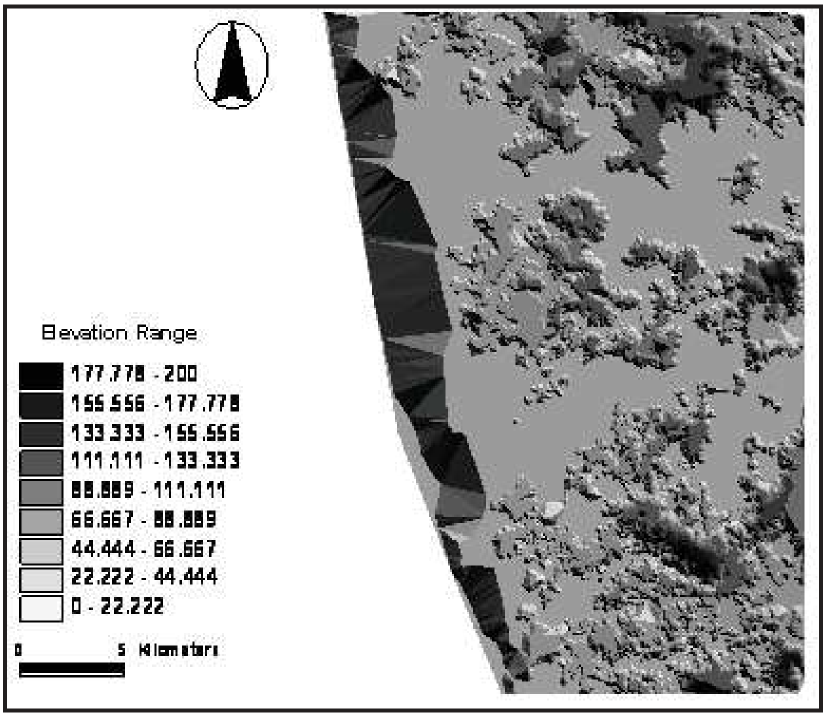

Figure 4: *DEM of the Study Area*

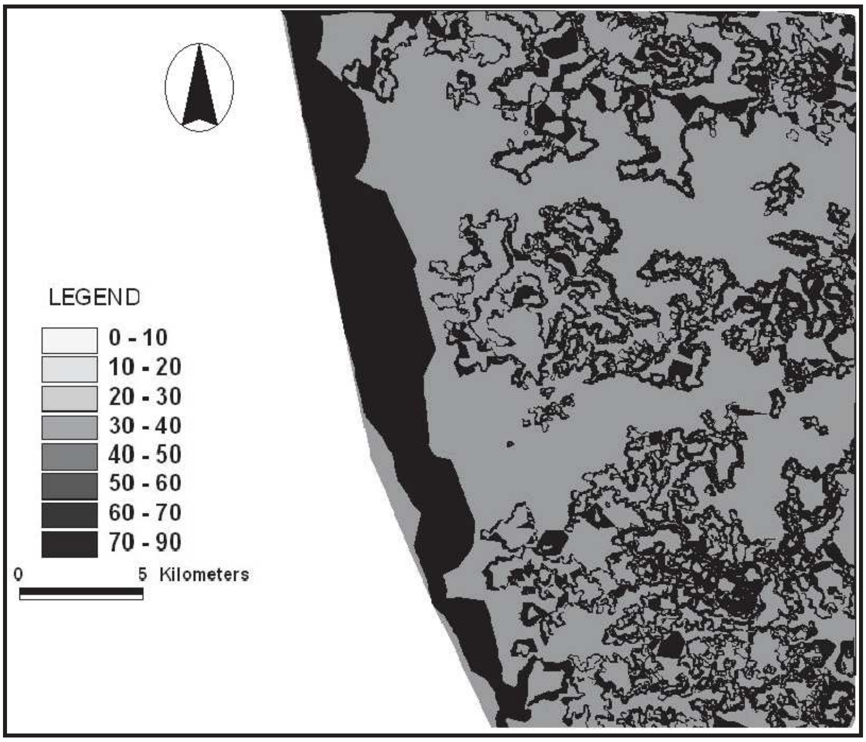

Figure 5: *Slope Map of the Study Area*

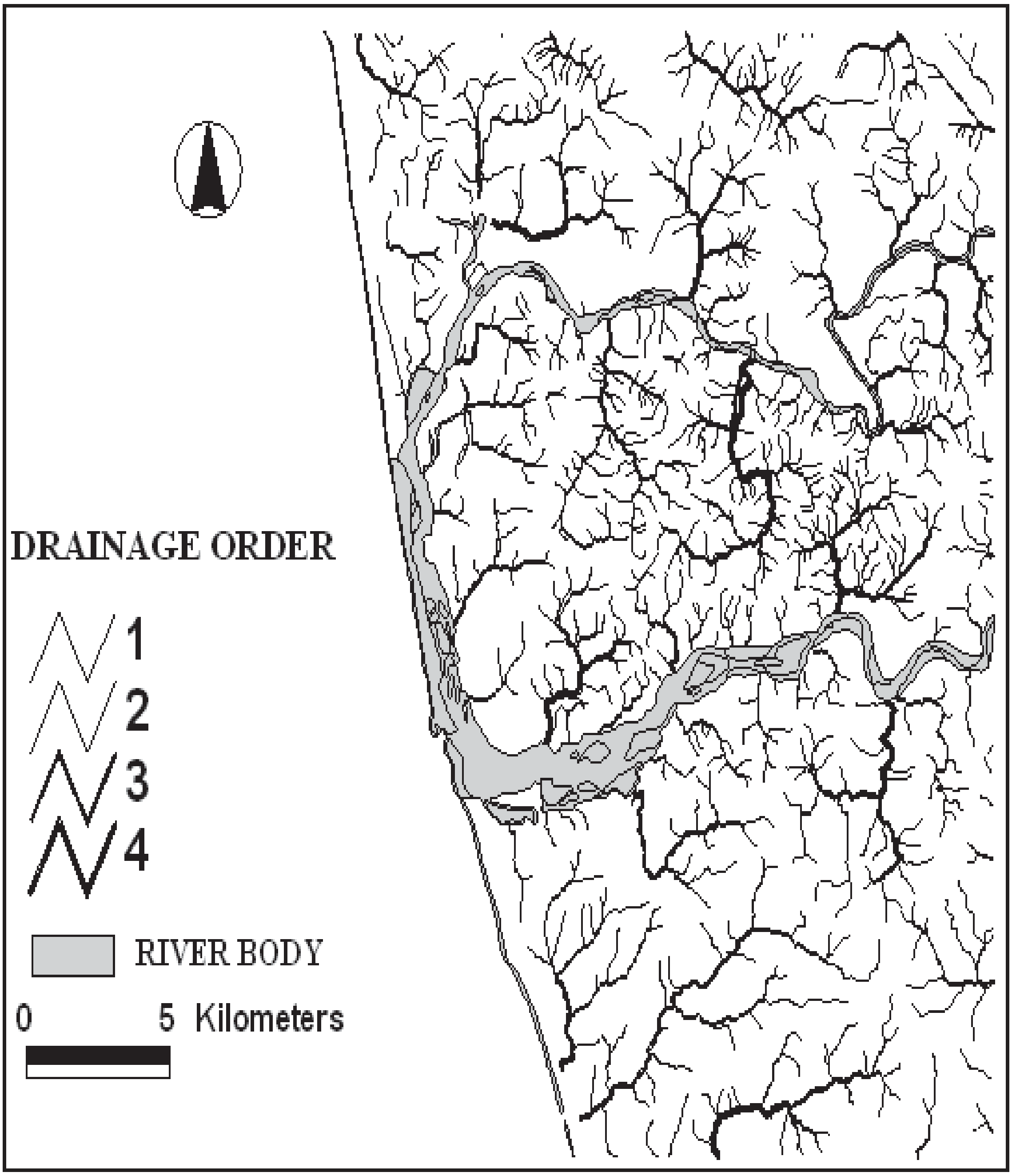

Figure 6: *Drainage Map of the Study Area*

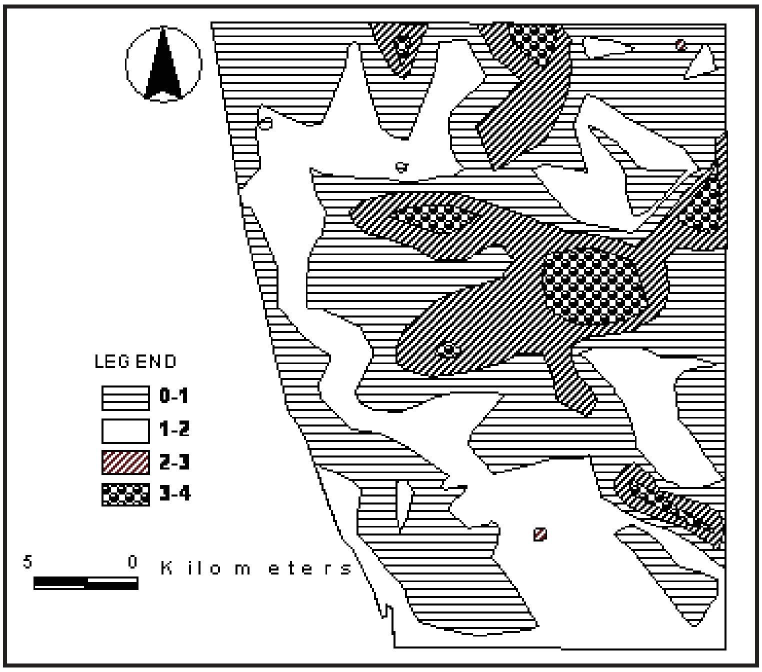

Figure 7: *Drainage Frequency of the Study Area*

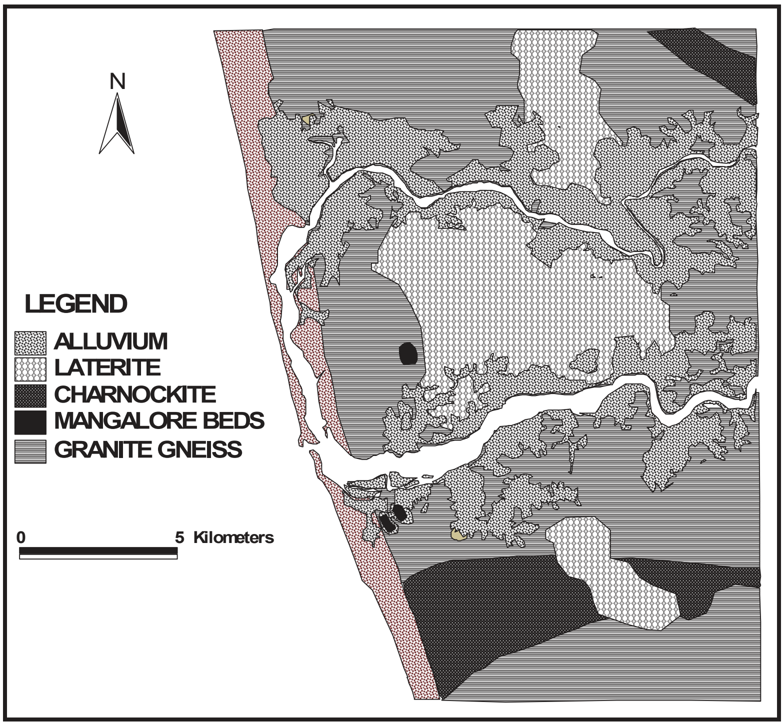

Figure 8: *Lithology Map of the Study Area*

Top layer is lateritised. Mangalore bed is similar to Warkalli beds of Kerala. Mangalore beds are acting as good ground water potential zones.

Land Use/Cover:

Land use/cover is one of the most important factors which have an influence on ground water movement (Fig: 9). Based on the interpretation of the satellite images six landuse/cover classes have been categorized. Agricultural land with irrigation facility is the good ground water potential zone, because of more infiltration and act as recharge site. Most of the cultivated land in the study area found in the alluvial plain and valley fill. In forest and agriculture plantation where vegetation checks the surface runoff, so it may help in recharge of ground water. In settlement area there is little scope for infiltration and transpiration and all the rainfall immediately becomes direct runoff producing high discharge. In areas like scrub land where scanty vegetation is present, there the low infiltration and high runoff rates are expected. Regions like spit and sandy beaches tend to have higher infiltration rates and therefore tend to produce less peak discharge. But near to beach and the river course in the tidal zone are influenced by brackish water, and the problems of salt water intrusion is noticed at few places.

Hydrogeomorphological Unit:

Based on the interpretation of the remotely sensed data products, various hydrogeomorphological features were identified and their relation with ground water potentiality are discussed below (Fig:10).

Valley Fills:

Valley fill zones are located adjacent to dissected pediment and pediplains. They vary in shape (some of them are U shape) and extent, and are filled with thick alluvium. They have been demarcated on the basis of their light reddish tone or sometimes dark greenish blue colour on IRS FCC images. In general, it is observed that adequate recharge source of ground water is met within valley fillings. Hence, in such places the ground water potential ranges from good to moderate.

Pediplain:

Pediplain is the vast undulating rolling plain surface resulting from the coalescence various pediments. This lies immediately adjacent to the coastal plain and extends up to foot hills of Western Ghats with an elevation ranging from 20 to 180m and covers major portion of the area. It is developed as a result of continuous process of pedimentation. The pediplains are predominantly covered by laterites and soils. They are considered as moderate ground water potential zones.

Dissected Pediment:

They make a surface with an elevation of 100m to 120m and having a thick lateritic cap and at places occur as duricrusts. Sheet erosion and colluvial deposits are seen associated with this unit. The area shows a high degree of dissection, highly dissected plateau with high relief form run-off zone and high drainage frequency, hence the dissected pediment constitute low ground water potential zone because a large amount of water goes as runoff.

Residual Hill:

These features have resulted due to scrap retreat and pediplanation process and are isolated remnants of granite/gneissic rock. The residual hills are identified based on their dark reddish color on False Colour Composites. This landform is seen at the eastern south- eastern part of the study area. These are identified as poor ground water potential zones.

Alluvial /Coastal Plains:

Alluvial zones are mainly of fluvial origin and are mainly seen in the coastal and river course, and also occur as flood plain. They are highly porous and permeable, because the sediment mainly consists of alternating thick sequence of clay, sand, gravel and pebbles. Paddy and sugarcane are the chief crops grown on the alluvial plains. Ground water prospect in this unit is very good

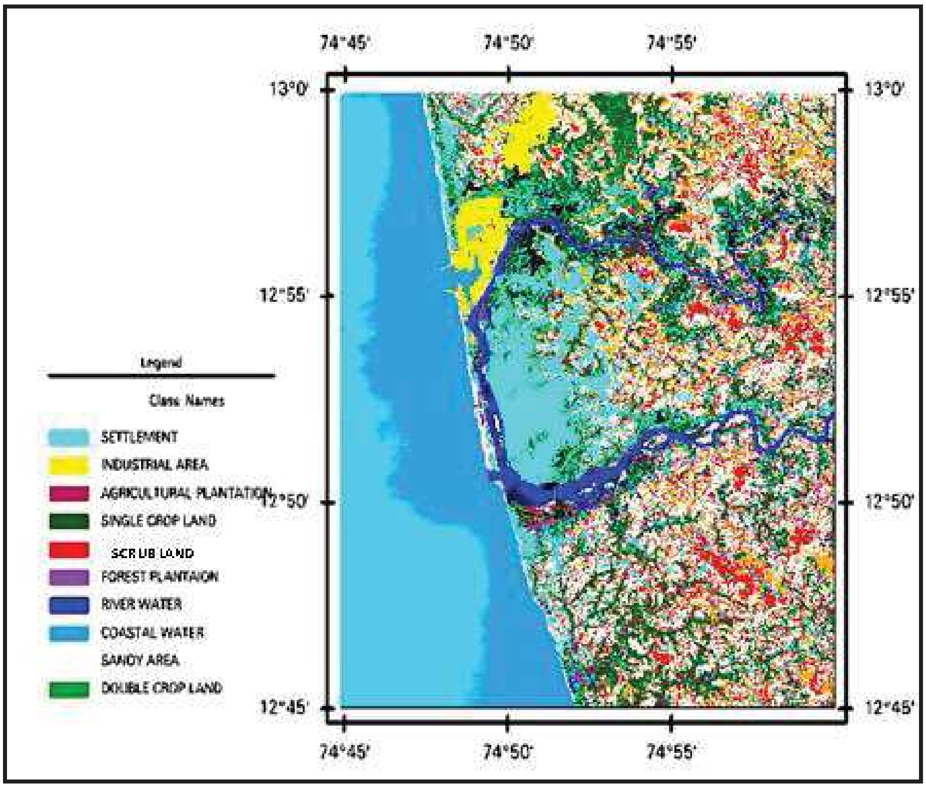

Figure 9: *Land Use/Cover Map of the Study Area*

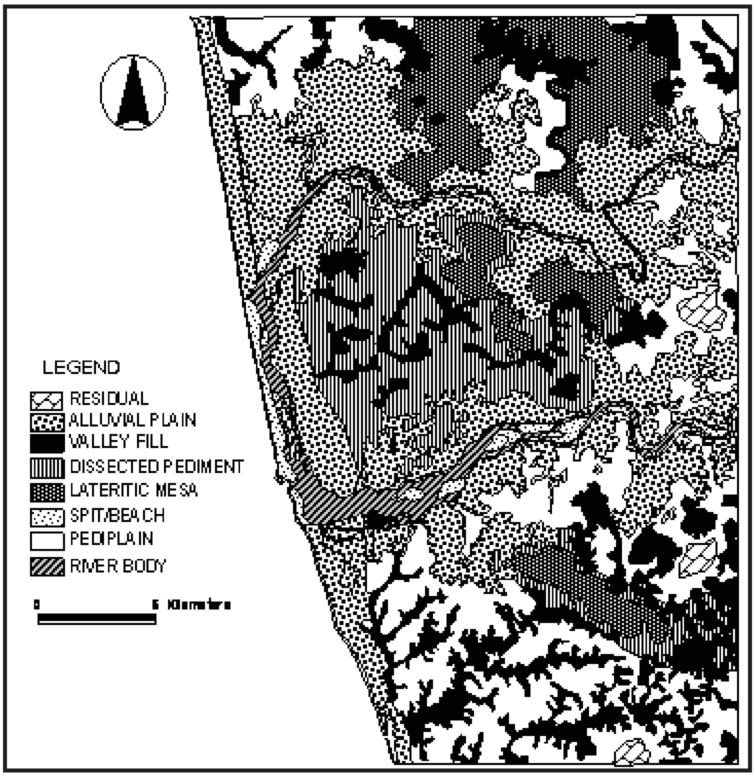

Figure 10: *Hydrogeomorhpology Map of the Study Area*

Lateritic Mesas and Duricrusts:

They are flat to nearly flat surfaces having gentle slope. Sparse to thin vegetation is commonly noticed on the crest and slopes, but in some places marked dense vegetation. The height of the mesas ranges from 20 to 160m. at some places laterite occur in the form of cuestas. Dissection Index is very high because of the laminar flow, which later concentrated along the valley. In many places the lateritic features are surrounded by gravel which are derived from the parent lateritic mesa and hence are called as lateritic gravels. These are moderate to poor ground water prospect zones.

Point Bars:

The low arcuate ridges of sand and gravel usually seen on the convex side of the meandering curves are called point bar deposits. Due to the accumulation of the sand and gravel on the convex side of the meander curve, the river erodes the concave side and there by accelerates the lateral erosion. Point bar deposits are very well developed along the Nethravathi channel.

Channel Bar Deposits:

These are sand gravel deposits found along the river courses. Channel bars near the Nethravathi and Gurpur river mouths have been stabilized by vegetation. Both point bars and channel bars have very good ground water prospect.

Well Inventory Data:

The available monthly water levels have been collected from Dept. of Mines and Geology for the last 10 years (1996-2006) in 5 observation wells. The monthly data are averaged for each month and then the mean of this average is taken which represent mean yearly value. This has been done for all observation wells. All the observation wells are dug wells piercing the soil and weathered mantle zone. The depth to water table is closely related and controlled by the topography, surface water, quantum of precipitation, lithology and etc. as the water table is a subdued replica of the land form. Observation well of Parangipet showed shallow water table and less fluctuation, because the well is situated in the alluvial plain with highly weathered zone with low relief. High fluctuation and deeper water level recorded in Bajpe, because the area is located on the Lateritic duricrusts, which can hinder the percolation of running/rain water and also many small ridges are seen around Bajpe which acts as an underground block for ground water movement. The thickness of weathered zone is meager in the hills and dissected pediment, where as more in the valley, alluvial plain and along lineaments.

Table 1: *Well Inventory Data of the Area*

Observation well no.	place	Water Level (m)		Water Level (m)		Fluctuation (m)
		BGL	AMSL	Max	Min	
1	Mangalore	6.9	21.53	9.57	3	6.6
2	Kavuru	8	48.37	10.7	3.9	6.87
3	Bajpe	8.7	54.23	12	2	9.95
4	Ganjimatta	5.9	148.3	7.43	3	4.43
5	Farangipet	6.1	75.67	7.91	3.5	4.37

Groundwater Prospects:

The study reveals that there is a good interrelationship among the geomorphic units, geological characteristics, lineaments, drainage and their frequency and ground water condition in the area. Drainage frequency increase from west to east and low frequency is observed along the Netravathi and Gurpur river courses. Comparison of geomorphological map with drainage frequency and slope map shows the geomorphological control over the same.

Comparison of the lineament map and drainage network map shows that many parts of river course as well as main streams follow lineaments. This observation reveals the structurally controlled nature of the Netravathi basin. Suitable weightage are given (Table-2) for each class in a thematic layers based on their behavior with respect to ground water control. The map highlighting the ground water potential zone was generated by integrating the thematic maps (lithology, structure, geomorphology, lineaments) and further analysis of data on water table, water depth and recharge condition of the terrain. Five ground water prospect zones have been identified such as excellent, very good, good, moderate and poor (Table-3) and (Fig:11). Excellent ground water potential zones cover nearly 39.07 km^2 (7.33%) of the area. Which includes river channel, point bar deposits, channel bar deposits and river islands. The depositional landforms comprises of alluvial plains and valley fills are grouped under very good ground water potential zones, covering 174.62 km^2 (32.68%) of the area**.** The alluvial plains are having very good unconfined aquifers. The open wells and tube wells in these zones yield good amount of ground water. Landforms such as shallow valley fill situated along dissected pediment and alluvial plains having moderate slope and drainage frequency are the geomorphic units having good ground water potential zone which occupies an area of 63.06 Km^2 (11.84%).

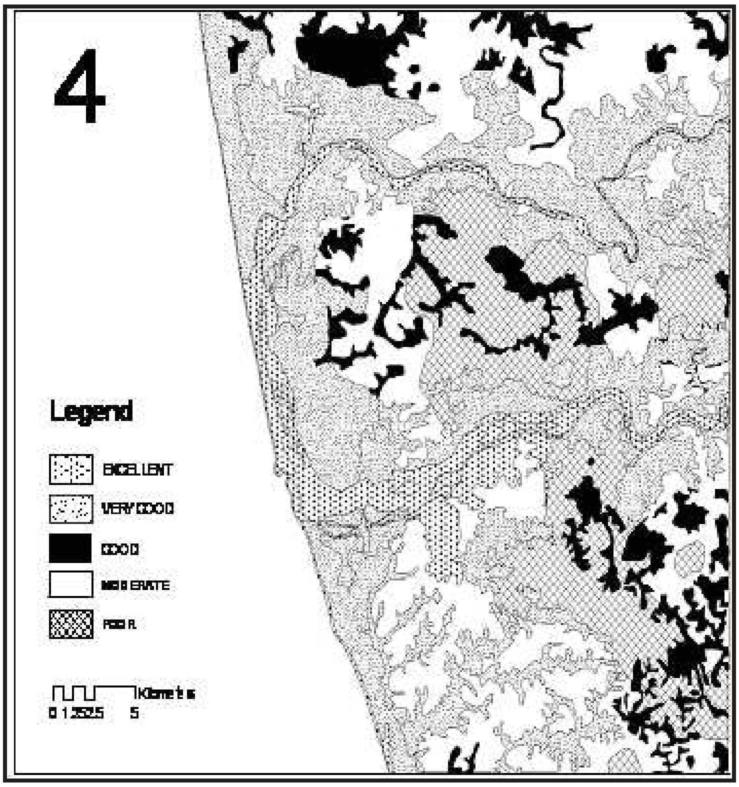

Figure 11: *Ground Water Potential Zones Map*

Table 2: *Weightage of different Parameter for Groundwater Prospects*

Sl. NO	Criteria	Classes	Weight
1	GEOLOGY	Alluvium	5
		Mangalore beds	4
		Laterite	3
		Charnockite	2
		Granitic Gneiss	1
2	HYDROGEOMORPHOLOGY	River body	6
		Beach / spit	5
		Valley fill	4
		Alluvial plain	4
		Pediplain	3
		Lateritic mesa	2
		Dissected pediment	1
		Residual hill	1
4	LAND USE/ LAND COVER	Water bodies	6
		Double crop land	5
		Agricultural Plantation	4
		Forest Plantation	3
		Single crop land	3
		Scrub land	2
		Built-up land	1
5	DRAINAGE FREQUENCY	Very low (0-1)	4
		Low (1-2)	3
		Medium (2-3)	2
		High (3-4)	1
6	SLOPE (DEGREE)	0-3	5
		4-9	4
		10-16	3
		17-25	2
		>26	1
7	LINEAMENT	Present	2
		Absent	1

Moderate potential zone covers an area of 177.39 Km^2 (33.31%) and it includes geomorphic units like pediplain and lateritic mesa**.** The thickness of weathering of the Pediplains vary widely. The gently undulating plains with moderate thickness of mantle constitute this unit and average thickness ranges from 10 to 20m. Here the aquifers are mainly unconfined in nature. Ground water prospects are good when the parent rock is jointed and fractured with intrusion. Laterites constitute a unique hydrologic province and groundwater occupies the micropores of lithomargic clay and weathered rock which constitute the aquifer. The thickness of the laterites ranges from 10-25m on an average and at places even more. The water table fluctuates highly in these places because of high porosity and permeability. It is also observed that the relict structures like bedding planes, pegmatitic veins, foliation and lineation and dykes etc., have a direct influence on the movement and storage of groundwater in the laterites. The poor ground water potential is dominated by the geomorphic units like dissected pediment, residual hills and linear ridges and it spread over 78.27 Km^2 (14.7%) area**.** Drainage frequency in this unit increases from centre to east and south east part of the study area. Mainly residual hills and linear ridges act as barrier for ground water movement at some places. Having favorable slope conditions and surface characteristics, this zone is ideal for runoff generation, in the absence of lineaments. The aquifers are gneissic rocks and sedimentary rocks with compact nature. The aquifer material is weathered and fractured. The depth of weathering is also low and not uniform as a result aquifers are characterized by low yield, less homogeneity and poor to moderate rate of success.

Table 3: *Groundwater Potential Zones*

Sl. No	Ground water Category	Area (SQ.KM)	percentage of the Area
1	EXCELLENT	39.07	7.33
2	VERY GOOD	174.62	32.68
3	GOOD	63.06	11.84
4	MODERATE	177.39	33.31
5	POOR	78.27	14.7

Conclusion:

The outcome of the study reveals that remote sensing techniques along with an integrated approach of GIS techniques are very useful in demarcation of the ground water potential zones. The ground water prospect map is a systematic effort and has been prepared by considering major controlling factors, which influence the water yield and quality of ground water. As industrial development and urbanization is progressing in Mangalore, water constitutes the key prerequisite. In this regard the generation of groundwater potential zone map is essential for planning and execution of ground water exploration. Groundwater condition is very good along river channels, point bars, channel bars, river island, alluvial plains and valley fills. The features like pediplain and lateritic mesa are considered as moderate potential zones. Poor potential zones are seen in dissected pediment, residual hills and linear ridges because of high drainage frequency, slope and surface condition. Those areas which are moderate to poor should be taken up for water resource management purposes with development of water harvesting structures.

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