IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 11, Issue 12 Ver. II (December 2018), PP 16-27
www.iosrjournals.org

Multi-Disciplinary Approach for Surface Mining Effects on Shallow Groundwater Potential Using Remote Sensing and Gis.

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Abstract : *Ground water is becoming a major concern with respect to surface mining. Two major concerns are ground-water quality and ground-water quantity, but only the quantity aspects are addressed in this paper. Mining exerts pressure on environment at many stages such as exploration, extraction, processing, and post closure operations. Increase in production and opening of new mines do generate pressure on environment. The key environmental problems arising out of mining activities are land degradation, surface water and groundwater, degradation of forest and loss of biodiversity, soil contamination, deterioration of natural drainage system, air pollution, noise and vibrations. The principle aim of this research is to evaluate the value of integration of remote sensing and GIS techniques in monitoring the impact of mining activity on groundwater resources in around the Pallakkapalayam Limestone Mine lease areas of Komarapalayam, Namakkal district, Tamil Nadu.*

Keywords: *Groundwater, degradation, mining, remote sensing and GIS*

Date of Submission: 10-12-2018 Date of acceptance: 25-12-2018

I. Introduction

Ground water occurs in a variety of ways, depending upon depth below land surface, rock type, and topography. Three important aspects of ground water related to the "hydrologic balance" are the storage capacity of rocks for ground water, the rate of movement of ground water and chemical quality. Rock units that have relatively high storage capacities and that allow relatively rapid movement of ground water are termed aquifers. A simple practical definition of an aquifer is a rock unit of other underground layer or zone that yields a sufficient quantity of water to a well or spring being used as a water supply source. This is generally at least one gallon per minute for domestic supplies for single families. Rock types that are usually considered aquifers, where they occur in thick enough units, are sandstone, limestone, basalt and coal. Thick coal seams sometimes are the best yielding aquifers in certain localities, because of the coal cleats or fractures. Shales, mudstones, and clays are usually not aquifer units. Ground water can be classified by depth. Shallow ground water usually supplies springs and dug wells, whereas deeper ground water supplies mostly drilled wells. Shallow ground water is intersected beneath the water table, and deeper ground water (in drilled wells) commonly is artesian water under significant pressure. Deeper ground water is usually at least 30 feet deep, and has typically been in the ground longer and is flowing slower than shallow ground water. Ground water typically moves at rates ranging from a few feet per year to a few feet per day, which is much slower than stream flow.

Indirect degradation of ground water could result from blasting, which causes a temporary shaking of the rock and results in new rock fractures near working areas of the mine. Blasting can also cause old pre-existing rock fractures to become more open or permeable, by loosening mineral debris or cement in these fractures; this could affect nearly vertical fractures located up to several hundred feet away from the surface mine, causing vertical leakage of pounded mine drainage from nearby abandoned deep mines to underlying aquifers. These deep mines could be situated in the same coal seam being surface mined or in a lower coal seam.

The need for better environment and health cannot be over emphasized. With increasing industrialization, urbanization, population growth, agricultural and mining activities, the global environment has become fragile and has been a cause for concern (SHIVARAJU, 2012). In his quest to satisfy his needs and aspirations for better living conditions through resource exploitation man has created an increasing number of environmental problems. He exploit nature, and in so doing upset the natural equilibrium which in turn have been proved to be harmful to man himself. Following each use of water and the exploitation of land and water resources, various forms of pollution contributes to the degradation of the environmental quality (UDIBA, et alii, 2012). Recently, there is growing awareness of impact on environment of effluents and solid wastes of anthropogenic origin and serious concern on the use of water as a receptacle for such waste. The notion therefore that water; one of nature's, greatest gift to man is inexhaustible and can assimilate and diffuse anything put into it is fast fading out (ASUQUO, 1999). Water is indispensable. It is not only essential for the survival of man but also for other living organism (PAVENDAN, et alii, 2011). It is an essential nutrient that is involved in every function of the human body and constitutes about two-third of the human body. The importance of water in our daily life makes it imperative that thorough microbiological and physio-chemical examinations be conducted on water.

Almost every major industrial and agricultural site has in the past disposed of its wastes on site, often in an inconspicuous location on the property. Every municipality has had to dispose of its waste at selected locations within its proximity. Accidental spills of toxic chemicals have also occurred, often without particular attention to or concern for the consequences—some practices of cleaning a toxic spill involve flushing it with water until it disappears into the ground. Past waste-disposal practices and dealing with spills have not always considered the potential for groundwater contamination. A gap exists between what is known about the quality of water resources and what resources users know about their drinking water (BACKER & TOSTA, 2011). As a result, a need exists to identify tools for bridging this knowledge gap by helping people who rely on UDWS to better understand the quality of their drinking water in rural areas. Internet-based Geographic information systems (GIS) technology is one contemporary tool that may provide resource users and stakeholders with groundwater quality information to make informed drinking water decisions.

Researchers have demonstrated that geospatial technology, such as GIS, benefits citizen education and decision-making due to its (a) ability to provide access to environmental data, (b) capacity to use environmental models though a user friendly interface, and (c) powerful visualization capabilities (VENTURA, 1995; DOBSON, 1997; SWEENEY, 1998; HAKLAY, 2003; ARGENT, 2004 and JANKOWSKI, 2009). IS a software system that enables users to organize and analyze spatial datasets (LONGLEY, GOODCHILD, MAGUIRE, & RHIND, 2005). Although GIS technology is useful for environmental management, it remains underutilized in the decision-making process due to its complexity and the specialized training necessary to use it appropriately (DESAI, GREENBAUM, & KIM, 2009). The need for training is compounded by limited environmental awareness, dispirit technology access (SIEBER, 2006) or diminishing interest among resource users and decision makers who could use geospatial technology to better understand the quality of natural resources and the environment (POCEWICZ, e 2012).

MOHAMMED ET AL. 2003) have carried out hydrogeomorphological mapping using remote sensing techniques for water resource management around paleochannels. GIS has been applied to groundwater potential modeling by (ROKADE et alii. 2007). The use of remote sensing and GIS tools to extract detailed drainage, slope, and geomorphic features in parts of Pallakkapalayam Limestone Mine lease areas of Komarapalayam suggests appropriate methods for groundwater potential zone studies. The aim of this study is to find out the suitable groundwater potential zone and way of proper groundwater management and identify the groundwater potential zones through recent scientific approaches of remote sensing and GIS techniques.

II. Data Used And Methodology

Following data products are used in the study area:

1. Cartosat -1 (PAN data) and Resourcesat (LISS III) products used to get Multispectral data of the study area
2. Survey of India toposheets 58E/14 & 15 on 1:50,000 scale used to prepare base Map.
3. Field observations and field studies carried out
4. Preparing and integrating different thematic layers viz., hydrogeomorphology, slope, drainage density, lineament density, DEM, lithology, land use/land cover.

The evaluation of groundwater potential in the area has been studied using the satellite imagery and preparing the different thematic layers based on the image and integrating the various thematic maps in GIS domain. Thematic maps pertaining to hydrogeomorphology, geology, drainage, lineaments, slope and DEM (Digital Elevation Model) are prepared using LISS III plus PAN merged data coupled with Survey of India topographical sheets on 1: 50,000 scale and Geological Survey of India geological map of the study area. The detailed methodological flow is given in Figure 2.1.

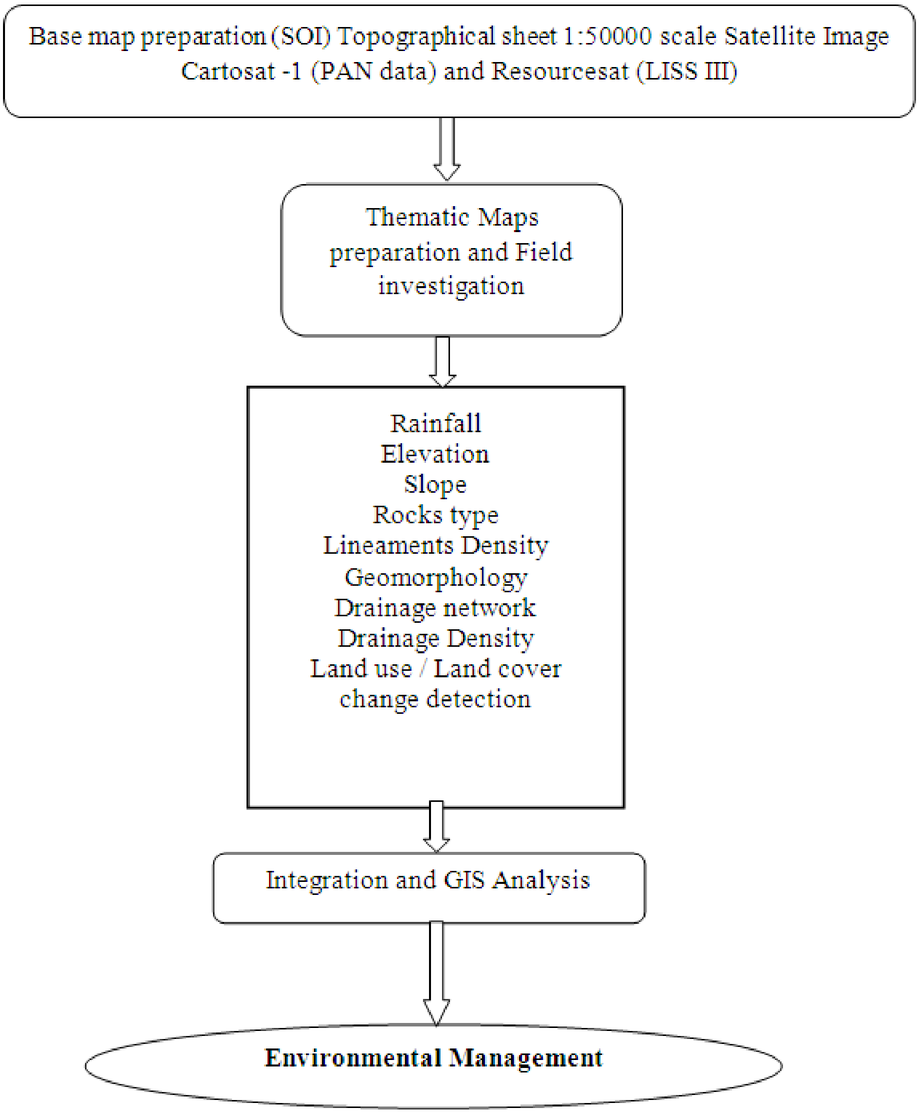

Figure 2.1 Detailed Methodology Flow chart

III. Study Area

The study area, lies between the latitudes 11°29'00" and 11°30'00" N and longitudes 77°46'40" and 77°51'40" E covering an area of 32.10.5 Ha (Figure 3.1). The base map was prepared from toposheets No 58E/14 and 58E/15 of 1:50,000 scale. The study area falls in the Namakkal District and Southeastern border of the Salem District.

The lease area is a plain ground having undulating surfaces of RL varying from 243 to 248 m. It is a plateau like area with an average annual rainfall of about 764 mm. The minimum temperature of this area is 20º c and the maximum temperature is 38º c. The annual mean relative humidity is 48%. In the lease area, since the northern side contour is higher than the southern side, the general drainage pattern is towards South.

Study area is characterized by a sub-tropical climate with moderate humidity and temperature. The weather is quite pleasant from November to February and becomes hot from March to June. The Maximum temperature ranges from 24°C to 40°C and the minimum temperature ranges from 20°C to 28°C The climate is tropical in Namakkal. In winter, there is much less rainfall than in summer. The average annual rainfall is 764 mm. The driest month is March. There is 8 mm of precipitation in March. Most precipitation falls in October, with an average of 184 mm.

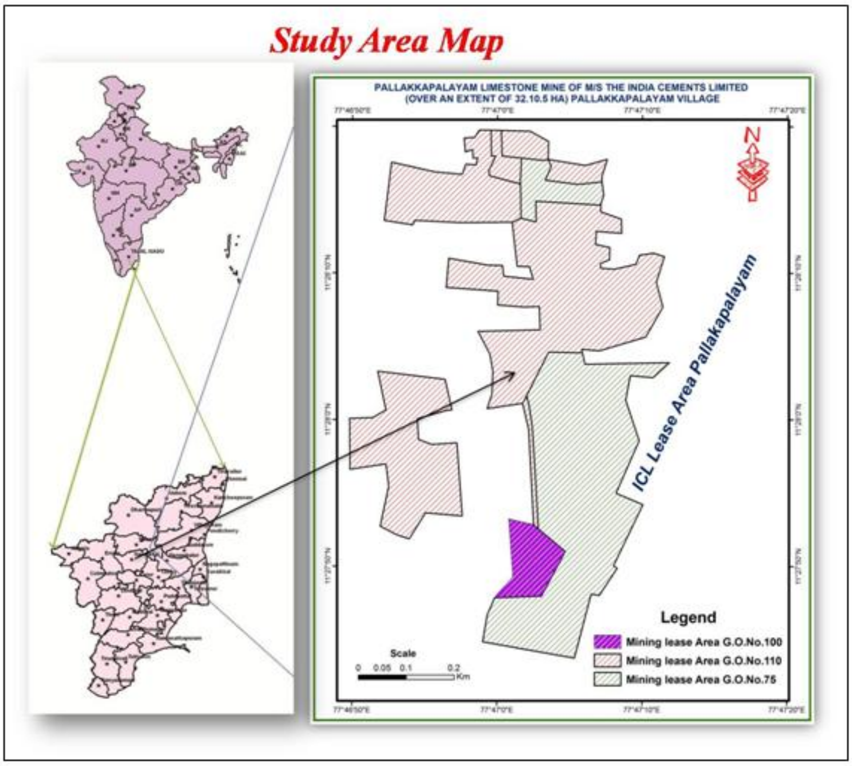

Figure 3.1 Study Area Map

IV. Regional Geology

The regional geology of the study area (Figure 4.1) forms high grade Archean of south India with a network of shear zones. The study area is mainly underlined by limestone and Hornblende-Biotite-Gneisses. Limestone is the dominant group of rocks covering major parts of the study area, followed by the Hornblende-Biotite-Gneissic rocks. Hornblende-biotite-gneiss is relatively porous and can be considered as favorable for groundwater storage. These rock types and their associated combinations usually act as favorable zones for groundwater.

The limestone deposit is metamorphic formation. The deposit is dipping towards north east and striking along south west to north east. The country rocks of this deposit are calc gneiss, biotite gneiss and pegmatite. The limestone formation was very much disturbed by batholithic intrusion of granite massif which dislocates the limestone in to several small bands with various structural attitudes.

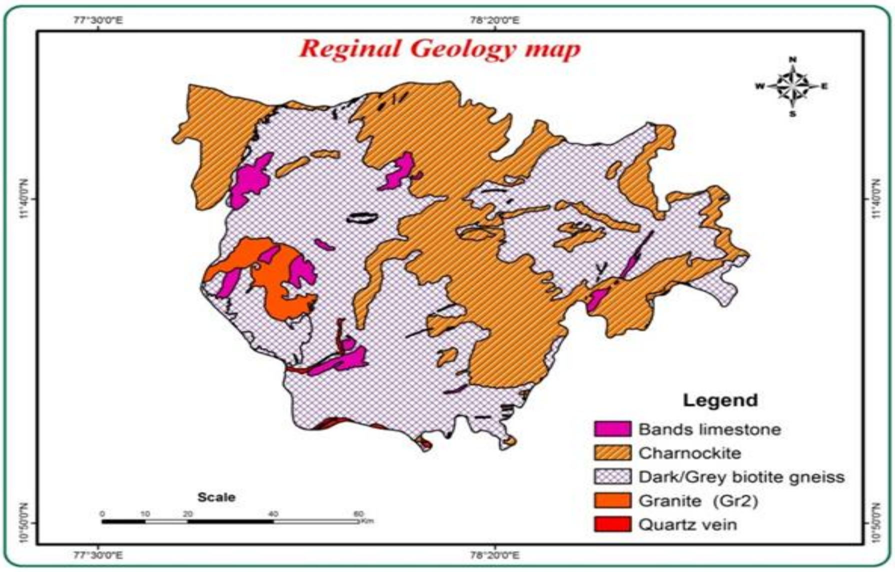

Figure 4.1 Geological Map of Salem and Namakkal Districts

The order of superposition of the formation is

AGE		FORMATION
Top soil	-	Recent
Granite Massif (Batholith) intrusion	-	Archean
Limestone	-	Archean
Peninsular Gneiss (Country Rock)	-	Archean

V. Hydro geomorphology

Hydro geomorphology focuses on the interaction and linkage of hydrologic processes with landforms or earth materials and the interaction of geomorphic processes with surface and subsurface water in temporal and spatial dimensions. The map is prepared based on the satellite imageries of LISS III, topographic maps and different hydro geomorphic units of the study area and is shown in Figure 5.1. The different hydrogeomorphic units have been classified as Denudational hills, Residual hills, Pediment inselberg complex, Pediments, Shallow weathered pediplains and Valley fills. Based on the standard visual interpretation methods have been adopted for this classification. The basic interpretation keys like specific tone, texture, size, shape and association have been used. These distinct geomorphic features result from the complexity of geomorphic evolution. The distribution and extent of these geomorphic zones vary from place to place. Similar observations were made by (LEBLANC et alii, 2007).

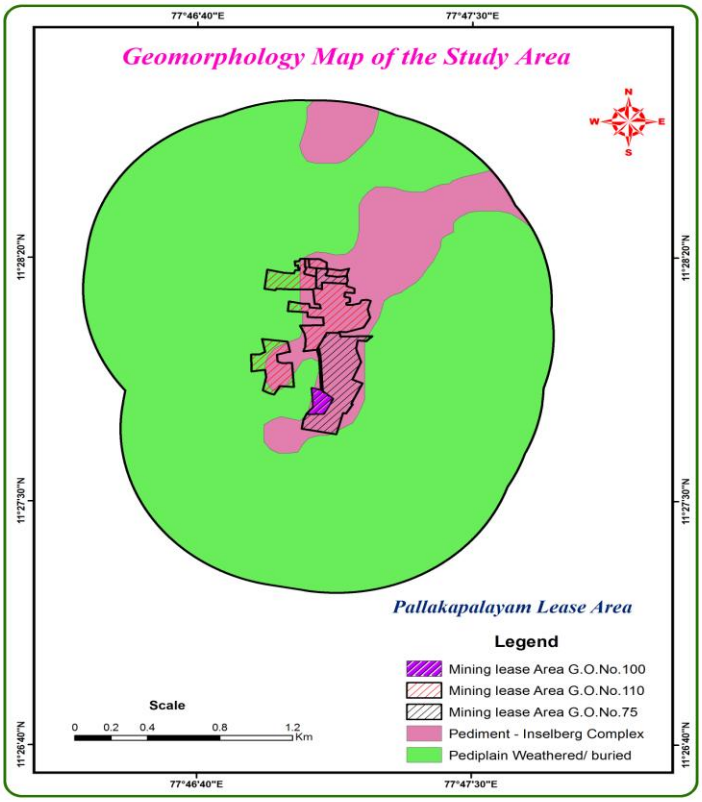

Figure. 5.1 Geomorphology Map of the Study Area

VI. Slope Analysis

Slope of the surface is one of the factors controlling the infiltration of groundwater into subsurface. Hence, it is an indicator for the suitability of 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. Slope is also a crucial parameter for occurrence and recharging conditions of groundwater in a particular area. The slope is measured in degrees (DAWOUD et alii., 2005; VITTALA et alii., 2005; SOLOMON AND QUIEL, 2006). Slope plays a key role in the groundwater occurrence as infiltration is inversely related to slope. A break in the slope (i.e. steep slope followed by gentler slope) generally promotes an appreciable groundwater infiltration. In the present study, the slope analysis has been carried out for the study area using Cartosat 1 PAN data in which ground contours of 3 m interval have been used for the analysis. The guidelines of All India Soil and Land Use Survey (AIS and LUS) on slope categories (Vide Soil Survey Manual, IARI, 1971) have been adopted a manual for classification of different category of slope (Table 6.1). The maximum and minimum elevations are 109 m and 300 m respectively. Slope map for the study area has been prepared and presented (Figure 6.1).

Table -6.1 Classification of different category of slope

Sl.No	Slope category	Slope%
1	Gently sloping	0 -5
2	Moderately sloping	5 -15
3	Strong sloping	15 – 25
4	Steep	25 – 35
5	**Very steep**	**>35**

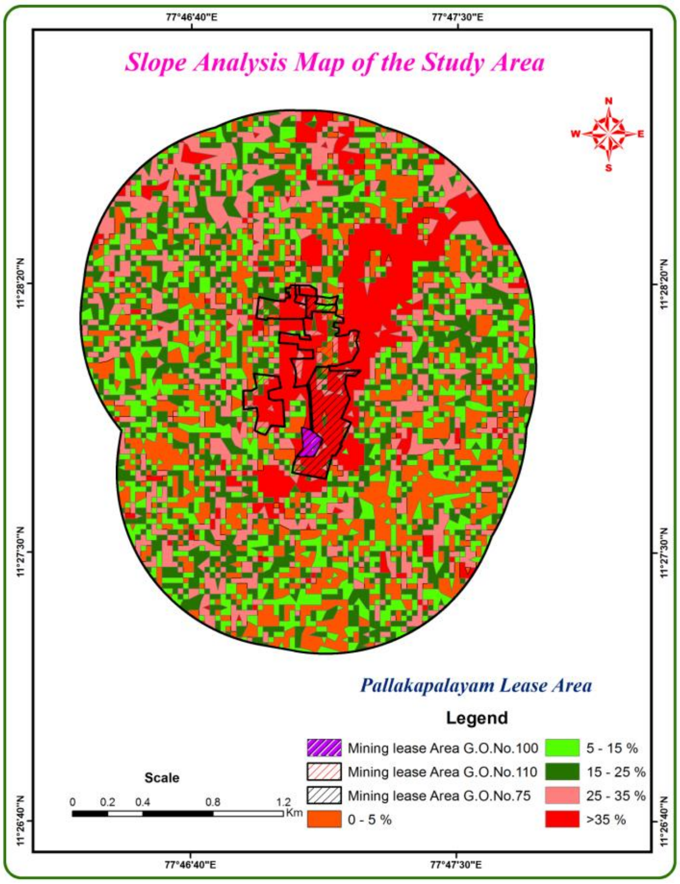

Figure 6.1 Slope Analysis Map

VII. Drainage Density

Drainage pattern reflects the characteristic of surface as well as subsurface formation. Drainage density (in terms of km/km2) indicates closeness of spacing of channels as well as the nature of surface material (PRASAD et alii., 2008). The more the drainage density, the 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. Here the drainage density of the study area is shown in Figure 7.1 It varies from 0.2 to 1.87 km/km2. The high drainage density area indicates low-infiltration rate whereas the low-density areas are favorable with high infiltration rate.

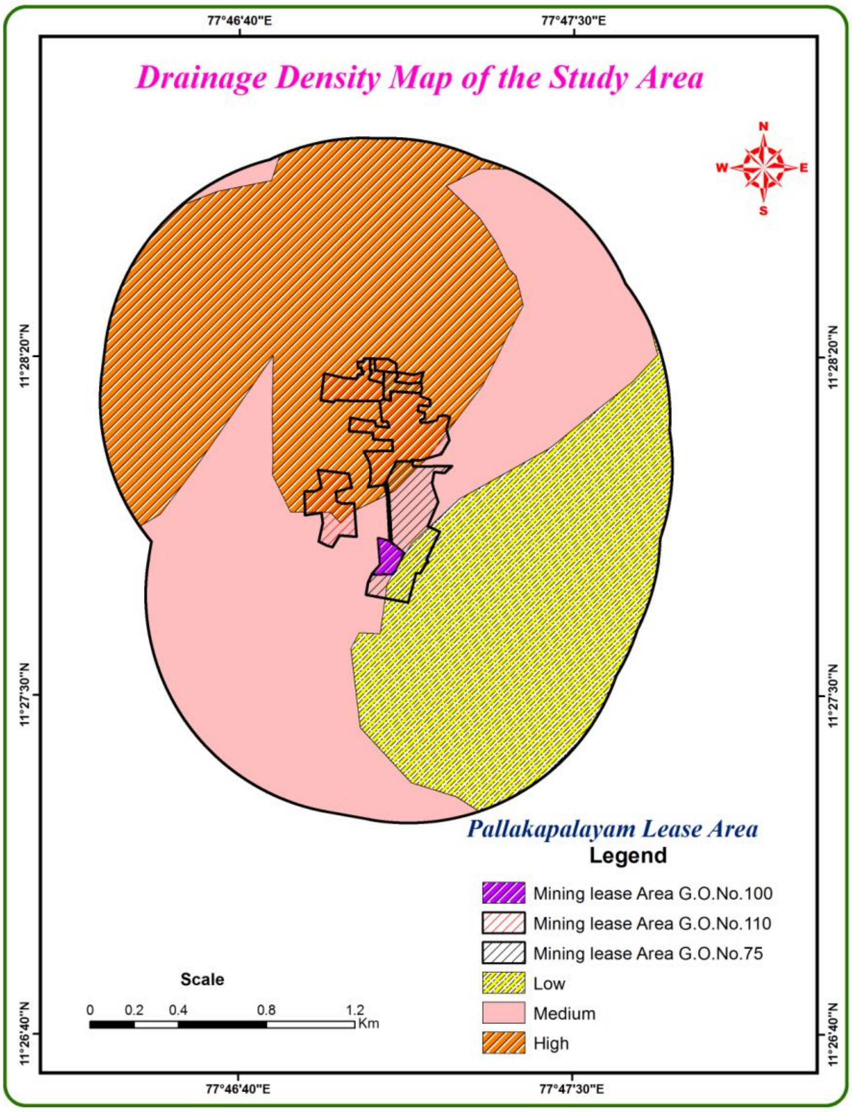

Figure 7.1 Drainage Density map

VIII. Lineament Analysis

Lineaments are important in rocks where secondary permeability and porosity dominate the inter granular characteristics combine in secondary openings influencing weathering, soil water and ground water movements. The fracture zones form an interlaced network of high transmissivity and acts as ground water conduits in massive rocks in inter fractured areas. The lineament intersection areas are considered to be good ground water potential zones.

In hard rock terrain the storage and movement of groundwater is mainly controlled by secondary porosity, i.e., presence of lineaments and fractures. Lineament study of the area from remotely sensed data provides important information on sub-surface fractures that may control the movement and storage of the groundwater. Subsurface permeability is a function of fracture density of rocks (MÜNCH AND CONRAD, 2007; VIJITH, 2007).The areas with higher lineament density and topographically low elevated grounds are considered to be the best aquifer zones. (Figure 8.1 (a) Lineament and 8.1 (b). Lineament Density map) In general, the river flows in NE-SW direction and the nature of the river in this sector clearly indicates the presence of NE-SW lineaments.

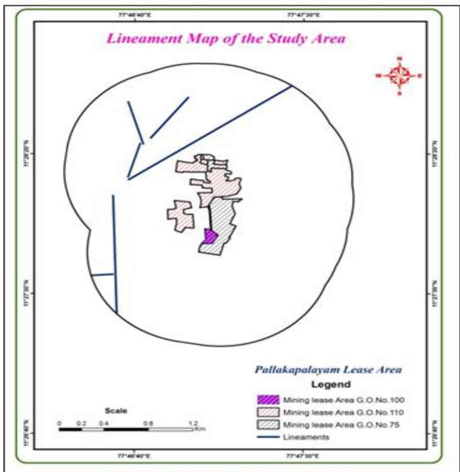

Figure 8.1 a Lineament map

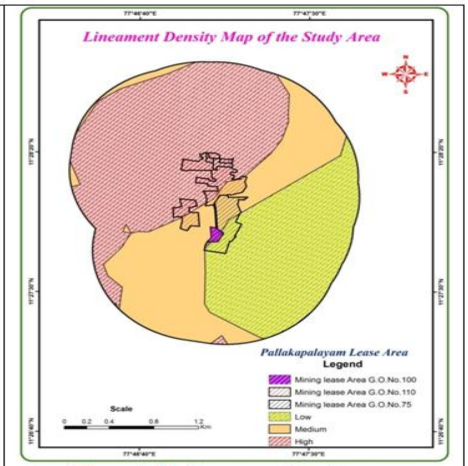

Figure 8.1 b Lineament Density map

IX. Land Use/Land Cover

In the present study, the land use/ land cover maps were prepared using satellite images on 1:50,000 scale in conjunction with collateral data like topographic maps on the same scale (Figure 9.1). The four main land use / land cover classes like built-up land (settlements), agricultural land, forest ,wastelands and water bodies were delineated based on the image characteristics like tone, texture, shape, colour, association, background, etc.,

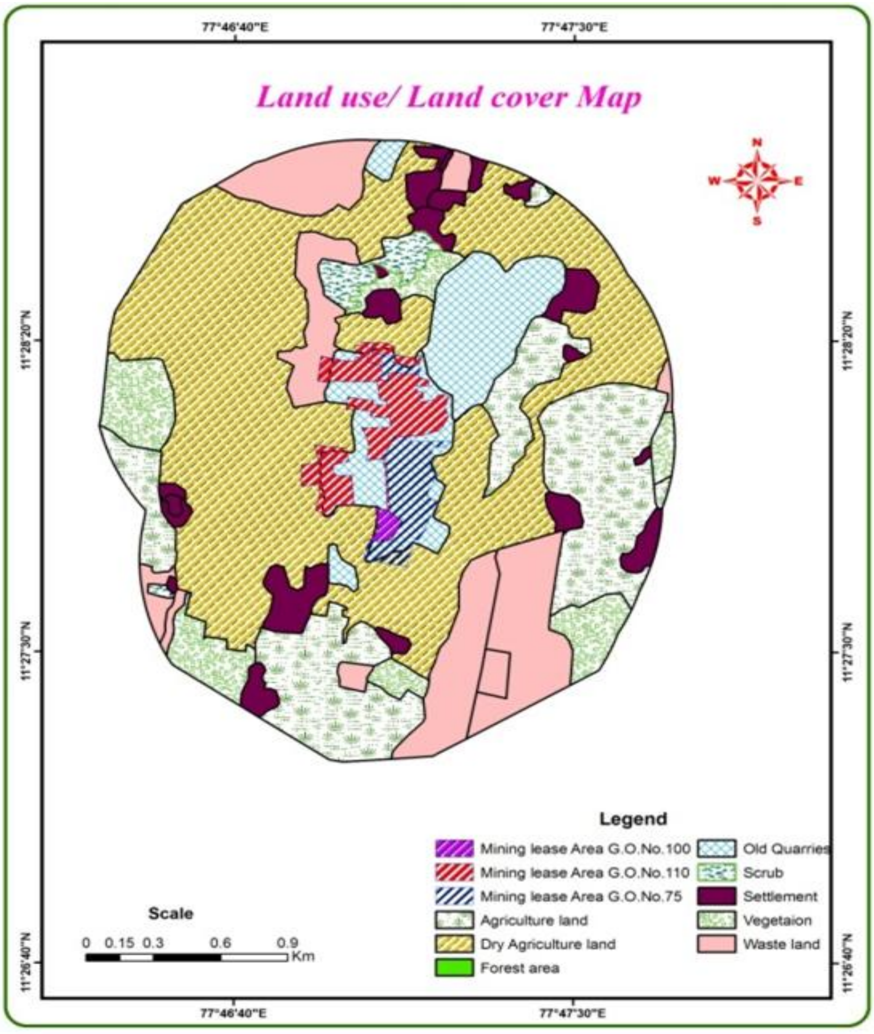

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Figure 9.1 Land use/ Land cover map

X. Elevation

An attempt has been made to create contour for the study area by incorporating the following input data.

Spot Height

Spot height values are the height values of points on the earth's surface. They normally represent heights above mean sea level. Spot height values of the study area are portrayed on maps with point symbols and annotation of the numerical value spot heights or soundings

Contours Lines

Contour lines connect a series of points of equal elevation and are used to illustrate topography, or relief, on a map. They show the height of ground above Mean Sea Level (M.S.L.) in either feet or meters and can be drawn at any desired interval. The contour Map is shown in Figure 10.1.

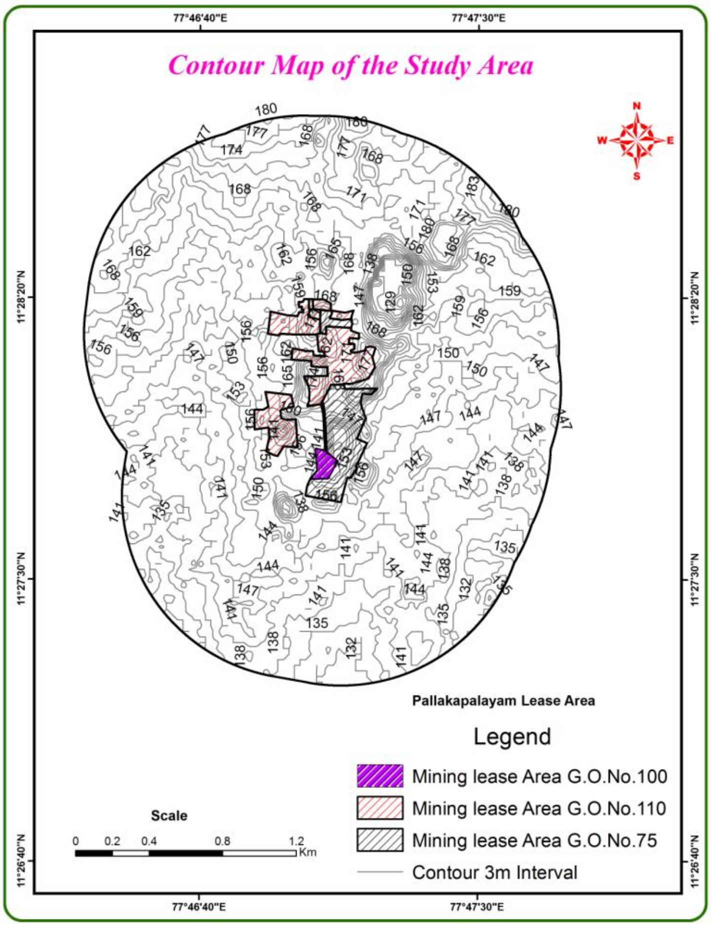

Figure 10.1Contour map of the study Area

XI. Groundwater Prospecting

The integration of various thematic maps represents that the study area is favourable for groundwater zone. It is assessed based on the following three steps.

1. Spatial database building
2. Spatial data analysis and
3. Data integration.

1. Spatial data base building

The tool provided in Arc Catalogue is being used to create a scheme for future data sets, tables, geometric networks and other items inside the database.

2. Spatial Data analysis

It is an analytical technique associated with the study of locations of geographic phenomena together with their spatial dimension and their associated attributes (like table analysis, classification, polygon classification and weight classification). The various thematic maps as described above have been converted into raster form considering cell width as 100 m to achieve considerable accuracy. These are reclassified and assigned suitable weightage in Table 11.1.

Table 11.1 Different parameters considered for groundwater prospects evaluation and their class Weights.

Hydrogeomorphology	
CATEGORIES	**WEIGHTAGE ASSIGNED**
Denudational Hills	1
Pediment	1
Pediplain	**3**
Residual Hill	1
Structural Hills	1
Slope	
0-5 % (Gentle slope)	**4**
5 – 15 %	2
15-25 %	1
25-35 %	1
>35 %	1
Drainage Density	
Low density/Coarse texture (0-1 km/km²)	***4***
Medium density/Medium texture(1-2 km/km²)	2
High density/High texture (2-4 km/km²)	1
Lineament Density	
High	**4**
Medium	2
Low	1
Relief in (m)	
109-146 m	**5**
146-177 m	4
177-210 m	3
210-242 m	2
>242	1
Land use/land Cover	
Settlement	1
Waste land	2
Forest	3
Scrub	4
Dry Agriculture land	**5**

XII. Data Integration

Each thematic map such as geology, geomorphology, lithology, soil, drainage density, lineament, slope, DEM and land use/land cover provides certain clue for the occurrence of groundwater. In order to get all this information unified, it is essential to integrate these data with appropriate factors. Although it is possible to superimpose this information manually, it is time consuming and error may occur. Therefore, this information is integrated through the application of GIS. Various thematic maps are reclassified on the basis of weight assigned and brought into the ‘‘Raster Calculator’’ function of Spatial Analysis tool for integration. A simple arithmetical model has been adopted to integrate various thematic maps by averaging the weight. The overlay analysis allows a linear combination of weights of each thematic map with the individual capability value with respect to groundwater potential.

The formula of the groundwater potential model (GP) is shown as below:

GP = Hg + Lt + S + Dd+ Ld + Te + Lu

Where;

Hg = Hydrogeomorphology
Lt= lithology (geology),
S=Slope
Dd = drainage density
Ld = lineament density,
Te=topographyelevation(relief) and Lu = land use

The final map has been categorized into five zones, from groundwater potential point of view as Excellent, Good, Moderate and Poor Table 12.1. The groundwater potential map for the study area thus derived is shown in Figure 12.1.

Table 12.1. Groundwater potential Zones

Sl.No	Prospective Zone	Area in Km2	Percentage
1	Good	0.021	06 %
2	Moderate	0.062	17 %
3	Poor (Run – off Zone)	0.267	76 %

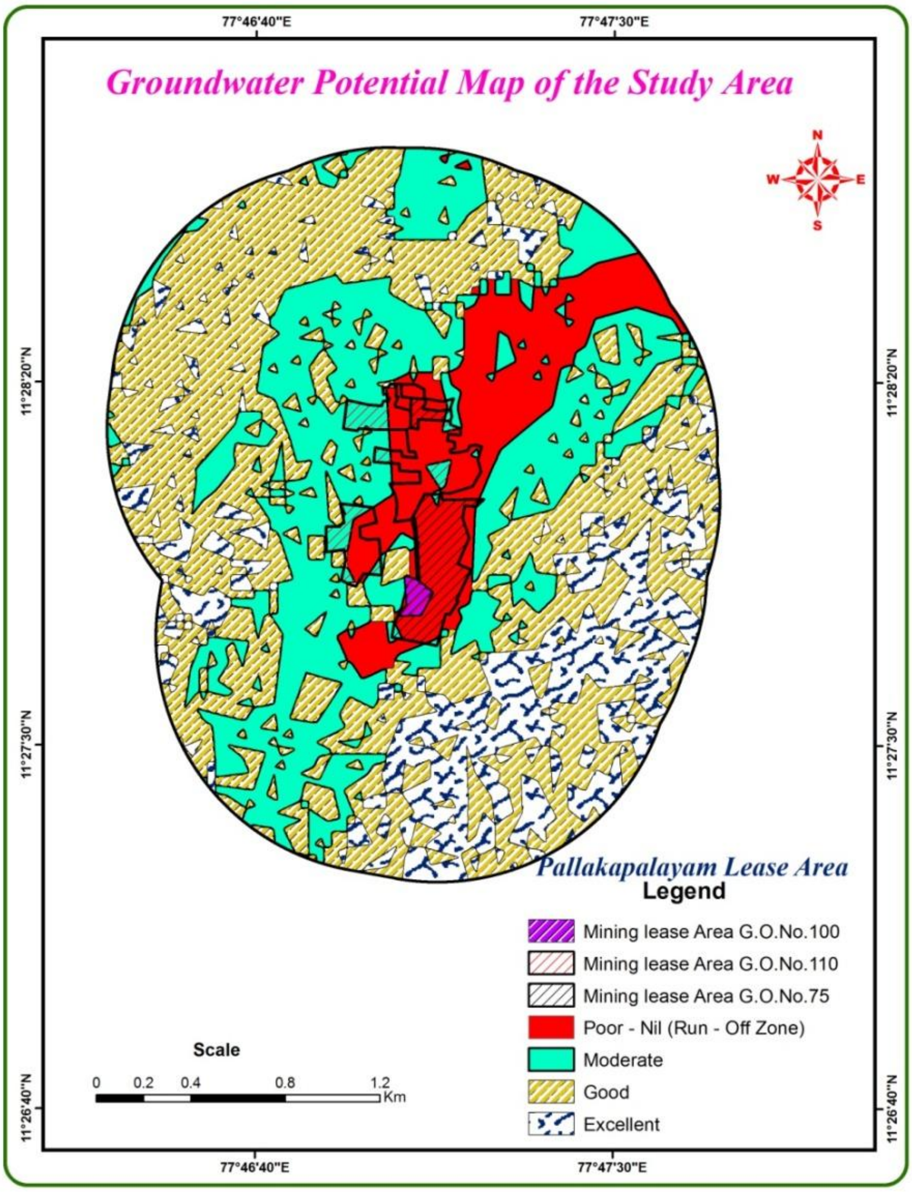

Figure 12.1 Ground Water Source Map

XIII. Conclusion

The study area falls in the Namakkal District and South Eastern border of the Salem District. This locality is dry land and agriculture based. Presently, the water supply is met mainly from tube wells. The tube wells are having the depth of above 200 meters. The lease area is a plain ground having undulating surfaces of RL varying from 243 to 248 m. It is a plateau like area with an average annual rainfall of about 900 mm. The groundwater of the study area is found in unconfined aquifers. The water level depends upon the slope and condition of the aquifers. The average water level of the lease area is 25 m as per the study and this is an unconfined aquifer fluctuate upto 40 mts. As per the slope analysis, the lease area mostly in high slope, so the area having high run off and less infiltration. As per the drainage density study, the lease area has high drainage density so that runoff is much higher. The lease area having low lineament density. After integration analysis, it is concluded that the lease area mostly covered under High run – off area. This indicates there is a poor groundwater infiltration. Therefore, it is concluded that the ground water table is located at the depth of 25 mt BGL and it may dry in extreme summer. The water touch in bore well are reported at deeper level >200mt in most of the bore well in this region. The mining effect of around this lease areas is depression of the water table. The consequences of water table depression due to mine dewatering. The mine dewatering can include: Decreased flows in streams, wetlands, and lakes that are in hydraulic continuity with the affected groundwater body. Many of these impacts can be anticipated before they occur and mining companies will generally take steps to mitigate them. The current multiparametric approach using GIS and remote sensing is holistic in nature and will minimize the time and cost especially for identifying groundwater-potential zones and suitable site-specific recharge structures in hard rock terrain on a regional as well as local scale, thus enabling quick decision-making for water management.

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Dr.M.Bagyaraj." Multi-Disciplinary Approach for Surface Mining Effects on Shallow Groundwater Potential Using Remote Sensing and Gis.. "IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 11.12 (2018): PP- 16-27.