DELINEATION OF GROUNDWATER POTENTIAL ZONES OF TUMKUR-GUBBI
WATERSHED OF SHIMSHA RIVER BASIN, KARNATAKA, INDIA, BY USING
REMOTE SENSING AND GIS TECHNIQUES

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Abstract

Remote sensing is one of the best tools considered for hydrogeological studies for recognizing both surface and subsurface water prospective zones. The present investigation emphasized the feasibility of remote sensing and geographic information system (GIS) techniques in hydrogeological studies, specifically in the delineation of groundwater potential zones in Tumkur-Gubbi watershed of Shimsha River is a tributary of River Cauvery, Karnataka, India. The detailed information of various thematic layers such as Geology, Lineaments, Geomorphology, Slope, Drainages, Soil and Land use/Land cover were assembled from IRS-P6, LISS-III, 22nd Dec, 2011 data and topographic maps of Survey of India(SOI) in 1:50,000 scale in addition, GIS techniques are used as a platform for manipulation and integration of various thematic layers. Based on the spatial distributions of the groundwater potential zone the amalgamated map is produced in which five categories of groundwater potential zones were recognized and classified as Good(covered 30% area), Moderate(covered 51% area), Moderate to poor(covered 3% area), Poor(covered 3% area), Poor to Nil (covered 6% area) and also Water body mask(covered 7% area). Geomorphologically Pediplains, Moderate and Shallow weathered/buried pediplains with prominent lineaments, soil moisture property and grain size are well suitable for groundwater exploration, development and management. The valley fills accompanying with the lineaments are highly promising regions for the extraction of ground water. The Landforms, Geology, Structures and Slope are the major controlling factors of the spatial distributions of the groundwater potential zones.

Keywords: Shimsha, Cauvery, Remote Sensing, GIS, Groundwater Potential, Lineament.
Introduction:

Water is one of the very important resources for all the living things on the earth. Without water no living organisms exist on the earth as of the other planets of the Universe. Among whole water on the earth 96.5% is concentrated in the oceans is not useful for domestic and agriculture purpose and apart from this the remaining water exists in the form of River, lakes, glaciers, water vapors, soil moisture and ground water.

The water stored underneath the earth surface in aquifers is referred as groundwater. In present days groundwater becomes major source for domestic and agricultural activities apart from the places with the availability of surface water such as rivers and lakes. Groundwater is the resource which is gathered in the porous underlined subsurface rocks. In the hard rocks such as Igneous and Metamorphic terrains the porosity permeability of the rocks only restricted to the structural features such as fractures, fissures, joints, lineaments and also weathering. So the groundwater occurrence and movements is being subsurface phenomenon in identification of groundwater potential zones in hard rock terrains are extensively depends on Geology, Lineaments, Geomorphology, Slope, Drainages, Soil and Land use/Land cover. Among different methods for identifications and mapping of groundwater potential zones among the geophysical and remote sensing methods are leading methods.

In the present days technologies are very advanced so the spectral, spatial and temporal data of the Remote sensing are useful in quick collection of useful basic information about the factors controlling the hydrogeological behavior of the terrain such as Geology, Lineaments, Geomorphology, Slope, Drainages, Soil and Land use/Land cover. Additionally the remote sensing provides the good platform for the study of large areas and facilitates quick and better assessment for management and development of the water resource information. Most of the researchers (SrinivasVittala et al, 2005, Preeja et al, 2011) are presented that the remote sensing has been a most efficient tool for the hydrogeological studies than that of the geophysical methods.

In the present days modern technologies such as geographical information system are using for the purpose of hydrogeological studies and delineation of groundwater potential zones (Jaiswalet al.2003). GIS techniques provide the facilities for the analysis of larger data sets and ground truth check is helpful for the further validation of results.

The present investigation is to the characterization of Tumkur -Gubbi watershed of Shimsha River Basin, Tumakuru, Karnataka based on the spatial variation of groundwater
potential zones, with the help of innovative remote sensing and GIS techniques (Figure 1). Due to depletion and uneven distribution of rainfall, nonexistence of adequate surface water, lack of water management techniques and the speedy progressive activities of the society growth finally lead to the overexploitation of groundwater resources. Identification of potential groundwater zones could benefits in correct utilization of both groundwater and surface water resources and there developments for reducing water scarcity problems and also improvements in agricultural and irrigation practices and income for typical living conditions of the public. Therefore, the ecological development of the basin needs cost efficient exploration and balanced groundwater resources exploitation.

**Study area:**

The Tumkur-Gubbi Watershed (study area) is located between Latitude 13°13’00” to 13°33'30” and Longitude 76°58’30” to 77°16’30” covers an area of about 624 Sq. km., and it forms the parts of Shimsha river basin comprising parts of Tumkur and Gubbitaluks of Tumkur district, Karnataka State (Figure 1). Topographically the Tumkur-Gubbi watershed is an undulating terrain with elevations varying from 1270 m to 742 m. above MSL, with an elevation difference of about 528 m from North East to South West. The drainages of the sub-watersheds show dendritic to sub dendritic pattern. From review of previous studies the Tumkur-Gubbi Watershed falls in one of the Hard rock terrains of Karnataka and belongs to one of the drought prone area. And it falls in tropical climatic regions with the average monthly temperature ranging between 17°C to 39°C is maximum during summer and average annual rainfall is 887mm.

**Data used and Methodology:**

The Survey of India topographic maps Nos. 57C/15, 57G/2, 57G/3, 57G/4, and 57G/6 on 1:50,000 scale along with IRS-P6, LISS-III, 22nd Dec, 2011 are used for the preparation of different thematic maps such as lithology, geomorphology, drainage, soil, land use/land cover and also verified by ground truth check, Slope and lineament maps were also prepared. All the thematic maps and ground water potential maps are prepared as per the technical guidelines of National Remote Sensing Agency (NRSA 1995). The weighted overlay criteria were used for delineation of ground water potential zones. The weightages of the individual thematic layers and features were ordered depending up on their suitability of infiltration and holding capacity of ground water. The spatial analyst using Arc GIS 10.2.2 are helpful in the
extraction of raster data from the features and also very useful in the analysis of the data. In this investigation the final integrated map of study area were derived based on the product of assigned weightage of different thematic layers according to their suitability.

Figure 1: Location map of Study Area

Results and Discussions:

Geology:

Geologically whole Tumakuru district is situated in West and East Dharwar Craton and is majorly belongs to the Archean complex and it is having fairly simple geology. The Archean rocks of Tumakuru district are represented by the crystalline schists, older granitic gneisses and newer granites. Amphibolites, metabasalts, tonalitic gneisses, migmatites, granites, granodiorites, grewackes-argillites, dolorites, limestone and dolomites are the major rock types emplaced in Tumakuru district. All the schist patches including chikanayakanahalli schist belt are scattered in the older gneissic complex and those are the evidences of repeated metamorphism which are observed in the outcrops (RadhakrishnaB.P and Vaidyanadhan R., 1997; Ramakrishnan M and VidyanadhanR., 2010).

In the study area there are mainly two types of rocks one is older pink and grey granitic gneiss and another one is younger granodiorites and granites among which the major portion is covered by younger granodiorites and granites are at the western part (Figure 2).
Both older pink and grey granitic gneiss and younger granodiorites and granites are traversed by intrusive dykes, this indicates that the study area forms a part of hard rock terrain. The rocky exposures of the younger granodiorites and granites are observed in the western part of the study area such as AjjiBetta, ArishanaBetta, BasthiBetta, TalavaraBetta, GundagalBetta, BhimanaBetta, KaradiGutta, NijagalBetta, RamadevaraBetta, SiddaraBetta. The low laying areas in the granites are weathered and decomposed which are also intruded by number of pegmatitic veins and traversed by well-developed joints. The eastern part of the study area is covered by older pink and grey granitic gneiss forms the basement rock which undergone number of pegmatitic intrusions with two sets of joints. Both this Granites and gneisses are having transitional and irregular contact between them. Comparatively older Gneisses are weathered and fractured than the younger granites so they are found in the form of mounds and small ridges exposed here and there at low laying areas. Both the rocks found in the study area belong to the igneous origin and they are hard rocks which has no primary porosity, therefore the infiltration and the movement of ground water are restricted to the secondary porosity such as fracturing and weathering processes originated from the diastrophic movements of the earth, which also undergone some younger dyke intrusions.

**Lineaments:**

The Lineaments are formed due to the diastrophic activities of the earth acts as surface indicator of subsurface fractures which is an essential characteristic of porosity and permeability of the underlined materials (SubbaRao 2006). Lineaments are hydrogeologically very important which provides the pathway for groundwater infiltration and movement (Srinivas et al., 2005). The fractures, folds and faults are the structures acts as secondary porosity and permeability in the hard rock terrains for the occurrence and movement of groundwater. From the worldwide researches it is concluded that the lineaments are the very important outlet for the groundwater occurrences in the compact impermeable rocks. In the fractured aquifer of hard rock terrain the alignment and the interconnection of fractured plane plays an important role in groundwater resource occurrence and movement, the zones with dense and interconnected fractures are potentially better for the groundwater extractions (Preeja et al 2011).

Generally the weathering thickness and fracturing of rock is more along the lineaments, therefore the surface drainages and groundwater movement follows along course of lineament so these are assumed as controlling factor of surface and groundwater
movements. The digitally processed LISS-III imagery using false colour composite bands provide satisfactory information about lineaments. The features such as topography of the terrain, vegetational arrangement, the straight drainage course and so on are helpful in the identification of majority of lineaments in the study area. Both major and minor lineaments are identified in the study area which is varying in length from a few meters to kilometers. Majority of lineaments in study area are oriented N–S, E-W and NNW–SSE directions high lineament density areas having more fractures where the ground water probability is more (Figure 2). The stream flows and nalas of the study area are controlled by the minor lineaments identified in the valley fills, pediments and structural hills.

**Figure 2: Geological Map of Study Area**

**Figure 3: Slope Map of Study Area**

**Slope:**

Rate of change of elevation is called as slope which is one of the chief factors for the flow of water as it controls the gravity effect on occurrence and movement of water. The rate of infiltration of water into the underlying fractured aquifer depends on the slope so it is useful in the determination of groundwater prospecting areas (Sreedhar et al., 2009). The slope is directly proportional to the runoff, runoff rate is more and the ground water recharge is less in the areas having steep slope and the runoff rate is less and the ground water recharge is more in the areas having gentle slope and undulating terrain (Preeja et al, 2011). In the gentle slope terrain the runoff rate is less and more time is available for infiltration so in this
case rate of infiltration depends on grain size and property of surface soil and subsurface fracture. In the steep slope terrain the runoff rate is more and rate of infiltration is very less even though the surface soil and subsurface fractures are suitable for infiltration. The slope is categorised into seven classes based on the variation in percentage as Very Steep Slope (35-50%), Moderately Steep Slope (15-35%), Strong Slope (10-15%), Moderate Slope (5-10%), Gentle Slope (3-5%), Very Gentle Slope (1-3%), Nearly Level (0-1%)(Figure 3).

**Geomorphology:**

Topographical study of any watershed and sub watershed is very important in hydrogeological investigation for groundwater in any crystalline rock terrains. For the identification of groundwater condition under the subsurface of an area the geomorphic features acts as a very good surface indicator. The geomorphological information provides effective basement for the development and management of groundwater resource of an area (Lazarus et al., 2014). The Tumakuru-Gubbi watershed belongs to one of the hard rock terrains in which upland areas are dominated in the eastern side exhibiting that denudational hills, inselberg, residual hills with undulating surface and the low land regions are towards the western side form gently undulating surface.

The wide groups of the landforms and their spreading are interpreted from LISS-III Lands at imagery and confirmed from the ground truth observations. The geomorphic evolutionary sequence in Tumakuru-Gubbi watershed is ranging from high elevated structural hills to the lower alluvial plane land indicating the complexity of the evolutionary sequences. There are different types of geomorphological units (Figure 5) were recognized in study area are enlisted in table 1 and there quantitative distributions area presented in figure 4.

The variation in the lithology of an area plays very important role in the distribution of geomorphological features. The high elevated regions of the study area are mostly characterized by the inselbergs, denudational hills, residual hills, ridge type structural hills. The lower regions are mainly characterized by valley fills, moderately and shallow weathered/buried pediplains.

Denudation hills are the group of hills occupies area ranging from 2*2 to 10*10 km² which are mainly formed due to the process of differential physical or chemical weathering and erosion (Preeja et al, 2011). Majorly it acts as a runoff zones. In case of larger areas it contributes substantial recharge to some favorable zones such as narrow valleys and lineaments with in the hills. Ridge type structural hills are the linear to accurate hills.
revealing definite structural trending hill ranges which are mainly controlled by complex folding, faulting and numerous criss-cross joints or fractures, which enable some amounts of infiltration and majorly act as runoff zone (Sankar, 2002). Residual hills are the resultants of the diminished products of the original mountain mass into a series of dispersed hillocks upended on the pediplains formed from the process of pediplanation. Some exposures of closepet granites occur as residual hills in the study area which acts as runoff zones. Inselbergs are the isolated hills raising sharply above the surrounding plain terrain generally consists of steep sloped granitic rocks occurs as smooth curved small hills which acts as major runoff zones. Based on the geomorphic characteristics among various units Denudational hills, Ridge type Structural hills, Residual hills and Inselbergs are considered as very poor to poor potential zones.

Pediment inselberg complex contains both pediments and inselberges. In which numerous inselberges are scattered with in pediments which could not map as separate individual units. Among this inselberg acts as runoff zones and pediments contributes low to moderate recharge. Pediments are the resultant products of some combined process such as weathering, erosion and sheet wash, which is showing even surface of erosion in insitu rocks situated between hill ranges and plain surface with gentle slope consisting of debris and undulating rocks (Vijay Kumar et al., 2009). Ground water condition in the pediments is controlled by the degree of weathering, underlying structures and arrangement of fractures (GirishGopinath and Seralathan, 2004). Geomorphologically Pediment inselberg complex, Pediments are poor to moderate potential zones.

Figure 4: Pie Chart representation of geomorphological distribution in Study Area
Pediplains are the plain land masses formed due to the process of continuous pedimentation. Commonly these areas are smoothly undulating terrains of huge extent slightly scattered with inselberg formed by the combination of quite a lot of pediments. The occurrence and movement of the ground water in the pediplain regions are mainly controlled by the fractures and fault zones (Pushpavathi, 2011). The study area belong to a hard rock terrain, hence pediplain acts as good recharge and storage areas which also depends on underlined material composition, weathering thickness, recharge environment etc. Based on the depth of weathering index the pediplains are classified into shallow weathered/buried pediplains(0-10m depth), moderate weathered/buried pediplains(10-20m depth) and deep weathered/buried pediplains(20-30m depth) those are also having same features as pediplains and exhibits slight changes based on their thickness of weathering. Geomorphologically Pediplains, Shallow, Moderate and deep weathered/buried pediplains are moderate to good potential zones.

Valley fills are formed due to the deposition of unconsolidated sediments due to gentle slope in the valleys and presence of any obstructions which reduces the velocity of flow of the streams(GirishGopinath, 2004). Valley fills are the very good aquifers for
extraction of ground water, because this are formed at depositional environment and also this acts as good zones for groundwater movement and recharge. Valley fills are formed due to the influence of fractures and joints so this exibits the linear landform features. The valley filled materials are vary in there texture and composition depending on the parent materials (Agarwal and Garg, 2000). Among other geomorphic characteristics Valley, Valley fills and Water body masks are considered as good to excellent potential zones.

**Drainages:**

The surface water of the study area is draining in to river shimsha is a tributary of river Cauvery. It flows from North East to South West direction with elevations varying from 1270 m to 742 m above MSL, with an elevation difference of about 528 m. The source of water for this river is pre-monsoon, monsoon and post monsoon rainfall. The surface and subsurface feature of the study area is reflected by the drainage pattern of the terrain. The drainage pattern of the study area is showing dendritic to sub-dendritic which is clearly indicating that the terrain is of granitic hill ranges (Figure 6) with 5th order stream and lower order streams are dominated. The morphometric analysis in the study area shows low to moderate drainage density (1.07 to 2.17 km/km²) in all sub-watersheds indicating strong permeable material with excellent vegetative cover and moderate relief. The stream frequency of the sub-watersheds ranges from 0.74/km² to 2.65/km² and lower value indicates good permeability, vegetation and infiltration capacity than the higher values. The Relief ratio is ranging from 0.009 to 0.023 suggesting the intensity of erosion which operates on the watershed slopes. The value of elongation and circulatory ratio shows that all the sub-watersheds having elongated shapes (Kiran Kumar et al., 2017).
Soil:

Soil is an unconsolidated material formed from the disintegration of parental rock materials due to the combined physical, chemical and biological weathering process. Soil plays a very important role in the hydrogeological studies of an area. Characteristics of soil are considerably very important which invariably controls surface runoff and infiltration of water into an aquifer system of an area. It is controlled mainly by the grain size and physical properties of soil under moisture condition. Soil in the study area are vary in their grain size, texture, thickness etc. are mainly depends on the parent materials, climatic condition, drainage density, intensity of rainfall and rate of erosion from higher elevation to the low land. The thickness of the soil cover are vary from place to place, the soil cover thickness is less in high elevated areas and more in the low laying areas. The six different types of soil texture are identified in the study area varies from sandy-skeletal soil to fine soil (Figure 7).
Figure 8: Land Use / Land Cover Map of the Study Area.

Land use Land cover:

Land use and Land cover studies is a basic information study about the utilization of land resources for various purposes based on the availability of the required resource and transportsations throughout the world (Nagarajan and poongothai 2012). Land use and Land cover exhibits the information about the past and present activities of human being and the extent of utilization of the different resources on the land, which also employs the future utilization of land by man. Land use mapping is one of the important tools for agricultural development studies and natural resource development and management such as forest, rock quarries, mines and water bodies. Land use and land cove of an area is also important in hydrogeological studies, because it directly impact on rate of evaporation, amount of groundwater infiltration and surface runoff that occurs during and after precipitation. Standard visual interpretation techniques of remote sensing were applied using satellite imageries to recognize and interpret the land use/land cover pattern of the area. For identification of land use/land cover features of study area IRS-P6, LISS-III, 22nd Dec, 2011, Imagery is used (Figure 8).
Groundwater Prospective Zones:

In the present investigation, an effort of generating groundwater prospect map is made through the integration of different thematic maps such as Geology, Lineament, Geomorphology, Slope, Soil and Land use/ Land cover with the help of remote sensing and GIS techniques. By the combination of those different thematic layers the groundwater potential zones are demarcated into Good, moderate, moderate to poor, poor, poor to nil. The details are tabulated in Table 2 and Figure 9 and 10.

![Groundwater Prospect Map of the Study Area](image1)

**Figure 9: Groundwater Prospectus Map of the Study Area.**

![Pie Chart representation of Groundwater Prospectus in Study Area](image2)

**Figure 10: Pie Chart representation of Groundwater Prospectus in Study Area**
<table>
<thead>
<tr>
<th>Groundwater Prospectus Zones</th>
<th>Litho Unit</th>
<th>Geomorphology</th>
<th>Slope Type &amp; %</th>
<th>Soil Family Texture</th>
<th>LU/LC Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>GRANODIORITE AND GRANITE</td>
<td>Valley Fill/ filled-in valley, Valley &amp; Waterbodies-masked area</td>
<td>Nearly Level (0-1%) &amp; Very Gentle Slope (1-3%)</td>
<td>Fine, Fine Loamy &amp; Waterbody-masked area</td>
<td>Waterbodies, Agricultural Land-Crop Land-Two crop area, Forest-Deciduous (Dry/Moist/Thorn)-Dense/Closed,</td>
</tr>
<tr>
<td>Moderate</td>
<td>GRANODIORITE AND GRANITE</td>
<td>Shallow weathered/shallow buried Pediplain&amp;Pediplain Eroded</td>
<td>Gentle Slope (3-5%)</td>
<td>Loamy &amp; Loamy Skeletal</td>
<td>Agricultural Land-Plantation-Horticulture Plantation, Agricultural Land-Crop Land-Kharif Crop, Built Up-Built Up (Urban)-Vegetated Area, Built Up-Mining / Industrial area-Industrial &amp; Forest-Scrub Forest</td>
</tr>
<tr>
<td>Moderate to Poor</td>
<td>PINK &amp; GREY GRANITE</td>
<td>Moderately weathered/moderately buried Pediplain&amp;Pediment/Valley Floor</td>
<td>Moderate Slope (5-10%) &amp; Strong Slope (10-15%)</td>
<td>Clayey Skeletal &amp; Sandy Skeletal &amp; Habitation-masked area</td>
<td>Agricultural Land-Crop Land-Rabi Crop, Agricultural Land-Fallow-Current Fallow, Built Up-Built Up (Rural)-Built Up area (Rural), Built Up-Built Up (Urban), Forest-Deciduous (Dry/Moist/Thorn)-Open, Wastelands-Scrub land-Dense scrub &amp; Forest-Forest Plantation,</td>
</tr>
<tr>
<td>Poor</td>
<td>DYKE</td>
<td>Inselberg&amp; Pediment - Inselberg Complex</td>
<td>Moderately Steep Slope (15-35%)</td>
<td>ROCK OUTCROPS</td>
<td>Built Up-Mining / Industrial area-Mine/Quarry, Wastelands-Gullied/Ravinous land-Gullied &amp; Tree Clad Area</td>
</tr>
<tr>
<td>Poor to Nil</td>
<td>DYKE</td>
<td>Denudational Hills, Residual Hill &amp; Ridge type Structural Hills</td>
<td>Very Steep Slope (35-50%)</td>
<td>DYKE RIDGES</td>
<td>Wastelands-Barren Rocky/Stony waste, Wastelands-Scrub land-Open scrub</td>
</tr>
</tbody>
</table>

Table 2: Showing Groundwater Prospectus Zones based on Litho Unit, Geomorphology, Slope, Soil Family Texture and LU/LC Classification.
Conclusion:

The present investigation is capable to reveal the information that the identification of favorable groundwater potential zones in hardrock terrains, which is carried out at Tumkur-Gubbi watershed of Shimsha River is a tributary of River Cauvery, Karnataka, India. The methodology of Remote sensing and Geographic Information System (GIS) is very beneficial in the identification, analysis and integration of different geospatial information such as geology, lineament, geomorphology, slope, drainage, soil and Land use/Land cover particularly for delineation of groundwater potential zone map. The groundwater potential zone map is indicating that half of the region (51% area) is covered by moderate potential zone and more probability of groundwater concentrations are indicated by the lineaments. Majority of the lineaments are aligned along the drainage system of the area, which are dominated with valley fills and acts as good groundwater potential aquifer system. The tropographically low laying ground combined with the good number of lineaments acts as the better aquifer horizon, if grain size and moisture properties of soil supports for the good infiltration rate. The good zones of ground water are distributed majorly along the buffer zones of valley and lineaments which are indicating that they are structurally controlled, emphasizing the significance of geomorphology and lineaments for groundwater investigations. The poor to nil groundwater potential zones are extended majorly along the denudational hills, residual hills, ridge type structural hills and inselbergs. Remote sensing and GIS techniques are economical, wide spread and less time consuming, which offers satisfactory support in studies related to groundwater in the regions where absence of earlier hydrogeological investigations and data. From the overall investigation author is concluded that the remote sensing and GIS techniques offered hypothetically efficient tools for groundwater resource studies and manipulating suitable exploration strategies. The integrated groundwater potential map might be beneficial for different purposes such as sustainable groundwater development and emphasize the significant areas for implementing projects and managements for both surface and groundwater conservations as well as its proper utilizations.

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References: