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# Evaluation of Groundwater Resource Potential using GIS and Remote Sensing Application

V.Sunitha, J Abdullah Khan., M. Ramakrishna Reddy, **
Dept of Geology, Yogi Vemana University, KADAPA-516003.
**Dept of Earth Sciences Yogi Vemana University, KADAPA- 516003.

**Abstract**
Environment and Development are the two wheels of the cart. However, they become antagonists at some points. It has been witnessed many a times that development is done at the cost of environment. Analysis and assessment tools like GIS along with Remote Sensing have proved to be very efficient and effective and hence useful for management of natural resources. Groundwater is a precious resource of limited extent. In order to ensure a judicious use of groundwater, proper evaluation is required. There is an urgent need of planned and optimal development of water resources. An appropriate strategy is required to develop water resources with planning based on conjunctive use of surface and subsurface water resources. Integrated remote sensing and GIS can provide the appropriate platform for convergent analysis of diverse data sets for decision making in groundwater management and planning. Sustainable water resources development and management necessarily depends on proper planning, implementation, operation and maintenance. The interpretation of remote sensing data in conjunction with conventional data and sufficient ground truth information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydrologic characters that may serve as direct or indirect indicators of the presence of ground and surface water. Remotely sensed data provides unbiased information on geology, geomorphology, structural pattern and recharging conditions, which logically define the groundwater regime of an area. Groundwater resource potential has been evaluated in Pulivendula-Sanivaripalli, Kadapa district, Andhra Pradesh, India, using remote sensing and Geographic information system. Under this study, three thematic maps viz. Geological map (Lithology and Structure), Geomorphological map and Hydro morphological maps were prepared. These thematic maps have been integrated with the help of GIS. Appropriate weightage has been assigned to various factors controlling occurrence of groundwater to assess the groundwater potential in each segment of the study area. The area has been classified into high potential, moderate potential, low potential and non-potential zones landforms ground water development on the basis of hydromorphological studies. Some of the favorable locations have been suggested to impound the excessive run off so as to augment the ground water resources of the area.
**Keywords:** Hard rock aquifer, Evaluation of groundwater potential, GIS, Remote sensing, Pulivendula, Kadapa district.

## I. INTRODUCTION

Water resources on land are very unevenly distributed both spatially and temporally. Idiosyncrasies of monsoon and diverse physiographic conditions give rise to unequal distribution of water. Over the years, increasing population, urbanization and expansion in agriculture has accentuated the situation. The dependency on the groundwater is expected to increase in future and the requirement in 2050 is estimated about more than three times to present level due to increase in population (Gupta and Deshpande, 2004). The aftermath of unscientific exploitation of groundwater is that we are moving towards water stress condition. Despite being a very important part of the nation's growth, water resources analysis has been fragmentary. An integrated study covering the aspect of watershed management and groundwater recharge is a crucial requirement of the present day (Choudhury, 1999).

Remote sensing and GIS are playing a rapidly increasing role in the field of hydrology and water resources development. Information from satellites is becoming more and more important for environmental research. An important part of this information concerns water – an element most essential for man, its phases and peculiarities. Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface (Choudhury, 1999). One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Saraf, 1999). However, the use of remote sensing technology involves large amount of spatial data management and requires an efficient system to handle such data. The GIS technology provides suitable alternatives for efficient management of large and complex databases. Watershed monitoring and management has been found to be economical and faster with the usage of the capabilities of a GIS. Erosion and sediment yield from the watershed can be assessed using a suitable model in raster GIS (Garg, 1991). On the basis of erosion and other environmental parameters, watershed prioritization can be carried out in GIS. In recent time many workers such as Raghuvansi et al., 2008; Prasad et al., 2008;Rokade et al., 2007; Jha et al., 2007 ; Leblanc et al., 2007; Saraf et al., 2004 and Teeuw,1995 used GIS for evaluation and management of groundwater resources of the various terrains. One of the greatest advantages of using remote sensing data for groundwater investigation and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Jaiswal et al., 2003; Murthy, 2000; Saraf and Choudhuray, 1998; Krishnamurthy et al.,1996).

A watershed, which is an area from which runoff resulting from precipitation flows past a single point into large stream, river or lake is taken as a unit for the study of drainage characteristics. Drainage system refers to the origin and development of streams through time. The location number and flow directions of different streams of a drainage system depends on the nature of slope, structural control, lithological characteristics, tectonic factors, climatic characteristics, vegetal characteristics etc. Geology, relief and climate are the primary determinants of running water ecosystems functioning at the basin scale (Mesa, 2006). Detailed morphometric analysis of a basin is a great help in understanding the influence of drainage Morphometry on landforms and their characteristics (Sreedevi P.D et al.,2009). Thus the study of drainage characteristics through morphometric analysis (quantitative description of the drainage basin geometry) of a watershed in a region gives much information regarding the denudational history, subsurface material, geological structure, soil type and vegetation status of that region, which play a crucial role in formulating a plan for watershed management.

Multidisciplinary scientific integrated surveys were carried out to quantify the resource potential of the area, to know the status of exploitation of resources and to identify any degradation due to unscientific management. The investigation agents broadly outline the development options based on available resources. The present study aims to study the present status of water resources, land resources, cropping patterns, forest cover etc., using satellites data, collateral data and field data and identifying the problems of environmental resources depletion and causes of depletion and to develop and test an integrated remote sensing and GIS technique in watershed planning and groundwater recharge investigations.

## II. DATA USED AND METHODOLOGY

The study used a satellite geocoded imagery (IRS P6 LISS-III), acquired June 2001 with spatial resolution of 30 meters, Survey of India toposheet 57 J 03 on 1:50,000 scale and tracing sheets. The digital data were processed for geometric and radiometric corrections using ERDAS image processing software. A number of softwares such as Arc GIS version 9.0, ERDAS Imagine version 9.1 and Microsoft office processing tools (Word, Excel) are used in the study. For processing ERDAS was considered useful. The study was applied both visual and digital Landsat image interpretation in order to generate various thematic maps respectively. The field equipments and tools used for fieldwork include Brunton compass, Garmin e Trex H (GPS) receiver, slope meter, digital camera, soil knife, hammer, and measuring tape. The main methodology of the research is to prepare thematic maps with the application of remote sensing and GIS software. The actual work involved a comprehensive gathering of information and linked to the related activities. The development and planning of such a vast area for a proposed project requires various data information from the field to identify the terrain characteristics, etc. This is composed of getting use of space images and GIS, complemented with truthing fieldwork as well as making use of the available information from several concerned agencies and sectors in the study area. The flow chart showing the methodology of land resources analysis is given in fig.2.

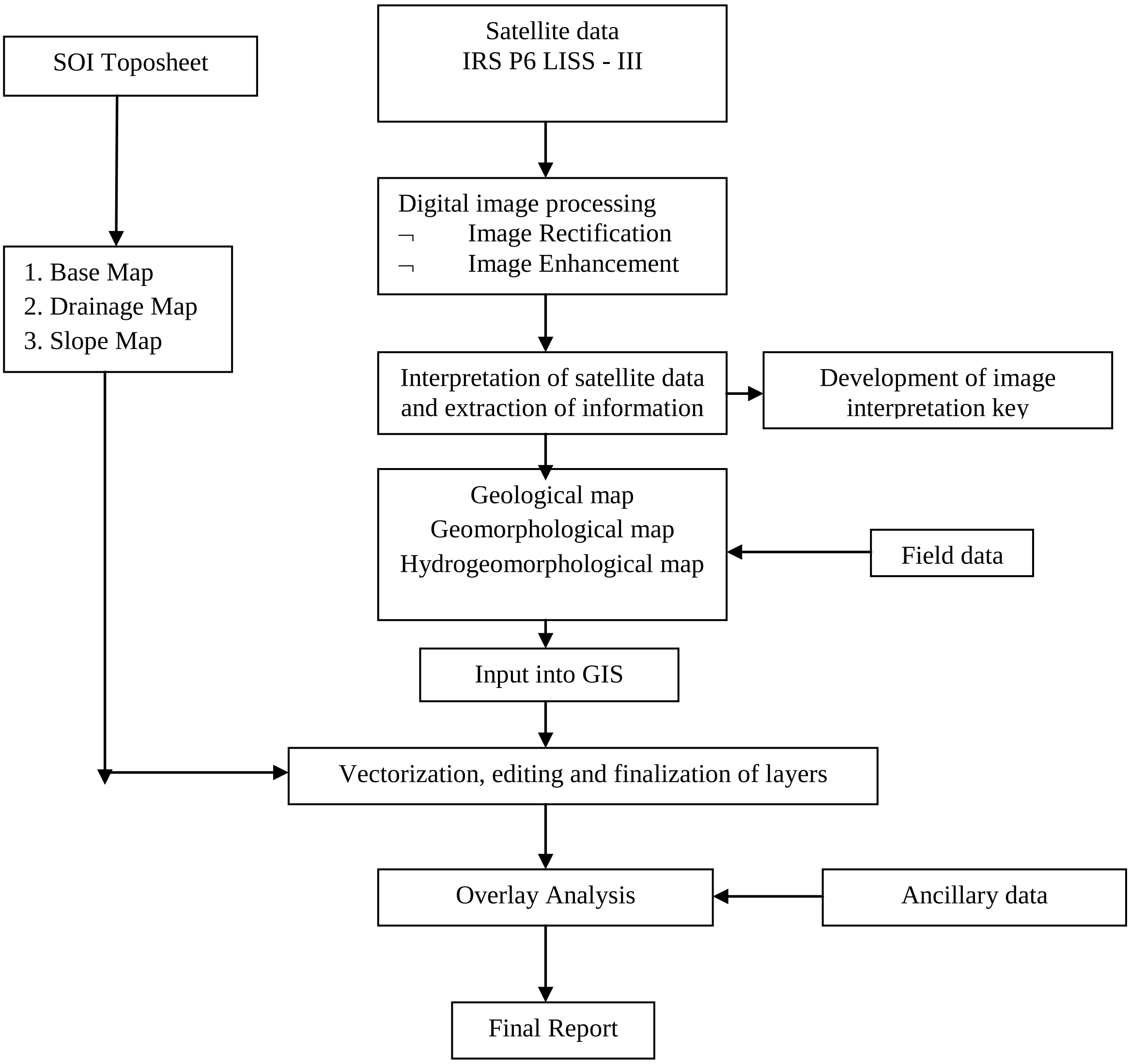



**Figure: 2 Flow chart showing the broad methodology**

A watershed is a geo-hydrological unit, which drains into common point. The watershed approach is a project based, ridge to valley approach for in situ soil and water conservation, afforestation etc. Unit of development will be a watershed area of about 500 ha. The thematic maps generated from satellite data for different themes such as land use/land cover, hydro geo -morphology, soils etc. may be used for selection of a watershed area. The project will primarily aim at treatment of non-forest wastelands and identified drought prone and desert areas.

Water management has increasingly been realized to be an essential component of sustainable water development. While no-one argues with the desirability of proper watershed management, achieving it has not been an easy task. It requires concurrent accomplishment of many tasks, among which are strict control of land-use practices, afforestation and forest management, and implementation of appropriate soil and water conservation practices.

**Criteria for Selection of Watersheds:-**

The following criteria may broadly be used in selection of the watersheds:

(a) Watershed area may be about 500 ha. However, if on actual survey, a watershed is found to have slightly less or more area, the total area may be taken up for development as a project.
(b) In case a watershed falls in two villages, it should be divided into two sub watershed areas confined to the designated villages. Care should be taken to treat both the sub watershed areas simultaneously.
(c) Watershed, which has acute shortage of drinking water.

(d) Watershed, which has a large population of scheduled castes/scheduled tribes dependent on it.
(e) Watershed that has a preponderance of non-forest wastelands/degraded lands.
(f) Watershed, which has a preponderance of common lands. However, in view of the fact that watershed development aims at poverty alleviation by improving productivity of land and generation of employment, projects not having preponderance of common lands may also be considered for sanction provided there is adequate justification.
(g) Watersheds where actual wages are significantly lower than the minimum wages.
(h) Watershed, which is contiguous to another watershed that has already been developed/ treated.
(i) Watersheds where People's participation is assured through raw materials, cash, contribution on labour etc. for its development as well as for the operation and maintenance of the assets created.

## III. THEMATIC MAPS PREPARED FOR THE DEMARCATION OF THE WATERSHED

**Preparation of Land Use – Land Cover Map:**

The knowledge of land use and land cover is very important for land planning and land management activities (Anji Reddy, 2002). The land use and land cover system adopted in mapping of earth surface features is a system derived from the United States Geological Survey (USGS) land use and land cover classification system. After preparation of the land use / land cover map, we can study the whole area, and would be easy to demarcate a watershed in the much needed locations. Land use / land cover map prepared using satellite imagery is shown below.

**Preparation of Slope Map:**

Slope of any terrain is one of the factors controlling the infiltration of groundwater into subsurface, hence an indicator for the suitability for groundwater prospect (Horton, 1932). In the gentle slope area the surface runoff is slow allowing more time for rain water to percolate, whereas high slope area facilitates high runoff allowing less residence time for rainwater and hence comparatively less infiltration (Montgometry, 2006). Slope analysis is an important parameter in geomorphic studies. The slope elements, in turn are controlled by the climatomorphogenic processes in the area having the rocks of varying resistance.

First, mark the horizontal distances for all the slope classes as per the scale of toposheet and specific contour interval on a strip of paper. Measure the contour separation perpendicular to the contour with the help of a graduated strip already prepared and assigns slope class to the space between the contours. Verify the break in slopes with the help of toposheets. Demarcate the slope classes with pencils of appropriate colors on tracing paper overlay on the toposheet. Table1 shows the slope angle, horizontal distance and colour scheme delineated on toposheet of 1: 50,000 scale with 20m contour interval.

**Preparation of Drainage Map:**

A drainage map based on the SOI toposheet (1:50,000 scale) and satellite imagery was prepared using ARC GIS-module. The number of streams present in the area is demarcated as shown in the adjacent map.The water category includes streams, lakes, canals and reservoirs. The major tanks/reservoirs in the study area present around Lakkasamudram, Reddivaripalli, Sanivaripalli, Gollapalle etc in Southern part of imagery only. Streams, canals are generally located in Northern part of imagery.Maddaleru river is flowing towards NW direction in the Southern Western part of imagery. The villages adjacent to the river are Sanivaripalli, Adavibrahmanpalli, Nakkalapalli, Dorigallu, Indukuru and Maartadu.

**Hydromorphology:**

Ground water occurrence in hard rock terrain is confined to certain landform and fractures. As the aquifer material and alluvium is usually confined to certain landform. Further lineaments, landform development and their elevation and their elevation and distribution is controlled by faults, streams, segments and fractures. Structurally exclusive litho units like dykes and acidic intrusive, it is evident from the above factors it is imperative that detail landform mapping cum classification elevation and an understanding of morpho techniques is imperative for ground water exploration in hard rock terrain.

It is a map which depicts various aspects of geomorphology, geology and character of aquifers so as to have an idea of the possibility of ground water in different units. The hydromorphologic map is to be prepared by demarcating the geomorphic units as the landforms as an important input for land management, soil mapping and identification of potential zones of ground water occurrence. The geological details like lithology, rock types and structural details are also depicted on this map since this information is necessary in identifying the ground water potential. For instance pediment, pediplain without fractures, joints and lineaments normally moderate to poor ground water prospect whereas the same geomorphic unit with a network of fractures, joints indicate good ground water prospects. Similarly pediplain area of crystalline/metamorphic rock is marked by poor to moderate ground water prospect whereas the same unit in sandstone or limestone sedimentary rock may have a good to moderate prospect.

The landforms in the study area is grouped under four categories as potential landform, moderate landform, low potential landform and non potential landform. The basis for classification is degree and density, intensity of the structural disturbances such as the extend nature of lineaments, landforms and depth of weathering.

**High Potential Landforms:**

All lineaments passing through pediplain dissected pediment and structural value as seen in the area Ambakapalle, Gulcheru quartzite, Kottala. High potential zones are observed at intermontanne valleys, in the Nallagondavaripalle. High potential zones are recognised in the imagery along fault zones. There are two major faults occur in the imagery, one in Nallapureddypalle, another fault trending NNE to SSW, in Nallapureddeypalle. Another high potential area is observed in the imagery around Lambadi tanda, because of intersection of lineaments and faults. Another high potential zone is observed at Gunakanapalli, where faults are intersected EW direction. In the southern part of area along the stream and one fault zone intersecting the stream, that high potential area is observed in Siddayagaripalle.

**Moderate Potential Landforms:**

The Geomorphological unit pediment has sometimes fractures controlled by joints, lineaments. There the moderate potential zone is available. The areas are observed in Kottapalle, Nallapasettipalle. Deeply weathered pediments, stream valleys controlled by structures and impermeable, Impervious lithounits dissected by lineaments places has seen in Mallepalle, Kottala, Buddayagaripalle.

**Low Potential Landforms:**

These include hard structural hills dissected by wide space joints. Pediplain has sometimes controlled by joints, fractures, lineaments, there the low potential zones are available, which are observed in chatram and sourounding places.

**Non Potential Landforms:**

Non potential areas are observed in Boymusalayyagaripalle, Chintalayyagari palle, Nallappasettipalle, Ramnagar, Rochavaripalle, Mallappakanuma, Nakkalapalle tanda etc.

**Watershed Demarcation and Morphometric analysis:**

After studying the total conditions of the area it is concluded that, the region is very poor in water resources, top priority should be given for its development. The ground water distribution in the study area is not uniform and it depends on the drainage pattern. For this watershed, near the village Krishnamgaripalli is demarcated so as to fulfill the needs. The watershed area is represented between Eguvapalli in the west and Krishnamgaripalli in the east. The demarcated watershed is named after Krishnamgaripalli village. The watershed covers an area of 332.5 sq. km (Fig. 4). It enjoys a tropical climate with rainfall between 100-150 cm annually.

**Morphometric Analysis:** Morphometry is the measurement and mathematical analysis of configuration of Earth surface, shape and dimensions of its landforms. The main purpose of the work is to discover holistic stream properties from the measurement of various stream attributes. The quantitative drainage analysis is done aspect wise such as linear aspects and aerial aspects.

**LINEAR ASPECTS**

1) **Stream order (U):** The first step in drainage basin analysis is designation of stream orders. The stream order is a measure of the degree of stream branch within a watershed. Each length of stream is indicated by its order for example first order, second order and third order etc. In the given watershed 4 stream orders have been calculated.
2) **Stream number (Nu):** The count of stream channel in its order is known as stream number. The number of streams decreases as the stream order increases. The demarcated watershed has the following stream orders and stream number.

| Si. No. | Stream order | Stream number |
|---|---|---|
| 1. | First order | 100 |
| 2. | Second order | 20 |
| 3. | Third order | 6 |
| 4. | Fourth order | 1 |

3) **Bifurcation ratio (Rb):** Bifurcation ratio is defined as the ratio of the number of streams one order to the number of the next higher order. It is given as below:

Bifurcation ratio (Rb) = Nu / (Nu+1)

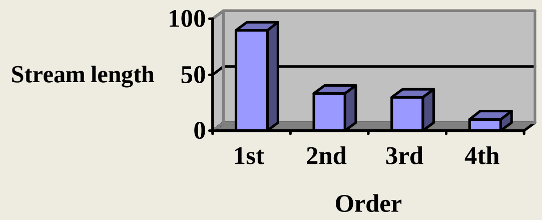
| No of order | Bifurcation ratio (Rb) |
|---|---|
| First order | 4.76 |
| Second order | 2.85 |
| Third order | 3 |

Bifurcation ratios characteristically range between 3 and 5. This indicates that in watershed geologic structures do not distort the drainage pattern. The hypothetical minimum value of 2 is rarely approached under natural conditions. Abnormally higher bifurcation ratios might be expected in regions of steeply dipping rock strata where narrow strike valleys are confirmed between hogback ridges.

4) **Stream length (Lu):** Mean length of a stream channel segments of order U is a dimensional property revealing the characteristic size of components of a drainage network and contributing basin area.

| No of order | Stream length (Lu) |
|---|---|
| First order stream | 98.75 |
| Second order stream | 33.25 |
| Third order stream | 29.75 |
| Fourth order stream | 10.25 |

**Figure showing relationship between stream length and stream order.**




5) **Stream length ratio (RL):** Stream length ratio is the ratio of main length (Lu) of segments of order U to main length of segments of the next lower order (Lu-1). Here the stream length ratio tends to be constant throughout the successive orders of a watershed. It indicates that stream lengths are decreasing with increase in the order of stream.

RL = Lu/(Lu-1)

| No of order | Stream length ratio (RL) |
|---|---|
| Second order stream | 1.85 |
| Third order stream | 1.66 |
| Fourth order stream | 2.06 |

## IV. AERIAL ASPECTS

1. **Drainage area:** Drainage areas are defined as the area which contributes water to a particular channel or set of channels. The basin area is one of the important parameters like that of the length of the draining the basin. In the demarcated watershed the total drainage area or basin area is about 332.5 sq.km.

**2. Drainage net:** Drainage net is related to the hydraulic geometry of stream channel. If the streams are relatively for apart then, the drainage net is less dissected. If the streams relatively low spaced then the drainage net is intensively dissected. Here in the Krishnamgaripalli watershed the drainage net is less dissected because the streams are relatively far apart.

**3. Drainage density (Dd):** Drainage density is the total length of the all streams in the basin to the area of whole basin. It is calculated as here under:

Dd = ε Lu/Au

= 162.95/332.5

= 0.490 km/sq. km

The low values of drainage density indicates the region is high resistant of highly permeable sub soil materials dense vegetation cover and low relief.

**4. Drainage texture:** Drainage texture is the measure of the closeness of the channel spacing and related directly to the drainage density. The drainage density values of the watershed are 0.490 km/ sq. km. i.e., less than two. Therefore the drainage areas have very coarse drainage texture.

## V. Conclusion:

From the above discussions it is concluded that Remote sensing and Geographical Information system (GIS) are very effective tools in the study of drainage characteristics in a region. Different components of watershed, such as drainage, physiography, land use etc., through remote sensing data in combination with SOI topographic sheets help to assess their potential land use. The total drainage area of basin is about 332.5 sq.kms with very coarse drainage texture and the drainage net is less dissected because the streams are relatively far apart. Bifurcation ratios characteristically range between 3 and 5 for watershed in which geologic structures do not distort the drainage pattern. Low values of drainage density indicates that the watershed region is high resistant of highly permeable sub soil materials dense vegetation cover and low relief.

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