Integration of Hydrogeological Factors for Identification of Groundwater Potential Zones Using Remote Sensing and GIS Techniques for Gadwal Basin, Telangana State

Vishnu P[1], Narsing Rao A[2]

[1]*Project Fellow, Department of Geology Osmania University, Hyderabad, India.*

[2]*Professor, Department of Geology, Osmania University, Hyderabad, India.*

Corresponding Author: vishnupulakaram@gmail.com

Abstract: Remote sensing data can be used as a reconnaissance and features identification tool for identifying surface and sub-surface water potential zone. The present study has been carried out to evaluate the potential zones for groundwater targeting using an integrated remote sensing data, Survey of India (SOI) topographical sheets and field verification. Four features (geomorphologic units, slope, drainage density and lineaments density) that influence groundwater occurrence were extracted and integrated to evaluate the hydro geomorphological characteristics of the study area and demarcate the groundwater potential zones. Thematic maps of the extracted features were prepared and integrated through geography information system (GIS) environment. The groundwater potential map was prepared by overlaying the thematic layers. Weightage percentages were assigned to the different parameters according to their relative importance to groundwater potentiality. The integrated map of the area shows different zones of groundwater prospects, viz. Good (45% of the area), Moderate (16% of the area), while poor made up of (33% of the area) and water body (6% of the area).

Key Words: —*Geomorphologic units, Hydrogeology, Remote sensing, GIS, Groundwater, Thematic layers.*

I. INTRODUCTION

Groundwater is a form of water held under the ground in the saturated zone that fills all the pore space of soils and geologic formations. It is formed by rainwater or snowmelt water that seeps down through the soil and into the underlying rocks. It is the major resource of water supply for about half of the nations. It plays a key role in nature. It provides more than half of humanity's freshwater for everyday uses such as drinking, cooking, and hygiene, as well as thirty percent of irrigated agriculture and industrial development. Groundwater potential zones can be said to be water bearing formation of the earth crust that acts as conduits for transmission and as reservoirs for storing water. Its identification and location are based on indirect analysis of some observable terrain features such as geologic, geomorphic, landforms and their hydrologic characteristics.

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Conventional approach of groundwater exploration using geological, hydrogeological, and geophysical methods are expensive due to high cost of drilling and time-consuming investigation. Furthermore, these methods of surveys do not always account for the different factors that control the occurrence and movement of groundwater. Remote sensing technique is popular due to several advantages of spatial and spectral data, having access to large coverage and inaccessible areas with regular revisit capability. It is also rapid and cost-effective tool that integrates valuable data on geology, geomorphology, lineaments, slope, morphometric etc. that helps in evaluating groundwater potential zone. The use of remote sensing and GIS techniques is a fast-emerging field in groundwater resource identification, mapping and planning. Remote sensing provides an opportunity for better observation and more systematic analysis of various geomorphic units, landforms, lineaments and drainages, due to its synoptic and multispectral coverage of a terrain. The techniques is increasingly used in prospecting for groundwater potential zones, because of their ability to identify and outline different ground features that may serve as direct or indirect indicators of the presence of groundwater resources. Reviewed papers on the application of remote sensing and GIS in groundwater potential mapping can be found in more recent studies have been carried out on the use of remote sensing data and GIS tools for defining the spatial distribution of different groundwater prospecting classes on the basis of hydro geomorphological units and other associated parameters. In this study the technique of remote sensing data and GIS were used to evaluate the hydro geomorphological characteristics of the study area and demarcate the groundwater potential zones for investigation and exploration of the resource in shallow aquifer using thematic maps of geomorphologic units, slope, drainage density and lineaments density. Result obtained from this analysis will help to narrow down the targeting area for further geophysical exploration for the resource.

II. Study Area

The study area is situated between 77°39’41.599” to 77°45’25.932” East longitudes and 16°12’23.804” to 16° 19’20.646” North latitudes forms part of survey of India toposheet numbers 56H/11, 56H/12, 56H/15, 56H/16. The total area covered is 83.75 Sq kms. Geologically the study area is situated in the Krishna basin in South India. The relief ranges from 324 m over the plains to the highest elevation of 371 m. The area is covered by thin surface soil with varying thickness ranging from 1- 5 m and few exposures of granitic hills.

The area is mainly flat and gently undulating terrain except in few parts. The occurrence and movement of groundwater is mainly restricted within the weathered and fractured granites. The amount of water that can be extracted from the fractured zones depends on the size and location of fractures. The climatic condition comprises of a mean temperature ranging from 19.3°C in January to above 41.2°C in May. The rainfall is uncertain and erratic with about 85 percent of the annual rainfall in the monsoon period, with an annual average of about 542 mm. The Soils of the area are excessively drained, permeable and have low to medium productivity. The red soil is comprised mainly of red loam and is very easy for cultivation purposes and responds to good manure and other treatments. This soil is particularly suited for growing vegetables.

The lithology of this study area consists of basic, intermediate and volcanics. Bands of iron formations, basic dykes, quartz veins and pegmatites. And hornblende within the schist belt. The major rock types are Granites and Gneisses, Amphibolites, Pink Granites, Epidote veins in and around dharur village to chinnachintharevula village.

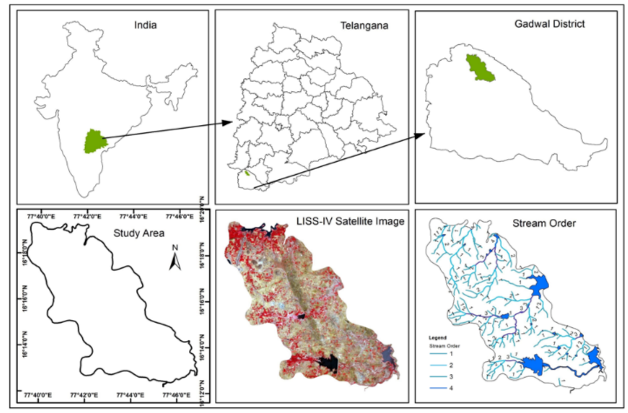
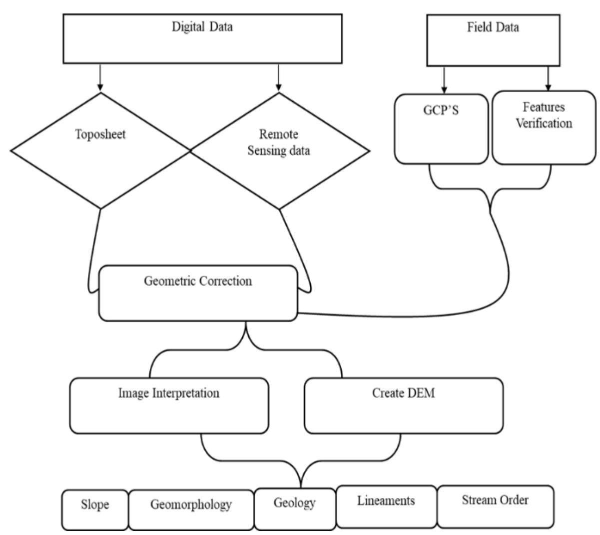


Fig.1. Location, LISS-IV Satellite Image and Stream order map of the study area

III. Material and Methods

Remote sensing data which comprises of 5.8 m resolution IRS-1D LISS-IV data, Digital Elevation Model (DEM) and Landsat image along with Survey of India (SOI) toposheets and field observation data were used in this study. The methodology includes generation of thematic maps showing drainage pattern, lineament, slope and geomorphologic units through processing and visual interpretations of remote sensed data. The identification and delineation of various units on the thematic maps was based on tone, texture, shape, colour etc. Thematic layers of geomorphologic units, slope, lineament and drainage density were generated and integrated in GIS environment to determine suitable zones for groundwater prospecting.



3.1 Hydro geomorphological Analysis

The relief, slope, depth of weathering, type of weathered material, nature of the deposited material and the overall assemblage of different landforms play an important role in defining the ground water regime, especially in the hard rocks and the unconsolidated sediments. Hydro geomorphological investigations include the delineation and mapping of various landforms, drainage characteristics and structural features that could have a direct control on the occurrence and flow of groundwater. Many of these features are favorable for the occurrence of groundwater and are classified in terms of groundwater potentiality as poor, moderate and good prospecting zones.

IV. RESULT AND DISCUSSION

The result of the study has brought out eight distinct geomorphic units, which are discussed systematically here with respect to groundwater prospect;

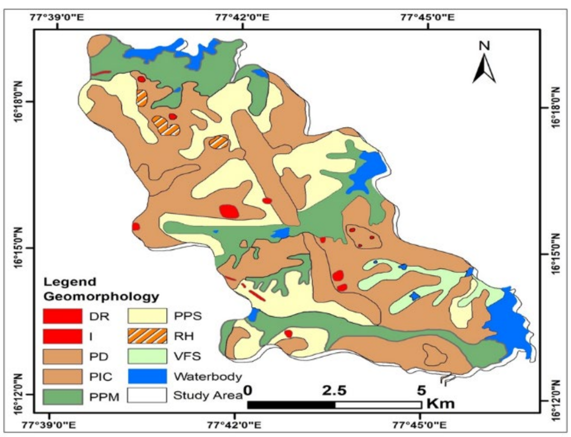


Fig.2. Map of geomorphic units of the study area

4.1 Geomorphology of the Study Area

The earth's surface forms are primarily due to hypogene or endogenous processes. Geomorphology is the science and study of landforms on the earth. Today, all watershed management planning processes in most of the countries are based on geomorphological units. The Geomorphology unites are dynamic in nature as they are affected by various human activities, including the expansion of cultivated and irrigated lands, industrialization, urbanization and others because it needs to monitoring, mapping for watershed management. Geomorphic units are classified on the basis of differential erosion processes. Mainly pediments and pediplain shallow of granites are predominant landforms.

Table.1. Features wise Percentage of Geomorphology units in Study Area

S. No	Units	Geomorphology	Percentage of Area
1	4	DR - Dolerite Ridge	0.12
2	12	I - Inselberg	0.71
3	11	PD - Pediment	25.87
4	5	PIC - Pediment Inselberg Complex	14.03
5	5	PPM - Pediplain Moderate	16.98
6	7	PPS - Pediplain Shallow	18.01
7	3	RH - Residual Hill	0.73
8	2	VFS - Valley Fill Shallow	2.59
9	12	Waterbody	4.39

Source: LISS IV Image

4.1.1 Dyke Ridge (DR): These landforms are generally acted as barriers for ground water movement. Dyke ridges are there in the present study area. It covers an area of 0.12 % in study area.

4.1.2 Inselberg (I): The term applied only to arid landscape features. However, the term inselberg has since been used to describe a broader geography and range of rock features, leading to confusion about the precise definition of the term. The term has been defined as "steep-sided isolated hills rising relatively abruptly above gently sloping ground". This definition includes such features as buttes; conical hills with rectilinear sides typically found in arid regions; regolith-covered concave-convex hills; rock crests over regolith slopes; rock domes. It covers an area of 0.71 %. in study area.

4.1.3 Pediment (PD): In the study area, pediments are gently sloping areas or erosion surface of bed rock. Pediments may or may not be covered by a thin layer of alluvium and are mostly developed at the foot of the hills. Pediment area is covered middle portion of the study area and in the southern portion of the study area. These landforms are fine texture. It covers an area of 25.87 % in study area.

4.1.4 Pediment Inselberg complex (PIC): This complex consists of small isolated like standing out prominently in a form because of their resistance to weathering. The pediments dotted with a number of inselbergs which cannot be separated and mapped as individual units are referred to as pediment inselbergs complex having moderate to strong slope. These are controlled by structure like joints, fracture and lineaments. The difference between the pediment inselberg complex and pediment inselberg is that in case of pediment inselberg, it is a single isolated low relief hill but in the case of pediment inselberg complex it is more than one isolated low relief hill but occurring closely. It covers an area of 14.03 % in study area.

4.1.5 Pediplain Moderately (PPM): Flat and smooth buried pediplain and pediment with moderately thick overburden are called pediplain moderate. Thickness of weathered material is high compare to pediplain shallow. The weathered materials are chiefly constituted by gneisses and migmatites. They are extended towards northeastern side of the study area. It covers an area of 16.98 % in study area.

4.1.6 Pediplain shallow (PPS): They are formed by coalescence of buried pediments, where a thick overburden of weathered materials accumulates. The intensely weathered areas of granitoids constitute these landforms. Varying thickness of shallow over burden can be observed in such areas. Weathering of the bedrocks has been initiated by fractures, joints and minor lineaments. These land forms are more area spread in study area. It covers an area of 18.01 % in study area.

4.1.7 Residual Hill (RH): Residual hills are the end products of the process of pediplanation, which reduces the original mountain masses into a series of scattered knolls standing on the pediplains. We can also say that the hard rock’s left behind after erosion are then called residual hills Residual hills occur as small hills comprise of more resistant formations formed due to differential erosion are found in the western and southern portions of the study area. In the imageries, these features occur as dark greenish brown patches with forest cover. It covers an area of 0.73% in study area.

4.1.8 Valley Fill Shallow (VFS): Alluvium or other material occupying areas below mountain slopes. It covers an area of 2.59 %. in study area.

V. LINEAMENTS DENSITY MAP

A lineament is usually defined as a straight or somewhat-curved feature in an image. In a satellite image, lineaments can be the result of man-made structures such as transportation networks (roads, canals, etc.), or natural structures such as geological structures (faults/fractures, lithological boundaries, unconformities) or drainage networks (rivers). Generally, lineaments are underlain by zones of localized weathering and increased permeability and porosity. Previous studies have revealed a close relationship between lineaments and groundwater flow and yield. Meanwhile, some researchers studied relationships between groundwater productivity and the number of lineaments within specifically designated areas or lineament density rather than the lineament itself. Therefore, mapping of lineaments closely related to groundwater occurrence and yield is essential to groundwater surveys, development, and management. Lineaments are usually extracted and interpreted from satellite imagery manually or automatically. The extracted linear features were further screen for non-geological features such as roads, fences, field boundaries, by comparing the lineament map with the corresponding toposheet map of the survey area and field verification, thereby deleting non-geological features and leaving only possible geological lineament. Lineament density map was prepared by dividing the study area into 1 km/1 km grids. The total length of lineament in each grid was measured and plotted in the respective grid centers. These values are joined by isolines to prepare a lineament density map as shown. The extension of large lineaments representing a shear zone or a major fault and can extend from hilly terrain to alluvial terrain. It may form a productive groundwater reserve. Similarly, intersection of lineaments can also be probable sites of groundwater accumulation. Therefore, areas with high lineament density may have important groundwater prospects even in hilly regions which otherwise have nil groundwater prospects than area with low density.

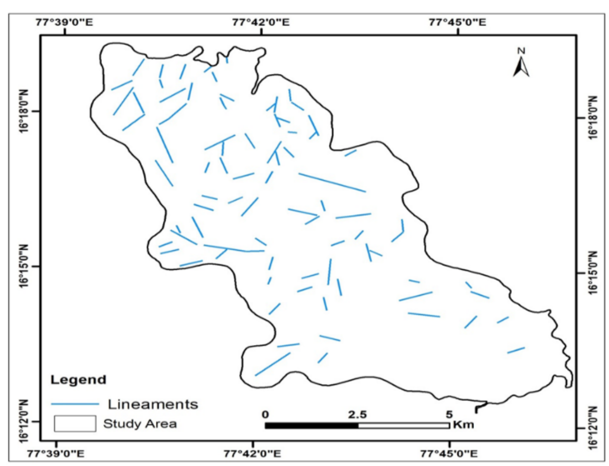


Fig.3. Lineament map of the study area

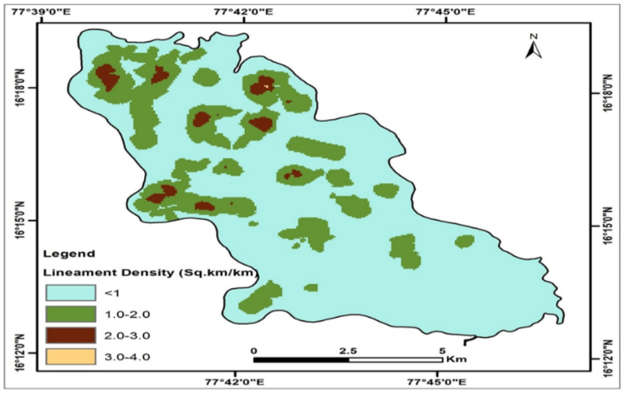


Fig.4. Lineament density map of the study area

VI. Slope

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 rock of varying resistance. Slope plays a key role in groundwater occurrence as infiltration is inversely related to slope. Slope map of the survey area was generated from DEM data using spatial analyst tool in Arc GIS. The slope varies between zero and 36 degree. Area of high slope value will cause more runoff and less infiltration thus, have poor groundwater prospect compared to low slope region.

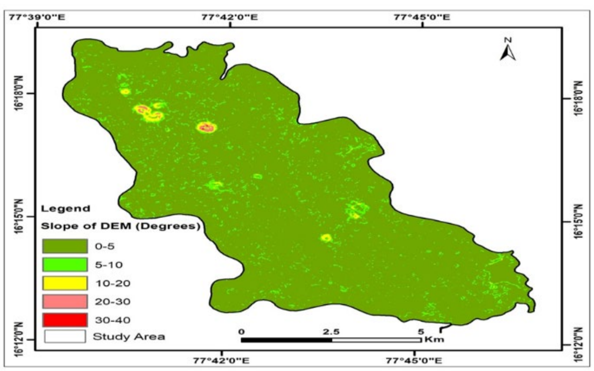


Fig.5. Slope map of the study area

VII. Drainage Density Map

The drainage is expressed as density map for easy characterization of runoff and infiltration of rainwater in the survey area. The drainage density map was prepared in similar way as the lineament density map by dividing the study area into 1 km/1 km grids. The total length of stream in each grid was measured and plotted in the respective grid centers. These values are joined by isolines and the resultant density map was plotted in Arc GIS. Drainage density is an inverse function of permeability, and therefore it is an important parameter in evaluating the groundwater zone. Area of high drainage density indicates less infiltration which favours runoff and hence acts as poor groundwater prospect, because major part of the rainwater over the area is lost as surface runoff with little infiltration for recharging the groundwater reservoir. On the other hand, low drainage density areas permit more infiltration and recharge to the groundwater reservoir, hence can be described as a good potential zone for groundwater prospect.

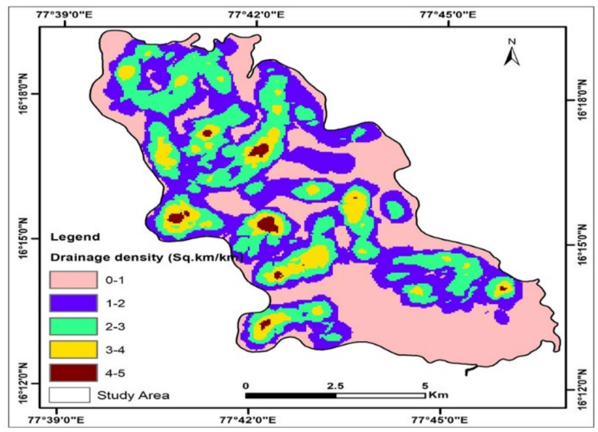


Fig.6. Drainage density map of the study area

VIII. Mapping Groundwater Potential Map

In this study the weighted index overlay analysis (WIOA) using a multi-criteria approach was used to investigate the potential zone for groundwater prospecting through integration of hydro geomorphological map, slope, lineament and drainage density map. All the thematic maps generated for the study area were integrated and projected to a common co-ordinate system through spatial analysis in Arc GIS and reclassified for weighted index overlay analysis (WIOA). The weighted index overlay analysis is a technique that applies a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis using a multicriteria approach. This analysis according to has no standard scale, but incorporates human judgment for its efficiency. For this work, each of the thematic maps was assigned a weight that represents its importance in respect to groundwater reserve based on criteria of previous work. Theme weight and class rank assigned to the different parameters considered for groundwater prospects evaluation in this study are given in Table1- 2

Table.2. Weightage and class rank of different parameters used for groundwater prospects

Theme	Classes	Rank	Weight
Hydro geomorphologic unit	Dolerite Ridge	8	35
	Inselberg	7	
	Pediment	1	
	Pediment Inselberg Complex	4	
	Pediplain Moderate	3	
	Pediplain Shallow	2	
	Residual Hill	6	
	Valley Fill Shallow	5	
Slope	0-5	1	20
	5-10	2	
	10-20	3	
	20-30	4	
	30-40	5	
Drainage	0-1	5	15
	1-2	4	
	2-3	3	
	3-4	2	
	4-5	1	
Lineament	<1	1	30
	1-2	2	
	2-3	3	
	3-4	4	

The groundwater potential zones were grouped into Three different potential zones viz; Good, moderate, and poor. High groundwater potential zones are seen at the central towards the northeastern, south part and constitute 45 % of the study area. This zone is associated with geomorphologic units of the pediments, Pediment inselberg complex and pediplain sallow with high lineament density in the southern part of the map. Moderate groundwater potential zones occupy the area of about 16 % of the total study area, scattered all over the map. The poor potential zone constitutes about 33 % of the study area and are mostly seen along denudational hills with steep slope and part of the pediments units that are associated with high drainage density.

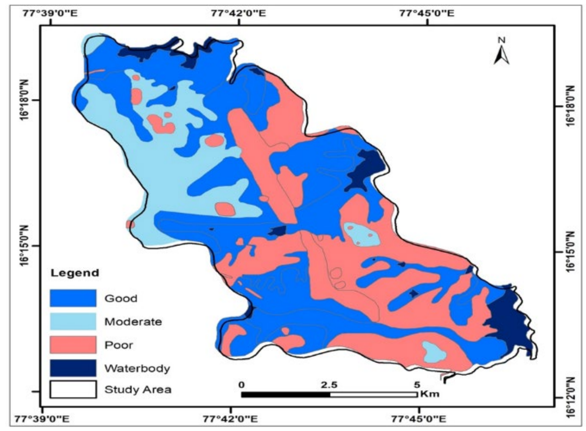


Fig.7. Map of groundwater potential zone

IX. Conclusion

The study area was able to reveal the use of remotely sensed data in identifying favorable zones for groundwater exploration in hard rock terrain. Groundwater prospects zonation based on this study clearly indicated that the combination of pediplain sallow, pediplain moderate, lineament and gentle slope areas are the favorable terrain conditions having good groundwater potential. Pediplain zones have much better prospects. The drainage density of the study area confirms to geohydrological conditions suitable for better surface permeabilities. On the whole, the data suggests good prospects for infiltration measures, presuming that such measures are in line with local hydrogeological conditions. The study area has good potential to harness groundwater.

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REFERENCES

[1]. Obi Reddy, G.P., Chandra Mouli, K., Srivastava, S.K., Srinivas, C.V. and Maji, A.K., “Evaluation of ground water potential zones using remote sensing data—a case study of Gaimukh watershed, Bhandra district, Maharashtra”, J Indian Soc. Remote Sens., 28. 19-32. 2000.

[2]. Singh, A.K. and Prakash, S.R., “An integrated approach of remote sensing, geophysics and GIS to evaluation of groundwater potentiality of Ojhala subwatershed, Mirzapur district, UP, India”, Map India conference. 2003.

[3]. Zuppi, G.M., “The groundwater challenge. In: Clinic C, Musu I and Gullino M.L (eds). Sustainable development and environmental management. Experience and case studies”, Dordrecht, Springer, 49-64. 2007.

[4]. Meijerink, A.M.J., “Groundwater. In: Schultz, G.A, Engman ET (eds) Remote sensing in hydrology and water management” Springer, Berlin, pp 305-325. 2000.

[5]. Nag, S.K. and Ghosh, P., “Delineation of groundwater potential zone in Chhatna Block, Bankura District, West Bengal, India using remote sensing and GIS techniques”, Environ Earth Sci., 2012.

[6]. Nag, S.K., “Application of lineament density and hydrogeomorphology to delineate groundwater potential zones of Baghmundi block in Prulia district, West Bengal”, Jour. Indian Soc. Remote Sensing, 33, 521-529. 2005.

[7]. Agarwal, E., Agarwal, R., Garg, R.D. and Garg, P.K., 2013. Delineation of groundwater potential zone: An AHP/ANP approach. J. Earth Syst. Sci. 122(3), 87-898.

[8]. reedevi, P.D., Owais, S., Khan, H.H. and Ahmed, S., “Morphometric Analysis of a Watershed of South India Using SRTM Data and GIS”, J. Geological Society of India 73, 543-552. 2009.

[9]. Raghu, V. and Reddy, K.M., “Hydrogeomorphological Mapping at Village Level Using High Resolution Satellite Data and Impact Analysis of Check Dams in Part of Akuledu Vanka Watershed, Anantapur District, Andhra Pradesh”, J. Ind. Geophys. Union, 15(1). 1-8. 2011.

[10]. Mondal, Md.S., Pandey, A.C. and Garg, R.D., “Groundwater Prospects Evaluation Based on Hydrogeomorphological Mapping using High Resolution Satellite Images: A Case study in Uttarakhand”, J. Indian Soc. Remote Sens., 36. 69-76. 2007.

[11]. NRSA., National rural drinking water mission methodology manual for preparation of groundwater prospects maps. National Remote Sensing Agency, Govt. of India, Hyderabad, 1999.

[12]. Hoffman, J. and Sander, P., “Remote sensing and GIS in hydrogeology”, Hydrogeol J., 15(1). 2007.