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Geospatial techniques and pumping tests for Delineation of Groundwater Potential Zones of Pedda Kedari Reserve Forest of Srikakulam District, A.P, India

Ch Kannam Naidu, Associate Professor, Civil Engineering Department, AITAM-Tekkali, Srikakulam District,A.P,India
Dr. E. Amminedu, Professor, Geo Engineering Department, Andhra University Visakhapatnam,A.P,India

Abstract:
The geospatial techniques and pumping tests were used in this research for delineating the groundwater potential zones through intersection, Lineament frequency, Lineament density, Groundwater level, Transmissivity, Permeability and Storage Coefficient . All the thematic layers have been extracted from the remote sensing satellite data (i.e. GeoEye-1 & LANDSAT ETM+), well inventory data and pumping tests. For the extraction of thematic layers and analysis, the ERDAS Imagine 9.1 and ArcGIS 9.3.1 softwares have been used. The delineated groundwater potential zones map have been validated with the Vertical Electrical Soundings (VES) data which are surveyed through the Electrical resistivity meter.Weighted Index Overlay Analysis (WIOA). The following thematic layers have been integrated in GIS environment which include Land use/Land cover, Geomorphology, Geology, Drainage density, Lineament

Keywords: Electrical resistivity meter, GeoEye-1, Geospatial techniques, LANDSAT ETM+, VES & Weighted Index Overlay Analysis

1. Introduction

Competition over freshwater resources has been increasing during a few decades due to the over growth of population, economic development, increased demand for agricultural products for both food and non-food use. So, we can't imagine a world without water!! [1]. The world's total water resources are estimated at 1.36 x 10^8 M ha-m. Of these gobal water resources about 97.2% is salt water found mainly in the oceans and only 2.8% is available as fresh water. Fresh water constitutes about 2.2% of surface water resource and 0.6% from groundwater resource [2]. In that ground water is most significant natural resource which supports both human needs and economic development. In the recent years enormous increased the demand for good quality water in the agricultural, industrial and domestic sectors to meet the growing needs. Groundwater is mostly preferred to meet this growing demand because of its lower level of contamination and wider distribution [3]. Due to the increasing of population, urbanization, deforestation and industrialization pressure on this resource is alarmingly increasing. The available surface water resources are inadequate to meet all the water requirements for various purposes. It may be noted that not only its demand has increased over the years but it seems that the demand will not be ceased. Hence, the delineation of groundwater potential zones has acquired great importance.

Remote Sensing is an excellent tool for researchers in understanding the "bewildering" problems of groundwater exploration. In recent years, satellite remote sensing data has been widely used in locating groundwater potential zones[1] [4], [5]. Its advantages of spatial, spectral and temporal availability of data have proved to be useful for quick and useful baseline information about the factors controlling the occurrence and movement of groundwater like geology, geomorphology, land use/ land cover, drainage patterns, lineaments etc [6], [7]. Excellent reviews of remote sensing applications in groundwater hydrology are presented in Farnsworth et [8], Waters et [9] and Engman and Gurney [10], which concluded that remote sensing has been widely used as a tool. In the recent years, modern technologies like Geographic Information System (GIS) and pumping tests are being used for various purposes such as groundwater investigations and many authors [11] have attempted to delineate groundwater potential zones. GIS techniques facilitate integration and analysis of large volumes of data, whereas, field studies help to further validate results. The integration of remote sensing and GIS has proven to be an efficient tool in groundwater studies [12], [13], [14], where remote sensing serves as the preliminary inventory method to understand the groundwater conditions and GIS enables integration and management of multi-thematic data. In addition, the advantage of using remote sensing techniques together with GPS in a single platform and integration of GIS techniques facilitated better data analysis and their interpretations [15]. In the present study Cooper and Jacob (1946) method was used for the analysis of pumping tests data [16]. The significance of the pumping tests is to know the subsurface groundwater potential information. Through pumping tests data, Transmissivity, Permeability and Storage coefficient values were found for twelve wells to generate the thematic layers.

In this study, Weighted Index Overlay Analysis (WIOA) approach for easy assessment of groundwater potential is adopted for GIS integration of thematic layers developed from the Remote Sensing data [17]. Remote sensing technique integrated with GIS platform through Weighted Index Overlay Analysis (WIOA) is found to be very effective tool for identification of potential zones for groundwater exploration [14].

II. Study Area: The present study area Pedda Kedari Reserved forest is located in Srikakulam district of North Coastal Andhra Pradesh, India. It lies between latitudes from 18° 37' 44"N to 18°43'52"N and longitudes from 84°09'45"E to 84°14'52"E. It covers an area about 46 sq km. The area occurs within the Survey of India toposheet of 74B/2 (Figure 1.0).

III. Data Used and Method: The Survey of India (SOI) toposheet (No. 74B/2 of 1:50000) along with existing data (NRSC Bhuvan data), Landsat data ETM^{+} (30 m spatial resolution) and GeoEye-1 satellite data (1.65m spatial resolution) were used for generation of various thematic layers such as Land use/Land cover, Geomorphology, Geology, Drainage density, Groundwater level, Lineament density, Lineament frequency, Lineament intersection, Transsmissivity, Storage Coefficient and Permeability.

The study area was delineated into three groundwater potential zones which

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include Good, Moderate and poor by weighted index overlay analysis (WIOA). The Groundwater Potential Index (GWPI) was used for this classification. GWPI was calculated by multiplying the rank and weightage of each thematic layer as expressed in the following equation.

GWPI = Σ [(Land use/Land cover feature rank x 1 + Geomorphology feature rank x 3 + Geology feature rank x 0 + Drainage density feature rank x 18 + Lineament Intersection feature rank x 4 + Lineament frequency feature rank x 24 + Lineament density feature rank x 8 + Groundwater level feature rank x 11 + Transmissivity feature rank x 4 + Permeability feature rank x 7 + Storage Coefficient feature rank x 21)]

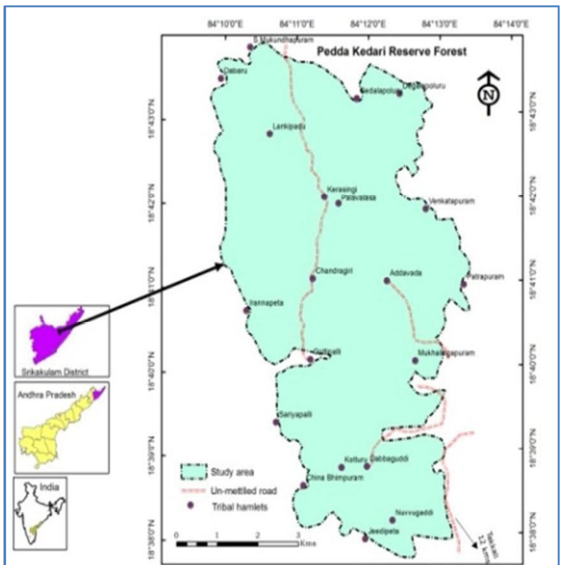

Figure 1.3. Location map of the study area

Figure 1. Location map of the Pedda Kedari Reserved Forest

In table 1.0, A- S.No., B- Thematic Layer

C- Good area of feature in each thematic layer

D- Weightage I calculations $\frac{Column\ C}{Sum\ of\ Column\ C}\ x\ 100$,

E- Moderate area of feature in each thematic layer,

F- Weightage II calculations $\frac{Column\ E}{Sum\ of\ Column\ E}\ x\ 50$

G- Weightage I + Weightage II (i.e. D + F)

H- Weightage calculations $\frac{Column\ G}{Sum\ of\ Column\ G}\ x\ 100$

Weightage calculations are shown in below Table 1.0

Table 1.0

A	B	C	D	E	F	G	H
1	LU/LC	0.00	0.00	3.25	0.98	1	1
2	GM	1.91	3.68	2.96	0.90	5	3
3	GL	0.00	0.00	0.00	0.00	0	0
4	DD	12.55	24.11	11.60	3.51	28	18
5	LI	1.06	2.03	10.64	3.22	5	4
6	LF	16.49	31.69	11.91	3.61	35	24
7	LD	4.55	8.75	8.77	2.65	11	8
8	GWL	4.86	9.33	24.03	7.28	17	11
9	T	0.00	0.00	20.89	6.33	6	4
10	K	0.00	0.00	35.70	10.81	11	7
11	S	10.63	20.42	35.39	10.72	31	21
Total		52.05	100.00	165.13	50.00	150	100

The groundwater potential (GWP) zones were categorized based on the GWPI values. From the range of GWPI values mean and standard deviation values were calculated. Based on the mean and standard deviation values the GWP zones were delineated. The delineated zones are shown in Table 3.0. The groundwater potential (GWP) zones were categorized based on the GWPI values. From the range of GWPI values mean and standard deviation values were calculated. Based on the mean and standard deviation values the GWP zones were delineated. The delineated zones are shown in Table 3.0

IV Results and Discussions: Groundwater potential zones were delineated from the following maps which include Land use/Land cover, Geomorphology, Geology, Drainage density, Lineament Intersection, Lineament frequency, Lineament density, Groundwater level, Transmissivity, Permeability and Storage Coefficient by weighted index overlay analysis (WIOA). Hence, all the thematic maps pertaining to the study area were prepared as per the methods explained earlier. The salient aspects of these thematic maps are described below.

1. Land use / Land cover: Land use describes how a piece of land is u sed whereas land cover describes the materials present on the surface (Sabin, 1987). From the existing data and GeoEye-1 satellite data of 1.65 m resolution, the land use/ land cover map was delineated. In the present study area the following six categories were delineated which include barren land, built-up area, crop land, deciduous forest, dense scrub and scrub and open scrub. (Figure 2.0). The groundwater potentiality is moderate in crop land and poor in remaining features.

The below Table 2.0 shows Thematic Layers, Featues, Feature ranks and Layer weightages

Table 2.0

S.N	Thematic layers	Category	Ran	Status
1	Land use/Land cover (LC/LC)	Barren land	1	Poor
		Built-up area	1	Poor
		Crop land	2	Moderate
		Deciduous forest	1	Poor
		Dense scrub	1	Poor
		Open scrub	1	Poor
2	Geomorphology (GM)	Pediment	2	Moderate
		Denudational hills – High	1	Poor
		Denudational hills-Moderate	1	Poor
		Denudational hills – Low	1	Poor
		Valley fills	3	Good
3	Geology (GL)	Granite gneiss	1	Poor
4	Drainage Density (DD)	< 0.5 km/km^2	3	Good
		0.5-1 km/km^2	2	Moderate
		>1 km/km^2	1	Poor
5	Lineament Intersection (LI)	< 2 Nos/Sq km	1	Poor
		2 – 4 Nos/ km^2	2	Moderate
		>4 Nos/ km^2	3	Good
6	Lineament Frequency (LF)	< 3 Nos/ km^2	1	Poor
		3 – 5 Nos/ km^2	2	Moderate
		>5 Nos/ km^2	3	Good
7	Lineament Density (LD)	< 2 km/km^2	1	Poor
		2 – 4 km/km^2	2	Moderate
		>4 km/km^2	3	Good
8	Groundwater Level (GWL)	< 1 m	1	Poor
		1-6 m	2	Moderate
		>6 m	3	Good
9	Transmissivity (T)	< 5 m^2/day	1	Poor
		5 – 104 m^2/day	2	Moderate
10	Permeability (K)	< 1 m/day	1	Poor
		1 - 864 m/day	2	Moderate
11	Storage coefficient (S)	0.1 - 0.2	2	Moderate
		> 0.2	3	Good

Table 3.0

S.No	Categories	GWPI range	GWP zone
1	>= Mean + SD	>= 222	Good
2	Mean to Mean + SD	194 - 222	Moderate
3	< Mean	< 194	Poor

2. Geomorphology

Geomorphology is the scientific study of the nature and history of the landforms on the surface of the earth and other planets, and of the processes that create them. The major geomorphic units identified in this study area are pediment, denudational hills (High, Moderate and Poor) and Valley fills (Figure 3.0). The groundwater potentiality is good in valley fills, moderate in pediment and poor in denudational hills.

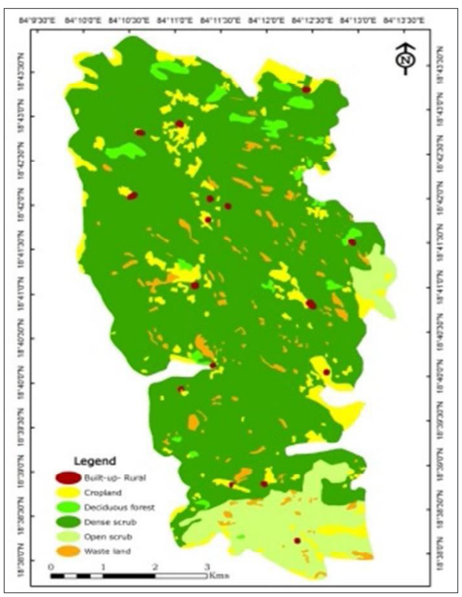

Figure 2.0 Land use/ Land cover map

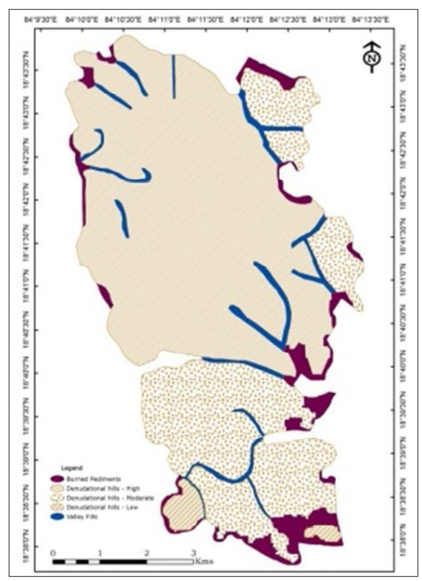

Figure 3.0 Geomorphology map

3. Geology

Geology plays an important role in the distribution and occurrence of groundwater. An understanding of the local geology was developed based on existing maps. The area is underlain by Granite gneiss (Figure 4.0). The groundwater prospects are poor in Granite gneiss [21].

4. Drainage Density

Drainage density is a measure of quantitative length of linear feature expressed in Sq Km grid. It helps to assess and understand the characteristics of runoff and groundwater infiltration in this area. Drainage network was extracted from Survey of India toposheet of 1:50000 scale using ArcGIS 9.3.1 software. The present study area is categorized in to three zones which include Good (< 0.5 km/Sq km), Moderate (0.5- 1 Km/ Sq Km) and Poor (>1 Km/ Sq Km) as shown in Figure 5.0. The area which is having poor drainage density indicates comparatively higher infiltration and low runoff, similarly the area which is having good drainage density indicates low infiltration and high runoff.

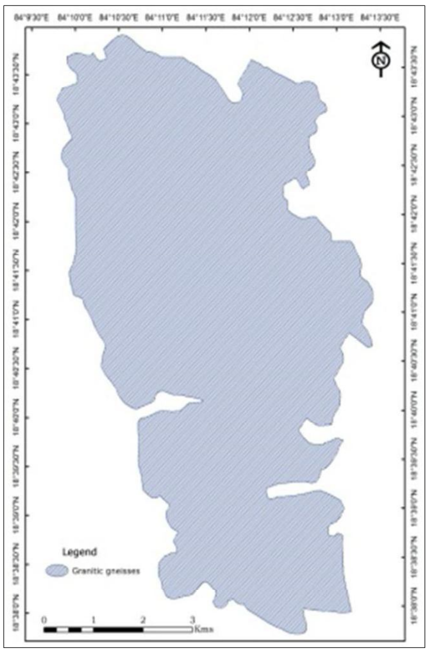

Figure 4.0 Geology map

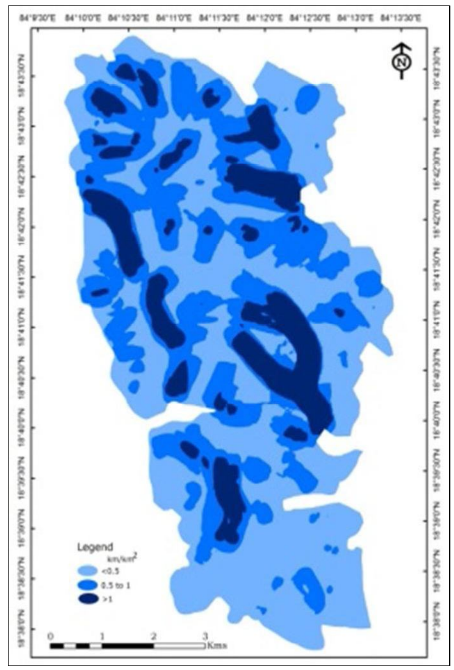

Figure 5.0 Drainage Density map

5. Lineament Intersection

Lineaments are defined as mapable linear surface features, which differ distinctly from the patterns of adjacent features and most probably reflect subsurface phenomena [17]. We are extracted the lineaments from Landsat ETM$^+$ with the help of ERDAS Imagine 9.1 software by using the application of the Sobel directional filters 5x5 and 7x7 in the directions N-S, E-W, NE-SW and NW-SE[19]. Lineament Intersection means a number of lineament intersections in a Sq km grid area. In this study area is categorized in to three zones which include Good (>4 No/Sq km), Moderate (2-4 No/Sq km) and Poor (<2 No/Sq km) as shown in figure 6.0.

6. Lineament Frequency: It means number of lineaments appeared in a Sq Km grid area. More the lineament in a Sq km grid area represents good groundwater potentiality. The study area is categorized in to three zones such as Good (>5 No/Sq km), moderate (3 - 5 No/Sq km) and poor (< 3 No/Sq km) as shown in figure 7.0.

7. Lineament Density: Lineament density map is a measure of quantitative length of linear feature expressed in Sq km grid. The study area has been classified in to three zones such as good (> 4 km/sq km), moderate (2 -4 km/sq km), and poor (< 2 km/sq km) as shown in figure 8.0.

8. Groundwater Level: Groundwater level is referring to the level, either below ground or above ordnance datum, at which soil or rock is saturated. This is also referred to as the water table and represents the top of the saturated zone. Above the water table lies the unsaturated zone. The study area has been classified in to three zones accordingly rise in water levels such as good (> 6 m), moderate (1-6 m) and poor (< 1 m) as shown in figure 9.0.

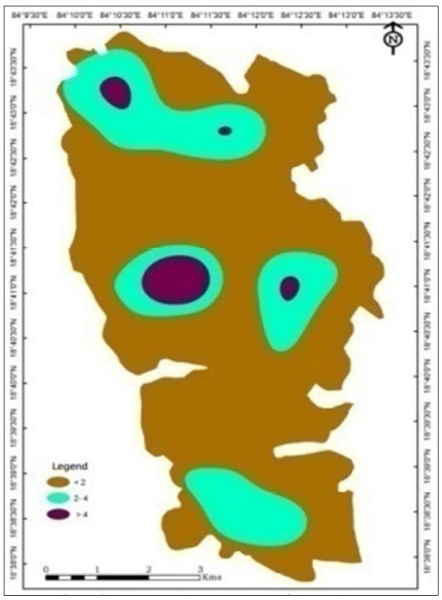

Figure 6.0 Lineament Intersection map map

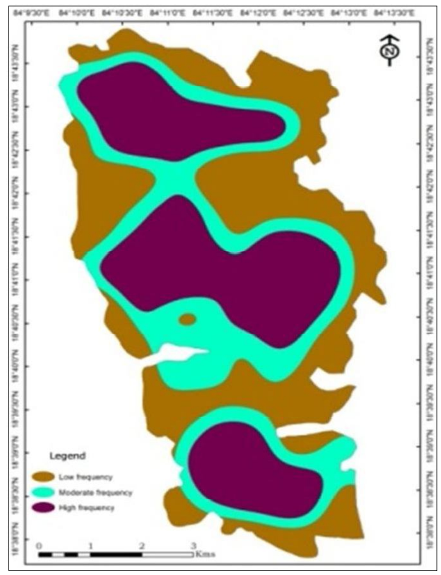

Figure 7.0 Lineament Frequency

9. Transimissivity : Transimissivity is the product of the average hydraulic conductivity (K) and the saturated thickness of the aquifer (H). Consequently, the transmissivity is the rate of flow under a hydraulic gradient equal to unity through a cross-section of unit width over the whole saturated thickness of the water bearing layer. It is expressed in m^2/day. The study area has been classified in to two zones such as good (> 5 m^2/day) and poor < 5 m^2/day) as shown in figure 10.0.

10. Permeability: Permeability or hydraulic conductivity is a measure of the capacity of a porous medium to transmit water. It is defined as the volume of water that will move in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. The dimensions of hydraulic conductivity are length per time or velocity. The study area has been classified in to two zones such as good (>1m/day) and poor < 1 m/day) as shown in figure 11.0.

11. Storage coefficient

Storage co-efficient or storativity is a dimensionless coefficient defined as the volume of water that a permeable unit will release from storage per unit surface area per unit change in head. In an unconfined unit, the level of saturation rises or falls with changes in the amount of water in storage due to specific yield. The study area has been classified in to two zones such as good (> 0.2) and moderate (< 0.2) as shown in figure 12.0.

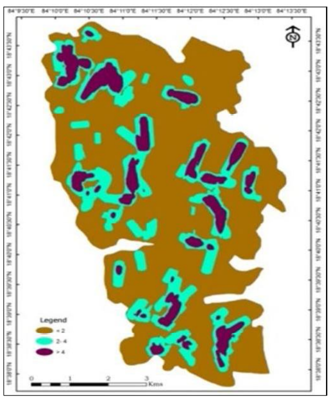

Figure 8.0 Lineament Density map

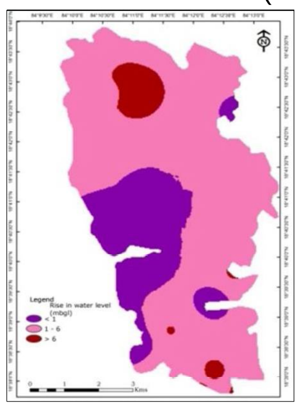

Figure 9.0 Groundwater Level map

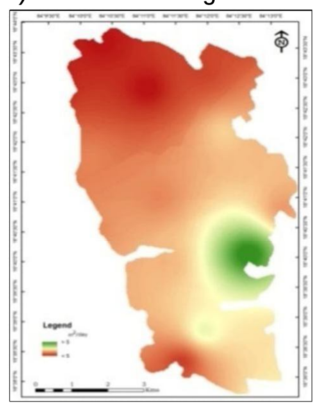

Figure 10.0 Transmissivity map

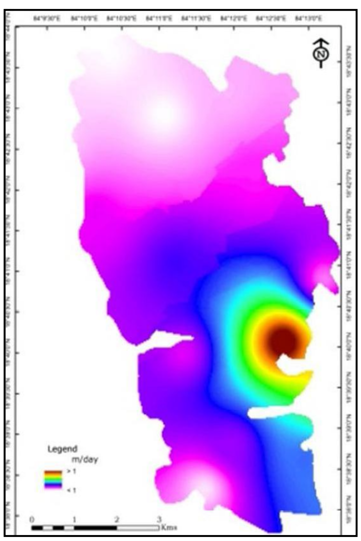

Figure 11.0 Permeability map

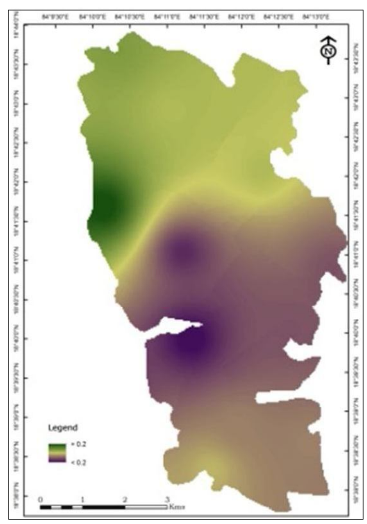

Figure 12.0 Storage map

12. Groundwater Potential Zone Mapping

The groundwater potential zones were delineated by Weighted Index Overlay Analysis (WIOA) by using the ArcGIS 9.3.1 [29]. In the Weighted Index Overlay Analysis, the ranks have been given for each individual feature of each thematic map and the weightages were assigned to the each thematic map which are shown in the Table 2.0. The GWPI calculations are given in the methodology. The groundwater potential zone of the study area has been delineated into three groundwater potential zones, namely good, moderate and poor (Figure 10.0). In this total (46 Sq.Km) study area, 7.36 Sq.Km area is belongs to good groundwater potential zone. Similarly, 14.18 Sq.Km area is belongs to moderate groundwater potential zone and 24.46 Sq.Km area is belongs to poor groundwater potential zone. The percentage of good groundwater prospects zone area is 16.02%, moderate area is 30.82% and poor area is 53.16%.

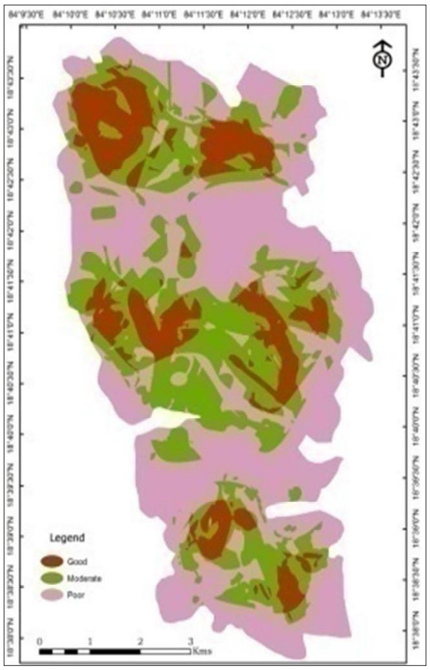

Figure 13.0 Groundwater Potential zone map

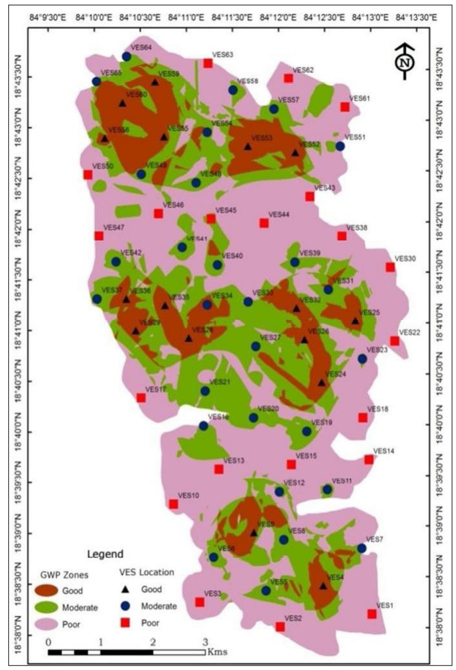

Figure 14.0 Validation of VES points depicting on Groundwater potential zones.

12. Validation of Groundwater Potential Zone Map

The groundwater potential zoning map was generated by using eleven thematic layers under GIS environment. This map has been validated with the electrical resistivity survey conducted by taking 65 vertical electrical soundings at various locations. Out of 17 points verified with VES locations corresponding to good zone of groundwater prospects in the study area, 16 points are corroborated with VES locations. Only one point was failed as a good which is located at VES 34. The rate of success for the delineated good prospective zone found to be 94.11%. Out of 27 points tested for moderated groundwater potential zone category, 26 points are corroborated with the VES data. In the poor category, 21 points were tested for poor prospective zone category, 20 points corroborated with the VES data (Figure 7.2). It is corroborated with the delineated zones indicating that the GIS analysis for delineation of the study area into different zones is very much useful. However, specific land use class can be checked for precise location of the proposed structure. The present utilization of land use/land cover of an area provides a clue about the level of utilization. It was found that the categorization of groundwater potential was in good agreement with the available water column in the area.

References

[1] Strzepek K., Boehlert, B. 2010: Competition for water for the food system, Phil. Trans. R. Soc. B; 365 (1554), pp. 2927– 40.

[2] Raghunath, H.M., 2006: Hydrology-Principles-analysis-design, Revised second edition, New Age International (P) Limited, New Delhi, pp. 3

[3] Biswas Arkoprovo., Jana Adarsa and Sharma Shashi Prakash, 2012: Delineation of Groundwater Potential Zones using Satellite Remote Sensing and Geographic Information System Techniques: A Case study from Ganjam district, Orissa, India, Research Journal of Recent Science, Vol. 1(9), pp.59-66.

[4] Srivastav P. and Bhattacharya A.K. 2000: Delineation of groundwater potential zones in hard rock terrain of Bargarh District, Orissa using IRS, Jour. India. Soc. Rem. Sen, 28(2-3), pp.129–140.

[5] Manimaran D. 2012: Groundwater geochemistry study using GIS in and around Vallanadu Hills, Tamilnadu, India, *Res.J. recent sci*, 1(6), Pp.32–37.

[6] Bobba A.G., Bukata R.P., and Jerome J.H.1992: Digitally processed satellite data as a tool in detecting potential groundwater flow systems, Journal of Hydrology. 131(1-4), pp.25-62.

[7] Meijerink A.M.J. 2000: Groundwater in G.A. Schultz & E.T. Engman (Eds), Remote sensing in hydrology and water management, Berlin: Springer, pp. 305-325.

[8] Fransworth, R.K., Barret, E.C., & Dhanju, M.S.(1984). Application of Remote Sensing to Hydrology including Groundwater. Paris: UNESCO.

[9] Waters P., Greenbaum P., Smart L and Osmaston, H.1990: . Applications of Remote Sensing to groundwater hydrology, Remote Sensing Review, 4, pp. 223-264.

[10] Engman E.t., and Gurney R.J. 1991:. Remote Sensing in Hydrology, London: Chapman and Hall.

[11] Shahid S., and Nath S.K. 2002: GIS integration of remote sensing and electrical sounding data for hydrogeological exploration, Journal of Spatial Hydrology, 2(1), pp 1-0.

[12] Krishnamurthy J. and Srinivas G. 1996: Demarcation of geological and geomorphological features of parts of Dharwar Craron, Karnataka, using IRS LISS-II data, International Journal of Remote sensing, 17(16), pp.3271-3288.

[13] Krishnamurthy J., Kumar N.V., Jayaraman V and Manivel M. 1996: An approach to demarcate groundwater potential zones through Remote Sensing and Geographic Information System, International Journal of Remote sensing, Vol.17, pp1867-1885.

[14] Saraf K. and Choudhary P.R. 1998: Integrated Remote Sensing and GIS for Groundwater Exploration and Identification of Artificial Recharge Sites, Int. Journal of Remote Sensing, Vol 19, No. 10, pp 1825-1841.

[15] Vijit, H. 200: Groundwater potential in the hard rock terrain of Western Ghats – a case study from Kottayam

district, Kerala using Resourcesat (IRS-P6) data and GIS techniques, Journal of the Indian Society of Remote Sensing, 35(2), pp.171-179.

[16] Cooper, H.H and C.E. Jacob, A. 1946: Generalized graphical method for evaluating formation constants and summarizing well field history, Am.Geophys. Union Trans, Vol.27, pp.526-534.

[17] Binay Kumar and Uday Kumar. 2010: Integrated approach using RS and GIS techniques for mapping of ground water prospects in Lower Sanjai Watershed, Jharkhand, International Journal of Geomatics and Geosciences, Volume 1, No 3, pp 587-598.

[18] O'Leary D. W. Friedman J. D and Pohn H. A. 1976: Lineament, linear, lineation: Some proposed new standards for old terms, Geological Society America Bulletin, Vol.87, pp.1463-1469.

[19] Amina Kassou, Ali Essahlaoui and Mohamed Aissa. 2012: Extraction of Structural Lineaments from Satellite Images Landsat 7 ETM+ of Tighza Mining District (Central Morocco), Research Journal of Earth Sciences 4 (2): pp.44-48, 2012.

[20] Kavitha Mayilvaganan M, Mohana P and Naidu K.B. 2011: Delineating groundwater potential zones in Thurinjapuram watershed using geospatial techniques, Indian Journal of Science and Technology, Vol. 4 No. 11 pp.1470-76.

[21] Dr. Md .Babar. 2005: Hydrogeomorphology fundamentals applications and techniques, New India Publishing Agency.

[22] Krishnamurthy J., Venkatesa K N., Jayaraman V. and Manivel M. 1996: An approach to demarcate ground water potential zones through remote sensing and a geographical information system, Intl. J. Rem. Sen, 7(10), pp.1867-1884.

[23] Etishree Agarwal., Rajat Agarwal., Garg R. D and Garg P. K. Delineation of Groundwater Potential Zone: An AHP/ANP approach.

[24] http://shodhganga.inflibnet.ac.in/bitstream/10603/10098/12/12_chapter%207.pdf, pp.174