JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.86, December 2015, pp.733-741

A Remote Sensing and GIS Based Approach to Evaluate the Ground Water Prospects of Baghain Watershed, Panna and Satna Districts of M.P., India: A Case Study

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Abstract: Remote Sensing and GIS, potential tools for facilitating the generation and use of thematic information, has been applied to assess the ground water potentiality of Baghain watershed falling in parts of the Panna and Satna districts, M.P. The role of various parameters namely drainage, lineament, lithology and geomorphology have been emphasized for delineation of ground water potential zones. IRS-1C, LISS III imagery (FCC) on 1:50,000 scale and topographic maps (63 D/5 and 63 D/6) along with field survey have been used as the data source. The various thematic maps have been integrated with the help of GIS applying Index Overlay model to demarcate different groundwater prospects. The resultant map indicates that high prospects is in fractured valley (FV) and pediplain-shallow (PPS) and the moderate prospects in pediment (PD), moderately dissected plateau (PLM) and slightly dissected plateau (PLS), while bute (B), escarpment slope (ES) and mesa (M) show poor prospects for ground water. The groundwater prospect units have been correlated with the discharge of well within the units and it has been found that values match with the units derived from this approach. This study shall be useful in targeting recharge sites as well as drilling sites. The present result shows that integration of all weighted attributes provides more accurate results in groundwater prospects identification.

Keyword: Index overlay model, GIS, Remote Sensing, Baghain watershed, Madhya Pradesh.

INTRODUCTION

In recent year, the use of remote sensing data and application of geographic information system (GIS) has been widely used in resources inventory, mapping, analysis, and monitoring and environmental management. Remote sensing provides very useful methods of survey, identification, classification, and monitoring of several forms of earth recourses, and helps in acquisition of data at periodic intervals.

Water has been one of the most important natural resource for the sustenance of life on the earth. The available surface water resources are inadequate to meet the water requirement for all purposes and hence the demand for groundwater has increased over the years. The assessment of quality and quantity of groundwater is essential for its optimum utilization. The occurrence and movement of groundwater in an area is governed by several factors such as topography, lithology, geological structures, depth of weathering extent of fracture, secondary porosity, soil, drainage pattern, landforms, land-use/land-cover, climatic conditions and interrelationship between these factors (Roy 1991, Greenbaum 1992, Mukhrjee 1996). In addition, quantitative morphometric parameters of the drainage pattern also plays a major role in evaluating the hydrology parameters, which is turn helps to understand the groundwater situation (Krishnamurthy and Srinivas, 1995).

The interpretation of satellite data in conjunction with sufficient ground truth information makes it possible to identify and outline various features such as geological structure, geomorphic features and their hydraulic characters (Das et al. 1997), which may serve as direct or indirect indicators of the presence of groundwater (Ravindran and Jeyaram, 1997). However, the quality and quantity of groundwater is controlled mainly by the interaction of topographical, geological, meteorological and pedological features. Moreover, groundwater distribution is not uniform and is subjected to wide spatio-temporal variations, depending on the underlying rock formation, their structural fabric, geometry, surface expression etc. Therefore, a detailed hydrogeomorphological mapping and delineation of groundwater prospect zones is important as it provides the current spatial disposition of basic information on geology, landforms, soil, land-use/land-cover, surface water bodies, etc. which are indicative of groundwater movement and localization (Murthy, 2000). It is obvious that groundwater cannot be seen directly from remote sensed data; hence, its presence must be inferred from identification of surface features, which act as an indicator of groundwater (Das et.al. 1997, Ravindran and Jeyaram 1997). Integrated analysis and study, besides mapping and delineation of potential areas on small and regional scale help in determination of aquifer characteristics, flow pattern, and correlation of lithology (Sabale et al., 2009). Such an approach has been applied successfully in delineation of groundwater potential sites / zones by various workers (Ahmad et al., 2010; Chatterjee et al., 2010; Lokesh et al., 2005; Mondal et al., 2007; Rao et al., 2009; Banerji, 2000; Srivastava, 2000 and Dasgupta, 1994).

In recent years, the importance of coupling remote sensing and GIS in groundwater potential assessment studies have been realised by many workers (Toleti et al. 2000; Bahuguna et al. 2003; Vijith 2007; Chowdhury et al. 2009; Suja Rose and Krishnan 2009; Pradeep Kumar et al, 2010; Vasanthavigar et al, 2011; Preeja et al. 2011).

Prabu Pothiraj and Baskaran Rajagopalan (2012) has used GIS and remote sensing based technique for evaluation of groundwater potential zones in a hard rock terrain of Vaigai sub-basin, India. Narendra et al. (2013) used integrated approach of Remote Sensing and GIS to delineate groundwater prospective zones in Narava basin, Visakhapatnam region, India. Senthil Kumar and Shankar, (2014) have assessed groundwater potential zones using GIS.

In the present paper, an attempt has been made to highlight the potential of remote sensing, GIS and index overlay model techniques to evaluate the groundwater prospects of Baghain watershed and to demonstrate the application of these emerging techniques in ground water studies.

STUDY AREA

The study area, Baghain watershed (Fig. 1) spreads 358.02 sq km covering parts of Panna and Satna districts of Madhya Pradesh and extends from 80º 20'35" E. to 80º 30'10" E longitude and 24º 43'36" N to 24º 51'35" N latitude. Geomorphologically, watershed exhibits smaller patches of mesa and butte in the central part of the study area with gentle slopes in remaining part. The area is delimited by

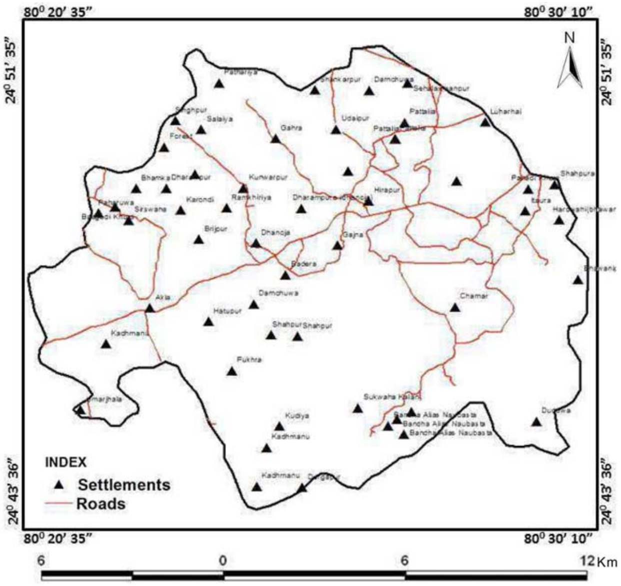

Fig.1. Study area

Rajapur forest in the north and Urdana protected forest in the south.

METHODOLOGY AND DATABASE

The study involves two major steps that include generation of thematic information and its analysis for ground water potentiality. The sequential steps in the study are: (a) base map preparation, (b) preparation and conversion of prepared thematic maps into digital format (digitization), (c) allocation of weight factor based on their relative importance over ground water prospects (Table 1) and (d) integration of thematic maps and identification of ground water prospects.

The Indian remote sensing satellite (IRS) IC, linear image self scanning LISS-III geocoded false color composite, generated from the bands 2, 3, and 4 on 1:50,000 scale was used. The Survey of India toposheet maps 63D/5, and 63 D/6 on 1:50,000 scale were used for the preparation of base map. The base map serves the purpose of delineating basin boundary, natural and cultural features and for geo-referencing. The imagery was visually interpreted to delineate geomorphologic units, lithological units and lineaments.

ArcGIS 9.0 software was used for preparation of groundwater prospects map. Weighted index overlay analysis was a simple mathematical model for a combined analysis of multi-parameters. Each thematic map was assigned a weight (Table 1) depending on its influence on the movement and storage of groundwater (Nag, 2005; Dinesh Kumar et al. 2007; Avtar et al. 2010; Preeja et al.

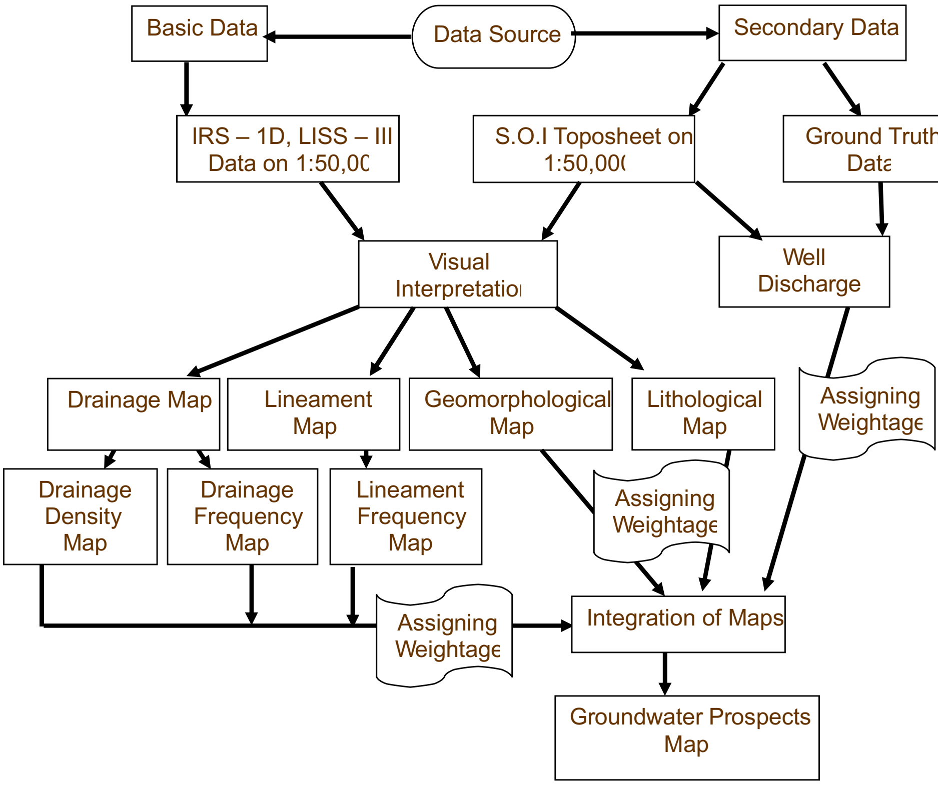

Fig.2 Methodology flowchart

2011). Relative ranking of each thematic unit in a theme were assigned as knowledge based hierarchy using Spatial Analyst tool of ArcGIS. The resultant map is classified into very good, good, moderate and poor groundwater prospect zones. The results were validated by well discharge data at different zones. The methodology adopted in this study is given in the flow chart (Fig.2).

The steps followed are:

i. Preparation of base map of the area using topographical maps of Survey of India
ii. Visual interpretation of satellite imagery (paper print) to delineate lithology, geomorphology, lineament, drainage etc.
iii. Field verification of interpreted units
iv. Collection of field based data viz. ground water table in pre-monsoon and post-monsoon
v. Digitisation of thematic maps using R2V software followed by application of Arc Info and Arc view software
vi. Preparation of ground water prospects map using Index Overlay method

maps.

Integration of Thematic layers

Index overlay model (Murthy et al., 2003) is used in this study for GIS modelling, as it provides quantitative approach to generate groundwater prospects map. Weightage has been assigned to each thematic map. Rating of individual units is assigned based on their relative role in ground water recharge. More rating means less runoff and more infiltration causing more groundwater recharge. Final weight values for each unit have been achieved by multiplying the ratings of the unit with the weightage of corresponding overlay.

Each thematic map was given unique weightage. Different units of thematic maps were assigned ratings in their polygon attribute table (PAT) by creating a column of ratings and final weights in created weight column by multiplication of rating of the unit and weightage of the thematic map. This operation is applied to all thematic maps. Afterwards thematic maps are integrated by union operation, which gives integrated polygons for all thematic map units by summation of weights for all units of different thematic maps. Thus from the PAT of integrated map, a range of weights is achieved and afterward this range is distributed into five ranges representing different ground water prospect categories namely excellent, good, moderate, low and poor. weightage and rating code for different themes and their units and final weights for each unit is shown in Table 1. The final product i.e. groundwater prospects map of the area is shown in Fig.11.

Table 1. Weightage distribution of various units

Map	Map Weight	Unit	Unit Ratings	Total Weight
Geomorphology	3	Bute	1	3
		Mesa	1	3
		Escarpment Slope	2	6
		Plateau Highly Dissected	2	6
		Plateau Moderately Dissected	2	6
		Plateau Slightly Dissected	3	9
		Plateau Undissected	3	9
		Pediment	4	12
		Pediplain Shallow	5	15
		Fracture Valley	6	18
Lithology	3	Ganurgarh Shale	1	3
		Bhander Shale & Limestone	2	6
		Panna/Jhiri Shales	2	6
		Kaimur Sandstone	3	9
		Rewa Sandstone	3	9
Drainage Density Length (m)/ km^2)	5	>5000	1	5
		4000-5000	1	5
		3000-4000	2	10
		2000-3000	2	10
		1000-2000	3	15
		<1000	4	20
Drainage Frequency (No./km^2)	5	18-20	1	5
		16-18	1	5
		14-16	1	5
		12-14	2	10
		10-12	2	10
		8-10	2	10
		6-8	3	15
		4-6	3	15
		2-4	4	20
		<2	4	20
Lineament Frequency (No./km^2)	5	<0.5	1	5
		0.5-1.0	1	5
		1.0-.15	1	5
		1.5-2.0	2	10
		2.0-2.5	2	10
		2.5-3.0	3	15
Discharge (LPM)	6	15-35	1	6
		35-55	2	12
		55-75	3	18
		75-95	4	24

RESULT AND DISCUSSION

Geological Setting

Lithological map has been prepared from the satellite data. The map was corrected after using the geological map of Geological Survey of India and limited field checks. The regional stratigraphic succession of the study area is as follows:

Supergroup	Group	Formation
Vindhyan Supergroup	Bhander Group	Upper Bhander Sandstones Sirbu Shales Lower Bhander Sandstones Bhander Limestone Ganurgarh Shales
	- - - - - - - Daimond Bearing Conglomerate - - - - - - -	
	Rewa Group	Gahadara Sandstone Jhiri Shale Itwa Sandstone Panna Shale
	- - - - - - - Daimond Bearing Conglomerate - - - - - - -	
	Kaimur Group	Baghain Sandstone Pipartola Cong.
	Semri Group	Palkawan Shale Pandwafall Sst.
- - - - - - - - - - - - - - - - Unconformity- - - - - - - - - - - - - - - - - - - -		
Bundhelkhand Granite	Intrusives Granites Older Metamorphics	

(Source: District resource map- Panna district, Madhya Pradesh, Geological Survey of India, 2000)

Bhander limestone, Ganurgarh shale, Rewa sandstone, Panna and Jhiri shale are the rocks exposed in the study area. Geology of the study area is shown in Fig.3 (Lithology map). The weight value of 3 has been assigned for lithology. The ratings for lithological units i.e. Ganurgarh shale, Bhander shale & limestone, Panna/Jhiri shales, Kaimur sandstone and Rewa sandstone have been assigned as 1,2,2,3 and 3 respectively based on their influence towards the groundwater recharge.

Geomorphological Units and Associated Features

Geomorphological units and associated features were identified and mapped in the investigated area through the visual interpretation of satellite data. The major identified geomorphic units are pediment (PD), pediplain shallow (PPS), fracture valley (FV), plateau slightly dissected (PLS), plateau moderately dissected (PLM), plateau highly dissected (PLH), butte (B), mesa (M), and escarpment slope (ES). The pediplain results from the weathering process under arid and semi arid conditions, representing the end stage of cyclic erosion. Generally, Groundwater potential depends upon the thickness of aquifer zone; thicker the aquifer zone, greater is the ground water potentials and vice versa. Geomorphological map of the study area is shown in Fig.4 and description of the geomorphic units and associated features is given below:

Pediplain Shallow (PPS)

The unit pediplain shallow (PPS) develops from the

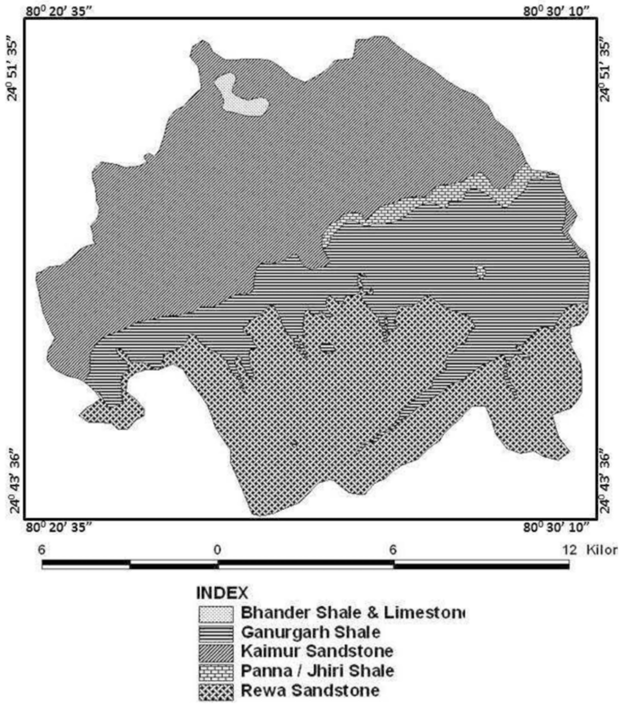

Fig.4. Lithological map

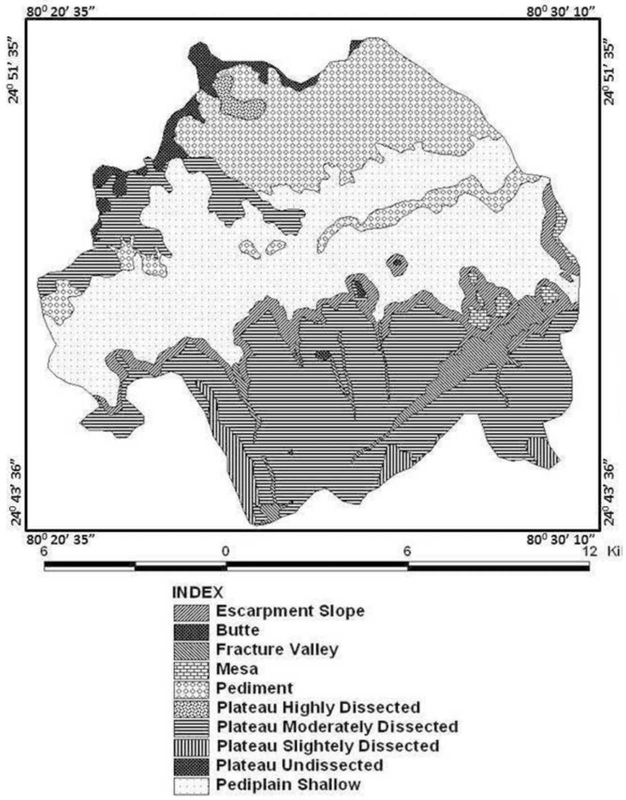

Fig.4. Geomorphological map.

continuous process of pedimentation. It has a flat surface, occupying an area of 62.04 sq.km (33.7%) with a weathered zone that extends upto a depth of 5 m. This unit has a thick soil cover and sparse vegetation. It occasionally shows the occurrence of lineaments and virtually dry environment. The area covered by this geomorphological unit can be used for development of groundwater resources in terms of shallow wells. Final integrated map shows that this area falls under moderate to very high groundwater prospects with 48-98 liter per minute (LPM) well discharge.

Pediment (PD)

Pediment is a broad, flat or gently sloping, erosional surface or plain of low relief. This geomorphic unit is dotted with rock outcrops with or without thin veneer of soil cover occupying an area of about 3.47 sq km. It occupies 1.88% of the total study area and forms the runoff zone. The final groundwater prospects map shows that the pediment area has limited groundwater prospects only along valley portions with 15 - 47 LPM well discharge.

Plateau Slightly Dissected (PLS)

Plateau slightly dissected is a type of plateau that is dissected by drainages and its original form is considerably changed. This unit occupies an area of 4.09 sq km (2.22%). It shows better groundwater prospects along the valley portion and recharge depend on its relative elevation compared to the surrounding landforms.

Plateau Moderately Dissected (PLM)

The unit represents a plateau, dissected by deep valleys/ gullies and occupies an area of about 58.41 sq km (31.75%). Shallow aquifer partially drains out into the deep valleys.

Plateau Highly Dissected (PLH)

This unit represents a plateau more frequently dissected by deep valleys separating individual mesa and buttes occupying an area of about 1.18 sq km (0.64%). In this unit, shallow aquifers fully drain out into deep valleys.

Fracture Valley (FV)

It is a low lying depressions and negative landform of varying size and shape occurring within the hills associated with stream/nala courses occupying an area of about 5.99 sq. km. (3.25% of total geographical area). It acts as a favorable zone for ground water accumulation and act as a discharge zone at places with springs and seepages.

Butte & Mesa (B & M)

A butte is an isolated hill with steep, often vertical sides and a small flat top, smaller than mesa.

Mesa is a medium size flat-topped hill having much larger tops than a Butte. Mesa is occupying an area of 1.58 sq. km. (0.85% of total geographical area) while Butte is occupying an area of 0.28 sq. km. (0.31%). Both the units form runoff zones without any significant recharge potential and Groundwater prospect.

Drainage Characteristics

Overall drainage of the study area exhibits a dendritic pattern. This may be due to more or less homogeneous lithology. The streams do not coincide with the lithological boundaries but at places, they follow litho-contacts. Drainage map is shown in Fig.5. Drainage density and frequency plays an important role in groundwater recharge. Fig.6 and Fig.7 respectively drainage density and drainage frequency maps.

Drainage density shows the distances amongst streams and provides length of streams within one unit area. High drainage density is indicative of high surface runoff and low groundwater recharge. The drainage density map shows that it ranges between 1 to 5 km per sq km and the density class falling in 1 - 2 km per sq km range occupies maximum area.

Drainage frequency shows the number of drainages per unit area. The drainage frequency map shows 10 frequency classes in the area where classes 2-4 and 4-6 occupy the maximum area.

Structure

Study area is mainly controlled by lineaments. Lineaments are classified on the basis of their length, lineaments with more than 4 cm (2 km on the ground) length as major lineament, and less than 4 cm (2 km on the ground) length as minor lineament. The southwestern portion of the study area mainly contains major lineaments. In the central portion, some escarpments are seen. Lineaments and escarpments are shown in structural map (Fig.8). Lineament intersection density map has also been prepared which is shown in Fig.9. Lineament intersection ranges between 0.5 no. to 3 nos. per sq km.

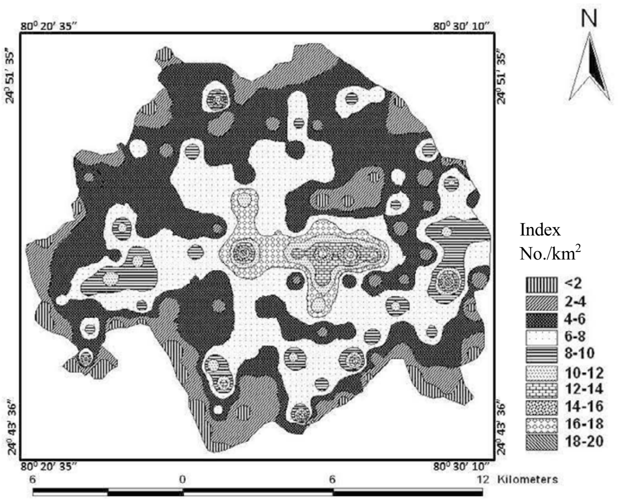

Fig.7. Drainage frequency map.

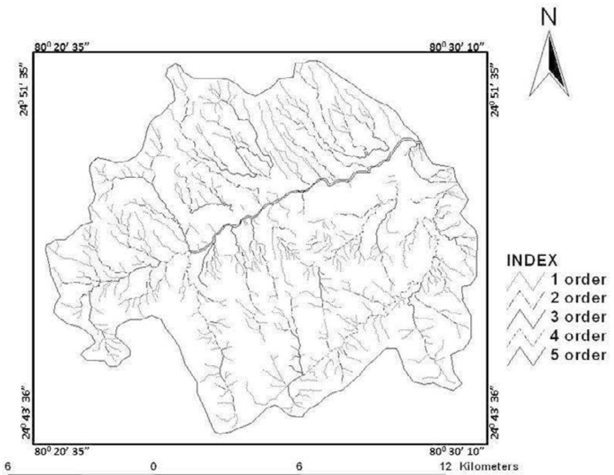

Fig.5. Drainage map

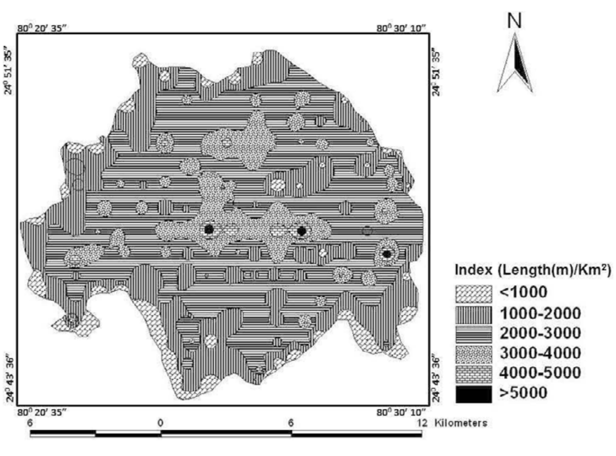

Fig.6. Drainage density map.

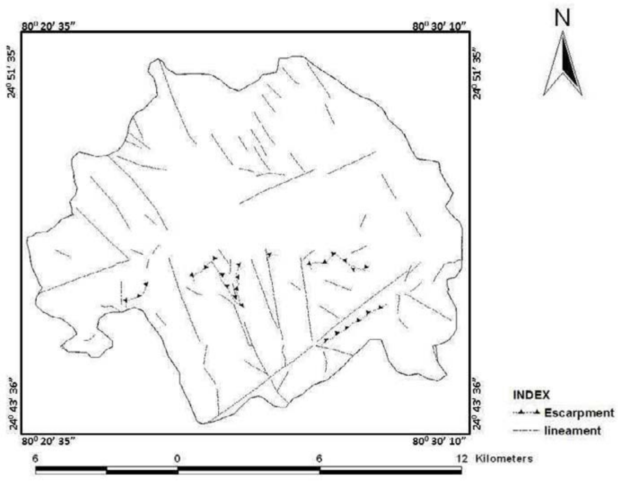

Fig.8. Structural map.

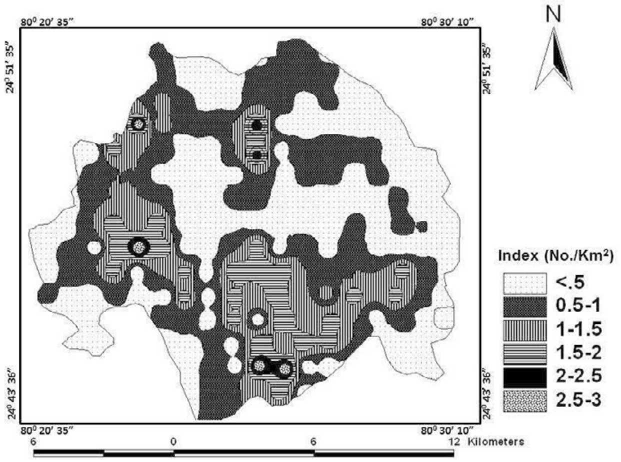

Fig.9. Lineament intersection frequency map.

CONCLUSION

The study exhibits that the area has a plain land with gentle slope, which is responsible for infiltration and groundwater recharge. Groundwater prospects map prepared by integration of all weighted and ranked thematic maps shows that the landforms FV, PPS and PD represent good; moderate to good and moderate groundwater prospects respectively and PLS, PLM PLH landforms represent moderate, moderate to poor, poor groundwater prospects (Fig.10) respectively. The ES, M & B landforms represent poor groundwater prospective zone, however, adequate groundwater recharge source can be expected surrounding the M & B, as it acts as a surface runoff zone. Intersection of lineaments and lineaments parallel to the drainage networks area can give better yields than the other areas.

To verify the outcome of final groundwater prospects maps, Well discharge map has been prepared and integrated with groundwater prospects maps. Well discharge indicates the aquifer characteristics. Good discharge means good prospect. The discharge map is shown in Fig.11. The

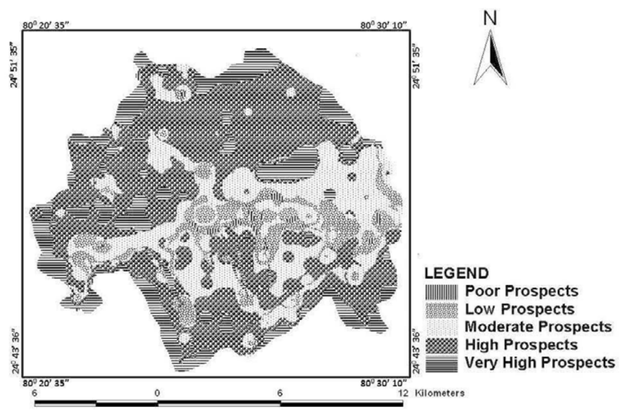

Fig.10. Groundwater prospects map

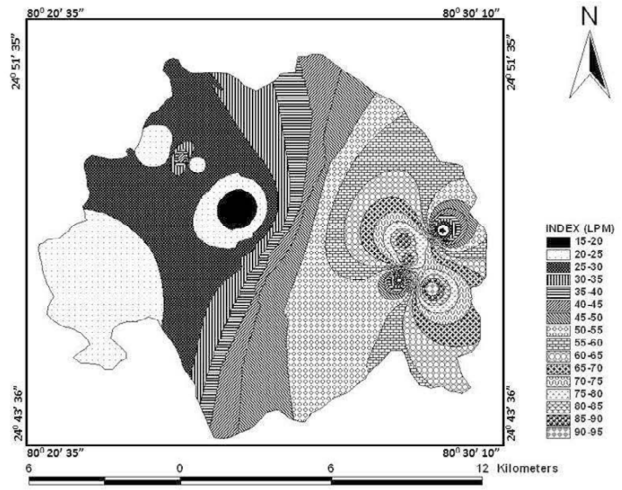

Fig.11. Well discharge map

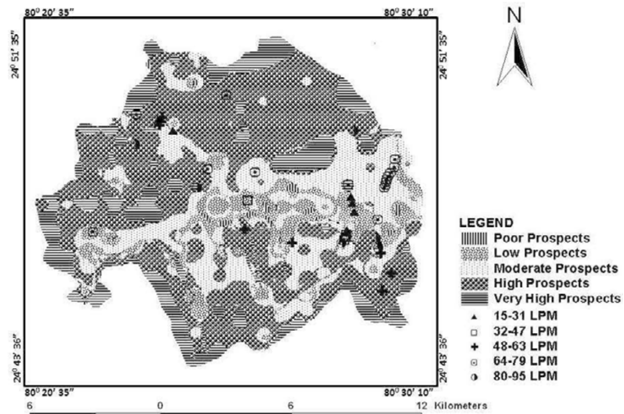

Fig.12. Integrated map of groundwater prospects and well discharge

integration of groundwater prospects map with yield map shows that very high groundwater prospect areas give good yield comparatively to high or moderate prospects zone areas (Fig.12). High discharge value falls on high / very high prospects zone, this method shows more than 70% accuracy for groundwater prospects mapping. This map also proves the accuracy assessment of index overlay method.

By suggesting appropriate recharge structures, the overall groundwater resource can be improved. The lineament can also be utilized to augment the groundwater resources. Good prospects are found in areas having high density lineament interaction.

Acknowledgement: Authors are grateful to the Director, CSIR-AMPRI, Bhopal, M.P. for permitting to publish the research work. Authors are also thankful to Director, National Remote Sensing Centre, Hyderabad for his valuable guidance and encouragement during the work.

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(Received: 17 January 2014; Revised form accepted: 12 August 2014)