Mapping of Lineaments for Groundwater Potentiality in Denwa Watershed Using Remote Sensing & GIS

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***Abstract*–**One of the complex geological processes with heterogeneous nature of aquifers, various rock compositions, fracture density and high degree of weathering is Groundwater. It is important to assess the Groundwater which falls under the fracture zones. The modern technology like Remote-sensing can become very useful in assessment of ground water. The major ejective of this study is to identify the Lineament in study region and represent them in the form of map in an exhumed Hydro-geological environment. Further, this study also aims to develop GIS based monitoring system which will determine micro-scale groundwater potential evaluation of Denwa watershed in central India with the help of remote sensing data. For the investigation of lineaments Digital Elevation Model (DEM) was generated and thematic maps, such as lineament frequency, density and intersection were prepared using interpolation technique. The obtained result reveals the importance of GIS and Remote-sensing technique to increase the lineament intersection and density in large amount. The proposed study will be helpful to provide an immense help for further inspection of quantitative evaluation of groundwater assessment.

Keywords*- Aquifers, Lineaments, Fracture Zones, Exhumed, DEM.*

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I. INTRODUCTION

Different geological and geographical appearances like shear zones, faults, rift valleys, truncation of outcrops, joints, fracture trends, Litho-contacts, lines of significant changes in sedimentation, topographic configuration like ridges or subsidiaries and vegetation alliance etc are employed by the term Lineament.

Groundwater exploration work was done by Lattman and Parizek (1964). In this investigation they mapped linear features (fracture traces) on stereo-pairs of aerial photographs in carbonate terrain in the eastern United States further the results reveals the relationship between yield and distance .

Further the use of Lineament mapping in geological applications was done long time ago. Hobbs (1904, 1912), used the term lineament in geology who defined lineaments as significant lines of landscape caused by joints and faults, revealing the architecture of the basement rocks. Further, new definition was introduced by O' Leary et al. (1976). It has been defined as "A Lineament on a regional scale is a linear or curvilinear features pattern or change in pattern that can be identified in a data set and attributed to a geologic formations or structure".

The above definition of lineament has been proposed in the proceeding of joint INDO-US workshop on geophysical Lineament and their tectonic significance introduced the lineament terminology. (1981, Geol. Society- Ind. Mem. No. 12, 195).

Geological studies with remote sensing images of linear features highlight the relationship between lineaments and groundwater flow and yield (Mabee et al., 1994; Magowe and Carr, 1999; Fernandes and Rudolph, 2001). Lineaments provided the pathway for groundwater movement and are hydro-geologically very important (Sankar et al., 1996). According to Hardcastle (1995), the mapping of lineaments is directly related to groundwater occurrence and yield which is important for groundwater surveys, development and management.

Because of heterogeneous nature of aquifers: owing to varying composition; fracturing density and weathering degree, complex geology ground water condition forms the multivariate situation which creates the complex situation such terrain. This leads to develop some necessity plans with advance technologies. In such kind of situation remote sensing technique plays a handy role to identify and demarcate lineaments which can achieve the goal of targeting ground water.

It yields information on lithology and structural fabrics, which are, loci for storing ground water. Surface appearances of lineaments are usually structurally controlled and therefore recognized very easily in satellite imagery by straight tonal alignments of linear or curvilinear features.

In this study we made an attempt to design the map based decision support system with the help of remote sensing and Geographic Information Systems (GIS) to produce a regional structural lineament map to determine the hydro geological implication of these lineaments by

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integrating them with (Digital Elevation Model [DEM] and geological map) and tried to analyze the lineament trends distribution using rose diagrams, lineament density maps and lineament intersection maps.

II. STUDY AREA

The Denwa watershed extends over approximately 2007 km^2 and lies between 22°15′ to 22°45′N latitude and 78°00′E to 78°45′E longitude in Satpura range in southern part of Madhya Pradesh, India. It originates at the altitude of 1329m in the Mahadeo Hills of Hoshangabad district in Madhya Pradesh (Figure 1). Generally the basin has continental type of climate with extreme hot summer and cold winter season. Pachmarhi is the one and only hill station of the state located in this watershed having a pleasant climate in summer due to high altitude, but become severe during winter. The maximum and minimum range of the basin temperature varies from 34.1 ºC to 40.7 ºC in summer season and 4.7 ºC to 16.0ºC in winter. The average rainfall is 125-175 cm with maximum rainfall of the state. The surface runoff goes to stream as instant flow. In Denwa basin rainfall is the direct recharge source of groundwater. The study area mainly depends on north-east monsoon rains brought by troughs of low pressure established in Bay of Bengal. The vegetation is tropical deciduous type.

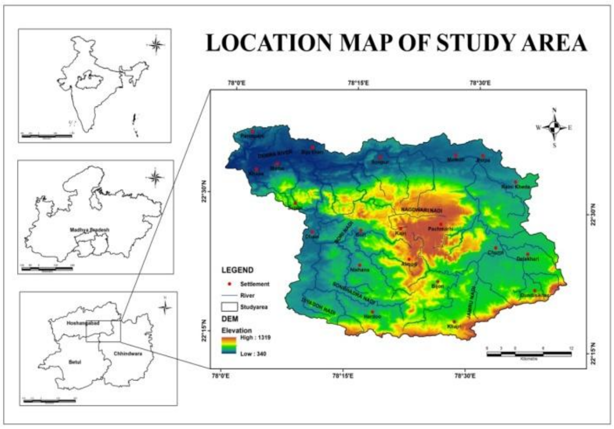

Figure1: Location of Study Area with ASTER 30m DEM

III. METHODOLOGY

The Indian Remote Sensing Satellite Landsat 7 Enhanced Thematic Mapper Plus (ETM+) geocoded False Colour Composites (FCC), on 1:50,000 scales used for the present study. The image comprises subsets from an original scene of path 145 and row 044 of Landsat 7 ETM+ of 2000. Landsat 7 ETM+ has an extra 15-m Panchromatic (Pan) band. The Landsat image of 2000 was downloaded free from the Global Land Cover Facility homepage (http://glcf.umiacs.umd.edu/index.shtml). The imagery was Geo-referenced with identifiable features such as road junctions and river bends on topographical map of the study area. The area studied was sub-setted and used for lineament mapping. Lineaments were delineated by visual interpretation of false colour composite (FCC) 471. The FCC was fused with the 15-m Pan 2000 image to enhance the interpretation. Hung et al. (2005) experimented that the application of higher-resolution 15- m Advanced Space-borne Thermal Emission and Reflection of Radiometer (ASTER) imagery yielded better results in lineament interpretation compared to Landsat imagery due to improved spatial resolution. After investigation of various band combinations FCC RGB 471 was selected for the proposed study.

Koch and Mather (1997) and Hung et al. (2005) define the importance of Lineament mapping in geographical region with geomorphological features such as aligned ridges and valleys, displacement of ridge lines, scarp faces and river passages, straight drainage channel segments, pronounced breaks in crystalline rock masses and aligned surface depression. Some of the major work in lineament study is done by Juhari and Ibrahim 1997, Koch and Mather 1997, Solomon and Ghebreab 2006. In their study they highlighted the relation of topographically negative lineaments correspond to joints, faults and probably shear zones. Yassaghi (2006) proposed the method to produce the lineament map which determine groundwater potential zone and eliminated the non-geological elements such as paths, roads, power cables and field boundaries.

The interpreted lineaments (Imagery of 2000) were digitized on-screen. Topographical features of the study area were used for the interpretation which underwent repeated checking to eliminate any unnecessary lineaments. After all the lineaments interpreted, were draped over DEM derived from ASTER imagery. Only lineaments that were consistent with topographically features were digitized.

IV. GEOLOGY

The study area is a part of the vast Satpura Gondwana basin with the representatives of the most important geological formations of India. Age of the formations is ranging from Archaean base to recent alluvium. The Satpura succession was deposited in a mega half graben bounded by basin margin fault controlled subsidence regimes with intervening tectonically static periods. According to Chakraborty and Ghosh (2005), "Subsidence rate varied across the basin resulting in an asymmetric basin fill with the thickness increasing towards the north."

Precisely, the Pachmarhi Formation comprises recurring sequence of multi-storey sandstones bodies which cropped out largely in the southern and central parts as lofty hills and plateau. Crookshank (1936) mentioned, “The Satpura Gondwana basin hosts a ~5 km thick silici-clastic succession (Permian-Cretaceous,) that unconformably lies over the Precambrian basement.” Regional strike of the basin-fill strata is NE-SW, and regional dip (~5°) directed towards north. The Permo-Cretaceous Satpura Gondwana succession has been consisted of seven major litho-stratigraphic units. Hierarchically, they are Talchir, Barakar, Motur, Bijori, Pachmarhi, Denwa and Bagra formations fashioned as oldest to youngest form. Barring the lowermost glacio-marine and glacio-fluvial deposits, the rest of succession largely comprises a variety of fluvial deposits with some records of fluvio-deltaic and fluvio-lacustrine sediments (Maulik et al., 2000; Ray and Chakraborty, 2002; Ghosh et al., 2004; Chakraborty and Sarkar, 2005; Ghosh et al., 2006; Chakraborty and Ghosh, 2008). In Satpura Gondwana basin, the periods of maximum subsidence are indicated by glacio-marine, fluvio-deltaic and fluvio-lacustrine regimes prevailed during Talchir, Barakar and Bijori sedimentation respectively. Chakraborty and Ghosh (2005) pointed out that after Bijori sedimentation; accumulation in Satpura Gondwana basin took place under alluvial regime indicating a decrease in the rate of subsidence. Eleven geologic features were identified and mapped by the Geological Survey of India, shown in Figure 2.

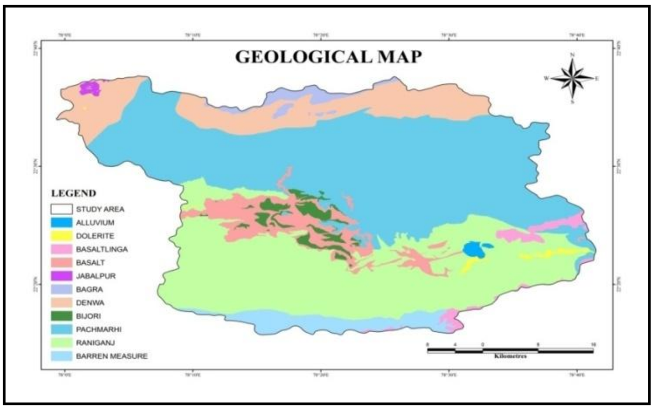

Figure2: Geological Map of Study Area

V. INTERPRETATION AND MAPPING OF LINEAMENTS

The lineaments interpretation from satellite imagery has become a revolution in the field of geo-science as they facilitate a synoptic overview of terrain. Thus, satellite data is very useful to delineate regional lineaments. The lineaments were identified by the surface signatures like straight drainage courses, litho-contacts, vegetation alignment etc. In this regard a lineament map has been generated using Landsat-7 ETM$^+$ satellite data. Taking into account the manner in which these lineaments are displayed on images is divided into following categories:

- A Lineament along litho structural contact.
- Topographic Lineaments.
- Fracture zone Lineaments.
- Lineament related to major faults.
- Geomorphic Lineaments.

VI. RESULTS AND DISCUSSION

A. *Lineament Analysis*

In the milieu of arranged examination subsequent to digitizing the lineaments, they were additionally assessed utilizing some fundamental parameters like lineament thickness (LD), lineament recurrence (LF) and lineament convergence (LI). The examination comes about are displayed as lineament outline, area and recurrence delineate, thickness outline, chart, lineament convergence guide and level of lineament crossing point (Figures 3, 4, 5, 6, 7, 8 and 9) individually.

Table No. 1 Length of Different Types of Lineaments

Sl. No.	Type	Description	Colour	No.	Length (km)
1.	Geomorphic	Ridge Parallel	Blue	4	12.53
2.	Geomorphic	Drainage Parallel/ Scarp	Green	43	92.66
3.	Structural	Joint/ Fracture	Pink	298	743.21
4.	Structural	Fault	Red	1	3.79
5.	Structural	Dyke	Yellow	37	123.63
Total				383	975.82

B. *Spatial Location and Frequency*

The spatial area of breaks (Fig. 4) shows scarcely homogeneous dispersion. The lineament recurrence delineate. 5) delineates lineament numbers to be in the scope of 0 and 7. Lion's share of the breaks are situated on the lithology that compares to coarse grained sandstone with periodic aggregate and earth groups of Pachmarhi arrangement which by and large alludes to profoundly permeable shake with outstanding penetrability. In this manner, its character speaks to an underlying sign for great hydrogeologic administration of amazing ground water possibility.

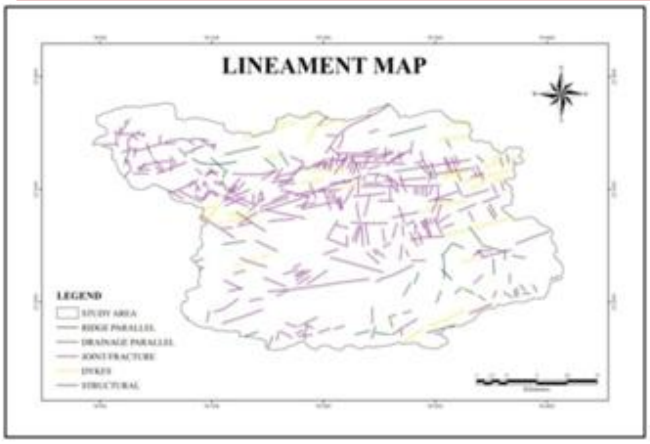

Figure3: Lineament Map of Denwa Watershed

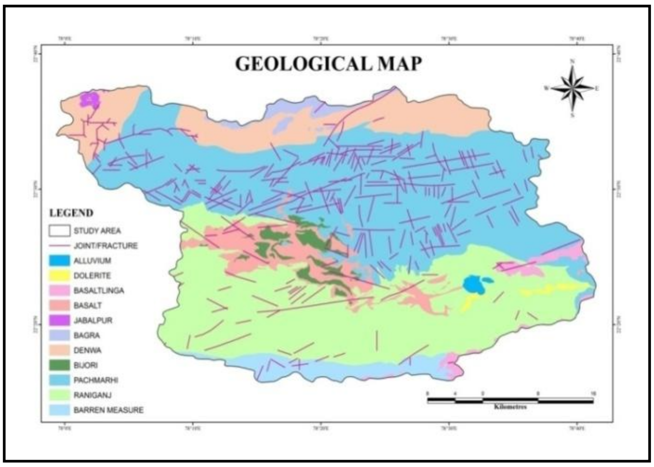

Figure 4: Spatial Location of Lineaments

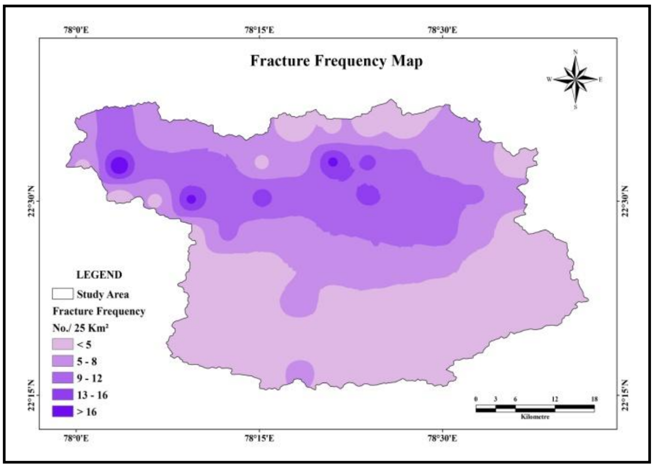

Figure 5: Lineament Frequency Map

C. Orientation

The spatial area of breaks (Fig. 4) shows scarcely homogeneous dispersion. The lineament recurrence delineate. 5) delineates lineament numbers to be in the scope of 0 and 7. Lion's share of the breaks are situated on the lithology that compares to coarse grained sandstone with periodic aggregate and earth groups of Pachmarhi arrangement which by and large alludes to profoundly permeable shake with outstanding penetrability. In this manner, its character speaks to an underlying sign for great hydrogeologic administration of amazing ground water possibility.

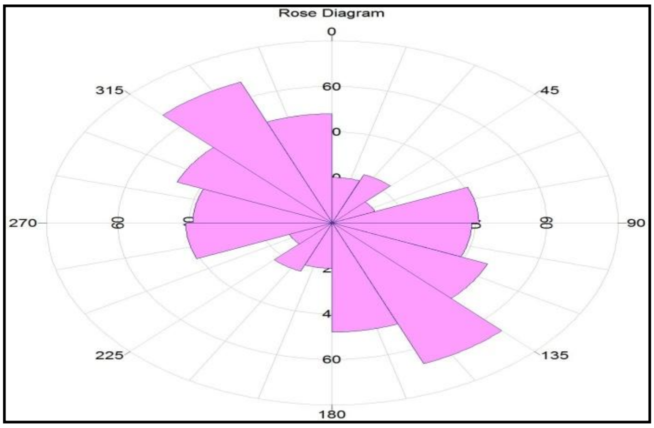

Figure 6: Lineament Rose Plot

D. Size of Lineaments

Break measurements (gap and obvious gap) are exceptionally hard to characterize; profundity of gaps makes the estimations significantly more entangled. In any case, length estimations can be taken generally effortlessly and they are likewise huge in light of the fact that a crack with a more prominent length influences the groundwater stream in a more overwhelming manner than those of littler length. The figured aggregate lengths of various lineaments are appeared in Table 2.

E. Density of Lineaments

The crack thickness investigation is utilized to compute recurrence of the breaks per unit region. A guide has additionally been set up by this investigation displaying centralizations of lineaments over the territory contemplated (Fig. 7). The guide in Figure 7confirms that high thickness, saw in zones of coarse grained Pachmarhi sandstone (11km/km2), suggests high level of pressure driven interconnection between the above lithologic units as surface water flows effectively through these discontinuities. Unexpectedly, low thickness is seen in various sorts of Deccan Trap shakes and in addition Barren Measure, Denwa arrangement of Lower Gondwana alongside conglomeratic dirt beds of Bagra development (1km/km2). The western piece of Raniganj sandstone and Bijori sandstone shows medium thickness (6km/km2). This confirms these lithologies are influenced by structural action.

F. Degree of Lineament Intersections

The level of anisotropy of groundwater stream in break arrange is dictated by the thickness of lineaments alongside

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level of lineament crossing point, as in conditions with a high level of interconnection where groundwater stream is smoother and more uniform. Break crossing point thickness is a guide demonstrating recurrence of convergences that happen in a unit territory.

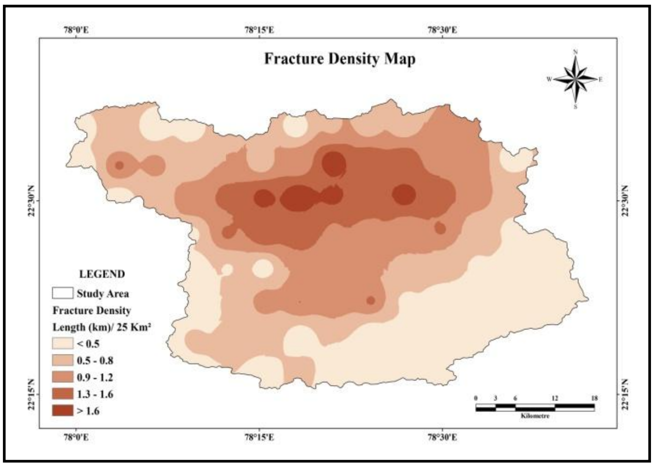


Figure7: Lineament Density Map

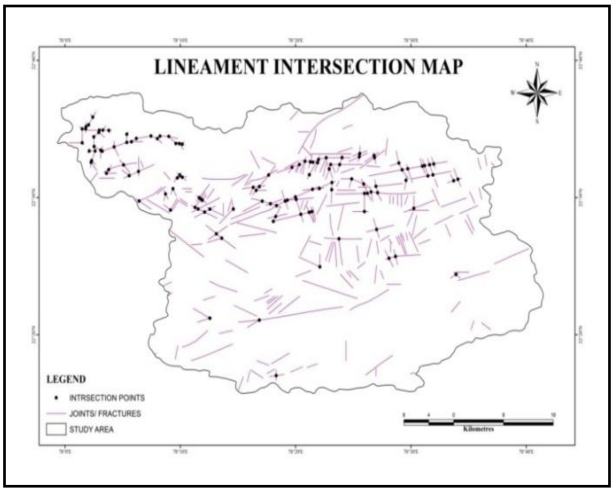


Figure 8: Lineament Intersection Map

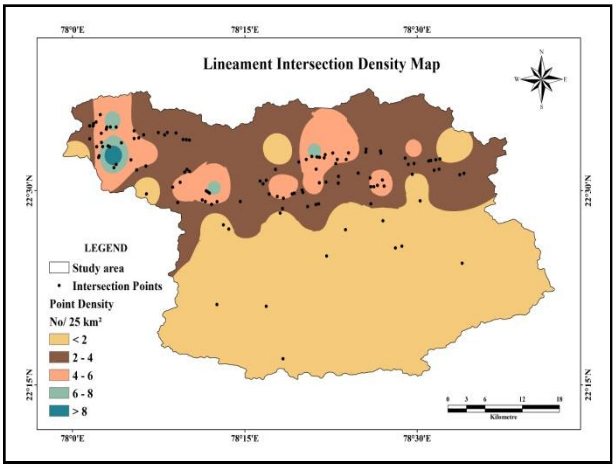
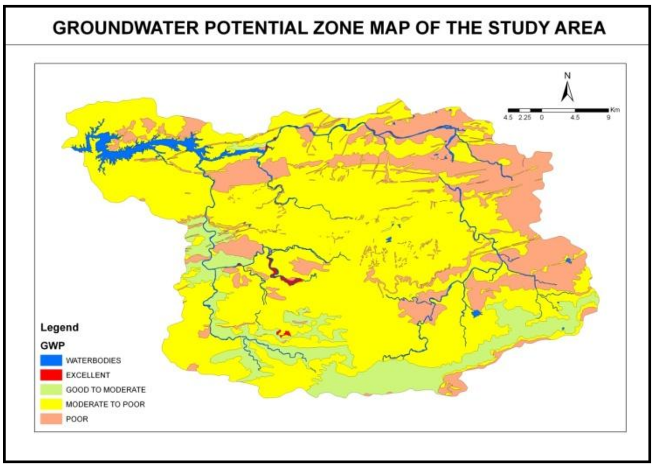


Figure9: Degree of Lineaments Intersection Map

Intersection density map is used to estimate the areas of diverse fracture orientations. If the fractures do not intersect in an area, the resultant map will be represented by a plain map with almost no density contours and the fractures are almost parallel or sub-parallel in an area. After superimposing lineament intersection map (Fig. 9) on lineament density map it becomes easy to interpret that areas of high and very high degree of intersection designates very high lineament density. The zones of high lineament intersection over the study area are feasible zones for groundwater potential evaluation.

G. *Discussions*

In the territory of Central Highland of India, GIS and remote detecting system turns out to be exceptionally useful instrument for Geo-hydrological elucidation of any physiographic unit of Denwa watershed which goes under the Pachmarhi Biosphere Reserve. In such sort of land nature area it is difficult to explore the Groundwater territory which requires extraction of information from pictures through remote detecting and GIS. Absence of adequate information and its quality started nitty gritty research on lineaments and auxiliary parts as noteworthy devices to portray the groundwater energize and release focuses, its stream and growth. The investigation result affirms that the remote detecting procedure is likewise fit for extricating lineament inclines in a blocked off tropical timberland. Remote detecting has turned into an extremely helpful apparatus in lineament distinguishing proof and mapping. The utilization of remotely detected information for lineament understanding is additionally exhibited in this examination. A Digital Elevation Model (DEM) was produced to enhance the understanding. Specifically, groundwater events in Gondwana development are chiefly controlled by lineaments relating to cracks, joints and blames. The spatial circulation of lineaments is additionally straightforwardly connected with groundwater release focuses wherever they create springs.



This study has led to the delineation of areas where groundwater occurrences are most promising for sustainable supply, suggesting where further geophysical surveys can be concentrated. It is therefore suggested that high lineament intersection and density should be combed with detailed geo-electrical surveys for quantitative evaluation of groundwater potential of study area.

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