IDENTIFICATION OF GROUND WATER POTENTIAL ZONES USING INTEGRATED APPROACH: A CASE STUDY ON SOME SUB-BASINS OF LOWER PENNA RIVER BASIN

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Abstract: Morphometric analysis is important in any hydrological investigation and it is inevitable in development and management of drainage basin. Geographical information system (GIS) has emerged as an efficient tool in delineation of drainage pattern and ground water potential and its planning. GIS and image processing techniques can be employed for the identification of morphological features and analyzing properties of basin. In the present study, morphometric analysis and prioritization of the 3 micro watersheds of Lower Penna river basin, lies in Nellore district, Andhra Pradesh state in India is carried out using remote sensing and GIS techniques. The morphometric parameters considered for analysis are stream order, stream length, stream length ratio, length of overland flow, bifurcation ratio, drainage density, stream frequency, basin shape, basin elongation, elongation ratio and compactness ratio. The thematic maps like geomorphology, land use land cover, rainfall distribution, were also considered for weighted overlay analysis. The micro-watersheds has sub-dendritic to dendritic drainage pattern. The highest bifurcation ratio among all the micro watersheds is 6.5 which indicate a moderate lineament structural control on the drainage. The maximum value of circularity ratio is 0.7850 for the micro watershed WS-3, which also has highest elongation ratio (0.71). The form factor values are in the range of 0.35 to 0.40 which indicates that the watershed has moderately high peak flow for shorter duration. The compound parameter values are calculated and prioritization rating of 3 micro-watersheds in part of Penn basin is carried out. The micro-watershed with the lowest compound parameter value is given the highest priority. Two micro-watersheds WS-1 and WS-3 having a micromum compound parameter value of 2.375 are likely to be subjected to moderate soil erosion.

Keywords - Morphometry, Micro-watershed, groundwater potential zones, Lower Penna basin.

I. INTRODUCTION

The study of stream order in drainage basin helps to identify the natural environment of a place. The Geographers, Geoscientist, Hydrologist and Geologists study stream order in drainage basin to get idea of the size and strength of specific waterways within stream networks and important component to water management. Stream orders have been classified based on its relative position in the stream network, which helps us to understand the similarities and differences between them. Different types of stream order classification system has been developed, in that one of the earliest method and most commonly used method was developed by Strahler in 1952. The study of streams and waterways in general is known as surface hydrology and is a core element of environmental geography. In recent years development of Geographical Information Systems helps the researchers and scientist to study the stream order accurately and easily. The current study also has been done using GIS technique to analysis groundwater potential using morphometric parameters of the micro-watershed of Lower Penna basin..

II. STUDY AREA

The study area is located in lower Penna basin which lies in the southern part of the SPSR Nellore district of Andhra Pradesh. (Fig. 1)

III. AIM AND OBJECTIVE OF THE STUDY

This study aims to generate and assimilate the data for an integrated study to assess the groundwater resource potential using RS & GIS with the following objectives:

- To prepare various thematic maps i.e., morphometric, geomorphology, Slope, Lineaments, Landuse and Landcover, Annual Average Rainfall distribution, related to Groundwater Potential delineation using GIS techniques.

- To develop the groundwater potential zones delineated map using Weighted Overlay analysis technique in GIS environment..

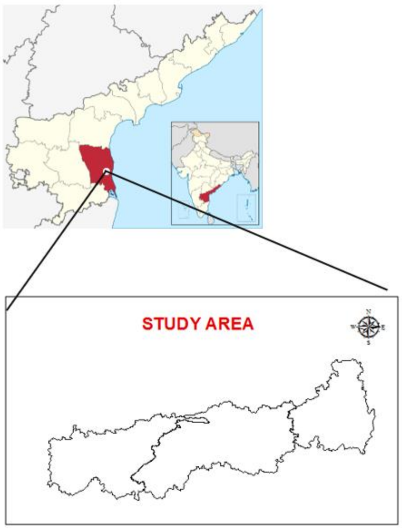

Fig. 1. Study Area

IV. METHODOLOGY

Weighted Overlay Analysis

The identification of groundwater prospective zones involves in Weighted Index Overlay Analysis (WIOA) approach taking into account on various thematic maps. (Fig.2)

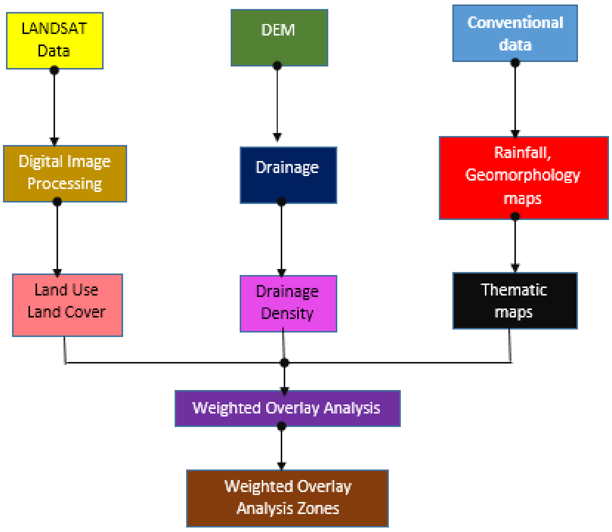

Fig. 2 Flow chart for the groundwater potential zones using GIS technique

Developing thematic maps using RS & GIS

Digital Elevation Model

The Shuttle Radar Topography Mission (SRTM) 30 m resolution was used for developing different maps in the present study. The void filled DEM was considered for the analysis which is the result of additional processing to address areas of missing data or voids in the SRTM Non-Void Filled collection.

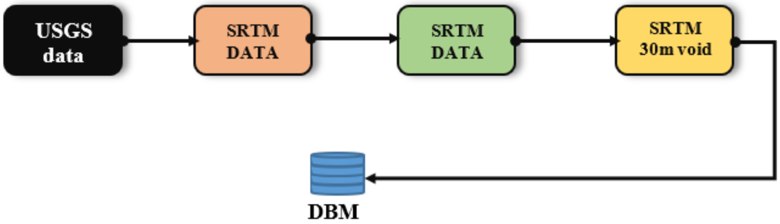

Fig.3 Process of preparing data base management for DEM analysis

Hydromorphology thematic map

The step by step process adopted for developing the morphology map from the Digital Elevation Map (DEM) with SRTM 30m resolution in GIS environment is shown in Fig. 4

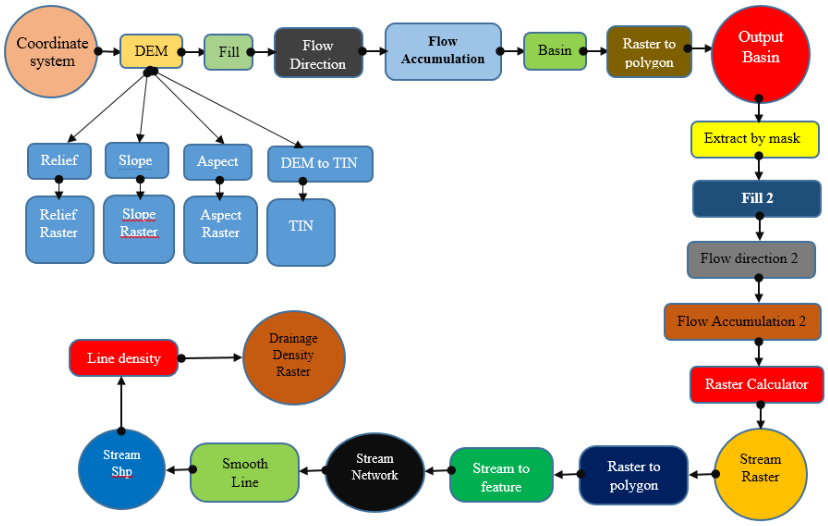

Fig.4 Flow chart of hydrological processes of study area

Geomorphology map

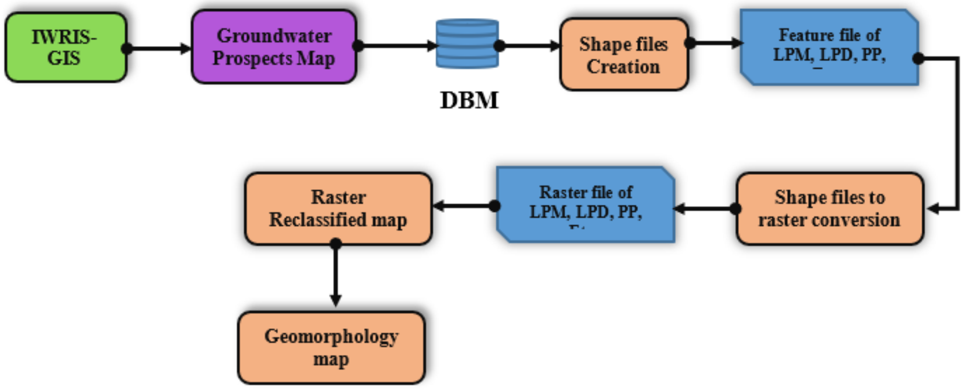

Fig. 5 Flow chart of Geomorphological processes of study area

Land use and Land cover thematic map

The Landsat 7 TM data of January 2018 covering the study area was downloaded from USGS data base. The downloaded image is stored into GIS data base management and further processed to develop the LULC map of the study area. The step by step process of developing LULC map is as shown in the Fig 6.

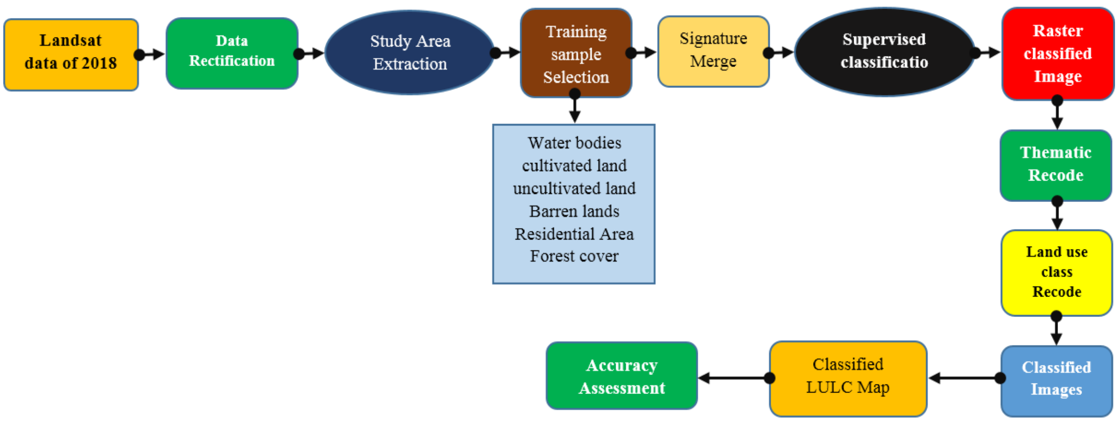

Fig. 6 Flow chart of LULC process of study area

Lineament map

The lineament thematic map of the study area was developed by creating features on satellite images in GIS environment by manual interpretation with the help of DEM and Google earth which are real time data for accurate validation. Further the lineaments map developed from the above mentioned sources was checked with the IWRIS-GIS data for the accuracy.

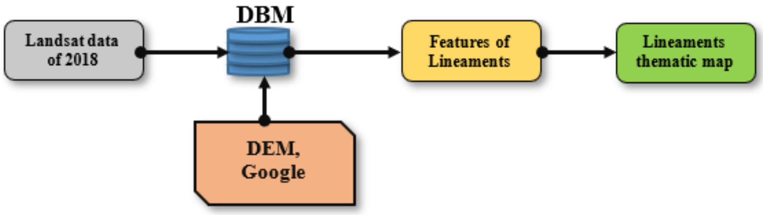

Fig. 7 Flow chart of lineament process of study area

Average Annual Rainfall distribution thematic map

The rainfall data acquired from the district irrigation department was arranged in the format as required for to be given into GIS-DBM. Later the given data was used to develop the rainfall distribution over the study area. The step by step process of developing the thematic map is as shown Fig.8

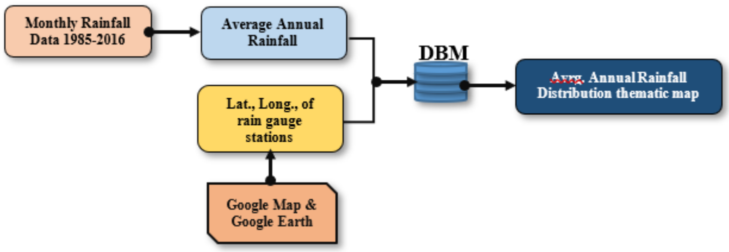

Fig. 8 Flow chat of average annual rainfall distribution thematic process of the study area

V. Quantitative Morphometric Analysis

The first step in morphometric analysis involves designation of the stream orders. A system oif channel ordering was suggested by Cravelius (1914), but the work of Horton 91932, 1945) marked the beginning of the wide-spread use of ordering systems in geomorphology. The usual method of ordering is the one that has been suggested by Strahler (1952). The nest step involves order analysis and this is carried out by measuring the length of each channel according to the order. Some of the morphometric variables can be measured directly from the map and these include basin area, lengths of the first order streams, second order streams, third order streams etc. Other variables derived from such direct measurements include measures of basin shape such as circularity, drainage density, bifurcation ratio and basin relief ratio.

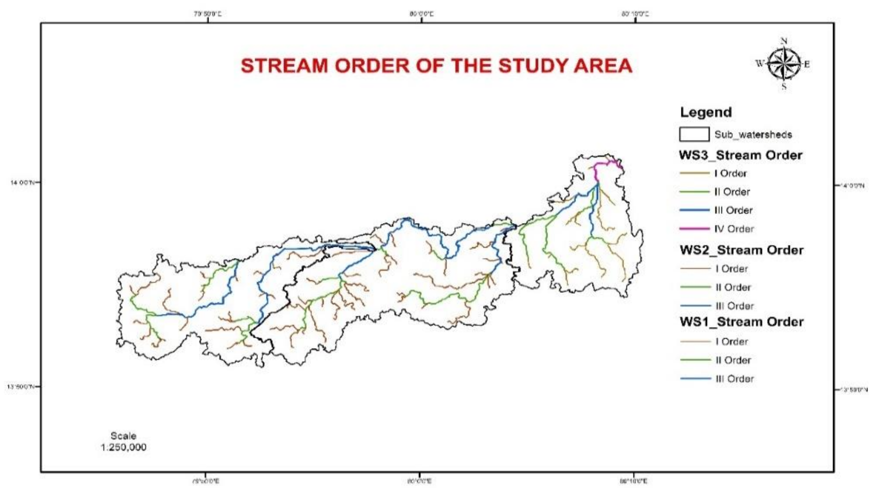

Fig 9. Stream Order of the study area

Drainage Basin

Three contiguous sub-basins in the lower Penna basin have been selected for the present study. The total area of all the three sub-basins is 352.75 sq km

Morphometric parameters

The following morphometric parameters that have a marked influence on the surface and ground water regimes of the region have been dealt with in detail.

Stream ordering & Stream Length

The average stream length is given by the ratio of total length of all streams of a given order to the number of streams of that order. (Table 1)

$$\bar{L}_u = \frac{L_u}{N_u}$$

where $\bar{L}_u$ = average stream length
L_u = total length of streams of order *u*
N_u = total number of streams of order *u*

Table 1: Stream Order, Mean Stream Length

Micro Watershed	Parameters	I Order	II Order	III Order	IV Order	All orders
WS1	Total Length	38690.97	18087.05	29056.61	Nil	85834.63
	No of streams	30.00	12.00	14.00		56.00
	Mean Stream Length	1289.70	1507.25	2075.47		1624.14
WS2	Total Length	74247.56	26630.57	27585.13	Nil	128463.45
	No of streams	39.00	20.00	14.00		73.00
	Mean Stream Length	1903.78	1331.53	1970.37		1735.23
WS3	Total Length	32756.64	20095.01	10434.12	4912.35	68198.12
	No of streams	18.00	7.00	5.00	5.00	30.00
	Mean Stream Length	1819.81	2870.72	2086.82	982.47	2259.12

Stream Length Ratio

Stream length ratio is defined as the ratio of mean length of streams of order *u* to the mean length of the streams of the next higher order.

$$R_L = \frac{R_l}{L_{(U+1)}}$$

where,
R_L = Stream length ratio
L_U = Mean length of stream channel segments of order *u*
$L_{(U+1)}$ = Mean length of stream channel segments of order (*u+1*)

he stream length ratios for WS1, WS2, WS3 are 1.68, 1.69 and 1.98 respectively. Compared to the values of stream length ratio in the neighboring sub-watersheds these values are found to be slightly higher indicating a greater runoff.

Length Of Overland Flow

Surface runoff follows a system of down slope flow from the drainage divide (basin perimeter) to the nearest river channel. The length of overland flow (Lg) is defined as the length of flow path projected to the horizontal, of non –channel flow from a point on the drainage divide to a point on the adjacent stream channel (Horton, 1954).

In the present analysis, for the four sub-watersheds studied, it can be seen that the average value of Lg is 0.67 . This relatively lower value indicates higher erodibility of the stream.

Bifurcation Ratio

Bifurcation ratio is the ratio of branching in drainage network. It is defined as the ratio of number of streams of order to the number of streams of next higher order.

$$\bar{R}_b = \frac{N_u}{N_{(u+1)}}$$

where,
$R_{b.}$ = Bifurcation Ratio
N_u = Number of streams of order u
$N_{(u+1}$ = Number of streams of order (u+1)

Among the three sub-watresheds studied, the highest bifurcation ratio is observed in WS3, which is nearly 2. In the subwatersheds WS1 and WS2, the bifurcation ratios are 1.68 and 1.69. These low values of R_b indicate the fact that these sub-watersheds are devoid of well developed joints and fissures. Low values of bifurcation ratio also indicate that the sub-watersheds are in their early stages of development and is not mature.

Drainage Density

Drainage density represents length of stream channel per unit area in the water-shed. It is an important indicator of linear scale of landform elements in stream eroded topography and does not change regularly with orders within the basins. The drainage density has been discussed and related to many parameters by several geomorphologists (Horton, 1945; Smith 1950; Chorley, 1957;

Melton 1958; Morisawa, 1962; Strahler, 1969; Grogory, 1976). Table 2 Categories of drainage conditions and drainage density range (After Deju, 1971).

Table 2: Drainage density classification

Drainage Conditions	Drainage Density Range in km^{-1}
Poor (P)	< 0.5
Medium (M)	0.5 to 1.5
Excellent (E)	< 1.5

Table 3 Drainage Density of the present watersheds

Micro-Watershed	Stream length of all orders in km	Area (km^2)	Drainage density (Dd) = Lu/A
WS1	85.835	117.671	0.729
WS2	128.463	160.275	0.802
WS3	68.198	92.089	0.741

Stream Frequency

Stream frequency is defined as the number of streams of a given order per unit area.

$$\bar{F_u} = \frac{N_u}{A}$$

Where,

F_U = Stress frequency for the streams of order

N_U = Number of streams of order U

A = Area of drainage basin in square kilometres

Stream frequency is used as a supplementary measure of the fineness of texture of topography. High stream frequency is found in areas of non-porous bed rocks, high rainfall and thin vegetation cover.

The stream frequency analysis for the four sub-watersheds is shown in table 4. The average stream frequency for all the four sub-watersheds studied ranges from 0.38 to 0.48. These low values of stream frequency are indicative of fine texture of the topograph more than high relief.

Table 4 Stream frequency

Micro Watershed	Total number of streams of all order	Area(km^2)	Fs = Nu/A
WS1	56	117.67126	0.476
WS2	73	160.274726	0.455
WS3	35	92.089293	0.380

Basin shape

Shape of the basin is one of the variables that influences run -off. In the present study the basin shapes parameters considered for the analysis, namely

1) Basin circularity
2) Basin elongation

Table 5 Circularity Ratios

Micro-Watershed	Area (km^2)	perimeter (km)	Circulatory ratio
WS1	117.67126	91.064	0.178
WS2	160.274726	96.089	0.218
WS3	92.089293	65.87	0.267

The average circularity ratio for the three sub-watersheds studied is 0.22. Thus, from the above discussion it can be inferred that the river system is in a youthful stage. This inference is also supported by the bifurcation ratio analysis.

Basin elongation

The shape of any basin is expressed by the elongation ratio Re which is defined as the ratio of the diameter of the circle with the same area as the basin to the maximum length of the basin (Schumm, 1956).

The basin elongation ratio for the three sub-watersheds studied is in the range 0.47 to 0.61. Values near to 1 are typical of regions of low relief or the shape of the drainage basin approaches a circle.

Table 6: Elongation Ratios

WS	Elongation Ratio
WS1	0.473
WS2	0.612
WS3	0.505

VI. THEMATIC STUDIES

Geomorphology

The geomorphology thematic map was delineated from the Indian water resources information system raster data set. The geomorphology of the study area is as shown in the Figure 10.

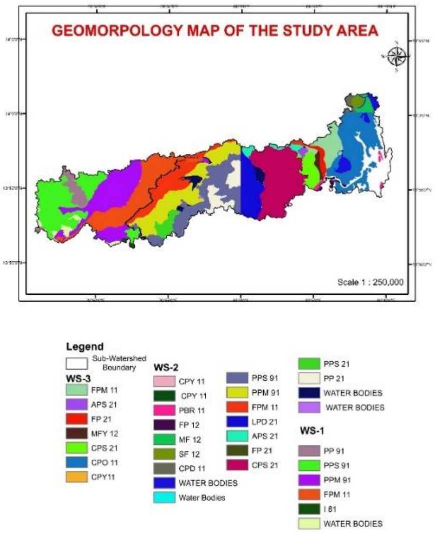

Fig 10. Geomorphological thematic map of the study area

Land Use and Land Cover

The FCC used for developing supervised classified LULC thematic map is shown Fig. 11 and the Post processed LULC thematic map is shown in Fig 12

Table 7 Land Use and Land Cover of the study area (sq.km)

MWSD NO.	LAND USE LAND COVER OF THE BASIN IN SQ.KM.							
	RIVER/ STREAM	WATER BODIES	CULTIVATED LANDS	UNCULTIVA -TED LANDS	BARREN LANDS	RESIDENTIAL	FOREST	Areas Sq.Km
WS1	13.613	3.696	49.32	38.313	1.814	10.853	*	117.60
WS2	1.321	8.906	57.546	65.382	1.833	4.429	20.762	160.17
WS3	*	12.076	38.824	41.128	*	*	*	92.02

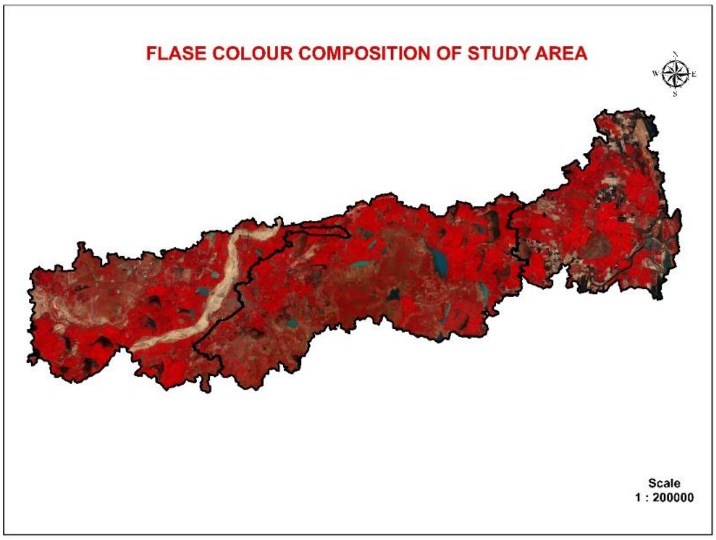

Fig 11 False Colour Composition of the study area

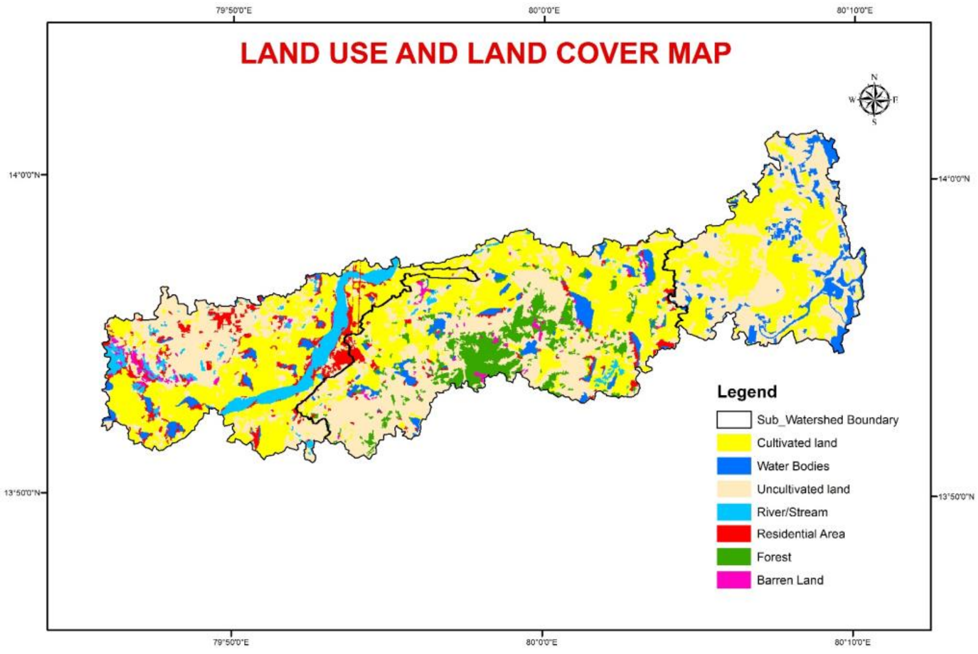

Fig. 12 Land Use & Land Cover Classification of the study area.

Table 8 Percentage cover of the study area (%)

MWSD. NO.	LAND USE LAND COVER OF THE BASIN IN SQ.KM.						
	RIVER/ STREAM	WATER BODIES	CULTIVATED LANDS	UNCULTIVATED LANDS	BARREN LANDS	RESIDENTIAL	FOREST
WS1	11.57	3.14	41.94	32.58	1.54	9.23	0.00
WS2	0.82	5.56	35.93	40.82	1.14	2.77	12.96
WS3	*	13.12	42.19	44.69	0.00	0.00	0.00

From the above tabulated results it is evident that the study area contain large area under cultivation followed by water bodies which are prospective land cover features for availability of the groundwater in the study area.

Watershed 1 which is having an area of 72% of area under cultivation, and remaining area under water bodies. Similarly, Watershed 2, Watershed 3, also contains maximum area under cultivation i.e. 78%, 55% respectively and 6%, and 13% respectively under water bodies and river/streams.

Rainfall

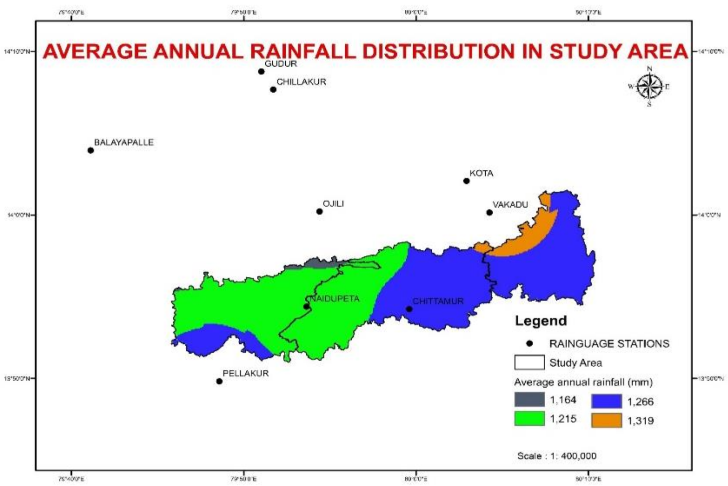

Fig. 13 Average Rainfall Distribution in study area

VII. WEIGHTED OVERLAY ANALYSIS

The following procedure was carried for developing the weighted overlay analysis thematic map. Land use land cover map, Drainage density, rainfall distribution map, geomorphology map, lineament map was considered for the overlay analysis by giving ranking to the each influencing domain of the respective thematic maps and weightage.

Table 9 Details of ranking and weightage for Overlay analysis

S.No	Domain effect	Rank	Weightage
1.	**Geomorphology Features**		**50**
	FPM 11	4	
	WATER BODIES	5	
	SF 12	4	
	LPD 822	2	
	LPD 821	2	
	MF 12	2	
	LPM 11	4	
	LPM 21	4	
	LPM 921	2	
	PPS 91	3	
	LPM 922	2	
	LPM59	2	
	CPD 11	4	
	LPD 21	2	
	CPO 11	5	
	APS 21	4	
	PPM 91	4	
	MFY 12	4	
	CPY 11	5	
	PBR 11	5	
	FP 12	5	
	PP 21	3	
	PP91	4	
	CPS 21	4	
	PPS 21	3	
	I 81	1	
2.	**Land use Land cover**		20
	Cultivated land	3	
	Un cultivated land	2	
	Residential area	5	
	Forest	4	
	Water Bodies	5	
	Barren lands	1	
3.	**Drainage Density**		10
	≤1	3	
	>1 - <2	4	
	>2 - <3	4	
	>3 - <4	5	
	>4 - ≤5	5	
4.	**Rain Fall (mm)**		10
	≤ 1113	3	
	> 1113 - < 1164	4	
	>1164 - < 1215	4	
	>1215 - < 1266	5	
	>1266 - ≤1319	5	
5.	**DEM (m)**		10
	<27	5	
	>27 - <54	4	
	>54 - <81	3	
	>81 - <108	2	
	>108 - ≤135	1	

The weighted overlay analysis using all the thematic maps was carried out in ArcGIS environment using spatial analysis tool. The resulting map of the overlay analysis is shown in the Fig.14

Table. 10 Distribution of groundwater potential zones under various classes

S.No.	Class	Area (sq.Km.)
1	Very Good	7.34
2	Good	146.89
3	Moderate	194.73
4	Low	0.56
5	Poor	17.14

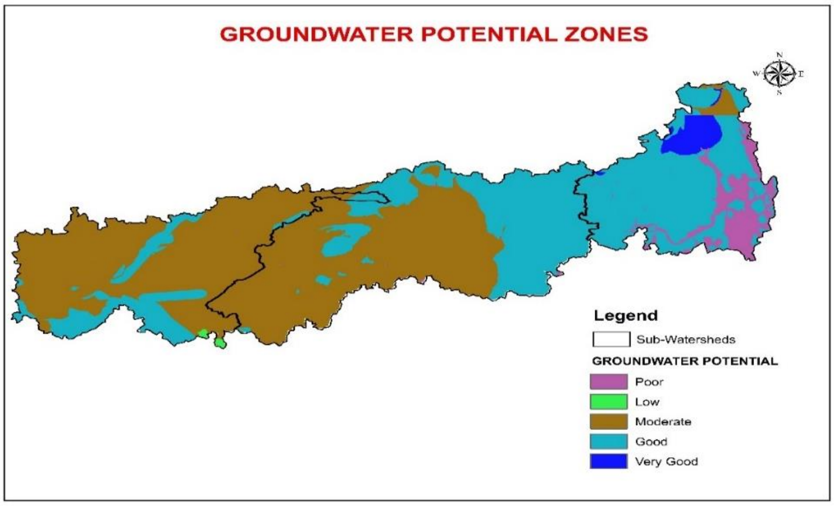

Fig. 14 Overlay Analysis thematic map of the study area

VIII. CONCLUSIONS

The morphometric analysis of Lower penna sub-basins using GIS retrieved that, Geographical Information System helps the researchers to analysis the drainage basin easily and accurately. The study of linear aspects of drainage basin result shows that, the basin has been formed in dendritic pattern with fourth order stream, plotting the logarithm of number of streams against stream order shows a straight line which states the number of streams usually decreases as the stream order increases. The result of relief aspect shows the study area is extremely rugged with high relief and high stream density, the result of arial aspect shows the texture of drainage is less and the result of elongation ratio indicates the drainage is high relief and steep ground slope. Integration of the thematic maps with hydro-morphology resulted in better result to delineate the groundwater potential zones in the study area.

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