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Integrated Approach for Groundwater Potential of Jhod Macro-Watershed in Nanded District, Maharashtra, India

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Abstract-: **The study area belongs to the Deccan trap basalts of late Cretaceous to early Eocene period. The groundwater in the study area is restricted mostly to the zones of secondary porosity developed due to fractures, joints, and weathering. In the present study, an attempt has been made to evaluate the geomorphic stages of the Jhod macro-watershed. The present study also attempts to select suitable geomorphic surfaces and morphometric attributes for groundwater exploration in hard rock areas especially Deccan basalt. Morphometric characteristics play a vital role on the hydrologic performance of the drainage basin. Hence, a number of parameters, which signify the drainage basin characteristics, such as bifurcation ratio, length and area ratios, basin configurations, drainage density, stream frequency, and the length of overland flow, are evaluated for the present study. The groundwater potentiality is moderate to good (with average yield 240 to 280 lpm in bore wells), in most part of the watershed, whereas the fractured zones in the weathered pediplains and alluvial plains are very good potential zones (with average yield >240 lpm in bore wells). The pediment surfaces are having moderate to poor groundwater potentiality, i.e. average yield 78 lpm in dug wells and 145 lpm in bore wells. Highly dissected plateau have the poor groundwater potentiality with average yield of 65 lpm in dug wells and 94 lpm in bore wells.**

Keywords: **Pediplain, Bifurcation ratio, Macro-Watershed, Pediment.**

I. INTRODUCTION

Water is a primary source of life and sustains all human activities such as domestic needs, agriculture, industries, etc. The available surface water resources are inadequate to meet the entire water requirement for various purposes. Hence, the demand for underground water has been increased over the years. One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction, and validation. In recent years, intensive use of satellite remote sensing has made it easier to define the spatial distribution of different groundwater prospect classes on the basis of geomorphology and other associated [1-8]. In many earlier studies, remote sensing techniques have been applied for groundwater prospecting [9-14]. The allocation and management of water resources are becoming a difficult task due to increasing demands, decreasing supply, and diminishing quality. On account of population growth and increasing irrigation demand, the groundwater is diminishing rapidly and as a result of it, the wells are drying up. The hydrogeological, geomorphological, and remote sensing data have been utilized for delineation of groundwater potential zones in the Deccan basaltic region of the Jhod macro-watershed of Godavari river, Parbhani district, Maharashtra state, India. Geoforum carried out detailed investigation of this watershed covering an area of 195.46 sq. km., enclosed in latitude 19o06’00”N and 18o54’00”S and longitude 77o09’00’’E and 77o00’00”W and falling in Survey of India Toposheet map No. 56E/4 and 56E/8 on the scale 1: 50,000

II. METHODOLOGY

The present research work emphasized the topographic characteristics of the study area with reference to drainage pattern, lineament pattern, and geomorphic surfaces. These features are believed to be directly relevant to the identification of groundwater potential zones. Drainage patterns (Fig. 1) are mapped from the toposheet maps. These patterns are important in establishing the pathways of surface water and their relationship with fractures and joints exposed in rocks [1, 2]. The morphometric analysis of the Jhod macro- watershed includes the determination of stream order, bifurcation, length and area ratio (Table 1). Further determination of morphometric attributes involves the calculation of form factor, circularity ratio, elongation ratio, drainage density, stream frequency, and length of overland flow (Table 2).

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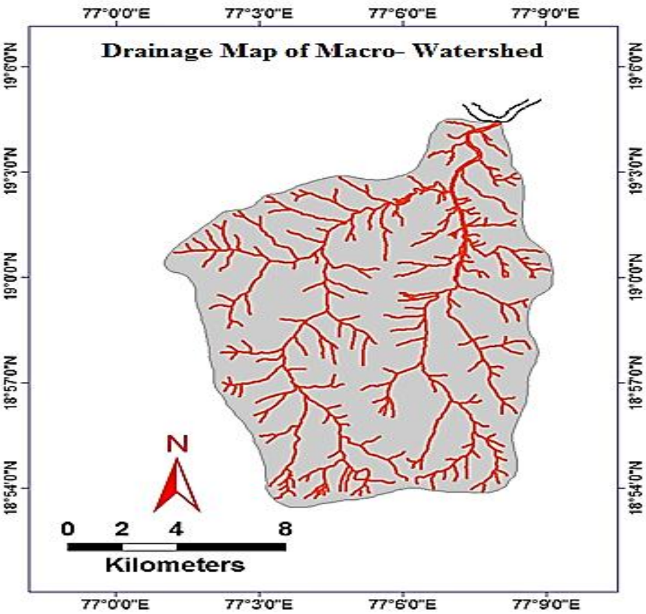

Fig.1 Drainage Map of Jhod Macro- Watershed

III. GEOLOGY OF THE AREA

Geologically, the study area belongs to the Deccan trap basalts of late Cretaceous to early Eocene period. Two types of basaltic lava flows occurring in the study area are massive (aa type) and vesicular amygdaloidal (compound pahoehoe type), which are at places separated by red bole beds and pipe vesicles. The groundwater in the study area is restricted mostly to the zones of secondary porosity developed due to fractures, joints, and weathering.

IV. HYDROGEOLOGY

The groundwater in the study area is restricted mostly to the zones of secondary porosity developed due to fractures, joints, and weathering. In Deccan Basalt terrain, groundwater occurs under phreatic conditions in the exposed lava flows and

Table 1. Bifurcation ratio, length ratio, and stream length of Jhod macro-watershed.

Stream order	No. of Stream	Bifurcation Ratio	Total Stream Length (Km)	Mean Stream Length (Km)	Length Ratio	Cum. stream length (Km)
1	208		138.1	0.66		138.1
		4.7			0.4	
2	44		72.3	1.64		210.4
		8.8			0.39	
3	5		20.65	4.13		231.05
		2.5			0.42	
4	2		19.6	9.8		250.65
		2			2.06	
5	1		4.75	4.75		255.4

Table 2. Morphometric Parameters of Jhod macro-watershed.

Stream Order	Fifth order
Form factor- F	0.42
Elongation ratio- E	0.73
Circularity ratio- Rc	0.73
Drainage density (Km/Km^2)	1.31
Stream frequency- ($Streams/Km^2$)	1.33
Length of overland flow (L) Km.	0.4

under semi-confined conditions in the flows at deeper level. Lithological constraints dictate that groundwater is present in the pore spaces of the vesicular basalt and in the jointed and fractured portions of massive parts of the flows. The primary porosity in the basalts is associated with the vesicles, which are the pore spaces developed due to the escape of volatile and gases when the lava erupts on the surface as a lava flow. The groundwater in the study area is therefore restricted mostly to the zones of secondary porosity developed in these rocks due to fractures, joints, and weathering. From the hydrogeological point of view, the frequency and extent of jointing, fracturing, and the flow contacts and weathering along them are the most significant parameters imparting permeability and porosity for forming suitable groundwater reservoirs in the Deccan Basalt terrain. The vesicular zones occurring in the upper parts of flows or units, though porous, are not permeable, as the vesicles are not interconnected. Second, the vesicles are generally filled with amygdules, green earth, glassy material, etc. The red bole layer, flow breccias with secondary mineral development, and the massive parts of the flow, with non-interconnected joints, are impervious. The secondary porosity (joints and fractures) generally reduces with depth and hence the near surface (unconfined) aquifer system rarely extends below 30m depth [8,13,14]. Well inventory was conducted by observing the dug wells and lithologs of various bore wells. Well depth, depth to water below ground level (bgl), water level fluctuations, and yield particulars with reference to geomorphic surfaces are given in Table 3.

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Table 3. Well inventory and yield particulars of wells in Jhod macro-watershed.

		Observation wells			Range of depth to water (m bg1)				
Sr. No.	Geomorphic Unit	Type	Nos	Range of depth (m)	Prem-onsoon	Post-monsoon	Watertable fluctuation (m)	Range of yield (1pm)	Av. yield (lpm)
1	Alluvial Plain	DW	5	8.5-9.5	1.5-4.5	0.5-2.5	1.0-2.0	160-240	200
		BW	4	30.0-45.0	2.5-6.5	1.0-4.0	1.3-2.7	245-305	280
2	Pediplain	DW	5	9.4-13.2	2.5-5.5	1.0-3.0	1.0-2.1	150-170	160
		BW	4	30.0-50.0	5.8-9.5	2.0-4.5	3.5-4.5	225-265	240
3	Pediments	DW	5	9.0-12.0	5.2-8.5	2.2-2.5	2.5-5.0	70-88	78
		BW	4	35.0-50.0	8.0-12.5	4.0-5.0	3.6-6.5	140-170	145
4	Highly Dissected Plateau	DW	4	8.2-12.5	6.0-12.0	2.8-6.0	3.5-6.0	60-71	67
		BW	4	40.0–50.0	11.0–20.5	5.0–10.2	6.3–10.2	85-101	93

V. GEOMORPHOLOGY

A. Drainage morphometry

In the present paper, the morphometric analysis and geomorphological surfaces of the Jhod macro-watershed are studied with reference to the groundwater potential. The drainage morphometry deals with the management and mathematical analysis of the configuration of the earth's surface and of the slopes and dimensions of its landforms. It is used to determine the geometry of the drainage basin especially its drainage network. As per the stream order method [15], the major stream of Jhod macrowatershed (Fig. 1) is of fourth order. Bifurcation ratio (Rb) is the ratio of the number of stream segments of a given order (Nu) and the number of stream segments of next higher order (Nu + 1). The values of bifurcation ratio of the watershed are between 2.0 and 8.8 (Table 1) indicating that the geological structures do not distort the drainage system [16]. The number of streams of each order is plotted against the corresponding stream order of the watershed (Fig. 2). The plot shows that the number of streams of given orders in the basin forms an inverse geometric sequence by decreasing systematically with increasing order in conformity to the 'law of stream numbers' [17]. The lengths of the various stream segments were measured order wise and the total lengths and the mean stream length for each order are computed. The length ratio, which is the ratio of the mean length of the streams of a given order to the mean length of the streams of the next lower order, was then calculated for each pair of order (Table 1). The plot of mean stream length of each order against stream order (Fig. 3) gives exponential form around the regression line. It is apparent from the plots that the average length of streams of a given order forms a direct geometric sequence by increasing systematically with order and conforms the 'law of stream length' [17], Table 3. Well inventory and yield particulars of wells in Jhod macro-watershed. For determining the shape of the drainage basin, a quantitative

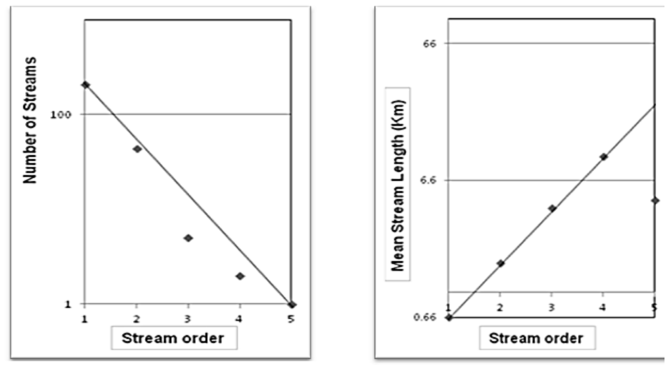

Fig. 3 Semilog plot of Number of stream vs stream orders and Semilog plot of Mean stream length (Km) vs stream orders.

study of the Jhod macro-watershed is carried out using three dimensionless ratios including The values of circularity ratio and elongation ratio indicate that the basin is moderately circular and somewhat elongated. The circularity ratio is a significant ratio, which indicates the stages of dissection in the study area. Its value (0.73) can be correlated with the youth stage of the cycle of the erosional development. In comparison [16] the value of elongation ratio (0.73) suggests that the basin is associated with strong relief and steep ground slope. The drainage density obtained is 1.31 km/km2 which is moderate value and indicate the watershed of weak impermeable subsurface rock or soil with sparse vegetation and mountainous relief. The stream frequency value obtained is 1.33 streams/km2. The term length of overland flow to refer the length of the run of the rainwater on the ground surface before it gets localized into definite channels [17]. Horton for the sake of convenience had taken it to be roughly equal to half the reciprocal of the drainage density. The length of overland flow for the Jhod sub-basin is 0.38 km which means that the rainwater has to run over this much distance before getting concentrated in stream channels and corroborate the medium drainage density derived for the area.

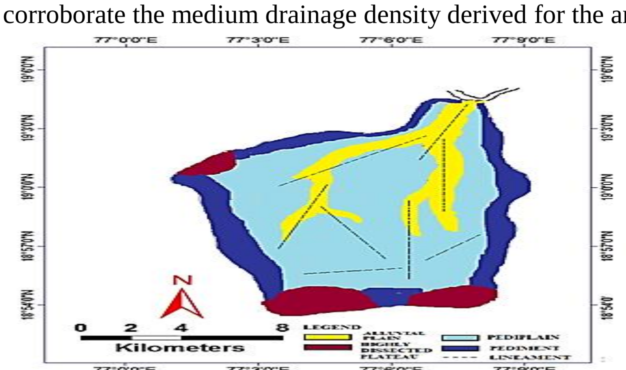

Fig. 4. Geomorphological map of study area.

B. Geomorphic surfaces

The geological, structure, drainage characteristics, hydrogeological, and well inventory data are integrated with the satellite information for the finalizations of geomorphological map (Fig. 4) and groundwater potential map (Fig. 5) of the area. Geomorphologically, the Jhod macro-watershed is classified into different geomorphic units, namely alluvial plain, pediplains, pediments, and highly dissected plateau, which are described below:

1. Alluvial plain

The alluvial plain is found in middle and southeastern part of the watershed area along the major stream. It is good potential zones for agriculture. It ranges in elevation from 358 to 378m above msl covering about 12.5% area of the Jhod macro-watershed. The morphometric attributes of the alluvial plain are: gentle gradient (5-10o), moderately coarse drainage density (1-1.3 km/km2), and moderate stream frequency (1.33-2 streams/km2). The materials in these surfaces mainly consist of alluvial deposits of the streams and the major Godavari river. Deposits are mostly composed of moderately thick gravels, pebbles, sand and silt. The groundwater potential ranges from good to very good. The water table is shallow, i.e. <3m bgl in bore wells and 1-2m bgl in dug well. The average yield of about 200 lpm in dug wells and 280 lpm in bore wells is obtained.

2. Pediplain

It is undulating to gently sloping part of the basin with slope angles of 0–5o. It lies parallel to the stream course and dominant in the southern part of the basin occupying 65.5% of the total area. It has low drainage density (1.6–2km/km2) and elevation range from 380 to 400m above msl. These areas are potential for intensive agriculture. Pediplains consist of thick weathered mantle in the form of black cotton soil underlained by weathered and fractured basalt. The pediplains have fairly good groundwater potential. The weathered zone thickness ranges from 6 to 12m. Dug wells are commonly seen in this zone. The irrigation in this zone is mainly done through dug wells and dug-cum-bore wells. Water table fluctuation ranges from 1.0 to 2.1m bgl in dug wells and 3.5 to 4.5m in bore wells. The average yield of dug wells is 160 lpm and bore well is 240 lpm.

3. Pediments

These are the gently sloping and undulating rock surface with or without a veneer of weathered material. Pediments are noted as a narrow strip adjoining the highly dissected plateau and at foothill zones. Pediments occupy about 12.8% of the area of the Jhod macro-watershed and range in elevation from 400 to 440m above msl. Morphometric attributes of the pediments are gently sloping surfaces (3–6◦), low gradient, moderate drainage density (1.5–2.0 km/km2), and moderate stream frequency (2.0– 2.5 streams/km2). Groundwater potential in pediments is poor except along fractures where limited quantity of groundwater can be obtained for domestic purpose. The water table fluctuations are ranging from 2.5 to 5m bgl in dug wells and 3.6–6.5m bgl in bore wells. The average yield of dug well is 78 lpm and of bore well is 145 lpm

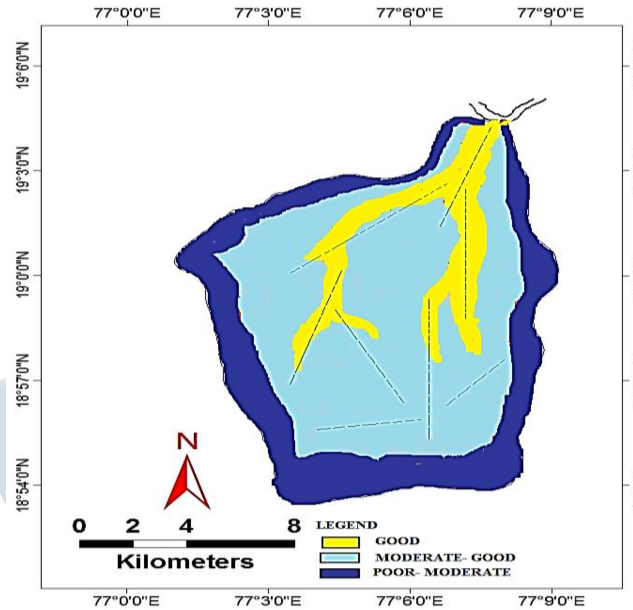

Fig. 5 Groundwater potential map.

4. Highly dissected plateau

This landscape unit is dominant in the major part of the northern, northwestern, and northeastern part of the Jhod macro-watershed area. The land of this unit is severely dissected by the streams of Jhod macrowatershed giving rise to a terrain consisting of flat-topped ridges and steep scarps. This unit has evaluation range of 450–490m above msl and occupies 7% of the total area. Morphometric attribute of this unit includes gentle gradient runoff, moderate drainage density (2–2.5 km/km2), and moderate stream frequency (2.5–3 streams/km2). In this geomorphic unit, the groundwater potentiality is poor. The water table fluctuations are ranging from 3.5 to 6.0m bgl in dug wells and >6m bgl in bore wells. The average yield in highly dissected plateau is 67 lpm in dug wells and 93 lpm in bore wells.

VI. RESULT AND DISCUSSION

Morphometry gives a little idea of erodibility of soil. Morphometric characteristics play a vital role in the hydrologic performance of the drainage basin. Hence, the parameters including bifurcation, length, and area ratio signify the drainage basin characteristics and are evaluated from the toposheet maps and the satellite imagery of the area.

These morphometric characteristics of streams of the macro-watershed (bifurcation ratio <8.8, Table 1) indicate that there is no structural or tectonic control on the drainage development [15]. The variation in area ratio (Table 1) might be due to change in slope and topography. The presence of low drainage density of macro-watershed suggests that the area is consisting of permeable subsurface soil and coarse drainage texture. Morphometric attributes such as form factor, circularity ratio, and elongation ratio (Table 2) reflect the early mature stage of erosional development. The values of circularity ratio and elongation ratio indicate that the basin is moderately elongated or subcircular. A circular watershed is more efficient in the discharge of run-off than an elongated watershed [22]. The Jhod macro-watershed is classified into different geomorphic units, namely alluvial plain, pediments, pediplains, and highly dissected plateau. The geomorphic characteristics and groundwater potential of each unit are described in the present paper. Alluvial plains are highly potential zones in the area. Groundwater potential in pediments is poor except along fractures where limited quantity of groundwater can be obtained for domestic purpose. The pediplains have fairly good groundwater potential. In highly dissected plateau, the groundwater potentiality is poor. The interpretation from the study will be useful to the decision makers and any other project implementing agencies engaged in watershed development programmes as well as central or state government schemes for rural development. Weathered alluvial plain and pediplains are very good potential zones. Highly dissected plateau and pediments with fractures have moderate groundwater potentiality. Yield of groundwater in highly dissected plateau is less as compared with other areas. Dug wells are recommended in the weathered pediplains. The technique of remote sensing is thus an important tool in preliminary investigation of groundwater condition for the area.

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