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Geomorphology and Morphometric Analysis Used as A Significant Indicator for Groundwater Prospects: A Case Study of the Kousika Manadi Sub Basin Vaigai River Tamil Nadu

KEYWORDS: Kousika Manadi, Geology, Geomorphology, Drainage Pattern, Morphometry.

G. Prithiviraj
Hydrogeology Laboratory, Department of Geology, Periyar University, Salem – 11

S. Venkateswaran
Hydrogeology Laboratory, Department of Geology, Periyar University, Salem – 11

ABSTRACT *A morphometric analysis was done to evaluate the drainage characteristics of Kousika Manadi sub basin using topographical maps with digital elevation data. This analysis can be achieved through measurement of basic, derived, and shape aspects of the sub basin. In the present study, quantitative morphometric analysis is carried out for 28 micro-watersheds of Kousika Manadi, which is located in Madurai and Virudhunagar districts, Tamil Nadu. Geological setting of the study area with all complexities leads to unique hydrogeological features. The study has strengthened in understanding the hydrological, geological and geomorphological characteristics of the Kousika Manadi sub basin.*

INTRODUCTION

The growth of population, in countries like India, and the consequent development, leads to increasing stress on water use, such as for drinking, irrigation and industrial needs. The increase in the usage of water has affected both surface and groundwater supplies, resulting in an acute water crisis. Efficient management planning for watershed development is, therefore, essential to increase the recharge of the basin. The siting of facilities to enhance the recharge is also of great importance in planning the development of watershed programs. Infiltrating recharge water, to reach the groundwater body, depends on the surface rock-permeability, which is generally low, especially in the hard rock terrain of Central and Southern India.

Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landforms (Clarke, 1966). Evaluation of the drainage characteristics of a basin, using quantitative morphometric analysis in relation to geomorphological features, which can provide useful information on the hydrological nature of rocks exposed within the drainage basin, is a reliable index of rock-permeability and also gives an indication of yield of the watershed basin (Wisler and Brater 1959; Venkatewaran et.al., 2012).

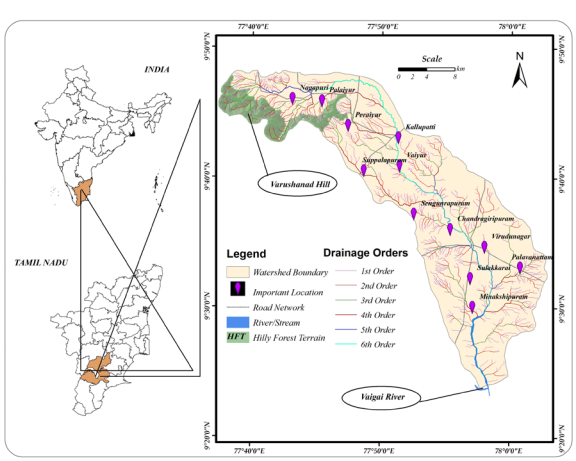

Figure 1: Study area map

METHODOLOGY

Drainage map of the study area have been prepared using Survey of India toposheet number 58 G/9, 58G/10, 58 G/13, 58 G/14, 58 G/15, 58 K/2 and 58 K/3 on 1:50,000 scale. The digitization of drainage map has been prepared and digital elevation data (Shuttle Radar Topography Mission) were used for the relief and slope maps haven prepared using by ArcGIS 9.3.1 of Kousika Manadi subbasin and drainage analysis was based on Horton (1945) and Strahler (1964). The morphometric variables were categorized into basic, derived and shape parameters.

GEOLOGY OF THE STUDY AREA

Geological formations ranging in age from Archaean to Pre-Cambrian. The geology of the Kousika Manadi sub basin consists of two varieties of lithology. The upper part of the study area covers granite and the remaining part covered by the quartz vein.

GEOMORPHOLOGY OF THE STUDY AREA

It has been classified into different geomorphic units such as denudational hills, pediment, residual hills, inselbergs, lateritic uplands, pediplain, flood plain and valley fills.

MORPHOMETRIC ANALYSIS

Basin wise morphometric analysis has alternated the attention and is still being used for deriving sensible conclusions regarding a particular behavior of any hydro geological study and evaluation of water resources. The river basin area is classified into 28 micro watersheds of sixth streams (Fig.2). The inter basin region spread over 42.6 sq.km including lower order streams that directly joins the main river course. The morphometric parameters have been considered for analysis is summarized in detail in Table. 1, 2, 3 & 4.

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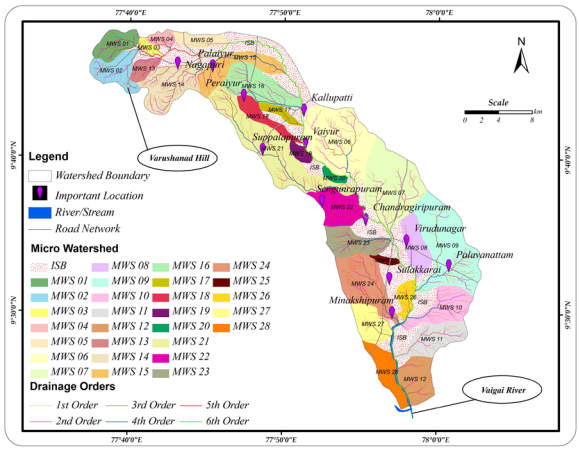

Figure 2: Drainage with Micro Watershed map of Kousika Manadi Watershed

Table 1
MORPHOLOGY ADOPTED FOR DRAINAGE MORPHOMETRIC PARAMETERS ANALYSIS

S.No.	Parameter	Formula	Previous Work
Basic Parameters			
	Area (A)	Area of the watershed	Horton. 1945
	Perimeter (P)	The perimeter is the total length of the watershed boundary.	Miller (1953),
	Length (Lb)	Maximum length of the basin	Horton 1945
	Stream Order (Nu)	Hierarchical rank	Strahler 1957
	Stream Length(Lu)	Length of the stream	Horton 1945
Derived Parameters			
	Bifurcation ratio (Rb)	Rb = Nu / N (u + 1)	Schumm 1956
	Stream length ratio (Rl)	Rl = Lu / Lu-1	Sreedevi et al. 2004
	Drainage density (Dd)	$\frac{\sum Lu/A}{\sum Lu/A}$	Horton. 1945
	Stream frequency (Fs)	$Fs = \sum Nu/A \sum Nu/A$	Horton. 1945
	Drainage texture (T)	T = Dd × Fs	Smith 1950
Shape Parameters			
	Elongation ratio (Re)	Re = 1.128 √A / L	Schumm (1956)
	Form factor (Ff)	Ff = A / Lb2	Horton (1932, 1945)
	Circularity index (Rc)	Rc = 4π A / P^2	Miller (1953), Strahler (1964)
	Length of overflow (Lg)	Lg = 1/2/2d	Horton. 1945

Note: A = Area ; P = Perimeter; Lb = Length; Nu = Stream order; Lu = Stream length;

BASIC PARAMETRES

Area (A)

The total drainage area is 677Sq.km, and the areas of each watershed are shown in Table 2. MWS-25 is the smaller than 28 watershed (A<2.6 Sq.km) and MWS-9 is bigger than the others (A>57.5 Sq.km).

Perimeter (P)

The P of the 28 watersheds is shown in Table 2. MWS-21 has the higher value (P>50 km), while the perimeter of MWS-21 is less (P<8.3 km) than the other watershed.

Basin length (Lb)

The values of Lb for the 28 watersheds are shown in Table 2. MWS-9 is the longer (L>13.5 km) while MWS-20 has the minimum value of L (L<3.3 km).

Stream order (Nu)

Stream order, or classification of streams based on the number and type of tributary junctions, has proven to be a useful indicator of stream size, discharge and drainage area (Strahler 1957). The number of streams (N) of each order (u) is presented in Table 2.

Stream length (Lu)

The stream length (Lu) has been computed based on the low proposed by Horton (1945) for all the 28 micro watersheds. The values of length (Lu) and total stream length (Lt) are shown in Table 2.

TABLE-2
BASIC PARAMETER OF KOUSIKA MANADI SUBBASIN

MSW	(A) Km^2	(P) Km	(L) Km	(Nu)	(Lu)Km
	13.6	15.5	6.1	42	39.2
	17.4	21.1	6.8	67	47.4
	3.5	8.9	3.6	29	17.3
	5.2	9.7	3.4	38	20.67
	9.3	15.2	6.8	6	8.9
	55.1	30	10.7	67	74.7
	50.4	30.2	12.1	47	55.4
	16.2	19.2	8.2	4	8.4
	57.5	38	13.5	60	69.4
	21.8	23.5	9.2	37	45.7
	21.6	22.4	9.4	31	37.1
	19.3	17.6	6.4	16	20.3
	6.6	11.1	4.6	20	19.6
	29.2	27.4	9.5	98	88.9
	22.2	28	12.3	41	46.9
	27.4	24.1	9.9	43	58.9
	5.1	13	6.1	12	11.7
	10.6	20.8	9.6	14	18.8
	4.2	8.7	3.6	9	8.4
	2.8	8.3	3.3	8	5.3
	55.2	50	21.2	83	95.3
	19.4	20.4	7.5	37	37.5
	18.7	20.8	7.9	43	42.7
	33	26.6	10.9	41	55.7
	2.6	8.3	3.7	4	7.7
	7.2	12.8	5	15	14.1
	15.8	16	6.3	15	18.3
	10	22	9.7	10	11.2

DERIVED PARAMETERS

Bifurcation ratio (Rb)

This is a very important parameter that expresses the degree of ramification of the drainage network. The values of Rb for 28 watersheds vary from 3.0 to 9.0 (Table 3).

Stream length ratio (Rl)

Rl successive streams orders varies due to differences in slope and topographic conditions, and has an important relationship with the surface flow discharge and erosional stage of the basin (Sreedevi et al. 2004). The values of Rl for the 28 watersheds vary from 1.02 to 41.07 (Table 3).

Drainage density (Dd)

It directly expresses the closeness of spacing of the streams and indirectly reflects the structural framework of the underlying rocks of the watershed basin. The Dd val-

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ues for the 28 watersheds vary from 0.52 (MWS-8) to 4.94 (MWS-3). (Table .3).

Stream frequency (Fs)
The Fs of the 28 watersheds are shown in Table 3. It ranges from 0.25 (MWS-8) to 8.29 (MWS-3).

Drainage texture (Dt)
The Dt value for the 28 watersheds are shown in Table 3.

It can be expressed by the equation (Smith1950). It ranges from 0.21 (MWS-8) to 3.92 (MWS-4).

SHAPE PARAMETERS

Elongation ratio (Re)
Elongation ratio (Re) was defined for Schumm (1956) as the ratio between the diameter of a circle of the same area as the basin (D) and basin length (L). The Re value for the watersheds are shown in Table 4.

TABLE-3
DERIVED PARAMETER OF KOUSIKA MANADI SUBBASIN

MSW	Stream length ratio (Rl)				(Lsm)	(Dd)	Bifurcation ratio (Rb)				(Fs)	(Dt)
	II/I	III/II	IV/III	V/IV			I/II	II/III	III/IV	IV/V		
1	0.38	0.25	0.13	-	4.93	2.88	4.33	5.50	3.00	-	3.09	2.71
2	0.35	0.29	0.08	-	4.42	2.72	6.40	6.00	3.00	-	3.85	3.18
3	0.59	0.54	18.18	1.67	41.7	4.94	4.00	4.00	2.00	3.00	8.29	3.26
4	0.47	0.61	0.53	-	4.83	3.98	5.67	3.00	4.00	-	7.31	3.92
5	0.16	-	-	-	1.78	0.96	6.00	-	-	-	0.65	0.39
6	0.29	0.18	0.14	-	4.22	1.36	6.20	3.50	5.00	-	1.22	2.23
7	0.31	0.13	0.10	-	3.16	1.10	4.89	5.50	3.00	-	0.93	1.56
8	0.37	-	-	-	1.02	0.52	4.00	-	-	-	0.25	0.21
9	0.28	0.27	0.07	-	4.37	1.21	5.09	4.67	4.00	-	1.04	1.58
10	0.28	0.23	0.31	-	6.23	2.10	4.25	5.00	3.00	-	1.70	1.57
11	0.21	0.18	-	-	4.58	1.72	6.00	6.00	0.00	-	1.44	1.38
12	0.34	0.16	-	-	3.92	1.05	3.75	5.00	-	-	0.83	0.91
13	0.18	0.13	-	-	16.1	2.97	9.50	3.00	-	-	3.03	1.80
14	0.32	0.17	0.14	0.32	3.47	3.04	6.07	4.75	3.00	3.00	3.36	3.58
15	0.28	0.22	0.48	-	8.16	2.11	5.43	4.50	3.00	-	1.85	1.46
16	0.25	0.13	0.27	-	5.82	2.15	5.00	5.00	3.00	-	1.57	1.78
17	0.53	0.71	-	-	4.83	2.29	3.67	4.00	-	-	2.35	0.92
18	0.24	0.33	-	-	3.76	1.77	6.50	3.0	-	-	1.32	0.67
19	0.38	-	-	-	1.75	2.00	4.50	-	-	-	2.14	1.03
20	0.26	-	-	-	1.89	1.89	8.00	-	-	-	2.86	0.96
21	0.38	0.22	-	-	5.06	1.73	4.33	5.50	5.00	-	1.50	1.66
22	0.33	0.14	-	-	4.06	1.93	4.50	9.00		-	1.91	1.81
23	0.34	0.22	0.32	-	5.82	2.28	4.44	5.50	3.00	-	2.30	2.07
24	0.26	0.18	0.10	-	3.84	1.69	4.75	5.00	3.00	-	1.24	1.54
25	0.19	0.00	-	-	1.54	2.96	4.00	-	-	-	1.54	0.48
26	0.41	0.59	-	-	4.84	1.96	4.67	4.00	-	-	2.08	1.17
27	0.26	0.29	-	-	3.96	1.16	4.67	4.00	-	-	0.95	0.94
28	0.36	2.94	-	-	17	1.12	4.50	3.00	-	-	1.00	0.45

Circularity index (Rc)
The circularity ratio (Miller 1953; Strahler 1964) is expressed as the ratio of the basin area (A) and the area of a circle with the same perimeter as that of the basin shown in Table 4.

Form factor (Ff)
Horton (1945) proposed this parameter to predict the flow intensity of a basin of a defined area. The Ff value for the watersheds are shown in Table 4.The lowest value of Ff recorded in MWS-28 (0.11) and highest value found at MWS-6 (0.48).

Length of overland flow (Lg)
It is the length of water over the ground before it gets concentrated into definite stream channels. The Lg values for the watersheds are shown in Table 4. The Lg for the study area ranges from high value of 0.96 (MWS-8) and low value of 0.10 (MWS-3).

TABLE-4
SHAPE PARAMETER OF KOUSIKA MANADI SUBBASIN

MWS	Elongation ratio (Re)	Form factor (Ff)	Circularity Index (Rc)	Length of Overflow (Lo)
1	0.46	0.37	0.71	0.17
2	0.43	0.38	0.49	0.18
3	0.59	0.27	0.55	0.10
4	0.61	0.45	0.69	0.13
5	0.43	0.20	0.51	0.52
6	0.35	0.48	0.77	0.37
7	0.32	0.34	0.69	0.45
8	0.39	0.24	0.55	0.96
9	0.31	0.32	0.50	0.41
10	0.37	0.26	0.50	0.24
11	0.37	0.24	0.54	0.29
12	0.45	0.47	0.78	0.48
13	0.53	0.31	0.67	0.17
14	0.37	0.32	0.49	0.16
15	0.32	0.15	0.36	0.24
16	0.36	0.28	0.59	0.23
17	0.46	0.14	0.38	0.22
18	0.36	0.12	0.31	0.28
19	0.59	0.32	0.70	0.25
20	0.62	0.26	0.51	0.26
21	0.25	0.12	0.28	0.29
22	0.41	0.34	0.59	0.26
23	0.40	0.30	0.54	0.22
24	0.34	0.28	0.59	0.30
25	0.59	0.19	0.47	0.17
26	0.50	0.29	0.55	0.26
27	0.45	0.40	0.78	0.43
28	0.36	0.11	0.26	0.45

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CONCLUSION

The morphometric analysis has been carried out through measurement of basic, derived and shape parameters of the subbasin. It has been found that the study area is a 6th order drainage basin. Dendritic drainage pattern is seen in the hilly and plateau parts of the drainage basin indicating the homogeneity in texture and structural control. From the study it can be concluded that areas drained by drainage orders of 1st, 2nd and 3rd have Bifurcation ratio between 3.0 to 6.4, indicating that these are not distorted by geological structures. The Bifurcation ratio in case of the 4th to the 5th drainage orders, it is less than 3.0. It is noted that, in the drainage basin that these areas are dominated by the presence of lineaments. The presence of the maximum number of the first order segments shows that the subbasin is subjected to erosion and also that some areas of the subbasin are characterised by variations in lithology and topography. The deviation of the mean stream length values from 1.02 to 41.7 clearly indicates the change in topographic elevation and slope of the Kousika Manadi watershed. The elongation ratio value of the Kousika Manadi watershed is 0.59 in MWS 3 and MWS 19, which indicates that the major part of basin is of high relief. The length of overland flow (Lo values) of the study area is 0.96 in MWS 8, indicating young topography. The slope of the basin ranges from a level slope in the plains (southern part) to a very steep slope in the northern part of the basin. Low relief to moderately relief is in the plains and high relative relief is in the hilly area. By the complete analysis of drainage basin parameters MSW - 20 can be considered as an area with good groundwater prospect as the area has permeable subsurface and condition favourable for infiltration of surface water.

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