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Geomorphometric analysis for water conservation in some part of Waghadi River, Wardha River Sub Basin, Maharashtra, India

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ABSTRACT

The study area is the important part of the hard rock terrain of the central India .The drainage pattern of the study area is dendritic to sub dendritic with stream orders ranging from I to V orders. Drainage density ranges from 2.02 to 2.31 km/km2 suggesting course to moderate drainage texture. The changes in values of stream length ratio indicate their late youth stage of geomorphic development. The values of bifurcation ratio ranging from 4.22 to 4.97 indicate that all the sub basins fall under normal basin category. The values of form factor and circulatory ratio, suggest that SW I, II are elongated. Elongation ratio indicates that the SW I region of high relief whereas the SW II is associated with moderate to low relief and gentle ground slope.

Keyword: Morphometry, Wardha River sub basin, remote sensing and GIS

I.INTRODUCTION

The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). Analysis of various drainage parameters namely ordering of the various streams and measurement of area different parameters as basins, perimeter of basin, length of drainage channels, drainage density, drainage frequency, bifurcation ratio, texture ratio and circulatory ratio (Kumar et al., 1999). Drainage characteristic of many river basins and sub basins in different parts of the globe have been studies using conventional methods (Horton,1945; Strahler,1957,1964; Krishnamurthy et al.,1996).Various scholars have carried out morphometric analysis of river basins by using remote sensing and geographical information systems (GIS).The large variety of factors that can affect the behaviour of a watershed fall into two categories, first the permanent characteristics of the drainage basin, such as, its size or drainage density i.e., drainage morphometry and second, transient or variable characteristics, such as the amount of precipitation, type of land use and so on. Extensive use of GIS techniques for assessing various terrain and morphometric parameters of the drainage basins and watersheds has been the hallmark of these studies, as they provide a flexible environment and a powerful tool for the manipulation and analysis of patial information. By computing different morphometric characteristics like linear, aerial and relief and assessing the topographical, geological and hydrological properties of watershed, the management of river basin can be the best to understand proper planning of any river basin (Angillieri, 2012; Kabite and Gessesse, 2018 ; Manjare et al., 2014, Reddy, et al. 2018; Manjare, et al. 2020; Shrivatra et al. 2021b). Many authors found remote sensing and GIS as an efficient tool to understand the morphometric behaviour of any plain topographical area, groundwater delineation (Sreedevi et al., 2005; Ansari et al., 2012; Bali et al., 2012; Pareta and Pareta, 2012; Parveen et al., 2012; Reddy, 2018; Manjare et al. 2020). Morphometric analysis of streams

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is an important aspect for characterization of watershed. Proper planning and management of watershed is very necessary for sustainable development (Chandniha and Kansal, 2017; A. Reddy, et al, 2018 Manjare et al, 2018). The measurement of various morphometric parameters namely- stream order, stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb),mean bifurcation ratio(Rbm), relief ratio (Rh) drainage density (D), stream frequency (Fs) drainage texture (Rt), from factor (Rf), circulatory ratio (Rc), elongation ratio (Re) length of overland flow (Lg) has been carried out and the data are presented in table 1.

Table1: Formulae adopted for computation of morphometric parameters

Sr.No.	**Morphometric parameters**	**Formula**	**Reference**
1	Stream Order	Heirachial rank	Strahler (1964)
2	Stream Length(Lu)	Length of the Stream	Horton (1945)
3	Mean Stream Length (Lsm)	Lsm=? Lu/Nu Where, Lsm= Mean Stream Length; Lu=Total Stream Length of order 'u'; Nu= Total no. of stream segments of order 'u'	Schumn(1956)
4	Stream Length ratio (RL)	RL=Lu/Lu-1 Where,RL=Stream Length ratio; Lu=Total stream length of the order 'u'; Lu-1=The total stream length of its next order	Horton (1945)
5	Bifurcation ratio(Rb)	Rb=Nu/Nu+1 Where,Rb= Bifurcation ratio Nu=Total no. of stream segments of order'u' Nu+1=Number of segments of the next higher order	Schumn(1956)
6	Mean Bifurcation ratio	Rbm=Average of Bifurcation ratios of all orders	Strahler(1957)
7	Releif ratio(Rf)	Rh=H/Lb Where,Rh= Releif ratio, H= Total Relief (Relative Relief) of the basin (km) Lb=Basic length	Schumn(1956)
8	Drainage Density (D)	D= Lu/A Where, D= Drainage Density, Lu=Toatl stream length of all orders, A= Area of the basin(km^2)	Horton (1945)
9	Stream Frequency(Fs)	Fs= Nu/A Where, Fs= Stream Frequency, Nu=Toatl no.of streams of all orders, A= Area of the basin(km^2)	Horton (1932)
10	Drainage Texture(Rt)	Rt=Nu/P Where, Rt=Drainage Texture, Nu=Total no.of streams of all orders, P=Perimeter(Km)	Horton (1945)
11	Form Factor(Rf)	Rf= A/Lb^2 Where, Rf=Form Factor, A=Area of the basin(km^2), Lb^2= Square of Basin length	Horton (1932)

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12	Circulatory Ratio (Rc)	$Rc=4*Pi*A/P^2$ Where ,Rc=Circulatory ratio, Pi=Pi value i.e., 3.14A= Area of the basin(km^2), P^2=Square of the perimeter (km)	Miller(1953)
13	Elongation ratio (Re)	Re=2√(A/π)/Lb Where.Re=Elongation ratio, A=Area of the basin(km^2) Pi='Pi' value i.e., 3.14, Lb= Basin length	Schumn(1956)
14	Length of overland flow (Lg)	Lg=1/D*2 where,Lg=Length of overland flow, D= Drainage Density	Horton (1945)

II.AREA OF STUDY

The study area lies between 19^0 55' 00''N to 20^0 25' 00''N latitude and 78^0 10 00''' E to 78^0 25 00''' E longitude and it called SW-I. SW II which is located in the south-east side of Yeotmal district in the central India with total area 917.83 km^2. It is covered in the Survey of India (SOI) toposheet numbers 55 L/7, L/8, L/11, L/12 & 56 I/5, I/9 on 1:50,000 scale (Fig.1).

III.METHODS OF INVESTIGATION

In the study area remote sensing and GIS techniques were used to determine the mathematical configuration of the sub basin. The drainage map of the study area has been prepared from digital data of IRS 1C and 1D of both LISS-III, PAN, SRTM DEM 90 m resolution and survey of India toposheets. The satellite imageries has geo-referenced and merged using image processing software ERDAS IMAGINE (V8.5) and ARC GIS 10.1.

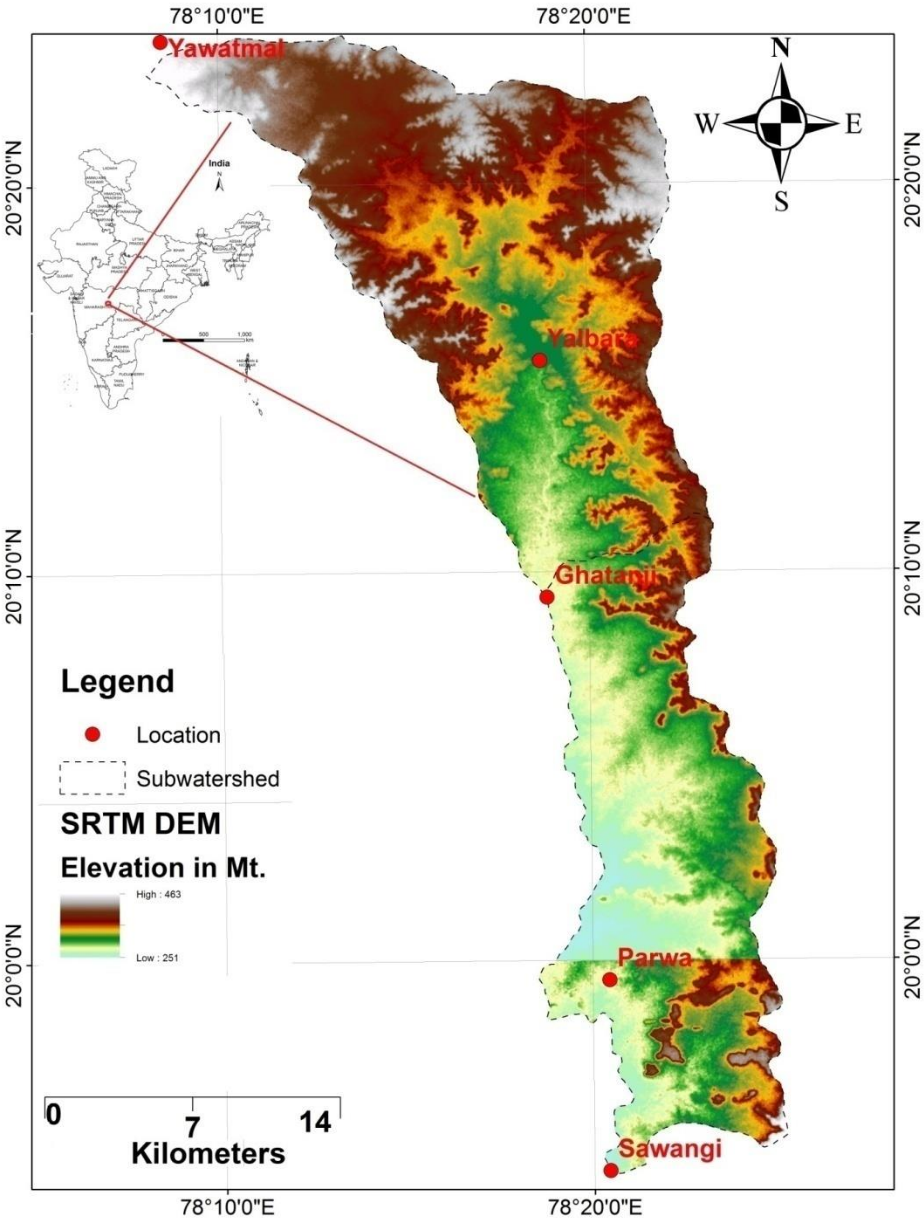

Fig. 1: Location and SRTM DEM map of the study area.

IV.LINEAR ASPECTS

The linear aspects include the stream order, stream length, mean stream length, stream length ratio and bifurcation, which were determined and results have been presented in table 1.

Stream Order

The first step in the drainage basin analysis is designation of stream orders which is not only the index, the size and scale, but also to afford and approximate index of the amount of stream flow, which can be produced by a particular network, stream order, number. The stream order is a measure of the degree of stream branching within a basin. Each length of stream is indicated by its order. The order wise stream numbers, area and stream length of the 4 sub-basins are presented in table 2. Out of four, three sub-basins have total 5 (1 to 5) stream orders & sub- basin SW IV have stream 4 (1to 4) orders of stream (Fig. 2).

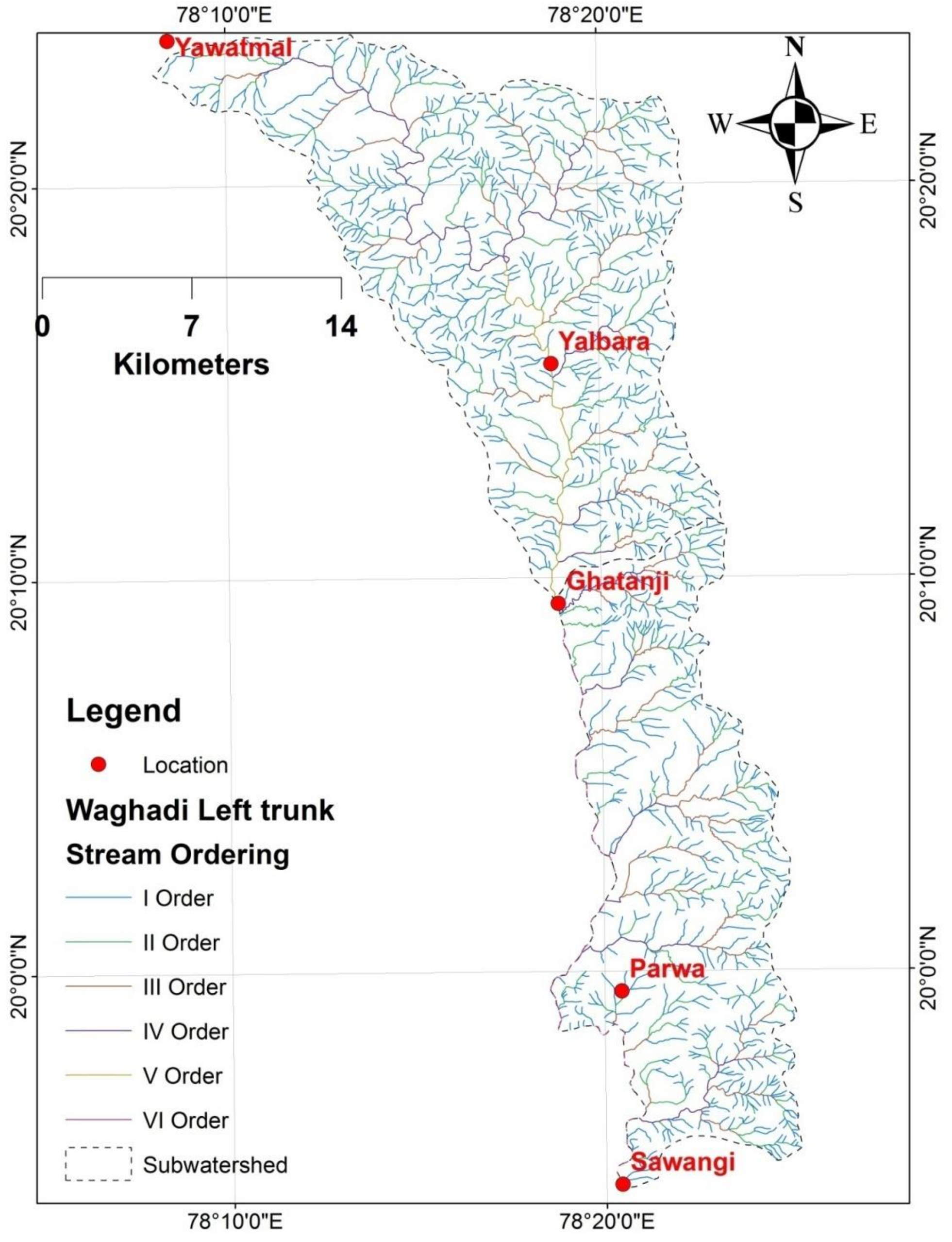

Fig. 2: Drinage map of the study area

Stream length

Stream length is measured from mouth of a river to drainage divide with the help of GIS software this has been computed based on the law proposed by Horton (1945) for all the sub basins of the study area. Usually the total length of stream segment is maximum in the first order streams & decreases as the stream order increase in the present case. The sub-basin SWI & SW III show variation from general observation (Table.2). This may be due to flowing of streams from high altitude, change in rock type & moderately steep slopes and probable uplift across the basin (Singh & Singh, 1997; Vittala et al., 2004 and chopra et al., 2005).

Mean stream length (Lsm)

Mean stream length (Lsm) is a characteristic properly related to the drainage network components and its associated basin surfaces (Strahler, 1964).This has been calculated by dividing the total stream length of order (u) by the number of streams of segments in the order. The mean stream length is presented in table 2. It is seen that, Lsm values exhibit variation from 0.63 to 35.88. It is observed that in all the sub-basin the Lsm value of the given order is greater than that of the lower order and less than that of its next order.

Stream length ratio (Rl)

The length ratio RL (which is ratio of mean length Lu of segments of order u to mean length of segments of the next lower order LU/(LU- 1) tends to be constant through the successive orders of basin. It indicates that the stream lengths are decreasing with increasing the order of stream. The stream length ratio between the streams of different order of study area shows a change in sub-basin I & II. This change might be attributed to variation in slope & topography, indicating the late youth stage of geomorphic development in the stream of the study area (Singh & Singh, 1997; Vittala et al., 2004).

Bifurcation ratio (Rb)

Bifurcation ratio is defined as number of streams of one order to the next higher order. Strahler (1957) demonstrated that bifurcation ratio shows a small range of variation for different regions or the different environments. According to Strahler (1964), the geological structure does not distort the drainage pattern if the Bifurcation Ratio (Rb) values stand between 3.0 and 5.0 for a catchment. The bifurcation ratio will not be precisely the same from one order to the next because of the possibility of variations in basin geometry and the lithology, but tends to be a constant throughout the series. When algorithm of number of streams is plotted against order, most drainage networks show a liner relationship, with small deviation from straight line. Bifurcation ratios characteristically range between 3 and 5 for watershed in which geologic structures do not distort the drainage pattern (Gokhale, 2005). Abnormally higher bifurcation ratios might be expected in regions of steeply dipping rock strata where narrow strike valleys are confirmed between hogback ridges. The mean bifurcation ratio for all four sub-basins ranges from 4.22 to 4.97 (Table 2). The direct relationship of bifurcation ratio to stream order is attributed to the semi arid climate characterized by short-duration flash floods.

V.RELIEF ASPECT

Relief is the elevation difference between the heights and lowest point on the valley floor of the region. The relief measurements like relief ratio, basin length and total relief have been carried out and the data given in table 2.

Relief ratio

The maximum relief to horizontal distance along the longest dimension of the basin parallel to the principle drainage line is termed as relief ratio (Schumn, 1956). Relief ratio has direct relation between the relief and channel gradient. The relief ratio normally increases with decreasing drainage area and size of the watersheds of a given drainage basin (Gottaschalk, 1964). In the study area, the values of relief ratio are ranging from 2.58 to 9.41 (Table 2). It is observed that the Rh values increase with decreasing drainage area and size of a given drainage basin as proposed by Gottaschalk (1964).

AERIAL ASPECTS

Aerial aspects include different morphometric parameters, like drainage density, texture ratio, stream frequency, form factor, circulatory ratio, elongation ratio and length of the overland flow. The values of these parameters are presented in table 2 and interpreted below.

Drainage density (Dd)

It is measured as a sum of the channel lengths per unit area and obtained by dividing the total stream length by total area of the basin. Drainage density is controlled by the type of formations in the basin areas with impervious formations will have higher drainage density than those with pervious formations (Gokhale, 2005). The drainage density is governed by the factors like rock type, run off intensity, soil type, infiltration capacity and percentage of rocky area. The drainage density in the sub-basins of the study area shows variation from 2.02 to 2.31 per km^2 suggesting low drainage density (Table 3). This low drainage density of the study area suggests that it has highly permeable sub-soil and coarse drainage texture.

Stream frequency /Channel frequency (Fs)

The total number of stream segments of all orders per unit area is known as stream frequency (Horton, 1932). The Fs values of the sub-basins of the study area are presented in table 2. It is noted that the values of Fs vary from 1.85 to 2.77 (Table 3). It is also seen that the drainage density values of the sub-basins exhibits +ve correlation with the stream frequency suggesting that there is an increase in stream population with respect to increasing drainage density.

Drainage texture (Rt)

IT is the total number of stream sequence of all orders per perimeter of that area (Horton 1945). It is one of the important concepts of Geomorphology which means that the relative spacing of drainage lines are numerous over impermeable areas than permeable areas. According to Horton (1945), infiltration capacity as the single important factor which influences drainage texture & considered drainage texture which includes drainage density & stream frequency. The values of drainage texture ratio of study area varies from 2.94 to 6.53. According to Smith (1950) there are five different classes of drainage texture based on drainage density. The drainage density less than 2 indicates very coarse, between 2 & 4 is related to coarse, between 4 & 6 is moderate, between 6 to 8 is fine where as above 8 is referred as very fine drainage texture (Table 3). The sub-basin 2 shows fine drainage texture indicating hard rock lithology whereas in other three sub-basins values of drainage texture ratio are bellow 6 indicating moderate drainage texture depicting the softer & more permeable rock formation.

Form factor (Rf)

Form factor may be defined as the ratio of the area of the basin and square of basin length (Horton, 1932). The value of form factor would always be greater than 0.78 for a perfectly circular basin. Smaller the value of form factor, more elongated will be the basin. Rf values of the study area are presented in Table 3. It is

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noted that the Rf values vary from 0.17 to 0.41 (Table 3). The values in all the sub-basin indicate that they are elongated to sun-circular in shape.

Circulatory ratio (Rc)

The circulatory ratio is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. It is the ratio of the area of the basins to the area of circle having the same circumference as the perimeter of the basin. In the study area, the Rc values are ranging from 0.32 to 0.48 (Table 3). All sub-basins have values of Re less than 0.5 indicating that they are elongated.

Elongation ratio (Re)

Elongation ratio is the ratio between the diameter of the circle of the same area as the drainage basin arid the maximum length of the basin. The elongation ratio values of the sub-basins vary from 0.27 to 0.72 (Table 3). The elongation ratio values generally exhibit variation from 0.6 to 1.0 over a wide variety of climatic and geologic types. Values close to 1.0 are typical of regions of very low relief, whereas values in the range 0.6–0.8 are usually associated with high relief. In case of SWI, II the elongation ratio is less than 0.6 indicating higher relief, whereas in sub-basins II value 0.72 indicates relatively low relief & gentle slope compared to other three sub-basins. A circular basin is more efficient in the discharge of run-off than an elongated basin (Singh and Singh, 1997). Based on the elongation ratio, it is also suggested that the sub-basins I, II are sub-circular to elongated in shape.

Length of overland flow (Lg)

The length of overland flow (Lg) approximately equals to half of reciprocal of drainage density (Horton, 1945). It is the length of water over the ground before it gets concentrated into definite stream channels. This factor basically relates inversely to the average slope of the channel and is quite synonymous with the length of the sheet flow to the large degree. The Lg values of the study area show variation from 0.86 to 0.98 (Table 3). The values of Lg are low in all four sub-basins indicating overall high relief in area of all the four sub-basins.

VI.CONCLUSION

The morphometric analysis of the drainage network shows dendritic to sub dendritic pattern with moderate to fine drainage texture in the study area. The stream length ratio in the study area varies from from 0.31 to 2.39 is might be due to change in topography & slope along the overall study area. The bifurcation ratio of the Wardha subwatersheds indicates that all the sub-basins fall under normal basin category. Presences of low to moderate drainage density in the sub basin assumig permeable subsoil & coarse drainage texture. The form factor & circulatory ratio values clearly exhibit that all basins are elongated in shape. Elongation ratio values for sub-basin I, II & are low indicating high relief where as elongation ratio value for sub-basin II is more than values of other three basins concluding relatively low relief. Remote sensing & GIS are immerged as efficient tools for delineating &updating drainage networks.

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Table 2: Calculation of different morphometric parameters of four sub basins of Wardha River sub basin

Sl no.	Sub basin name	Stream Order	Basin area	Stream No.(Nu)					Stream Length in Km (Lu)				
				I	II	III	IV	V	I	II	III	IV	V
1	SW I	V	203.94	434	107	19	04	1	278.34	106.65	39.18	14.35	34.38
3	SW II	V	163.92	234	39	23	7	1	165.65	60.75	52.14	33.27	35.88
Sl no.	Sub basin name	Mean Stream Length in Km					Stream length ratio (RL)						
		I	II	III	IV	V	I	II	III	IV			
1	SW I	0.64	0.99	2.06	3.58	34.38	0.38	0.36	0.36	2.39			
3	SW II	0.70	1.55	2.26	4.75	35.88	0.36	0.85	0.63	1.07			
Sl no.	Sub basin name	Bifurcation ratio (Rb)				Mean Bifurcation ratio (Rbm)							
		I	II	III	IV								
1	SW I	4.05	5.63	5.75	4	4.85							
3	SW II	6	1.6	3.14	7	4.43							

Table 3: Calculation of different Aerial morphometric parameters of four sub basins of Wardha River sub basin

Sl no.	Sub basin name	Perimeter	Basin length	Total relief	Relief ratio	Elongation ratio	Length of Overland
1	SW I	86.98	34	320	9.41	0.47	0.86
2	SW II	79.55	28	110	3.92	0.51	0.94
Sl no.	Sub basin name	Drainage density	Stream frequency	Texture ratio	Form factor	Circulatory ratio	Basin Area
1	SW I	2.31	2.77	4.98	0.17	0.33	203.94
2	SW II	2.12	1.85	2.94	0.20	0.32	163.92

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