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Morphometric analysis in some part of Wardha River Sub Basin, Maharashtra, India

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ABSTRACT

Study area is part of Purna River sub basin comprises mainly with Basaltic terrain. Morphometric analysis reveals the development of land surface processes and provides an insight into hydrologic behaviour of watershed. A sub-watershed each was selected to represent landform on basalt, terrain. The low mean bifurcation ratios in all three sub-watersheds suggested stability of the landforms. Drainage density was relatively coarser in all the sub-watershed on basaltic rock. The drainage network was dendritic in the sub-watershed on basalt, sub-dendritic in nature which indicates humongous topography. The study area has the fifth order stream in SW-I and SW-II. The morphometric analysis of sub-watersheds shows the variation in stream ratio might be due to changes in slope in the area as well as presence of different topographic features. 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 . Elongation ratio indicates & IV are 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

Morphometry is the measurement and mathematical analysis of **the** configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy, Maji, & Gajbhiye, 2002). Hydrologic and geomorphic processes occur within a watershed. Therefore, morphometric characterization at the watershed level brings out the information on development of land surface processes and provides an insight into the hydrologic behaviour of a watershed (Altaf, Meraj, & Ramshoo, 2013; Singh, 1998). Morphometric analysis also helps to understand initial slope or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). These studies are made for a range of objectives including prioritization of watersheds (Biswas, Sudhakar, & Desai, 1999), to understand ground water hydrology (Nag & Chakraborty 2003), to study the drainage network as influenced by bedrock geology (Nag & Chakraborty 2003; Sameena, Krishnamurthy, & Jayaraman, 2009) and others.

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 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). Remote sensing technology deals the requirements of reliability and speed, and is an ideal tool for generating spatial information which is pre-requisite for planned and balanced development at watershed level (Nag SK, 1998). The geographical information system (GIS) technology provides suitable alternatives for efficient management of large databases. Integration of remote sensing data and GIS technologies has proved to be an efficient tool for water resources development and management projects as well as for watershed characterization and prioritization (Kumar et al. 2000; Manjare, 2020).

GIS technique are effectively used in recent times in determining quantitative description of basin geometry i.e., morphometric analysis. GIS provides an excellent means of storing, retrieving, manipulating and analysing geo-referenced drainage information (Reddy et al., 2002; Manjare et al 2020). The water resources development technologies are not based on annual rainfall there variability in space and time also play an important role in determining the suitable sites for water conservation. The application of advanced technologies (remote sensing and GIS) and watershed as the basic management unit. Digital elevation model based terrain imaging, processing of topographic aspects in morphometric studies made GIS a dominant tool (Patel et al., 2016, Manjare, 2022) in understanding basin structure (Thomas et al., 2011, Bali et al., 2011, Kumar et al., 2018; Manjare, 2020). Thus, DEM is the principal dataset for various purposes in hydrology, morphometry, etc. (Kumar et al., 2017, Manjare, 2020). Other basin characteristics such as travel time, time to peak and intensity of erosional processes can be predicted with better insight and accuracy through morphometric analysis (Altaf et al. 2013), and it could be a good alternative in ungauged watersheds where information on hydrology, geology, geomorphology and soil are scarce (Sreedevi et al., 2009; Magesh et al., 2013, Manjare et al., 2014, Ready, 2018 , Manjare, 2020). In the present study the use of RSGIS techniques for morphometric analysis of sub watershed in some part of Katepurna river sub basin. The sub watershed extraction has been done using SRTM DEM of 30 mt.

spatial resolution and labelled as mini watershed i.e sub watershed one SWS-I SWS-II respectively for better understanding of the morphology and morphomerty of the sud watershed..

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).

Methodology and Data used

Methodology

The IRS P6 LISS-III of 23.5 mt s of spatial resolution has rectified geometrically and registered with SOI topographical maps on 1:50000 scale using ERDAS IMAGINE 9.6 image processing software with digital image processing techniques. The false colour composite generated from green, red and near infrared (NIR) spectral bands (2, 3, and 4). Linear, equalization and root enhancement techniques have been followed in enhancing the satellite imagery for better interpretation of the geological, geomorphological and elevation map. ARC GIS 10.6 software were used to analysed elevation map and digitization, editing and topology creation has been done in GIS environment.

Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM)

Digital Elevation Model (DEM), Digital Elevation Data (DED), Digital Terrain Data (DTD) or Digital Terrain Model (DTM) all consists of different arrangements of individual points of x (east-west direction) and y (north-south direction) coordinates of horizontal geographic positions. Z is the vertical elevation value that is relative to a given datum for a set of x, y points (Bernhardsen, 1999, Bolstad & Stowe, 1994, Welch, 1990). The elevation in the study area ranges from 239 m to 553 m above mean sea level which indicating 314 m of relative relief in the study area (Fig.4).

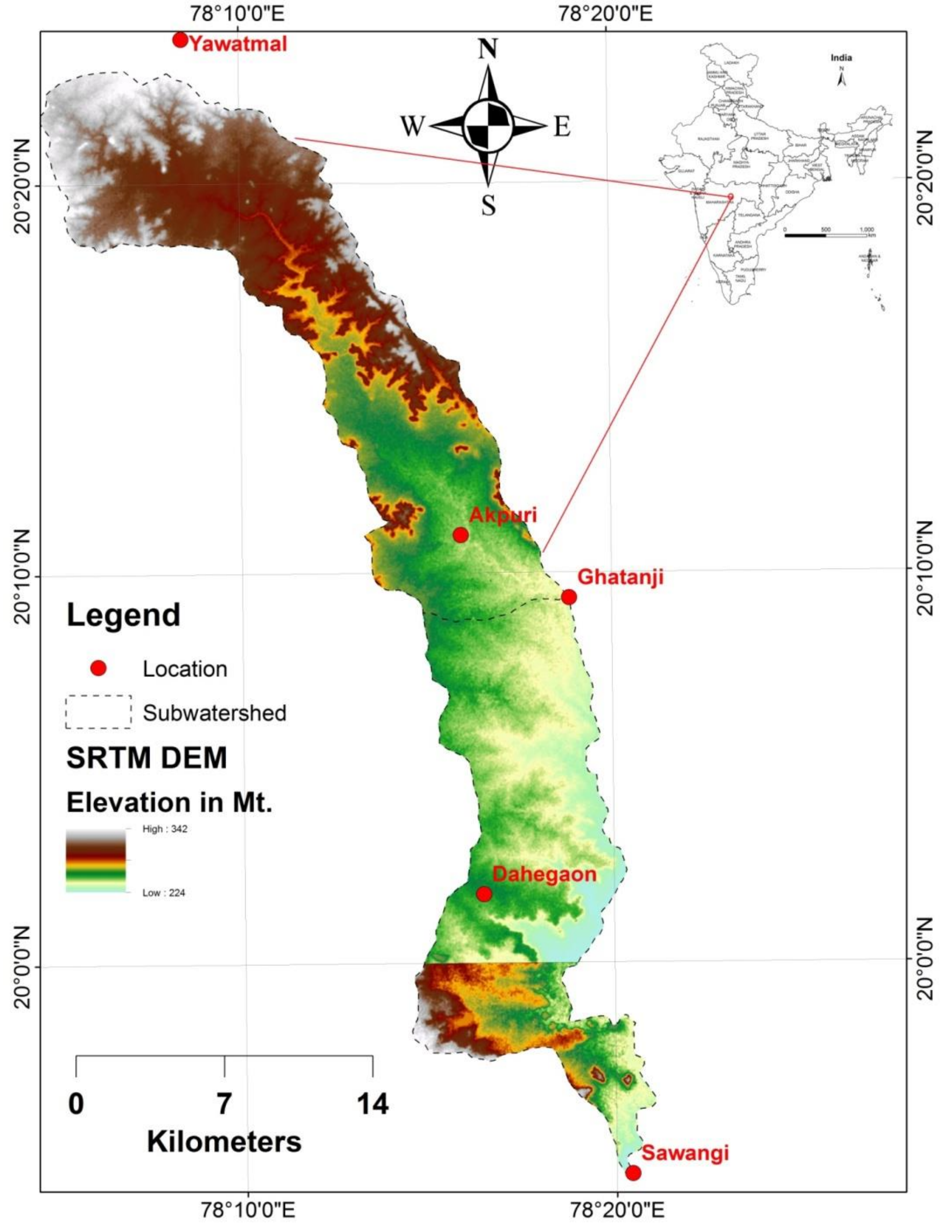

Fig. 1: Location and SRTM DEM map of the study area.

III. Morphometric analysis

Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimensions of its landforms (Clarke, 1966). The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). 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 fexture (Rt), from factor (Rf), circulatory ratio (Rc), elongation ratio (Re) length of overland flow (Lg) etc. 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)
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=$2\sqrt{(A/\pi)}/Lb$ 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)

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

Stream Order (Nu)

Based on the hierarchic making of streams, the designation of stream order is the first step in morphometric analysis of a drainage basin (Strahler, 1957). The area under study shows allocated as 5^{th}order stream. The stream order and stream number is presented in (Table 2). Out of three sub watershed, SW-1 and SW-3 has 5^{th} order stream while SW-2 has 4^{th} order stream (Fig. 1) . 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).

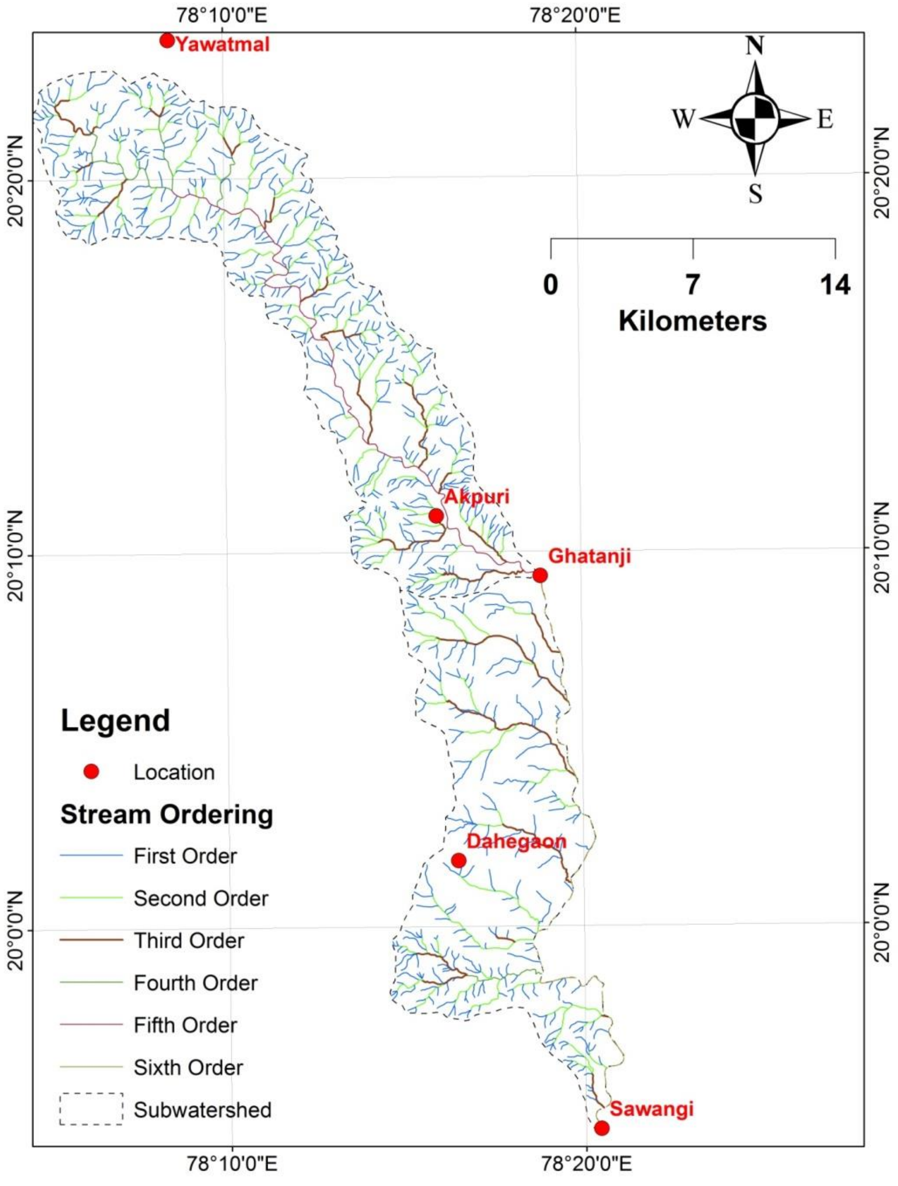

Fig. 2: Drainage map of the study area

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-watershed 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)

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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 & III. 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. 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.

Relief Aspect

Relief ratio

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

Drainage density (Dd)

Drainage density (Dd) is the total stream length in a given basin to the total area of the basin (Strahler, 1964). Over a wide range of geologic and climatic types, the low drainage density is more likely to occur in regions of highly permeable sub soil material under dense vegetative cover and where relief is low. In contrast high Dd is favoured in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Iqbal M, Sajjad H, 2014). 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

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low drainage density (Table 2). 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)

Drainage frequency is directly related to the lithological characteristics. The number of stream segments per unit area is termed stream frequency or drainage frequency (Horton, 1945). 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 which indicate the basin has low relief whereas remaining and SW-3 show high value which indicate the basin has high relief (Table 2).

Drainage texture (Rt)

Drainage texture is the total number of stream segments of all order in a basin per perimeter of the basin (Horton, 1945, Smith (1950) has classified drainage texture into 5 different texture i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8). The Dt values in all sub watershed ranges from 6.53to 5.92 4.78 which indicating that all the sub-watersheds have fine drainage texture (Table 5).

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 2. It is noted that the Rf values vary from 0.17 to 0.41(Table 2). The values in all the sub-basin indicate that they are elongated to sun-circular in shape.

Circulatory ratio (Rc)

The circulatory ratio is similar measure as elongation ratio, originally defined (Miller, 1953) as the ratio of the area of the basin to the circle having same circumference as the basin perimeter. The value of circulatory ratio varied from 0 (inline) to 1(in a circle). 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 watershed. 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 2). All sub-basins have values of Re less than 0.5 indicating that they are elongated.

Elongation ratio (Re)

Elongation ratio (Re) is the ratio of diameter of a circle of same area as the basin to the maximum basin length (Schumm, 1956). Areas with higher elongation ratio values have high infiltration capacity and low runoff. A circular basin is more efficient in discharge to runoff than an elongated basin (Iqbal M, Sajjad H, 2014).The value of Re varies from 0 (in highly elongated shape) to unity i.e. 1.0(in the circular shape).

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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 2). 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. **Length of overland flow (Lg)**

Overland flow (Lg) is defined as the length of the water that is flowing over the surface area before it reaches the main river, effecting the geo-hydrological characteristics and physiography of the watershed (Horton 1945). Rainwater after saturating surface soil and filling the pore space of soil extra water flows as overland flow (Suresh 2000). The length of overland flow (Lg) approximately equals to half of reciprocal of drainage density (Horton, 1945). The Lg values of the study area show variation from 0.86 to 0.98 (Table 2). The values of Lg are low in all four sub-basins indicating overall high relief in area of all the four sub-basins.

IV.CONCLUSION

The morphometric analysis based on several parameters through which the watersheds have been delineate and classified in to sub watersheds three sub watershed. The morphometric analysis of the drainage network shows dendritic to sub dendritic pattern with moderate to fine drainage texture in the study area. Dd values, the study area mostly falls under low drainage density zone (<2 km/km^2) which indicates low relief, low slope, high infiltration capacity and low water regimes throughout the basin. 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. The values of Lg are low in all four sub-basins indicating overall high relief in area of all the four sub-basins. 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. In the study area, the Rc values are ranging from 0.32 to 0.48 shows all sub watershed have values of Re less than 0.5 indicating that they are elongated. Remote sensing & GIS are immerged as efficient tools for delineating &updating drainage networks.

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

Sl no.	Sub watershed Code	Stream Order	Basin area	Stream No.(Nu) I	II	III	IV	V	Stream Length in Km (Lu) I	II	III	IV	V
1	SW I	V	325.61	602 1	136	29		5	412.32	146.05	72.56	46.10	20.02
2	SW II	V	224.36	433 -	82	25	06	-	276.08	87.83	62.91	28.42	--

Sl no.	Sub watershed Code	Mean Stream Length in Km I	II	III	IV	V	Stream length ratio (RL) I	II	III	IV
1	SW I	0.68	0.93	2.50	9.22	20.02	0.35	0.49	0.63	0.43
2	SW II	0.63	1.07	2.51	4.73	--	0.31	0.71	0.45	--

Sl no.	Sub watershed Code	Bifurcation ratio (Rb) I	II	III	IV	Mean Bifurcation ratio (Rbm)
1	SW I	4.42	4.68	5.8	5	4.97
2	SW II	5.28	3.28	4.1	--	4.22

Sl no.	Sub watershed Code	Perimeter	Basin length	Total relief	Relief ratio	Elongation ratio	Length of Overland
1	SW I	92.10	28	200	7.14	0.72	0.93
2	SW II	92.19	31	80	2.58	0.27	0.98

Sl no.	Sub watershed Code	Drainage density	Stream frequency	Texture ratio	Form factor	Circulatory ratio
1	SW I	2.14	2.73	6.53	0.41	0.48
2	SW II	2.02	2.43	5.92	0.23	0.33

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