Morphometric Analysis of Raghunathapalli Watershed, Jangaon District, Telangana State, India

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Abstract: A morphometric analysis involves the quantitative measurements and calculation of landforms. It enables the analysis of geohydrological characteristics of a drainage basin in relation to terrain features and flow patterns. The study area is located in Raghunathapalli watershed of Jangaon District. The majority of morphological characteristics show that the river basin features are subject to considerable geological (younger granites – PGC II) and Geomorphological controls (Elongation shape, high elevated area to surroundings, dis-position of landforms etc). Analyzing the morphometrics of river basins yields important information for sustainable planning and management. It guides decisions on flood control, allocation of water resources, development of infrastructure, land use, soil conservation, and protection of ecosystems. Incorporating these findings into the planning process allows for the attainment of more robust and sustainable natural resource management, while reducing environmental damage and the risk of disasters.

Keywords: Morphometric Analysis, Drainage, Geology, Geomorphology, Management, Quantitative Measurement

1. Introduction

Morphometry is a mathematical analysis of the earth's surface and its shape and size of landforms is the most efficient way to isolate an issue (Sangle & Yannawar 2014). It enables to precisely characterise landform geometry to collect, organize, analyze, and visualize data. A morphometric analysis of a river basin gives a quantitative description of its drainage system, which is an important aspect of basin (Farrukh Altaf et al 2013). A drainage basin is a three-dimensional area in which surface water from precipitation, such as rain, snow and sleet, hail and frost, flows to or joins another body of water, such as a river, a lake, a reservoir, an estuary, a wetland, a sea or an ocean, before flowing out of the basin through surface runoff, flow and groundwater flow.

The watershed area is a problematic one in terms of Groundwater extraction as per previous Groundwater Estimation Committee (GEC) reports showing a gap between recharge and drawl. As per previous periodic assessment reports (2008, 2013 & 2020 years) of dynamic ground water resources of Telangana State Ground Water Department (SGWD) carried out in collaboration with Central Ground Water Board (CGWB) clearly show that the project area is a problematic one in terms of groundwater overuse category. To deal with this, a study for understanding drainage morphometry is crucial for assessing groundwater potential and managing it, comprehending topographical and landform changes, basin management and environmental evaluation. Some of these are discussed in another paper entitled "Appraisal of Water Resources Development Action Plan for groundwater recharge in Raghunathapalli Watershed, Jangaon District, Telangana State, India." (Prakash et al., 2023). The storage to basin system includes interception of vegetation, surface storage, transpiration and evaporation of soil moisture and groundwater, among other factors. Physiographic characteristics of a drainage basin include size, shape, drainage density, tributary size and length, elevation and slope, soil type, rainfall type and intensity, prior conditions, evaporation and evaporation rates, urbanization, deforestation, afforestation and water extraction (Pande et al., 2015. There are three main aspects to analyze the drainage basin characteristics: Linear (one dimension), Aerial (two dimension), Relief aspects (three dimensions).

Raghunathapalli watershed is flowing from North West to South East directions. It is split in to two parallel sub basins where they will meet at the exit of the watershed. There are two major lineaments trending in NW-SE directions while other lineaments are showing in NNE-SSW direction. A major dyke is running across the watershed, almost dividing it in to northern and southern parts of watershed. Several dykes and Quartz veins are located in Northern part of the watershed.Survey of India Topographic maps on 1:25,000 scale are used for getting raw input data on drainage / stream network. Understanding the characteristics of drainage basins for the efficient and sustainable management of the catchments to ensure reliable water security and increase agricultural yields is essential for the assessment of morphometric parameters. A drainage morphometry shall describe the linear, areal or relief properties of each drainage basin. The different morphometric characteristics like linear parameters (stream order, stream number, bifurcation ratio, strength length, mean stream length), areal or basin parameters (circularity ratio, elongation ratio, drainage density, drainage frequency) and relief parameters (dissection index, ruggedness index, hypsometric characteristics) are important for any river basin management. It provides an excellent idea of how to address morphological, hydrological related management procedures.

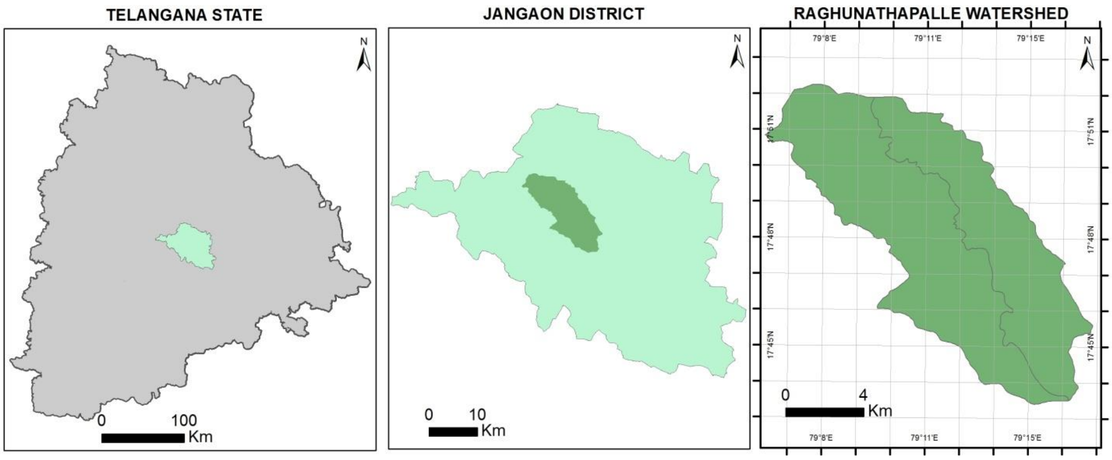

Figure 1. Location Map of Raghunathapalli watershed

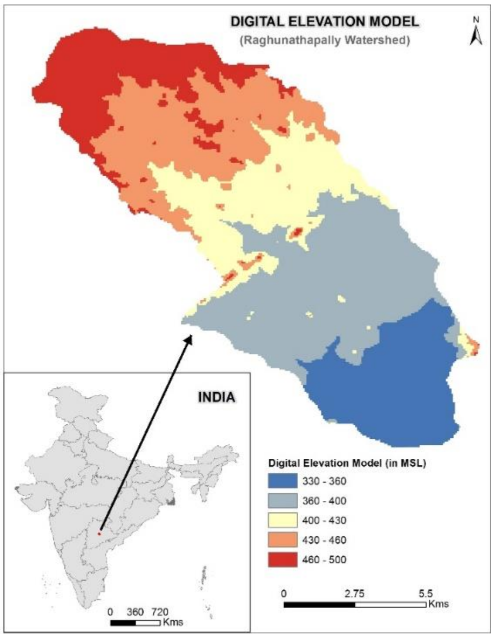

Figure 2. Digital Elevation Model (DEM) of the study area

2. Study Area

The Raghunathapalli watershed is located in Sub-watershed of Aleru Vagu at the drainage divide between Godavari and Krishna Basins. The Aleru Vagu is sub-sub-basin of Musi Sub basin. The Musi Sub basin is part of Krishna basin in southern India. The project area encompasses Survey of India (SoI) toposheet nos. 56O1/SE, 56O1/SW, 56O/2NE, 56O/5SW, 56O/6NW, with tributaries flowing during the Monsoon season only. The geographic location of the watershed lies in between Latitudes 17.702937° - 17.876163° North and Longitudes of 79.121032° - 79.284125° East. It covers parts of Raghunathapalli (Southern side), Narmetta (North Western side) and Jangaon (North Western side) Mandals of Jangaon District, Telangana state, India. The Areal extent is 126 Sq Kms. The location map is shown in figure 1.

3. Methodology

The base input stream network for carrying out morphometric analysis is updated with high resolution satellite data (IRS LISS IV + Cartosat 1 fused product) when any deviations are observed in the course network. Strahler's stream order system has been used to rank the drainage basin's channel segment. The smallest streams, known as first-order streams, are called tributaries because they do not receive water flow from other sources. First-order streams are the smallest type of streams globally and are made up of small tributaries. These streams flow into larger ones and supply them with water, but they do not typically receive water themselves. When two or more than two first-order streams meet in downstream, the second-order stream is formed. It continues with further higher order. Streams of the first and second order usually originate on steep terrain and flow swiftly before slowing down and joining the next higher-order water body. Streams from the first to the third order are also referred to as headwater streams and encompass all water bodies in the upper region of the watershed. To supplement the stream network, the Digital Elevation Model (DEM) is prepared from contour data by making use of Spatial Analyst tools in Arc GIS 10.1 software as shown in figure 2.

4. Morphometric Parameters

The following parametres covering morphometric analysis are carried out under linear (1 Dimension), areal (2 Dimensions) and relief (3 Dimensions) categories. The computation of morphometric analysis based reference is shown in Table 1-3 (Sangle & Yannawar 2014; Ziaur 2012; Avijit, et al., 2019) and the stream order map is shown in figure 3.

Table 1. Morphometric Analysis computations table

Sl. no	Morphometric Parameters	Method ology
1	Stream order (u)	Hierarchical order
2	Stream Length (Lu)	Length of the stream
3	Mean Stream Length (Lsm)	$Lsm = \frac{Lu}{Nu}$; km Where, Lu=Mean stream length of a given order Nu= Number of stream segments
4	Bifurcation Ratio (Rb)	$Rb = \frac{Nu}{Nu^{+}1}$ Where, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order
5	Mean Bifurcation Ratio	Rbm = Average of bifurcation ratios of all orders
6	Drainage Density (D)	$D= \frac{\Sigma Lu}{Au}$; $\frac{km}{km^2}$ Where, Lu=Total Stream length of all orders (km) Au=Area of the Basin (km^2)
7	Drainage Texture(Rt)	$Rt = \frac{\Sigma Nu}{P}$ Where, Nu= Stream Number, P = Perimeter (km)
8	Stream Frequency (Fs)	$Fs = \frac{\Sigma Nu}{Au}$ Where, Nu=Total number of streams in the basin Au= Basin Area (km^2)
9	Length of Over Land Flow (Lg)	$Lg = \frac{1}{(D \times 2)}$ Km Where, D = Drainage density (km/km^2)
10	Form Factor (Rf)	$Rf = \frac{Au}{(Lb^2)}$ Where, Au=Area of the Basin (km^2) Lb=Maximum Basin length (km)
11	Circularity Ratio (Rc)	$Rc = \frac{4 \times \pi \times Au}{P^2}$ Where, Au= Basin Area (km^2) P= Perimeter of the basin (km), Π = 3.14
12	Elongation Ratio (Re)	$Re= \frac{\sqrt{Au}}{Lb} \times \frac{1}{\pi}$ Where, Au= Area of the Basin (km^2) Lb=Maximum Basin length (km), Π = 3.14
13	Relief Ratio (Rh)	$Rh = \frac{H}{Lbmax}$ Where, H = Maximum basin relief (km) Lbmax= Maximum basin length (km)
14	Ruggedness Number (HD)	HD= H×Dd Where, H= Maximum basin relief, Dd= Drainage density
15	Relative Relief (Rhp)	$Rhp =\frac{H}{P}$ Where, H = Height difference between highest and lowest P = Perimeter of the basin (km)

Table 2. Bifurcation Analysis

Stream Order	Nos	Bi-Furcation Ratio	Average Bi-Furcation Ratio
1	222	1.85	
2	120	2.86	
3	42	1.40	1.80
4	30	1.11	
5	27		
Grand Total	**442**		

Table 3. Stream Length Analysis

			Mean stream length	Stream length ratio
Order	**Nos**	**Length, mtr**	**Lsm**	**RL**
1	222	1,25,290	564.37	
2	120	66,340	552.83	0.53
3	42	23,718	564.71	0.36
4	30	24,585	819.49	1.04
5	27	20,506	759.50	0.83
6	1	188	0.42	0.01
Total	**442**	**2,60,626**		

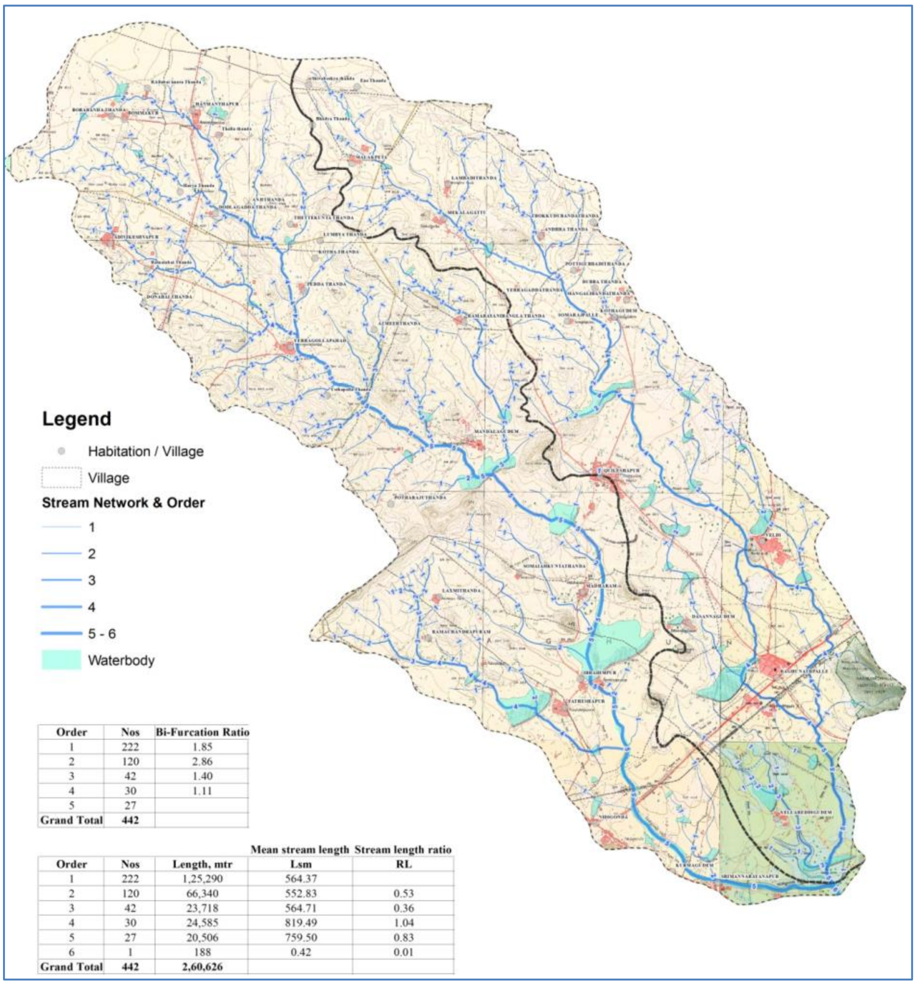

Figure 3. Stream Order Map and morphometric analysis

Drainage Density = $\frac{\text{Total Stream Length (Kms)}}{\text{Area of the Basin (Sq Km)}} = \frac{260.62}{126.36} = 2.06$

Drainage Texture = $\frac{\text{Stream Number}}{\text{Perimeter (Km)}} = \frac{442}{57.92} = 7.63$

Stream Frequency = $\frac{\text{Total No.of Streams}}{\text{Area of the Basin (Sq Km)}} = \frac{442}{126.36} = 3.50$

Length of Overland flow = $\frac{1}{(\text{Drainage Density} \times 2)} = \frac{1}{(2.06\times2)} = \frac{1}{4.12} = 0.24$

Form Factor = $\frac{\text{Area of the Basin (Sq Km)}}{(\text{Maximum Basin Length}^2\text{,Km})} =$

$\frac{126.36}{(21.3^2)} = \frac{126.36}{453.69} = 0.28$

Circularity Ration = $\frac{4 \times \pi \times \text{Area of the Basin (Sq Km)}}{(\text{Maximum Basin Length}^2\text{,Km})}$

$= \frac{4 \times \pi \times 126.36}{57.92^2} = \frac{1587.89}{3354.73} = 0.47$

Elongation Ratio = $\frac{\sqrt{\text{Area of the Basin (Sq Km)}}}{\text{Maximum Basin Length,km}} \times \frac{1}{\pi} =$

$\frac{\sqrt{126.36}}{21.3} \times \frac{1}{\pi} = 0.17$

Relief Ratio = $\frac{\text{Maximum Basin Relief (km)}}{\text{Maximum Basin Length (km)}} = \frac{84}{21.3} = 3.94$

Ruggedness Number = Maximum Basin Relief × Drainage Density = 480×2.06 = 988.8

Relative Relief = $\frac{\text{Height difference between highest and lowest}}{\text{Perimeter of the basin}} = \frac{500-330}{57.92} = \frac{170}{57.92} = 2.94$

5. Conclusions

According to the study, the Raghunathapalli River has a length of 26.30 km and is a sixth order stream. The total length is calculated from farthest point or highest point of the watershed where the first order stream originates to the point until the 5th and 6th order streams meet at a single point.

The basin is dominated by lower order streams, also characterised by a dendritic and semi-dendritic drainage system which provides an indication of prevalence of homogenous lithology. The Bi-furcation ration is in the range of 1-3 which indicates less geological distortion on drainage network. Due to its high sloping course in upper reaches, the lower order streams (1st and 2nd order) are more in number. The presence of young topography i.e. alkali feldspar granites around the stream concerned is also indicated by a larger number of streams in higher reaches. Its significant morphological change can be seen from a sudden decrease in the third and fourth order of streams. The drainage density of 2.06 suggests that the basin has a coarse drainage density (2-4) category indicating initial increased flow velocity and infiltration will be affected slightly.

The basin appears to be an elongated drainage basin with an elongation ratio of 0.17. This indicates that the basin can also prone to erosion (Ajay 2020). The lower values near to 0 are elongated basins and the values close to 1 are circular basins. An elongation ratio of 0.17 suggests a lesser elongated watershed. That means that the water flow is low, which in turn encourages erosion. Elongated watersheds will have high relief and steep slopes indicating potential erosion. The form factor value of 0.28 suggested that the watershed is an elongated, resulting in a flatter peak flow over an extended duration. Relative relief (local relief) value of 2.94 which is below 100, suggests that it falls in Low relative relief. The length of the streams in each order tends to be increased exponentially with an increase in number of streams.The length of the river varies with increasing order in the Raghunathapalli basin. The highest stream length (125.29 km) is recorded for 1st order streams followed by 2nd order streams (66.34 km). Then 3rd, 4th and 5th order streams showing more or less uniform lengths of 23.71 km, 24.58 km and 20.50 kms. Whereas 6th order stream is showing a length of 0.19 kms only.

The upper reaches of the watershed have a higher number of 1st and 2nd order streams because of high sloping area. The more density of streams in the upper reaches indicating a younger topography, e.g. Alkali Feldspar granites on the stream at issue. Satellite Remote Sensing techniques map discontinuities like fractures, joints, faults, and fissures affecting ground water availability. These zones are promising for aquifer availability in country rocks. Major lineaments are oriented NW-SE, while others show NNE-SSW direction. In the study area, two major streams running in NW-SE direction are merging at the watershed mouth. The results of morphometric analysis helps in formulating micro-watershed level water resource action plans, especially in a hard rock terrain like the Raghunathapalli watershed in Jangaon District.

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