Morphometric Analysis Using Geo spatial Techniques in Brahmanavellamla Watershed, Nalgonda mandal and Nalgonda district, Telangana state, India

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Abstract - **The study area falls in Nalgonda Mandal, Nalgonda district in Telangana state covering an area of 142 Sq.km. The entire area is falling under Brahmanavellamla watershed drainage system. Morphometric analysis is carried out using IRS P6-LISS IV Satellite imagery (2017) and thematic layer prepared by using GIS software. Morphometric analysis is important in any hydrological investigation and it is inevitable in development and management of drainage basin. The development of Morphometric techniques was a major advance in the qualitative and quantitative description of the geometry of the drainage basins and its network which helps in characterizing the drainage network. The geomorphological properties which are important from the hydrological studies point of view include the linear, aerial and relief aspect of the watershed. In the present study a Morphometric analysis of Brahmanavellamla watershed drainage area has been carried out using remote sensing and geospatial techniques in GIS. This technique is found relevant for the extraction of river basin and its Drainage network. The extracted drainage network was classified according to Strahler's system of classification and it reveals that the terrain exhibits dendritic to sub-dendritic drainage pattern. The various linear parameters (Stream order, Stream number, Stream length, stream length ratio, Bifurcation ratio, Drainage density, Texture ratio, Stream frequency) and shape factors (Compactness coefficient, Circularity ratio, Elongation ratio, Form factor) of the drainage area were computed. Hence, it is concluded that GIS techniques proved to be a competent tool in Morphometric analysis.**

Index Terms - **Morphometric, Remote Sensing & GIS, Drainage, Stream Order and Brahmanavellamla watershed, Nalgonda.**

INTRODUCTION

The development of a drainage system over space and time is influenced by several variables such as geology, structural components, geomorphology, soil and vegetation of an area through which it flows. Geomorphometry is the Measurement and mathematical analysis of earth's surface and its dimensions of the landforms (Lark, 1966) Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of basins Strahler (1964). It is important in any hydrological investigation like assessment of groundwater potential, groundwater management, basin management and environmental assessment. Various hydrological phenomena can be correlated with the physiographic characteristics of a drainage basin such as size, shape, slope of the drainage area, drainage density, size and length of the contributories, etc. Rastogi and Sharma (1976). The Morphometric analysis can be performed through measurement of linear, aerial, relief, gradient of channel network and contributing ground slope of the basin Nautiyal (1994), Nag and Chakra borty (2003). The dynamic nature of runoff is controlled by the geomorphologic structure of the catchment area and the induced runoff is very sensitive towards the Morphometric characteristics of the contributing area Rudraiah et al. (2008) In India. The surface runoff and flow intensity of the drainage system can be estimated using the geomorphic features associated with Morphometric parameters Ozdemir and Bird (2009). Pioneer work on basin morpohmetry has been carried out by (Horton (1932), Horton (1945) and Miller (1953). The present study depicts the process to evaluate the various Morphometric parameters of Nalgonda mandal in using geospatial tectonics.

2. STUDY AREA

2.1. Location and Extent

The study area under part of the Musi River is one of the tributary of river Krishna which is flowing in the Nalgonda district. The study area covers 7 villages and 6 mini villages. The average annual rainfall in the study area is 759 mm. The South West Monsoon sets in by May and withdraws by the December. About 75% of annual rainfall is received during the Monsoon months, of which more than 85% occurs during July, August and September. The study area lies in between Latitudes:1700'00"-1709'00"N. and Longitudes: 7908'00"-79012'00"E. Study area is located in ~90 km away from Hyderabad City and it is crossed by National Highway NH65 (Fig. 2.1).
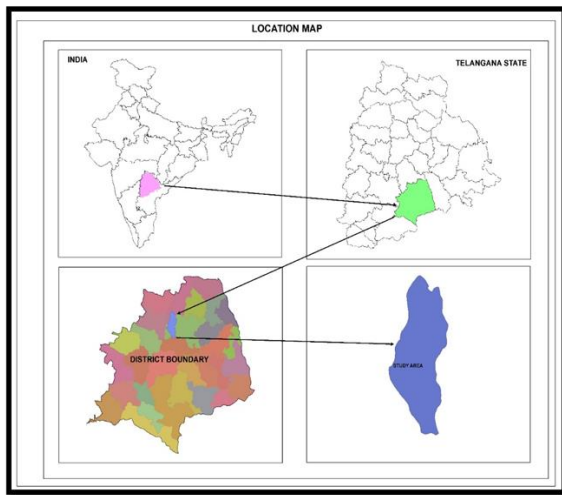

Fig.2.1. Location map of the study area.

2.2. Morphometric analysis

The study area was delineated using the Survey of India topographic maps to a scale of 1: 25,000. The ridgelines in the Toposheet were identified, which act as dividing lines for the runoff. Keeping in mind the functional are a requirement of the study area, the stream network was digitized in GIS software.

2.3. Methodology

The present study is based on Survey of India (SOI) topographic maps of E44N4 56 (O/4) scale 1, 50,000. The satellite data has been used for updating of drainage and surface water bodies. The IRS P6 LISS-IV is a multi-spectral high resolution camera with a spatial resolution of 5.8m at nadir. Precision geocoded cloud free data was used to meet the requirement of area under study. Satellite image of the Nalgonda mandal is shown in map. The first step in the quantitative analysis of drainage basin is designation of stream order. The term "stream order" is a measure of the position of a stream in the hierarchy of tributaries. In the present study, the channel segment of the drainage basin has been ranked according to Strahler's stream ordering system. According to Strahler (1964), the 1st order streams are those, which have tributaries. The 2nd order streams are those, which have tributaries only of 1st order streams, where two 2nd order channels join, a segment of 3rd order is formed. When two 3rd order segments join, a 4th order channel is formed and so on. Morphometric analysis was carried out for the Nalgonda mandal drainage area. The parameters computed in the present study using RS and GIS technique includes stream order, stream length, bifurcation ratio, drainage density, stream frequency, form factor, circulatory ratio, elongation ratio, relief ratio and ruggedness number. The input parameters for the present study such as area, perimeter, elevation, stream length etc. were obtained from digitized coverage of drainage network map in GIS environment.

Table: 2.1. Methods of Calculating Morphometric Parameters

	Morphometric Parameters	Methods
	Stream order (U)	Hierarchical rank
Linear Parameters	Stream length (Lu)	Length of the stream
	Mean stream length (Lsm)	Lsm = Lu/Nu where, Lu=Stream length of order „U" Nu=Total
	Stream length ratio (Rl)	Rl=Lu/Lu-1; where Lu=Total stream length of order „U",
	Bifurcation ratio (Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream

	Morphometric Parameters	Methods
Aerial Parameters	Drainage density (Dd)	Dd = L/A where, L=Total length of streams; A=Area of
	Stream frequency (Fs)	Fs = N/A where, N=Total number of streams; A=Area of
	Texture ratio (T)	T = N1/P where,N1=Total number of first
	Form factor (Rf)	Rf=A/(Lb) 2 ;where, A=Area of watershed,
	Circulatory ratio (Rc)	Rc=4πA/P2 ;where, A=Area of watershed, π=3.14,

Relief Parameters	Basin relief (Bh)	Vertical distance between the lowest and highest points of
	Relief ratio (Rh)	Rh=Bh/Lb; Where, Bh=Basin relief; Lb=Basin length
	Ruggedness number (Rn)	Rn = Bh × Dd Where, Bh =Basin relief; Dd=Drainage

Elongation ratio (Re)	Re=2√(A/π)/Lb ;where, A=Area of watershed, π=3.14,
Length of overland flow (Lof)	Lof = 1/2Dd where, Dd=Drainage density
Constant channel maintenance (C)	Lof = 1/Dd where, Dd=Drainage density

2.4. Physiography

Nalgonda mandal is located in the Central Part of the District. The study area is bounded on the North by Narkatpally, West by Munugode mandal and South by Kanagal mandal, and East by Thipparthy Mandal. Study area elevation varies from 296 to 204m MSL. A major part of the mandal is covered by Brahmanavellamla watershed which rises in Nalgonda and Narkatpally. The major landforms in granitoid rocks are Pedi plains (Shallow and moderately weathered - 5 to 20m) covering 60% of total area as observed by the satellite imagery with limited field checks; about 5% area is covered with pediment and inselbergs zone. Valley zones are covered by 30% of the area.

2.5. Drainage and Rainfall

The study area drainage pattern is mainly dendritic drainage. All streams are flow from NS direction The District has an average actual rainfall of 756.4 mm during 2010-2021 years. The bulk of which is received through the Southwest Monsoon during the period from June to September.

2.6. Geology and Structures

The area is underlain by older hard rock's like different varieties of granite and gneisses which are intruded by dolerite dykes / quartz veins. Stratigraphically the area predominantly exposes rocks of Peninsular Gneissic Complex (PGC) along with basic dykes (Proterozoic). The PGC comprises two varieties of granitoids rocks viz., older granite gneiss varieties and younger granite - alkali feldspar Granite is widely distributed throughout the area. It is grey to pink, medium to coarse granite, porphyritic or non-porphyritic and massive. Basic intrusive which include dolerite, dyke rocks in the area. Generally dolerite dykes appear to be very hard and compact and poorly devoid of fractures, whereas the Pegmatite veins / Quartz reefs are highly fractured.

2.7. Hydrogeology

In the district granite/gneisses, dolerite dykes at various places. However majority of the area is occupied by hard rock formations like gneissic complex. Only less amount of the area is occupied by other formations. In hard rock formations there is lack of primary porosity. However the aquifer system is developed because of secondary porosity due to various tectonic disturbances and weathering activity. The deeper aquifer system is developed due to major faults, joints, fractures, crevices, shear zones etc. It is observed that the ground water prospects in moderately weathered Granite gneiss / granitoids rock and valleys is in the order of 100-200 lpm, whereas it is 50-100 lpm in Shallow weathered Granite gneiss rocks and valleys. In the pediment zones of granitic rocks, the expected yield of the wells is in the order of 10-50 lpm. In highly dissected hills, the prospects are low to poor (0 to 10 lpm).
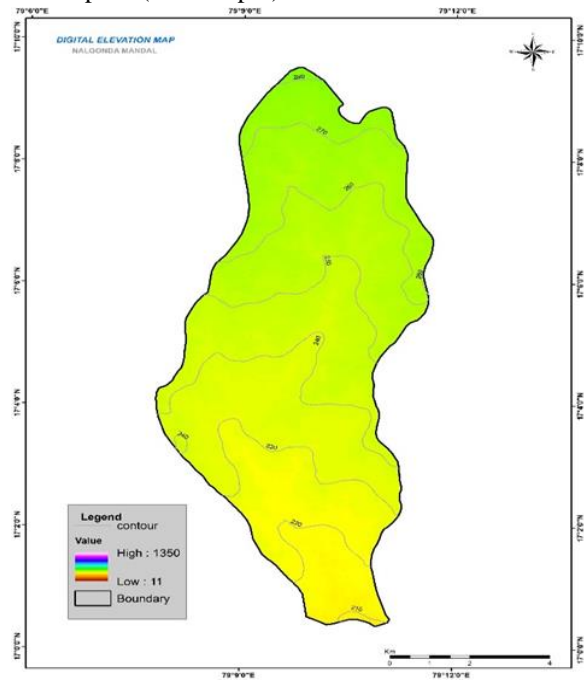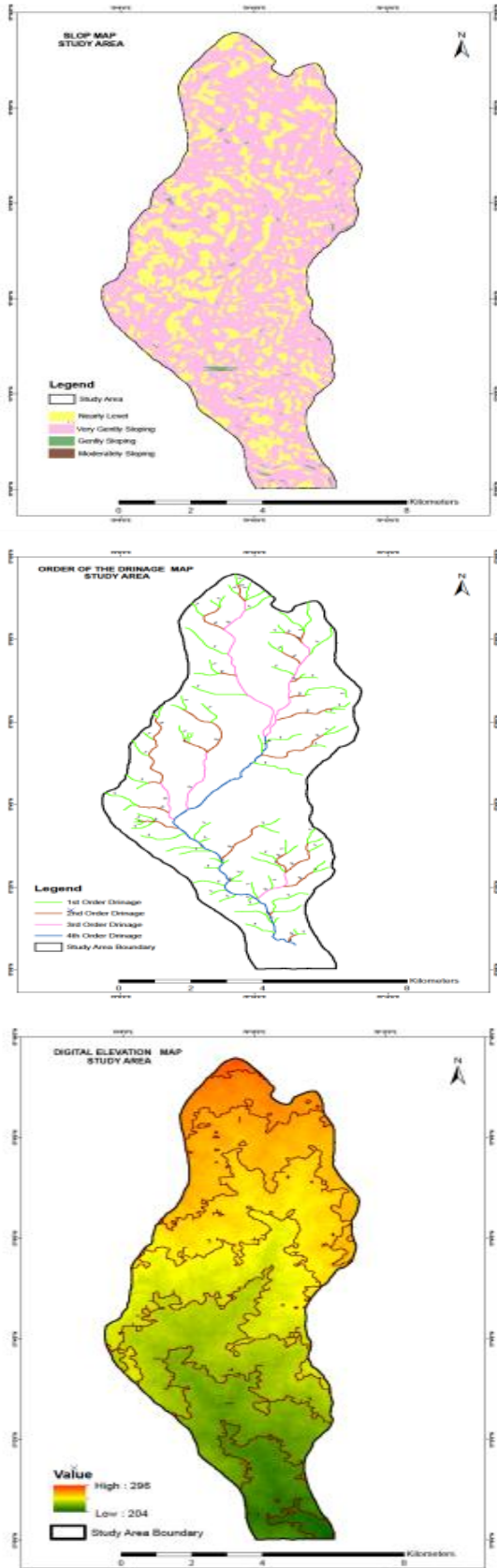
Fig: 2.1 Analysis maps of the study area.

3. RESULTS

The study carried out has been divided into three sections the first section deals with applicability of Horton's laws of stream numbers and stream lengths in the study area. The second section deals with the various linear and shape Morphometric parameters. The total study area drainage is 142 km2. The drainage pattern is dendritic to sub-dendritic nature and it is influenced by the general topography of the area. The stream orders of Nalgonda Mandal drainage area varies from 1 to 4 and the total number of stream segments of all orders recorded was 176. Orders of stream network indicated 91 of 1st orders, 39 of 2nd order, 21 of 3rd order and 25 of 4th order. The drainage map of the study area is shown in (Fig. 3.1).The values of different geomorphological parameters were calculated by using the methodology as discussed in materials and methods.

3.1. Stream order (u) :
The concept of stream order was introduced by Horton in 1932. Stream ordering is a widely applied method for stream classification in a river basin. Stream ordering is defined as a measure of the position of a stream in the hierarchy of tributaries Leopold et al. (1964) and the streams of Brahmanavellamla watershed Drainage area has been demarcated according to the Strahler's system of stream ordering. The stream order and the total number of stream segments in each order for the area are shown in the (Table 2). The area has been designated as a fourth-order drainage area.

1. 1st order streams- Single stream.
2. 2nd order streams- Joining of two first order streams will form second order.
3. 3rd order streams- Joining of two second order streams will form third order.
4. 4th order streams- Joining of two third order streams will form fourth order.
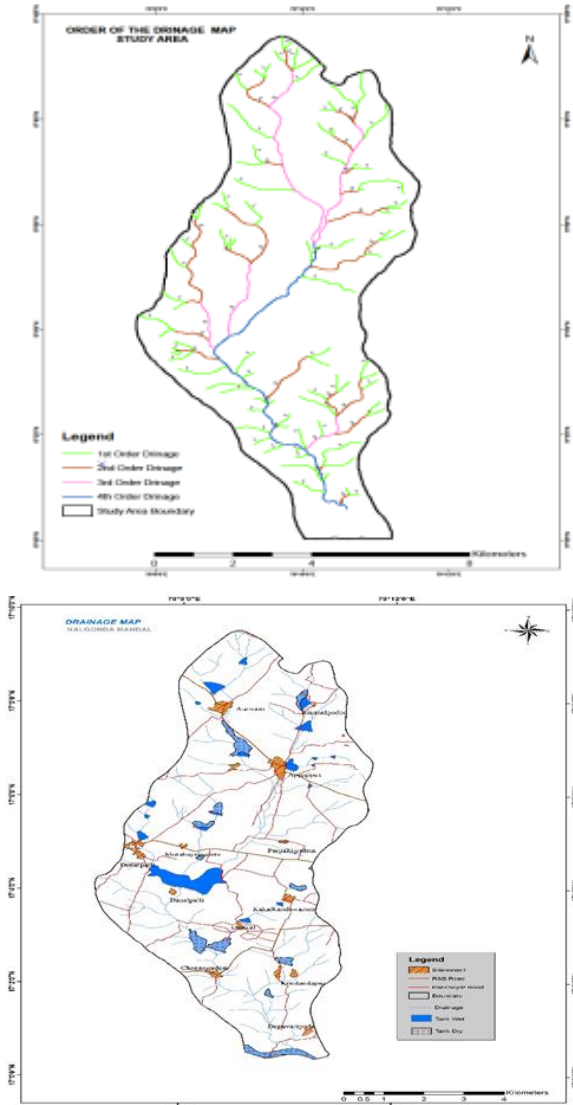
Fig: 3.1 Order of the Drainage and Drainage map in the study area

3.2. Stream Number (Nu):

The number of streams of different orders and the total number of streams in the basin are counted independently. Generally, the number of streams gradually decreases as the stream order increases; the variation in order and size of tributary basins is largely depends on physiographic and structural condition of the region. The total stream segments in the study area are 176.

3.3. Stream Length (Lu):

Stream length is indicative of chronological developments of the stream segments including interlude tectonic Disturbances. The stream length is

measured from mouth of the river to the drainage divide near the source. "Lu" has been computed on the basis of Horton's law of stream length, which states that geometrical similarity is maintained in the basins of increasing orders. The stream length of various orders is presented in the (Table 2). Generally, the total length of stream segments is the maximum in first-order streams and decreases with an increase in the stream order. The law holds true in the present case study. The results reveal that the first-order streams are short in length and are found in the upstream area. Streams with relatively short lengths are representative of areas with steep slopes and finer texture, whereas longer lengths of stream are generally indicative of low gradients Strahler (1964).

Total length of streams $(Lu) = 59.63+25.85+18.25+1.67=116.43$Km

Table: 3.1. Stream parameters of the study area.

Steam Order	No. of Streams N_u	Total length of streams in km L_u	
1	91	59.68	
2	39	25.85	
3	21	18.24	
4	25	12.67	
Total	176	116.43	
Bifurcation ratio			
1st order	2nd order	3rd order	4th order
2.33	1.85	-	0.84

3.4. Stream Length Ratio (RI):

It is the ratio between the lengths of streams in a given order to the total length of streams in the next order. Is then calculated for each pair of the orders. Length ratio is for 1st-2nd and 2nd -3rd order of the alluvial plain basin are higher than the basin of other two zones. The Rl values for the Nalgonda Mandal drainage area vary widely are strongly dependent on the physiographic and the slope.

3.5. Bifurcation Ratio (Rb):

The term „bifurcation ratio is indicating (Rb) was introduced by Horton in 1932. Rb is related to the branching pattern of a drainage network and is defined as the ratio of the number of streams of any given order to the number of streams in the next higher order in a drainage basin. It is a dimensionless property and shows the degree of integration prevailing between streams of various orders in a drainage basin. Rb shows a small range of variation for different areas or for different environments except those where the

powerful geological control dominates. The Rb for the Nalgonda mandal drainage area varies from 1.85 to 2.33.

3.7. Basin Relief (R):

The relief (R) is defined as the differences in elevation between the highest and the lowest points on the valley floor of a study area. Basin relief is an important factor in understanding the Denudational characteristics of the basin and plays a important role in landforms, drainage development, surface and sub-surface water flow, permeability and erosion properties of the terrain. From the morphometric study, it should be noted that the maximum relief value of Nalgonda Mandal drainage area is 8.5.

3.8. Relief Ratio (Rh):

The relief ratio has been widely accepted as a effective measure of gradient aspect of the basin, despite uncertainties surrounding definition of its component measurements and may be unduly influence by one isolated peak within the basin Sharma (1981). Schumm (1956) defined relief ratio as the ratio of maximum relief to horizontal distance along the longest dimension of a basin parallel to the main drainage line and it measures the overall steepness of the river basin. The value of relief ratio in the Nalgonda Mandal drainage area is 0.417. This is a dimensionless height-length ratio and allows comparison of the relative relief of any basin regardless of difference in scale or topography. Relief ratio is identical with the tangent of the angle of slope of the hypotenuse with respect to Vertical (Strahler, 1964). Thus is measure the overall steepness of a drainage basin is an indicator of intensity of erosion processes operating on the slope of the basin. Relief ratio normally increases with decreasing drainage area and size of a given drainage basin (Gottschalk, 1964).

3.9. Ruggedness number (Rn):

It is the product of the basin relief and drainage density. The ruggedness number of the basin is 810. The low value of ruggedness number indicates low erosion intensity in the basin. High values of ruggedness number occur when slopes of the basin are not only steeper but long.

3.10. Drainage density (Dd):

Drainage density (Dd) is one of the important indicators of the landform element and providesa numerical measurement of landscape dissection and runoff potential (Chorley 1969). Dd is defined as the total stream length in a given basin to the total area of the basin (Strahler 1964). Dd is related to various features of landscape dissection such as valley density, channel head source area, relief, climate and vegetation, soil and rock properties and landscape evolution processes. A low drainage density indicates permeable sub-surface strata and has a characteristic feature of coarse drainage. (Strahler (1964) noted that low drainage density is favoured where basin relief is low and vice versa. The Drainage density of the Nalgonda Mandal drainage area which indicates that the study area has a weak or permeable subsurface material with intermediate drainage and low relief.

Drainage density (D) = L/A
Drainage density (D) = 116.43/142= 0.819

3.11. Stream frequency (Fs):

Stream frequency is defined as the ratio of the total number of stream segments of all the orders in the basin To the total area of the basin. "Fs" in an index of the various stages of landscape evolution. The occurrence of streams segments depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and soil permeability. The stream frequency for the Nalgonda Mandal drainage area is 1.239. The stream frequency is dependant more or less on the rainfall and the physiography of the region.

3.12. Texture Ratio (T):

It is total number of stream segment of all order per perimeter of the Mandal area. The texture ratio of the study area is 2.10 the value of drainage texture is the greater than 8 indicate very fine texture including higher runoff potential of the study area. While medium value is moderate in nature and lower value is coarser in nature indicating less runoff potential.

Texture ratio (T) = N/p
Texture ratio (T) = 91/43.2
Texture ratio (T) = 2.10

3.13. Form factor (Ff):

Form factor is the numerical index. Horton (1932) defined form factor (Ff) as the ratio of the basin area and square root of the basin length. Form factor is the numerical index (Horton, 1932) commonly used to represent different basin shapes. Nalgonda Mandal my study drainage area Ff value is 16.06.

3.14. Circularity ratio (Rc):

Miller (1953) defined circularity ratio (Rc) as the ratio of the area of a basin to the area of a circle having the Same circumference as the perimeter of the basin. The "Rc" is influenced more by the lithological characteristics of the basin rather than anything else. The low, medium and high values of the circulatory ratio are indications of the youth mature and old stages of the life cycle of the tributary basins. Nalgonda Mandal drainage area is in the youth stage of its development with a circulatory ratio of 41.2.

Basin circularity Ratio (Rc) $= \underline{4 \pi A / P^2}$
Where;
A = Area of the river basin in km^2
P = Perimeter of the river basin in km.
Rc $= 4 * \pi * 142/(43.2)2$
Basin circularity Ratio (Rc) = 41.2

3.15. Elongation Ratio (Re):

Elongation ratio (Re) is defined as the ratio of diameter of a circle having the same area as of the basin and maximum basin length (Schumm 1956). It is a measure of the shape of the river basin and it depends on the climatic and geologic types. These basins are efficient in the discharge of runoff than the elongated basin because concentration time is less in circular basins. The "Re" value of Nalgonda Mandal drainage area is 7.212, which indicates low relief with steep slope and elongated in shape.

Elongation Ratio (E) $= \underline{2\sqrt{A/\pi}}$
Where;
A = Area of the river basin in km^2
l = Total length of main stream in km
Elongation Ratio (E) = 7.212

3.16. Length of over land flow (Lg):

Length of the overland flow (Lg) is the length of water over the ground before it gets concentrated into definite Stream channels. "Lg" can be defined as the mean horizontal length of flow path from the divide to the stream in a first-order basin and is a measure of stream spacing and degree of dissection and is approximately one-half the reciprocal of the drainage density (Chorley 1969). From the Morphometric analysis, the Lg Value for Nalgonda Mandal drainage area is 0.409. The low Lg value indicates that the rain water had to travel relatively medium distance before getting concentrated into stream channels.

3.17. Constant of channel maintenance (C):

Constant of channel maintenance(C) is the 1 divided by the drainage density.
Constant of channel maintenance (C) = 1/Dd
Where;
D= Drainage density
Constant of channel maintenance (C) = 1/0.819
Constant of channel maintenance (C) =0.409

Table: 3.2 Morphometric Parameters of the study area

Morphometric parameters	Symbol/formula	Results
Area(sq km)	A	142
Perimeter(km)	P	43.2
Drainage density(km/sq.km)	$D=L_u/A$	0.819
Stream frequency	$F_s=N_u/A$	1.239
Texture ratio	$T=N_1/P$	2.10
Basin length(km)	L_b	17
Constant channel maintenance	$C=1/Dd$	1.22
Circularity ratio	$R_C= 4\prod A/P^2$	41.2
Form factor ratio	$R_f= A/L_b^2$	0.44
Stream order up to		4th
Bifurcation ratio	$Rb = Nu/ Nu+1$	5.02
Basin Relief		8.5
Relief ratio	$Rh=Bh/Lb$	0.417
Length of overland flow in Km	$Lof = 1/2Dd$	0.409
Elongation ratio	$Re=2\sqrt{(A/\pi)}/Lb$	7.212
Ruggedness number	$Rn = Bh \times Dd$	810

CONCLUSION

The present study has proved that the geo processing technique used in GIS is an effective tool for computation and analysis of various Morphometric parameters of the basin and helps to understand various terrain parameters such as nature of the bedrock, infiltration capacity, surface runoff, etc.One of the purposes of fluvial morpohmetry is to derive information in quantitative from about the geometry of the fluvial system that can be correlated with hydrologic information. The Nalgonda mandal Brahmanavellamla watershed drainage area is well drained in nature with the stream order varying from 1 to 4. The basin is dominated by lower order streams and the total length of stream segments is maximum in first order streams. Nalgonda mandal drainage area is an elongated basin with moderate relief and steep slope due to the lower elongation ratio 7.212. Stream

frequency and drainage density are the prime criterion for them Morphometric classification of drainage basins, which certainly control the runoff pattern, sediment yield, and other hydrological parameters of the drainage basin. The Dd appears significantly medium in Nalgonda Mandal drainage area, which is an indicative of existence of impermeable rocks and moderate relief, causing more infiltration and high groundwater prospects. The quantitative analysis of linear, relief and aerial parameters using GIS is found to be of immense utility in river basin evaluation, basin prioritization for soil and water conservation and natural resource management. The geo processing techniques employed in this study will assist the planner and decision makers in basin development and management studies. The complete Morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect.

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