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KEYWORDS :

# Drainage Morphometric Characteristics Of Venkatagiri Watershed, S.P.S. Nellore District, Andhra Pradesh

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## ABSTRACT

*The morphometric characteristics and their related parameters of Venkatagiri watershed have been quantitatively derived using the topographical maps on a scale of 1:50,000. The Venkatagiri watershed covers an area of 1164 Km2 and the river originates from Velikonda hill ranges and flows from south-west to north-east and joins the Upputeru river before it joins the Bay of Bengal. The relative relief of the watershed is 1028 mts, and the major rock types of the area are granites and gneisses. The dendritic pattern of drainage is observed because of the presence of granites and gneisses to a large extent in the watershed area. The Venkatagiri watershed is a 6th order stream and elongated in shape. The bifurcation ratio is 4.24 indicates the mature stage of development of the watershed. The other morphometric parameters such as drainage density, frequency, stream length ratio, elongation ratio and circularity ratios are also analyzed which shows the relationship among the various attributes of the morphometric aspects.*

## INTRODUCTION

The Venkatagiri watershed, a tributary to Upputeru River originates from Velikonda hill ranges and drains through the 6 mandals of S.P.S. Nellore district, Andhra Pradesh. The Venkatagiri stream flows from South-west to North-east and joins the Upputeru river before it joins the Bay of Bengal. The Venkatagiri watershed covers an area of about 1164 sq.kms and it lies between $13^0 52^I 24^{II}$ to $14^0 14^I 57^{II}$ N latitudes and $79^0 25^I 28^{II}$ to $79^0 48^I 22^{II}$ E longitudes. The relative relief of the watershed is 1028 mts with maximum and minimum heights ranging between 1054 mts and 26 mts respectively.

The major rock types in the Venkatagiri watershed area are enriched with granites and gneisses. The other rock types of the watershed are Dharwar schists, pegmatites metavolcanics , phyllites and alluvium. The climate of the watershed is semi-arid in nature. It is characterised by general aridity but receives rain during the monsoon for a short period in the year. The watershed receives an annual average rainfall of 1094 mm out of which 80 to 90 percent occurs in the two monsoon periods.

## Analysis and Discussion

Primarily the study is based on the published and derived data. The drainage morphmetric characteristics of the Venkatagiri watershed has been derived from the base map prepared from Survey of India topographical maps on 1:50,000 scale. The quantitative analysis of the morphometric characteristics such as stream order, stream length, bifurcation ratio, drainage density, stream frequency, relief ratio, elongation ratio and circulatory ratio has been analyzed for Venkatagiri watershed and the results are tabulated in the following table 1. For the convenience Venkatagiri watershed is divided into 5 microwatersheds and the analysis is presented below.

The drainage pattern of the watershed is characterized by irregular branching of tributaries flowing from all directions with an angle less than $90^0$. Hence, the dendritic pattern of drainage is observed due to the presence of granites and gneisses to a large extent.

**Table 1: Stream orders and Stream lengths of Venkatagiri watershed.**

| micro watershed/ watershed | Stream numbers of different orders | | | | | | | Order wise stream lengths(Km) | | | | | | | Stream length ratios | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Total | 1 | 2 | 3 | 4 | 5 | 6 | Total | 1/2 | 2/3 | 3/4 | 4/5 | 5/6 |
| 1. | 318 | 75 | 15 | 1 | - | - | 407 | 218 | 104 | 50 | 27 | - | - | 499 | 2.10 | 2.08 | 1.85 | - | - |
| 2. | 385 | 77 | 19 | 6 | 2 | 1 | 490 | 238 | 109 | 39 | 31 | 30 | 19 | 466 | 2.18 | 2.79 | 1.26 | 1.03 | 1.58 |
| 3. | 364 | 83 | 24 | 5 | 2 | - | 478 | 258 | 117 | 52 | 38 | 12 | - | 477 | 220 | 2.25 | 1.37 | 3.17 | - |
| 4. | 98 | 15 | 4 | - | - | - | 117 | 62 | 29 | 11 | - | - | - | 102 | 2.14 | 2.64 | - | - | - |
| 5. | 122 | 26 | 5 | 1 | - | - | 154 | 88 | 38 | 29 | 9 | - | - | 164 | 2.32 | 1.31 | 3.22 | - | - |
| Venkatagiri Watershed | 1287 | 276 | 67 | 13 | 4 | 1 | 1646 | 864 | 397 | 181 | 105 | 42 | 19 | 1708 | 2.18 | 2.19 | 1.72 | 2.50 | 2.21 |

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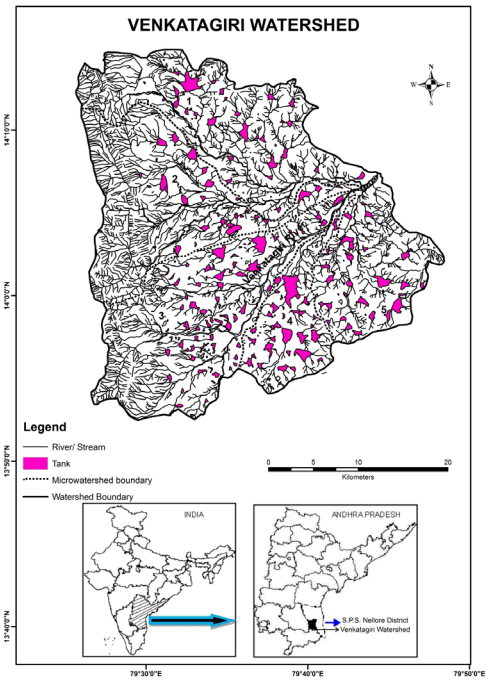
**Fig.1: Location map of Venkatagiri watershed.**




## LINEAR ASPECTS

The linear aspects of the watershed are stream orders (U), stream length (Lu) and stream frequency (Fs).

**Stream orders (U):** The Venkatagiri watershed is a 6th order stream covering a total area of 1164 S.q.Kms. There are 5 microwatersheds among which 2nd microwatershed is 6th order, 3rd microwatershed is 5th order stream and nos 1 and 5 are 4th order streams and microwatershed no. 4 is 3rd order stream. The variation in the order is due to the variation in the size of microwatersheds and the physiography and structural aspects of the area.

**Stream Length (Lu):** The total stream lengths of different orders of Venkatagiri watershed and streams of all microwatersheds have been measured and tabulated. Horton's law (1945) of stream length supports the theory that geometrical similarity is noticed generally in the watershed of increasing order (Strahler, 1964). It is also noticed that the total length of stream segments are maximum in case of first order streams. For all the micowatersheds, the stream length decreases as the order increases and it is found low in the case of higher order streams. The geometric relationship is also shown graphically (Fig-2) in the form of regression lines which are fitted for the Venkatagiri watershed and as well as 5 microwatersheds and satisfies the Horton's law (1945).

**Stream Length Ratio (Rl):** According to Horton (1945), the stream length ratio is the ratio of the mean lengths of streams of one order to that of next lower order. The law of stream lengths states that the mean length of stream segments of each of the successive order of a watershed tends to approximate a direct geometric series with the stream length increasing towards higher stream orders.

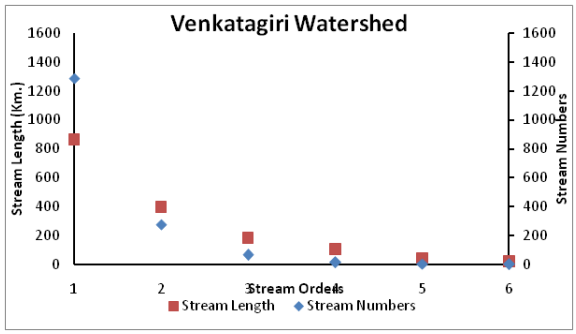
The stream length ratio (Rl) can be calculated by using the formula.

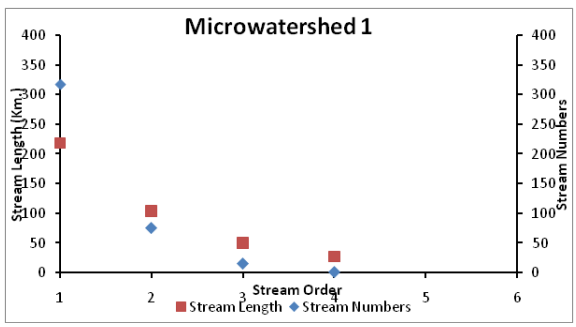
$$Rl = \frac{Lu}{Lu - 1}$$

Where Rl = Stream length ratio

Lu = Mean stream length order 'u'

Lu-1 = Mean stream length of segment of the next lower order.



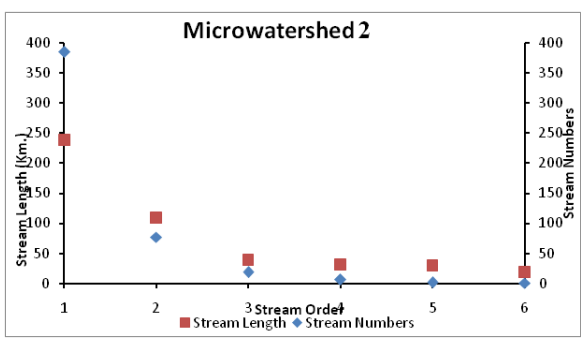
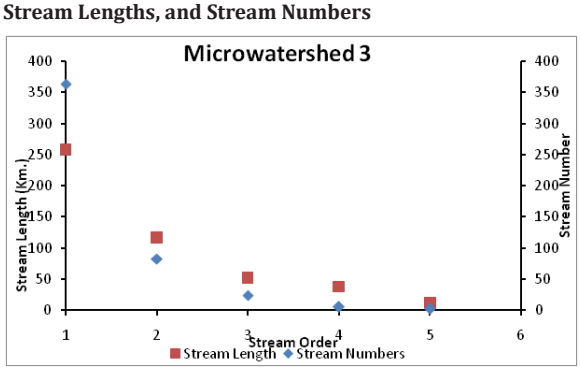
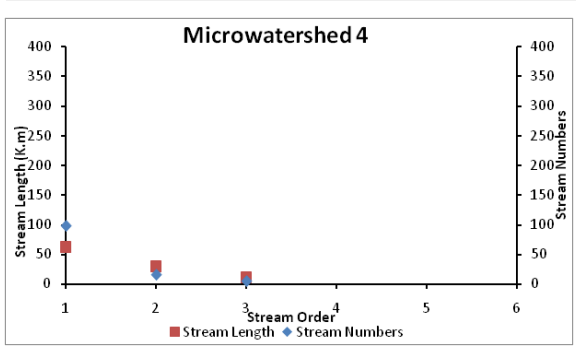




**Fig. 2: Geometric Relationship between Stream Orders, Stream Lengths, and Stream Numbers**



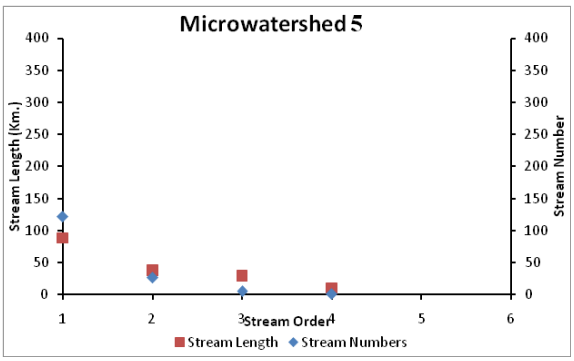



**Fig. 2: Geometric relationship between Stream Orders, Stream Lengths, and Stream Numbers.**

The stream length ratios are changing haphazardly both at the watershed and microwatershed levels as the values of the stream length ratios vary from a minimum of 1.03 to a maximum of 3.17 for the microwatersheds, while it ranges from 1.72 to 2.50 for the Venkatagiri watershed. The stream length ratio has an important relationship with the surface flow discharge and erosional stage which are attributed to the differential resistance of the rocks present in the watershed.

**Stream Frequency (Fs):** The stream frequency of a watershed is defined as the ratio between the total number of segments cumulated for all orders within an watershed and the watershed area (Horton, 1945)

$$Fs = \frac{\sum Nu}{A}$$

Where Fs = Stream frequency

$\sum Nu$ = Total number stream segments of all orders

A = Total area of the watershed

The stream frequency of the Venkatagiri watershed is 1.41 Km/Km2, while the stream frequencies of microwatersheds 1 to 5 are 1.44, 1.79, 1.36, 0.89 and 1.24 km/km2 respectively (Table 2). The stream frequencies are mainly dependent on the development of stream segments in the watersheds and are affected by rainfall and temperature.

Table. 2 Morphometric parameters of Venkatagiri watershed.

| Micro-watershed/ watershed | Area in $Km^2$ | Stream Frequency ($KM/KM^2$) | Length in Km | Form Factor | Elongation Ratio | Circulatory Ratio |
|---|---|---|---|---|---|---|
| 1. | 283 | 1.44 | 43 | 0.12 | 0.36 | 0.48 |
| 2. | 273 | 1.79 | 32 | 0.15 | 0.37 | 0.41 |
| 3. | 352 | 1.36 | 47 | 0.14 | 0.47 | 0.50 |
| 4. | 132 | 0.89 | 22 | 0.16 | 0.82 | 0.48 |
| 5. | 124 | 1.24 | 18 | 0.28 | 0.48 | 0.84 |
| Venkatagiri watershed | 1164 | 1.41 | 47 | 0.32 | 0.43 | 0.94 |

**Watershed Length (L):** The watershed length is the longest length of the watershed from the source to the mouth (Gregory and walling, 1973). The length of Venkatagiri watershed is 47 kms while the length of 5 microwatersheds is 43,32,47,22 and 18 kms respectively.

**DIMENSIONLESS FACTORS**

**Form Factor (Ff):** The form factor of a watershed is expressed as the ratio of average width of watershed where axial length is the distance along the longest watershed dimension parallel to the main drainage line. Hence, the form factor is expressed as

$Ff = Au/Lb^2$

Length of the watershed is the longest dimension from mouth to the farthest point on the perimeter of the watershed and width is measured normal to the length.

The form factor of the Venkatagiri watershed is 0.32, while the form factors of 5 microwatersheds are 0.12, 0.15, 0.14, 0.16 and 0.28 respectively. The index of form factor shows the inverse relationship with peak discharge.

**Elongation Ratio (Re): T**he elongation ratio (Re) is measured by using the following formula : $Re = \frac{2A/\delta}{L}$

Where Re is the elongation Ratio, 2 is constant, and A is the area of the watershed and L is the maximum length of the watershed.

The elongation ratio of Venkatagiri watershed is 0.43 and the 5 microwatersheds of elongation ratios are 0.36, 0.37, 0.47, 0.82 and 0.48 respectively. The variations in the elongated shapes of the microwatersheds are due to the guiding effect of structures such as thrusting and faulting of the rock formations.

**Circularity Ratio (Rc) :** The circularity ratio is the quantitative measure of the watershed and is expressed as the ratio of the watershed area (Au) to the area of a circle (Ac) having the same perimeter of the watershed (Strahler, 1964 and Miller, 1953).

It is affected by the lithological character of the watershed and is expressed as :

$$Rc = \frac{4\delta A}{P^2}$$

Where Rc is the watershed circularity ratio, 'P' is the perimeter of the watershed, 4 is constant and 'A' is the area of the watershed.

The circularity ratio is more influenced by watershed length, frequency and gradient of streams of various orders besides slope conditions and drainage pattern of the watershed. It is a significant ratio which indicates the stage of dissection in any region. Its low, medium and high values are indicative of the youth, mature and old stages of the fluvial cycle of the tributary basins of the study region.

The circularity ratio of the Venkatagiri watershed is 0.94, where as the the 5 microwatersheds circularity ratios are 0.48, 0.41, 0.50, 0.48 and 0.84 respectively (Table. 2 ). The high value of circularity ratio of Venkatagiri watershed indicates the late maturity stage of topography whereas the microwatersheds from 1 to 4 are with medium values shows the nearly maturity stage of topography and the microwatershed 5 with high value of circularity ratio is in late maturity stage of topography. This anomaly is due to diversity of slope, relief and structural conditions prevailing in the watershed.

**MEASURE OF INTENSITY OF DISSECTION**

**Drainage Density (Dd):** The drainage density is defined as the length of the streams per unit of a drainage area divided by the area of the drainage basins (Horton, 1932). It is expressed as:

$$\text{Drainage density (Dd)} = \frac{Lu}{A}$$

Where Lu = length of all order streams

A = the area of the watershed

The Venkatagiri watershed is fairly drained basin with dendritic pattern. The parameters such as drainage density, frequency and texture provide the link between the form attributes of the watershed and processes operating along the river course. These are the valuable parameters which reflect the topographic, lithological, pedological and vegetative controls.

The drainage density of Venkatagiri watershed as a whole is 1.47 km/km2 and the densities of microwatersheds from 1 to 5 are 1.76, 1.71, 1.36, 0.77 and 1.32 respectively (Table 3). The drainage densities of Venkatagiri watershed and as well as the

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microwatersheds reveal that the nature of subsurface strata is permeable in character with coarse drainage texture, since the values are less than 5.0.

Table 3: Drainage density, texture and Bifurcation Ratios of Venkatagiri Watershed

| Micro Watershed/ Watershed | Drainage Density (Km/Km²) | Drainage Texture | Bifurcation Ratio(Rb) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Rb1 | Rb2 | Rb3 | Rb4 | Rb5 | Mean Rb |
| 1 | 1.76 | 2.53 | 4.24 | 5.0 | 15.0 | - | - | 8.08 |
| 2 | 1.71 | 3.06 | 5.0 | 4.05 | 3.17 | 3.0 | 2.0 | 3.44 |
| 3 | 1.36 | 1.85 | 4.39 | 3.46 | 4.8 | 2.50 | - | 3.79 |
| 4 | 0.77 | 0.69 | 6.53 | 3.75 | - | - | - | 5.14 |
| 5 | 1.32 | 1.64 | 4.69 | 5.20 | 5.0 | - | - | 4.96 |
| Venkatagiri watershed | 1.47 | 2.07 | 4.66 | 4.12 | 5.15 | 3.25 | 4.0 | 4.24 |

**Drainage Texture (T):** According to Smith (1950), The Drainage texture of the watershed is expressed as:

Drainage Texture (T) = Dd x Fs

Where Dd is drainage density and Fs is stream frequency

The drainage texture of Venkatagiri watershed is 2.07 where as the texture of 5 microwatersheds are 2.53, 3.06, 1.85, 0.69 and 1.64 respectively (Table 3).The drainage texture values of the whole watershed and all microwatersheds are less than 4.0 indicating the coarse texture drainage.

**Bifurcation Ratios (Rb):** The term Bifurcation Ratio was introduced by Horton in 1932 to express the ratio of the number of streams of any given order to the number in the next lower order. According to strahler (1964), the ratio of number of streams of a given order (Nu) to the number of segments of the higher order (Nu+1) is known as the bifurcation ratio (Rb). Hence, it is expressed as

$$\text{Bifurcation Ratio (Rb)} = \frac{Nu}{Nu+1}$$

The mean bifurcation ratio of Venkatagiri watershed as a whole is 4.24 and they vary from a minimum of 3.25 to a maximum of 5.15**.** The above values of bifurcation ratios are common in the areas where geological structure does not exercise a dominant influence on the drainage pattern.

The bifurcation ratios of all the microwatersheds vary from a minimum of 2.0 to a maximum of 15.0. The higher values of bifurcation ratios of microwatersheds are the result of large variations in frequencies between successive orders indicating the mature topography which is the result of the process of drainage integration.

**MEASURES INVOLVING HEIGHTS**

**Relief:** The relief of the watershed is an important factor in understanding the denudation characteristics of the rock formations. Relief is the difference between the maximum and minimum contour levels of the watershed above the mean sea level. The maximum height of the Venkatagiri watershed is 1054 mts and the minimum is 20 mts. Hence, the relief of the watershed is 1034 mts.

**Slope:** Slope is an important parameter in the geomorphic study and it is controlled by the climatomorphogenic processes in the area and the rocks of varying resistance. Wentworth's (1930) average slope method has been employed in the present study to determine the slope of Venkatagiri watershed. The slope of the watershed varies from 0 to $20^0$. High degree of slope is noticed in the western part of watershed which are mostly occupied by quartzites and basic intrusives. The shale and limestone formations are characterized by low slope areas showing less than $2^0$ in the remaining part of the watershed.

**Relief Ratio:** The relief ratio is expressed as the ratio of relative relief to the longest axis of the watershed:

$$\text{Relief ratio} = \frac{H-h}{L}$$

Where H = highest elevation in the watershed

h = lowest elevation in the watershed and

L = longest axis of the river.

The relief ratio of the Venkatagiri watershed is 0.032 while that of the microwatersheds from 1 to 5 are 0.016, 0.032, 0.017, 0.0018, and 0.0044 respectively. Generally the relief ratios of the watershed and as well as microwatersheds are low which is characteristic feature of the low resistant rocks of the Venkatagiri watershed area.

**Gradient Ratio:** This is an indicator of river/stream channel slope. The Venkatagiri watershed has a gradient slope of 0.022, while the gradient slopes of microwatersheds from 1 to 5 are 0.017, 0.026, 0.017, 0.002 and 0.004 respectively, showing low to moderate gradient ratios.

**Table 4 : Relief and Gradient aspects of Venkatagiri watershed**

| **Micro watershed/ watershed** | Relief | | | | | Gradient | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Elevation in (m) | | Relative Relief (H-h) metres | Largest axis 'L' Km | Relief ratio H-h/L | **Elevation at** | | Fall in Hight (a-b) | Length of main Stream 'L' | Gradient Ratio (a-b/L) |
| | Max 'H' | Min 'h' | | | | Source (a) | Mouth 'b' | | | |
| 1. | 712 | 20 | 692 | 43 | 0.016 | 712 | 20 | 692 | 40 | 0.017 |
| 2. | 1054 | 20 | 1034 | 32 | 0.032 | 1054 | 20 | 1034 | 39.5 | 0.026 |
| 3. | 828 | 20 | 808 | 47 | 0.017 | 828 | 20 | 808 | 46 | 0.017 |
| 4. | 60 | 20 | 40 | 22 | 0.0018 | 60 | 20 | 40 | 19 | 0.002 |
| 5. | 100 | 20 | 80 | 18 | 0.0044 | 100 | 20 | 80 | 20 | 0.004 |
| Venkatagiri Watershed | 1054 | 20 | 1034 | 47 | 0.032 | 1054 | 20 | 1034 | 47 | 0.022 |

**CONCLUSION**

The drainage morphometric analysis of Venkatagiri watershed reveals some complex morphometric characteristics of the Venkatagiri stream. The Venkatagiri watershed is a $6^{th}$ order stream with dendritic pattern of drainage, which is characteristic of granitic and gneissic formations occupied predominantly in the watershed area. High degree of slope is noticed in the western part which are occupied by Pullampeta and Bairenkonda quartzites, granites, gneisses, and phyllites. In low slope areas having less than $4^0$ slope on the eastern side are also occupied by granites, gneisses, Dharwar schists and pegmatites. In almost all the cases the watershed and microwatersheds lengths decreases as the stream order increases and they are lowest in case of highest stream orders supporting Horton's law of stream numbers and stream lengths ratios. It is also noticed that stream length ratios are changing haphazardly both at the watershed and microwatersheds showing the relationship with the surface run off and erosional stage of the streams. The variation in elongation ratios of Venkatagiri watershed and microwatersheds are due to the elongated nature of the rivers and also due to the guiding effect of thrusting and faulting. The drainage density values of watershed and microwatersheds are less than 5.0, because the subsurface formations are permeable in character with coarse drainage texture. The bifurcation ratio values ranges from 2.0 to 15.0 of the microwatersheds. The higher values are the result of large variations in the frequencies between successive orders showing the mature topography which is due to the result of the process of integration. Generally the relief ratios of watershed and microwatersheds are low which is due to the presence of low resistance rocks distributed in the study area.

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