CHAPTER IV

MORPHOMETRIC ANALYSIS OF HEMAVATHI WATERSHED

4.1. INTRODUCTION

Morphometry represents the topographical expression of land by way of area, slope, shape, length, etc. These parameters affect catchment stream flow pattern through their influence on concentration time (Jones, 1999). The significance of these landscape parameters was earlier pointed out by, who observed that stream flow can be expressed as a general function of geomorphology of a watershed. Morphometric analysis of drainage basins thus provides not only an elegant description of the landscape, but also serves as a powerful means of comparing the form and process of drainage basins that may be widely separated in space and time (Easterbrook, 1993).

In the early days, most basins were described as well-drained or poorly drained or they were connoted descriptively in the Davisian scheme as being youthful, mature or old, The mechanics of how river channels actually form within a basin and how water gets into the channels was only understood in vague terms by both geologist and hydrologists. Measurement and quantitative expression of drainage basin began with the work of James Hutton in 1775. Subsequently, a great step forward was made by Horton (1932) when he crystallized previous works added new measures and proposed general methods for the description of drainage basins characteristic (Gregory and Walling, 1973).

The quantification of geotectonic structures was introduced by Horton, who studied the origin of river networks. Many hydrologic measurements are available to quantify the description of river networks and drainage basins. As a result, a series of power-law type of relations, have been extended by other investigators. The recent development of fractal theory has provided new horizons to this field of study considering that many kinds of landforms are fractals and multi-fractals.

Hydrologists and geomorphologists have recognized that certain relations are most important between runoff characteristics and geographic characteristics of drainage basin system. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of
drainage area, drainage density, size and length of the contributories. The quantitative analysis of drainage system is an important aspect of characteristics of watershed region. Drainage pattern refers to spatial relationship among streams or rivers, which may be influenced in their erosion by inequalities of slope, soils, rock resistance, structure and geological history of a region. Morphometry is the measurement and mathematical analysis of the configuration of the earth’s surface, shape and dimension of its landforms (Clarke, 1966).

A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behaviour of surface drainage networks. Most previous morphometric analyses were based on arbitrary areas or individual channel segments. Using watershed as a basic unit in morphometric analysis is the most logical choice. A watershed is the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner. In fact, they are the fundamental units of the fluvial landscape and a great amount of research has focused on their geometric characteristics, including the topology of the stream networks and quantitative description of drainage texture, pattern and shape. The morphometric characteristics at the watershed scale may contain important information regarding its formation and development because all hydrologic and geomorphic processes occur within the watershed.

Every hydrologic design is different because the factors that affect the design vary with location. Thus it is necessary to make measurements at the design site. Factors such as the following may be important: the size, the slope and the land use of the watershed. However, the morphometric analysis of the catchment will provide information on runoff process in the basin. The geomorphologic studies are helpful in regionalising the hydrologic models. The linking of geomorphologic parameters with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behaviour of different basins.

Morphometry is essentially quantitative, involving numerical variables whose values may be recovered from topographic maps. The importance of morphometric variables is their usefulness for comparisons and statistical analyses. This study
involves evaluation of streams through the measurement of various stream properties, analysis of various drainage parameters namely ordering of the various streams and measurement of area of basin, perimeter of basin and length of drainage channels, Drainage Density (Dd), Drainage frequency, Bifurcation Ratio (Rb), Texture Ratio (T) and Circulatory Ratio (RC). Quantitative description of the basin morphometry also requires the characterization of linear and areal features, detailed analysis of drainage parameters is of great help in understanding the influence of drainage morphology on landforms and their characteristics.

4.2. OBJECTIVES

- To study the different drainage aspects of Hemavathi watershed and to understand the relationship of the drainage network.
- To study the quantitative analysis of drainage system.
- To study the linear aspect of drainage network.

4.3. METHODOLOGY

The morphometric analysis of the Hemavathi Watershed was based on topographical map on 1:50,000 scale. Using of Arc/GIs was prepared the base map and drainage map of Hemavathi Watershed. The morphometric parameters were divided in three categories: basic parameter, derived parameters and shaper parameters. Area, Perimeters, Basin Length, Stream Order, Stream Length, Maximum and Minimum Heights and slope come under first categories. Those of the second categories are Bifurcation Ratio, Stream Length Ratio, Stream Frequency, Drainage Density, Drainage Texture, Basin Relief and Relief Ratio. The Shape parameters are Elongation Ratio, Circularity Index and Form Factor. The drainage network of the basin was analysed as per Horton.S and laws and the stream ordering was made after Strahler.
4.4. MORPHOMETRIC ANALYSIS OF HEMAVATHI WATERSHED

Morphometry is the measurement and mathematical analysis of configuration of the earth surface, shape and dimension of its landforms in a given drainage basin (Clarke 1966). Morphometric study is the typical representation of drainage basin which reflects their geology, climate, vegetation cover and fluvial process. The morphometric evaluation of drainage data provides a quantitative explanation of basin geometry used to reveal the geomorphic and geological history of each drainage basin. The study of morphometric properties of drainage basin becomes more imperative because of their significance in development of land forms and understanding the hydrological properties of the basin. The morphometric analysis can be done through the three different types of parameters, i.e., basic parameters, drainage parameters and shape parameters.

Map No: 4.1: HEMAVATHI WATERSHED: STREAM ORDER

4.4.1. SIGNIFICANCE OF MORPHOMETRIC ANALYSIS

Drainage basins are the arteries of the earth's surface ecology. It provides the living environment to different species. Drainage basins are separate physiographic units that represent various fluvial land features. In the present morphometric investigation, analysis about drainage basin, pattern and network gives a clear cut view of the underlying rock
lithology, minerals, run off and erosional history of a region. It also provides information regarding the slope, deposition character and geology and soil character of the basin.

4.4.2. BASIC PARAMETERS

First and foremost analysis in morphometric is basic parameters. Some of the basic parameters are area of the study region, perimeter, basin length, streams order, stream number, stream length and slope. Further studies are a concentration of all these parameters.

4.4.2.a. Area (A)

Drainage area is defined as collecting area from which water would go to stream or river. The boundary of area is delineated by ridge separating water flowing in opposite direction. The parameters which are governed by the area of drainage basin are classed as aerial aspects of basin. Aerial aspects include different morphometric parameters like drainage area, drainage density, stream frequency, drainage intensity and drainage texture, constant of channel maintenance, form factor, circulatory ratio and elongation ratio. Hemavathi watershed located between 12°10’ N to 13° N and 74°, 40’ E to 76°, 15’ E. The total drainage area of Hemavathi Watershed is 5,698.65 km$^2$. And Hemavathi River has three sub watersheds. The area of basin is measured and verified through digitized map.

4.4.2.b. Perimeter (P)

The perimeter of a drainage basin is defined as the horizontal projection of its water divide. It delimits the area of the drainage basin on the map and is always smaller than the true length of the water divide. However, being determined more easily than the later, it is always used for topographical purposes. The water divide is the line linking the points of greatest height between two drainage basins and separating their surface run off. Perimeter length is the linear length of a drainage basin. One can measure this length with string, map wheel or digitizer. Perimeter is the total length of the drainage basin boundary. The perimeter of Hemavathi watershed is 480 km.
4.5.2.c. Basin Length

The length in a straight line from the mouth of the stream to the farthest point on the drainage divides of its basin. The basin length corresponds to the maximum length of the basin. The basin length of the study area is 260 kms. The total stream length in Hemavathi watershed is 4766.66 kms.

4.5.2.b. Stream order (Nu)

Strahler’s system of streams analysis is probably the simplest and most used system. His stream ordering method is, each finger tip channel is designated as a segment of the first order. At the junction of any two first order segment, a channel of the second order channel, whereupon a segment of third order results and so forth. The study area has totally 6 order streams in Hemavathi drainage basin.

The designated stream order is the first step in drainage basin analysis. This method was devised by Strahler (1964) and is adopted for the present study. The order of a given stream stretch is its location in the stream network within a basin. A stretch which receives flow directly from flow on the ground surface alone such as rills and gullies and forms no other stream is called a first order stream. When two such streams merge together, these forms second order stream. Then two second orders combine to form a third order stream and so on. Likewise the channel develops its next orders.

The trunk stream through which all the discharge of water and sediments passes therefore has the high stream order. Generally, higher numbers of orders reflect well resistant underlying rock system. Accordingly stream numbers have been counted order wise from the Hemavathi main basin and sub basins and these have been ordered on the basis of Strahler’s method. As in general, the number of streams decreases with increasing order.

4.5.2.e. Stream Numbers

The counts of stream channel in its order are known as stream number. The number of the stream segments decreases as the order increases, the higher amount streams order indicates lesser permeability and infiltration. The number of streams had high influence, on slope character of that region. The total number of streams are 1991, in that 1\textsuperscript{st} order streams are 1553, 2\textsuperscript{nd} order streams are 331, 3\textsuperscript{rd} order streams are 81, 4\textsuperscript{th} order streams are 20, 5\textsuperscript{th} order streams are 5 and one is indicating 6\textsuperscript{th} order stream. (Table 4.1)
4.5.2.f. Stream Length (Lu)

Stream length is the total length of streams in a particular order. Stream length is measured from confluence region of the river Hemavathi to drainage divide with the help of Arc GIS software. This has been computed based on the law proposed by Horton (1945) for all sub basins of the study area. Horton’s law of stream length states that the total length of stream segments of a given order in a basin length is inversely related to stream order.

Generally, total length of stream segments decreases with increasing stream order. Table shows that total length of stream segments is at maximum in case of first order streams and decreases as the order increases. Deviations from the general behaviour indicate that the terrain is characterized by high relief or moderate steep slope, underlying by varying lithology and probable uplift across the basins (Singh.S and Singh.M.C. 1977). Such deviation occurs in the sub basins of Duggamma Eru and Upper Goddar Vanka.

The stream length of various orders has been measured from topographical map. Horton’s law (1932) of stream length supports the theory that geometrical similarity is preserved generally in the basins of increasing order (Strable 1964). The stream length of the various segment are measured with the help of GIS software. All stream orders show that the total length of stream segment (Table 4.1).

According to this table length of 1st order stream is 2485.58 km, 2nd order is 1145.94 km, 3rd and 4th order is 870.83km and 292.63 km and 5th order stream length is 144.44 km and last order i.e., 6th order stream length is 127.24 km. The total stream length is 4766.66 kms.

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Stream Order</th>
<th>Number of Streams</th>
<th>Stream Length (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemavathi Watershed</td>
<td>1</td>
<td>1553</td>
<td>2485.58</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>331</td>
<td>1145.94</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>81</td>
<td>570.83</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>20</td>
<td>292.63</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>5</td>
<td>144.44</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>127.24</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6</strong></td>
<td><strong>1991</strong></td>
<td><strong>4766.66</strong></td>
</tr>
</tbody>
</table>

Source: computed by the author.
4.5.2.g. Slope

The slope angle of a basin is a morphometrical factor of hydrological relevance. Steep slopes generally have high surface run-off values and low infiltration rates. Sediment production thus tends to be high except when largely barren slopes are concerned (Verstappen.H 1983).

Map No: 4.2: HEMAVATHI WATERSHED: SLOPE-2006

4.5.3. DERIVED PARAMETERS

Second and important analysis part is derived parameters. These parameters studied the bifurcation ratio, drainage density, stream frequency, texture ration and length of over land flow of the Hemavathi watershed.

4.5.3. a. Bifurcation Ratio (Rb)

The term bifurcation ratio is used to express the ratio of the number of streams of any given order to the number of streams in next order (Schumn 1956). Table 4.2 shows the bifurcation ratio of the Hemavathi watershed. This table shows the number of streams and the bifurcation ration of the streams. According to this table bifurcation ratio of the 1\textsuperscript{st} stream order is 4.69, 2\textsuperscript{nd} and 3\textsuperscript{rd} is 4.08 and 4.05, 4th is 4.00
and bifurcation of the 5th stream is 5.00. Average is 4.36 this result indicate the watershed region it have homogenous geological structure.

Table No: 4.2: HEMAVATHI WATERSHD
BIFURCATION RATIO OF THE STUDY AREA

<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Number of Streams</th>
<th>Bifurcation ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1553</td>
<td>4.69</td>
</tr>
<tr>
<td>2</td>
<td>331</td>
<td>4.08</td>
</tr>
<tr>
<td>3</td>
<td>81</td>
<td>4.05</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>4.00</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5.00</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>-</td>
</tr>
</tbody>
</table>

Average Bifurcation 4.36

Source: computed by the author

4.5.3.b. Drainage Density (Dd)

Drainage density is defined as the total length of stream orders per drainage area. It is the ratio of total channel segment lengths cumulated for all orders within a basin area, which is expressed in terms of miles/ Sq.mile or km/sq.km. Density factor is related to climate, type of rocks, relief, infiltration capacity, vegetation cover, Surface roughness and run off intensity index. The drainage density indicates the closeness of spacing of channels (Horton 1932).

An important indicator of the linear scale of land forms elements in stream eroded topography is drainage density introduced by Horton. Drainage density is simply the ratio of total channel segments length cumulated for all orders within a basin to the basin area. This ratio may be thought of as an expression of spacing of channels. If geometrical similarity exists between two drainage systems, their drainage densities will be related in the same ratio as inverse of the linear scale ratio. Thus broadly considered, drainage density is simply one of several linear measures by which the scale of features of the topography can be compared.

The drainage density of the study area is 0.836 indicate low drainage density, it suggest that the low density indicate that the basin highly permeable subsoil and thick vegetative cover (Naga, 1998).
4.5.3.c. Stream Frequency (Fs)

Stream frequency of the basin may be defined as the ratio of the total numbers of segments cumulated for all orders with a basin to the basin area (Horton 1945). The average stream frequency is 0.349. The Fs values of the sub basins are computed and represented.

4.5.3.d. Texture Ratio (T)

Texture ratio is an important factor in the drainage morphometric analysis which is depending on the underlying lithology infiltration capacity and relief aspect of the terrain. The texture ratio of the Hemavathi watershed is 3.235.

4.5.2.e. Length of over Land Flow (Lg)

Surface runoff follows a system of down slope flow paths from the drainage divide to the nearest channel. Horton (1945) defined length of overland flow as the length flow path, projected to the horizontal of non channel flow from point on the drainage divide to a point on the adjacent stream channel. He further noted that Lg is one of the most important independent variable affecting both hydrologic and physiographic development of drainage basins. The length of overland flow is approximately equal to the half of the reciprocal of drainage density. This factor basically relates inversely to the average slope of the channel. Table shows the length of overland flow for Hemavathi basin and sub basins are 0.598.

Table No: 4.3: HEMAVATHI WATERSHED

<table>
<thead>
<tr>
<th>DERIVED PARAMETERS</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Density</td>
<td>0.836</td>
</tr>
<tr>
<td>Stream Frequency</td>
<td>0.349</td>
</tr>
<tr>
<td>Texture Ratio</td>
<td>3.235</td>
</tr>
<tr>
<td>Length of Over Land Flow</td>
<td>0.598</td>
</tr>
</tbody>
</table>

Source: computed by the author.

4.5.4. SHAPE PARAMETERS

Final step is shape of the watershed region, in the shape parameters it include elongation ratio, circularity ratio and form factor ratio. Shape will contribute to the
speed with which the runoff reaches a river. A long thin catchment will take longer to drain than a circular catchment.

### 4.5.4.a. Elongation Ratio (Re)

Elongation ratio is defined as the ratio between the diameter of a circle of the same area as the basin and the maximum basin length (Schuman 1956). It is very significant index in the analysis of basin shape to give an idea about the hydrological character of the drainage basin.

Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). These values can be grouped in to three categories namely; Circular, Oval and Elongated.

Elongation ratio is another parameter introduced to analyze the basin shape. This is defined as the ratio of diameter of circle having area equal to the basin area to the basin length. The elongation ratio of the study area is 0.184 it indicate the Hemavathi watershed region is rotundity and low degree of integration within a basin.

### 4.5.3.b. Circularity Ratio (Rc)

Basin circularity ratio is defined as the ratio of the basin area to the area of a circle having circumference equal to the perimeter of the basin. This method is introduced for visualizing the shape of the basin. Rc is influenced more by the length, frequency and gradient of streams of various order rather than slope conditions and drainage pattern of the basin. For the Hemavathi watershed the circularity ratio is 0.310. It indicates strongly elongated and highly permeable homogenous geologic materials

### 4.5.3.c. Form Factor Ratio (Ff)

Horton (1932) defined form factor as the ratio of basin area to the square of basin length. Horton (1945) proposed this parameter to predict the flow intensity of a basin of a defined area. The indices such as circularity ratio, elongation ratio watershed shape factor and unity shape factor are the measures to compare basin shapes. Basin shape is very important factor influencing the peak flow and other
hydrograph characteristics such as steepness of rising and recession limbs the time spread of hydrograph etc.

The form factor value of the study is 0.084. According to this result the region is nearly elongated shape.

**Table No: 4.4: HEMAVATHI WATERSHED: SHAPE PARAMETERS**

<table>
<thead>
<tr>
<th>SHAPE PARAMETERS</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elongation Ratio</td>
<td>0.184</td>
</tr>
<tr>
<td>Circularity Ratio</td>
<td>0.310</td>
</tr>
<tr>
<td>Form Factor Ratio</td>
<td>0.084</td>
</tr>
</tbody>
</table>

Source: computed by the author.

4.6. CONCLUSION

The quantitative analysis of morphometric parameters is found to be immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at micro level. The morphometric analysis carried out in the Hemavathi watershed. Bifurcation ratio for the study area is the expected values relative to mountainous of highly dissected areas. The mean/average bifurcation ratio (4.36) indicates that the drainage pattern is not much influenced by geological structures. This value also is in relationship with the elongate shape of the basin.