DRAINAGE
MORPHOMETRY
4.0.0. GENERAL:

Drainage analysis of the Valgalamanda river basin has been studied with reference to the a). Drainage on various lithologies, b). Morphometric analysis c). Watershed and d). Surface water resources. These are detailed below.

4.1.0. Drainage on various lithologies

Drainage on the quartzite on the western side is mainly structurally controlled on the slopes of the quartzite. The drainage pattern can be considered as sub-parallel. Most of the first order streams are shorter in length compared to the first order streams in the adjacent lithologies. As the lithology involved is a hard rock with steeper slope and the streams are structurally controlled, the density is comparatively more.

At the foot of the hills the lithology involved is ‘fanyglomerate’ - a loose material with comparatively higher degree of permeability and porosity. Hence, the spacing between the first order streams is more than the space that is observed on the quartzite. The same is the case with the second order streams. Further, there are number of tanks in the foot hill area. Most of the first and second order streams debouch in to the tanks. Hence, the length of these streams is much less.

The plain country is basically covered by the granitoid, The pattern of drainage on this unit is dendritic. However the major order streams and the small rivers are all controlled by the structures, i.e., the lineaments. As in the other cases, the first and second order streams run into tanks that make these as small and discontinuous streams. Thus, the entire terrain is characterized by the sub-parallel and dendritic pattern of drainage.

4.2.0. Morphometric analysis:

Any study of drainage analysis should be quantitative rather than descriptive. This can be achieved by the morphometric analysis of any river basin. Hence, the river Valagalamanda basin has also been subjected to the morphometric analysis. The drainage map of the basin is given as the figure # 4-1.
Horton (1945) was the pioneer to establish the relationship between morphometry, hydrology and landscape evolution and statistical method for the analysis of drainage basins. Later, Clarke (1970) defined morphometry as the measurement and mathematical analysis of the configuration of the earth's surface and the shape and the dimensions of its land forms.

This analysis helps in characterising the basin, comparing the characteristics of several drainage networks and examining the affects of variables like lithology, rock structure and rain fall on the drainage network.

Zernitz (1932), Horton (1945) and Miller (1953) carried out quantitative geomorphic study of drainage basins. Schumm (1956) has described the relationship between channel length, drainage basin area, stream order, number and constant of channel maintenance etc.

This exercise has been done to understand the infiltration, runoff and recharge conditions. Further, drainage density, stream order, stream frequency, bifurcation ratio, shape, relief ratio help in the basin evaluation studies for ground water occurrences.

4.2.1. Basin characters:

This basin studies have been done to know the movement of surface and sub-surface water. The characters vary from basin to basin lithology and structures control the linear, areal and relief aspects of any drainage basin. With the said background the linear, areal and relief aspects of the river Valagamanda basin are detailed in the following pages.

4.2.2. Linear Aspects of the basin:

4.2.2a. Stream order (I):

There are different methods of designating the stream order. However, the modified method of Strahler (1952) is adopted for the present analysis and the number of segments of each order is tabulated in table 4-1. The Valagalamanda basin is a 6th order basin with 575, 176, 30, 7, 2 and 1 segments in first, second, third, fourth and sixth orders.
respectively. It is further observed that the total number of streams gradually decreases as the stream order increases. This observation leads to the recognition of bifurcation ratio (Rb).

4. 2. 2b. Bifurcation ratio (Rb)

Bifurcation ratio (Rb) is the ratio between the number of a given order (Nu) to the number of segments of the next higher order (Nu+1)

Mathematically it is designated as \( R_b = \frac{N_u}{N_u+1} \).

The Bifurcation ratio for each set of streams has been calculated and presented in table 4-1. The bifurcation ratio ranges from 2 to 5.9 with a mean value of 3.8 that indicates a mature stage (Horton, 1950), which is also further confirmed by hypsometric curve, (Fig. 4-2)

![Hypsometric curve of the basin.](image)

4. 2. 2c. Stream Length (L)

The stream length has an important relationship with the surface flow discharge, longer the stream length, the slower the appearance of flood and larger the surface flow. Horton’s law of stream length supports the theory that geometrical similarity is preserved generally in the basins of increasing order (Strahler, 1964). It is clear that the total length of stream segments is maximum in the case of first order streams. In almost all the cases, the stream length decreases as the order increases and it is lowest in case of the higher order streams.
According to Horton’s principle, the number of streams are negatively correlated with the order. Valagalamanda basin shows a near perfect correlation with the plots located very near the regression line.

### Table: 4-1. Morphometric characters of the Valagalamanda basin.

<table>
<thead>
<tr>
<th>Stream order ‘u’</th>
<th>Total No. of streams ‘Nu’</th>
<th>Bifurcation ratio ‘Rh’</th>
<th>Mean length of Stream ‘Lu’ in km</th>
<th>Length ratio ‘RL’</th>
<th>Mean area ‘Au’ in sq.km</th>
<th>Area ration ‘Ra’</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>575</td>
<td>3.3</td>
<td>0.63</td>
<td>2.21</td>
<td>0.36</td>
<td>4.25</td>
</tr>
<tr>
<td>2</td>
<td>176</td>
<td>5.9</td>
<td>0.93</td>
<td>1.73</td>
<td>1.53</td>
<td>6.11</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>4.3</td>
<td>3.16</td>
<td>2.56</td>
<td>9.35</td>
<td>4.32</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>3.5</td>
<td>5.28</td>
<td>1.95</td>
<td>40.42</td>
<td>3.51</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>2.0</td>
<td>9.5</td>
<td>3.8</td>
<td>141.84</td>
<td>2.00</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>5.0</td>
<td></td>
<td></td>
<td>284.06</td>
<td></td>
</tr>
</tbody>
</table>

4. 2. 2d. Stream Length Ratio (RL): Horton, observed that mean length of channel segments of a given order if smaller than that of the higher order in a particular ratio called ‘Length Ratio,’ which is defined as the ratio of the mean channel length of an order (Lu) to that of lower order (Lu-1). Mathematically the length ratio RL can be given by the formula $$RL = \frac{Lu}{Lu-1}.$$  

The length ratio of the Valagalamanda basin is 0.87 and values are presented in table 4-1. The stream length ratios of the basin are changing haphazardly. Their values range from 1.73 to 3.8. The study of stream lengths which states that the cumulative mean lengths of stream segments of successive orders of a basin tend to form a direct geometric sequence in which the first is the average length of first order segments. Thus, the law is presented mathematically in the following way $$Lu = L_1.R_1^{(u-1)}.$$ In the case of the Valagalamanda basin, when the order of streams is plotted against the cumulative mean length of streams, it clearly follows the Horton’s Law ( Fig. 4-3).
Fig. 4-3. Relationship between mean lengths to stream order

4.2.2e. Basin Length (L):

Basin length has been given different meanings by different workers Schumm (1956), Gardiner (1975) and Cannon (1976). According to Gregory and Walling (1973), the basin length (L) is the longest length of the basin one end being the mouth. Length of the Valagalamanda basin is 29 km.

4.3.0. Areal aspects of the basin:

Law of stream areas is governed by the mean basin areas of successive stream orders that tend to form a direct geometric series beginning with the mean basin area of the first order basins and increases with the constant area ratios, (Schumm, 1956). The law can be stated mathematically as $A_u = A_1 R_u{(u-1)}$.

Where $A$ is mean area of the basin of ‘u’ order, $A_1$ is the mean basin area of the first order basin and $R$ is an area ratio similar to the length ratio RL. The basins of different orders from 1 to 6 have been calculated and the corresponding area ratios are determined as 4.04 for the Valagalamanda basin. The mean area plotted against stream orders exhibits a positive relation (Fig. 4-4).

Fig. 4-4. Relationship between mean area and stream order.
4.3. 1. Basin Shape:

The shape or form of a drainage basin may have an effect on the discharge characteristics of a basin. Some important basin parameters are given in table 4-2. Different values obtained using methods suggested to quantify the shape of the basin like elongation ratio, circular ratio etc are presented in the table (4-2).

4.3.2. Form Factor (Ff):

Form factor of a drainage basin is expressed as the ratio of basin area (A) to the square of the basin lengths (L^2). The form factor is expressed as $Ff = A / L^2$ (Horton, 1932).

The form factor of the Valagalamanda basin is 0.337.

Table: 4-2. The shape measures of the Valagalamanda sub-basin.

<table>
<thead>
<tr>
<th>Shape factor</th>
<th>Definition</th>
<th>Values</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form Factor (Ff)</td>
<td>Basin area</td>
<td>0.337</td>
<td>Horton (1932)</td>
</tr>
<tr>
<td>Shape S</td>
<td>(Basin Length)^2 Basin area</td>
<td>2.961</td>
<td>Corps of Engineers USA</td>
</tr>
<tr>
<td>Shape S</td>
<td>Basin length</td>
<td>1.705</td>
<td>Horton (1932)</td>
</tr>
<tr>
<td>Circulatory Ratio (Re)</td>
<td>Basin area. Area of circle with same parameter as the basin</td>
<td>0.634</td>
<td>Millers (1932)</td>
</tr>
<tr>
<td>Elongation ratio (Re)</td>
<td>Diameter of circle of the basin Perimeter Maximum length</td>
<td>0.655</td>
<td>Schumun (1956)</td>
</tr>
<tr>
<td>Lemniscate ratio ‘K’</td>
<td>(Basin Length)^a Basin area</td>
<td>2.961</td>
<td>Chorley (1957)</td>
</tr>
</tbody>
</table>
4. 3. 3. Elongation Ratio (Re):

The elongation ratio (Re) is calculated by using the formula, \( Re = 2(\sqrt{A/\pi})/L \)

Where \( 2(\sqrt{A/\pi}) \) is the diameter of the circle having the perimeter of the basin and \( L \) is the maximum length of the basin. The elongation ratio Re of the basin is 0.655 showing an extremely elongated shape of the basin which is due to the guiding effect of thrusting and faulting (Schumm, 1956).

4. 3. 4. Circularity Ratio (Re):

The Circularity ratio has been used as quantitative measure and is expressed as the ratio of basin area (A) to the area of circle (Ac) having the same perimeter as the basin (Strahler, 1964 and Miller, 1953). It is affected by the lithological character of the basin. It is expressed as \( Rc = 4\pi A/P^2 \) where P is the basin perimeter and A is the area of basin.

The ratio is more influenced by length, frequency and gradient of streams of various orders besides slope conditions and drainage pattern of the basin. It is a significant ratio, which indicates the stage of dissection in any region. It’s low, medium and high values are indicative of the youth, mature and old stages respectively of the cycle of the basin.

The circularity ratio of the basin is 0.634. The high circularity ratio of the basin indicates the mature stage of topography.

4. 3. 4. Drainage density (Dd):

Drainage density is an important factor affecting the flow, infiltration capacity etc. It is defined as the ratio of the total channel lengths with in the basin to the total basin area. The unit is km/sq.km. The drainage density of the Valagalamanda basin is 2.41 k/sq.km which is graded as coarse textured basin (Singh, 1967).

Inverse of drainage density is termed as constant of channel maintenance ‘C’. The unit of ‘C’ is sq.km/km that indicates the number of sq.km of water shed surface required to sustain 1 linear km of the channel. The ‘C’ of the Valagalamanda basin is 0.41 sq.km/km.
4. 3. 5. Stream Frequency (Fs):

The stream frequency of the basin may be defined as the ratio between the total number of segments cumulated for all orders within a basin and the basin area (Horton, 1945). It can be stated as below

\[ Fs = \frac{\sum Nu}{A} \]

Where \( Fs \) = stream frequency

\( \sum Nu \) = Total number of stream segments of all orders.

\( A \) = Total area of the basin.

The stream frequency of the basin is 2.78 km/km² indicating the development of the stream segments in the basin area is affected by rainfall and temperature.

1.5. Drainage Texture:

It can be expressed by the equation (Smith, 1950)

\[ T = Dd \times Fs \]

Where \( T \) = drainage density

\( Fs \) = stream frequency

Based on the values of drainage texture it is classified as

- Coarse - For 4.0 and below
- Intermediate - For 4.0 to 10.0
- Fine - For 10.0 to 15.0
- Ultra Fine (bad land topography) - Above 15.0

The drainage texture of the Valagalamanda basin is 1.14 indicating a Coarse texture.
4. 4. 1. Slope analysis:

Slope analysis is an important aspect of geomorphic studies. The Valagalamanda river basin slope varies from $0^\circ.54^1$ to $28^\circ.06^1$. The slope values are higher in the western region of the basin and they are gentle in the remaining part of the basin. The overall slope of the basin is towards eastern direction. The slope map (Fig. 3-26) when correlated with the geological map (Fig. 3-2) shows that the western side of the basin has vertical slope comprised of the Velikonda hills constituted by quartzites and the remaining part of the basin is represented by the Archaean terrain of crystalline rocks having gentle slope towards east. This area having the gentle slope is proved to be potential zone for ground water accumulation.

4. 4. 2. Hypsometric analysis:

The hypsometric curve of the basin (Fig. 4-5) compares very well with that of the type curve depicting mature stage of the cycle of erosion. This conclusion is in conformity with the conclusion arrived based on the study of Bifurcation ratio (Rb).

4. 4. 3. Relief ratio:

The relief ratio is calculated by using the following formula

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

Where $H = \text{Highest elevation in the basin}$, $h = \text{lowest elevation in the basin}$

$L = \text{longest axis of the basin}$

The relief ration of the Valagalamanda basin is 0.026. The relief ratio of the basin is high which is a characteristic feature of highly resistant rocks (Quartzites) on the western side of the area.
4.4.4. Gradient Ratio:

It is an indication of channel slope. It is calculated by the following formula gradient ratio 
\[ \text{gradient ratio} = \frac{H-h}{L}, \]
where \( H \) = highest elevation point from the source point of stream, \( h \) = lowest 
elevation point at the mouth of the stream, \( L \) = length of the main stream. Gradient value 
of the Valagalamanda basin is 0.025, showing moderate to high gradient. The details 
worked out are given in the form of a table (Table - 4-3).

Table 4-3. The details of the Valagalamanda basin.

<table>
<thead>
<tr>
<th>No.</th>
<th>Details</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basin area (A)</td>
<td>284.06 sq km</td>
</tr>
<tr>
<td>2</td>
<td>Maximum length of the</td>
<td>29 km</td>
</tr>
<tr>
<td>3</td>
<td>Maximum width of the</td>
<td>1' km</td>
</tr>
<tr>
<td>4</td>
<td>Perimeter of the basin (P)</td>
<td>75 km</td>
</tr>
<tr>
<td>5</td>
<td>Diameter of circle of the</td>
<td>19.01 km</td>
</tr>
<tr>
<td>6</td>
<td>Area of the circle with same</td>
<td>447.38 sq km</td>
</tr>
<tr>
<td>7</td>
<td>Basal Channel Length</td>
<td>1' km</td>
</tr>
<tr>
<td>8</td>
<td>Cumulative channel length</td>
<td>24.5 km</td>
</tr>
<tr>
<td>9</td>
<td>Drainage density (Dd)</td>
<td>2.41</td>
</tr>
<tr>
<td>10</td>
<td>Drainage Density (Dd)</td>
<td>1.1</td>
</tr>
<tr>
<td>11</td>
<td>Stream Frequency (Fs)</td>
<td>2.78</td>
</tr>
</tbody>
</table>