CHAPTER 3

HYDROMORPHOMETRY
3.1 INTRODUCTION

Hydromorphometric analysis is a simple tool with not much of initial expenditure to study the river basin within the four walls of the laboratory and choose the area of possible groundwater potentials for further field studies. The amount of water reaching a stream system is dependent on the morphometry of the basin, total precipitation, losses due to evaporation and absorption by soils and vegetation. Hence a detailed groundwater investigation of a river basin warrants a thorough knowledge of the nature and behaviour of the surface streams in quantitative terms. These studies throw light on the lithology, structure, relative infiltration, run off, erosional aspects and the stage of maturity of the basin itself.

3.2 MATERIALS AND METHODS

The drainage and contour maps of the basin have been used for the construction of spatial maps. Toposheets 48L-13; 48P-1,2,5,6,9,10,11; 48O-4,8,12 on a scale of 1:50,000 has been used to make the drainage and contour maps.

The delimitation of the basin has been done after tracing the drainage lines on a good quality tracing paper (Fig. 3.1). The foremost step in any drainage basin analysis is the designation of sub basins based on their stream order, which is useful not only to index the size and scale but also to afford an approximate index of the amount of stream flow which can be produced by a particular nature. The simpler system of stream ordering proposed by Strahler (1957) has been followed in this work. After assessing the order of the streams, number of streams of each order was counted. Then stream length of each order was measured by opisometer.

The drainage frequency, drainage density, relative relief and slope are the variables used in the spatial analysis of Nethravathi river basin. For the construction of
Fig 3.1 - Drainage network of the river basin
isopleth maps, the basin is divided into grids of 4 Km$^2$. The drainage frequency, density, relative relief and slope values are calculated for each grid and plotted at the centre of the grid. By using the values of each grid, isopleth were drawn to prepare spatial maps of drainage frequency, drainage density, relative relief and slope.

3.3 CLASSIFICATION OF SUB BASINS

The Nethravathi river basin network contains mainly three streams namely Nethravathi (Nethravathi sub river basin), Kumaradhara (Kumaradhara sub river basin) and Gurupura (Gurupura sub river basin) streams. There are twenty seven 5th order streams, five 6th order streams and two 7th order streams in the basin. The entire basin is an 8th order fluvial system.

Nethravathi sub river basin: The Nethravathi stream is a 7th order basin. The Nethravathi stream rises in the NE part of the full basin at an altitude of about 1680 m. The stream traverses nearly 108 Km before joining the Arabian sea.

Kumaradhara sub river basin: The Kumaradhara stream is also 7th order basin. The confluence of Gundia stream and Yenakalu stream gives rise to Kumaradhara stream. The Kumaradhara stream originates in the SE part of the full basin at an altitude of about 1230m and merges with Nethravathi stream near Uppinangadi.

Gurupura sub river basin: Gurupura basin is 6th order. Two streams namely Savanalhalla and Aladangadi streams join together to form the Gurupura stream. The Gurupura stream originates in the NE part of the basin at an altitude of about 1890 m and runs parallel to the coast for about 1 Km before merging with the Nethravathi stream near the river mouth. In contrast to the other two sub basins, the Gurupura stream originates on the slopes of the Western ghats. The total channel length is 87Km.
3.4 NETWORK ANALYSIS

Drainage area, perimeter, total number of streams, total length of streams, length of the basin, relief ratio, drainage texture, texture ratio and constant of channel maintenance are the parameters considered for the network analysis. The same were calculated for the three sub basins separately and also for the entire basin (Table 3.1)

The area ($A_u$) of the basin has been measured with a planimeter and the area of the entire basin is $4256.80 \text{ Km}^2$. Among this the Kumaradhara sub basin accounts for $1849.94 \text{ Km}^2$, the Nethravathi sub basin accounts for $1582.86 \text{ Km}^2$ and the Gurupura sub basin accounts for $824 \text{ Km}^2$.

The perimeter ($P$) is measured by using an opisometer and is the length of the divide that surrounds the basin. The perimeter of the entire basin is 380 Km. The Nethravathi sub basin has a perimeter of 265 Km and that of the Kumaradhara sub basin is of 230 Km and the Gurupura sub basin is of 180 Km. The area and perimeter values of the basin indicate that the Kumaradhara sub basin constitute a larger watershed and though the area of the Nethravathi sub basin is lower than that of Kumaradhara, the water divide (perimeter) on the surface is longer and within it accommodates a compact river system.

Kumaradhara sub basin consists of maximum number of streams (6102) followed by Nethravathi (5166) and Gurupura (1520) sub basins. The total number of streams of the entire basin is 12788. Length wise Kumaradhara sub basin has the maximum length of streams (5116.75 Km) followed by Nethravathi (3357.25 Km) and Gurupura (1250.25 Km) sub basins. The total length of the streams of the entire basin is 9724.25 Km. The variation in the total number of streams and total length of
### TABLE 3.1 - NETWORK PARAMETERS

<table>
<thead>
<tr>
<th></th>
<th>Area (Km²)</th>
<th>Perimeter (Km)</th>
<th>N</th>
<th>L (Km)</th>
<th>LB (Km)</th>
<th>Rh</th>
<th>T</th>
<th>Tu</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nethravathi sub basin</td>
<td>1582.86</td>
<td>265</td>
<td>5166</td>
<td>3357.25</td>
<td>55</td>
<td>30.5</td>
<td>6.91</td>
<td>19.49</td>
<td>0.47</td>
</tr>
<tr>
<td>Kumaradhara sub basin</td>
<td>1849.94</td>
<td>230</td>
<td>6102</td>
<td>5116.75</td>
<td>60.5</td>
<td>19.83</td>
<td>9.14</td>
<td>26.53</td>
<td>0.36</td>
</tr>
<tr>
<td>Gurupur sub basin</td>
<td>824</td>
<td>180</td>
<td>1520</td>
<td>1250.25</td>
<td>57</td>
<td>33.16</td>
<td>2.80</td>
<td>8.44</td>
<td>0.66</td>
</tr>
<tr>
<td>Nethravathi River basin</td>
<td>4256.80</td>
<td>380</td>
<td>12788</td>
<td>9724.25</td>
<td>102</td>
<td>12.06</td>
<td>6.90</td>
<td>35.66</td>
<td>0.43</td>
</tr>
</tbody>
</table>

N - Total number of streams
L - Total length of streams
LB - Length of the basin
Rh - Relief ratio
T - Drainage texture
Tu - Texture ratio
C - Constant of channel maintenance
streams in the basin is mainly because of variation in precipitation, morphology and lithology of the terrain.

The length of the basin (Lb) is also measured and it is the distance between the mouth of the river and the farthest point on the perimeter of the catchment (Gardiner, 1975). The length of the entire basin is 102 Km, while among the sub basins the length of Nethravathi, Kumaradhara and Gurupura sub basins are 55 Km, 60.50 Km and 57 Km respectively.

Relief ratio (Schumm, 1956) is a ratio between total relief and longest dimension of the basin (Rh = RR/Lb where Rh is relief ratio, RR is relative relief and Lb is length of the basin). It gives the intensity of erosional processes. The relief ratio is maximum for Gurupura sub basin because of the high total relief (1890m) and shorter length of the basin (57 Km) and it is 33.16. In the Nethravathi sub basin a lower total relief (1680m) reduce the relief ratio to 30.5. The relief ratio of Kumaradhara sub basin is 19.83 and this is due to the lowest total relief (1230m) and the higher basin length(60.50 Km). In the entire Nethravathi river basin system, the total relative relief is 1230m with a basin length of 102 Km bringing the relief ratio to a low value of 12.06.

The drainage texture (Horton, 1945) is a measure of relative spacing of drainage lines, which includes frequency and density (T = Fu X du where T is drainage texture, Fu is the drainage frequency and Du is drainage density). The drainage texture of the entire basin is 6.90 and it is 6.91, 9.14 and 2.80 for Nethravathi sub basin, Kumaradhara sub basin and Gurupura sub basin respectively.

Texture ratio (Strahler, 1954) is defined as proximity of one channel to other (Tu = Nu/P where Tu is texture ratio, Nu is number of streams and P is basin
perimeter). The texture ratio for the entire basin is 35.66 and in the Nethravathi, Kumaradhara and Gurupura sub basins the texture ratio is 19.49, 26.53 and 8.44 respectively. In the Gurupura sub basin the value of the texture ratio is low though the perimeter is small. This is because of fewer number of streams generated in the catchment and hence more groundwater recharge is expected here.

The Constant of channel maintenance (C) is a measure of texture similar to drainage density (Horton, 1945; \( C = 1/D_u \)). The values of constant of channel maintenance are 0.47, 0.36 and 0.66 for Nethravathi, Kumaradhara and Gurupura sub basins respectively and it is 0.43 for the entire basin. The value of constant of channel maintenance which is lowest in Kumaradhara sub basin suggests that this basin requires an average less area for the development of channel than the other sub basins. Hence the chance of groundwater recharge is less in this area.

High values of relief ratio, drainage texture, texture ratio and constant channel maintenance brings high discharge of surface water in a short duration and result in low infiltration of water. Hence areas characterised with low values of relief ratio, drainage texture, texture ratio and constant channel maintenance values can be taken as areas for further detailed hydrogeological investigations.

3.5 SPATIAL ANALYSIS

3.5.1 Introduction

Spatial analysis is one of the methods to derive the quantitative data of a variable from a topographic sheet or aerial photos/satellite imageries and to prepare univariable maps to understand the spatial pattern. Attempts have been made to use the spatial analysis of geomorphic variables to analyse and interpret the land forms
3.5.2 Drainage Frequency And Density

The drainage frequency (Horton, 1945) is defined as the number of streams per unit area ($F_u = N_u/A_u$ where $F_u$ is drainage frequency, $N_u$ is number of streams of order $u$ and $A_u$ is area of basin). Drainage density (Horton, 1945) is the length of stream per unit area ($D_u = L_u/A_u$ where $L_u$ is total length of the streams of order $u$ and $D_u$ is drainage density).

To understand the variation of drainage frequency and density on a regional scale within the basin and to appreciate the impact of other variables on these parameters, spatial maps of frequency and density were constructed. The basin was divided into grids of 4 Km$^2$ each and the total number of streams counted for each grid was divided by the area of the grid to obtain drainage frequency values. Similarly, the total length of streams were measured in each grid and the total channel length was divided by the area of the grid to obtain drainage density values. These values were plotted at the centre of the grid to draw isopleth lines.

The stream frequency varies from 0 to 13 (Fig 3.2). The drainage frequency of the basin has been categorised as follows:

- 0 - 5 -------> Low
- 5 - 10 -------> Medium
- 10 - 13 -------> High
Fig 3.2 - Drainage frequency map of the river basin
Low frequency dominates the area of investigation. About 3114 Km$^2$ of the basin has low frequency. The area having medium frequency amounts to 1102.809 Km$^2$ and the high frequency is confined to 40 Km$^2$. The stream frequency increases from west to east with high frequency in the mountainous region. The high frequency terrain also occur as pockets in the central and south eastern parts of the basin.

The drainage density varies from 0 to 6 Km and increases from west to east (Fig. 3.3). The drainage density of the basin is categorized as follows:

- Low -------> 0 - 2 Km
- Medium ---> 2 - 4 Km
- High -------> 4 - 6 Km

The area covered by low drainage density amounts to 1767.80 Km$^2$ whereas the area covered by medium density is 2239.60 Km$^2$ and 249.40 Km$^2$ area of the basin is covered by high density. High density terrains are noticed at the south eastern corner of the basin as well as at the north eastern parts of the basin.

Low frequency and moderate density dominate the basin. The possibility of occurrence of groundwater potential zones mainly depends upon the drainage density. Low drainage density implies high voids ratio and hence high potentiality of water and vice versa (Sreenivasa Rao et al, 1994). The frequency and density increase from west to east. The drainage frequency and density depend on factors like lithology, structure, relief, slope, infiltration capacity, vegetation, etc. The Nethravathi river basin being a humid tropical basin experiences heavy rainfall for about four months in a year. The amount of precipitation increases from west to east because of the orographic precipitation. The average slope is almost zero in the coastal tract, but increases gradually towards ghats and rapidly in the eastern hilly tract. Because of the
Fig 3.3 - Drainage density map of the river basin
heavy precipitation and high slope of the scarp, slope initiated streams are numerous in the eastern part of the basin. Here surface runoff exceeds infiltration. All these conditions favor the initiation of streams and accounts for high drainage frequency and density towards the eastern part of the basin. The low to moderate slope and relief, varying thickness of soil cover hinder the initiation and development of drainage net, thus making the western and middle part of the basin as a zone of low to moderate drainage frequency and density.

Low frequency and density indicates higher permeable subsurface formations and higher groundwater recharge. Hence the areas with low frequency and low density can be considered as groundwater potential areas.

3.5.3 Relative Relief

The relative relief (Glock, 1932) which is also known as local relief represent the variation of altitude in a unit area with respect to its base level (RR = Z-z where Z is height of highest point and z is the height of the lowest point and RR is the relative relief). This parameter helps to ascertain the amplitude of available relief (Glock, 1932), but does not take into account the dynamic potential of the terrain (Anil Kumar and Pandey, 1982).

The basin was divided into grids of 4 Km² each and the differences in maximum and minimum altitude (relative relief) was obtained for each grid. The relative relief (mts/unit area) thus obtained has been used for the construction of isopleth map (Fig. 3.4). The isopleths were drawn at an interval of 20m up to 100m relative relief values and at 100m interval above 100 m relative relief values. It is clear from the figure 3.4 that the relative relief increases from west to east. Three categories
Fig 3.4 - Relative relief map of the river basin
of relative relief have been made based on the values of relative relief which are as follows:

Low --------> 0 - 100
Medium -----> 100 - 200
High --------> 200 - 500

The western part of the basin is characterised by low relative relief and covers an area of 2189.40 Km². An area of 1347.50 Km² covering the eastern part of the basin is having high relative relief. The central part of the basin is having moderate relative relief and it covers an area of 719.90 Km². Higher values of relative relief suggests rugged topography.

3.5.4 Slope

The slope is defined as the loss or gain in altitude per unit horizontal distance in a direction. The slope map prepared is based on the Wentworth's (1930) formula which is as follows:

\[ \tan \theta = \frac{\text{Number of contours cutting per mile} \times \text{Contour interval}}{3361} \]

Since in the study all measurements are in Km and m the above given formula is modified as follows:

\[ \tan \theta = \frac{\text{Number of contours cutting per Km} \times \text{Contour interval}}{636.6} \]
By using the slope values of grids, isopleths are drawn with an interval of 5° (Fig. 3.5). In the Nethravathi river basin the average slope increases from 5° in the west to 55° and above in the east. The western and central parts of the basin is characterised with slope values less than 20°. The northern sector of the central parts and eastern parts are typically a terrain of high slope values (20° - 55°). The southern sector of the central part of the basin is conspicuous by slope value of <10° and forms a considerably large patch. The slope values have been categorised as follows:

- Low ————> 0 - 20
- Medium ———> 20 - 40
- High ————> 40 - 55

The western part of the basin is characterised by low slope values and it covers an area of 2643.80 Km². The middle parts of the basin is having medium slope and it covers an area of 970.30 Km². The eastern part of the basin is of high slope and it covers an area of 642.70 Km². Higher the slope, higher the run off and lower the recharge. Hence the areas having low slope can be considered as sites of groundwater recharge.

3.6 INTER SUB-BASIN AREAS

Figure 3.1 shows the drainage net of the Nethravathi river basin. There are many number of small basins within a basin. Areas lying between adjacent sub-basins and surrounding the main trunk stream is called the inter sub basin areas. Drainage density, drainage frequency, etc are very low in these zones and hence form moderately high groundwater potential areas for further exploitation.
Fig 3.5 - Slope map of the river basin