CHAPTER V

MORPHOMETRIC ANALYSIS
Morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth’s surface regarding the shape and dimensions of its landforms.

The main aspects examined are the area, altitude, volume, slope profiles and texture of the land as well as the various characteristics of rivers in drainage basins. The results are represented by graphs, maps and other statistical indices.

Considering the drainage basin as fundamental geomorphic unit, morphometric analysis recently has got considerable importance in the field of geomorphology. The understanding of drainage basin nature in terms of its geometry, landscape evolution, relation of various controlling factors of nature, i.e. climate, lithology etc. in the evolution of landscape and comparison with other river basins are usually done. In other words, to identify the morphometric behaviour of the intricate network of drainage which sculptures the earth, various quantitative techniques are adopted to analyse the complex geomorphology of an area and the parameters are quantitatively expressed to exhibit the drainage basin character.

METHODOLOGY

The drainage basin area may be defined as the area which contributes water to a particular channel or set of channels
(Leopold et al., 1964). The delimitation of sub-basins in the Son catchment has been done on the basis of perennial streams marked on the toposheets. The measurements for the morphometric analysis has been taken from the quarter inch topographical sheets Nos. 63 D, 63 H, 63 I, 63 P, 64 A, 64 E, 64 F, 64 I, 64 J, 64 M.

First of all, the perimeter of the Son river basin has been demarcated. The whole river basin has been divided into sub-basin demarcating the perimeters of the basins of the major tributaries by marking of water-divides. There are eight sub-basins in the Son river basin named after their trunk stream - Mahanadi, Johilla, Banas, Gopad, Rihand, Tipan, Kunuk and Keuai. These are the sub-basins formed by the tributaries of the main channel, i.e. the Son river.

Stream numbers, stream lengths, spot heights, contour crenulation and area form the basic data for finding out the various linear, areal and altitudinal aspects of the drainage basin. Formulae are given in Appendix – 3.

I LINEAR ASPECTS

Linear aspects are studied through the following parameters:

STREAM ORDER (O)

The streams are ordered to measure the position of the stream in the hierarchy of the stream network and it is useful in ascertaining the dimension of the river basin. Streams
STRAHLER’S STREAM ORDERING SYSTEM
(AN EXAMPLE)

First order
Second order
Third order
Fourth order

Fig. 51
have been ordered according to Strahler's (1952) method (Fig. 5.1).

**NUMBER OF STREAMS (N_s)**

The total number of streams of every order has been found out in the various sub-basins of the Son catchment.

**LAW OF STREAM NUMBERS:** The number of streams of different orders in a given drainage basin tend closely to approximate an inverse geometric series in which the first term is unity and the ratio is the bifurcation ratio (Horton 1945).

The stream orders have been plotted on the abscissa and the number of streams of each order on the ordinate of semi-logarithmic paper and the Horton's law of stream numbers has been tested separately in the case of every sub-basin and then in the Son river basin.

**LENGTH OF THE STREAMS (L)**

The length of the streams of various orders are measured with an opisometer and tabulated for various sub-basins. The total length of all sub-basins for all orders has been calculated and this is the value for the Son river basin as a whole.

**LAW OF STREAM LENGTHS:** Horton's law of stream lengths states that "the average lengths of streams of each of the different orders in a drainage basin tend closely to approximate a direct geometric series in which the first term is the average length of streams of the 1st order" (Horton op. cit). To test the Horton's law of the area, mean stream lengths of every order
have been plotted on the ordinate against the stream orders on the abscissa.

**STREAM LENGTH RATIO (rl)**

It is the ratio of the mean length of streams of a given order and the mean length of streams of the next higher order. Stream length ratios have also been plotted on the semilogarithmic paper to find out the relation between stream orders and stream length ratios in various sub-basin as well as in the Son river basin.

Horton's method of ordering streams is different from Strahler's method with respect to the length of the stream segments of various orders, therefore log-log graphs of total stream length of different orders have also been plotted (Strahler 1956). These plots confirm the revised law of stream lengths. The law states that "the total length of stream of each of the different orders in a drainage basin tends closely to appropriate an inverse logarithmic series in which the first term is the total length of streams of the highest order" (Chorley, 1957).

**PERCENTAGE ANALYSIS OF LINEAR ASPECTS**

The stream lengths of the various orders were determined in terms of the total length expressed in percentage, in order to examine their contribution to the total stream length. It is expected by the author, that there must be either a constant trend in the lengths of the various orders or there must be
some functional relationship with the total length. The percentages of stream numbers of various orders of the total has also been calculated and analysed. There is a correlation between the percentage of the stream numbers and stream lengths in a river basin in a given order. The percentage analysis has been represented by the following graphical methods:

1. Curves are drawn for percentages of length and numbers. The per cents are shown on the ordinate against the stream orders on abscissa.

2. Column charts for per cents of lengths and numbers for every order has been drawn. Correlation of per cent share between the columns representing length and numbers and between various orders becomes easy.

3. To find out whether the relation between per cent of lengths and numbers in a definite order is constant or variable, a curve is drawn with lengths on the abcissa and numbers on the ordinate.

4. The per cent data of various sub-basins has been plotted on the semilogarithmic paper. Two separate plots have been prepared each for lengths and numbers against successive orders. The plots provide the range of the per cent of lengths and numbers in various sub-basins for every order. This is not a curve rather it is distribution of points which indicates the range of dispersion.

AREAL ASPECTS

BASIN AREA (A)

Basin areas of various sub-basins have been found out
by graphical method after determining the perimeters of the sub-basins.

BASIN CONFIGURATION

The shape has been studied in terms of the following parameters:

1. FORM FACTOR (Ff) : Horton (1942) described the shape of the basin as form factor. It is the ratio of the area of the basin to the square of the basin length (L).

2. CIRCULARITY RATIO (Rc) : According to Miller (1953) "It is the ratio of the basin area to the area of the circle with the same perimeter". This parameter provides a quantitative expression of the shape of the basin.

3. BASIN ELONGATION (E) : Schumm (1958) defined the basin elongation as the ratio of the diameter of the circle with the same area as the basin to the basin length. It is inversely related to the circularity ratio.

4. LAMNISCATE (K) : It is an expression of shape of the basin. It is related to area, length of the basin and circle (Chorley, 1957).

DRAINAGE NATURE

The nature of the river basin is expressed in terms of drainage density, drainage texture, drainage frequency, drainage intensity.
1. **DRAINAGE DENSITY (Dd)**: Horton (1932) defines 'Dd' as the total length of streams per unit area within the river basin. The Son river basin has been superimposed on 2"x2" grids and grid-wise drainage density has been calculated.

2. **TEXTURE**: Smith (1950) has graded 'Dd' and expressed it as a measure of fineness of the drainage basin and named it drainage texture. It indicates the relative spacing of the stream segments. The different classes of drainage texture are given below:

   \[
   \begin{array}{cccc}
   \text{Dd/mile}^2 & 2 & 2-4 & 4-6 & 6-8 \\
   \text{Texture} & \text{very coarse} & \text{Coarse} & \text{Fine} & \text{Very fine}
   \end{array}
   \]

3. **STREAM FREQUENCY (F)**: Stream frequency is the number of streams per unit area.

4. **DRAINAGE INTENSITY (D1)**: It is the ratio of stream frequency to the drainage density.

**LENGTH OF OVERLAND FLOW (Lg)**

Horton (1945) used this measure to describe the length of water cover over the ground before it becomes concentrated in definite stream channels. It is approximately equal to half the reciprocal of the Dd. It is one of the most important variables affecting both the hydrological and physiographic development of the drainage basin.

**BIFURCATION RATIO (Rb)**

It is the ratio of the number of streams of a given order to the number of streams of the next higher order. The natural
tendency of the streams to develop tributaries is indicated by Rb. It shows the frequency with which streams of a given order enter the streams of the next higher order. Rb is directly proportional to basin areas. According to Strahler (op. cit) "it shows a small range of variation from region to region or environment to environment except where powerful geological control dominates, it can also be the effect of different lithologies".

BASIC LENGTH (L)

Among the various methods, the one proposed by Gregori and Walling (1973) is adopted here to find the basin length — the basin length is the longest length in the basin, one end being the mouth and the other on the perimeter.

PERIMETER (P)

The perimeter of the basin is determined by drawing orthogonal lines normal to contours. It encircles the basin.

PROFILES

Serial profiles have been drawn along all the longitudes and latitudes of the area. Composite, superimposed and projected profiles have also been prepared. Thalweg profiles are drawn for all the major tributaries along with the Son river.

ALTITUDE FREQUENCY CURVE

This curve is very important for the reconstruction of the erosion surfaces. Miller (1964) states that "A statistical
count of the number of hill tops in each altitude range may reveal a preponderant frequency at certain levels. This in turn may give a clue to the presence, in former times, of preponderance of land area at this level, i.e. flat land, perhaps representing an erosion level, now dissected into hill tops". The heights are plotted on ordinate and the frequency of the hill tops are plotted on abscissa.

**MERITS OF MORPHOMETRIC ANALYSIS**

1. It is useful for quantitative representation and statistical analysis of descriptive data of river basins.

2. Morphometric analysis minimises the subjective factor in landform analysis, being more objective in nature.

3. It is useful for the detailed study of basin configuration which cannot be emphasised in a purely qualitative description.

4. It is convenient for the comparison of drainage basin characteristics in quantitative terms and it is an important tool in geomorphic studies.

5. It helps in establishing the denudation chronology of a study region.

6. It has application in the field of resource development, specially that of water, mineral and engineering planning.
MORPHOMETRIC ANALYSIS OF THE SUB-BASINS
OF THE SON CATCHMENT

MAHANADI SUB-BASIN

The river basin is covered by the quarter inch topographical sheets Nos. 63 D and 64 A and occupies the areas of Jabalpur, Mandla and Shahdol districts of Madhya Pradesh.

LINEAR ASPECTS

STREAM ORDER

Mahanadi is a 6th order stream.

STREAM NUMBER

There are 1372 streams of all orders. Various orders and successive stream number are tabulated in Table 5.1.

LAW OF STREAM NUMBERS: The straight line on the plot profoundly supports the validity of Horton's law in the area (Fig. 5.2 A).

STREAM LENGTH

Total stream length is 2983 miles. Orderwise stream lengths and mean stream lengths are shown in Table 5.1.

LAW OF STREAM LENGTH: The plot of mean stream lengths against successive orders on the semi-logarithmic paper support the law of stream lengths. The points indicates to a gradual increase, they do not form a perfect geometric sequence. There are departures of the points from a straight line. Mahanadi is a
MAHANADI SUB-BASIN

A. LAW OF STREAM NUMBERS
   - Number of streams vs. stream orders
   - Log-log plot

B. LAW OF STREAM LENGTHS
   - Mean stream length vs. stream orders
   - Semilog plot

C. MEAN LENGTH RATIO
   - Ratio of mean lengths vs. stream orders
   - Log-log plot

Fig. 5.2
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of stream segments (N&lt;sub&gt;1&lt;/sub&gt; to N)</td>
<td>Per cent share</td>
<td>Stream length (Miles)</td>
<td>Per cent share</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of Columns III &amp; IV</td>
<td>Average stream length (Miles)</td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1038</td>
<td>75.65</td>
<td>1784</td>
<td>59.80</td>
<td>4.0</td>
<td>1292</td>
<td>5168</td>
<td>1.7</td>
</tr>
<tr>
<td>II</td>
<td>254</td>
<td>18.5</td>
<td>569</td>
<td>19.07</td>
<td>4.3</td>
<td>313</td>
<td>1345.9</td>
<td>2.2</td>
</tr>
<tr>
<td>III</td>
<td>59</td>
<td>4.3</td>
<td>338</td>
<td>11.33</td>
<td>3.6</td>
<td>75</td>
<td>270</td>
<td>5.7</td>
</tr>
<tr>
<td>IV</td>
<td>16</td>
<td>1.16</td>
<td>134</td>
<td>4.49</td>
<td>4.0</td>
<td>20</td>
<td>80</td>
<td>8.3</td>
</tr>
<tr>
<td>V</td>
<td>4</td>
<td>0.29</td>
<td>116</td>
<td>3.88</td>
<td>4.0</td>
<td>5</td>
<td>20</td>
<td>29</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>0.07</td>
<td>42</td>
<td>1.407</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1372</td>
<td></td>
<td>2983</td>
<td>3.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1705(B)</td>
<td></td>
<td>6883.9(A)</td>
</tr>
</tbody>
</table>
large river basin and has various rock types. Difference in rock resistance and resulting local slope conditions must have influenced the mean stream lengths. It is necessary to recall here that resistant rocks and gentle slope give rise to long streams, soft rocks and steep slope supports smaller lengths (Fig. 5.2 B).

STREAM LENGTH RATIO

The plot clearly indicates that the ratios do not form any sequence at all (Fig. 5.2 C). This indicates that some factors are active in controlling the stream length ratio. These are differential rock resistance and high sinuosity. Softer coal bearing lower Gondwanas are present with hard sandstone, etc. and this causes the resultant high sinuosity and the length ratio.

PERCENTAGE ANALYSIS

1. The column chart (Fig. 5.3 A) indicates that the 1st and 2nd orders have less share of stream length.

2. The curve of per cent of stream numbers is smooth whereas the per cent curve of stream length shows deflection of points (Fig. 5.3 B).

3. The curve of percentages of lengths against stream numbers support the results of 'laws of stream' and is indicated by the deflection of points of 1st and 2nd orders on the plot. The mathematical curve is drawn to find out the geometric progression (Fig. 5.3 C).
MAHANADI SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig. 5.3
II AREAL ASPECTS

BASIN AREA (A)

The river basin occupies a considerably large area of 2446.08 square miles.

BASIN CONFIGURATION

1. Form Factor: Ff for the present river basin is 0.38.
2. Basin Circularity: The value of Rc for the river basin which is 0.262 indicates that the shape does not correspond to a circle.
3. Basin Elongation: The value of E for the present river basin is 0.69. The element of elongation is more in the shape of drainage basin.
4. Lamniscate: Though the river basin has a high value of basin elongation it is proportionate as far as shape is concerned in terms of elongation and circularity. The value 0.87 supports above analysis.

DRAINAGE NATURE

1. DRAINAGE DENSITY: The average Dd of the drainage basin is 1.22 miles/mile$^2$. Dd distribution in the sub-basin (Fig. 5.21): The high Dd area (1.8 to 2 miles/mile$^2$): This area is situated in the SSW part of the river basin which is high relief area and lies just below the high water divide between Son and the Narmada catchments. The streams are consequent in nature. Though this forms a small part of the river basin, it is an example of the direct relation between Dd and relief.
The Medium Dd area (1.5 to 1.7 miles/mile$^2$): The NNE part of the river basin has this moderate Dd. The area geologically consists of Vindhyan. These are consequent streams formed on the Kaimur.

The Low Dd area (0.9 to 1.5 miles/mile$^2$): Rest of the drainage basin has low Dd. A remarkable patch of low Dd ranging between 0.9 to 1.1 miles/mile$^2$, can be seen in the middle western part of the river basin. This area is a low relief area characterised by long streams.

2. DRAINAGE TEXTURE: It is very coarse.

3. STREAM FREQUENCY: The F is 0.56 streams/mile$^2$. This sub-basin of the Son catchment has a moderate F. Maturely dissected high relief area specially the upper valley area and northern high areas have given rise to a better average stream frequency in the sub basin.

4. DRAINAGE INTENSITY: The ratio of F to Dd, which is DI, is 0.459.

LENGTH OF OVERLAND FLOW

The value of Lg for the present river basin is 0.409 miles.

BIFURCATION RATIO

Average Rb is 3.98. This is a river basin with moderate relief and simple geological and structural conditions. The Rb of various orders shows constant relation, i.e. the Rb does not vary with the stream orders (Table 5.1). Weighted mean Rb is 4.03.
BASIN LENGTH

The length of the basin is 80 miles.

BASIN PERIMETER

The perimeter of the basin is 342 miles. The perimeter is in the form of a smooth line except the south western and southern margins of the river basin.

STREAM ENTERANCE ANGLES

The Mahanadi river joins the Son river just after the conspicuous turn of the Son river, i.e. at the point where the turn is completed and the Son flows in a NE direction. The confluence angle with the Son is \(180^\circ\), which is noteworthy.

RELIEF ASPECTS

LONGITUDINAL PROFILE

Analysis of thalweg profile, which is in the form of a smooth concave curve indicates that the river has graded itself. Normal drops of the heights at various points on the thalweg show that the river valley does not have any complexities. It is remarkable that the river is flowing at a considerably high level and meets the Son river at a height of approximately 1250 feet above MSL (Fig. 5.23).
BANAS SUB-BASIN

The Banas river basin lies in the Shahdol, Sidhi and Surguja districts of Madhya Pradesh state and is covered by the quarter inch topographical sheets Nos. 63 H and 64 E.

LINEAR ASPECTS

STREAM ORDER

Banas river is a 6th order stream.

NUMBER OF STREAMS

Total number of streams of all orders are 1200. The stream numbers of various orders are given in Table 5.2.

LAW OF STREAM NUMBERS: The plot on the semilogarithmic paper profoundly supports the Horton’s law of stream numbers for the Banas river basin. The stream numbers and successive orders have an inverse geometric relation (Fig. 5.4 A).

STREAM LENGTHS

The total stream length is 1681 miles. Orderwise stream length is shown in Table 5.2.

LAW OF STREAM LENGTHS: The analysis of the plot indicates a typical trend which is unusual in the Son sub-basins. All the points of various orders and successive lengths form a direct geometric series excluding the mean stream length of 6th order stream. The average mean length of 6th order is 1 mile. Mathematically it should be at least 50 miles whereas the mean
Figure 5.4

BANAS SUB-BASIN

LAW OF STREAM NUMBERS

LAW OF STREAM LENGTHS

MEAN LENGTH RATIO

STREAM ORDERS

A

B

C

Fig. 5.4
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of stream segments (N₁ to N)</td>
<td>Number</td>
<td>Percent</td>
<td>Stream length (Miles)</td>
<td>Percent</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of Columns III &amp; IV</td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>936</td>
<td>78.00</td>
<td>928</td>
<td>55.2</td>
<td>1139</td>
<td>5250.79</td>
<td>0.99</td>
<td>0.556</td>
</tr>
<tr>
<td>II</td>
<td>203</td>
<td>15.91</td>
<td>361</td>
<td>21.47</td>
<td>4.61</td>
<td>249</td>
<td>1098.09</td>
<td>1.778</td>
</tr>
<tr>
<td>III</td>
<td>46</td>
<td>3.83</td>
<td>180</td>
<td>10.70</td>
<td>4.41</td>
<td>58</td>
<td>222.14</td>
<td>3.91</td>
</tr>
<tr>
<td>IV</td>
<td>12</td>
<td>1.0</td>
<td>124</td>
<td>7.37</td>
<td>3.83</td>
<td>14</td>
<td>84.00</td>
<td>10.33</td>
</tr>
<tr>
<td>V</td>
<td>2</td>
<td>0.16</td>
<td>87</td>
<td>5.17</td>
<td>6.00</td>
<td>3</td>
<td>6.00</td>
<td>43.5</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>0.08</td>
<td>1</td>
<td>0.059</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1200</td>
<td>1681</td>
<td>4.17</td>
<td>1463(B)</td>
<td>6661.02(A)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

105
length of 5th order if assumed mathematically, should be less than the actual mean length (Fig. 5.4 B). The area is a maturely dissected river basin. No profound lithological or structural control is evident. The cause of this anomaly lies in the shifting of the river course. The flow of Banas was deeply affected during the changes in the shifts of the courses of the Son river (Singh, 1966). The tributaries of Banas must have been affected during this change. This change has influenced the flowing direction as well as the stream lengths. The shifts could also be guided by the process of grading of higher order stream. The Son river is very close (within 2 miles reach) to these 5th order streams. These join to form a sixth order stream which is only 1 mile(app. ) in length then it joins the Son (of 7th order). It is concluded that the present anomaly in the mean stream lengths has come into existence due to the process of gradation and the shifting of main streams.

STREAM LENGTH RATIO

Plot of stream length ratio indicates the same anomalies mentioned above and thus supports the conclusions drawn(Fig.5.4 C).

PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Percentage analysis clearly indicate some disturbance regarding the length of streams of various orders, which is discussed earlier.

1. It can be seen in the column chart (Fig. 5.5 A). That the
BANAS SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

**Fig. 5.5**

- **Graph A**: Histogram showing stream numbers and lengths (per-cent) against stream orders.
- **Graph B**: Graph showing stream numbers and lengths (per-cent) against stream orders.
- **Graph C**: Graph showing stream numbers and lengths (per-cent) against stream length (%).
mathematically assumed value is much more in comparison to the actual length of 6th order stream, i.e. the share of 6th order length is very less.

2. The curve of stream number is smooth whereas the curve showing percentages of lengths shows deflection of points (Fig. 5.5 B).

3. The curve showing percentages of stream lengths and numbers has a steep drop from the point of 1st order stream which indicates an anomaly in lengths. The proposed curve is drawn by dash line (Fig. 5.5 C).

AREAL ASPECTS

BASIN AREA

The catchment area of Banas river is 1348.8 sq. miles.

BASIN CONFIGURATION : Basin configuration comprises the following factors:

1. FORM FACTOR : \( F_f = 0.339 \) for the present river basin.

2. BASIN CIRCULARITY : The value of \( R_c \) is 0.47.

3. BASIN ELONGATION : The ratio is 0.65. It is concluded that the element of elongation is comparatively more in the present river basin, but the river basin is neither too circular nor too elongated.

4. LAMNISCATE : The value of \( K \) is 0.90. The ratio indicates that the shape of the river basin is proportionate.
DRAINAGE NATURE

1. DRAINAGE DENSITY: The lower valley area has the highest value of Dd, i.e. 1.7 to 2 miles/sq. mile. This Dd is concentrated in the areas of granitic gneisses of Archaeans, Upper Vindhyans and Bijawars. The dissimilar rock resistance must have produced high relief and thus causing high Dd. Upper valley area and the whole southern river basin has Dd ranging from 1.37 to 1.67 miles/mile$^2$. This area is mainly occupied by the Upper Gondwana Group of rocks.

    Normally in Son catchment, it has been found that the Dd in the higher valley areas is high, the main reason being the high relief in these areas. But Dd analysis in Banas river basin gives opposite picture. It seems that the lower valley area of the Banas is occupied by different lithologies, whereas the upper valley area is occupied by only Upper Gondwana Group of rocks. The reasons of high Dd are the smooth meanders of lower valleys and changes in the rock resistance in the lower valley area (Fig. 5.21).

2. DRAINAGE TEXTURE: The texture of the drainage is very coarse.

3. FREQUENCY: The stream frequency is 0.889 streams/mile$^2$. This sub basin of the Son catchment has the highest F. Though the major part of the river basin is occupied by Mahadeva formations, there are other geological formations with considerably different rock resistance in the basin. This variation and throughout high dissection supports this high F.
This is a maturely dissected river basin and at this stage of cycle of erosion, the relief is high, consequently the F is high (Fig. 5.22).

4. DRAINAGE INTENSITY: DI is 0.71 in the present river basin. This value is also highest in the Son catchment. This indicates that these are closely spaced stream network in comparison with other sub-basins of the Son catchment.

LENGTH OF OVERLAND FLOW (Lg)

The Lg is 0.40 miles.

BIFURCATION RATIO

Average Rb is 4.17. The Rb of various orders are normal except the Rb of IV and V order streams which is 6 (Table 5.2). There are two 5th order streams whereas there are twelve 4th order streams. The resultant Rb is 6 which is caused by the high relief. Weighted mean Rb is 4.55.

BASIN LENGTH

The river basin has a low basin length of 63 miles.

BASIN PERIMETER (P): It is 189 miles. The basin perimeter is less. Study of contours on the topographical sheets indicates that though the water divides are well defined the perimeter is smooth.

STREAM ENTRANCE ANGLES

The Banas river joins the Son river at a low angle
of approximately 52°. This indicates that both the rivers are flowing approximately at the same height in the area of confluence.

RELIEF ASPECTS

LONGITUDINAL PROFILE

The overall thalweg has a concave shape but noteworthy convexity appears at a portion of the longitudinal profile. (Fig. 5.23). It can be concluded that the river is not graded yet. It can be a matter of load transformation and the ability of river to dispose it downward (Cotton, 1949). Another reason may be that the rock groups of varying resistance have restricted the river to be graded on the Upper valley of the stream or it can be said that in order of gradation, it is a stage of the river valley that has appeared as convexity in the thalweg profile.

GOPAD SUB-BASIN

The Gopad river originates from Deogarh hills in Ambikapur district covering an area of 2106.72 sq. miles. The Gopad river basin is an important sub basin of the Son catchment. Rocks of Bijawars, Semries, Damuda, Mahadeva Groups and Deccan Traps are exposed in the basin. The area lies in Ambikapur, Sidhi and Surguja districts of Madhya Pradesh.
LINEAR ASPECTS

STREAM ORDER

Gopad is a 6th order stream.

STREAM NUMBERS

There are 1692 streams of all orders in the river basin. Number of streams of various orders are tabulated in Table 5.3.

LAW OF STREAM NUMBERS: As described in the methodology at the beginning of the Chapter, the plot on the semi-logarithmic paper has been prepared (Fig. 5.6 A). Minor deflections of points of 1st order and the 5th order, the straight line confirms the Horton's law of stream numbers. The minor deflections of the point of number of streams of the 1st order from the straight line indicates the impact of differential geology and that of slope on the initiation of streams. The number of 5th order streams does not decrease after the fourth order streams in a geometric series. In fact it does not gives a real inverse relation. The reason is that there are only two fifth order streams, whereas 18 fourth order streams. One of the 5th order streams more or less covers the whole river basin and has large number of 4th order streams. It may be influenced by the structure of the underlying rocks to some extent, but it seems more apparent that it is a matter of stage of the fluvial cycle and local slope conditions.

STREAM LENGTHS

The total length of streams of all orders is 3033 miles.
<table>
<thead>
<tr>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Number of stream segments (N₁ to N)</td>
<td>Percent share</td>
<td>Stream length (Miles)</td>
<td>Percent share</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of Columns III &amp; IV</td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1308</td>
<td>77.3</td>
<td>1953</td>
<td>64.39</td>
<td>4.418</td>
<td>1604</td>
<td>7086.47</td>
</tr>
<tr>
<td>II</td>
<td>296</td>
<td>17.4</td>
<td>494</td>
<td>16.28</td>
<td>4.418</td>
<td>363</td>
<td>1603.73</td>
</tr>
<tr>
<td>III</td>
<td>67</td>
<td>3.9</td>
<td>313</td>
<td>10.32</td>
<td>3.72</td>
<td>85</td>
<td>316.2</td>
</tr>
<tr>
<td>IV</td>
<td>18</td>
<td>0.06</td>
<td>124</td>
<td>4.08</td>
<td>9.00</td>
<td>20</td>
<td>180</td>
</tr>
<tr>
<td>V</td>
<td>2</td>
<td>0.1</td>
<td>132</td>
<td>4.35</td>
<td>2.00</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>0.05</td>
<td>17</td>
<td>0.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1692</td>
<td>3033</td>
<td>4.71</td>
<td>2075(B)</td>
<td>9192.4(A)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Length of streams of various orders is given in Table 5.3. The average stream length of the Gopad river basin is 1.79 miles.

LAW OF STREAM LENGTH: The plot confirms the Horton's law of stream lengths (Fig. 5.6 B). Horton stated that if the river basin has a homogeneous climate, lithology and has a simple structure, the average stream lengths when plotted against orders form a direct geometric series. In this respect deflection of 5th order's point is noteworthy. There are two fifth order streams in the river basin and these cover a large part of the basin meandering smoothly over their flood plain and share a greater stream length. It may be possible that structural control has given rise to the present drainage status. Apart from this, it is also possible that the 5th order stream has established itself on the area in order of grading itself and gains a high mean stream length.

STREAM LENGTH RATIO

Stream length ratio has been calculated and given in the Table 5.3.

The plot of the length ratios on the semi-logarithmic paper indicates that points are in a geometric progression with a few exceptions which indicate the complexities (Fig. 5.6 C). The deflection of the length ratio point of the streams of I and II orders is caused by the nature of stream initiation, which is controlled by slope in the present case. The major
GOPAD SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig. 5.7
deflection of the point of the IV and V order ratio from a regular succession of the geometric series, seems to be due to some structural influence. This conclusion is also confirmed by the plots of mean stream length and Rb. Differential lithology may also have an influence over this ratio.

PERCENTAGE ANALYSIS: As described in the methodology, percent of stream numbers and lengths to the total(s) of every order have been found out and plotted on graph paper for the comparison and to find out the deflection of points from mathematical succession.

1. Column Chart (Fig. 5.7 A) indicates that the length of 1st and 2nd order streams has a less share in the total length.

2. The curve of percentage of numbers is smooth whereas the curve showing per cent of lengths possesses anomalies (Fig. 5.7 B).

3. Curve of length (on abcissa) and numbers (on ordinate) is smooth and deflection of points are noteworthy (Fig. 5.7 C).

The results of the percentage analysis supports the conclusions drawn by the laws of stream lengths and numbers.

AREAL ASPECTS

BASIN AREA

The area of the Gopad river basin is 2106.72 sq. miles.
BASIN CONFIGURATION

It comprises the following parameters:

1. FORM FACTOR: The value of Ff for the river basin is 0.397.

2. BASIN CIRCULARITY: The value of basin circularity for the Gopad sub basin is 0.347. It indicates that the shape of the basin does not correspond to the shape of a circle.

"Irregularities in the drainage basin, a function of relief and slope increases the perimeter and this decreases circularity ratio" (Sidhu and Pandey, 1974). The view is true for the present river basin. The ratio also indicates the presence of low dipping beds in the area.

3. BASIN ELONGATION: The value of basin elongation is 0.711. It indicates an elongated shape of the river basin and is inversely related to Re. Comparatively resistant rocks in the sub basin and the length of streams must have influenced this ratio.

4. LAMINICATE: The value of K for the river basin is 0.86.

DRAINAGE NATURE

It comprises the study of following drainage basin properties:

1. DRAINAGE DENSITY: Dd of the present drainage basin is 1.43 miles/mile². The drainage basin possesses the highest Dd in the various sub basins of the Son catchment. It seems
high relief in the upper valley areas and the joints in underlying rocks have played an important part in the comparatively high Dd in the river basin. The catchment area lies in the high relief topography of Deogarh hills and Sonpar hills.

In the present drainage basin, the lower valley areas with broad channels occupied by Bijawar rocks have the highest Dd 2.5 miles/mile$^2$ whereas the Upper Gondwana areas have moderate Dd (1 to 1.5 miles/mile$^2$) and the Upper Gondwana areas (mainly hard sandstones) has the lowest Dd 0.5 to 1 mile/mile$^2$ (Fig. 5.21).

It can be said that apart from the geology, climate and relief have played an important role in the distribution of drainage density in the river basin.

2. TEXTURE: According to Smith's (1950) classification, the basin has a 'very coarse' texture.

3. STREAM FREQUENCY: The stream frequency of the Gopad river basin is 0.803 streams/mile$^2$. In the Son river basin frequency of this sub basin is moderately high in comparison to the other sub basins.

4. DRAINAGE INTENSITY: It is 0.558 for the present drainage basin.

LENGTH OF OVERLAND FLOW (Lg)

The Lg is 0.34 miles for the basin.
BIFURCATION RATIO

The average Rb being 4.7 indicates towards a complex nature of the drainage basin. Rb derived from IV and V order streams is 9 (Table 5.3). It is the highest value of Rb in the present drainage basin. It indicates existence of some structural complexity in the area. Differential geology may be a supporting reason for this high Rb. Difference in rock resistance, mode of erosion and stream initiation in various rock types must have supported this high value of Rb. But the high value indicates to some strong controlling factor such as structural control. The plots of law of stream numbers and lengths profoundly support the view. The value of weighted mean Rb is 4.43.

BASIN LENGTH

The basin length of the Gopad river basin is 72.8 miles. Resistant rocks and stream lengths have supported the 'L'.

PERIMETER

P is 276 miles. The perimeter of the drainage basin is not smooth. Differential lithology has enhanced the perimeter.

STREAM ENTRANCE ANGLES: The angle of confluence of Gopad and Son rivers is 35°. This acute angle came into existence because the slopes of the channel of the tributary (Gopad) and the confluent stream (Son) are nearly same (Horton, 1945).
RELIEF ASPECTS

THALWEG PROFILE

The study of the thalweg of the valley indicates the significant characters of the river. The thalweg of the Upper valley is steeper and is characterised by the Gondwana Group of rocks and is a highly dissected area. The channel has eroded and cut into these beds, producing there by a steep gradient. The moderate steepness of middle valley thalweg is associated with Damuda Series, whereas the river flows on a considerably gentle slope in its lower valley. This part is occupied by Lametas and Talchir formations of the Gondwana Super Group and Bijawars. The lower most part the thalweg is mainly controlled by the Son base level.

The thalweg of the river shows two well-defined breaks in slopes at the heights of 2000 feet and 1000 feet respectively. The 2000 feet break in slope lies in the Surguja district 14 to 16 miles north of Sonhat. The break in slope seems to be retreating. A knickpoint at the height of 1000 feet lies in the Sidhi district approximately 8 miles WNW of Jiawan village. This is caused due to an oblique fault between Lower Proterozoic Bijawar group and Semri Group (Upper proterozoic - Vindhyan Super Group). A water fall is caused due to this fault near Rehi village. Gradient of the thalweg profile indicates that the knick point is also retreating towards upper valley (Fig.5.23).
RIHAND SUB-BASIN

Rihand is the largest sub-basin of Son catchment. The river basin lies in the Sidhi and Surguja districts of Madhya Pradesh and a small part lies in the Mirzapur district of Uttar Pradesh. The river basin covers parts of following quarter inch topographical sheets Nos. 64 I, 64 J, 64 M and 64 N.

LINEAR ASPECTS

STREAM ORDER

The Rihand is a sixth order river.

NUMBER OF STREAMS

The total number of streams of all orders are 2641. Order-wise number of streams are shown in Table 5.4.

LAW OF STREAM NUMBERS: The inverse geometric series formed by the points of numbers with successive orders on the semilog paper confirms the validity of the Horton's law of stream numbers for the present river basin (Fig. 5.8 A).

STREAM LENGTH

The total stream length of all orders in the river basin is 5685 miles. Lengths of various orders are given in Table 5.4.

LAW OF STREAM LENGTHS: Through the analysis of the plot, it is concluded that though all the points do not fall on a
RIHAND SUB-BASIN

A

B

C

Fig. 5.8
### Table 5.4

**Linear Properties of HINAND Sub-Basin**

<table>
<thead>
<tr>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
<td>Number of stream segments (N₁ to N)</td>
<td>Stream length (miles)</td>
<td>Per cent share</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of columns III &amp; IV</td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>2007</td>
<td>75.9</td>
<td>3613</td>
<td>63.5</td>
<td>4.11</td>
<td>2495</td>
<td>10254.4</td>
</tr>
<tr>
<td>II</td>
<td>488</td>
<td>18.47</td>
<td>981</td>
<td>17.25</td>
<td>4.477</td>
<td>597</td>
<td>2672.76</td>
</tr>
<tr>
<td>III</td>
<td>109</td>
<td>4.12</td>
<td>563</td>
<td>9.90</td>
<td>3.63</td>
<td>139</td>
<td>504.57</td>
</tr>
<tr>
<td>IV</td>
<td>30</td>
<td>1.13</td>
<td>279</td>
<td>4.90</td>
<td>5.0</td>
<td>36</td>
<td>180.00</td>
</tr>
<tr>
<td>V</td>
<td>6</td>
<td>0.227</td>
<td>149</td>
<td>2.62</td>
<td>6.00</td>
<td>7</td>
<td>42.00</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>0.03</td>
<td>100</td>
<td>1.75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 2641 | 5685 | 3.64 | 3274(8) | 13653.73(A)
straight line, the deviations are insignificant and the mean stream length is intended to form a direct geometric relation with the increasing stream orders and the plot confirms the law of stream lengths for the river basin (Fig. 5.8 B).

STREAM LENGTH RATIO

The plot indicates two specific displacement of points. These are length ratios of I and II order streams and of II and III order streams. These points are of smaller order streams which are in young stage and are affected mostly by slope and rock resistance (Fig. 5.8 C).

PERCENTAGE ANALYSIS

The conclusions drawn by percentage analysis of linear aspects are:

1. The column chart (Fig. 5.9 A) indicates that I and II order streams have a less share of stream length.

2. The curve of per cent share of stream numbers is smooth but it indicates that the mathematically brought out per cent of stream numbers of IIIrd and IVth orders is more than actual. The curve showing length is smooth and only indicate the minor deflection of II order's per cent share (Fig. 5.9 B).

3. The curve showing per cent of numbers on ordinate and lengths on abscissa indicates anomalies because the river basin is large with variations in lithology, relief and other factors (Fig. 5.9 C).
RIHAND SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig. 5.9
AREAL ASPECTS

BASIN AREA: The area of Rihand river basin is 5354.24 sq. miles.

BASIN CONFIGURATION

1. FORM FACTOR: The value of Ff is 0.36 for the present river basin.

2. CIRCULARITY RATIO (Rc): The value of Rc is 0.287. It can be concluded that the river basin do not correspond to a circle in shape.

3. BASIN ELONGATION: The ratio is 0.67. It indicates an elongated shape of the river basin.

4. LAMNISCATE: The value 0.88 indicates to a proportionate shape of the river basin.

DRAINAGE NATURE

1. DRAINAGE DENSITY: The average Dd is 1.06 miles/sq. mile.

The lower valley area has high Dd ranging from 1.75 to 2.3 miles/mile². Middle river basin area has the Dd between 1 to 1.5 miles/mile² and the higher valley area 0.7 to 1 mile/mile² with some exceptions of high Dd patches in high relief areas (Fig. 5.21).

The analysis indicates that the same trend of Dd distribution has been found in the Banas sub basin of Son catchment in which the high Dd is concentrated in the lower valley area.
It seems that apart from lithological control one more factor is influencing the Dd in the river basin. The water discharge in the lower valley area is highest because all the lower order streams bring the water in higher order streams. On the other hand, in this comparatively plain area meanders have also exaggerated the stream lengths. It is important to note that the same higher Dd area has been chosen for the Rihand reservoir.

2. DRAINAGE TEXTURE: Texture of the drainage basin is very coarse.

3. FREQUENCY: The river basin has a low frequency of 0.49 streams/mile$^2$. The morphometric analysis indicates that this is a mature to old river basin and the low F is a matter of the stage of the cycle. Per cent analysis and column chart also indicate this low F in the river basin.

4. DRAINAGE INTENSITY: DI is 0.46 for Rihand river basin.

LENGTH OF OVERLAND FLOW (Lg)

Lg is 0.47 miles.

BIFURCATION RATIO

The average Rb is 4.64. This is a moderately high Rb in the normal Rb group (that is 2 to 5). Whereas the Rb of various orders reflect approximately a constant relation with each other. The Rb of different orders are moderately high.
Therefore, Rb of 5th and 6th order which is 6, is not important in the present case. This is in fact that outcome of the elongated shape of the basin. The general trend of the Rb(s) in the present river basin may have been caused by different geology in different part of the river basin.

**BASIN LENGTH**

Basin length is 122 miles.

**BASIN PERIMETER**

The perimeter of the river basin is 484 miles.

**STREAM ENTRANCE ANGLE** : The Rihand joins the Son river forming a 'right' angle.

**RELIEF ASPECTS**

**THALWEG PROFILE** : Analysis shows that the river valley has a simple thalweg profile but a typical trend is there. In the middle valley area, approximately 15 miles from the origin, the curve of the profile does not show any drop in the gradient and this is continuous at least upto 90 miles. When the stream enters from the high areas of pat country to the low relief area of Surguja basin (average height 450 to 600 m above MSL) the gentle slope of the Surguja basin controls the gradient of thalweg profile (Fig. 5.23).
JOHILLA SUB-BASIN

The Johilla sub-basin of the Son catchment lies in the Shahdol district. The area falls in the quarter inch topographical sheets Nos. 64 A, 64 E and 64 F. The morphometric analysis has been done in terms of the following parameters:

LINEAR ASPECTS

STREAM ORDER

Johilla is a 5th order stream. It is a narrow and elongated river basin, that is why instead of forming higher orders the tributary streams join the trunk stream directly without flowing to a considerable distance.

STREAM NUMBERS

The total number of streams of various orders are 763. Orderwise stream number are given in Table 5.5

LAW OF STREAM NUMBERS: A perfect inverse relation between stream numbers and increasing stream order profoundly supports the Horton's law for the river basin.

STREAM LENGTH

The total stream length of all orders is 1560 miles. Table 5.5 show the stream lengths of various orders.

LAW OF STREAM LENGTHS: By analysis the plotted mean stream lengths against the stream orders it is concluded that though the mean stream lengths are not increasing in perfect
JOHILA SUB-BASIN

LAW OF STREAM NUMBERS

LAW OF STREAM LengthS

MEAN LENGTH RATIO

NUMBER OF STREAMS

MEAN STREAM LENGTH

MEAN LENGTH RATIO

STREAM ORDERS

Fig. 5.10
<table>
<thead>
<tr>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Number of stream segments (N₁ to N)</td>
<td>Percent share</td>
<td>Stream length (Miles)</td>
<td>Percent share</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of Columns III &amp; IV</td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>602</td>
<td>78.89</td>
<td>984</td>
<td>63.0</td>
<td>4.66</td>
<td>731</td>
<td>3406.46</td>
</tr>
<tr>
<td>II</td>
<td>129</td>
<td>16.90</td>
<td>315</td>
<td>20.19</td>
<td>4.77</td>
<td>156</td>
<td>744.12</td>
</tr>
<tr>
<td>III</td>
<td>27</td>
<td>3.53</td>
<td>100</td>
<td>6.4</td>
<td>6.75</td>
<td>31</td>
<td>209.25</td>
</tr>
<tr>
<td>IV</td>
<td>4</td>
<td>0.52</td>
<td>89</td>
<td>5.70</td>
<td>4.00</td>
<td>5</td>
<td>20.0</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>0.13</td>
<td>72</td>
<td>4.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>763</td>
<td>1560</td>
<td>3.045</td>
<td>923(B)</td>
<td>4379.33(A)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
mathematical sequence, the departures of the points from the straight line are not significant. These deflections are caused by differential erosion (Fig. 5.10 B).

STREAM LENGTH RATIO

The plot indicates that the stream length ratios do not form any sequence at all (Fig. 5.10 C). The impact of differential geology and high relief throughout the river basin is confirmed here by the stream length ratio analysis. High sinuosity, specially in the western part of the river basin, must be having an influence over the length ratio.

PERCENTAGE ANALYSIS

1. Column chart indicates that the first and second order streams share less percentage of stream length (Fig. 5.11 A).

2. Both the curves of lengths and numbers are smooth and no significant anomalies are there (Fig. 5.11 B).

3. The curve of length drawn on abcissa and numbers on ordinate is also gentle and smooth (Fig. 5.11 C).

The percentage analysis indicates that Johilla river basin is free from any major complexities. It is a high relief area with uniform dissection throughout the river basin.

AREAL ASPECTS

BASIN AREA

The area of the river basin is 1176.16 sq. miles.
JOHILA SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig 5.11
BASIN CONFIGURATION

1. FORM FACTOR: The value of form factor of the river basin is 0.159.

2. CIRCULARITY RATIO: The Rc is 0.17. The ratio indicates that the river basin is not correspondent to a circle.

3. BASIN ELONGATION: The value of basin elongation is 0.5. The element of elongation is far more greater than circularity. It is a narrow and elongated river basin with V shaped valleys and high relief.

4. LAMINISCATE: Though the value of K is 0.97 but it is a misleading value. The layout of the river basin is curved and accurate length of basin cannot be derived (by which the value of K is obtained) that is why the validity of this parameter is questionable.

DRAINAGE NATURE

1. DRAINAGE DENSITY: Average Dd is 1.32 miles/mile$^2$. This is among the high Dd in the sub basins of Son catchment. The gridwise Dd (Fig. 5.21) varies between 1.1 to 2.3 miles/mile$^2$. The impact of lithology over the Dd in the present river basin is not noteworthy. The high relief areas which are concentrated around the source of the river have high Dd ranging between 1.7 to 2.3 miles/mile$^2$. The rest of the river basin has a uniform Dd ranging between 1.1 to 1.5 miles/mile$^2$.

2. DRAINAGE TEXTURE: Texture of the river basin is very coarse.
3. **FREQUENCY**: \( F \) is 0.648 streams/mile\(^2\) in the river basin. It has moderately high \( F \) in the sub basin of Son catchment. High relief and steep slopes have supported the stream initiation causing moderately high stream frequency.

4. **DRAINAGE INTENSITY**: The value of DI is 0.49 for the present river basin.

**LENGTH OF OVERLAND FLOW**

The \( Lg \) is 0.378 miles. It is among low \( Lg \) in the Son catchment.

**BIFURCATION RATIO**

The average \( Rb \) for the Johilla river basin is 5. It is the highest limit of the normal \( Rb \) (2 to 5). High relief throughout the river basin has given rise to the present \( Rb \). The \( Rb(s) \) of the various orders are constant except the ratio of 3rd and 4th orders which is 6.6. There are 27 streams of 3rd order whereas only four 4th order streams. In this narrow river basin streams of smaller order directly join the higher order streams and they do not form many streams of higher orders. It seems that the area is in young to mature stage and is characterised by high dissection and steep slopes.

Weighted Mean \( Rb \) is 4.74 in the river basin.

**BASIN LENGTH**

It is 86 miles. The layout of the river basin is semi-circular in shape that is why the 'L' is not a straight line.
PERIMETER

The perimeter of the river basin is 275 miles. Being a high relief and dissected area the water divides are sharp. This line encircling the river basin is not smooth and is zigzag that is why the perimeter is more though the area of the river basin is not very large.

STREAM ENTRANCE ANGLES

Johilla meets the Son at 90°. This indicates that the slope of Johilla river's thalweg is steeper than that of Son in the area of confluence structural control confluence may also be the reason of this right angle.

RELIEF ASPECTS

LONGITUDINAL PROFILE

Two breaks in the slope appears on the thalweg profile of the river valley (Fig.5.23). The first break is marked by the immediate steep gradient from the height of 2250 feet to 2000 feet within two miles. Second break is at the height of 2000 feet to immediate drop of 1500 feet within three miles. These breaks actually are not at a point, but these are marked changes in the slope within a small area. Change in rock resistance could be a reason for these breaks but no clear evidence is there. On both these points of change in slope small tributaries are joining the trunk stream. It seems that the amount of debris load transferred on to the main river has forced the trunk stream to steepen itself in order to dispose it off. The Johilla river makes a number of meanders in this
area and flood plain though of limited breadth can be marked. The confluence of any active tributary may cause a break in slope like this (Cotton 1949).

KUNUK SUB BASIN

Major part of the Kunuk river basin lies in the Shahdol and Surguja districts of Madhya Pradesh. The basin area lies in topographic sheet No. 64 E.

LINEAR ASPECTS

STREAM ORDER

Kunuk is a 5th order stream.

STREAM NUMBERS

There are 198 streams of all orders in the river basin. Number of streams of various orders are shown in Table 5.6.

LAW OF STREAM NUMBERS: The plot confirms the Horton's law in the drainage basin has an inverse relation with stream numbers of successive orders (Fig. 5.12 A).

STREAM LENGTH

The total stream length is 389 miles. Orderwise stream length is given in Table 5.6.

LAW OF STREAM LENGTHS: The plot of mean stream lengths against successive orders indicate that the points are not forming a perfect geometric sequence. Deflection of higher orders points
<table>
<thead>
<tr>
<th>Column No.</th>
<th>Parameters</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of stream segments ($N_1$ to $N$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orders</td>
<td>Per cent share</td>
<td>Stream length (Miles)</td>
<td>Per cent share</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of Columns III &amp; IV</td>
<td>Average stream length (Miles)</td>
<td>Mean length ratio</td>
</tr>
<tr>
<td>I</td>
<td>155</td>
<td>78.2</td>
<td>238</td>
<td>61.18</td>
<td>5.16</td>
<td>185</td>
<td>954.6</td>
<td>1.53</td>
</tr>
<tr>
<td>II</td>
<td>30</td>
<td>15.5</td>
<td>70</td>
<td>17.99</td>
<td>3.00</td>
<td>40</td>
<td>120.0</td>
<td>2.33</td>
</tr>
<tr>
<td>III</td>
<td>10</td>
<td>5.05</td>
<td>44</td>
<td>11.31</td>
<td>5.00</td>
<td>12</td>
<td>60.0</td>
<td>4.4</td>
</tr>
<tr>
<td>IV</td>
<td>2</td>
<td>1.01</td>
<td>16</td>
<td>4.11</td>
<td>2.00</td>
<td>3</td>
<td>6.0</td>
<td>8.0</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>0.50</td>
<td>21</td>
<td>5.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>198</td>
<td>389</td>
<td>3.7</td>
<td>240(B)</td>
<td>1140.6(A)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
is noteworthy. Low relief of lower valley area has most of
the higher order streams. Gentle slope and comparatively
later stage of cycle has exaggerated the stream lengths (Fig.
5.12 B).

MEAN LENGTH RATIO

The plot of the mean length ratio indicates that the
actual mean length ratio of III and IV order streams is higher
in comparison to the mathematical expression on the plot (Fig.
5.12 C).

PERCENTAGE ANALYSIS

1. The column chart (Fig. 5.13 A) indicates that the higher
order streams share more stream length to the total,
whereas I and II order streams share a less percentage of
stream length.

2. The curve showing per cent share of number of streams to
the total is smooth whereas the curve showing length has
anomalies. The curve confirms the results of mean stream
length analysis i.e. the higher order streams, specially
III and IV orders, have a high percentage of stream length.
The deflection from the mathematical curve can be seen in
Fig. 5.13 B.

3. The curve showing percentages of stream numbers against
stream lengths confirm the previous results. It also
indicates to a smaller share of stream length of the II
order streams (Fig. 5.13 C).
KUNUK SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig 5.13
AREAL ASPECTS

BASIN AREA

The catchment area of Kunuk river is 317.76 sq. miles.

BASIN CONFIGURATION

1. FORM FACTOR: The value of $F_f$ for the river basin is 0.25.

2. CIRCULARITY RATIO: The value of $R_c$ is 0.39. This indicates that the river basin is less proportionate to a circle.

3. BASIN ELONGATION: The value of $E$ is 0.56 for the present river basin. The value indicates to a moderately elongated shape.

4. LAMINISCATE: The value of $'K'$ is 0.94. This indicates to a proportionate shape of the river basin.

DRAINAGE NATURE

1. DRAINAGE DENSITY: The average $D_d$ is 1.22 miles/mile$^2$. The gridwise $D_d$ ranges between 1.1 to 1.57 (Fig. 5.21). The higher $D_d$ areas are concentrated in the high and dissected north-eastern, southeastern, north-western and south-western parts of the river basin. The main high relief area comprises of Mahadeva formations. The western high relief area is characterised by plutons. Damuda group forms the middle plain area of the river basin, which has low $D_d$.

2. STREAM FREQUENCY: The Kunuk river basin has a moderately
high stream frequency amongst the sub-basins of Son catchment. The high F is related to high relief in the most part of the river basin.

DRAINAGE INTENSITY: The DI is 0.51 for the present river basin.

LENGTH OF OVERLAND FLOW

Lg is 0.40 miles.

BIFURCATION RATIO

The average Rb which is 3.79 indicates a river basin of moderate relief having simple structure and geology. Rb of various stream orders are shown in Table 5.6.

WEIGHTED MEAN BIFURCATION RATIO: The value of the ratio is 4.75.

BASIN LENGTH

The L is 35.6 miles.

BASIN PERIMETER

P is 100 miles. The river basin has a smooth perimeter except along the eastern margin of the river basin.

ANGLE OF CONFLUENCE

The Kunuk river joins the confluent river Son at an angle of 83° (app.). This indicates that the thalweg slope of the tributary stream is greater at the site of confluence.
RELIEF ASPECTS

LONGITUDINAL PROFILE

It is a simple thalweg profile which is concave in nature (Fig. 5.23). The profile is a bit steeper in upper valley area where the river descends from resistant Mahadeva formations.

KEUAI SUB-BASIN

The Keuai river basin lies in the Surguja and Shahdol districts and falls in topographical sheets Nos. 64 E and 64 L.

LINEAR ASPECTS

STREAM ORDER

Keuai is a 5th order stream.

NUMBER OF STREAMS

There are 147 streams of all order in the river basin. The number of streams of various orders are given in Table 5.7.

LAW OF STREAM NUMBERS: The straight line on the plot forms an inverse geometric series and thus confirms the Horton's law of stream numbers for the Keuai river basin (Fig. 5.14 A).

STREAM LENGTH

The total stream length of all orders is 378 miles. The stream lengths of various orders are tabulated in Table 5.7.
KEUAI SUB-BASIN

LAW OF STREAM NUMBERS

LAW OF STREAM LENGTHS

MEAN LENGTH RATIO

NUMBER OF STREAMS

MEAN STREAM LENGTH (MILES)

MEAN STREAM LENGTH (RATIO)

STREAM ORDERS

A

B

C

Fig. 5.14
<table>
<thead>
<tr>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>112</td>
<td>76.00</td>
<td>209</td>
<td>55.29</td>
<td>139</td>
<td>575.46</td>
<td>1.86</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>18.38</td>
<td>78</td>
<td>20.6</td>
<td>32</td>
<td>172.8</td>
<td>2.88</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>03.4</td>
<td>48</td>
<td>12.69</td>
<td>7</td>
<td>17.5</td>
<td>9.6</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1.36</td>
<td>16</td>
<td>4.23</td>
<td>3</td>
<td>6.0</td>
<td>8.0</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>0.68</td>
<td>27</td>
<td>7.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>147</td>
<td>378</td>
<td>3.51</td>
<td>181(B)</td>
<td>771.76(A)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LAW OF STREAM LENGTHS: The plot indicates that the mean stream lengths are not increasing in a perfect geometric sequence. Deviation of the points of higher order streams is noteworthy. The points of higher order streams on the plot indicate that they attain high mean lengths than the mathematical increase suggested by the plot (Fig. 5.14 B). The streams of higher orders have graded themselves and these are long meandering streams thus having higher mean length. The impact of Son river base level is also evident here.

MEAN LENGTH RATIO

Departures of the points on the plot indicate that the mean length ratios do not form a geometric series, i.e. does not have an inverse relation with increasing stream orders (Fig. 5.14 C). The upper valley area is a high relief area whereas the lower valley area is nearly plain. The streams of lower valley area attain their maximum length specially the higher order streams, whereas lower order streams of high relief area are smaller in length. Even though these are large in number they do not altogether share a considerable amount of total stream length. The upper valley area mainly comprises of Upper Gondwana resistant rocks, which form high relief area, thus there area a number of small streams. On the contrary, the softer rocks of Lower Gondwana lie in the lower valley area which is more or less plain and long streams with less frequency occurs. Same conditions of rock groups and relief prevails in the adjacent Kunuk sub-basin of Son catchment, and similar ratios and mathematical results are acheived (Gupta, 1987).
KEUAI SUB-BASIN

PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig. 5.15
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

1. The column chart indicates that the higher order streams share a high percentage of stream lengths whereas the percent shared by lower orders is less (Fig. 5.15 A).

2. The curves of percentages of lengths and numbers elaborate the anomaly described above. Firstly, deflections of points of higher orders, specially of III and V orders from the mathematical curve express large share of stream length. Secondly, deflection of III order point which indicates to a less share of stream numbers (Fig. 5.15 B).

3. The curve indicating the length and numbers (plotted on the abscissa and ordinate respectively) confirms the above conclusions (Fig. 5.15 C).

AREAL ASPECTS

BASIN AREA

The area of the river basin is 394.88 sq. miles.

BASIN CONFIGURATION

It is studied in terms of following parameters:

1. FORM FACTOR: The value of the form factor for the river basin is 0.3.

2. BASIN CIRCULARITY: The value of Rc is 0.49. This value indicates a normal basin neither circular nor too elongated. The dendritic type of drainage helped in attaining the present configuration of the river basin.
3. **BASIN ELONGATION**: The value of $E$ is 0.61. The element of elongation is slightly more because of the exaggerated length of higher order streams.

4. **LAMNISCATE**: The value of lamniscate is 0.92. The ratio close to 1 indicates a proportional shape of the river basin.

**DRAINAGE NATURE**

1. **DRAINAGE DENSITY**: The average $D_d$, which is 0.95 miles/mile$^2$, is the lowest $D_d$ in the sub-basins of Son catchment. $D_d$ in the river basin varies between 0.77 to 1.5 miles per mile$^2$. The area around Mahora pahar (3372') has the highest $D_d$ in the sub-basin. The $D_d$, 1 to 1.5 miles/mile$^2$ is concentrated in the areas occupied by the Mahadeva formations of Upper Gondwanas. This high $D_d$ area is characterised by higher relief and intense dissection. The lower $D_d$ between 0.77 to 1 mile/mile$^2$ are found in the area occupied by Damuda group of Lower Gondwanas rocks. This is nearly plain area.

2. **FREQUENCY**: The $F$ is 0.37 stream/mile$^2$ in the river basin. The present drainage basin has the lowest stream frequency in all the sub-basins of the Son catchment. Less number of streams in the lower valley plain area, which form a major part of the river basin, is the reason for the low stream frequency.

3. **DRAINAGE INTENSITY**: The $D_i$ is 0.38.

**LENGTH OF OVERLAND FLOW**

$L_g$ is 0.526 miles. Keuai attains the highest value of
Lg in the Son basin.

BIFURCATION RATIO

The average Rb is 3.51 for the Keuai river basin. The Rb(s) of various orders are not constant. There are twenty-seven II order streams, whereas only five 3rd order streams and the resultant Rb is 5.4. It may be concluded that the higher order streams which are in mature to old stage and are nearly graded. These are less in number and are mainly concentrated in the lower basin area. On the other hand, upper basin has lower order streams which are large in number due to high relief and young to mature stage of topography.

Weighted Mean Bifurcation Ratio is 4.26.

BASIN LENGTH

'L' is 36.2 miles.

BASIN PERIMETER

P is 100 miles. Water divide is smooth because of low relief in western, southern and eastern parts of the river basin. Only northern boundary has high relief and forms a zigzag perimeter.

STREAM ENTRANCE ANGLE

The angle of confluence is very low 11°. The Keuai and Son flows at same level in the area of confluence.
RELIEF ASPECTS

THALWEG PROFILE

The thalweg slope is very steep in the upper valley portion. Within eight miles from the origin, the valley descends from a height of 3000 feet to 1600 feet. Further on the thalweg is gentle sloping without showing any significant drop. The thalweg gives the picture of the slope condition of the river basin at a glance (Fig. 5.23).

TIPAN SUB-BASIN

Tipan is the smallest sub-basin of the Son catchment. It lies in the Shandol and Bilaspur districts of Madhya Pradesh and falls in Survey of India topographic sheet No. 64 E and 64 F.

LINEAR ASPECTS

STREAM ORDER

The Tipan is a 4th order stream.

STREAM NUMBERS

There are 145 streams of all orders in the river basin. The number of stream of various orders are shown in Table 5.8.

LAW OF STREAM NUMBERS: The plot on the semilogarithmic paper shows an inverse geometric relation between stream numbers and successive orders, thus confirming the Horton's law. The area has a homogeneous and simple geology (Fig. 5.16 A).
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Column No.</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of stream segments ($N_1$ to $N$)</td>
<td>Percent share</td>
<td>Stream length (Miles)</td>
<td>Percent share</td>
<td>Bifurcation ratio</td>
<td>Number of streams involved in the ratio</td>
<td>Product of Columns III &amp; IV</td>
</tr>
<tr>
<td>Orders</td>
<td></td>
<td>I</td>
<td>114</td>
<td>78.6</td>
<td>237</td>
<td>62.8</td>
<td>4.38</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II</td>
<td>26</td>
<td>17.9</td>
<td>80</td>
<td>21.2</td>
<td>6.5</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>III</td>
<td>4</td>
<td>2.75</td>
<td>40</td>
<td>10.6</td>
<td>4.0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IV</td>
<td>1</td>
<td>0.68</td>
<td>20</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>145</td>
<td>377</td>
<td>4.96</td>
<td>175(A)</td>
<td>828.2(B)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 5.8
LINEAR PROPERTIES OF TIPAN SUB-BASIN
STREAM LENGTH

The total stream length is 377 miles in the river basin. Order wise stream length is given in Table 5.88

LAW OF STREAM LENGTHS: The plot of mean stream lengths against their successive orders form a direct geometric series, thus confirming the Horton's law for the Tipan river basin. Straight lines of both the plots of stream numbers and lengths against their successive orders, and the profound confirmation of Horton's law of stream numbers and lengths indicate that there is homogeneity in geology, structure, climate and relief in the river basin (Fig. 5.16 B).

MEAN LENGTH RATIO: The deflection of points on the plot is noteworthy (Fig. 5.16 C). The reason of this deflection must lie in the gentle slope towards the centre of the basin.

PERCENTAGE ANALYSIS

1. Column chart indicates that the streams of higher order share more percentage of stream lengths (Fig. 5.17 A).

2. The curve showing stream numbers indicates that the III order has a low per cent of stream numbers. The curve showing length is not smooth because of the large share of stream length gained by the higher order stream (Fig. 5.17 B).

3. The curve showing steep drop from the I order stream indicates that the per cent share of length is less in lower order streams (Fig. 5.17 C).
TIPAN SUB-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

Fig. 5.17
AREAL ASPECTS

BASIN AREA

The catchment area of Tipan river basin is 288.32 sq. miles.

BASIN CONFIGURATION

Following parameters reveal the shape of the river basin:

1. FORM FACTOR: Ff is 0.174 for the sub-basin.

2. CIRCULARITY RATIO: The value of Rc is 0.62 for the present drainage basin.

3. BASIN ELONGATION: This ratio is 0.472 for the drainage basin.

4. LAMNISCATE: The value of K is 0.97. This indicates that the Tipan drainage basin has a proportionate shape. Though the element of Rc is more but it is not dominant.

DRAINAGE NATURE

1. DRAINAGE DENSITY: Average Dd of the drainage basin is 1.3 miles/sq. mile. Gentle slope and long rivers have supported the Dd.

2. DRAINAGE TEXTURE: The drainage basin has a very coarse texture.

3. STREAM FREQUENCY: The drainage basin has a low drainage
frequency of 0.50 streams/mile². Low relief throughout the sub basin is the reason for low stream frequency.

4. DRAINAGE INTENSITY: The Di is 0.38. The drainage area is close to the Son river and due to the effect of Son base level the area has very low relief thus the stream numbers are limited apart from the stream lengths which are exaggerated by the gentle slope, specially of the higher order streams.

LENGTH OF OVERLAND FLOW

The Lg is 0.38 miles.

BIFURCATION RATIO

The average Rb is 4.96. Rb of various orders are moderately high and the Rb of 2nd and third order streams is 6.5 (Table 5.8). There are only four 3rd order streams whereas 26 second order streams. It is a small river basin and IIInd order streams directly join the IVth order stream which is the trunk stream. The pinnate type of drainage pattern must have influenced the Rb, because the semi-parallel type of streams of I and II orders are long enough and they join the IV order stream directly, unlike the dendritic type of pattern.

Another aspect which is noteworthy here is that the streams seem to have graded themselves and bifurcation of tributaries from the main streams no longer depends upon the initial relief and structure.
These conclusions explain why an area of simple geology, structure, and low relief such as small Tipan drainage basin has moderately high Rb.

WEIGHTED MEAN BIFURCATION RATIO is 4.73.

BASIN LENGTH

The drainage basin has the basin length of 40.6 miles.

BASIN PERIMETER

The river basin has a small perimeter of 79 miles. The line encircling the drainage basin is smooth because the water divides are not sharp except in the SW area which separates the present basin from the Johilla river basin.

STREAM ENTRANCE ANGLE

Tipan river joins the Son river forming an angle of 90°.

RELIEF ASPECTS

LONGITUDINAL PROFILE

The thalweg profile indicates negligible drop in the gradient throughout its length. It seems that whole Tipan drainage basin is influenced by the Son river base level thus having a very low relief area and graded streams (Fig. 5.23).
MORPHOMETRIC ANALYSIS OF SON RIVER BASIN

"Understanding of the relationships between basin characteristics is necessary because relationships can be compared from one area to another and this knowledge is necessary before extensions can be made spatially before relations between particular drainage basin characteristics and drainage basin properties can be sought" (Gregori and Walling, 1973).

For micro study and in order to get accurate results no sampling method is applied but the morphometric analysis of every sub basin of Son catchment has been done in previous pages. Through this analysis detailed morphometric properties and their behaviour have been studied. Every sub-basin has its own specific character regarding the various parameters. By studying all the sub-basins in detail it has been possible to evaluate the different parameters in each one of them. In this way comparison of the drainage sub basins of the Son river basin in quantitative terms is possible. This is an important aspect and contribution of morphometric analysis.

No two drainage basins in nature can be exactly alike. They always have their own specific characters because the evolution and development of any drainage basin is controlled by a number of factors i.e. climate, geology, structure, vegetation cover, stage of cycle of erosion etc. Any of these factors can be dominant in a drainage basin and can be a secondary factor in another, in other words, every sub-basin
has its own dimension and characteristics or morphometric behaviour which come into existance as a result of the efficiency of one of the controlling factors.

It is observed that though the value of various parameters show specific characteristics and within a drainage basin, they are not altogether different from one another. In this respect the example of Kevai and Kunuk river basins is interesting. These adjacent drainage basins have similar geology, climate and vegetation cover. When the values of parameters were compared it was found that they have similarity not only in areal aspects but in linear and relief aspects also.

The statistical data for the various drainage basins of the tributaries of Son catchment are averaged and then the values for the Son river basin have been derived. Rest of the parameters have been calculated separately for the Son river basin such as basin length, basin perimeter, elements of basin configuration etc. (Table 5.11).

LINEAR ASPECTS

Linear aspects comprise of the following parameters:

STREAM ORDERS (O)

In the hierarchy of stream orders the trunk stream of the Son river is designated as the 7th order stream.
STREAM NUMBERS (Ns)

There are 11,247 stream segments of all orders in the Son river basin. The first order streams are highest in number. The total number of streams decreases as the order increases. The total number of streams of various orders are tabulated in Table 5.10.

LAW OF STREAM NUMBERS: The straight line of the plot on semilogarithmic paper strongly confirms the validity of Horton's law in the Son river basin. The points indicate an inverse geometric relation between stream numbers and increasing stream orders (Fig. 5.18 A).

STREAM LENGTH (L)

The total length of all orders in the river basin is 22,192 miles. The order wise length of streams is tabulated in Table 5.10. The first order streams have the largest share in the total stream length because of their large number though they are small in length. Mean stream length of every order has also been determined.

LAW OF STREAM LENGTHS: The mean stream lengths when plotted against successive stream orders, indicate a regular decrease, though the points do not form a perfect geometric series. It indicates that the mean stream lengths do not have a perfect inverse relation with stream order in a true mathematical sequence (Fig. 5.18 B).
<table>
<thead>
<tr>
<th>Name of the Sub-Basin</th>
<th>Stream Numbers (N&lt;sub&gt;1&lt;/sub&gt; to N)</th>
<th>Stream Length (L) (in miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STREAM ORDERS</td>
<td>STREAM ORDERS</td>
</tr>
<tr>
<td></td>
<td>I       II     III    IV     V     VI   VII</td>
<td>I       II     III    IV     V     VI   VII</td>
</tr>
<tr>
<td>Gopad</td>
<td>1308    296   67     18     2     1   -</td>
<td>1953    494   313    124    132    17   -</td>
</tr>
<tr>
<td>Banas</td>
<td>936     203   46     12     2     1   -</td>
<td>928     361   180    124    87     1   -</td>
</tr>
<tr>
<td>Khandi</td>
<td>2007    488   109    30     6     1   -</td>
<td>3613    981   563    279    149    100  -</td>
</tr>
<tr>
<td>Mahanadi</td>
<td>1038    254   59     16     4     1   -</td>
<td>1784    569   338    134    116    42   -</td>
</tr>
<tr>
<td>Johilla</td>
<td>602     129   27     4      1     -   -</td>
<td>984     315   100    89     72     -   -</td>
</tr>
<tr>
<td>Kunuk</td>
<td>155     30    10     2      1     -   -</td>
<td>238     70    44     16     21     -   -</td>
</tr>
<tr>
<td>Keuai</td>
<td>112     27    5      2      1     -   -</td>
<td>209     78    48     16     27     -   -</td>
</tr>
<tr>
<td>Ilipan</td>
<td>114     26    4      1      1     -   -</td>
<td>237     80    40     20     -     -   -</td>
</tr>
<tr>
<td>Son Valley</td>
<td>2423    535   110    19     0     1    1</td>
<td>3941    1108  598    202    46     111.2 100</td>
</tr>
<tr>
<td>Total</td>
<td>8695    1988  437    104    17     5    1</td>
<td>13887   4056  2224   1004    650    271.2 100</td>
</tr>
</tbody>
</table>

*Table 5.9: Son River Basin*
SON RIVER BASIN

A

NUMBER OF STREAMS

10,000

100

10

1

1 2 3 4 5 6 7

MEAN STREAM LENGTHS (MILES)

100

10

1

1 2 3 4 5 6 7 8

B

STREAM ORDERS

C

MEAN LENGTH

RATIO

MEAN LENGTH RATIO

Fig. 5.18
STRAHLEK'S LAW OF STREAM LENGTH

TOTAL STREAM LENGTH (MILES)

STRAHLEK'S LAW OF STREAM LENGTH

SON RIVER BASIN

ACCORDING TO STRAHLER
Though all the points do not fall in a straight line the deviation of the points is not very significant. The 'law' was postulated assuming that the whole area should have a similar geology, simple structure, insignificant variation of climate and vegetative cover etc. In this respect it can be concluded that the large area such as that of the Son river basin has variations in these factors. They must have affected the intensity and mode of erosion, thus the drainage shows the resultant trends. Resistance of rock, relief, initial slope, climate, stage of the fluvial cycle are the main factors which are associated with length. A specific factor or the combination of various factors have affected the stream segments locally. This has been proved while analysing the sub-basins. When an overall picture has been drawn, the anomalies are clearly indicated by the slight deviations of the points from a straight line.

STREAM LENGTH RATIO (r1)

The length ratio should be approximately constant for a given drainage basin and this increase in mean stream length should be roughly three times with each increase in order (Strahler, 1952). But it is not so in the present case as the data indicates. The Table 5.10 shows that all the ratios vary between 1.28 to 3.96. They do not indicate a constant trend when plotted (Fig. 5.18 C). According to Strahler, chance variation in the configuration of any drainage system can produce inequalities of observed length ratio from one order to another.
PERCENTAGE ANALYSIS OF THE LINEAR ASPECTS

The plots of percentages of stream numbers and lengths to the total gives interesting results about the drainage of the area.

1. COLUMN CHART: The per cent share of stream numbers decreases as the order increases and the per cent share of stream length increases with the increase in order. Though the increase in length does not follow a constant trend, it can be said that the per cent share of stream length is greater in higher orders and per cent share of stream numbers is greater in lower orders specially in the 1st and 2nd orders streams (Fig. 5.19 A).

2. CURVES: These curves clearly indicate the stream orders which do not follow the constant trend either in stream length or in stream numbers. Immediate drop in the curve showing numbers from first order's per-cent to the second is noteworthy. The third order stream has less per cent share of stream numbers in comparison to the mathematical expression (Fig. 5.19 B).

There is minor deflections of points in the curve showing per cent share of lengths.

3. The third graph (Fig. 5.19 C) is a curve showing per-cent share of numbers (on ordinate), against the per cent share of stream lengths (on abscissa). The curve is smooth except for the deflection of the point indicating that of II order stream
SON RIVER-BASIN
PERCENTAGE ANALYSIS OF LINEAR ASPECTS

A

B

C

Fig. 5.19

STREAM NUMBERS AND LENGTHS (PER CENT)

0 1 2 3 4 5 6 7

0 1 2 3 4 5 6 7

0 10 20 30 40 50 60 70

STREAM ORDERS

STREAM ORDERS

STREAM LENGTHS (%)

II

NUMBER

LENGTH

III

VI

VII
that has a less per cent of length.

4. The plot of percentages of stream numbers of every order on a semilogarithmic paper (Fig. 5.20 A) indicates that the share of stream numbers of various orders to the total is proportionate, that is why the points form a geometric series.

The plot of percentages of stream lengths indicates an approximate geometric progression though not a perfect series. The percentages of stream lengths of various orders form an inverse relation with the stream order i.e. the per cent share of the length to the total, decreases as the order increases.

The plots of percentages of stream lengths and numbers of various sub basins to their successive orders on semi-log paper is prepared to see the trends of these percentages for all the sub basins at a glance.

5. In the plot showing percentages of numbers, it can be seen that as the order increases the variations between the sub-basins for a fixed order also increases. It is interesting to note that the 5th and 6th orders have the highest variation among the sub-basins, i.e. the fifth order has the highest range in sharing the number of streams to the total in the sub-basins of Son catchment. This may be a matter of the gradation of higher order streams. Differential geology and mode of erosion may also be influencing this variation.

6. The percentages of stream lengths of various sub basins have also been plotted against the stream order to find out
SON RIVER BASIN

PERCENT ANALYSIS OF LINEAR ASPECTS

A

Percentage of Stream numbers and lengths of various orders in Son River Basin

B

Range of percentage of Number of streams in various Sub-basins among the stream orders

C

Range of percentage of stream lengths in various Sub-basins among the stream orders

Fig. 5.20
the correlation among various sub basins. Analysis of this plot indicates two things.

First: The per cent share of the stream length in various sub basins varies greatly in the higher orders. There are four 6th order streams in the Son drainage basin and all of them not only vary in the share of the length, they show a wide range of dissimilarity in the percentages.

Second: The 4th and 5th order streams of all the sub-basins do not show any accordance with the mathematical series. It is important to note that the mean length ratio of same orders shows dissimilarity as it has the highest value of r lie 3.96. The Rb of the same orders is highest in the Son drainage basin i.e. 6.117.

In this way it can be said that percentage analysis helps to study the nature of stream length and numbers in detail.

AREAL ASPECTS

BASIN AREA (A)

The catchment area of Son river basin is spread over 46820.673 sq kms.

BASIN CONFIGURATION

The shape of the drainage basin is studied in terms of the following parameters:

1. FORM FACTOR (Ff): The value of Ff for the river basin is 0.61.
SON RIVER BASIN
DRAINAGE DENSITY

SCALE

Fig. 5.21
<table>
<thead>
<tr>
<th>Stream Order</th>
<th>Column No. I</th>
<th>NUMBERS</th>
<th>LENGTHS</th>
<th>NUMBERS</th>
<th>LENGTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Stream Segments (N₁ to N)</td>
<td>'d'</td>
<td>Number of Streams involved in the ratio</td>
<td>Product of Column III &amp; IV</td>
<td>of No. to the Total Numbers</td>
</tr>
<tr>
<td>I</td>
<td>8695</td>
<td>4.373</td>
<td>10683</td>
<td>46684.71</td>
<td>77.30</td>
</tr>
<tr>
<td>II</td>
<td>1988</td>
<td>4.549</td>
<td>2425</td>
<td>11031.32</td>
<td>17.67</td>
</tr>
<tr>
<td>III</td>
<td>437</td>
<td>4.202</td>
<td>541</td>
<td>2273.28</td>
<td>3.88</td>
</tr>
<tr>
<td>IV</td>
<td>104</td>
<td>6.117</td>
<td>121</td>
<td>740.15</td>
<td>0.92</td>
</tr>
<tr>
<td>V</td>
<td>17</td>
<td>3.4</td>
<td>22</td>
<td>74.8</td>
<td>0.15</td>
</tr>
<tr>
<td>VI</td>
<td>5</td>
<td>5.0</td>
<td>6</td>
<td>30.0</td>
<td>0.04</td>
</tr>
<tr>
<td>VII</td>
<td>1</td>
<td></td>
<td></td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>11247</td>
<td>4.606</td>
<td>13798(B)</td>
<td>60834.26(A)</td>
<td>22192</td>
</tr>
</tbody>
</table>

\[ \bar{x} = \text{mean} \]
2. CIRCULARITY RATIO (Rc): The low value of Rc i.e. 0.26 indicates that the shape does not correspond to a circle.

3. BASIN ELONGATION (E): The value of E is 0.885. It indicates an elongated shape of the river basin.

4. LAMNISCATE (K): The value of K is 0.482. The value indicates that the Son river basin is not very proportionate and balanced as far as shape is concerned. The element of elongation is dominant.

DRAINAGE NATURE

1. DRAINAGE DENSITY (Dd): The average Dd of the Son drainage basin is 1.33 miles/mile².

   It is clear after drainage density analysis of various sub-basins of Son catchment that the average Dd as well as the ranges of Dd vary in different sub-basins depending on the dominant controlling factors which have local importance.

   For the drainage density analysis grid wise Dd data has been determined (Gregory and Walling 1973) and the isopleth map was not drawn because it generalises the distribution and the abrupt changes in a group of data (Fig. 5.21).

   The area has been divided into five drainage density groups:

   (1) LOW Dd AREA (< 0.5 MILES/MILE²): This low Dd is rare in the drainage basin. A very small area on the NNW part of the drainage basin has this low Dd.
(ii) MODERATELY LOW Dd (0.5 - 1 MILE/MILE²) : Moderately low Dd is found in two areas of the river basin. First, southwestern middle part of the drainage basin. This area is a part of Keuai sub-basin of the Son catchment and the northern part of the Son valley just north of Anuppur (Shahdol district). Second, south-eastern part of the Son drainage basin (i.e. upper Rihand valley area specially the area adjoining the left bank) has this moderately low Dd. Both the areas are occupied by Lower Gondwana lithology. These are low relief areas.

(iii) MODERATE Dd (1 - 1.5 MILES/MILE²) : The whole middle Son river basin from east to west and SW has moderate Dd. This Dd group covers the largest area of the drainage basin. The dominant rock group of this area is Upper Gondwana, and the Deccan Trap forms a small area. The NNE part of the river basin also has moderate Dd. This area is drained by lower order tributaries of Son valley. The area is characterised by low relief, and occupied by Bijawars.

(iv) MODERATELY HIGH Dd (1.5 to 2 MILES/MILE²) : This area is spread all over the northern part of the Son drainage basin from east to west. Two things are important about this area of moderately high Dd, firstly, the area comprises of the lower valley areas of all the major tributaries of the Son river (i.e. higher order streams), secondly, the area is occupied by various rock groups and thus the change in rock resistance is evident. The main lithological groups are Archaeans, Upper and Lower Vindhys and Bijawars. Other areas of this Dd range is concentrated in high relief areas.
in small patches.

(v) HIGH Dd AREA (2 to 2.5 MILES/MILE$^2$) : The main area of this Dd group is concentrated in the ENE part of the drainage basin. This is now occupied by the Rihand reservoir. It is the lower Rihand valley area. The area is occupied mostly by Damuda group of rocks.

Other areas of high Dd groups are present in very small pockets. It seems that the change in rock resistance must have influenced these high Dd areas (IV and V of Dd groups), but these are moderate relief areas and the lower valleys (or the higher order streams) must have a bearing on these high Dd areas. Because the lower orders collect and transport water to these streams which are graded. These rivers form meanders and the lengths are exaggerated over the gentle slope of the lower valley areas.

An analysis of the sub-basins shows that the geology has less bearing on the Dd. It is so because the local relief and its effects seem to be important but when overall analysis has been done, it is found that the geology is the major controlling factor and other are relief, slope, stream order etc.

STREAM FREQUENCY (F)

1. LOW STREAM FREQUENCY (< 0.4 STREAMS/MILE$^2$) : This low F is found only in southern middle part of the river basin which is occupied by Keuai sub-basin. The lower valley area which forms a major part, has a very low stream frequency because of
SON RIVER BASIN
STREAM FREQUENCY

Streams / mile²

- 0.4
- 0.4 - 0.5
- 0.5 - 0.7
- 0.7 - 0.9

5 5 20 Kms
4 0 4 8 16 Miles

Fig. 5.22
gentle slope. This forms a low relief area occupied by Lower Gondwana rocks.

2. **MODERATELY LOW STREAM FREQUENCY (0.4 - 0.5 STREAMS/MILE$^2$)**: Mainly the eastern part of the river basin has this frequency group, and a small area of this group lies in the southern part of the drainage basin. These areas are occupied by Rihand and Tipan sub-basins respectively. Mature to old stage of landscape has given rise to moderately low F in these areas as this stage is characterised by low relief and fewer streams of nearly graded nature.

3. **MODERATELY HIGH STREAM FREQUENCY AREA (0.5 - 0.7 STREAMS/MILE$^2$)**: Moderately high frequency tract lies in the western and south-western parts of the drainage basin. These are highly dissected areas mainly occupied by Traps. This tract lies in the Mahanadi and Johills sub basins. A small area lies in the middle part of the river basin which is characterised by high relief and is occupied by Upper Gondwana rocks.

4. **HIGH STREAM FREQUENCY (0.7 - 0.9 STREAMS/MILE$^2$)**: Central part of the drainage basin has the highest stream frequency. This comprises of Son valley tract, Banas and Gopad catchment areas. High dissection specially in the upper valley areas and differential lithology is the reason of this high F in the river basin.

**DRAINAGE INTENSITY (Dl)**

The ratio between F to Dd is 0.495 or 0.495:1 in the
Son river basin.

LENGTH OF OVERLAND FLOW (Lg)

The Lg is 0.408 miles for the Son river basin.

BIFURCATION RATIO (Rb)

The average Rb is 4.377. This is a moderately high Rb among the normal ratios (i.e. 2 to 5). This indicates that the river basin has moderately high relief with a variety of geological rock groups. Some of the sub-basins have high Rb for example Johilla 5.04, Tipan 4.96, Gopad 4.71. Apart from this, within some sub-basins Rb of some of the orders are high as for example 6 and 9 in Banas and Gopad rivers respectively. When averaged these distinguished values lose their importance. The average Rb of the Son river basin is the representative of the Rb of the whole Son river basin. (Table 5.11).

The Rb(s) are exaggerated by structural complexities. Thus the average Rb of the Son river basin implies that the area is free from these complexities. But this does seem to be true. It may be concluded that by grading themselves the rivers have adjusted over the underlying rock. The gradation and thus the resultant decrease in relief (specially in higher order stream areas) have occurred. Thus the structure is not so important as to influence the branching system (or the Rb) strongly.

BASIN LENGTH (L)

The basin length of the Son river basin is 171 miles.
### Table 5.11
**SON RIVER BASIN**
Morphometric Properties

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Parameters</th>
<th>Gopad</th>
<th>Banas</th>
<th>Rihand</th>
<th>Johilla</th>
<th>Mahanadi</th>
<th>Kunuk</th>
<th>Keuai</th>
<th>Tipan</th>
<th>Son</th>
<th>Total/Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum order</td>
<td>VI</td>
<td>IV</td>
<td>VI</td>
<td>VI</td>
<td>V</td>
<td>V</td>
<td>V</td>
<td>IV</td>
<td>VII</td>
<td>VII</td>
</tr>
<tr>
<td>2</td>
<td>Number of streams</td>
<td>1692</td>
<td>1200</td>
<td>2641</td>
<td>763</td>
<td>1372</td>
<td>198</td>
<td>147</td>
<td>145</td>
<td>3089</td>
<td>11247</td>
</tr>
<tr>
<td>3</td>
<td>Total length (in miles)</td>
<td>3033</td>
<td>1681</td>
<td>5685</td>
<td>1560</td>
<td>2983</td>
<td>389</td>
<td>378</td>
<td>377</td>
<td>6106.2</td>
<td>22192.2</td>
</tr>
<tr>
<td>4</td>
<td>Average stream length (in miles)</td>
<td>1.79</td>
<td>1.4</td>
<td>2.1</td>
<td>2.05</td>
<td>2.1</td>
<td>1.9</td>
<td>2.6</td>
<td>2.5</td>
<td>1.97</td>
<td>1.973</td>
</tr>
<tr>
<td>5</td>
<td>Bifurcation ratio</td>
<td>4.71</td>
<td>4.17</td>
<td>4.64</td>
<td>5.045</td>
<td>3.98</td>
<td>3.79</td>
<td>3.51</td>
<td>4.96</td>
<td>4.606</td>
<td>4.377</td>
</tr>
<tr>
<td>6</td>
<td>Weighted Mean Rb</td>
<td>4.43</td>
<td>4.55</td>
<td>4.17</td>
<td>4.74</td>
<td>4.03</td>
<td>4.75</td>
<td>4.26</td>
<td>4.73</td>
<td>-</td>
<td>4.408</td>
</tr>
<tr>
<td>7</td>
<td>Area (Sq Miles)</td>
<td>2106.72</td>
<td>1348.8</td>
<td>5354.24</td>
<td>1176.16</td>
<td>2446.08</td>
<td>317.76</td>
<td>394.88</td>
<td>288.32</td>
<td>4581.92</td>
<td>18014.88</td>
</tr>
<tr>
<td>8</td>
<td>Basin Perimeter (Miles)</td>
<td>276</td>
<td>139</td>
<td>484</td>
<td>275</td>
<td>342</td>
<td>100</td>
<td>100</td>
<td>79</td>
<td>-</td>
<td>932</td>
</tr>
<tr>
<td>9</td>
<td>Basin Length (Miles)</td>
<td>72.8</td>
<td>63</td>
<td>122</td>
<td>86</td>
<td>80</td>
<td>35.6</td>
<td>36.2</td>
<td>40.6</td>
<td>-</td>
<td>171</td>
</tr>
<tr>
<td>10</td>
<td>Form Factor</td>
<td>0.397</td>
<td>0.339</td>
<td>0.36</td>
<td>0.159</td>
<td>0.38</td>
<td>0.25</td>
<td>0.30</td>
<td>0.17</td>
<td>-</td>
<td>0.61</td>
</tr>
<tr>
<td>11</td>
<td>Circularity Ratio</td>
<td>0.347</td>
<td>0.47</td>
<td>0.287</td>
<td>0.17</td>
<td>0.26</td>
<td>0.39</td>
<td>0.49</td>
<td>0.58</td>
<td>-</td>
<td>0.26</td>
</tr>
<tr>
<td>12</td>
<td>Elongation Ratio</td>
<td>0.71</td>
<td>0.67</td>
<td>0.67</td>
<td>0.45</td>
<td>0.69</td>
<td>0.56</td>
<td>0.619</td>
<td>0.47</td>
<td>-</td>
<td>0.88</td>
</tr>
<tr>
<td>13</td>
<td>Lenniscate</td>
<td>0.86</td>
<td>0.90</td>
<td>0.88</td>
<td>0.97</td>
<td>0.87</td>
<td>0.94</td>
<td>0.92</td>
<td>0.97</td>
<td>-</td>
<td>9.10</td>
</tr>
<tr>
<td>14</td>
<td>Drainage density (Miles/Miles)</td>
<td>1.439</td>
<td>1.247</td>
<td>1.06</td>
<td>1.32</td>
<td>1.22</td>
<td>1.22</td>
<td>0.95</td>
<td>1.307</td>
<td>1.33</td>
<td>1.23</td>
</tr>
<tr>
<td>15</td>
<td>Stream Frequency (Streams/Miles)</td>
<td>0.803</td>
<td>0.889</td>
<td>0.49</td>
<td>0.648</td>
<td>0.56</td>
<td>0.62</td>
<td>0.37</td>
<td>0.50</td>
<td>0.67</td>
<td>0.616</td>
</tr>
<tr>
<td>16</td>
<td>Drainage Intensity</td>
<td>0.558</td>
<td>0.71</td>
<td>0.46</td>
<td>0.49</td>
<td>0.459</td>
<td>0.51</td>
<td>0.389</td>
<td>0.38</td>
<td>0.50</td>
<td>0.495</td>
</tr>
<tr>
<td>17</td>
<td>Lg (Miles)</td>
<td>0.347</td>
<td>0.40</td>
<td>0.47</td>
<td>0.378</td>
<td>0.409</td>
<td>0.40</td>
<td>0.526</td>
<td>0.38</td>
<td>0.37</td>
<td>0.408</td>
</tr>
<tr>
<td>18</td>
<td>Area (Sq. Miles)</td>
<td>2106.72</td>
<td>1348.8</td>
<td>5354.24</td>
<td>1176.16</td>
<td>2446.08</td>
<td>317.76</td>
<td>394.88</td>
<td>288.32</td>
<td>4581.92</td>
<td>18014.88</td>
</tr>
</tbody>
</table>
THALWEG PROFILES: RIVER SON AND ITS TRIBUTARIES
VERTICAL SCALE EXAGGERATED 211.2 TIMES

Fig. 5.23
BASIN PERIMETER \( (P) \)

The \( P \) of the Son river basin is 932 miles. The river basin has sharp water divides especially on the northern (Kaimur) and southern (Maikal plateau, pat country) margins. Thus the perimeter is not smooth and the value of \( P \) is high.

STREAM ENTRANCE ANGLES

This has been discussed separately while dealing with the sub basins of the Son catchment.

RELIEF ASPECTS

LONGITUDINAL PROFILE

The Son river originates from a height of 2296 feet (app.). The thalweg profile of Son river has a simple concave curve. At the confluence of Rihand (a tributary of Son) river it attains a height of 500 feet (approximately). Different tributaries meet the Son river at various heights (Fig. 5.23). The longitudinal profile do not indicate any significant complexity.

PROFILES

Serial profiles at the interval of 15' along all the longitudes and latitudes falling in the area, covering the adjoining areas, have been drawn. These serial profiles along the longitudes were superposed to construct superimposed profile (Fig. 7.1). In a similar way east-west series of profiles are superposed to form superimposed profile along
latitudes. Afterwards projected and composite profiles have been drawn separately from west to east and north to south (Fig. 7.2 and 7.3 respectively).

Analysis and study of profiles have been done to understand the physiography and denudation chronology of the area.

VALLEY CROSS PROFILES: Cross sections have been prepared to check the knick points and to study slopes and denudation chronology.

ALTIMETRIC FREQUENCY CURVE: Altimetric frequency curve has also been drawn for the study of denudation chronology of the area (Fig. 7.4).