Drainage Morphometry

Morphometry is defined as the measurement of the shape. It can also be defines as the measurement and mathematical analysis of various landform parameters. Morphometric studies were first initiated by R.E. Horton and A.E. Strahler in the 1940s and 1950s. The main purpose of this work was to discover holistic stream properties from the measurement of various stream attributes.

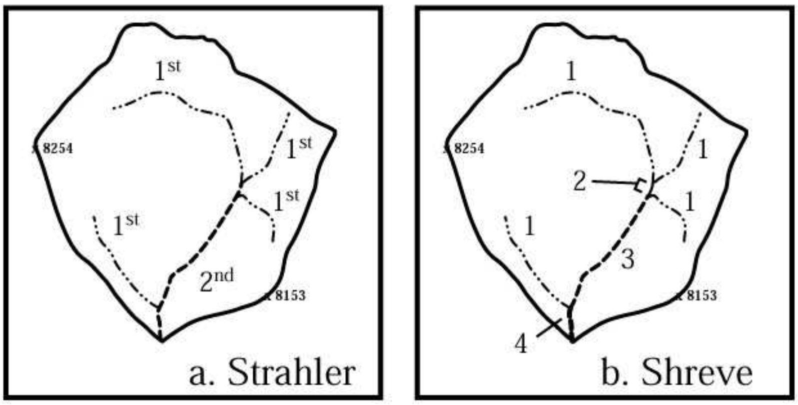
The fundamental unit of virtually all watershed and fluvial investigations is the **drainage basin**. An individual drainage basin is a finite area whose runoff is channeled through a single outlet. In its simplest form, a drainage basin is an area that funnels all runoff to the mouth of a stream. Drainage basins may be delineated on a topographic map by tracing their perimeters or **drainage divides**. A drainage divide is simply a line on either side of which water flows to different streams.

Morphometry is essentially quantitative, involving numerical variables whose values may be recovered from topographic maps. The importance of morphometric variables is their usefulness for comparisons and statistical analyses. Systematic description of geometry of drainage basin requires measurement of linear, areal and relief aspects of the basin.

LINEAR ASPECTS

1. Stream Orders - The first step in drainage basin analysis is order designation. Two principal stream order schemes are in use.

The **Strahler Order system** designates 1st order streams as those that lack a tributary. Second order streams are formed at the junction of 1st order streams (Figure 4). Third order streams are formed at the junction of 2nd order streams, fourth at the junction of 3rd order streams, and so forth. Note that stream order only increases when two streams of the **same order** join. Therefore, where a 2nd order stream joins a 3rd order stream there is no change in stream order; the 3rd order stream remains 3rd order.



The **Shreve Magnitude system** designates streams that lack a tributary as magnitude 1. Where streams join, their magnitudes are added together. Therefore unlike the Strahler system, magnitudes increase at **all** junctions in the Shreve system. For instance, where a magnitude 2 stream joins a magnitude 3 stream, the magnitudes are added to form a magnitude 5 stream. Note that in such a case there is *no* magnitude 4 stream. A convenient component of the Shreve system is that a stream's magnitude corresponds to the number of magnitude 1 or 1st order streams contributing to the channel.

2. Stream Number - The number of stream segments present in each order is counted and recorded. Graphical representation of this data on semi-log paper yields straight line. The number of stream decreases as the order number increases.
3. Bifurcation ratio -The ratio between the numbers of stream segments of a given order (S_o) to the number of segments of the next higher order is termed as bifurcation ratio (R_b). The bifurcation ratio is not same from one order to the next order because of possibility of changes in the watershed geometry and lithology, but tends to be consistent throughout.

$$R_b = \frac{S_{o-1}}{S_o}$$

Bifurcation ratio characteristically ranges between 3.0 and 5.0 for watersheds in which the geological structures do not distort the drainage pattern.

4. Stream Length - The length of various stream channels is a dimensionless property. The total length and the mean length of each order may be computed. The length ratio is the ratio of mean length of the stream of a given order to the mean length of the stream of the next lower order and It is calculated for each pair of orders. The mean length of stream increases with the increasing order.

AREAL ASPECTS
1. Drainage area - The ridge line or water divide or basin boundary is traced from toposheet or aerial photograph or satellite imagery. The area enclosed by the water divide/ catchment area is calculated.
2. Shape Parameters - The shape of the basin can be defined by using following parameters:

i) Elongation ratio – It is the ratio between the diameter of a circle of the same area as the drainage basin and the maximum length of the basin.

$$Re = \frac{2\sqrt{Au/\pi}}{Lb}$$

Au= Area of the basin in km^2
Lb= Maximum length of the basin

The ratio genrally ranges from 0.6 to 1.0. The basins with elongation ratios of 0.6 to 0.8 are generally associated with strong relief and steep ground slopes, whereas values in the range of 0.8 to 1.0 are typical of regions of low relief.

ii) Form Factor – It is the ratio of the basin area to the square of the basin length as suggested by Strahler (1968).

$$Rf = \frac{Au}{Lb^2}$$

Lb= Length of the basin, Au=Area of the basin

iii) Circularity ratio – It is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin.

$$Rc = \frac{4\pi Au}{P_r^2}$$

Lb= Length of the basin, Pr= Perimeter of the basin, Au=Area of the basin

3. Drainage Density - The number of 1st order streams in a basin of a given size is dependent upon a variety of climatic, geologic, and hydrologic factors. For instance, holding all other variables constant we would expect that a drainage basin in an arid climate would have *more* 1st order streams than a watershed in a more humid climate. Similarly, increasing relief is associated with increasing stream densities. Although the number of streams in a given order is a crude measure of drainage density, we define **drainage density (Dd)** much more explicitly as

$$Dd = \frac{\sum L}{Au}$$

where L denotes stream lengths and Au is drainage basin area. Horton (1932) had emphasized that permeability has a fundamental influence on drainage density.

4. Stream Frequency - Stream frequency can be defined as the number of stream segments per unit area. It can be obtained by dividing the total number of streams by the area of basin.

5. Infiltration number - It is the product of drainage density and stream frequency and gives an idea about the infiltration characteristics of the basin. The higher the number, the lower is the infiltration and higher runoff.

6. Length of overland flow – Horton (1945) used this term to refer to the length of run of rain water on the ground as sheet wash before it gets localized into defined channels. It is assumed to be about half the distance between the channels. Horton took it roughly equal to half of the reciprocal of drainage density.

RELIEF ASPECTS

Relief measures are indicative of potential energy of a drainage system.

1. **Channel gradient** – The total drop in elevation from the source to the mouth of main channel and the also the horizontal distance along the channel is measured to calculate the channel slope or gradient.
2. **Mean basin slope** - Mean basin slope can be calculated by multiplying the contour interval by the total length of contours in kms. And dividing the product by the basin area.
3. **Maximum basin relief** – It is the elevation difference between the basin outlet and highest point on the perimeter.
4. **Relief ratio** – It can be obtained by dividing the maximum basin relief to the maximum measured length of the drainage basin parallel to principal drainage line. The relief ratio is a measure of overall steepness of a drainage basin and is the indicator of the intensity of the erosion process operating on the slope of the basin.
5. **Relative relief** – It can be calculated by Horton formula

   Relative relief = (100XMaximum basin relief) / Perimeter of basin in meters
6. **Ruggedness number** – It is the product of maximum basin relief and drainage density. Its higher values occur when slope of the basin are not only steep but also long as well.

------xxx------xxx------xxx------xxx

A stream is classified as a body of water that flows across the Earth's surface via a current and is contained within a narrow channel and banks.