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Geomorphological Study of Myntdu River Basin

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ABSTRACT

Hydrogeomorphological parameters of drainage network provide simple means, specially in mountainous and ungauged catchments to develop empirical rainfall-runoff relationships, synthetic hydrograph parameters and to develop regional Geomorphological Unit Hydrograph. In this case study, a 1 : 50,000 scale Survey of India map of Myntdu river basin has beeen used. The map is digitised using Calcomp digitising tablet in AutoCad. The geomorphological parameters consisting of linear, areal and relief aspects of the drainage network of the basin have been worked out using the facilities of AutoCad and by developing some computer programs which can handle DXF files (ASCII format) of AutoCad.

The report also briefly reviews various methods of estimation of geomorphological parameters established by numerous investigators throughout the globe. The resluts would be utilised in various hydrological studies now ongoing in the area in connection of a proposed hydroelectric power project. Patricularly the quantitative estimates of the geomorphological parameters for the basin would be utilised for the development of Geomorphological Instantaneous Unit Hydrograph for the basin.

1.0 INTRODUCTION:

River basins and its characteristics are controlled by nature and its hydro-climatic parameters are mostly interrelated with each other. Watershed managers require to understand and synthesize hydrologic response of such basin for which they have started looking into its basin characteristics or morphologic features and establish connection of fluvial geomorphology to hydrology. Geomorphology, the science of evolution of land forms in terms of lithology, structure , climate & other climatic factors, had been mostly qualitative in its initial stage. Now with the rational relation between the average response of a basin with given geomorphologic properties established, greater need for quantitative information is felt for. To evaluate or predict the run-off response of a river basin hydrologists are faced with the vexed problem of non availability of flow precipitation data. Therefore, measurable basinal features of drainage network which have been considered and shown to have potential to describe some of the hydrograph parameters of the ungauged system have encouraged hydrologists for hydrologic simulation and applying relationships developed for gauged basins at ungauged locations through hydrograph correlations.

The geomorphological characteristics which relate to hydrology, as suggested by many investigators, consist of **Linear Aspect** of channel system dealing with one dimensional overland flow lengths & length of streams etc, **Aerial Aspect** of catchment relating to basin shape & drainage texture and **Relief Aspect** of channel network/catchment describing elevation difference etc. The first two categories of measurements are planimetric and the third category treats the vertical inequalities of the drainage basin form. Some typical catchment characteristics have also been identified which will be useful to derive unit hydrograph for the catchment. Some of the studies where quantitative geomorphological characteristics have been applied to describe hydrologic properties such as run- off response or flow hydrograph etc. are as follows.

- Development of empirical formula using geomorphological parameters
- Regional Unit Hydrograph Studies
- Regional Flood Frequency Analysis
- Development of Geomorphological Instantaneous Unit Hydrograph
- Hydrologic modelling studies.

Estimation of linear and areal aspects of a drainage network consists of measurement of length and area of numerous entities (small sub divisions of the map) resulting in a tedious and time consuming process. In order to mechanise this process, an attempt has been made to make use of digitised map of the basin.

This report attempts to estimate the various geomorphological characteristics of Myntdu river basin within North Eastern Region with the help of established laws and procedures. In absence of sufficient network of hydrologic observation sites the geomorphological parameters derived for the basin would be very helpful for further hydrologic studies specially in development of a GIUH for the area and synthesizing other model parameters. Meghalaya State Electricity Board (MeSEB) has since proposed one hydroelectricity project at basin outlet for which various hydrological studies are ongoing. The geomorphological parameters estimated from digitised map should be helpful in these studies specially in developing Geomorphological Instantaneous Unit Hydrograph (GIUH) for the area.

2.0 METHODOLOGY:

Procedure for estimation of various geomorphological parameters of the river basin, in requirement of many hydrological studies, is described in this section. For the purpose, the basin map of Myntdu river is delineated from Survey of India toposheets at 1:50,000 scale (Topo sheet no. 83C/3 and 83C/7). The delineated map with the stream network and contours, at 100 m interval, is digitised using Calcomp digitising tablet in AutoCad. Then the digitised map is edited in accordance with the original toposheet map. The ordering of stream is done as per Strahler's scheme. The micro-catchments for each and every individual stream is also delineated considering the contours and nearby streams. Once these micro-catchments are marked over the digitised map, the area and length of each stream of different order are calculated. Some computer programs are developed to estimate the centre of mass of the basin, average length and area of different order streams and estimation of R_b , R_d, R_a and R_l. The geomorphological parameters that are used in hydrological models and having potential to describe basin characteristics are broadly grouped under three categories.

i. Linear Aspect of the Channels system
ii. Areal Aspect of the Catchment
iii. Relief Aspect of the Basin

Based on the methodology and works done by many earlier investigators like Horton (1945), Strahler (1953,1956,1964,1968), Chroley (1957), Miller (1953), Schumm (1954) , Bernard (1935), Snyder (1938), Linsley (1943), Jetter (1944), Lucas (1944) , Taylor(1952), Eaton (1954), Yonezol (1956), Muckus (1975), Nash (1960), Gray (1961), CWC (1980), Gundlach (1975) etc., the parameters under these three aspects are studied and quantified as described below.

2.1 Linear Aspect of the Drainage Network:

Linear aspect of basin characteristics includes overland flow lengths of channels of all orders. Usefulness of ordering channel system lies on the hypothesis that basin size, channel dimension and stream flows are proportional to the stream orders provided investigation is made for quite large number of watersheds. Two basins having different linear measures can be compared with respect to corresponding points in their geometry through use of dimensionless order number. However, such comparisons should be made at locations in the two systems that have similar geometry, that is, second order stream third order streams and so forth.

2.1.1 Stream Orders:

Horton (1945) pioneered quantitative study of channel networks by classifying the channels by order in United States. This was slightly modified by Strahler (1952). Melton (1959) explained the mathematical concepts involved. As per Strahler's scheme of ordering in a channel network map showing the intermittent and permanent flowlines located in clearly defined valleys the smallest unbranched (finger tip) tributaries are designated as **order 1**. The point at which two first order streams join a channel segment of **order 2** is formed. Where two streams of 2nd order join, a segment of **order 3** is formed and so on. The main or trunk channel carrying the entire discharge of the drainage basin upstream of basin outlet is obviously the segment of highest order. Parameters under linear aspect of channel system and their estimations are described below.

2.1.2 Length of Main Channel (L):

This is the length of the longest water course when projected on a horizontal plan from the basin mouth to the farthest point on the basin boundary. To measure this length there are several conventional methods like pair of dividers, thread length, edge of paper strip, opsimeter and so on. This can also be done by Analog to Digital convertor by tracing along the main channel with the cursor which records the x and y co-ordinates of closely spaced points. The digitized co-ordinates of the main channel points are stored in computer and distance between two points is calculated from

Distance = ((x^2) + (y^2))$^{0.5}$

Length f the channel is the summation of all segmental distances. For the purpose a subroutine 'LENGTH' is already available at NIH. Similarly length of all streams of all orders can be found out.

However, in this case, the stream length is measured by subroutine available in AutoCad (AREA)

2.1.3 Length of the Main Channel between the Outlet and Point Nearest to c.g. (L_c):

It is the length of the main channel measured from the outlet of the catchment to a point on the stream nearest to the centroid of the basin (C.G.of the plane area of the drainage basin). The centroid is found out by developing a subroutine which directly takes the DXF format (output from AutoCad) input for the boundary. The logic used for finding out CG (X,Y) is as follows.

$$X = \frac{\sum_{i=0}^{m} A_i * X_i}{\sum_{i=0}^{m} A_i}$$

$$Y = \frac{\sum_{i=0}^{m} A_i * Y_i}{\sum_{i=0}^{m} A_i}$$

2.1.4 Length of basin/valley length (L_v):

It is the distance from the outlet of the basin to the farthest point in the basin. In this study, a farthest point on the ridge is assumed by eye estimation then a circle is drawn using outlet point as centre and it's distance from the assumed farthest point as radius. If the circle does not intersect anywhere else on the boundary, it is the farthest point else the same procedure is repeated till the farthest point is identified. Then the valley length is calculated using subroutine DIST of AutoCad.

2.1.5 Total Length of Channels:

This is the total length of channel segments of all orders within the basin. Total length of channels gives an idea of overland flow and channel flow in the watershed. For this a subroutine is developed which gives the number of streams of different order and their length.

2.1.6 Wandering Ratio:

This is the ratio between main stream length along the course to the straight line distance between the two extremes, outlet and farthest point in basin boundary. While this factor broadly indicates the amount of deviation of main stream fr m straight line path. it does not necessarily explain the meandering of the main stream.

2.1.7 Bifurcation Ratio (R_b):

The ratio number of stream segments of a given order N_u to the number of segments of the higher order N_{u+1} is termed as Bifurcation Ratio, R_b.

$$R_b = N_u/N_{u+1}$$

Calculation on an average value of R_b for a given channel network can be made by determining the slope of the fitted logarithm regression of number of streams (ordinate) and stream order (abscissa) with the condition that the no. of the highest order stream is unity.

This means a plot of the Log N_u vs u will approximately yield a straight line with negative slope. The magnitude of the slope is the logarithm of R_b (identical to the regression co-efficient b). If the R_b is estimated to be 3.52, this means that on the average there are 3

1/2 times as many channel segments of any given order as of the next higher order. Taking precipitation and other factors uniform, an elongated basin (high R_b) would give rise to a hydrograph of low but extended flow peak where as a round basin (low R_b) would produce a sharp peak. For a basin with a dipping rock strata where narrow valleys are confined between high ridges the R_b may be abnormally high. Strahler concludes that R_b characteristically ranges between 3.0 and 5.0 for watersheds in which the geologic structures do not distort the drainage pattern. The theoretical minimum possible value of 2.0 is rarely approached under natural conditions. The bifurcation ratio is however, not the same from one to the next order but will tend to be constant throughout the series. This is the basis of Horton's law of stream numbers.

For analytical estimation of R_b a subroutine is developed which uses the method of least square error withe the condition that the no. of highest order stream is unity.

2.1.8 Law of Stream Numbers:

Horton's (1945) law of stream Numbers states that the number of streams of a given order follows an inverse geometric relationship with stream number :

$$N_u = (R_b)^{k-u}$$

Where k = Order of trunk segment i.e. the highest order of the stream in the drainage basin.

u = Order of interest

From above equation it follows:

$$\log Nu = (k-u) \log Rb$$

or $$\text{Log } Nu = a-bu$$

Where, $a = k \log Rb$

$b = \log Rb$ or $Rb = \log (b)^{-1}$

These results have been confirmed many times using Strahler's order system.

2.1.9 Division Ratio (R_d):

Scheidegger (1966a, 1966b) showed that R_b is constant in a horton network only if the streams of order u receive tributaries of order u-1. Thus if the lost segments are removed and the ratio of N_{u-1} and N_u is computed according to Horton, then this ratio is the division ratio. Evidently R_d is analogous to R_b except for exclusion of lost segments.

2.1.10 Average Stream Length (L_u):

Mean length L_u of a channel segment of order u is a dimensional property revealing characteristic size of components of a drainage network and its contributing basin surfaces. Law of stream length (Horton, 1945) states that the average length of streams of each of the different orders tend to approximate a direct geometric series (In which the first tern is average length of first order stream) with the relation

$$L_u = L_{u-1} * R_l$$

Where L_u = average length of streams of order u
R_l = a constant called length Ratio discussed later

The validity of law of stream length relating R_l when Strahler ordering is used has been studied by several authors Maxwell (1960) & Melton (1957) and indicated considerable variation in segment length data from a geometric series. If it is assumed that the Horton's law of stream length is valid then the Length Ratio R_l of above equation is obtained for the watershed as the antilogarithm of regression co-efficient of a line fitted by inspection or by least square method to the plot of logarithm of stream length on order. Nroscuc (1959) found that substituting cumulative mean length for average length and cumulative R_l in the equation, the geometric series was indeed obtained. Of interest to the estimation of channel storage capacity for an entire watershed, is Horton's observation that the laws of stream numbers and lengths can be combined as product to yield an equation for the total length of channels of a given order 'u' knowing only the R_b and R_l, the mean length L_l of the first order segments and the order of the trunk segment.

In this report L_u is calculated from the linear measurement of channel segments directly from AutoCad (AREA), i.e. total length of each order is divided by the number of segments of that order such that:

$$L_u = (\Sigma L_u)/N_u$$

2.1.11 Stream Length Ratio (R_l):

This is the ratio of mean length L_u of segments of order u to mean length of segm nts of the next lower order L_{u-1}

$$R_l = L_u / L_{u-1}$$

Horton stipulated that R_l tends to be constant throughout the successive orders of a watershed. Its value is normally between 1.5 and 3.5 in natural drainage networks. It is useful in synthesizing hydrograph characteristics.

2.1.12 Basin Perimeter (P):

Basin perimeter is the total length of the basin boundary or the length measured along the divide between basins and may be used as an indicator of basin size and shape. It was emphasized by Smith (1950) in his derivation of Texture ratio.

2.1.13 Fineness Ratio (R_f):

The ratio of the channel length to the lengths of the basin perimeter is termed by Melton (1957) as the fineness ratio which indicates fineness of the topography.

2.1.14 Watershed Eccentricity (τ):

Black (1972) gave the expression for τ as follows.

$$\tau = \frac{\sqrt{abs(L_c^2 - W_1^2)}}{W_l}$$

Where

L_c = Length from the watershed mouth (outlet) to the C.G of watershed.

W_l = the width of the watershed at the centre of mass and perpendicular to Lc.

When $L_c = W_1$ eccentricity become zero. Greater is the value of $(W_l\text{-}L_c)$ or $(L_c\text{-}W_l)$ more will be the eccentricity, lesser will be the compactness of watershed near the mouth and lower will be the flood peak.

2.1.15 Length of Overland Flow (L_o):

Horton (1945) defined L_o as the length of flow path, projected to the horizontal of non-channel flow from a point on the drainage divide (basin boundary) to a point on the adjacent stream channel. It is the length of overland flow of water before it joins a channel. The average length of overland flow Lo is approximately half the average distance between stream channels and is therefore approximately equal to half the reciprocal of drainage density (discussed in Areal Aspects in clause 2.2.3) such that:

$$L_o = 1/2D$$

Horton noted that length of overland flow is one of the most important independent variables affecting both the hydrologic and physiographic development of drainage basins.

2.2 Areal Aspect of Watershed:

Areal measures of a drainage basin network relate to many of its hydrologic characteristics. Some of these characteristics and methodology of estimation adopted by various investigators are described below.

The basin area is the plane area within the perimeter along the drainage divide. It is one of the most important characteristics of the basin reflecting the run-off process. The area of the basin of a given order u is defined as the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and including all tributaries of lower order. Thus Schum (1956) stated that the area of basin of fourth order A_4 would cumulate the area of all first, second and third order basins plus all additional surface elements, known as **INTER BASIN AREAS**, contributing directly to a channel of order higher than first. Estimation by comparison of watershed, tracing with square or rectangle of known dimension, polar planimeter, Dot grid, strip sub division , geometric sub division, Analog to digital converter are some methods to measure basin ar a. However, in this study, the area is calculated using subroutine AREA of AutoCad.

2.2.1 Law of Stream Areas and Area Ratio (R_a):

The concept of law of stream area is same as the law of stream length and stream number. Horton (1945) stated that mean basin areas (A) of progressively higher orders should increase in a geometric sequence as do stream lengths. Schumn (1954) expressed this relationship in a law of stream areas which states that mean basin areas of the stream of each order tend closely to approximate a direct geometric sequence in which the first term is the mean area of the first order, mathematically

$$A_u = A_{u-1} \; (R_a)^{u-1}$$

Where A_u = mean area of basin of order u.
R_a = an area ratio analogous to R_l

2.2.2 Drainage Density (D):

Horton (1945) defined drainage density as the ratio of total channel segment lengths of all orders within a basin to the area of the drainage basin projected to horizontal and expressed as the number of miles of channels per square mile of basin area.

$$D = \frac{\sum_{u=1}^{k} \sum_{i=1}^{n} L_{u_i}}{A}$$

Dimensionally this ratio reduces to inverse of length (L^{-1}) and hence is a quantity dependent on the level of resolution of the map from which lengths are measured.

Drainage density characterises textural measure independent of basin site and considered to be a function of climate, lithology, stage of development etc. In fact the drainage density is constant everywhere in the basin and the average length of contributing hill slope is approximately half the average distance between stream channels as expressed in clause 2.1.13. Various Investigators measured drainage density for different geologic and climatic conditions.

2.2.3 Constant of Channel Maintenance (C):

Schum (1956) used this term as the inverse of drainage density i.e.

$$C = (1/D)$$

2.2.5 Stream Channel Frequency (F):

Stream Frequency or Channel Frequency was defined by Horton (1945) as the numbers of stream segment per unit area or

$$F = (N / A)$$

Where N = Total stream segments of all orders

A = Drainage area of the basin

Relationship between drainage density (D) and stream frequency both of which measure the drainage texture (but each treating as distinct aspect) was studied by Mellon (1958). Although both the terms measure different properties, Melton found a dimensionally correct equation as

$$F = 0.694\ D^2$$

This implies that the dimensionless ratio F/D^2 approaches a constant value of 0.694 independent of scale.

2.2.5 Circularity Ratio (R_c):

Miller (1953) introduced a dimensionless circularity ratio which is defined as the ratio of the basin area to the area of a circle having circumference equal to the perimeter of the basin.

The value of this ratio approaches one as the shape of the basin approaches a circle. Miller found the value consistently in the range of 0.6 to 0.7 for first and second order basins in homogeneous shales and dolomites, indicating the tendency of small drainage basins in homogeneous geologic materials to preserve geometrical similarity. By contrast first and second order basins situated on the flanks of moderately dipping quartzite strata of Clinch Mountain, Virginia, were strongly elongated and had values of R_c between 0.4 to 0.5.

2.2.6 Elongation Ratio (R_e):

Schumm (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. Obviously for a circular basin the value tends to unity. This ratio runs between 0.6 to 1.0 over a wide variety of climatic and geologic types. Values near to 1.0 are typical of regions of very low relief, where as value in the range of 0.6 to 0.8 are generally associated with strong relief and steep ground slopes.

2.2.7 Form Factor (R_f):

Horton (1932) used this dimensionless quantity which he defined as the ratio of basin area (A) to the square of the maximum basin length (L_v).

$$R_f = A/L_v^2$$

This is a quantitative expression of basin shape (outline form). In its inverted form, it was used in unit hydrograph applications by the U.S. Army Corps of Engineers.

2.2.8 Compactness Ratio (R_k):

Basin shape has been defined by an alternate descriptor based on perimeter rather than area. The compactness ratio is the ratio of the catchment perimeter to that of the equivalent circle having area as that of the basin.

$$R_k = (0.282\ P) / A^{1/2}$$

2.2.9 Watershed Shape Factor (R_s):

This was defined by Wu et al (1964) as the ratio of main stream length L to the diameter D of a equivalent circle having same are as the basin.

$$R_s = (L/D)$$

2.2.10 Unity Shape Factor (R_u):

Smart & Surkan (1967) used the unity shape factor to be defined as the ratio of the basin length L_v to the square root of the basin area (A).

$$R_u = (L_v / A^{1/2})$$

2.3 Relief Aspect of the Drainage Basin:

Relief morphometry of river basin describes variation of elevations between the highest and the lowest points. This is significant to study the flow phenomena in the watershed. The potential energy of flowing water from high altitude gets converted to kinetic energy which is related to slope. Various losses of water like storage, infiltration, evaporation etc. and travel time are inversely related to slope. The parameters relating to relief aspect of the drainage network are as follows.

2.3.1 Basin Relief (H):

Relief is the elevation difference between two reference points. Maximum basin relief (H) is the elevation difference between the highest point in the catchment divide and the catchment outlet. Methods of measurement of basin relief adopted by various investigators are different. Schumm measured basin relief along the longest dimension of the basin parallel to the principal drainage line. Basin relief may also be obtained by determining the mean height of the entire basin perimeter above the mouth, thus minimizing the spurious effects of sharply pointed summits.

2.3.2 Relief Ratio (R_h):

Relief ratio is the ratio of the maximum basin relief (H) to the catchment's longest horizontal straight distance measured in a direction parallel to that of the principal water course. Schumm (1956) explained that taking vertical and horizontal distances as legs of a right angled triangle, relief ratio is equal to the tangent of the lower acute angle and is identical with the tangent of the angle of slope of the hypotenuse with respect to the horizontal.The relief ratio thus measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion processes operating on slopes of the basin.

2.3.3 Relative Relief (R_{hp}):

Melton (1957) used the term relative relief which is basically the ratio of the basin relief to the perimeter and expressed in percent as

$$R_{hp} = (100\ H\ /\ P)$$

Where,

H = Maximum basin relief

P = Basin perimeter

2.3.4 Ruggedness Number (R_n):

To take into account of both slope steepness and length , a dimensionless ruggedness number has been used by Melton (1957) and Strahler (1958). It is defined as the product of relief H and drainage density D (both in same unit) i.e.,

$$R_n = H \times D$$

3.0 PROBLEM DEFINITION:

Hydrological studies in drainage basins and sub basins often suffer setbacks due to lack of various long term data. Then there is the need to extrapolate the results of few small sub systems (where only short term data are available) to other hydrologically similar regions which mostly remain ungauged for want of enormous resource and time involved in instrumentation & monitoring them. The measurable geomorphological parameters which have since been considered and shown to have potential to describe some of the hydrograph properties for ungauged basins provide simple means for hydrologic simulation, hydrograph synthesis and for development of empirical relationships to quantify some elements of flow processes.

The existing network of hydrometeorlogical observation in Myntdu basin is inadequate for systematic hydrologic studies. Moreover, the channel network of the basin is very complicated. Even many of the major streams remain dry during winter and experience flash flood during rainy days. Therefore, geomorphological parameters of the basin may provide comparison while extrapolating the results to larger basins.

4.0 THE STUDY AREA:

The Myntdu river basin is located in Jaintia hills District of Meghalaya, in the north eastern part of India, in the southern slope of the state adjoining Bangladesh. Its geographic location extends from 92° 15′ to 92° 30′ E longitude and 25° 10′ to 25° 17′ N latitude (Fig. 1). The area is narrow and steep, laying between central upland fall of the hills of Meghalaya. The fall of hills at many places is sudden and sharp, forming deep georges and river valleys. The catchment area is about 340 sq km and elevation range varies from about 1372m to 595m. The Myntdu river in the upper reaches originates from the place Mih Myntdu at an elevation of 1372 m and flows towards south for a distance of about 10 km with a steep gradient upto an elevation of about 1220 m. From this point river takes a sharp bend towards east and flows for a distance of about 11 km through a quite wide and flat valley full of cultivation and thickly populated villages. In the next 27 km the river gradually drops by about 595m and flows mostly through narrow valleys towards south west for the first 16 km while during the next 11 km it flows towards south upto an elevation of 595 m near Leska where two tributaries of Myntdu namely Umshakaniang from the west and Lamu from the east meet the main river. At Leska, a hydro power project has been proposed by Meghalaya State Electricity Board and still it is at design and investigation stage.

4.1 Climate:

The climate is moderate being sub-tropical with medium to sparse vegetation. Summer temperature varies from 24°C to 32°C and in winter temperature ranges between 3°C to 12°C. Sometimes during winter frost occurs in high hills located in the catchment, but there is no instance of snowfall.

The main rain season in this area is May to October. There is also some precipitation

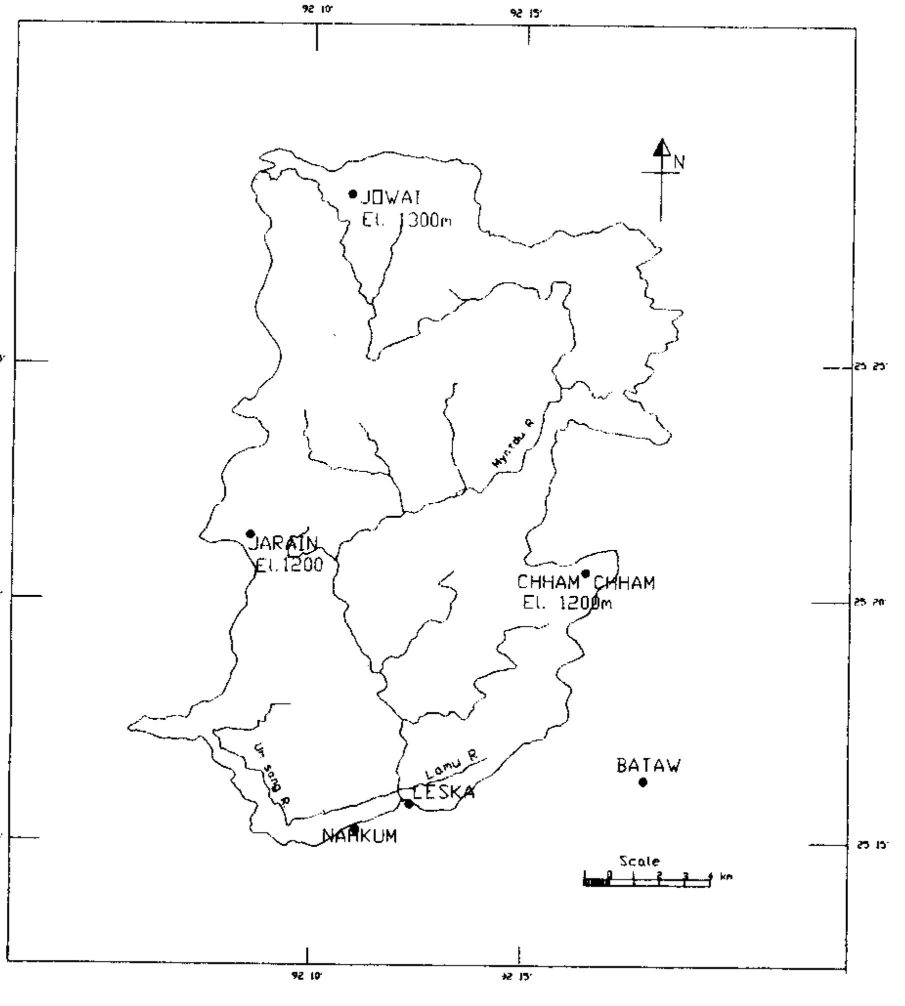

Fig. 1. Location Map of Myntdu River Basin

during pre-monsoon and post monsoon periods. The annual rainfall in the catchment varies from the 3537 mm to 13710 mm. The lack of forest cover in the catchment with steep slopes gives instantaneous runoff, allowing little time for ground water storage.

4.2 Water Resources:

The river Myntdu is endowed with vast water resources potential for irrigation and power generation. The river has surplus water during rainy season. The yield is variable within wide limits from season to season. The monthly average yield during the lean season of about four months, from November to February is 92 Mm^3 and 1951 Mm^3 during rest of the year. There is also appreciable variation in the annual yield from year to year. river. At Leska, a hydro power project has been proposed by Meghalaya State Electricity Board and still it is at design and investigation stage. The project is aimed at harnessing the water of river Myntdu and its tributaries by constructing a dam for power generation through a run of river scheme.

4.3 Vegetation:

The sub tropical humid climate with very heavy rainfall helps the nature to keep the hills covered with green vegetation. the variation in elevation and rainfall pattern gives it a vivid type of flora and fauna, many of this are not to be seen in any other parts of the country. This area is characterised by jhoom cultivation which involves the destruction of forest cover, for putting in seeds for crops. Orchards of orange is very common in this area. The principal crop is paddy. The area is very leanly populated. The barren land covers the maximum part (76.63 %). Wherever there is depression between the high lands, thick jungle of mixed forest grow due to good soil by the outwash of the slopes.

5.0 ANALYSIS AND DISCUSSION OF RESULTS:

To estimate the hydrogeomorphologic parameters of Myntdu basin the topographic map delineating the basin divide and other topographic features has been prepared from toposheets published by Survey of India in the scale of 1:50,000. The stream net-work has been ordered using Strahler's ordering procedure, shown in Fig. 2. It is principally a six order network having 1148 first order, 233 second order, 45 third order, 12 fourth order, 2 fifth order and 1 sixth order streams contained in the drainage area under investigation of 339.78 sq km. Contour map of the basin , at 100m contour interval, is shown in Fig. 3.

From the digitised map the basic linear parameters like basin perimeter, length of streams, basin length etc. have been measured. The basic parameters of areal aspects like basin area, areas of different order streams etc. are measured from the map and other derived parameters are estimated with the relationships discussed in Art. 2. The number, lengths and areas of different channel segments are furnished in Table 1. Individual streams falling into different higher order streams are calculated by developing a subroutine and presented in Table 2 in matrix form.

Table 1

Measurement of drainage network					
Stream order	Stream Nos.	Stream length	Average length	Area	Average area
1	1148	609.985	0.5313	196.740	0.1714
2	233	180.259	0.7736	184.918	0.7936
3	45	100.328	2.2295	190.836	4.2408
4	12	59.758	4.9798	216.487	18.0406
5	2	28.767	14.3835	173.855	86.9275
6	1	15.235	15.2350	339.776	339.7760

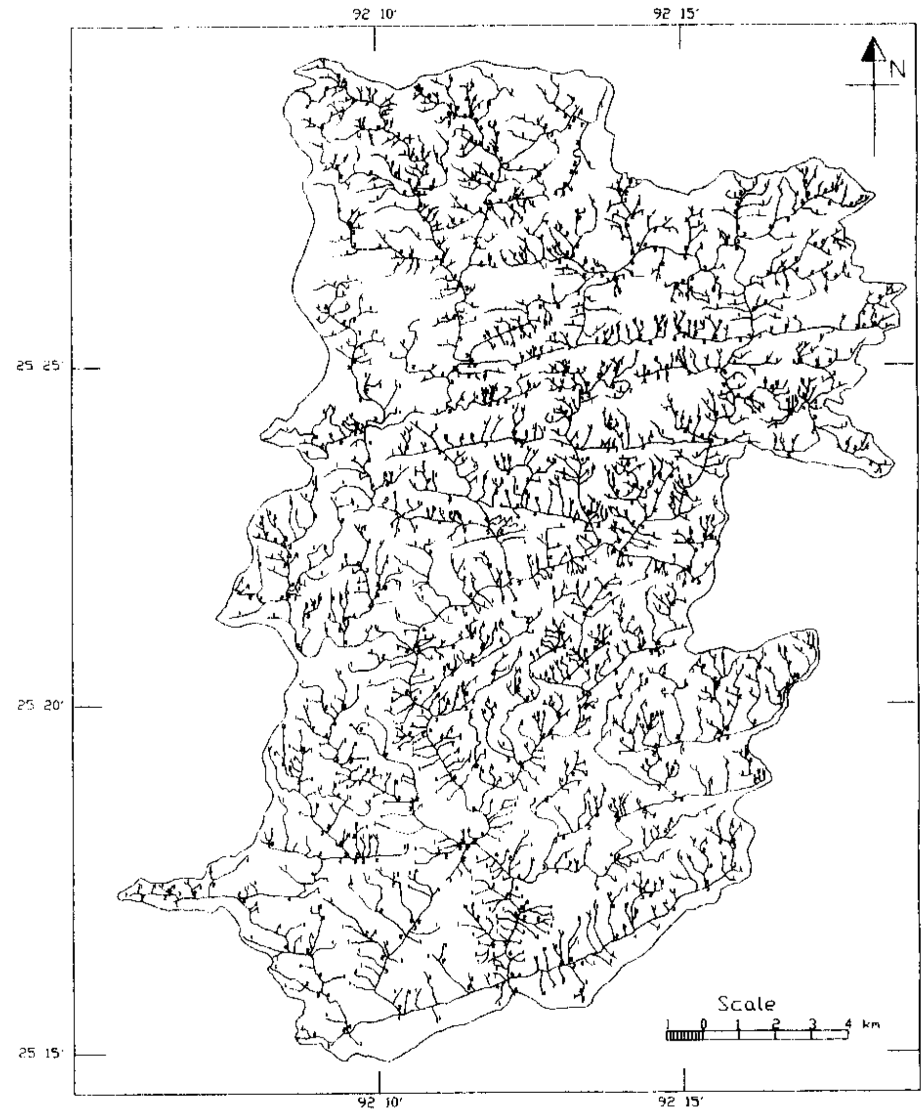

Fig. 2. Drainage network of Myntdu river basin

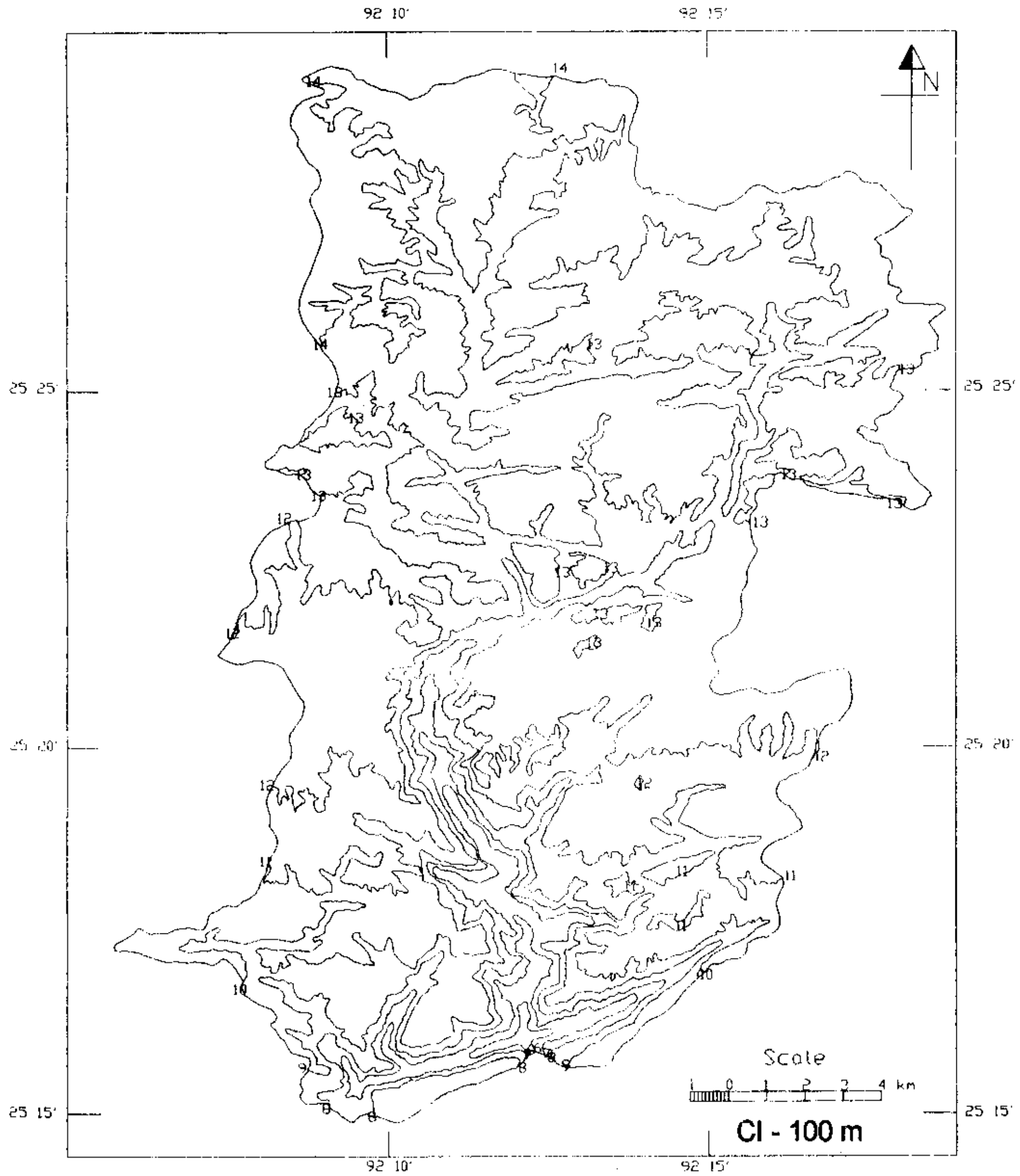

Fig. 3. Contour map of Myntdu river basin

Table 2

Streams falling under different orders							
Stream orders	1	2	3	4	5	6	Total
1		709	189	128	68	54	1148
2			152	43	22	16	233
3				30	11	4	45
4					7	5	12
5						2	2
6							1

The results of the study in respect of linear, areal and relief aspects are discussed below.

5.1 Linear Aspect of Myntdu River Basin:

The parameters studied under this aspect and their quantitative measures are furnished in Table 3.

Table 3

Linear aspect of Myntdu basin		
S.No.	Parameters	Value
1.	Length of main channel, L	51.778 km
2.	Length upto centroid, L_c	16.155 km
3.	Total length of channel, L_t	994.332 km
4.	Mean Length of overland flow L_o	0.1709 km
5.	Basin perimeter, P	113.583 km
6.	Watershed eccentricity, τ	0.2324 km
7.	Stream Length ratio, R_l	2.1232
8.	Wandering ratio, R_w	1.9897
9.	Fineness ratio, R_f	0.4559
10.	Division ratio, R_d	4.4015
11.	Bifurcation ratio, R_b	3.6648
12.	Length of Basin/ Valley Length, L_v	26.023 km
13.	Drainage Density, D	2.9264 km/ sq km

It can be seen from the Table 1 that the average length (total length divided by the number) of stream increases with increasing order. Whereas number of stream shows a decreasing trend from lower order to higher order. The non dimensional parameters (i.e., bifurcation ratio and length ratio estimated), reflect the peak time characteristics of the Myntdu basin and may be used in the hydrological modelling. The measure of length upto centroid may be useful in the regional unit hydrograph studies. The other linear measures shown in Table 3 for the basin will also be useful to describe the various hydrologic properties of the network. Method for estimation of eccentricity of the basin is presented in Fig. 4. It is evident from Fig. 5, hypsometric curve of the basin, that the basin is in moderately active stage. Fig. 6 shows the variation of stream number with stream order. The negative slope of the line confirms the law of stream numbers indicating reduction of number from lower to higher orders. Fig. 7 shows the variation of stream number with stream order for estimation of R_d. Fig. 8 represents the variation of average area of different order stream wrt stream order. Fig. 9 shows plot of the quantities of stream order vs average stream length. The plot shows the increasing trend in average length with increasing order following Horton's Law of stream length. The profile of mainstream of Myntdu river is shown in Fig. 10.

5.2 Areal Aspect of Myntdu Basin:

The basinal properties of the Myntdu drainage network in terms of areal measures as described in Art. 2. have been studied and the parameters of areal aspects are estimated as presented in Table 4

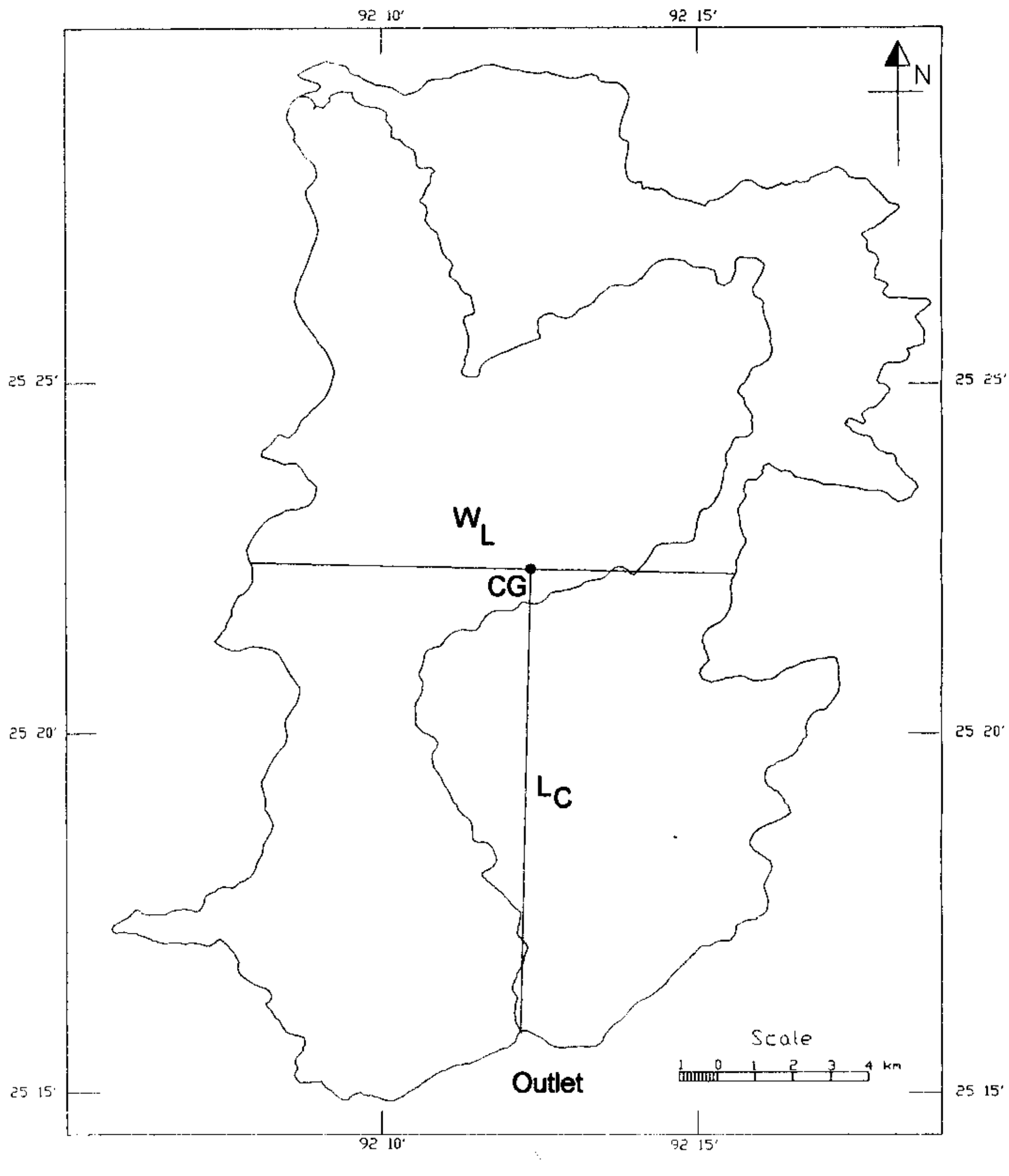

Fig. 4. Eccentricity of Myntdu river basin

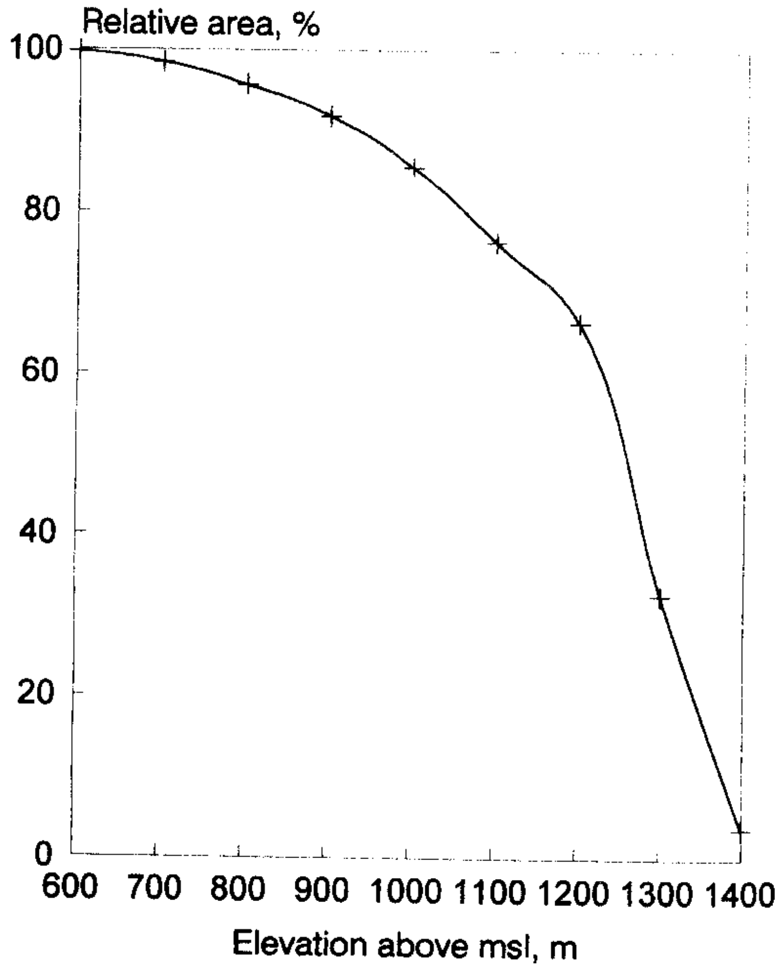

Fig. 5. Hypsometric curve for Myntdu River Basin

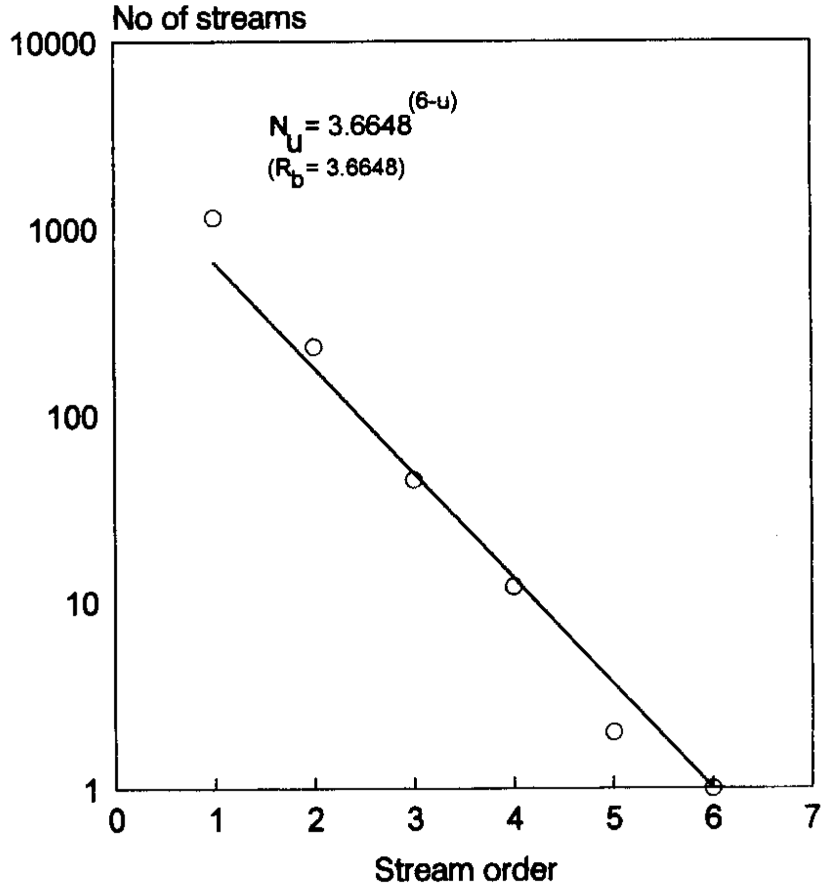

Fig. 6. Variation of no. of streams with stream order

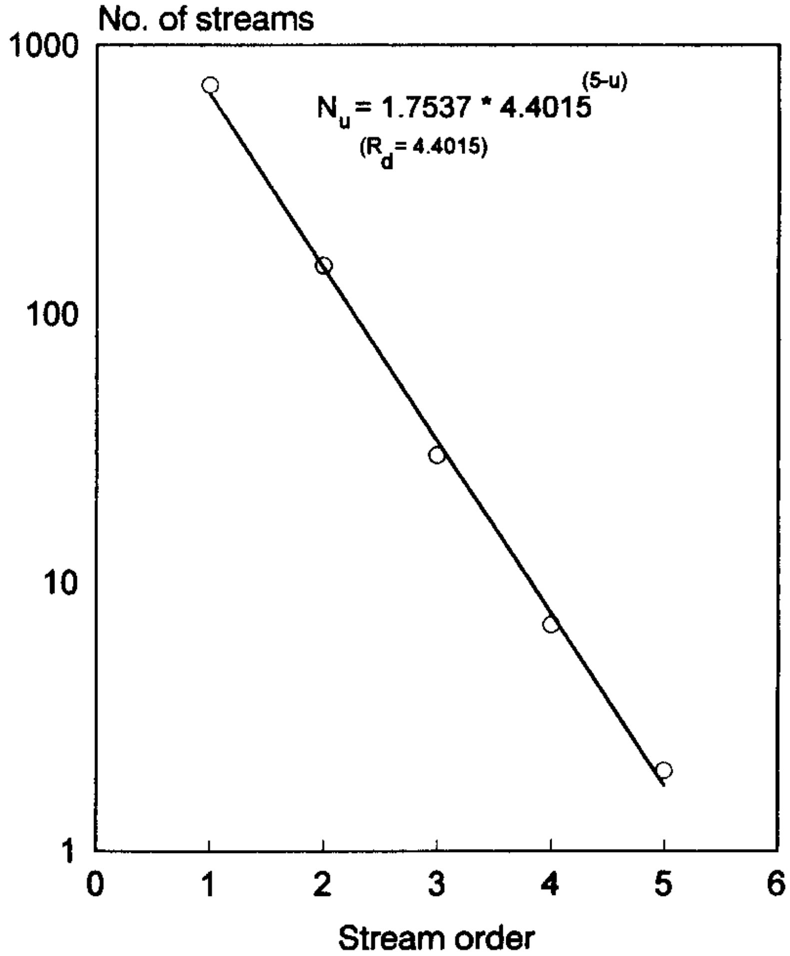

Fig. 7. Estimation of division ratio (R_d)

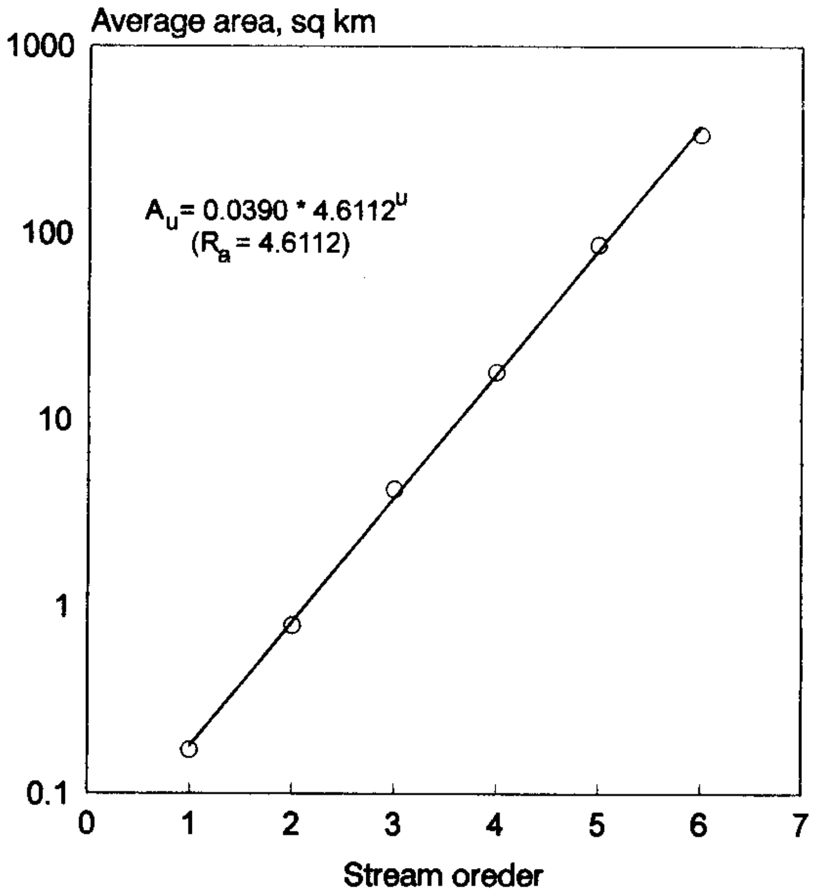

Fig. 8. Variation of stream order with average area

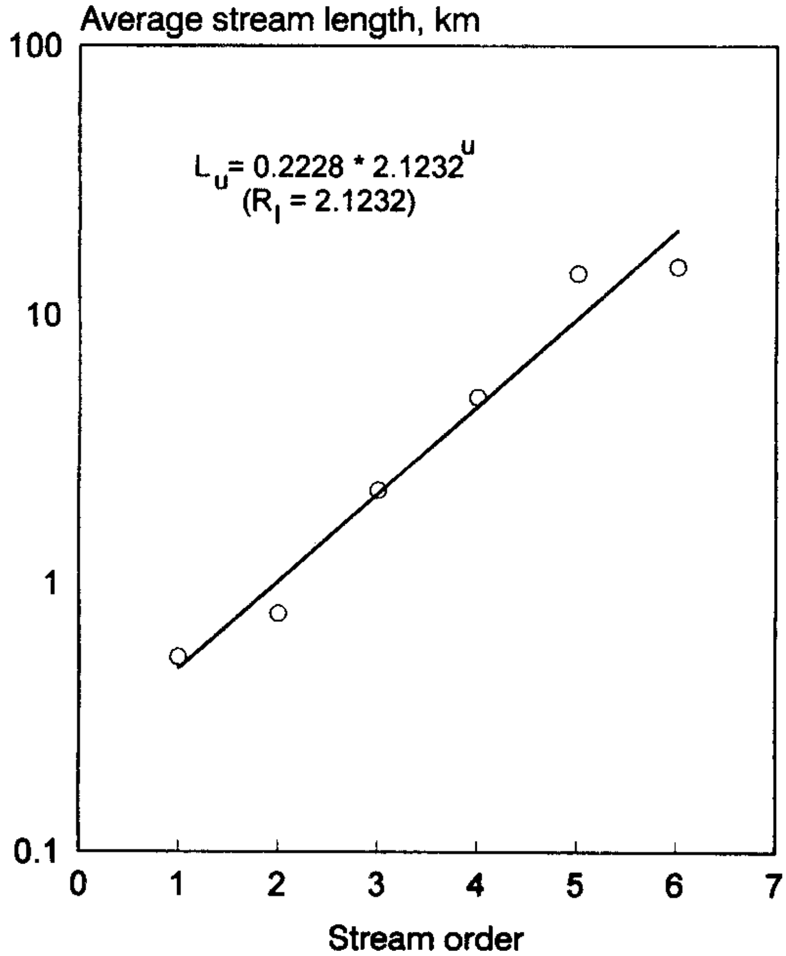

Fig. 9. Variation of stream order with mean stream length

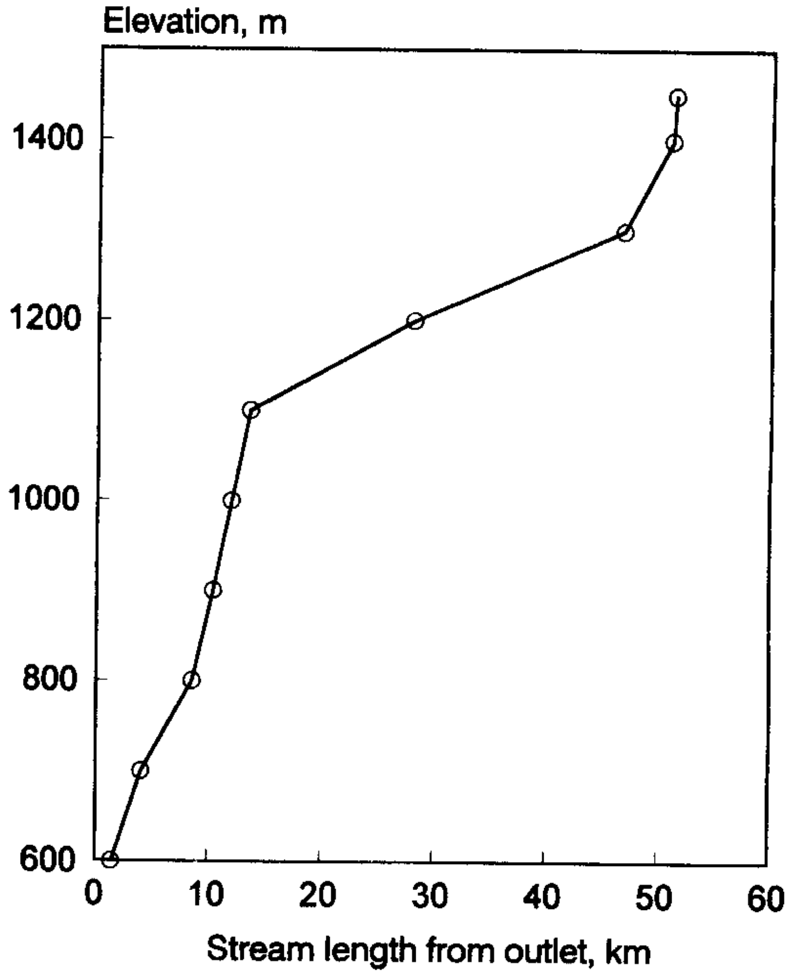

Fig. 10. Profile of main stream

Table 4

Areal aspect of Myntdu river basin		
Sl. No.	Parameters	Value
1.	Drainage Area, A	339.778 sq km
2.	Drainage Density, D	2.9264 km/sq km
3.	Constant of channel maintenance, C	0.342 sq km/ km
4.	Channel segment frequency, F	4.241 per sq km
5.	Circularity Ratio, R_c	0.3310
6.	Elongation Ratio, R_e	0.7990
7.	Watershed Shape Factor, R_s	2.7780
8.	Unity shape factor, R_u	1.4118
9.	Form factor, R_f	0.1267
10.	Compactness ratio, R_k	1.7382
11.	Area ratio, R_a	4.6112

From Table 3 and Table 4 it is observed that there is an increasing trend in the mean areas of different order streams with increasing order which confirms the Schum's Law of stream areas as discussed Art. 2. A plot to this effect between mean areas and orders is shown in Fig.8. The other areal measures furnished in the Table 4 above are regarded to have effect on peak and shape of the basin hydrograph and may be used in modelling the hydrological response of the basin when flow records are not available.

5.3 Relief Aspect of Myntdu Basin:

The geomorphological parameters of interest to hydrology, under this aspect has been described in Art. 2.3 and accordingly these have been estimated. The results are furnished in Table 5. The relief aspect parameters of the basin which are mostly non dimensional have significant effect on overland flow governing the flow processes.

As discussed in earlier articles these areal descriptors are of great importance specially for a mountainous catchment like Myntdu to understand the storage and flow characteristics, intensity of erosion processes operating on slope, comparison of basins for hydrograph synthesis etc.

Table 5

Relief aspects of Myntdu river basin		
Sl. No.	Parameters	Value
1.	Basin Relief, H	0.7770 km
2.	Relief Ratio, R_h	0.0299
3.	Relative relief, R_{hp}	0.6840 %
4.	Ruggedness number, R_n	2.2761
5.	Average slope of watershed, S_a	0.0588

6.0 CONCLUDING REMARKS:

In India, not enough successful applications of geomorphological characteristics to specific hydrologic studies in a basin and then transforming the results to other basins have yet been documented. There are, therefore, many limitations in substituting the results of such applications for more traditional tools of hydrologic methods.

The hydrogeomorphological parameters of Myntdu basin have been estimated from a digitised basin map where basic map data can be retrived and manipulated quickly, accurately and inexpensively.

The estimated geomorphological parameters of Myntdu basin covering linear, areal and relief aspects as been presented in the report, will be helpful in estimating and modelling the flow process of the basin.

In the Myntdu basin the existing network of hydrometeorlogical observation is not adequate. With the estimated geomorphological parameters of the basin it is now possible to extend the work for development of synthetic Geomorphological Instantaneous Unit Hydrograph and evaluation of important hydrologic model parameters like that of Nash Model (Nash,1960) for the basin.

The geomorphological characteristics of Myntdu basin will provide a simple means to compare it with other basin to regionalise the experimental results.

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