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Morphometric Characteristics of Dikrong River Catchment in the Foot-Hills of Arunachal Himalayas

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Abstract: Morphometric characteristics is an important parameter of landforms of the earth surface. It is directly or indirectly related to the morphology, geology, climate, soil, and vegetation of the area which are inter-related complex natural phenomena. The morphological characteristics are constant over time while the other characteristics are changing. Dikrong river catchment is located in the foot-hills of Arunachal Himalayas where more than 80% area is under hilly topography. The morphometric characteristics of Dikrong river catchment is controlled by its geological formation. Maximum number of first order river are found in the upper hilly areas which is greatly influence in reducing lag time because of feeding more water of first water rivers. High drainage density and frequency is found in the middle and upper part of the river catchment.

Keywords- *Arunachal Himalayas, Dikrong river, drainage density, foot-hills, morphometric, slope*

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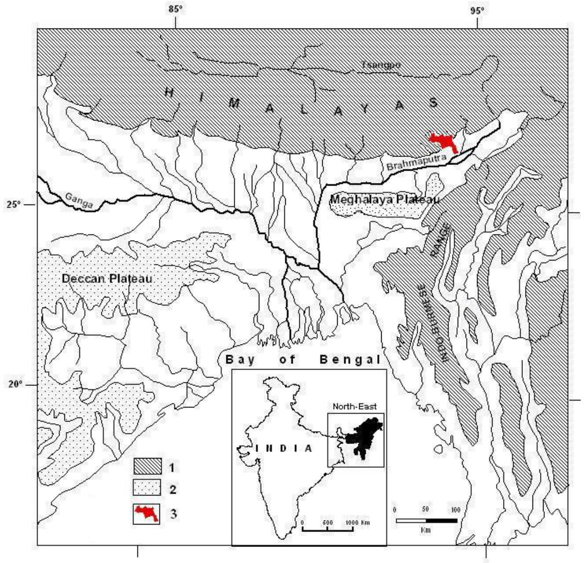
I. INTRODUCTION

Morphometric characteristics of landforms is the measurement and mathematical calculation of shape and dimension of particular landforms of the earth surface [1-4]. The morphometric analysis of drainage basin or river catchment are describe by its quantitative techniques through measurement of stream ordering, stream length, bifurcation ratio, relief features, slope etc. [5-7].Spatial variation in the intensity and amount of runoff is largely dependent on land surface conditions. In most of the geographical studies, physiographic conditions of landscape include most of elements related to geomorphology, geology, climate, soil and vegetation to understand the nature of inter-related complex natural phenomena. However, in the studies of land surface conditions for assessing surface runoff, the meteorological parameters are changing over time that form the basis of runoff production, while land surface conditions mainly the stream ordering, stream length, bifurcation ration, drainage frequency, drainage density, slope, soil and land use/land cover are considered 'constant' over time but they are 'spatially variable' and have effect on location of saturated areas; their extent and pattern generate the runoff [8-10].Use of remote sensing and GIS techniques in morphometric analysis are increasing day by day throughout the world as well as in India [11-18]. It is an important tools in the delineation, updating and calculating morphometric characteristics of drainage basin. The analysis of morphometric characteristics has been used to assess ground water potentiality, watershed management, construction of multi-purpose dams, mapping of flood prone and erosion prone areas [19-23]. For this purpose, the present paper examines the morphometric characteristics of Dikrong river catchment of about 1,556 sq. km area of which more than 80% is under the hill topography in the foot-hills of Arunachal Himalayas.

II. STUDY AREA

Dikrong river catchment is located in the foot-hills of Arunachal Himalayas and lies between 26˚55´N to 27˚22´N latitudes and 93˚13´E to 94˚0´E longitudes (Fig.-1) with its transitional characteristics of its location as it falls under Inter Tropical Convergence Zone (ITCZ) where climate is monsoonal in this part of Asian region. Being its location in the loop of Eastern Himalayas, it is more humid and has different hydrological characteristics than the other parts of North-East Region of the Country. Geologically, the catchment is located in the lower fault line which divides the river catchment into two topographic features: (i) the lower piedmont hills where erosion processes are prevalent and (ii) alluvial plains of depositional processes where frequent floods are experienced [24-25]. However, the flood responses are more related to piedmont hill- topography and land use of its upper part that influence the water flow and discharge of river channels.



1=Areas above 1600 m a.s.l., **2**= Areas of 900 to 1600 m a.s.l. **3**= Study Area

Fig.-1: Location of the Study Area

The length of the main river is recorded 145 km with an average slope of 5-15% with the perimeter of 264 km. Topographically, hill slopes are steep covering an area of about 61.54% with its narrow flat valleys located in the upper parts of the river catchment. Such topography helps in accelerating the saturation processes and fast flow while the lower part is gentle plain accommodating about a quarter part of the catchment (27.01%) with sediment deposition. Average temperature is recorded 15.15°C in January (moderately cold) and 26.96°C in July (Hot). Sometimes rainfall is high during pre-monsoon period (April) but July is the peak of monsoon when it precipitates up to 602 mm to 986 mm. Post-monsoon showers which occur from October onwards are helpful for soil recharge and vegetation growth. Due to thick fertile soils (1.2 m to 1.8 m) having 200 mm of water retention capacity and high nutrient contents promote vegetal growth [26-27].

III. METHODS AND MATERIAL USED

There are numerous methods for morphometric analysis of drainage basin like Strahler [28], Horton [29], Schumm [30], Smith [31] and Hadley and Schumm [32] etc. The present study of morphometric characteristics of Dikrong river catchment is carried out with the help of following formula (Table-1):

Table-1: Morphometric Parameters and Methods used for Dikrong River Catchment

Sl No	Parameter	Formula	References
1.	Stream order	Hierarchial rank	Strahler [28]
2.	Stream length (Lu)	Length of the stream	Horton [29]
3.	Mean stream length(Lsm)	Lsm = Lu/Nu	Strahler [28]
4.	Stream length ratio (RL)	RL = Lu/(Lu - 1)	Horton [29]
5.	Bifurcation ratio (Rb)	Rb = Nu/Nu + 1	Schumm [30]
6.	Drainage density (Dd)	Dd = Lu/A	Horton [29]
7.	Stream frequency (Fs)	Fs = Nu/A	Horton [29]

The drainage and contour maps of the study area were prepared with the help of using Survey of India toposheets (No. 83E/3, 83E/4, 83E/7, 83E/8, 83E/11, 83E/12, 83E/15, 83E/16 and 83F/13 of R.F. 1:50,000). The relief and slope map was prepared by digitizing the contour map and using Digital Elevation Model (DEM) technique in putting digitized map into GIS environment with its spatial resolution of 30m*30m.

IV. RESULTS AND DISCUSSION

The river catchment is irregular but shaped longitudinally North-South with a wider distance along MBT which changes the drainage system of the catchment. Branched pattern is evolved in general but some areas have different drainage orders and densities.

(i) Drainage System: It forms a system of flow of water as per slope and elevation. The number, size, and shape of the drainage basin found in an area vary with the scale of examination. Drainage system of Dikrong river catchment follows the dendritic pattern and elongated in shape. It drains more than 80% in the foot-hill of Arunachal Himalaya and reaches the Brahmaputra by flowing plains in Assam (Fig.-2).

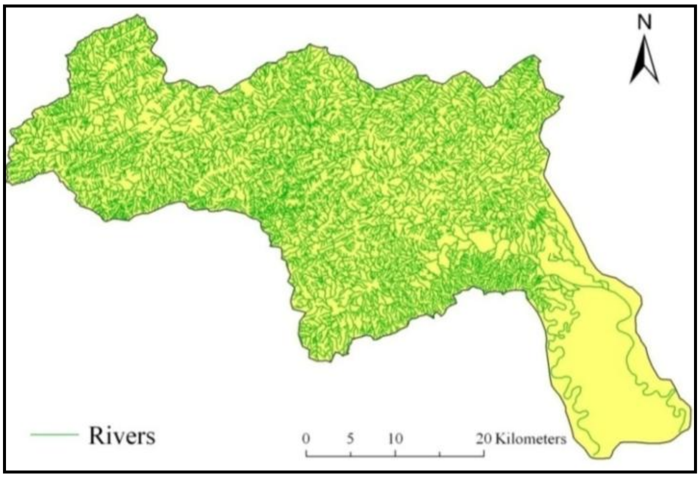


Fig.-2: Drainage System of Dikrong River Catchment

(ii) Stream Ordering: A river system is consists of several segments and each segment has its own morphometric characteristics [33]. The process of stream ordering was suggested by Gravelius [34] and the works of Horton [35, 29] was the milestone regarding the stream ordering in geomorphology. Horton's stream ordering system was so complicated in the sense of subjective decision in projecting the order of streams and all the smallest tributaries do not fall into same stream order category [36]. Horton's stream ordering method further modified and simplified by Strahler [28]. According to Strahler, a single finger trip stream has been designated as first order, the two first order stream form a second order stream, two second order stream produced the third order stream and so on. In winter season first and second order stream become dry as the water falls down.

The stream ordering map (Fig.-3**)** prepared basing on Strahler [28] technique for the Dikrong river catchment shows that the drainage of the river catchment consists of 7th order stream system. It include 4,647 in number first order, 1,089 second order, 258 third order, 57 fourth order, 14 fifth order, 4 sixth order and one 7th order streams (Table-2).

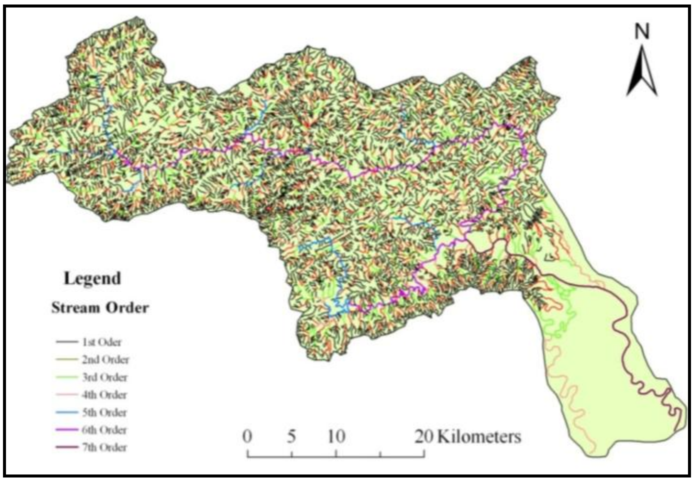


Fig.-3: Stream Ordering of Dikrong River Catchment

(iii) Stream Length: The total stream length of the different stream order was calculated from digitized streams for Dikrong river catchment (Table-2). It shows that the total stream length of the study area is 4317.16 km. Out of total stream length, the first order stream accounts for 60.11 % length of total length of all rivers. It is followed by 19.08 %, 10.25 %, 4.62 %, 2.08 %, 2.70 % and 1.16 % for second order, third order, fourth order, fifth order, sixth order and seventh order stream respectively.

The mean stream length is found at seventh order stream system (49.91km) and the minimum at first order stream (0.56 km). So the length ratio of different stream orders ranges from 1.35 to 4.56. On the other hand, bifurcation ratio is similar in the entire part of river catchment (Fig.-4).

In general, it may be said that the stream length by their orders diminishes following concave nature while mean stream length follows convexity. It shows well-drained conditions and channels of first order feeds water to the mouth smoothly by reducing lag time and saturated areas at the top of hills. Bifurcation ratio is also equal at almost all orders except 7th order when channels become river in depositional plain part of the river catchment.

Table-2: Channel Network and its Morphometric Characteristics

Stream Order	No. of Stream	Length (km)	Length (%)	Mean Stream Length (km)	Stream Length Ratio	Bifurcation Ratio
1	4647	2595.13	60.11	0.56		4.27
2	1089	823.67	19.08	0.76	1.35	4.22
3	258	442.61	10.25	1.72	2.27	4.53
4	57	199.46	4.62	3.50	2.04	4.07
5	14	89.66	2.08	6.40	1.83	3.50
6	4	116.72	2.70	29.18	4.56	4.00
7	1	49.91	1.16	49.91	1.71	
Total	6070	4317.16	100.00			

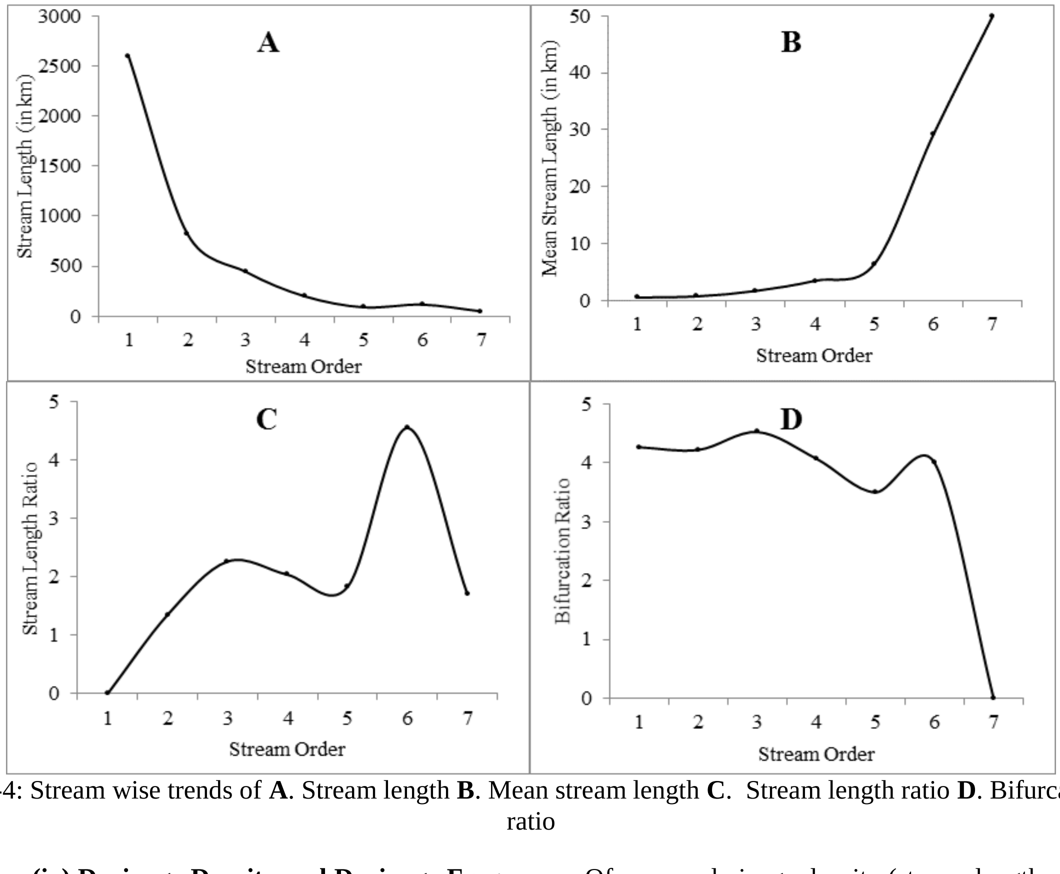
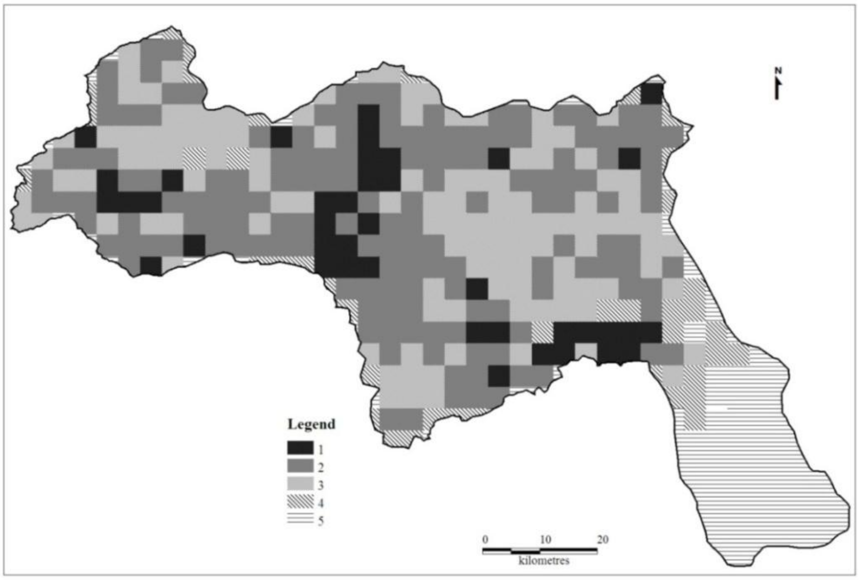


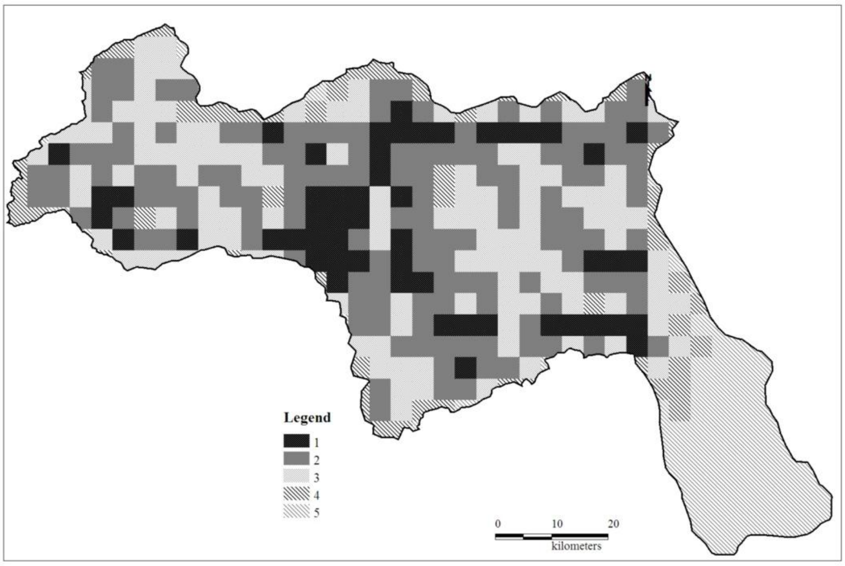
Fig.-4: Stream wise trends of **A**. Stream length **B**. Mean stream length **C**. Stream length ratio **D**. Bifurcation ratio

(iv) Drainage Density and Drainage Frequency: Of course, drainage density (stream length per unit area) and drainage frequency (number of streams per unit area) are generally positively related because areas having more number are accounted for larger stream length and *vice-versa.* But it may not be true in all areas. However, high density and high stream frequency areas might have less accumulation of flowing water and release more water to nearby areas. That is why, these parameter of land surface are inversely proportional to flow accumulation. High and very high drainage density (above 3 km/sq km) was calculated in the middle and upper parts of the Dikrong river catchment while moderate drainage density (2-3 km/ sq km) area were located mostly in the lower parts of MBT in the river catchment. The lower plain areas of the Dikrong river catchment have low and very low drainage density (below 2 km/sq km) (Fig.-5). Perhaps flow accumulation conditions are remarkable in lower reaches of low drainage density areas of the river catchment. Almost similar pattern of drainage frequency are observed in the ricer catchment (Fig.-6).



Abbreviations: Drainage Density (in km/sq. km) **1.** Very High (Above 4) **2.** High **(**4-3) **3.** Moderate (3-2) **4.** Low (2-1) and **5.** Very Low (Below 1)

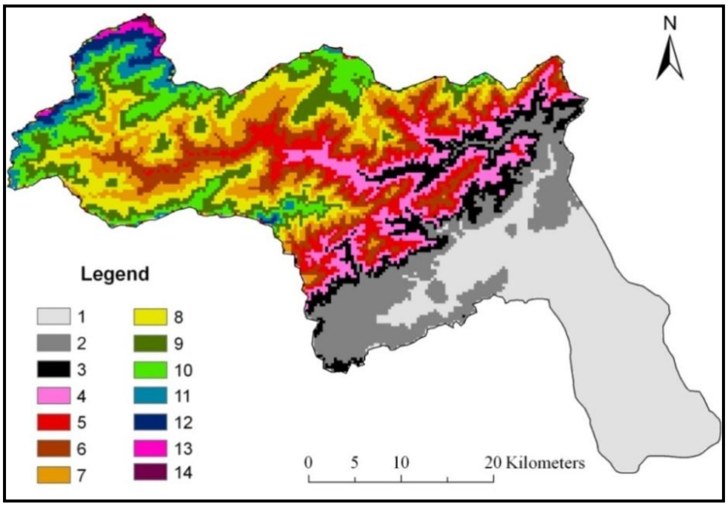
Fig.-5: Pattern of Drainage Density in the Dikrong River Catchment



Abbreviations: Drainage Frequency (in number/sq. km) **1.** Very High (Above 20) **2.** High (15 – 20) **3.** Moderate (10 – 15) **4.** Low (5 -10) and **5.** Very Low (Below 5)

Fig.-6: Pattern of Drainage Frequency in Dikrong River Catchment

(v) Relief Features Relief features are shown by mapping contours from toposheets (at 100 m interval) distributing them for highlight detail features using DEM at 30m*30m spatial resolution shows that more than one-third area of the river catchment has low relief features (0-400 m) as depositional plains, while the higher elevated areas (1000-1800 m) also account for about one-third part that is located in the north-central part of the river catchment (Fig.-7, Table-3).



Abbreviations: Elevation in meters **1**.0 – 200 **2**. 200 - 400 **3**. 400 - 600 **4**. 600 - 800 **5**. 800 – 1,000 **6**. 1,000 – 1,200 **7**. 1,200 – 1,400 **8**. 1,400 – 1,600 **9**. 1,600 – 1,800 **10**. 1,800 – 2,000 **11**. 2,000 – 2,200 **12**. 2,200 – 2,400 **13**. 2,400 – 2,600 **14**. Above 2,600

Fig.-7: Digital Elevation Model (DEM) of Dikrong River Catchment

Table-3: Area Covered by Different Elevations in Dikrong River Catchment

Sl. No.	Elevation (m)	Area (ha)	Area (%)	Cumulative Area (%)
1	0-200	37229.16	23.92	100.00
2	200-400	20539	13.20	76.08
3	400-600	9867.48	6.34	62.88
4	600-800	9647.88	6.20	56.54
5	800-1000	10751.45	6.91	50.34
6	1000-1200	12250.88	7.87	43.43
7	1200-1400	14642.12	9.41	35.56
8	1400-1600	13312.99	8.55	26.15
9	1600-1800	11510.69	7.40	17.60
10	1800-2000	8857.65	5.69	10.20
11	2000-2200	4043.12	2.60	4.51
12	2200-2400	2053.35	1.32	1.91
13	2400-2600	814.22	0.52	0.59
14	2600-2800	105.02	0.07	0.07
	Total	155625.00	100.00	

Hypsometric curve of Dikrong river shows the normal condition flow from its origin at 2800 m upto 2200 m altitude, after that it changed its flowing paths. In the altitude of 600 m the river again changed its paths to reach its mouth in the plains (Fig.-8).

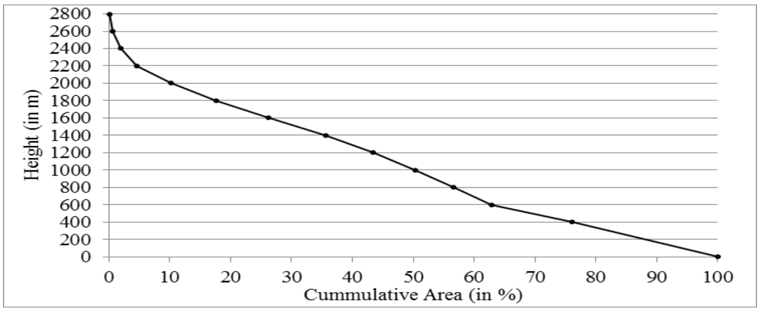
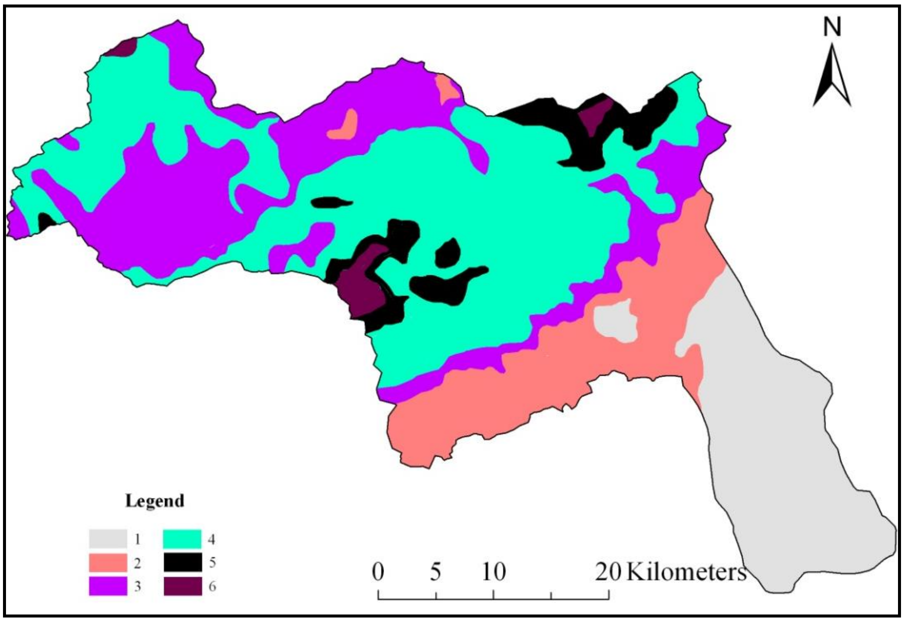


Fig.-8: Hypsometric Curve showing Relief Features

(vi) Relative Relief: Relative relief refers to absolute slope of the specific area as it is based on the difference in height between the highest and lowest elevations in a particular unit area [37]. The upper reaches of Dikrong river catchment enjoy the high relief features, while the flat areas of lower part have smooth low relief like oxbows, *beel*, meanders and other low land features which helps to retain flowing water of the rivers in such low relief areas. But the extents of such areas are about 402.7 sq km (25.88%) with plain topographic features (Fig.-9, Table-4).



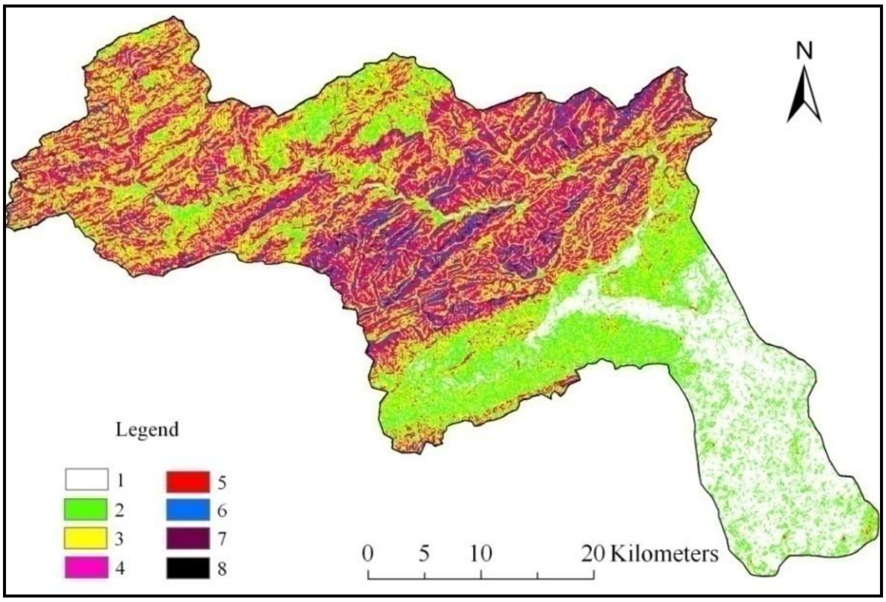
Abbreviations: **1**= Very Low (0-100m) **2**= Low (100m-300m) **3**= Moderate (300m-500m) **4**=High (500m-700m) 5= Very High (700m-900m) **6**= Extremely High (Above 900m)

Fig.-9: Pattern of Relative Relief

Table-4: Area Covered by Different Relative Relief group of Dikrong River Catchment

Relief Category	Elevation (in m)	Area (in ha)	Area (%)
Very Low	>100	27613.43	17.74
Low	100-300	23000.50	14.78
Moderate	300-500	40269.00	25.88
High	500-700	51805.37	33.29
Very High	700-900	10616.00	6.82
Extremely High	>900	2320.70	1.49
Total		155625.00	100.00

(vii) Slope: The slope is an important attribute of land surface that has direct controls the amount of runoff and also mechanism of surface and subsurface flow [36]. In present discussion, slope variation within the river catchment and its effect on hydraulic conductivity that is an important parameter of runoff, are described in its regional pattern. In fact, steepness of surface slope increases the speed of surface and sub-surface flow by increasing value of hydrological conductivity as Darcy law states. On account of higher K value the sub-surface flow comes out as surface in the form of springs that feed water to the first order streams to increase discharge rate of the catchment. Secondly, the flow of surface water is speed up by the steep slopes that reduces the amount of infiltrated water and increases amount of direct runoff.The slope gradient variations are interpreted to classify the river catchment into its eight different standard categories using DEM with spatial resolution of 30 m*30 m (as used earlier part of discussion). They are: Very Gentle (2- 4 %), Gentle (4-10 %), Moderate (10-20 %), Moderately Steep (20-35 %), Steep (35-60 %), Very Steep (60-100 %), Most Steep (100-175 %), and Extremely Steep (above 175 %).Lower part of the river catchment has gentle to very gentle slopes where river meanders, oxbows and other depositional features of low lying are seen. The runoff processes in this area are different from the areas of upper catchment where undulating slopes of its moderate degree (10-20%) and flat hill tops are featured (Table-3.4). Due to impact of MBT the central parts of the river catchment have steep to very steep slopes (10-100%). Valley bottoms have moderate slopes (Fig.-10 and Table-5).



Abbreviations: Slope in percent; **1**= Very Gentle (2- 4), **2**= Gentle (4-10), **3**= Moderate (10-20), **4**= Moderately Steep (20-35), **5**= Steep (35-60), **6**= Very Steep (60-100), **7**= Most Steep (100-175), **8**= Extremely Steep (above 175).

Fig.-10: Slope Variations in the Dikrong River Catchment

Table-5: Area Covered by Different Slope Category of Dikrong River Catchment

Slope	Slope Category (in %)	Area (in ha)	Area (in %)
Very Gentle	2-4	12347.55	7.93
Gentle	4-10	29696.86	19.08
Moderate	10-20	17804.13	11.44
Moderately Steep	20-35	28464.08	18.29
Steep	35-60	37603.31	24.16
Very Steep	60-100	4766.00	3.06
Most Steep	100-175	23300.29	14.97
Extremely Steep	>175	1642.78	1.06
Total		155625.00	100.00

V. CONCLUSION

In the end of the discussion, it can be said that the morphometric features that influence the hydrological processes, are manifestations of geological structure. The entire river catchment is therefore, divided into two: the upper part of MBT where denudational hills, inter mountain valleys and hill-crust are major features to make land surface more sloppy with indifference hydrological processes and the lower part of MBT where depositional processes with flat land of gentle slopes and deep sandy soils are the land surface conditions to yield less runoff; even than it comes under flood affected areas due to low-lying container features of Dikrong river catchment. There are some specific findings inferred from the present analysis:

(i) The morphometric features of Dikrong river catchment is control by its geological structure.

(ii) The drainage frequency was observed almost similar throughout the river catchment. Maximum number of 1st order river found in the upper hilly areas, which indicates well-drained conditions and rivers of first order feeds more water and release to the mouth smoothly by reducing lag time.

(iii) Due to geological conditions and morphometric features, the high relief and moderately steep to most steep slope of the river catchment was found in middle and upper part of the catchment which creates flood problems in the lower reaches.

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