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Fluvio - Morphometric Characteristics of Chenga River Basin of Darjeeling District, West Bengal

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Introduction - The operational behaviour of a small river in respect to its length and channel width, channel morphology is one of the important aspects. The flow characteristic has a great importance in studying the behaviour of the river. River hydraulics which deals with the study of water of the river at motion or rest and another is river mechanics which the study of effects of forces on river water and produce the important aspects of channel morphology and channel flow characteristics. The flow behaviour of river water is a subject matter of river hydraulics which is very much influenced by the different properties of the water. According to Department of the U.S Army Corps of Engineers Washington, DC 20314-1000 River Hydraulics presents some basic principles and technical procedures for analysis of open channel flows in natural river systems. The main objectives are -

- To measure the velocity and discharge and their relationship between different channel geometry.
- To observe the fluvio-geomorphological features in the study area.

Methodology - Different maps like drainage map, slope map, contour map, watershed map etc and location map of the study area are prepared in GIS platform. For drainage basin maps the satellite image of the study area is downloaded from the USGS Earth Explorer portal. Downloaded satellite image is then processed in GIS Platform and extract salient features of the study area for my project work. Mathematical and statistical calculations were done in Ms Office Excel 2010 for this work. Global Mapper also used to calculate the river length, basin area and basin perimeter and other geomorphic properties.

Field data are collected for further discussion on the River Morphology and Flow Behaviour and the cross profiles are drawn in MS Excel 2010 along the channel and across the channel. The distance between survey points was estimated by 30 metre tape and mobile topographer app to show the geographical coordinates. To measure the velocity of the river, ‘Floating Ball Method’ has been applied. For this estimation, a 10 metre reach of the survey site has been selected. With a Stopwatch, it is estimated the time required of a floating ball to travel this distance. The same technique has been followed a number of times to calculate a mean surface velocity of the river. After getting the velocity of the following water, we have used to basic formula of discharge estimation.

Q = w*d*v

Where, Q = Volume of discharge in cumec (m^3/s)
d = Mean depth of the active Channel (m) w = Width of the flowing water (m)
v = Velocity of the following water (m/s)

Study Area - Chenga River is a tributary of Mahananda River system, which is one of the major river systems of Darjeeling district in west Bengal. It is coming from the lower hills of Mirik Hill and then flow through Naxalbari Block and entered in Phansidewa Block and confluence with Mahananda River. The characteristic of the drainage basin is dendritic pattern. The total length of the stream is 66 km, and the basin area is 127.46 km^2, with a perimeter of 60.889 km. The basin area is extended from $26^{0}35^{'}00^{''}$ N to $26^{0}49^{'}40^{''}$ N, latitude and from $88^{0}11^{'}05''$ E to $88^{0}16^{'}55^{''}$ E longitude.

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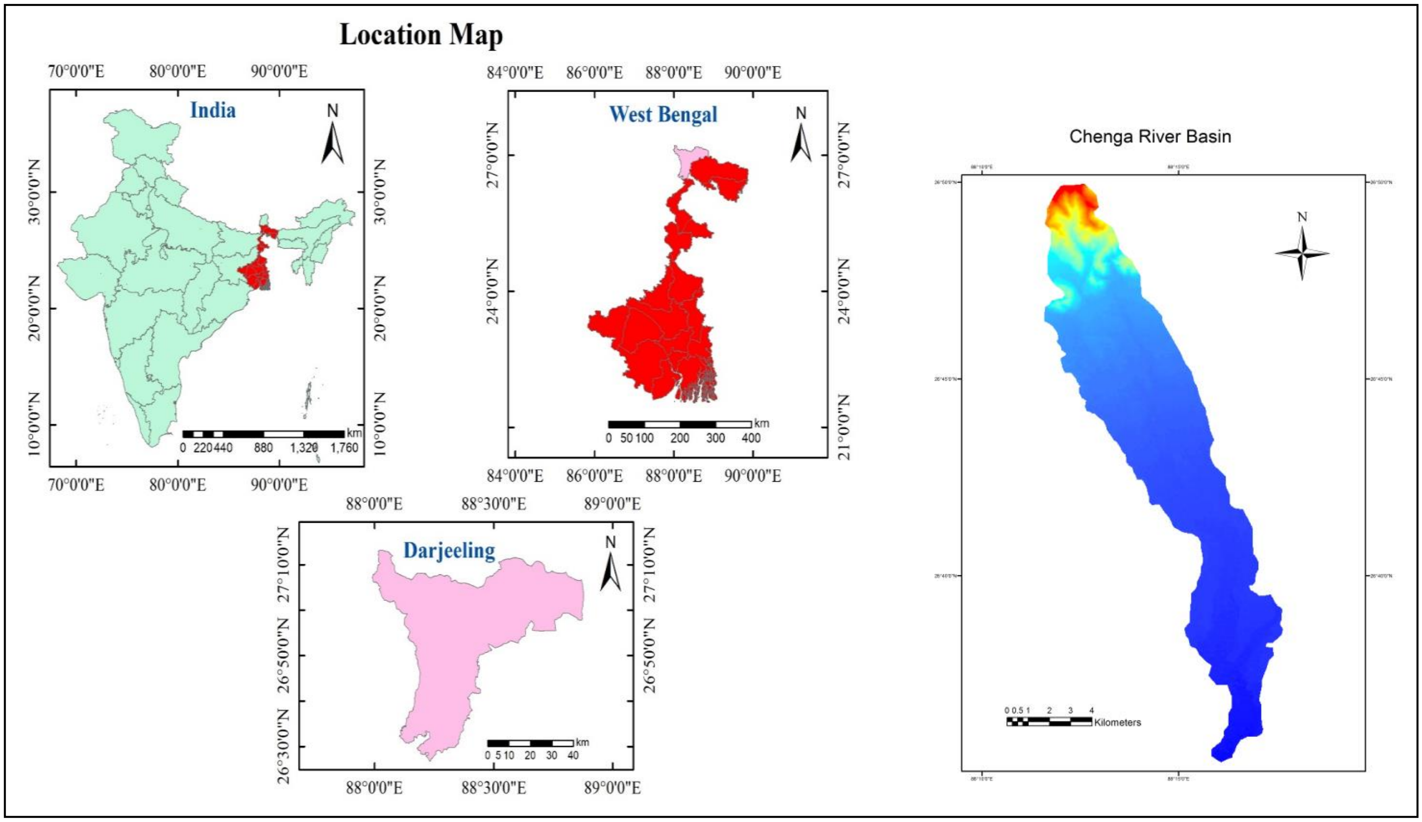
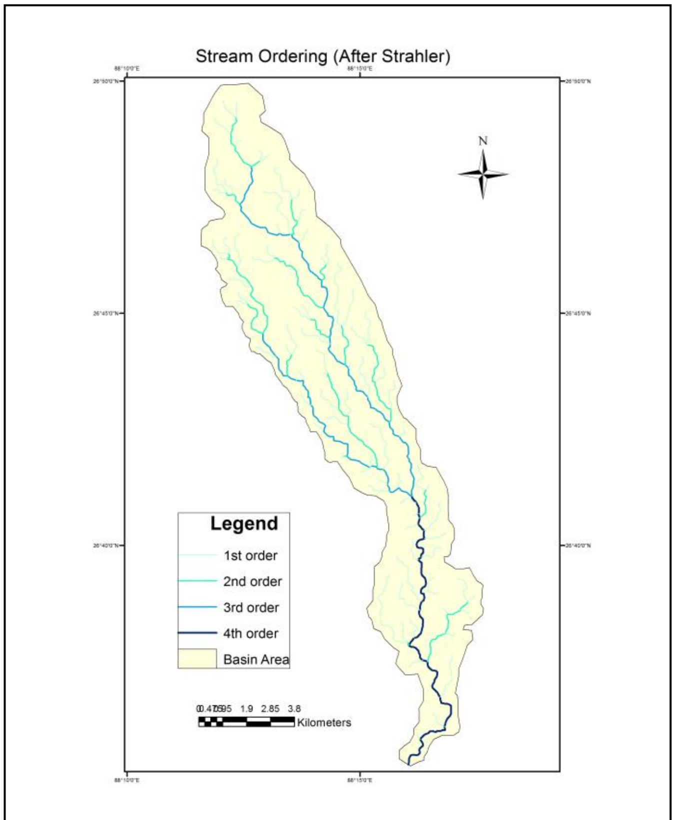


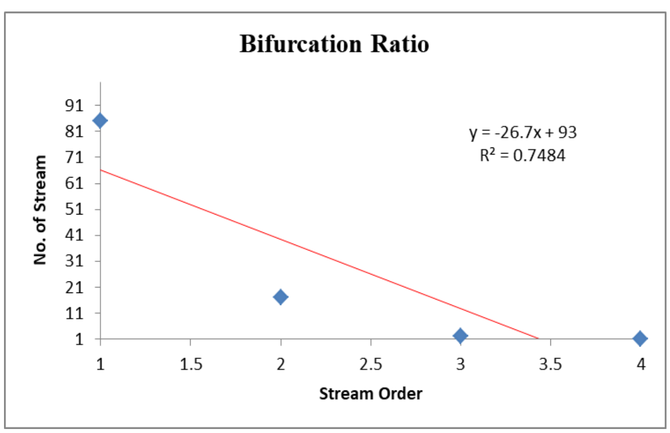
Stream Ordering - This method helps to classify the stream number of a particular basin in a hierarchical order. Among the different methods of stream ordering, Strahlar (1954) method of stream ordering has been applied here. According to Strahler (1954), a stream without any tributary is a first order. Two first orders join to form a second order; two second orders join to form a third order stream and so on. In the study area, we can see here up to 4^{th} order stream which is surveyed for extraction of data to analyse the project work.



Bifurcation Ratio - Bifurcation ratio is related to the branching pattern of the drainage network and is defined as a ratio of the number of streams of a given order (N_u) to the number of the next higher order N_{u+1} and is expressed in the following equation:

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

Stream Order (u)	**No. of Streams (N_u)**	**Bifurcation Ratio**
1	85	-
2	17	5
3	2	8.5
4	1	2



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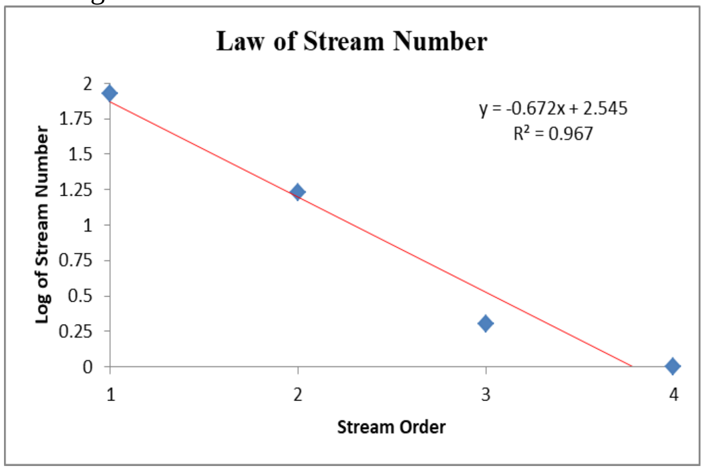
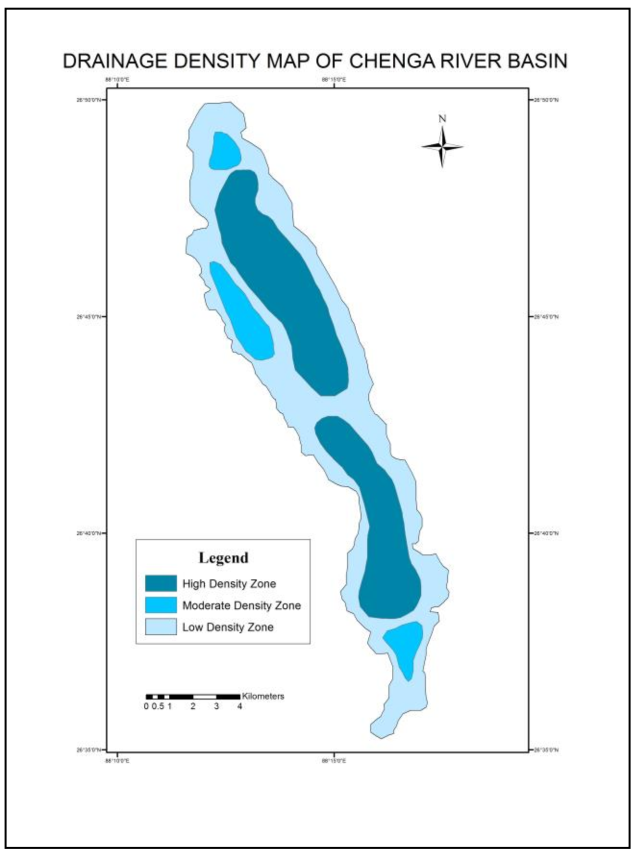
Law of Stream Number - The law of stream number relates to the definite relationship between the orders of the basins and stream number. R.E. Horton's law of stream number states (1945) that "the number of stream segments of successively lower orders in a given basin tend to form a geometric series beginning with the single segments of the highest order and increasing according to a constant bifurcation ratio".



Drainage Density - "Drainage density" is an expression of the total length of an actual number of stream segments per unit area, and is considered as a meaningful index of potential sustainability in terms of water availability from a basic input in the agricultural land use operation. In the study area we can see five different zones. The formula for calculation is,

Drainage Density = Length of Streams / Area



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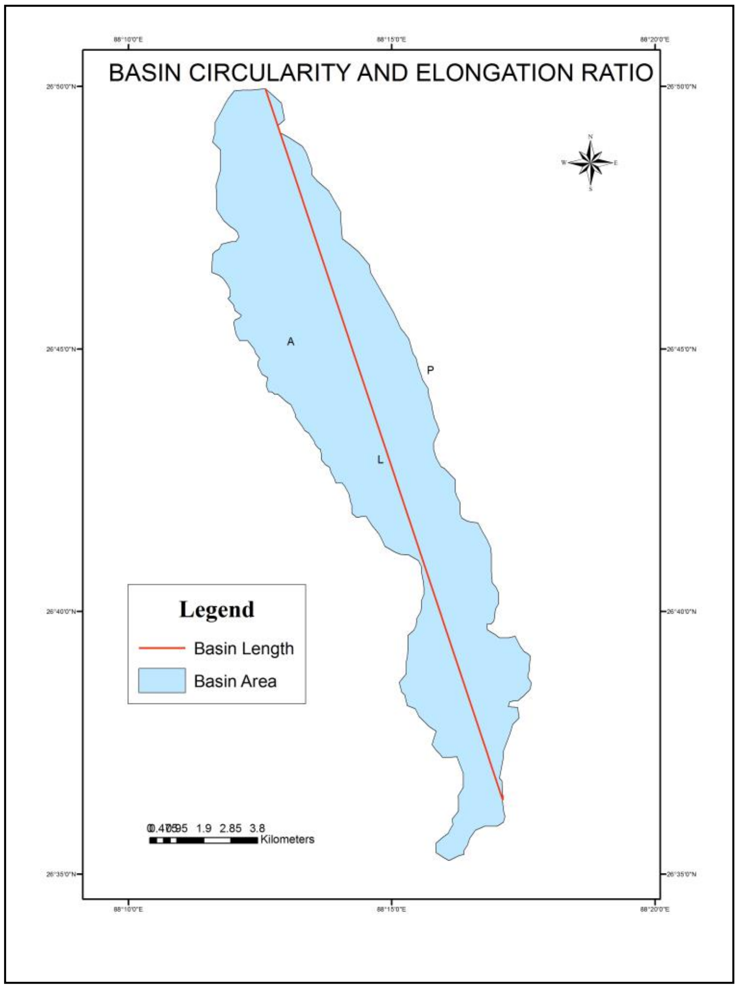
Elongation Ratio (R_e) - It is the ratio between the diameters of a circle of the same area as the drainage basin to the maximum length of the basin (L_b) (Schumm, 1956). It ranges between 0.6 -1.00 based on different climatic conditions and geologic formations. The elongation ratio is equal to 1 for a circular basin and approaches 0 for a linear one. Values in the range of 0.6-0.8 are generally associated with strong relief and steep grounds. The values around 1.00 are typical of regions of very low relief. Elongated basins with high bifurcation ratio yield a low but extended peak flow while circular basins with low bifurcation ratio produce a sharp peak flow. The elongation ratio is calculated as:

$$R_e = (2\sqrt{A/\Pi}) / L_b$$



The elongation ratio for most of the watersheds as well as for the entire Chenga basin is 0.49, indicating a highly elongated basin with strong relief and steep topography in the upper reaches but the maximum river is flowing through a plain region.

Circularity Ratio (R_c) - Circulatory ratio is the ratio of the basin area (A) to the area of the circle of basin perimeter (P) (Miller, 1953). It is the measure of the degree of circularity of the given basin. High value indicates old stage topography. R_c approaching 1 indicates circular shape of the basin Circularity and old stage topography. The circularity ratio has been found out by using the following formulae:

$$R_c = 4\Pi A / P^2$$

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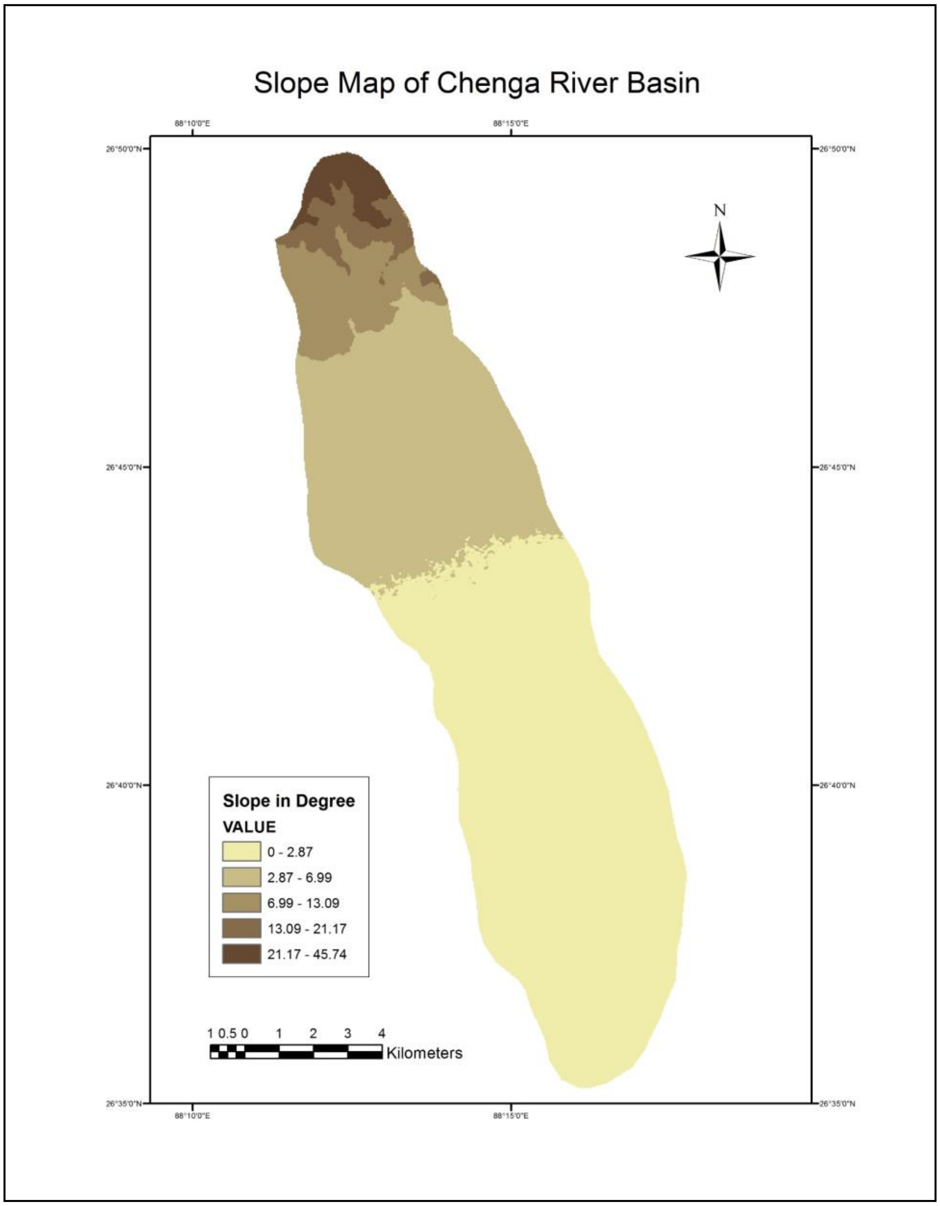
The circularity ratio of the watersheds is 0.43, which means that the basin is not circular

Slope of the Basin - Slope is the measures of steepness or the degree of a feature relative to the horizontal plane. The study area divided into 5 different slope units. The value of slope below 2.87 is mainly seen downstream of the basin. The slope of the second group is 2.87 to 6.99 which is found in the northern portion of the previous group. The slope of the third group with a value of 6.99 to 13.09 is found in between the slope of fourth group and second group. The slope of the 4th class is between 13.09 to 21.167 is found below the Mirik hills and the piedmont area of the basin, and the slope of the 5th class is between 21.167 to 45.74 which are found in the extreme northern part of the upstream area.



Fluvial Characteristics - Rough river channels contain a large quantity of rocks, pebbles and boulders, either at the bottom of the river or embedded with on its sides. A large value of friction is created between water molecules and these stones and creates resistance and reduces the river's velocity. In a smooth river channel, with fewer pebbles and rocks, velocity is higher because there is less friction causing energy to be expanded as it flows.

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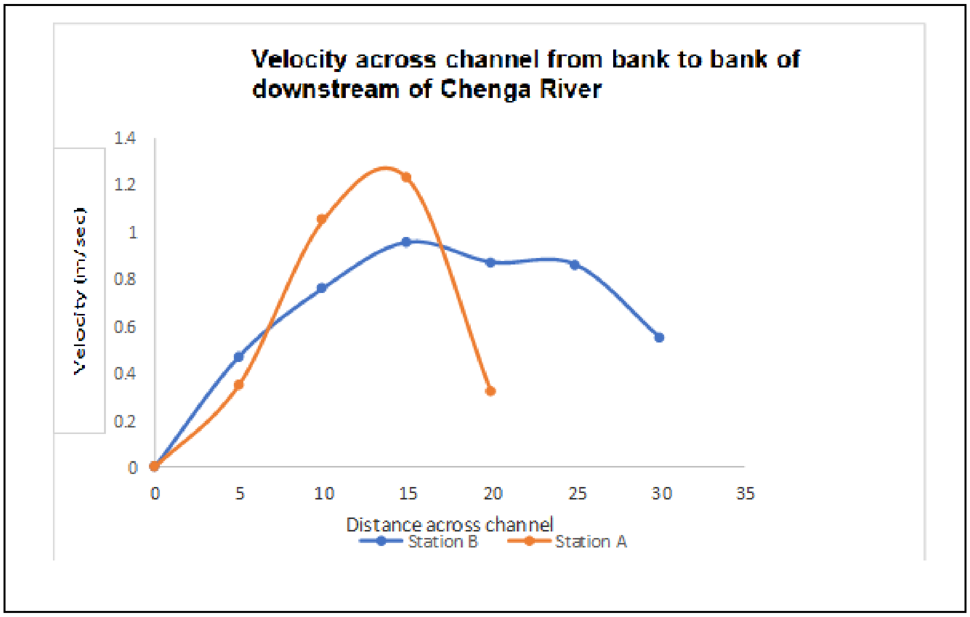
Gradient of River Bed: In the basin, the velocity of the stream is controlled by several features like width, depth, velocity and slope of the channel. The velocity of the stream is higher in the 1st survey site than the 2nd one because the river bed has greater slope and minimum width than the 2nd site.

Velocity and its Distribution - Stream velocity, involved in defining regimes of flow, is important and need to examine its distribution in a channel and its effects, Nordin (1963) found that velocity varies logarithmically in vertical profile with the maximum velocity generally occurring near, but somewhat below, the water surface. Savini and Bodhaine (1971) graphed the velocity profile as a smooth curve with velocity increasing from the bed to the water surface. The change in velocity is more rapid near the bed and the boundary conditions also effect the velocity distribution and causing turbulence and greater velocity variations at the stream bed and banks.



Velocity and Discharge: The amount of water flowing in the stream or river, commonly expressed in cubic feet per second or gallons per day. The velocity of the river is measured by the current meter and there also another method which is called Float Ball method. The velocity of the river also express in cubic metre per second. Discharge is a volume of water moving down a stream or a river per unit of time, commonly expressed in cubic feet per second. In general, river discharge is computed by multiplying the area of water in a channel cross- section by the average velocity of the water in that cross- section.

Discharge = Area * Velocity

Estimation of Stream Velocity and Discharge of Chenga River

(Float - Ball method)

Stream Velocity (m/s) Estimation				
Floating No.	**Distance (m)**	**Travel Time (Second)**	**Mean Travel Time (second)**	**Velocity of Stream (m/s)**
1	10	28.56	19.5675	0.511
2		9.56		
3		8.88		

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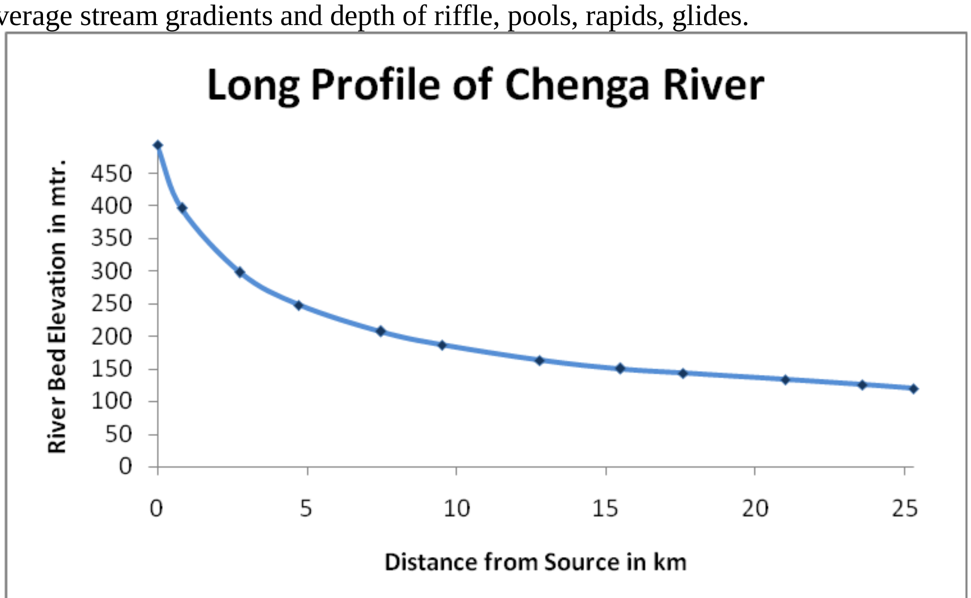
4		31.27		

Stream Velocity (m/s)				
Floating No.	**Distance (m)**	**Travel Time (second)**	**Mean Travel Time (second)**	**Velocity of stream (m/s)**
1	10	21.48	14.38	0.69
2		13.16		
3		10.45		
4		11.5		
5		11.58		
6		18.11		

Geometry of channel (Wetted section and estimation)					
Station	**Width (mtr)**	**Mean Depth (mtr)**	**Cross - Section Area (mtr^2)**	**Stream Velocity (mtr./sec)**	**Stream Discharge (m^3/s)**
A	30.5	0.6017	18.352	0.511	9.38
B	23.7	0.62	14.694	0.69	10.14

The mean velocity of Chenga River at first site is 0.511 m/s and the amount of discharge is 9.38 m^3/s or cumec and the velocity of at second site is 0.69 m/s and the discharge is 10.14 m^3/s. The result indicates the amount of discharge is very high because in rainy season as there is no permanent glacial in the upstream to supply water continuously throughout the season in the stream. It was also noticed that the discharge is changing with respect to the width, depth and velocity. Here we can see the discharge is greater in the first site than the second site.

Long and Cross Profile of the Chenga River - Longitudinal profile of a river indicates the graphical representation of elevations along the distance of the river using line graph from its upstream to downstream. The longitudinal profile helps to identify average stream gradients and depth of riffle, pools, rapids, glides.



Distance from	**River Bed Elevation**

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Source (km)	**Above msl (mtr.)**
0	493
0.81	396
2.76	298
4.73	248
7.49	207
9.52	187
12.8	163
15.5	150
17.6	143
21	134
23.6	126
25.3	120

Cross profile has been prepared across the basin at different parts of the basin form source to its confluence with Mahananda River. The section lines are so chosen that they show the situation of erosional and depositional activity of the river.

River cross section data of survey area

Cross Profile	**Channel Width in mtr.**	**Channel Depth in mtr.**	**Cross Profile**	**Channel Width in mtr.**	**Channel Depth in mtr.**
1	0	0	**7**	0	0
	7.5	0.9		5	0.61
	22.5	1.8		10	0.57
	37.5	3.12		15	0.49
	52.5	2.2		20	0.37
	67.5	0.51		25	0.21
	73.2	0		30	0.17
2	0	0		35	0.11
	25	3.21		37.4	0
	50	2.78	**8**	0	0
	75	1.91		25	3.17
	100	1.07		50	3.07
	125	0.91		75	2.12
	150	0.4		100	1.17
	171	0		126	0
3	0	0	**9**	0	0
	25	0.85		25	2.18
	50	1.91		50	1.17
	75	3.1		75	0.87
	100	3.31		100	0.57
	125	4.07		125	0
	150	4.2	**10**	0	0

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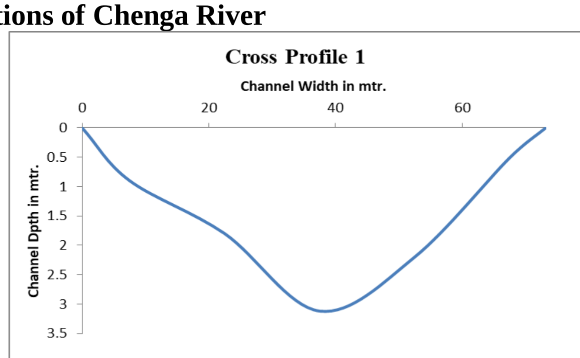
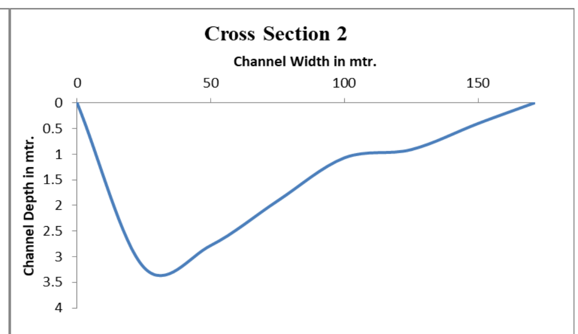
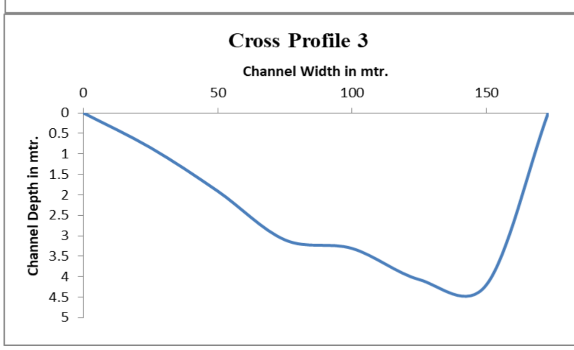
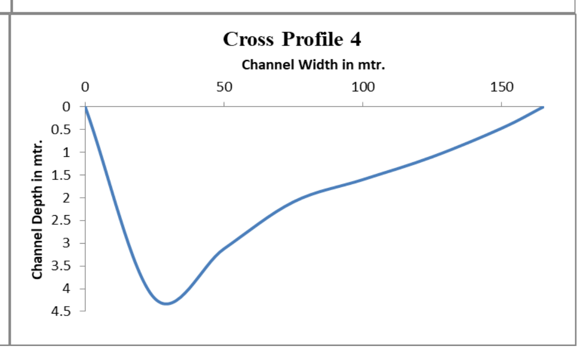
	173	0		5	0.51
	0	0		10	0.41
	25	4.21		15	0.31
	50	3.12		20	0.31
4	75	2.09		25	0.26
	100	1.6		30	0.21
	125	1.1		35	0.14
	150	0.47		42	0
	165	0		0	0
	0	0		5	0.65
	25	1.07		10	0.8
	50	2.12	**11**	15	0.6
5	75	1.41		20	0.66
	100	1.07		25	0.53
	125	0.86		30	0.37
	150	0.61		30.5	0
	176	0		0	0
	0	0		5	0.53
	25	0.41	**12**	10	0.88
6	50	0.37		15	0.62
	75	0.61		20	0.45
	100	0.51		23.7	0
	118	0			

Cross sections of Chenga River









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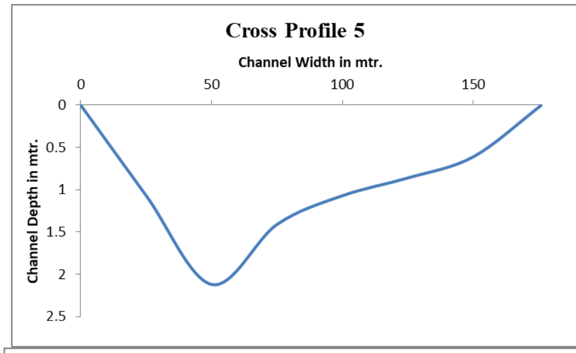

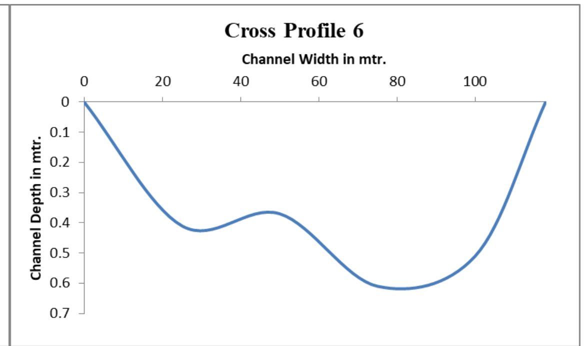

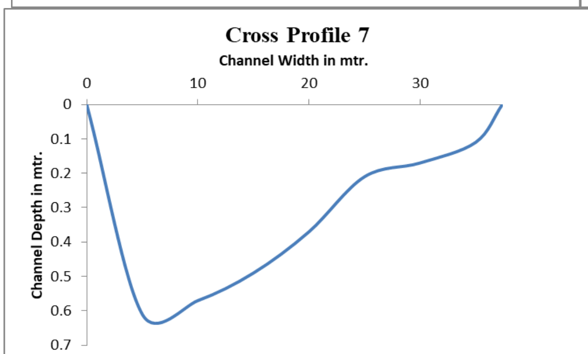

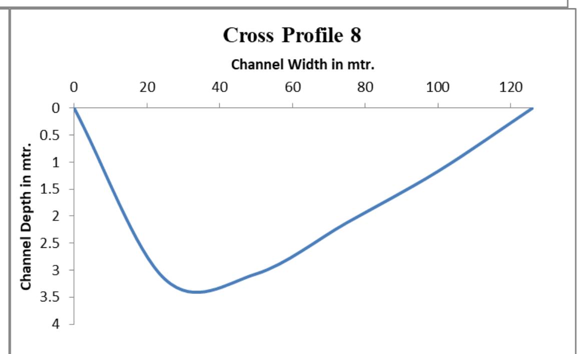

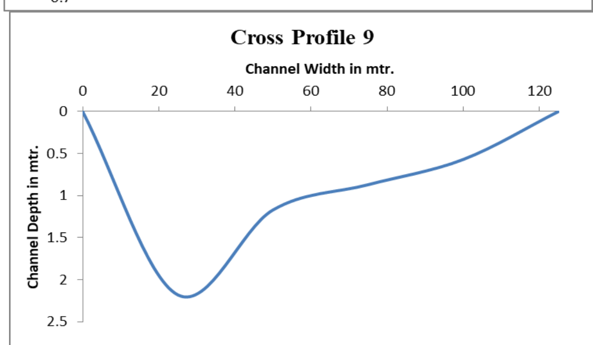

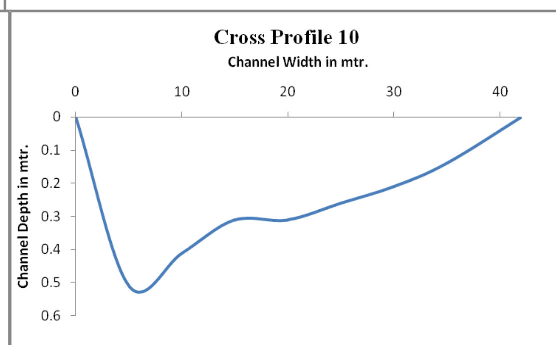

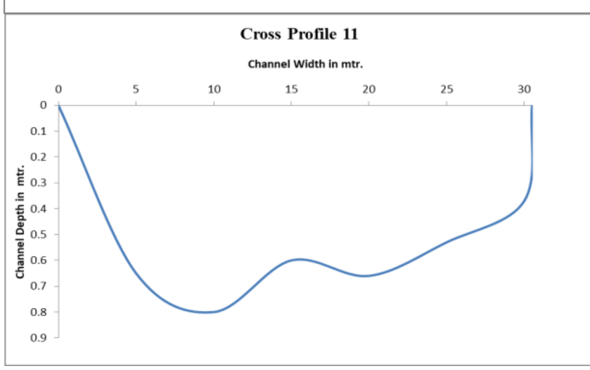

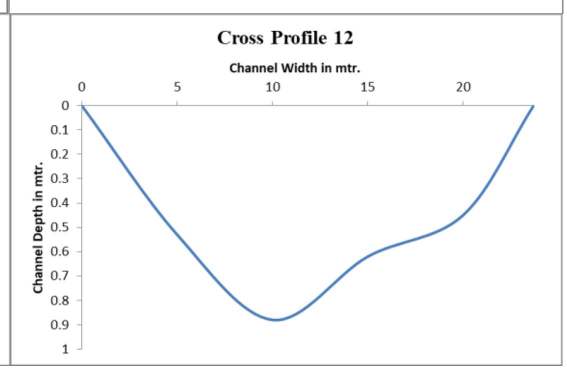

The cross profiles show that down cutting of the river course is higher on the right bank of the river while the left bank the amount of erosion is less than the amount of depositional activity. During the geomorphological investigation and field survey in the Chenga River, a number of fluvio – geomorphological features have been identified in the field and they are measured based on their basic geometry.

Gravel Bed River - In general, the principle of river science says towards downstream the size of bed particle decreased. The size of the boulder varies from more than 300 mm in the upstream to silt (0.002 mm) in a confluence of a natural river course. In the present study, the downstream of the Chenga River is a typical example of gravel bed river, because the size of the average bed particle varies between 20 – 80 mm. However, towards upstream the size of the bed particle is increased and became pebbles and cobbles.

River Terrace - A terrace is a roughly flat surface that is limited by the sloping surface on either sides of the valley floor or flood plains that are left sitting on the valley sides after river down cutting. Sometimes, the river valleys are frequented by several terraces on the either side wherein there are arranged in step – like forms. River terraces are generally formed due to dissection of fluvial sediments of flood plains deposited along the valley floor two major type of river terraces are -

a) **Paired terraces:** Equal number of terraces on the either side of the valley

b) **Unpaired terraces:** Unequal number of terraces besides the floor.

In the study area it was identified that in the downstream of the Chenga River Basin the basin was demarked by some terraces on the right bank of the river whereas no terraces formed on the left bank of the Chenga River. In addition, the regional underlying structure may induce to shift the river towards east only; therefore, the terraces are formed on the right bank only. Genetically, the terraces on the Chenga River are aggradational due to the very thick deposition of upstream sediments of the foothill of the Shiwalik range.

Pools and Riffle - With the passage of time, the river channel tends to develop deeper and shallower sections along the path of the stream. In fluvial geomorphology, the deeper parts are called 'Pool' and shallower one calls 'Riffle'. From ecological point of view, pools are playing very significant role as they are the habitable section of river biota. Existing of pool in stream indicates the healthy ecosystem of the river. The Major finding from the above analysis and discussion are as follows:

- Dynamics characteristics of the river affects the channel properties like width, depth, velocity and also effects on erosion, transportation and deposition.
- The velocity of Chenga River is much higher in the rainy season due to excess amount of supply of water in a narrow channel width and produce high amount of discharge.
- Open Channel flow of Chenga River mainly depends on slope and friction. In the upstream, the flow is non uniform because of greater slope and friction with river bed material. On the other hand, in the downstream the flow is uniform because the gentle slope and friction is less.
- The cross section area of the Chenga River the river shifting from west to east and these produce multiple unpaired terraces on the left bank. Therefore, right side of the river has high velocity and maximum depth and deep bank erosion also has occurred. This is the main problem for the river side situated settlements and cultivated land.
- The downstream area of the basin comes under the alluvial plain region and due to the unconsolidated character of lithology; the trunk side is prone to erosion and land loss.

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