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Geomorphological parameters of a catchment based on toposheets of different scale: A comparison

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ABSTRACT : Geomorphological parameters are a prerequisite in development of Geomorphological Instantaneous Unit Hydrograph. In this study geomorphological parameters of the catchments of river Bino, a tributary of Ramganga river, located in the Himalayan region in India, was explored manually by utilizing a combination of toposheets on Inch and Quarter inch scale. Comparison was made to know how the parameters changed with scale of toposheets. It was found that most of the parameters varied little but, basin order and main stream length varied significantly.

KEY WORDS : Bino, Ramganga, Himalayan, Catchment, Geomorphologic parameters

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Geomorphology is a science, which deals with the basin composition with respect to the topographical and geometric configurations of the basin. It is well known fact that the climatic as well as geomorphological characteristics affect the basin response to a considerable extent. Thus, the linking of geomorphological parameters with the hydrological characteristics of a basin is likely to provide a more realistic representation of the hydrologic behaviour of different types of catchments, particularly the ungauged ones. Before taking up the studies related with hydrologic simulations using the geomorphology, the important geomorphological parameters had to be quantified from the available topographical map of the catchment. These parameters play a vital role in development of Geomorphological Instantaneous Unit Hydrograph.

Horton (1945) originated the quantitative study of channel networks. He developed a system for ordering stream networks and derived laws relating the number, length and catchment area associated with streams of different orders. He introduced the term composition of the drainage network (basin) as ‘ composition ‘ implies the numbers and lengths of streams and tributaries of different sizes and orders, regardless of their pattern.

Under the impetus supplied by Horton, the description of drainage basins and channel networks was transformed from a purely qualitative and deductive study to a rigorous quantitative science capable of providing hydrologists with numerical data of practical value.

Strahler (1957) slightly modified Horton’s (1945) classification scheme. He explained geometrical and mechanical aspects of drainage basins on the basis of dimensional analysis. He has also given the concept of statistical and morphometric anlysis.

In this paper an attempt has been made to manually explore the geomorphological parameters of the catchment of river Bino by utilizing combination of toposheets on two different scales. The objective was to explore how the parameters changed with scale of toposheets.

METHODOLOGY

The study area selected was catchment of river Bino, a tributary of Ramganga river. It is hilly catchment in the Himalayan region in India, located between 29^0 47' N and 30^0 2'15" N latitude and 79^0 6' 15" E and 79^0 17' 15" E longitude in the Ranikhet forest sub-division. The Bino catchment is a narrow valley draining from north to south. Maximum and minimum elevations in the catchment are 2913 m and 840 m above the mean sea level, respectively. Bino catchment comprises of an area of 304.76 sq km with its mean length as 30 km and the mean width as 12 km. Geomorphological parameters of the Bino catchment were analysed by using a combination of the survey of India toposheets, No.53 N/4, 53 N/8, 53 O/1, 53 O/5 on inch scale

(1 inch = 1 mile) and 53 N, 53 O on quarter inch scale (1 inch = 4 mile).

Streams of the catchment were delineated and ordered according to Strahler's (1957) ordering scheme. Streams with different orders were marked with different colours to facilitate counting and measurement. Numbering of streams of a particular order was done starting from the lower most point or the gauging site of the watershed, on the principle that no streams is crossed in the process. Numbering as well as the measurement was done from the left side of the main stream. The methodology suggested by Chow, 1964, is used for quantification of the important geomorphological parameters.

Elongation ratio (R_e):

It is computed as the ratio of diameter of a circle of the same area as the ratio of the basin to the maximum basin length.

Ciruarity ratio (R_c):

It is computed as the ratio of basin area to the area of a circle having the same perimeter as the basin.

Bifurcation ratio (R_B):

The bifurcation ratio (R_B) represents that on an average, there are R_B times as many streams of any given order as of the next higher order. The bifurcation ratio between two consecutive stream orders was calculated by using the following relationship (Horton, 1945):

$$R_B = \frac{N_W}{N_{W+1}} \quad (1)$$

where, N_w = Number of streams of order w, N_{w+1} = Number of streams of order w+1,

w = stream order, w = 1, 2, 3, ... Ω, where, Ω represents the basin order (highest stream order).

Stream length ratio (R_L) :

The stream length ratio (R_L), represents that the mean stream length of any given order is R_L times of the preceding lower order. The stream length ratio between two consecutive orders is calculated by the following formula (Horton, 1945).

$$R_L = \frac{\bar{L}_W}{\bar{L}_{W-1}} \quad (2)$$

where, L_w = Mean stream length of order w, L_{w-1} = Mean stream length of order w-1.

The mean stream length of order w, was obtained by dividing the total length of all the streams (L_w) of order w, with the number of streams (N_w) of order w. This could be represented by the equations as below:

$$\bar{L}_W = \frac{\sum_{i=1}^{N} L_{w_i}}{N_W} \quad (3)$$

Stream area ratio (R_A):

The stream area ratio, R_A represent that the mean stream area of a given order is R_A times that of the previous lower order. Stream area ratio between two consecutive orders of the stream was estimated by using the following formula proposed by Horton (1945).

$$R_A = \frac{\bar{A}_W}{\bar{A}_{W-1}} \quad (4)$$

where, $\bar{A}_W$ =Mean area contributing surface runoff of the streams of order w.

$\bar{A}_{W-1}$ =Mean area contributing surface runoff to the streams of order w-1.

The mean area $\bar{A}_W$ contributing surface runoff to the streams of order w was obtained by dividing the total area contributing surface runoff (A_w) in streams of order w with total number of streams (N_w) of order w. That is

$$\bar{A}_W = \frac{\sum_{i=1}^{N} L_{w_i}}{N_W} \quad (5)$$

R_{BA}, R_{LA} and R_{AA} for the entire basin:

Estimation of average value of bifurcation ratio (R_{BA}), stream length ratio (R_{LA}) and stream area (R_{AA}) for the entire basin of river Bino was done, by fitting linear regression equations, respectively, between log values of the number of streams (N_w), mean stream length (L_w) and the mean stream area (A_w) as the dependent variables and order of the stream as the independent variable (Chow, 1964). The parameters R_{BA}, R_{LA} and $R_{AA.}$ were estimated by taking antilog of slope values of the respective regression lines.

Form factor (R_f) :

It is a dimensionless ratio of a basin area A to the square of basin length L thus, it is computed as, $R_f = A \backslash L^2$

Stream frequency:

It is computed as the number of stream segments per unit area.

$$F = \frac{N}{A} \quad (6)$$

where,

N = Total number of segments of all order within the given basin.

Slope:

Slope (S_L) is simply the gradient or vertical distance between two points, whose elevations are known, divided by the horizontal distance between them.

RESULTS AND DISCUSSION

Drainage network map of the catchment was prepared on both the scales and shown in Fig. 1 and Fig. 2. Different geomorphological parameters like: - Stream order (w), Total number of streams (N_w), Mean stream length (L_w), Mean stream area (A_w), Bifurcation ratio (R_B), Stream length ratio (R_L), Stream area ratio (R_A) are worked out and are shown in Table 1 and 2. Some important linear and areal parameters of the catchment are shown in Table 3.

There seems to be little effect of scale of map on parameters such as Bifurcation ratio (R_B), Stream length ratio (R_L), Stream area ratio (R_A), Elongation ratio (R_e), Circularity ratio (C_r), and form factor (R_f), but, stream order (w), stream frequency (F) and length of main stream (L_W) varied significantly. The mainstream length (L_W) is represented by ABC and QR, respectively on inch and quarter inch scale maps (Fig. 1 and 2). The value of L_W on quarter inch scale map is 17230.23 meter while on inch scale map it is 25401.93 meter. Thus, there is a difference of 8171.7 meter in the mainstream length between the two scale of map used in the study. Stream order (w) of Bino catchment is 6 on Inch scale but it is 4 on quarter inch scale map. The river segment PQ in Fig. 2 is of order 3, perhaps due to non-inclusion of finer streams in that scale of map. Therefore, the segment PQ could not be included in mainstream length

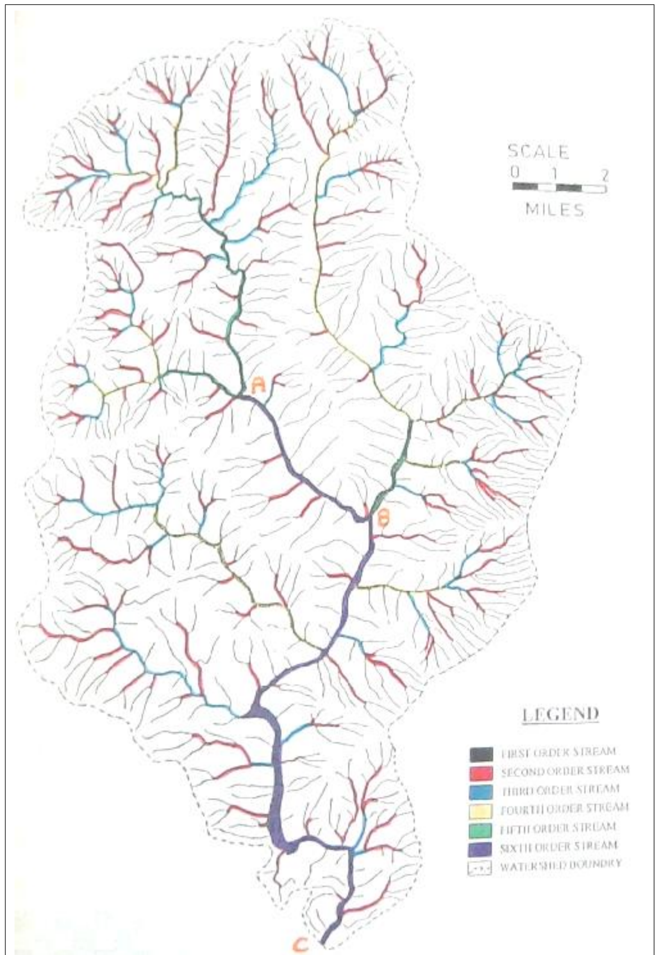

Fig. 1 : Drainage network map on inch scale

Table 1 : Geomorphological parameters of Bino catchment for different stream orders on inch scale

Stream order	Total number of streams	Mean stream length (m)	Mean stream area (km^2)	Bifurcation ratio	Stream length ratio	Stream area ratio
(w)	(N_w)	(L_w)	(A_w)	R_B	R_L	R_A
1	720	778.45	0.282	4.897	-	-
2	147	899.17	1.640	3.868	1.175	5.896
3	38	1300.41	6.75	4.222	1.445	4.117
4	9	3885.25	31.46	3.0	2.913	4.54
5	3	5637.83	97.47	3.0	1.45	3.10
6	1	25401.93	304.76	-	4.505	3.13

Table 2 : Geomorphological parameters of Bino catchment for different stream orders on quarter inch scale

Stream order	Total number of streams	Mean stream length (m)	Mean stream area (km^2)	Bifurcation ratio	Stream length ratio	Stream area ratio
(w)	(N_w)	(L_w)	(A_w)	R_B	R_L	R_A
1	41	2676.0	3.886	4.1	-	-
2	10	4383.57	23.296	5.0	1.638	5.994
3	2	8741.81	139.20	2.0	1.994	5.975
4	1	17230.24	304.76	-	1.971	2.184

Table 3 : Important linear and areal parameters of the catchment			
Parameters	Notation	Inch scale	Quarter inch scale
Perimeter of the basin	P	88.93 km	88.13 km
Mean length of watershed	L	30 km	30 km
Mean width of watershed	W	12 km	12 km
Elongation ratio	R_e	0.525	0.53
Circularity ratio	C_r	0.484	0.45
Bifurcation ratio (Basin)	R_{BA}	3.7184	3.578
Stream length ratio (Basin)	R_{LA}	1.981	1.8731
Stream area ratio (Basin)	R_{AA}	4.0144	4.4229
Form factor	R_f	0.3386	0.34
Stream frequency	F	3.01 per sq. km.	0.18 per sq. km
Slope of main stream	S_L	0.009287	0.00856

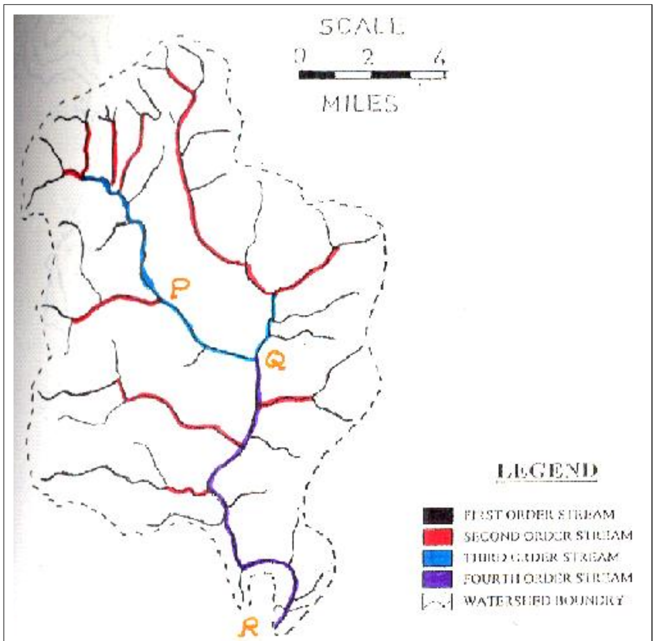

Fig. 2 : Drainage network map on quarter inch scale

of the drainage network map on the quarter inch scale. Due to this reason the mainstream length on both the scale of map are different. Effect of scale of map is visible on stream order (w) and length of mainstream (L_W). This demand for choosing appropriate scale of toposheets while going for Geomorphological Instantaneous Unit Hydrograph studies.

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