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THE SIGNIFICANCE OF CONFLUENCES IN DRAINAGE BASIN DYNAMICS

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ABSTRACT : While analysing streams, especially of identical orders, one is confronted with the problem of explaining their varying capabilities. This has been partially resolved by defining an index where in the number of confluences of streams of identical order, have been taken into consideration as the determining factor. In addition an attempt has been made to reveal the relationship (cumulative regenerative relationship) existing between the power factor of a stream on one hand and various basin parameters on the other. This attempted index helps to establish, thought not wholly, the strength of the stream in the absence of discharge data.

The consideration of confluences in analysing the basin dynamics is indispensable, for the total aggregation of streams uniting to form major ones reflect the position of a stream in the hierarchy of power. (Power here, refers to the ability and strength of a stream to erode and transport). Streams with higher confluence numbers rank higher in the power hierarchy, whilst streams with few tributaries i. e. few confluences rank lower in the hierarchy of power. Hence the studies of confluences become significant for they reflect the power of a stream to erode.

' Union ' The Nature's Law

Streams also like other dynamic variable in nature, gain strength by unions. This nature's law of union, and the power so gained by unions of streams, is the underlying principle, on which the method of designation of order as suggested by R. E. Horton, (1945), A. N. Strahler (1952) etc. is based (Hagget & Chorley 1969). A qualitative description of the erosional capacity would be that higher order streams would have greater power to erode than lower order streams.

However, in nature bifurcation ratios above ' 2 ' clearly indicate that numerous streams, which could be called as " subordinate " streams (Fig. 1) join the trunk or streams of higher order directly; and so their existence is not revealed by the order of the trunk stream. In the Strahler's method of ordering, which is widely adopted the order of the trunk stream (order n) is not changed by the addition of tributary streams of lower order (n–1, n–2 etc.). Though Shreve's (1957) and Scheidegger's (1965) methods give importance to the tributary streams, their methods become unmanagable for basins with high number of streams (Gregory and Walling 1973).

These " subordinate " streams have a share in the erosive power of the trunk stream, and so they connot be ignored.

Thus, to bring out the actual erosional capacity or power of a stream, an index has been defined. This index takes into account, the number of confluences of identical orders. The author is aware of the fact that the capacity of a stream to erode is governed by many other factors like nature of rock, slopes, climate etc. But assuming other things to be same, the defined index aids in the assessment of the power of a stream. This index has been termed as $_tP$ index.

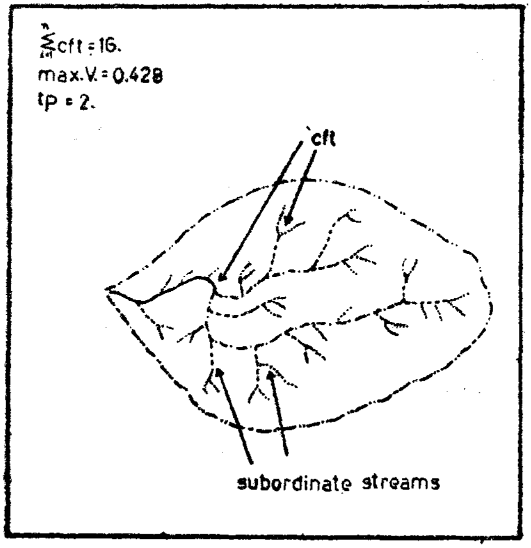

Fig. No. 1

'Cft' or confluences of identical order streams and subordinate streams.

Index of Union

The Index of Union (I. U.) is a step to specify the relative ability and power ($_tP$) of streams, that they have gained by the union of 'subordinate' streams of identical order.

The I. U. can be mathematically expressed as :

$$\text{I. U.} = \frac{(\text{Or} - 1)}{\sum_{i=1}^{n} \text{cft.}}$$

where

Or = Order of the stream (based on Strahler's method).

$\sum_{1-1}^{n}$ cft = Total number of confluences of the streams of identical order (Fig. 1).

The I. U. values for a particular order are given in Table I. All the calculated I. U. values for a particular order will always be less than the given values, irrespective of the basin size. Such values can be obtained up to K^{th} order. The table also shows that the I. U. values are inversely proportional to the total number of coufluences of the streams of identical order.

The Ploting of standard union curve and standard confluence number curve, when stream has an ideal network (bifurcation ratio = 2) shows that as the order of stream increases, the number of confluences increases, but the maximum value (max. V.) of the I. U. decreases (Fig. 2).

Table I

Order	maximum value of I. U.
1	0.000
2	1.000
3	0.666
4	0.428
5	0.266
6	0.161
7	0.095
8	0.055
9	0.031
10	0.017

Table gives the maximum value of I. U. from Ist to 10th order streams.

After ploting, confluence number against order, it was observed that there exists a simple geometric relationship between number of confluences and order, on semilogarithmic paper, as in the case of order versus number, length and area.

The 'Power' factor

The I. U. values are employed to establish the actual power of a stream by the formula given below. The power is obtained with reference to the power of an ideal stream (bifurcation ratio = 2), which is assumed to be 1.

$$t_P = \frac{\text{max. V.}}{\text{I. U. c}}$$

where

^{t}P = Times power, where 1 is the reference value. Aprox. to the nearest integer.

I.U.c = Calculated I. U. for that stream.

max. V. = The maximum value of the limit of I. U. for that order (See Table I).

The ^{t}P denotes how many times a stream of order 'n' can erode when compared with the ideal stream (R_b = 2) of same order. The ^{t}P value expresses that with the given number of confluences (Strahler's method) there would have been ^{t}P 'K' order streams; but since the subordinate streams join the trunk stream directly, they have not been able to affect the order of the parent stream. The ^{t}P values give a measure to compare the relative power of streams of identical order also. For instance, a sixth order stream with ^{t}P = 4 indicates that it has the power of four six order streams. And thus, is more powerful than a sixth order stream with ^{t}P = 2, i. e. having the power of only two six order streams.

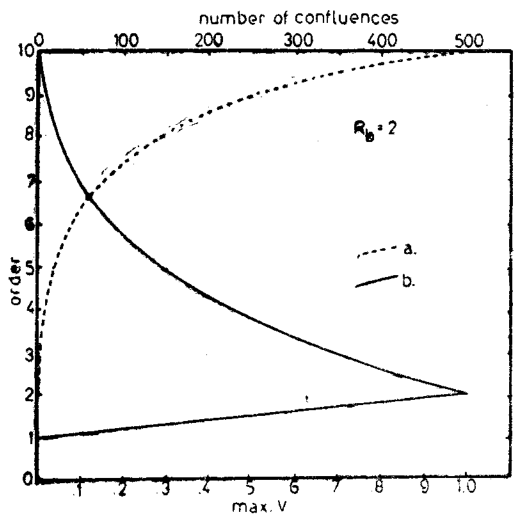

Fig. No. 2

Standard Curves of (a) Order versus number of confluences (b) order versus Index of Union, when bifurcation ratio is two.

Cumulative regenerative relationship

A major problem in the comprehension of the relationship that exists between ^{t}P and other basin parameters, is to distinguish between the dependent and the independent parameters. For instance, large catchment area would mean higher power or tp value. This power factor would accelerate erosion and recession of divides and slopes. This recession would in turn lead to an increase in the power of the stream. Such mutual relationship or interdependence can be called as 'regenerative relationship'. All such increments build up to define a cumulative regenerative relationship'.

'The study of ten sample basins, which were chosen at random (Table II) showed that various basin parameters, have a high positive relation with the tp value or power factor. (correlations are between 0. 73 & 0.92). These parameters could be attributed to the cumulative regenerative relationship.

Table II

Toposheet No.	Name of the stream	Order	tp
73 G/2	Lunga	4	5
47 J/1	Perjun	5	2
47 J/1	Kaman	5	4
47 B/13	Vidhane	5	3
47 B/13	Panvel's southern branch	5	3
47 J/1	Kar	5	9
47 I/3	Kas (upto Ambi)	5	8
45 J/10	Saraswati	5	8
73 G/2	Radai	5	1
53 E/16	Khaneda	6	9

Table gives the order and tp values of the ten sample basins.

Eight basins, out of the ten sample basins are of fifth order. In ideal conditions one would expect all basins to be identical in all respect. But observations show that, owing to different power functions, the various basin parameters such as catchment area, basin width, dissection index etc. have different values.

After the ^{t}P values were derived for all the sample basins and were correlated with various basin parameters, (Fig. 3) it was found that ^{t}P value depends explicitly on various basin parameters.

The similar relative positions of the points on all the graphs, indicate the characteristic explicit dependence of ^{t}P and the basin parameters. This explicit dependence further emphasises the regenerative action, which is positive in nature.

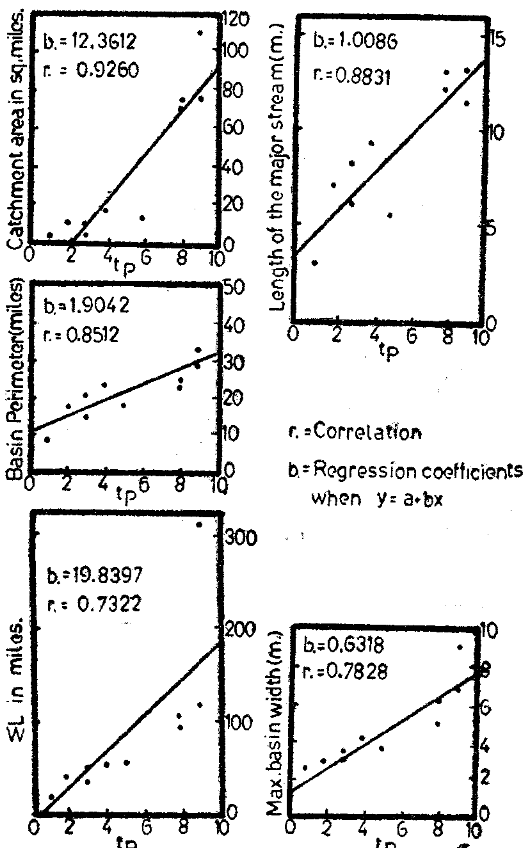

Fig:No.3

tp. Versus various basin parameters.

Regression coefficients and ^{t}P

The calculated 'b' coefficients (when $y = ab^{x}$) of all the fifth order sample basins also demonstrate an analogous relationship. The ploting of ^{t}P values versus 'b' coefficients of all the sample basins (Fig. 4) show that there exists a very high correlation between the two variables (correlation– 0.9152). This indirectly indicates that,

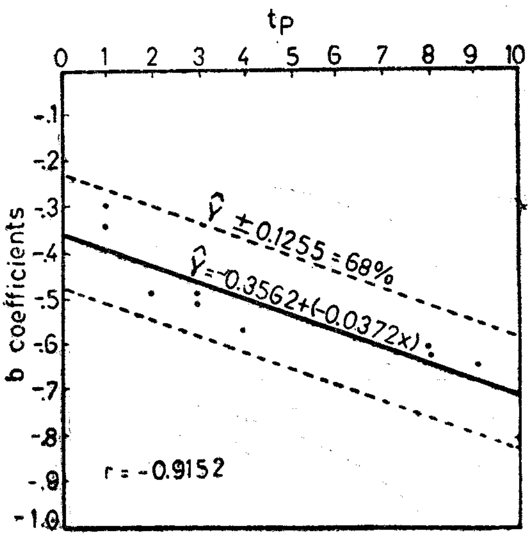

Fig. No. 4

Regression coefficients versus tp of, 5th order sample basins.

greater numbers of confluences are reflected beside steepness of the regression lines, by high ^{t}P values.

The ^{t}P values also facilitates the study of the evolutionary development of drainage network. The ^{t}P values were calculated for a graphic example of drainage network development, provided by the stream networks mapped by Parker (1976).

The results showed that the lower ${}^{t}P$ value is associated with the basin, in the initiation stage. Whilst, highest ${}^{t}P$ value was found to be associated with the eleboration stage. Higher order basin having low ${}^{t}P$ value was found to be in the stage of integration. The derived ${}^{t}P$ values were stable between the stage of elaboration and the stage of integration.

Conclusion

On the basis of the preceding discussion, it can be concluded that the defined ${}^{t}P$ index can be employed to obtain the power of a stream to erode in the absence of discharge data. The index provides a measure to specify the relative ability and power of streams, especially of indentical orders, other things being the same. The capacity of a stream to erode is, found to be directly proportional to $\sum_{i=1}^{n}$ cft and the ${}^{t}P$ value.

The existing high positive correlation between ${}^{t}P$ and various basin parameters, explains why a stream of order 'n' has broad valley, large basin and more catchment area and why another basin of same order has narrow valley and insignificant basin.

Two basins of identical order and approximately similar basin parameters indicate the latent power of the stream, with high ${}^{t}P$ values.

Basins with abnormally high first order streams do not reflect their correct erosional power because, many first order streams fail to become identical order streams before uniting.

The ${}^{t}P$ values can be obtained from large scale maps for micro-level studies for more precise and correct reflection of the power of a stream whilst, small scale maps can be used to derive the ${}^{t}P$ values for macro-level studies.

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