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DRAINAGE CHARACTERISTICS OF PAGERU RIVER BASIN, CUDDAPAH DISTRICT, ANDHRA PRADESH

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ABSTRACT : The study presented here was undertaken to determine the drainage characteristics of Pageru river basin using the topographical maps on a scale of 1:50,000. The total area of Pageru river basin is 480 Km^2 and it is divided into X sub-basins for the analysis. The drainage pattern of the basin is dendritic type and it is a VIth order stream. The elongation ration of the basin is 0.53. The varieties of the elongated shape of the basins are due to the guiding effect of Thrusting and faulting. The drainage density of the basin as a whole is 1.37Km/Km2. Bifurcation ratio ranges from 2 to 4.31 with a mean of 3.61. The relief ratio of the basin is 0.0069.

Key Words : Drainage density, Bifurcation ratio, Relief ratio, Pageru river basin.

INTRODUCTION

Pageru river basin being a land area of geohydrological importance, due to its vast drainage capacity, suffers from acute water problem, soil erosion, vegetation loss and land degradation. In order to prepare a comprehensive watershed development plan, it becomes imperatively necessary to understand the topography, erosion status and drainage pattern of the region (Misra, 1988).

In Pageru river basin of Cuddapah District, the topography is undulating, and slope is moderate to steep. The area suffers from the absence of perennial surface water resources rendering the Ground water potential limited in the basin area. In this paper an attempt has been made to study the drainage characteristics of Pageru river basin using the topographical maps.

STUDY AREA

Pageru is a tributary of Pagaghni river that rises from Seshachalam hill ranges flows easterly and joins the Pennar near Kamalapuram in Cuddapah district. The catchment area of the basin is 480 km^2 located in the Survey of Indian toposheet numbers 57 J/6, J/7, J/10 and J/11 on a scale of 1:50,000. The basin area lies in between Latitudes 14°29'04" and 14°39'51" N and Longitudes 78°19' 12" and 78°41'32" E (Fig. 1).

GEOLOGY

The rock formations of the study area are classified as Cuddapah super group and Kurnool group. The oldest are Tadipatri formations belonging to lower Cuddapah super group composed of slaty shales with interbedded thin layers of siliceous limestone, quartzite and basic intrusive sills. The Tadipatri formations are overlain by the rocks of the Kurnool group which include quartzite, limestone and shale. Alluvium of holocene and recent age is more or less stratified deposit of gravel, sand, silt, clay occuring all along the course of the stream. The alluvium at the confluence near Putlampalli is found to comprise sand of variable thickness and is

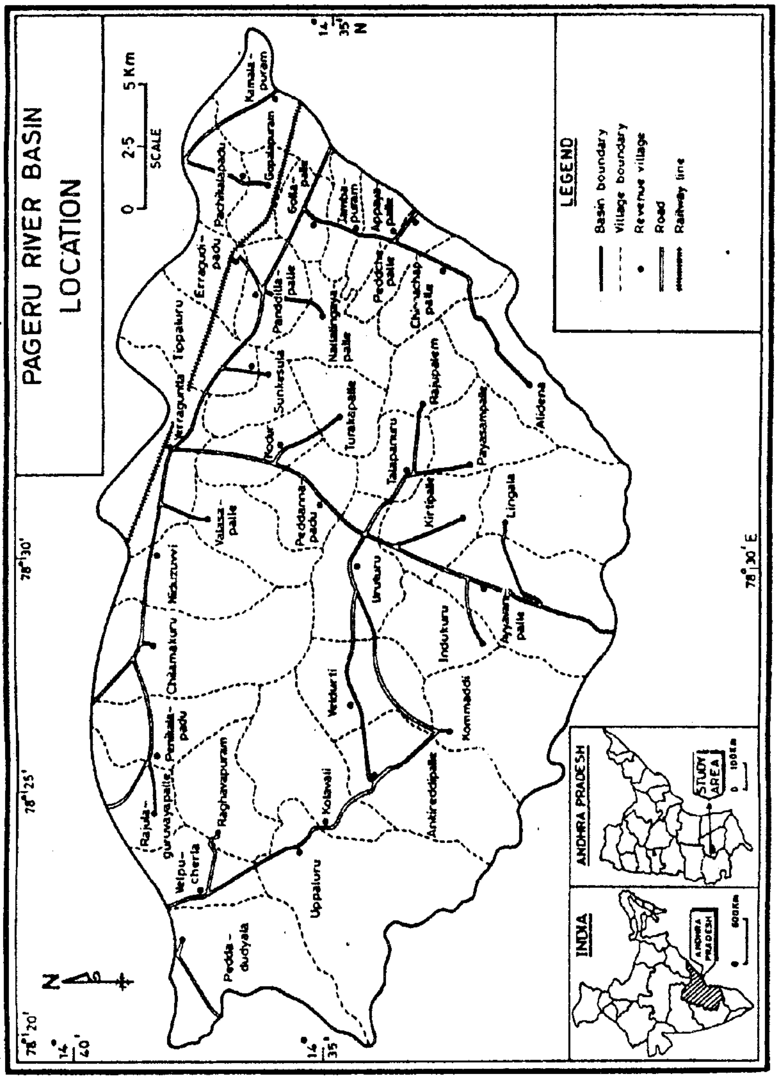

Fig. 1 : Pageru River Basin - Location

composed of sandy aquifers occupying the eastermost part of the study area (Fig. 2).

Climate

The general climate of Pageru river basin is semi-arid in nature. The temperature reaches high in the month of April and it is low in the month of December. The temperature gradually rises from the month of January and reaches maximum in the month of April and decreases gradually from May and reaches minimum in the month of Decempber. The relative humidity shows seasonal variations generally fluctuating with rainfall and temperature apart from the diurnal variations. The relative humidity is more during monsoon and winter period due to increase in rainfall and decrease in temperature. The relative humidity is less in summer due to the combined effect of high temperature and low rainfall.

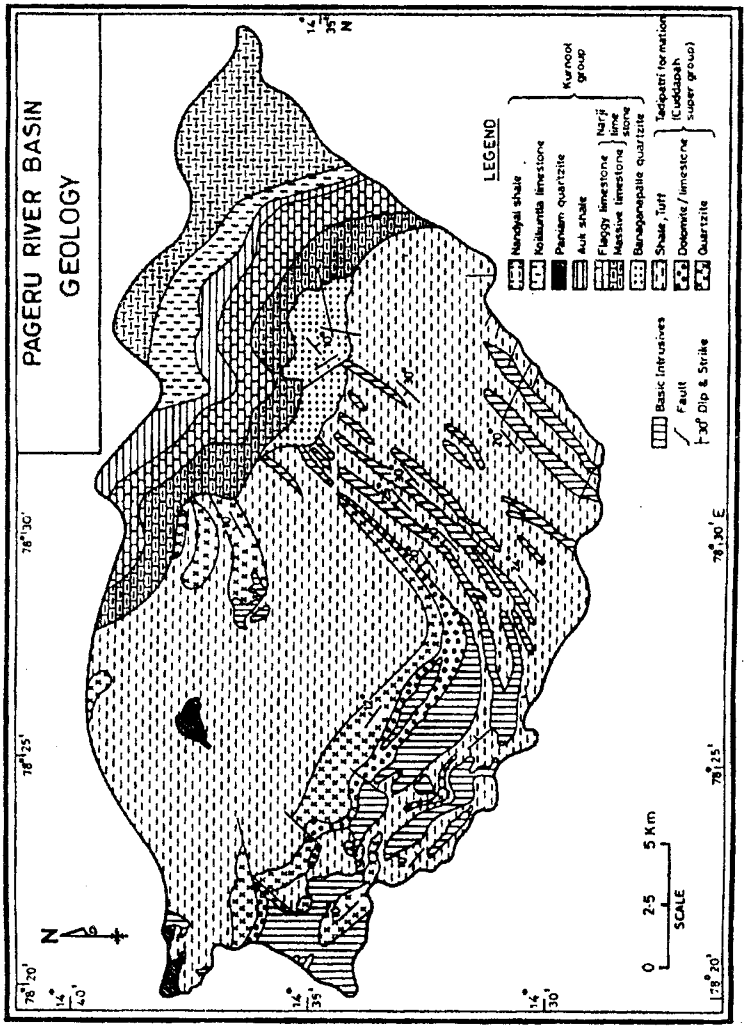

Fig. 2 : Pageru River Basin - Geology

The Pageru river basin receives an average annual rainfall of 580.79 mm. with significant seasonal variations. Usually the region receives its first spell of rainfall from pre monsoonal convectional showers in the month of May. But its occurrence is erratic. The intensity and amount of rainfall is unpredictable during the southwest monsoon period (June to September). Infact, highest rainfall occurs in the basin during the Northeast monsoon period (October and November). The period between January and May is the main dry season and receives some rainfall due to convections or winter cyclonic disturbances.

MATERIALS AND METHODS

The morphometric analysis of Pageru river basin has been made based on the published topographical maps on 1:50,000 scale. The quantitative analysis of the morphometric characteristics of the basin include stream orders, stream numbers, stream lengths, bifurcation ratios, basin circularity, drainage density, drainage frequency, drainage texture, relief ratio etc. which determine the geomorphic stage of development of the area on the basis of hypsometric integrals.

RESULT AND DISCUSSION

The total area of Pageru river basin is 480 Km^2 and it is divided into ten sub-basins for analysis (Figure 3). The area of ten sub-basins from I to X are 20.16, 65.31, 88.69, 17.74, 22.56, 57.57, 100.78, 11.29, 11.57 and 94.33 Km^2 respectively (Table 1). The drainage pattern

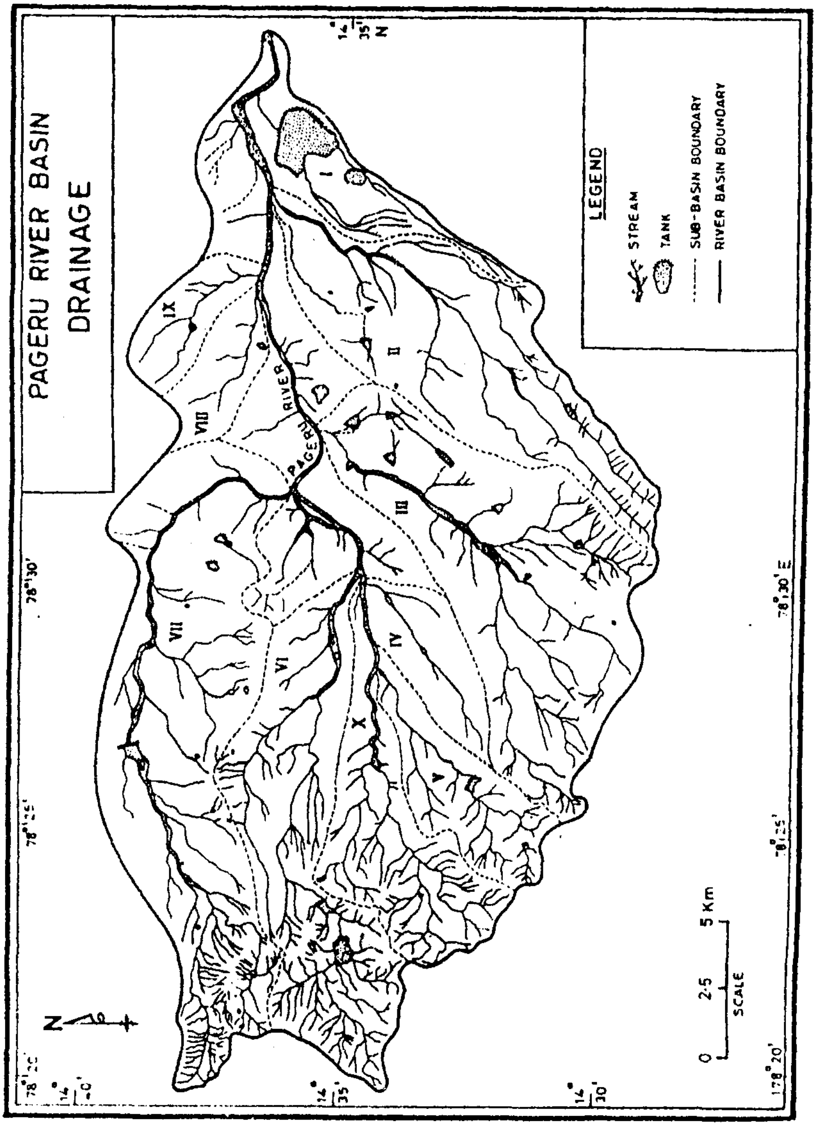

Fig. 3 : Pageru River Basin - Drainage

Table 1

Morphometric Parameters of Pageru River Basin

Basin / Sub-basin	Area in Km^2	Stream Frequency	Length (in Km) (Km / Km^2)	Form Factor	Elongation Ratio	Circulatory Ratio
Sub-basin-I	20.16	0.55	10.00	0.20	0.46	0.26
Sub-basin-II	65.31	1.09	18.50	0.19	0.49	0.47
Sub-basin-III	88.69	1.16	17.50	0.29	0.61	0.54
Sub-basin-IV	17.74	0.28	7.00	0.36	0.68	0.65
Sub-basin-V	22.56	2.04	10.50	0.20	0.51	0.45
Sub-basin-VI	57.57	3.24	21.00	0.11	0.37	0.28
Sub-basin-VII	100.78	1.56	28.00	0.13	0.41	0.37
Sub-basin-VIII	11.29	0.44	5.0	0.45	0.76	0.52
Sub-basin-IX	11.57	0.52	6.00	0.32	0.64	0.65
Sub-basin-X	94.33	1.27	37.00	0.07	0.30	0.13
Pageru river basin	480.00	1.41	47.00	0.22	0.53	0.50

of Pageru river basin is dendritic in nature which is commonly found in horizontal sedimentary rocks.

Stream Order (U)

The streams of the Pageru river basin have been ranked according to the Strahler's (1964) stream ordering system and the number of streams of each segment (Nu) of the order (U) is presented in Table 2.

It is obvious that the total number of streams gradually decreases as the stream order increases. From the stream order analysis, X sub-basin is designated as 6th order stream covering an area of 94.33km^2. Where as VII sub-basin is designated as 5th order stream covering an area of about 100.78 km^2. Sub-basins II, III, V and VI are identified as 4th order sub-basins with an area covering 65.31, 88.69, 22.56 and 57.57 km^2 respectively. The sub-basin I is identified as 3rd order sub-basin with an area covering 20.16km^2. The sub-basins VIII and IX are identified as 2nd order sub-basins with an area covering 11.29 and 111.57 km^2 respectively. The variation in order and size of the tributary basins is largely due to physiographic and structural conditions of the region.

Stream Length (Lu)

The total stream lengths of all the sub-basins of various orders have been computed with the help of Rotameter from topographical sheets. Horton's law of stream lengths supports the theory that geometrical similarity is preserved generally in the basins of increasing order (Strahler, 1964). It is clear that the total length of stream segments is maximum in case of first order streams. In almost all cases, the basin length decreases as the order increases and it is lowest in case of the highest order streams. This geometric relationship is shown graphically in the form of a straight line when the log values of these variables are plotted on an ordinary graph (Figure 4). Using the log values of stream numbers and the order of streams, the regression lines are fitted for the basin as a whole as well as for ten sub-basins.

Table 2

Stream Orders and Stream Lengths of Pageru River Basin

Basin /	Stream numbers in different orders							Order wise total stream lengths (Km)							Stream length ratio				
Sub-Basin	1	2	3	4	5	6	Total	1	2	3	4	5	6	Total	1/2	2/3	3/4	4/5	5/6
Sub-basin-I	7	3	1	–	–	–	11	9.0	10.0	2.0	–	–	–	21.0	0.90	5.00	–	–	–
Sub-basin-II	60	8	2	1	–	–	1	36.0	27.0	12.0	4.0	–	–	79.0	1.33	2.25	3.00	–	–
Sub-basin-III	82	18	2	1	–	–	103	62.5	24.0	12.0	6.5	–	–	105.0	2.60	2.00	1.84	–	–
Sub-basin-IV	4	1	–	–	–	–	5	5.0	6.0	–	–	–	–	11.0	0.83	–	–	–	–
Sub-basin-V	34	9	2	1	–	–	46	19.0	8.0	2.5	6.0	–	–	35.5	2.37	3.20	0.41	–	–
Sub-basin-VI	117	29	7	1	–	–	154	71.0	25.5	10.5	17.0	–	–	124.0	2.78	2.42	0.61	–	–
Sub-basin-VII	116	30	8	2	1	–	157	78.0	20.0	11.5	16.0	9.5	–	135.0	3.90	1.73	0.71	1.68	–
Sub-basin-VIII	4	1	–	–	–	–	5	3.5	4.0	–	–	–	–	7.5	0.87	–	–	–	–
Sub-basin-IX	5	1	–	–	–	–	6	8.5	2.5	–	–	–	–	11.0	3.40	–	–	–	–
Sub-basin-X	89	20	7	2	1	1	120	63.5	16.5	12.5	1.5	15.0	17.5	126.5	3.80	1.32	8.30	0.10	0.85
Pageru river basin	518	120	29	8	2	1	678	356 0	143.5	63.0	51.0	24.5	17.5	655.5	2.48	2.27	1.23	2.08	1.40

According to Horton's principle the number of streams are negatively correlated with the order. Pageru river basin shown a near perfect correlation with the plots falling very near the regression line and even at the sub-basin level the correlation is perfect.

Stream Length Ration (RL)

The stream length ratios of the drainage basins of the study region have been calculated by applying the following formula :

$$RL = \frac{Lu}{Lu\text{-}1}$$

Where RL = Stream length ratio

Lu = Mean stream length order 'u'

Lu-1 = Mean stream length of segment of the next lower order

The stream length ratios are changing haphazardly both at the basin and sub-basin levels. The values of the stream length ratios vary from 0.10 to 8.30 for sub-basins, while it ranges from 1.23 to 2.48 for the whole basin. The stream length ratio has an important relationship with the surface flow discharge and erosional stage of the basin (Table 2).

Stream Frequency (Fs)

The stream frequency of a basin may be defined as the ratio between the total number of segments cumulated for all orders within a basin and the basin area (Horton, 1945).

$$Fs = \frac{\Sigma Nu}{A}$$

Where Fs = Stream frequency

ΣNu = Total number of stream segments of all orders

A = Total area of the basin

The stream frequency of the whole basin is 1.41 km/km^2, while the stream frequencies of the I to X sub-basins are 0.55, 1.09, 1.16, 0.28, 0.04, 3.24, 1.56, 0.44, 0.52 and 1.27 km/km^2 respectively (Table 1). The development of the stream segments in the basin area is affected by rainfall and temperature.

Basin Length (L)

Basin length has been given different meanings by different workers (Schumm, 1956, Gregory and Walling, 1973); Gardiner, 1975 and Cannon, 1976). According to Gregory and Walling (1973), the basin length (L) is the longest length of the basin and end being the mouth. The length of the Pageru river basin is 47.0 km while the lengths of the ten sub-basins are 10.0, 18.5, 17.5, 7.0, 10.5, 21.0, 28.0, 5.0, 6.0, and 37.0 km respectively (Table 1).

DIMENSIONLESS FACTORS

Form Factor (Ff)

Form factor of a drainage basin is expressed as the ratio of average width of basin where axial length is the distance along the longest basin dimension paralled to the main drainage line. So, the form factor is expressed as

$$Ff = Au / Lb^2$$

Length of the basin is the longest dimension from mouth to the farthest point on the perimeter of the basin, and width is measured normal to the length.

The form factor of the Pageru river drainage basin is 0.22 while the form factors of ten sub-basins are 0.20, 0.19, 0.29, 0.36, 0.20, 0.11, 0.13, 0.45, 0.32 and 0.07 (Table 1). The index of form factor shows the inverse realtionship with squre of the axial lenght and as direct relationship with peak discharge.

Elongation Ration (Re)

The elongation ration (Re) is calculated by using the following formula.

$$Re = \frac{2 A / \pi}{L}$$

Where Re is the elongation ratio, 2 is constant, A = area and L is the maximum length of the basin.

The elongation ration of the Pageru river basin is 0.53, and the ten sub-basins are 0.46, 0.49, 0.61, 0.68, 0.51, 0.37, 0.41, 0.76, 0.64, and 0.30 showing extremely elongated nature (Table 1). The varieties of the elongated shape of the basins are due to the guiding effect of thrusting and faulting.

Circularity Ratio (Rc)

The circularity ratio has been used as a quantitative measure and is expressed as the ratio of basin area (Au) to the area of a circle (Ac) having the same perimeter as the basin

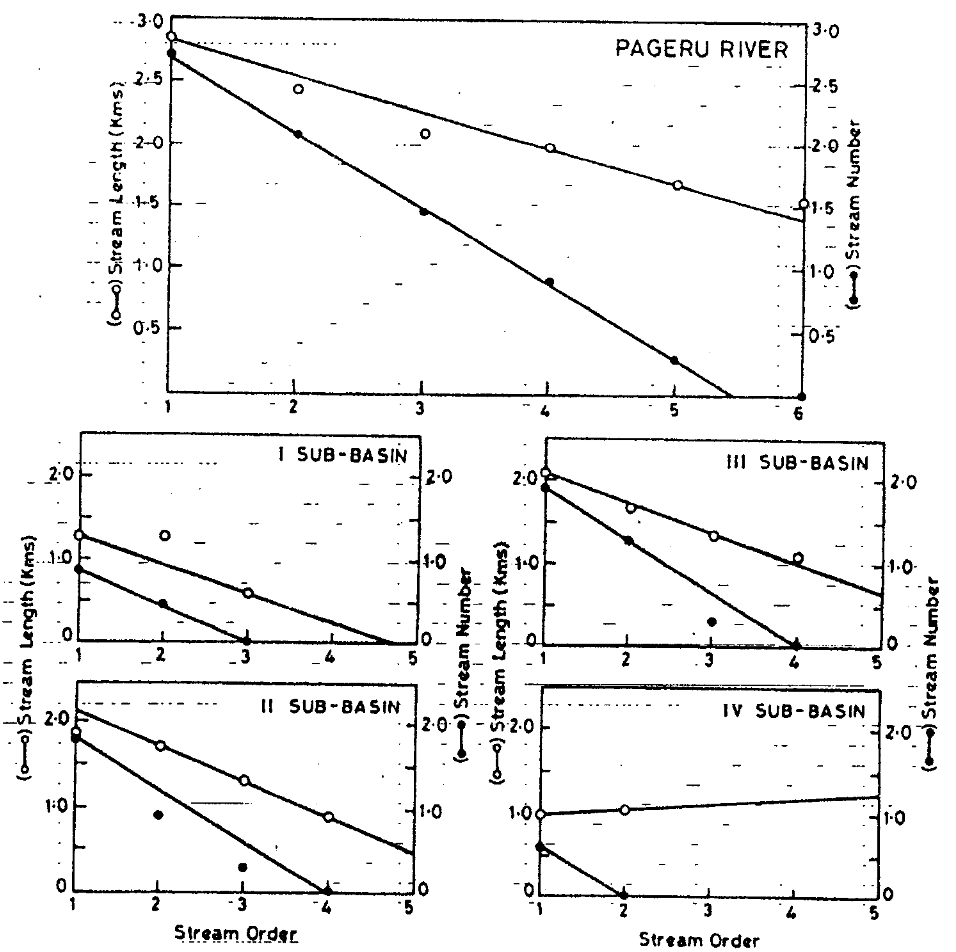

Fig. 4 : Geometric Relationship between stream orders, stream lenghts and stream numbers

(Strahler, 1964 and Miller, 1953). It is affected by the lithological character of the basin. It is expressed as

$$Rc = \frac{4 \pi A}{P^2}$$

Where Rc is the basin circularity, 'P' is basin perimeter, '4' is constant and 'A' is the area of the basin.

The ratio is more influenced by length, frequency, and gradient of streams of various orders besides slope conditions and drainage pattern of the basin. It is a significant ratio which indicates the stage of dissection in any region. Its low, medium and high values are indicative of the youth, mature, and old stages of the cycle of the tributary basins of the study region.

The circularity ratio of the Pageru river basin is 0.50, while that of the ten sub-basins are 0.26, 0.47, 0.54, 0.65. 0.45, 0.28, 0.37, 0.52, 0.65 and 0.13 (Table 1). The high value of circularity ratio for IV and IX sub-basins indicates the late maturity stage of topography and the other sub-basins reveal nearly mature stage of topography. This anomaly is due to diversity of slope, relief and structural conditions prevailing in this basin.

MEASURE OF INTENSITY OF DISSECTION

Drainage Density (Dd)

According to Horton (1932), the drainage density is defined as the length of streams per unit of a drainage area divided by the area of the drainage basins. It is expressed as

$$Dd = \frac{Lu}{A}$$

Where Lu = Lengths of all the order channels

A = Area of the basin

The Pageru river basin is a fairly well

Table 3

Drainage Density, Texture and Bifurcation Ratios of Pageru River Basin

Basin / Sub-basin	Drainage Density (Km/Km^2)	Drainage Texture Rb1	Bifurcation Ratios Rb2	Rb3	Rb4	Rb5	Mean	Rb
Sub-basin-I	1.04	0.57	2.30	3.00	–	–	–	2.65
Sub-basin-II	1.21	1.32	7.50	4.00	2.00	–	–	4.50
Sub-basin-III	1.84	2.13	4.55	9.00	2.00	–	–	5.18
Sub-basin-IV	0.62	0.17	4.00	–	–	–	–	4.00
Sub-basin-V	1.57	3.20	3.77	4.50	2.00	–	–	3.42
Sub-basin-VI	2.61	8.46	4.03	4.14	7.00	–	–	5.005
Sub-basin-VII	1.34	2.09	3.86	3.75	4.00	2.00	–	3.40
Sub-basin-VIII	0.66	0.29	4.00	–	–	–	–	4.00
Sub-basin-IX	0.95	0.49	5.00	–	–	–	–	5.00
Sub-basin-X	1.34	1.70	4.45	2.85	3.50	2.00	1.00	2.76
Pageru river basin	1.37	1.03	4.31	4.13	3.62	4.00	2.00	3.61

drained basin with dendritic pattern. The significance of a stream network has been recognised, based on drainage density, frequency, and texture which are sensitive parameters that provide the link between the form attributes of the basin and processes operating along the stream course. These parameters serve as valuable indices which reflect the topographic, lithological, pedological, and vegetational controls.

Drainage density of Pageru river basin as a whole is 1.37 km / km^2 while those of the ten sub-basins are 1.04, 1.21, 1.84, 0.62, 1.57,

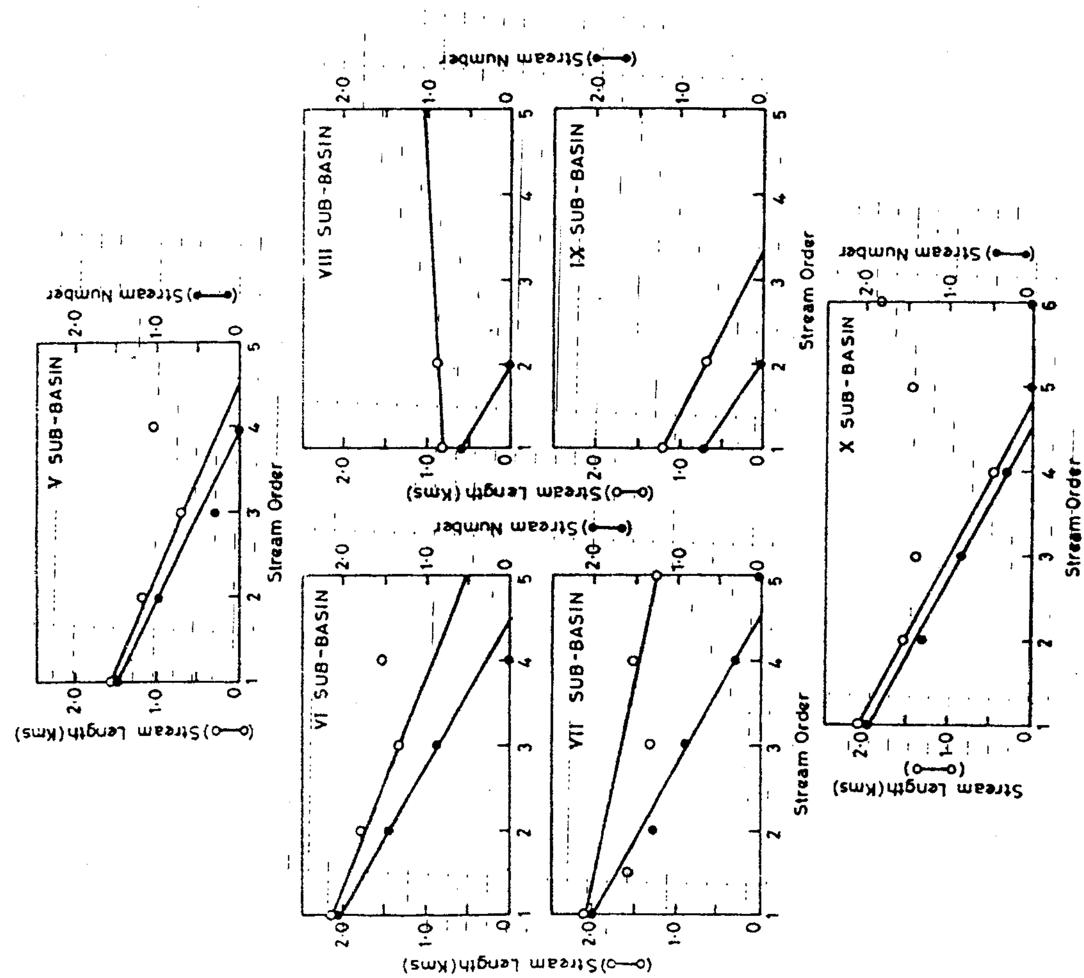

Fig. 5 : Geometric Relationship between stream orders, stream lenghts and stream numbers

2.61, 1.34, 0.66, 0.95, and 1.34 km / km^2 (Table 3). The drainage density of Pageru river basin as well as those of the sub-basins reveal that the nature of subsurface strata is permeable, which is a characteristic feature of coarse drainage since the density values are less than 5.0.

Drainage Texture (T)

It can be expressed by the equation (Smith, 1950).

T = Dd X Fs

T = Drainage texture

Dd = Drainage density

Fs = Stream frequency

Based on the values of drainage texture it is classified as

For 4.0 and below	-	Coarse
From 4.0 to 10.0	-	Intermediate
above 10.0	-	Fine
above 5.0	-	Ultra fine (bad land topography)

The drainage texture of the Pageru river basin as a whole is 1.03, while that of the ten sub-basins are 0.57, 1.32, 2.13, 0.17, 3.20, 8.46, 2.09, 0.49 and 1.70 (Table 3). The drainage texture of the whole basin and sub-basins are coarse texture as the values are less than 4.0, while that of the VI sub-basin has intermediate texture.

Bifurcation Ratios (Rb)

Horton (1932) introduced the term 'bifurcation ratio' to express the' ratio of the number of streams of any given order to the number in the next lower order. According to Strahler (1964), the ratio of number of streams of a given order (Nu) to the number of segments of the higher order (Nu+1) is termed as the 'Bifurcation Ratio (Rb)'. Therefore, it is expressed as

$$Rb = \frac{Nu}{Nu+1}$$

Bifurcation ratio varies from 2.00 to 4.31 for Pageru river basin with a mean of 3.61. (Table 3). Usually these values are common in the areas where geologic structure does not exercise a dominant influence on the drainage pattern.

The sub-basins bifurcation ratio values range from 1.0 to 9.0. The higher values of bifurcation ratio for few sub-basins are the result of large variations in frequencies between successive orders and indicate the mature topography.

MEASURES INVOLVING HEIGHTS

Relief

Basin relief is an important factor in understanding the denudational characteristics of the basin. Relief is the difference between the maximum and minimum contour levels of the basin above the mean sea level. The maximum height of the Pageru river basin is 449 m and the minimum is 127 m. Therefore the relief of the basin is 322 m (Figure 5).

Slope

Slope analysis is an important parameter in geomorphic studies. the slope elements, in turn, are controlled by the climatomorphogenic processes in the area underlying the rocks of varying resistance. An understanding of slope distribution is essential, since slope map provides data for planning, settlement, mechanization of agriculture, afforestation, deforestation, planning of engineering structures, morphoconservation practices etc. Though various methods are used to carry-out the slope analysis, Wentworth (1930) average slope method has been employed in the present study using topographic maps on a scale of 1:50,000 (Figure 6). The Pageru river basin area slope varies from 0°54' to 16°37'. High

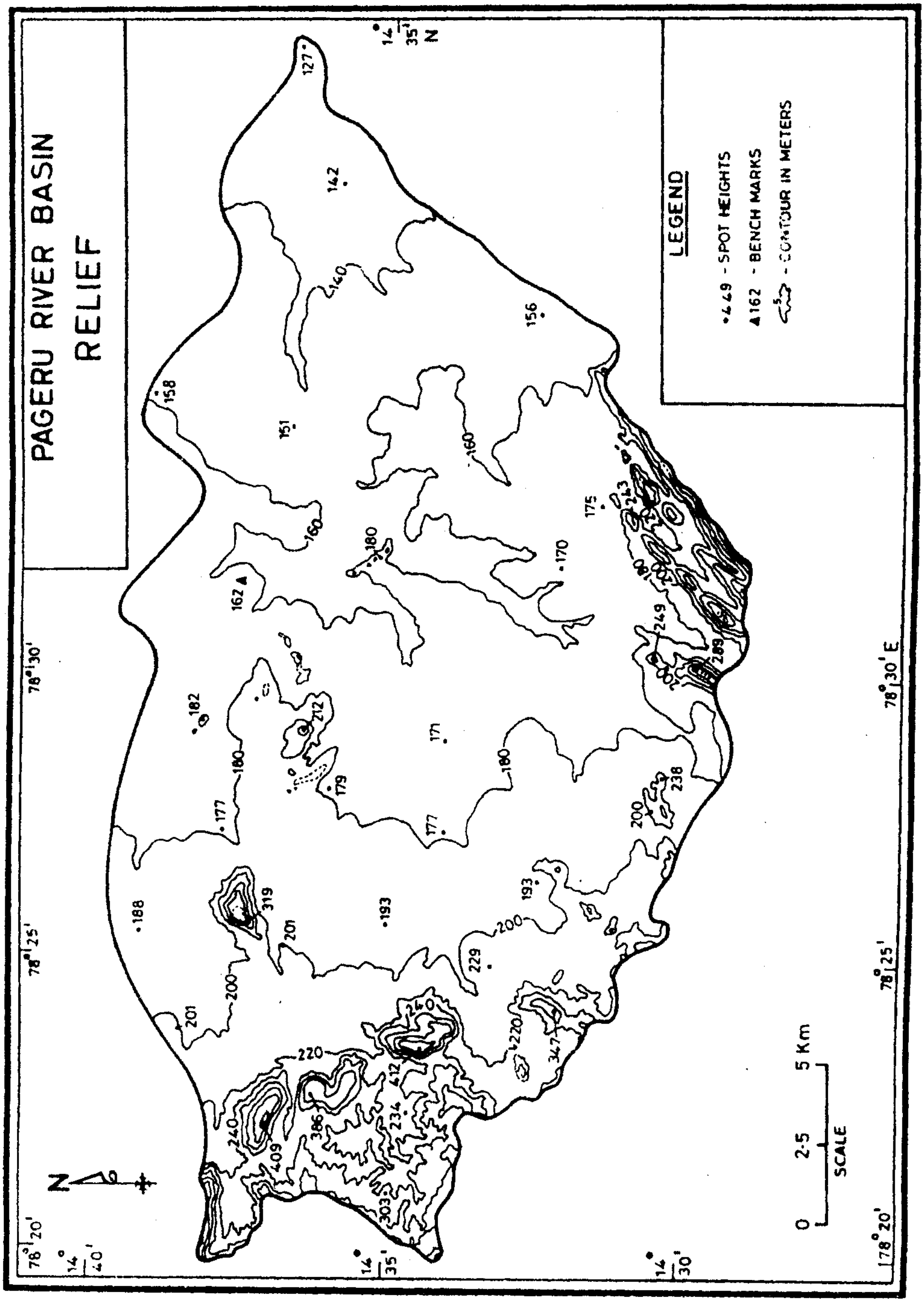

FIG. 5

Fig. 6 : Pageru River Basin Relief

degree of slope is noticed in the western and southern parts of the basin, mostly occupied by the quartzite and basic intrusives. The shale and limestone formations are characterized by low slope areas showing less than 2° in the remaining part of the basin.

Relief Ratio

The Relief ratio is calculated by using the following formulae.

$$\text{Relief Ratio} = \frac{H\text{-}h}{L}$$

Where H = highest elevation in the basin

h = lowest elevation in the basin

L = longest axis of the basin

The relief ratio of the Pageru river basin is 0.0069, while that of the ten sub-basins are 0.0025, 0.0132, 0.0117, 0.0086, 0.0166, 0.0137, 0.0101, 0.0048, 0.0042, and 0.0060 (Table 4). Generally the relief ratios of the basin and as well as the sub-basins are low which is a characteristic feature of the less resistant rocks of the area.

Gradient Ratio

It is an indication of channel slope. The basin has a gradient ratio of 0.0069, while that of the ten sub-basins are 0.0028, 0.0078, 0.0062, 0.0057, 0.0055, 0.0137, 0.0098, 0.0040, 0.0038, and 0.0048, showing low to moderate gradients (Table 4).

CONCLUSION

The quantitative analysis of various aspects of drainage network characteristics of river basin reveals some complex morphometric attributes. The streams of lower orders mostly dominate the basin. The development of stream segments in the basin area is affected by

Table 4

Relief and Gradient Aspects of Pageru River Basin

Basin / Sub-basin	Relief					Gradient				
	Elevation in 'm'		Relative Relief (H-h)	Longest axis 'L' Km	Relief Ratio (H-h/L)	Elevation at		Fall in Height (a-b)	Length of Main Stream 'L'	Gradient Ratio (a-b/L)
	Max 'H'	Min 'h'				Source 'a'	Mouth 'b'			
Sub-basin-I	156	131	25	10.0	0.0025	158	130	28	10.0	0.0028
Sub-basin-II	380	135	245	18.5	0.0132	280	135	145	18.5	0.0078
Sub-basin-III	363	158	205	17.5	0.0117	270	160	110	17.5	0.0062
Sub-basin-IV	220	160	60	7.0	0.0086	200	160	40	7.0	0.0057
Sub-basin-V	347	172	175	10.5	0.0166	230	172	58	10.5	0.0055
Sub-basin-VI	449	160	289	21.0	0.0137	449	160	289	21.0	0.0137
Sub-basin-VII	438	155	283	28.0	0.0101	430	155	275	28.0	0.0098
Sub-basin-VIII	164	140	24	5.0	0.0048	160	140	20	5.0	0.0040
Sub-basin-IX	165	140	25	6.0	0.0042	163	140	23	6.0	0.0038
Sub-basin-X	347	127	220	37.0	0.0060	306	127	179	37.0	0.0048
Pageru river basin	449	127	322	47.0	0.0069	449	127	322	47.0	0.00069

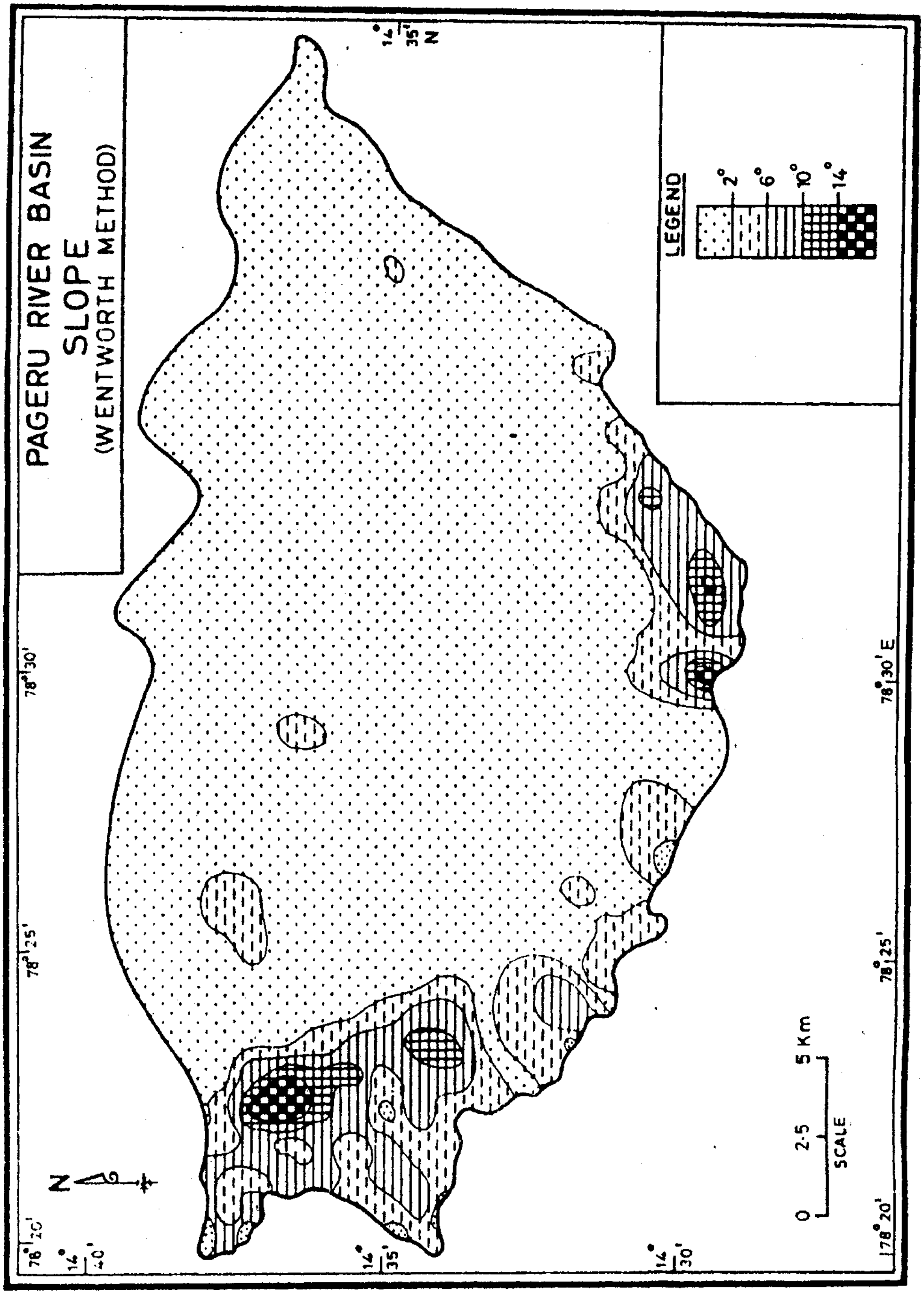

Fig. 7 : Pageru River Basin - Slope (Wentworth Method)

rainfall. The elongated shape of the basin is mainly due to the guiding effect of thrusting and faulting. The erosional processes of fluvial origin have been predominately influenced by the sub-surface lithology of the basin. The study reveals that the drainage area of the basin is passing through early mature stage of the fluvial geomorphic cycle. The analysis also indicates some relations among the various attributes of the morphometric aspects of the basin and helps to understand their role in sculpturing the surface of the region.

REFERENCES

Cannon, J. P., 1976. *Generation of Explicit Parameters for a Quantitative Geo morphic Study of the Mill Creek Drainage Basin.* Oklahoma Geology notes, Vol. 36, No. 1, p. 13-17.

Gardiner, V., 1975. *Drainage Basin Morphometry.* British Geom. Group, Tech. Bull. No. 14, 48 p.

Gregory, K. J. and Walling, D. E. 1973. *Drainage Basin Form and Process A Geomorphiological Approach.* Arnold, London.

Horton. C. R., 1932. *Drainage Basin characteristics.* Trans. Amer. Geophys. Union, Vol. 13, p. 350-361.

Horton, R. E., 1945. *Erosional Development of Streams and Their Drainage Basins; Hydrophysical Approach to Quantitative Morphology.* Geol. Soc. America Bull., Vol. 56, p. 273-370.

Miller, V. C., 1953. *A Quantitative Geomorphic Study of Drainage Basin Characteristics in Clinch Mountain Area, Virginia and Tennessee.* Technical report, 3, Office of the Naval Research. Dept. of Geology, Columbia Univ., New York.

Misra, N. 1988 Hypsometric Integral. *A basis for determining the erosion status and priority numbers of unganged watersheds.* Journal of soil and water conservation, India. 32 (1 and 2) : 38-45.

Schumm, S. A. 1956. *Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey.* Natl. Geol. Soc. America. Bull., Vol 67, p. 597-646.

Smith, K. G., 1950. *Standards for Grading Texture of Erosional Topography.* Amer. Jour. Sci. Vol. 248, p. 655-668.

Strahler, A. N., 1964. *Quantitative Geomorphology of Drainage Basin and Chan nel Networks.* In : V. T. Chow (Editor), Hand Book of Applied Hydrology, McGraw Hill Book Co., New York. p. 4-76.

Wentworth, C. K., 1930. *A Simplified Method of Determining the Average Slope of Land Surfaces.* American Jour. Sciences. Vol. No. 20, p. 184-194.

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