Bulletin of Pure and Applied Sciences.
Vol.40F, Geology (Geological Science), No.1,
January-June 2021: P.112-122
Original Research Article

Print version ISSN 0970 4639
Online version ISSN 2320 3234
DOI: 10.5958/2320-3234.2021.00010.X
Available online at www.bpasjournals.com

Drainage Morphometric Investigation of Nimni Watershed, Chhatarpur District, Madhya Pradesh, India

[1]O.P. Sahu, [2]Pitambra Sahu, [3]Pradeep K. Jain, [4]R.B. Golekar*

Author's Affiliations:
[1] Department of Geology, Government Model College, Shahpura, Dindori, Madhya Pradesh 481990, India
[2] Department of Geography, Government Thakur Ranmat Singh College Rewa, Madhya Pradesh 486001, India
[3] Department of Geology, Government Maharaja Post Graduate College, Chhatarpur, Madhya Pradesh 471001, India
[4] Departments of Geology, G. B. Tatha Tatyasaheb Khare Commerce, Parvatibai Gurupad Dhere Arts and Shri. Mahesh Janardan Bhosale Science College, Guhagar District Ratnagiri, Maharashtra 415703, India

***Corresponding Author: Rushikesh Baburao Golekar**, Department of Geology, Khare Dhere Bhosale College, Guhagar District Ratnagiri, Maharashtra 415703, India

E-mail:rbgolekar@gmail.com

(Received on 17.02.2021, Accepted on 22.05.2021)

ABSTRACT
The present paper deals with drainage morphometric investigation of Nimni watershed, Chhatarpur District, Madhya Pradesh, India. A morphometric analysis of the Nimni watershed has been carried out to characterize the nature of drainage network. The linear, areal and relief aspects of the drainage basin have been determined. The morphometric parameters have been computed on the basis of drainage map prepared on 1:50,000 scale. These parameters includes Stream order, Lengths of stream, Bifurcation ratio, Drainage density, Length of overland flow, Stream frequency, Form factor, Circulatory ratio, Elongation ratio, Lemniscate's ratio, Basin relief, Relief ratio, Ruggedness number and Ground surface slope. The drainage area of the Nimni watershed is 98 km^2. The stream order of the basin is mainly controlled by physiographic and lithological conditions of the area. The increase in stream length ratio from lower to higher order shows that the study area has reached a mature geomorphic stage. The geomorphic analysis of Nimni watershed reveals that the present drainage basin exhibits uneven topography, presence of hard rock terrain and dendritic to sub-dendritic drainage pattern. The dendritic drainage pattern exhibits the presence of hard and resistant rocks referable to Bundelkhand Granite Complex.

KEYWORDS: *Drainage Morphometry, Nimni Watershed, Chhatarpur District, Madhya Pradesh.*

INTRODUCTION

The morphometric analysis of a drainage basin has been proposed by Horton (1945). The quantitative description of a drainage basin includes measurements of linear, areal and relief features. The quantitative drainage basin analysis deals with determination of morphometric parameters. The analysis involves preparation of a drainage map, ordering of streams, measurement of the catchment area, length and perimeter of the channels, drainage density, drainage texture, drainage pattern, bifurcation ratio and circulatory ratio (Kumar et. al., 2000).

The morphometric analysis deals with the measurements of landforms. Clarke (1966) considered that the morphometry involves the measurement and mathematical analysis of configuration of the earth surface and the shape and dimensions of its landforms. The computation of hydrological parameters of drainage basin provides valuable clue for understanding the runoff and groundwater conditions of the basin or watershed. The morphometric parameters are determined by using conventional methods adopted by Horton (1945), Strahler (1957, 1964), Morisawa (1959) and Leopold and Miller (1956). The results of drainage morphometric analysis of the basin are providing data on relationship between drainage basin parameters and hydrological / geomorphological characteristics of the area.

Study area

For the purpose of present study Nimni watershed has been selected from Kushiyar river basin. The Kushiyar is tributary of River Ken and Ken is tributary of river Yamuna. The river Yamuna is Major Tributary of River Ganga and Ganga is largest river in the India. The present study area lies between 25°08'00'' N to 25°13'30''N latitude and 80°15'00'' E to 80°21'00''E longitude and covers an area about 98 km^2 (Fig. 1). The present study area is belongs to the survey of India toposheet No. 63 C/8. Geologically, the study area is cover with the Bundelkhand Granites ranging in age from Late Archean to Early Proterozoic (Sarkar et. al., 1985). The Bundelkhand Granites were exposed in the form of small hillocks, which give rise to undulating and elevated ground. It varies greatly in texture, mineralogical composition and colour from one exposure to another. Three types of granites (Fine Grained Pink Granite, Medium Grained Pink Granite and Gray Porphyritic Granite) are recognized in the studied region on the basis of variations in texture and colour (Jhingran 1958; Saxena 1961; Basu 1986; Sahu, 2006 and 2007). The geological succession of the study area is given in Table 1.

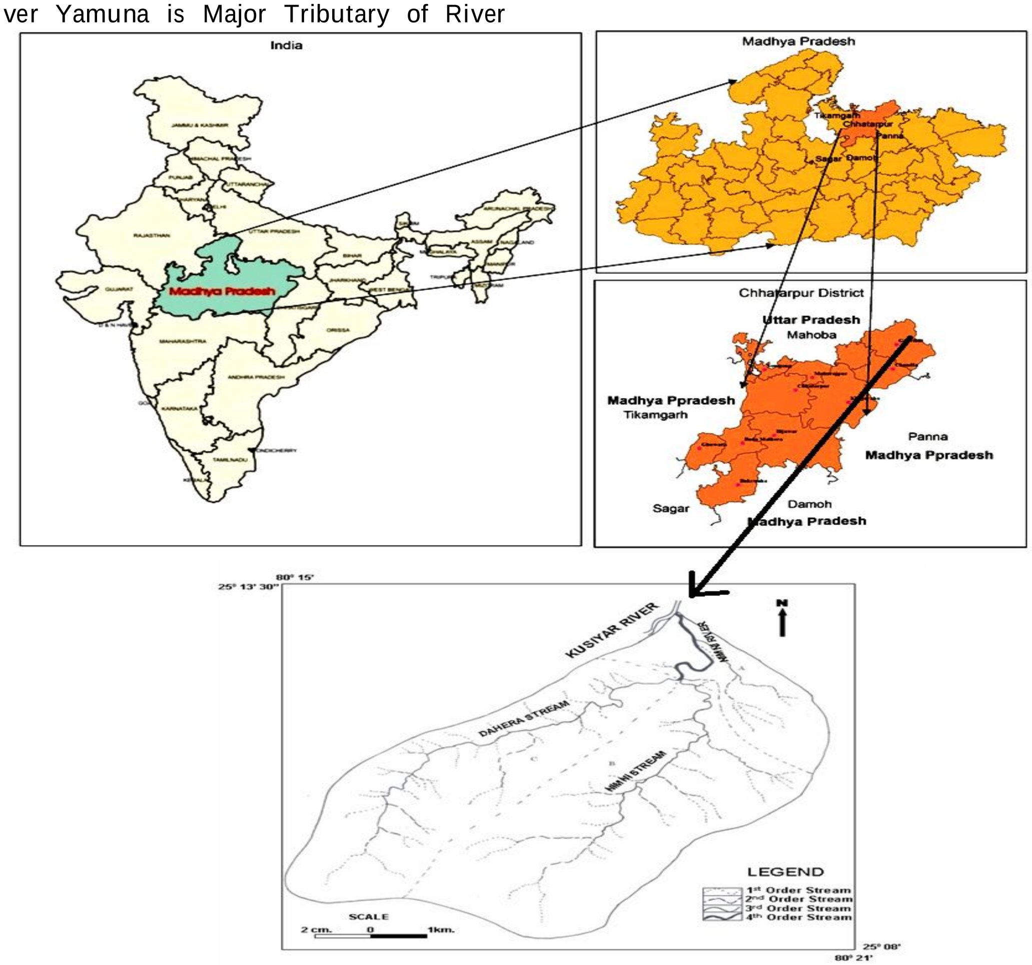

Figure 1: Location map of the Nimni watershed, district Chhatarpur, Madhya-Pradesh

Table 1: Geology of the Nimni Watershed, Chhatarpur district, Madhya Pradesh

Geological Formation	Lithology
Bundelkhand Granitic Complex	Fine Grained Pink Granite
	Medium Gained Pink Granite
	Gray Porphyritic Granite

MATERIAL AND METHODOLOGY

As reference and base map preparation, SOI toposheets 63 C/8 on 1:50000 scales in paper format were used. The SOI toposheets were geometrically rectified and geo referenced to world space coordinate system using digital image processing software (AUTOCAD) and digitization work has been carried out for entire analysis of basin morphometry. The order was given to each stream followed by Strahler (1952) stream ordering technique. Analysis of various drainage parameters were carried out namely ordering of the various streams and measurement of area of basin, Perimeter of basin, Length of drainage channels, Bifurcation ratio (Rb), Drainage density (Dd), Circulatory ratio (Rc), Stream frequency (Fs), Elongation ratio (Re), Form factor (Rf), Basin relief (Rr) , Relief ratio (Rh), Length of overland flow (Lo), Lemniscate's ratio ((RL)), Ruggedness Number (Rn) and Ground Surface Slope (Sg).

RESULT AND DISCUSSION

An attempt has been made to visualize inter-relationship of different morphometric parameters in order to delineate the terrain characteristics and groundwater potential for the planning of watershed management in Nimni watershed. The study area extends over an area of 98 km^2. The geomorphic analysis of Nimni watershed reveals that the dendritic to sub-dendritic drainage patterns were observed. Detailed drainage morphometric analysis of Nimni watershed has been carried out. The sub-watersheds have been analysis can be achieved through measurement of linear, aerial and relief aspects and slope contribution. The river basin has been classified into 3 sub-watershed designated as sub-watershed 'A', 'B' and 'C' (Fig. 2). Calculated drainage morphometric parameters of these three sub watersheds were depicted in the table 2 and 3.

LINEAR ASPECTS

Stream Order

The procedure of determination of stream number suggested by Horton (1932, 1945) has been modified by Strahler (1952, 1957) and Chow (1964). The Strahler's (1952) system for stream ordering has been followed. It has been observed that the Nimni River is a fourth order stream.

Stream Number

The number of stream channel in its order is termed as stream number. The number of stream segments decreases as the order increases (Table 2). Ideally, in a basin, the number of segment streams decrease with increase in stream order and a straight line curve is formed. The graphs of stream order (u) versus log of stream number of the sub-watersheds 'A', 'B', and 'C' were depicted in Fig. 3, 4 and 5, respectively.

Bifurcation Ratio

Bifurcation Ratio has been defined as the ratio of the number of streams of one order to the number of the next higher order (Horton, 1945, Strahler, 1952). In the Nimni watershed, the calculated average values of bifurcation ratio in the show a variation from 1.0 to 9.0 (Table 2), which indicates the existence of an elongated basin (Horton, 1945) characterized by steeply dipping rock strata (Strahler, 1964).

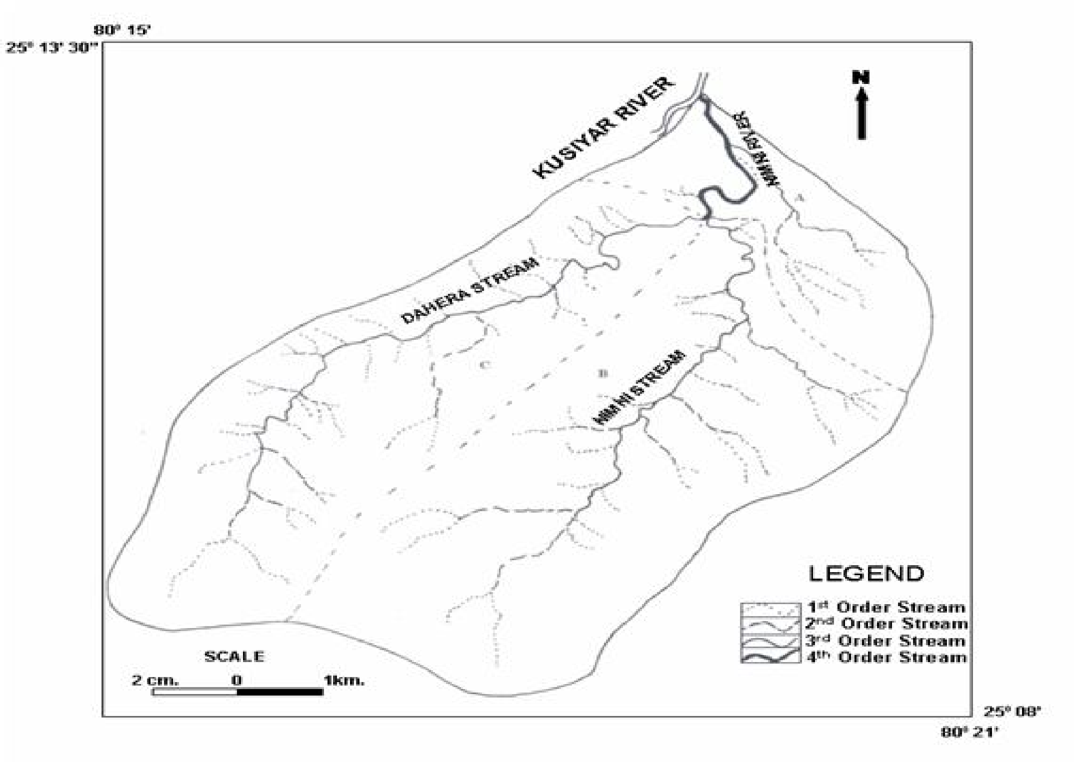

Figure 2: Drainage map of Nimni Watershed, Chhatarpur District, Madhya Pradesh

Table 2: Morphometric parameters of Nimni Watershed, Chhatarpur District, Madhya Pradesh

Sr. No.	Morphometric Parameters	Nimni Watershed		
		Sub-watershed 'A'	Sub-watershed 'B'	Sub-watershed 'C'
1	Number of First order stream (Nu)	08	29	38
2	Number of Second order stream (Nu)	03	08	09
3	Number of Third order stream (Nu)	01	01	01
4	Number of Fourth order stream (Nu)	01	-	-
5	Total Number of stream (Σ Nu)	13	34	48
6	Length of First order stream (km) Lu	05	17	19.5
7	Length of Second order stream (km.) Lu	02	06	07.5
8	Length of Third order stream (km.) Lu	01.5	09.5	07
9	Length of Fourth order stream (km.) Lu	04.5	-	-
10	Total length of stream (km.) Σ Lu	13	32.5	34
11	Basin perimeter (P)	14.5	23	22
12	Area of basin in km^2 (A)	15	42	41
13	Length of the basin in km (Lb)	05.5	0.25	09.5
14	Highest elevation within the sub-basin in m (H max)	140	220	191
15	Lowest elevation within the sub-basin in m (H min)	120	140	140

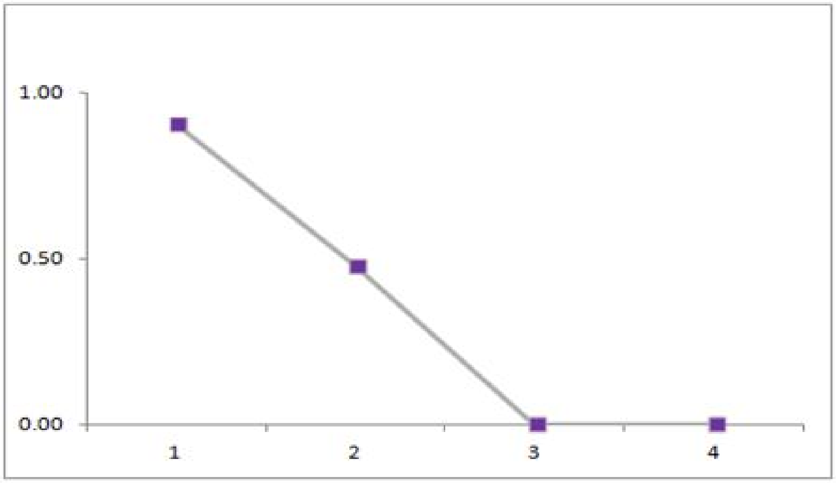

Figure 3: The graphs of stream order (u) versus log of stream number of sub-watershed 'A'

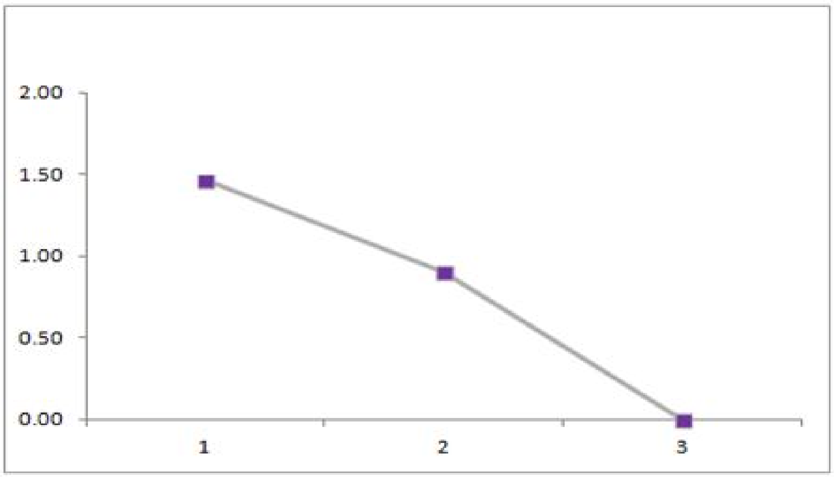

Figure 4: The graphs of stream order (u) versus log of stream number of sub-watershed 'B'

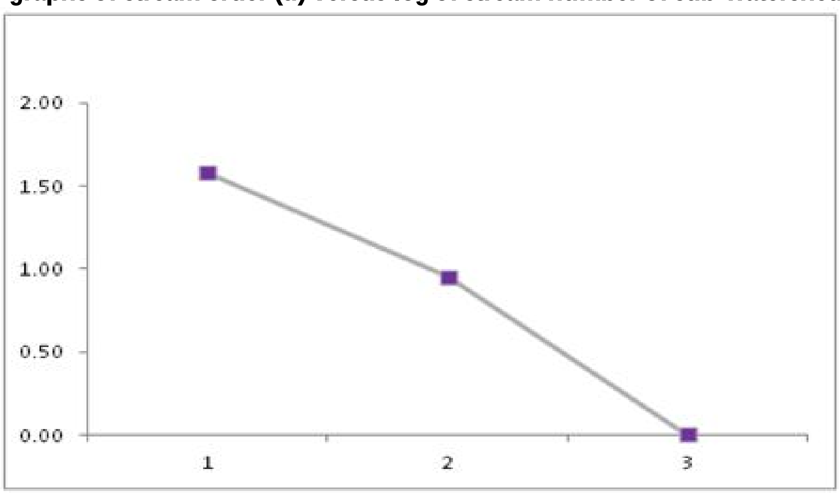

Figure 5: The graphs of stream order (u) versus log of stream number of sub-watershed 'C'

Stream Length

Length of the stream is indicative of the contributing area of the basin of that order. The maximum length of stream has been observed in the sub-basin C in the Nimni River basin (Table 2). Stream length is one of the most important hydrological features of the basin as it reveals that the surface run-off behaviors, The quantity of streams of different orders in a sub-watershed is count and their lengths from mouth to drainage divider are measured. The stream length (Lu) has been computed using Horton method (Horton, 1932). The graphs of stream order versus log of stream length depicted in Figures 6, 7 and 8 for sub-watersheds 'A', 'B', and 'C', respectively. Generally total length of stream segments is maximum in first order streams and decreases as the stream order increases. But in present study, sub-watershed 'A' 4th order stream having more length as compared to 3rd order stream, thus figure 7 slopes at the point of 3rd order sharply increases to 4th order. The somewhat like same result occurs in sub-watershed 'B' which indicates 3rd order stream having more length as compared to 2nd order stream, thus figure 8 slopes at the point of 2nd order increases to 3rd order.

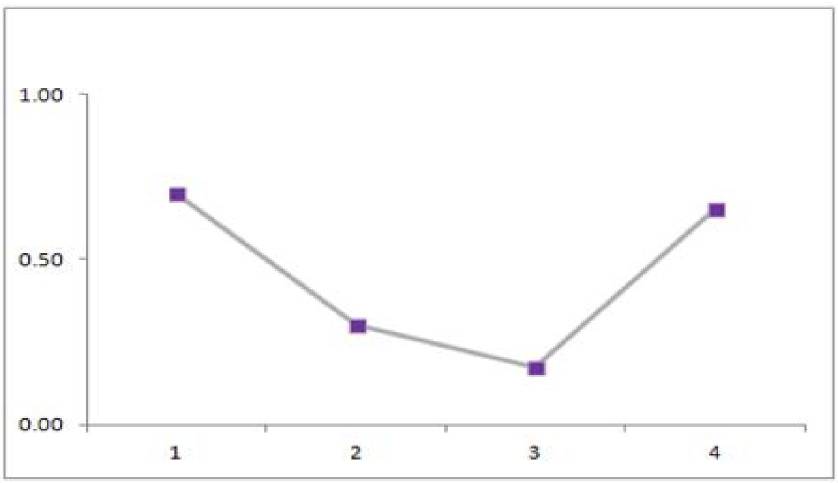

Figure 6: The graphs of stream order versus log of stream length of sub-watershed 'A'

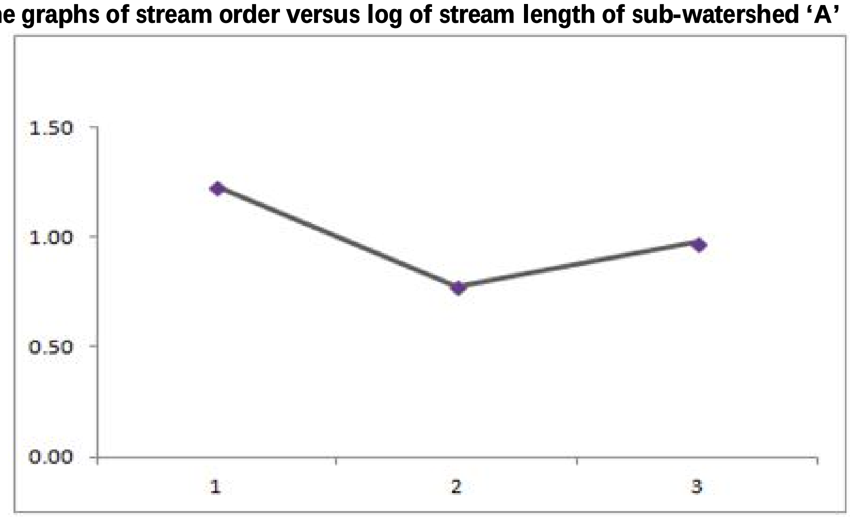

Figure 7: The graphs of stream order versus log of stream length of sub-watershed 'B'

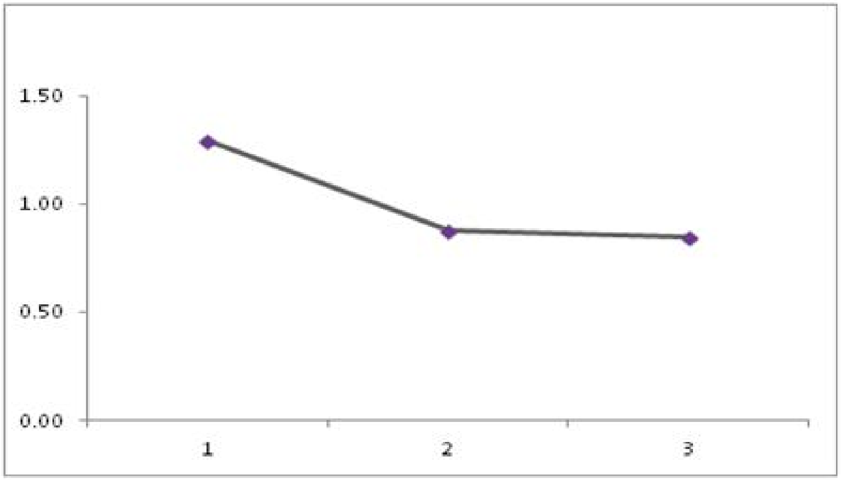

Figure 8: The graphs of stream order versus log of stream length of sub-watershed 'C'

AREAL ASPECTS

Drainage Density

The term drainage density has been defined by Horton (1932, 1945) as 'the ratio between the cumulative length of channel segments of all orders within a basin per unit area and is obtained by dividing the total stream length by total basin area'. High drainage density is the resultant of weak or impermeable sub surface material, thin vegetation and mountainous relief low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. Drainage density is calculated by given formula,

Dd = Lu / A (1)

Where,

Dd= drainage density

Lu= total stream length

A= basin area

The drainage density is described as low when < 2 km/ km^2, moderate when it is between 2 to 5 km/ km^2 and high when it is > 5 km/ km^2. The drainage density of Nimni watershed ranges from 0.77 to 0.86 with an average value of 0.82, which is considered to be low drainage density (Table 2).

In general, high Dd values are the result of weak or impermeable sub-surface material, sparse vegetation and mountainous relief whereas regions having highly resistant rock or highly permeable sub-soil materials, thick vegetative cover and low relief give rise to low Dd values. Low drainage density leads to coarse drainage texture signifying the area having permeable sub-soil material while high drainage density leads to fine drainage texture thereby implying relatively impermeable rock structure (Patil et al., 2026). This suggests the Nimni watershed have coarse drainage texture and its possibility of presence of permeable sub-soil material. Also suggesting the Nimni watershed is most vulnerable for groundwater recharge and it will helpful of rainwater harvesting and artificial recharge because of presence of permeable rocks.

Stream Frequency

Horton (1945) introduced stream frequency as the number of stream's segment per unit area and discussed the importance to groundwater recharge characteristics in a river basin. It is obtained by dividing the number of stream to the total drainage basin area.

Stream Frequency (Fu) = Nu / A (2)

Where,

Nu= Total Number of Streams, A = Basin area.

Table 3: Morphometric Parameters of the Nimni Watershed, Chhatarpur district Madhya Pradesh

Sr. No.	Parameters	Formula	Nimni River Basin		
			Sub-watershed 'A'	Sub-watershed 'B'	Sub-watershed 'C'
01	Bifurcation Ratio (Rb)	(1^{st} / 2^{nd})	2.66	3.62	4.22
		(2^{nd} / 3^{rd})	3.00	8.00	9.00
		(3^{rd} / 4^{th})	1.00	-	-
02	Drainage Density (Dd)	Lu / A	0.86	0.77	0.82
03	Length of Overland flow (Lo)	½ Dd	0.57	0.64	0.60
04	Stream Frequency (Fu)	Nu / A	0.86	0.80	1.17
05	Form Factor (Rf)	$A / (Lb)^2$	0.089	0.039	0.035
06	Circulatory Ratio (Rc)	$4 \pi A / P^2$	0.896	0.997	1.063
07	Elongation Ratio (Re)	$(2 / Lb)\sqrt{A/\pi}$	0.336	0.223	0.044
08	Lemniscate's Ratio (RL)	$Lb^2 / 4A$	2.816	3.148	7.048
09	Basin Relief (H)	H1-H2	20	80	51
10	Relief Ratio (Rh)	H / Lb	0.0036	0.0096	0.0053
11	Ruggedness Number (Rn)	H × Dd	0.017	0.061	0.042
12	Ground Surface Slope (Sg)	H × 2 Dd	0.034	0.122	0.084

Generally high stream frequency is related to impermeable subsurface material, sparse vegetation, high relief and low infiltration capacity of the region (Patil et al., 2016). The stream frequency is categorized as 1) Poor (below 2.5 / km^2), 2) Moderate (2.5-3.5 / km^2), 3) High (3.5-4.5 / km^2) and 4) Very High (Above 4.5 / km^2). The stream frequency of sub-watersheds of Nimni watershed is varied from 0.867 to 1.170 with an average value of 0.948. The stream frequency value seen that it belongs to poor category this is an indications of lack of variation in surface relief.

Form Factor

The ratio of the basin area to the square of basin length is called the 'Form Factor'. It is a dimensionless property and is used as a quantitative expression of the shape of basin form. Form factor of the basin calculated by using following formula,

Form Factor (Rf) = $A / (Lb)^2$ (3)

Where,

Lb= Longest Basin length, A = Basin area.

Value of Form Factor nearing to zero indicates a highly elongated shape and the value that is closer to 1 indicates circular shape. Basins with high form factors experience large peak flows of shorter duration, whereas elongated water shades with low form factors experience lower peak flows of longer duration.

In Nimni River basin form factor values is ranged from 0.035 to 0.089 with an average of 0.543. The mean values of form factor of Nimni watershed is closer to 1 this suggest that the area is somewhat like circular in nature. The Nimni watershed experience a large peak flows in shorter duration because of form factor values is closer to 1.

Circulatory Ratio

Miller (1953) defined Circulatory Ratio as 'the ratio of basin area to area of circle with same perimeter'. It is a dimensionless ratio and is expressed by symbol Rc.

Circulatory Ratio (Rc) = $4 \pi A / P^2$ (4)

Where,

P= Perimeter of Basin, A = Basin area

The shape of basin changes with the order and with increasing size of drainage area. The large basins would be more or less circular in case of region with homogenous rocks and structures. The circularity ratio is usually 1, for the theoretical circular basin. The computed values of Circulatory Ratio (Rc) in Nimni watershed showed a range from 0.896 to 1.063 with an average value of 0.985, which indicates that the river basin is circular and also indications of presence of homogenous rocks.

Elongation Ratio

Schumm (1956) defined Elongation Ratio as 'the ratio of the diameter of a circle of the same area in the basin to the maximum basin length'. The elongation ratio is calculated by given formula,

Elongation Ratio (Re) = $(2/Lb)\sqrt{A/\pi}$ (5)

Where,

Lb= Longest Basin length, A = Basin area.

Schumm (1956) observed that under different climatic and geologic type the value ranges from 0.6 to 1.0 and the value near to 1.0 reveals an area with very low relief whereas the values ranging from 0.6 to 0.8 represents an area characterized by strong relief and steep ground slope. In the present drainage basin, the determined values of Elongation Ratio (Re) vary from 0.044 to 0.336 with an average value of 0.201, indicating that the area represents a low relief. A circle basin is more capable for discharge of run-off than an elongation basin. These values can be grouped into 4 categories namely (a) circle (> 0.9), (b) Oval (0.9 to 0.8), (c) Less elongated (<0.7), the elongation ratio of sub-watersheds of the study area varies from to 0.336 to 0.044 indicates less elongated basin. This suggests that all the three sub watersheds from Nimni watershed are less capable for discharge of runoff.

Lemniscate's Ratio

According to Chorley et al (1957) Lemniscate's Ratio is based upon the expression of the basin with lemniscate's curve. Lemniscates ratio is defined as,

Lemniscate's (K) = $Lb^2 / 4A$ (6)

Where,

Lb= Longest Basin length, A = Basin area.

The values of Lemniscates Ratio (K) calculated for the study drainage basin indicate a range from 2.816 to 7.048 with an average value of 4.337. The higher value of lemniscates ratio indicates elongated shape of the basin.

Length of Overland Flow

The 'length of Overland Flow' has been used to the length of the sum of the rainwater on the ground surface, before it gets localized in definite channels, since length of overland flow as an average is about half of the distance between the stream channels. Length of overland flow (Lg) is calculated by given formula,

Lg = 0.5 × Dd (7)

Where,

Lg=length of overland flow

Dd= drainage density

Horton (1945) has treated it to be roughly equal to half of the reciprocal of the drainage density. In the Nimni River Basin, Length of overland flow varies from 0.576 to 0.646 with an average of 0.608. This value suggests that the Nimni watershed flows through low slope topography and travel time is longer before meeting with the main river.

RELIEF ASPECTS

Basin Relief

The difference between the highest and lowest point in a basin has been described as the Basin Relief by Strahler (1952).

Basin Relief (H) = H1-H2 (8)

Where,

H1 = Highest Elevation, H2 = Lowest Elevation

In the study area values of Basin Relief are noted as 20 m, 80 m and 51 m respectively of sub-watershed 'A', 'B' and 'C' (Table 2) indicates basin relief is low.

Relief Ratio

Schumm (1956) defined 'Relief Ratio' as 'the ratio between the total basin relief (i.e., the difference in elevation of the highest and the lowest points of a basin) and basin length, measured as the longest dimension of the drainage basin'. In a general way, the relief ratio indicates overall slope of the basin.

Relief Ratio (Rh) = H / Lb (9)

Where,

H =Basin Relief, Lb = Longest length of Basin.

In the study area, values of relief ratio (Rh) ranged from 0.0036 to 0.0096. Sub-watershed 'A' having lower value of basin relief indicates the existence of flat basin with low intensity of erosion whereas Sub-watershed 'B' shows higher value, reveals that this watershed has high relief with high intensity of the erosion process.

Ruggedness Number

A product of the relative relief and drainage density in which both the terms are expressed in the same units of the measurement has been described as the Ruggedness Number. The ruggedness number is high when both the relative relief and the drainage density are high (Sharma, 1986).

Ruggedness Number (Rn) = H × Dd (10)

Where,

H = Basin Relief

Dd = Drainage Density

Generally the ruggedness values range from as low as 0.06 in subdued low relief to over 1.0 in mountain ranges or badlands topography (Babar, 2005). The values of ruggedness number (Rn) of Nimni watershed is ranged from 0.017 to 0.061, indicating the prevalence of almost flat terrain topography in the Nimni watershed.

Ground Surface Slope

Horton (1945) suggested that the slope of ground surface can be represented in terms of "H" and "D" by the following equation,

Sg = H × 2 Dd (11)

Where,

Sg = Slope of ground surface, H = Basin relief, Dd = Drainage density

In the study area, the values of ground surface slope is ranged from 0.034 to 0.122 with an average of 0.08 suggesting that the slope of ground surface is maximum in sub-watershed 'B'.

CONCLUSIONS

In the present paper, morphometric analysis of the Nimni watershed, based on several drainage parameters using GIS tools for drainage analysis, has been delineated. It is inferred that the Nimni Watershed is a fourth-order stream. Nimni watershed is mainly dominated by lower order streams. The morphometric analysis is carried by the measurement of linear, aerial and relief aspects of basins. Detailed morphometric study of all sub-watersheds shows dendritic to sub-dendritic drainage patterns, which indicate homogenous lithology and variations of values of bifurcation ratios among the sub-watersheds attributed to difference in topography and geometric development. The tributaries join the main stream at different angles and show irregular branching in all directions. It has been observed that the dendritic to sub dendritic drainage pattern developed in the area is characterized by flat lying beds of plains and plateau and in massive crystalline rocks. The dendritic drainage pattern exhibits the presence of hard and resistant rocks belonging to massive igneous rocks.

The maximum stream order frequency is observed in case of first-order streams and then for second order. Hence, it is noticed that there is a decrease in stream frequency as the stream order increases and vice versa. The values of stream frequency indicate that all the sub-watersheds shows positive correlation with increasing stream numbers with respect to increasing drainage density. The drainage density values of the Nimni watershed is below five revealing that the subsurface area is permeable, a characteristic feature of coarse drainage texture. The Elongation ratio (Re) value of Nimni sub-watersheds is ranged from 0.044 to 0.336 this suggesting the area is highly susceptible for erosion. The used approach in this study includes a comprehensive morphometric analysis that can be applied for any drainage system elsewhere. Also establish the major parameters required to evaluation of water resources and their hydrological regime, thus it is recommended to apply similar studies in anywhere in India.

Acknowledgements

The authors acknowledge the officials Vikram University Ujjain (M.P.) India, Govt. Model College, Shahpura Dindori (M.P.) India, Government Thakur Ranmat Singh College Rewa (M.P.) India, Government Maharaja Post Graduate College Chhatarpur (M.P.) India, and G. B. Tatha Tatyasaheb Khare Commerce, Parvatibai Gurupad Dhere Arts and Shri. Mahesh Janardan Bhosale Science College, Guhagar District Ratnagiri (M. S.) India.

REFERENCES

1. Babar Md. (2005). Hydrogeomorphology Fundamentals application and techniques a text book. 137 p.
2. Basu, A.K. (1986). Geology of Parts of Bundelkhand Granite Massifs, Central India, *Record GSI*, 117, Part.-1, 61-124.
3. Chorley, R.J., D.E.G. Malm and H.A. Pogorzelski (1957). A new standard for estimating basin shape. *Amer. Journ. Sci*. 255, 138-141.
4. Chow, V.T. (1964). Hand book of applied hydrology section 4-II Geology 4, 39-76.
5. Clarke, J. J. (1966) Morphometry from map. Essays in geomorphology. Elsevier, New York, pp.235–274
6. Horton, R.E. (1932). Drainage basin characteristics. *Trans. Amer. Geophysics, Union*. 14, 350-361.
7. Horton, R. E. (1945). Erosional development of streams and their drainage basins: Hydrological approach to quantitative geomorphology, *Bulletin of the Geological Society of America*. 56, 275-370.
8. Jhingran, A. G. (1958). The Problem of Bhundelkhand granite and genesis, Presidential address Proc. 45th Indian science Congress.
9. Kumar, R., Kumar, S., Lohani, A.K., Nema, R.K., Singh, R.D. (2000). Evaluation of geomorphological characteristics of a catchment using GIS. *GIS India*. 9(3), 13–17
10. Miller, V.C., 1956 : A quantitative geomorphic study of drainage basin characteristics in the clinch mountain area, Virginia and Tennessee, Department of Geology, Columbia University, Contract N 6 ONR 271-30, Technical Report 3, pp.1-30.
11. Morisawa, M.E. (1959). Quantitative geomorphology of some watersheds in the Appalachian Plateau. *Bull. Geol. Soc. Amer*. 73 (9), 1025-1046.
12. Patil, J. D., Suryawanshi, R. A. AND Golekar, R. B. (2016). Drainage Morphometric and Geomorphic Landform Development Study Using Geographical Information System For Chikotra River Basin, District Kolhapur Maharashtra, India. *International Journal of Earth Sciences and Engineering*. 9(1). pp. 207-218.
13. Sahu, O.P. (2006). Dissertation on Hydrogeological and Environmental studies of Nimni River micro basin, M.Sc. Dissertation, Govt. P.G. College, Chhatarpur, Madhya Pradesh, India.
14. Sahu, O.P. (2007). Quantitative and Qualitative investigation of shallow Hydrogeological regime of Nimni River basin, Chhatarpur district, Madhya Pradesh, M. Phil, Thesis Vikram University Ujjain (M.P.) India.
15. Sarkar, S.N. (1980). Precambrian Stratigraphy and geochronology of peninsular India: - a review. *Indian Jou. of Earth Science*. 7 (1), pp-12-25.
16. Saxena, M.N. (1961). Bundelkhand granite and associated rocks from Hamirpur, and Jhansi district U.P., India, res. Bull.(NS) of Punjab University 12(I & II), 85-107.
17. Schumm, S.A. (1956). The evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey, *Bull. Geol. Soc. Amer*. 67, 597-646.
18. Sharma, V.K. (1986). Geomorphology, Earth Surface Processes and Forms, Tata Mc Graw-hill Publishing Company Limited, pp.244.
19. Strahler, A .N. (1969). Physical Geography, 3rd edition, John Wiley and Sons, incense Newyork.
20. Strahler, A.N. (1952). Dynamic basis of geomorphology, *Bulletin of the Geological Society of America*. 63, 923-928.
21. Strahler, A.N. (1957). Quantitative analysis of water shed geometry. *Trans Amer. Geophysical Union.* 38, 913-920.
22. Strahler, A.N. (1958). Dimensional analysis applied to fluvialy eroded landforms, *Geol. Soc. Amer. Bull.* 69, 279-300.
23. Strahler, A.N. (1964). Quantitative geomorphology of drainage basins and channel networks in Handbook of Applied Hydrology (edited by V.T. Chow), Part - 4 pp.39- 76.

How to cite this article: Sahu, OP., Sahu, P., Jain, PK., Golekar, R.B. (2021). Drainage Morphometric Investigation of Nimni Watershed, Chhatarpur District, Madhya Pradesh, India**.** *Bulletin of Pure and Applied Sciences- Geology,* 40F(1), 112-122.