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# Remote sensing and GIS based morphometric characterization of Bichiya river watershed of Rewa district, MP

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**Abstract**
Remote Sensing & GIS technique was used for extracting geomorphological characteristics of watersheds. Its application provides an efficient and accurate means for evaluation of these characteristics. Drainage system delineation is important to better understand hydrologic system, water resource management and its planning. Morphometric analysis of any drainage basin in a systematic method has a great importance in understanding hydrological behavior of the basin. Morphometric parameters describe the topology, the structure, the platform and the relief of basin area. Its characteristics are commonly used for planning & management of regional hydrological models. Physical characteristics of watershed provides some pre-information mainly runoff, stages of its development and soil loss productivity characteristics. Morphometric parameters *viz*; Stream order, Stream length, Bifurcation ratio, Drainage density, Drainage frequency, Drainage texture, Form factor, Circularity ratio, Elongation ratio and Compactness ratio etc. were measured for prioritization and compound parameter values were calculated and finally prioritization of seven sub watersheds was marked.
Morphometric parameters are relevant and useful to identify various characteristics of drainage Watershed. Patterns, shape, stage of stream, as well as help to correlate with lithological characteristics. GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation and their updation. Stream order show the Watershed is 5th order watershed with dendritic drainage pattern and with homogeneous nature and some area with parallel drainage pattern. The average Bifurcation Value of study area 2.98, usually these values are common in the areas where geologic structures do not exercise a dominant influence on the drainage pattern. The Drainage density of Watershed is 1.75indicating moderate drainage densities. The Moderate drainage density indicates the Watershed is permeable. It also shows the Texture of Watershed is Moderate.

**Keywords:** Remote sensing, GIS, Morphometric analysis, and prioritization

## Introduction
Water is a natural resource and a basic human need. It gives life and livelihood. It is also a basic need for any planning and development. Due to population growth, irrigation and industrialization the demand for water has gone to a large extent. So watershed management is necessary and is an important part of sustainable development. Morphometric analysis of a watershed is an important aspect in watershed management. Detailed morphometric analysis of a watershed is helpful in understanding the influence of fluvial morphometry. Morphometric analysis of any watershed provides an account about the topography of the area, geological condition and runoff potential. Morphometric analysis is the measurement of 3 dimensional geometry of landforms and has traditionally been applied to watershed, drainages, hill slopes, and other group of terrain features (Barber, 2005) [1]. The morphometric characteristics of a watershed represent its attributes and can be helpful in synthesizing its hydrological behavior. Morphometric parameters affect catchment stream flow patterns through their influence on concentration time (Jones, 1999) [2]. Morphometric parameters *viz*; Stream order, Stream length, Bifurcation ratio, Drainage density, Drainage frequency, Drainage texture, Form factor, Circularity ratio, Elongation ratio and

Compactness ratio, etc. were measured for prioritization and compound parameter values were calculated and finally prioritization of seven sub watersheds was marked. In this study morphometric analysis and prioritization of Bichiya river watershed is which is a tributary of Beehar river has been done. Remote Sensing and GIS is an advance technology for morphometric analysis. The technology provides capability to obtain synoptic view of a large area in a limited time period. GIS is used for spatial planning & management which have easy accessing capability and time consuming power in the manipulation and retrieval of data. Remote Sensing and GIS has effective tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process.

In present scientific and satellite era, remote sensing and geographical information system (GIS) techniques are used as a very effective medium to explore the relationship among spatial variables (Srivastava *et al*. 2010; Srivastava *et al*. 2012a; Srivastava *et al*. 2012b; Srivastava *et al*. 2012c). The morphometric parameters represents reasonably simple approach to illustrate fluvial characteristics and geological characteristics, which enhance the interrelationships between lithological and hydrology of that particular region. Watersheds are delineated accurately and all significant morphometric parameters are calculated which are very useful for identification of deficit and surplus groundwater zones.

## Study Area

The Bichiyais small tributary of Beehar river. It is located in the Rewa district of Madhya Pradesh. The study area of bichiyatributary lies between $81^0$10’00’’E to $81^0$40’00’’ E longitude and $24^0$20’00’’ N to $24^0$50’00’’N latitude (Fig-1). The major part of the area consists of shale with sandstone bands of Meso-Proterozoic Era. Rest area consists Upper Rewa Sandstone, thick bedded massive sandstone with quartzite, Kaimur sandstone and small area of alluvium sand/silt of Holocene. Humid subtropical climate prevails which is interrupted by summers having highest temperature of 47 ºC creating semi-arid conditions[3]. January is the coldest month having temperature of 5–8 ºC. Annual average rainfall is around 85% during August and varies throughout the year showing lowest in April-May. Agriculture is the main source of economy of the district. Both surface and ground water are used for irrigation. The area is characterized by alluvium, moderately coarse grains and hard rocks.

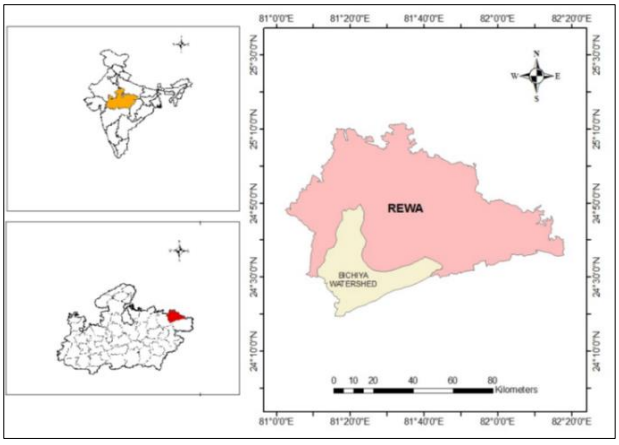
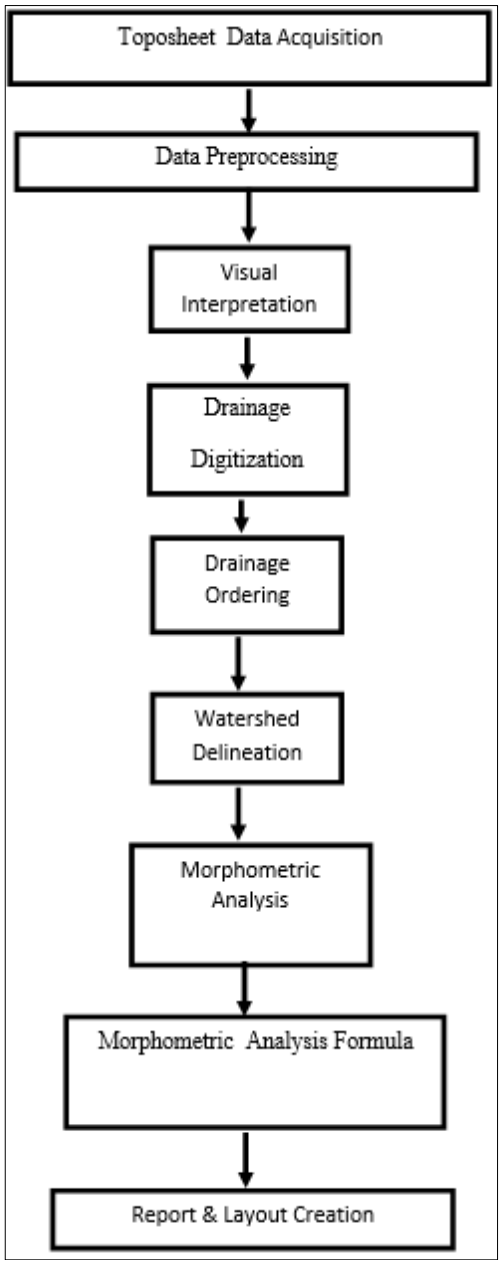



**Fig 1:** Location Map

## Methodology

The watershed boundary of the study area is delineated using Survey of India toposheet no. 63H/2, 3, 5, 7, 10, and 11 on 1:50000 scale. Morphometric characterization was carried out in all the sub-watersheds for further analysis in GIS environment. Using GIS technique morphometric characteristics *viz*; Stream number, stream order, stream length, bifurcation ratio, drainage density, drainage texture, drainage frequency, circularity ratio, elongation ratio, form factor and compactness ratio were obtained. The drainage map and contour map were created through digitization process for length, area, perimeter, elevation, etc.




Flow Chart

## Morphometric Characterization

Morphometry incorporates as the measurement and mathematical analysis of drainage basin. According to Strahler, 1964 [6] morphometric analysis of a drainage basin provides a quantitative description of the drainage system which is an important aspect for the drainage basin characterization. The basin morphometric characteristics of the various basins have been studied by many scientists

using Remote Sensing and GIS methods (Krishnamurthy and Srinivas, 1995) [4]. GIS technology is an integrated approach that plays a significant role for sustainable development and management of watersheds (Khan *et al*., 2001) [5].

Figure 1 is a sketch of boundary including the stream networks. The linear, areal, and relief parameters have been examined and detailed in the following along with the highlights of the results.

**Linear Aspect**

The linear aspects of morphometric analysis such as stream order, stream length, mean stream length, stream length ratio and bifurcation ratio are discussed in the following sections.

The classification of streams based on the number and type of tributary junctions, has proven to be a useful indicator of stream size, discharge, and drainage area (Strahler 1964) [11]. schemes for ordering the network all the "fingertip" tributaries are designated as first order stream and where two of them join they form a second order stream likewise two second order stream join to a third order stream and so on to the stream of fourth, fifth and higher order.

When two channel of different order are join together then the higher is maintained. Drainage patterns of stream network from the basin have been observed as mainly of dendritic type which indicates the homogeneity in texture and lack of structural control. The properties of the stream networks are very important to study basin characteristics. Tabulation of the order (u) specific number of streams (N). MW is designated as a fifth order watershed with three fifth order tributaries and whole sub-watersheds considered for the present study are of fourth order.

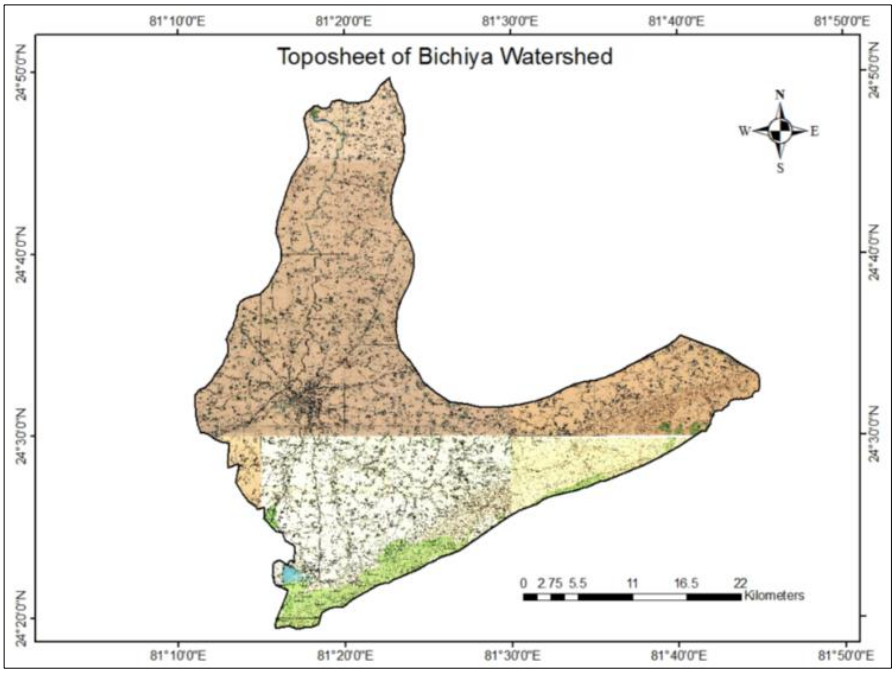



**Fig 2:** Top sheet of Study Area

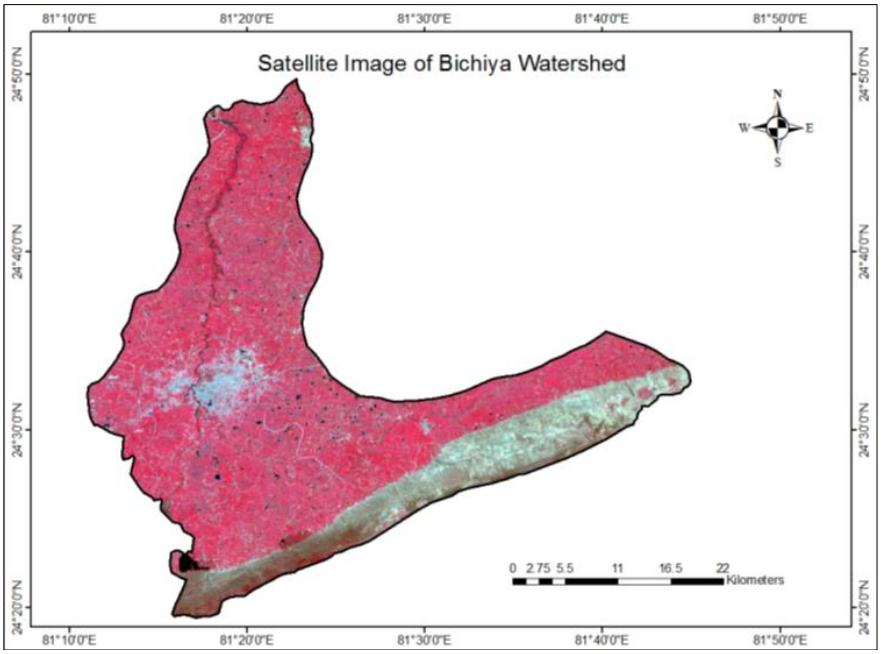



**Fig 3:** Satellite Map of Study Area

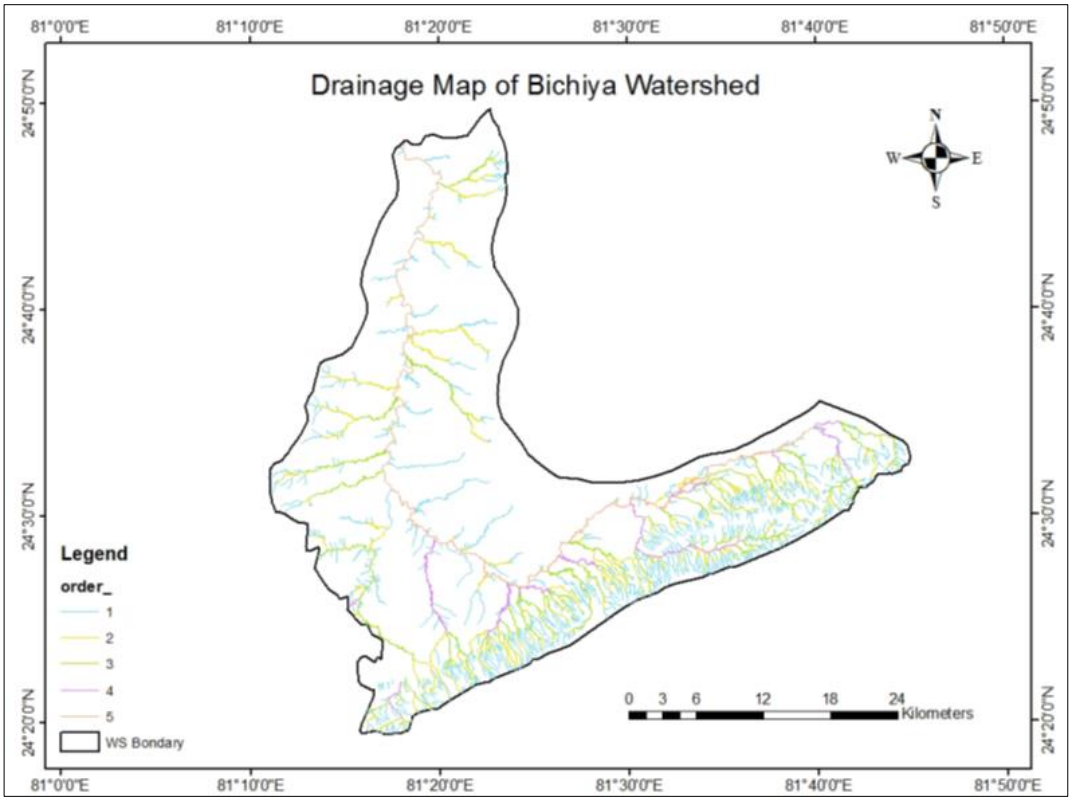



**Fig 4:** Drainage Map

### Stream number (Nu)

The number of streams of each order in a given watershed is known as stream number. Law of stream order (Horton 1945) [11] describes that the number of streams of each order forms an inverse geometric sequence against stream order. The total no of order wise stream segments is known as stream number. Nu is number of streams of order u. Total No of Stream and their order wise addition is given in following table.

**Table 1:** Drainage Order

| Sr. No | Drainage Order | No of Drainage / order |
|---|---|---|
| 1 | 1st Order | 769 |
| 2 | 2nd Order | 218 |
| 3 | 3rd Order | 63 |
| 4 | 4th Order | 16 |
| 5 | 5th Order | 4 |
| | Total | 1070 |

Total no of stream in given area is 1070

### Stream Length- Lu

Stream length means the length of stream in Particular Order (Horton 1945) [11]. It reveals the surface runoff characteristic. The stream of relatively smaller length is characteristics of areas with larger slopes and finer textures. Longer lengths of streams are generally indicative of flatter gradient. Generally, the total length of stream segments is maximum in first order stream and decreases as stream order increases. The numbers of streams are of various orders in a watershed are counted and their lengths from mouth to drainage divide are measured with the help of GIS software. The change may indicate flowing of streams from high altitude and moderately slopes. The observation of stream order verifies the Horton's law of stream number. Total length of Stream in every order of study area is given in following table.

**Table 2:** Show the stream length

| Order No | Stream Length(km/sqm) | Total No of Stream |
|---|---|---|
| 1 | 1329.145 | 769 |
| 2 | 277.594 | 218 |
| 3 | 213.121 | *63* |
| 4 | 75.604 | *16* |
| 5 | 110.037 | *4* |

Total Length of stream in all order is 2005.50 (km/sq)

### Bifurcation ratio

The ratio of the number of stream segments of a given order to the number of segments of next higher order (Schumm 1956) [9]. It is calculated by dividing the number of streams in one order to number of stream in next higher order. Strahler demonstrate the Bifurcation ratio show a small range of variation of different or environmental condition except where the geology dominate. The bifurcation ratio "Rb" is calculated by the following formula.

**Table 3:** "Rb" = Nu/ Nu+1

| Sr. No | Bifurcation Ratio(Rb) | No of Drainage |
|---|---|---|
| 1 | 3.52 | 769 |
| 2 | 3.46 | 218 |
| 3 | 3.93 | 63 |
| 4 | 4 | 16 |
| 5 | 0 | 4 |

Average Bifurcation Ratio is 2.98

### Drainage Density

Drainage density is an important aspect in morphometric analysis. Drainage density is the total length of all the streams divided by the total area of the drainage basin (Horton 1932) [10]. It indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. High drainage density is the resultant of weak or impermeable

subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964) [11]. The Moderate drainage density indicates the basin is highly permeable subsoil and vegetative cover (Nag, 1998). It is a measure of how well or how poorly a watershed is drained by stream channels.

Dd = Lu/A

Lu = Total length of Stream Segment and A = Area of River watershed
Drainage density for given area is 1.75.

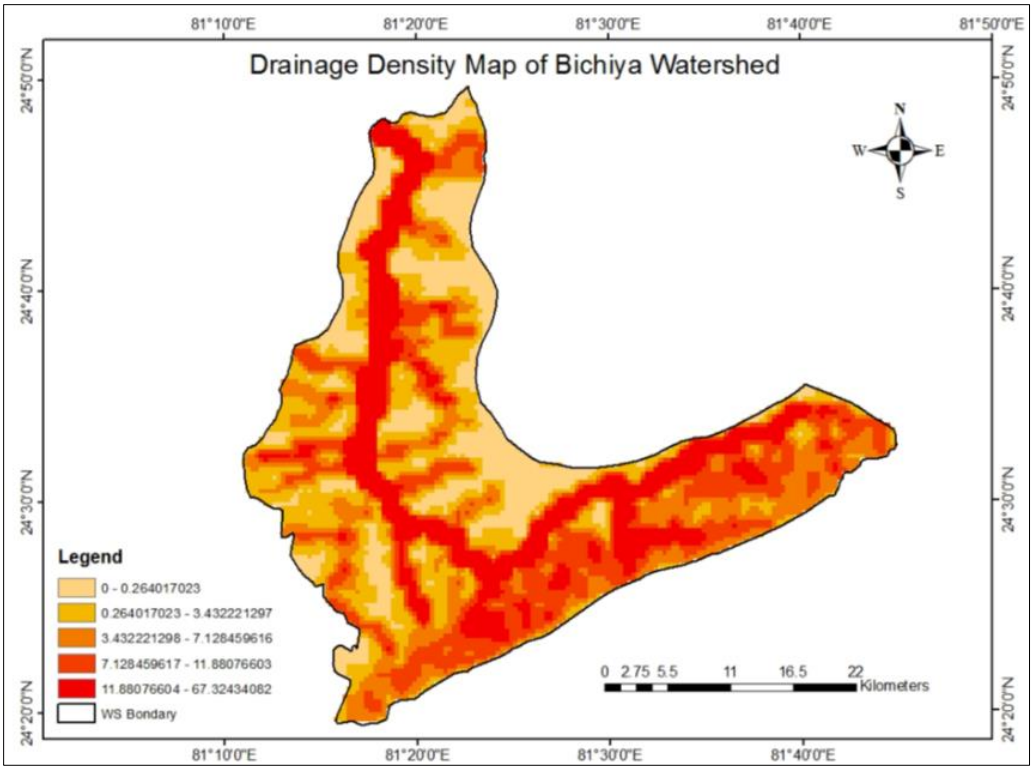



**Fig 5:** Drainage Density Map

There are different types of stream ordering system that are available. Strahler method is widely used by its simplicity.

**Stream Frequency (Fs)**
The Stream frequency is firstly introduced by Horton (1945) [11]. Stream frequency or channel frequency (Fs) is the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density.

Fs =ξ Nu / A

Nu= All order stream segment No and A = Area of Basin
1070/1145.19 = 0.93
Stream frequency for giver area is 0.93

**Texture Ratio**
Drainage texture ratio (T) is the total number of stream segments of all orders per perimeter of that area. It depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development.

**Length of overland flow**
The Length of Overland Flow (Lg) is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton, 1945) [11]. The length of overland flow is approximately equal to the half of the reciprocal of drainage density.

**Constant channel maintenance**
Schumm (1956) [24] used the inverse of drainage density as a property termed constant of stream maintenance C. This constant, in units of square feet per foot, has the dimension of length and therefore increases in magnitude as the scale of the land-form unit increases.
Specifically, the constant C provides information of the number of square feet of watershed surface required to sustain one linear foot of stream.

**Result & Discussion**
Morphometric parameters are relevant and useful to identify various characteristics of drainage Watershed. Patterns, shape, stage of stream, as well as help to correlate with lithological characteristics. GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation and their updation. Stream order show the Watershed is 5th order watershed with dendritic drainage pattern and with homogeneous nature and some area with parallel drainage pattern. The average Bifurcation Value of study area 2.98, usually these values are common in the areas where geologic structures do not exercise a dominant influence on the drainage pattern. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964) [11]. The Drainage density of Watershed is 1.75indicating moderate drainage densities. The Moderate drainage density indicates the Watershed is permeable. It also shows the Texture of Watershed is Moderate. Stream frequency of Watershed which show positive correlation with drainage

density in the watershed indicating an increase in stream population with respect to increase in drainage density.

**Table 4:** Stream Parameter of Bichiya River Watershed

| Stream | | | | | |
|---|---|---|---|---|---|
| Order | 1 | 2 | 3 | 4 | 5 |
| Number of stream | 769 | 218 | 63 | 16 | 4 |
| Total length(km) | 1329.145 | 277.594 | 213.121 | 75.604 | 110.037 |
| Bifurcation ratio | 3.52 | 3.46 | 3.93 | 4 | 0 |

**Table 5:** Basin Morphometric Parameters

| S.no. | Parameters | Computed value |
|---|---|---|
| 1. | Basin area | 1145.19 sq km |
| 2. | Basin perimeter | 207.299 km |
| 3. | Circulatory ratio | 0.181 |
| 4. | Mean bifurcation ratio | 2.98 |
| 5. | Drainage density | 1.75 |
| 6. | Number of stream | 1070 |
| 7. | Elongation ratio | 0.81 |
| 8. | Form factor | 0.51 |
| 9. | Stream frequency | 0.93 |
| 10. | Basin length | 46.98 km |
| 11. | Total stream length | 2005.50km |
| 12. | Average stream length | 401.1km |
| 13 | Mean stream length | 1.87 |

The stream of relatively smaller length is characteristics of areas with larger slopes and longer lengths of streams are generally indicates the basin is flat. The complete morphometric analysis of drainage Watershed indicates that the given area is having good groundwater prospect.

## Conclusion

The morphometric analysis of the drainage basin and channel network play an important role in understanding the geo-hydrological behavior of drainage Watershed and expresses the prevailing climate, geology, of the catchment. Morphometric analysis is very important for water conservation, as well as controlling floods. Remote sensing and GIS is very efficient tool which is very promising for the Morphometric analysis and could help in disaster management. Through these tools a synoptic estimation of the Bichiya Watershed morphometric analysis are made to deduce the nature of the Watershed. This study would help the local people to utilize the resources for sustainable development of the Watershed area.

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