MAT JOURNALS

Journal of Remote Sensing GIS & Technology
Volume 1 Issue 3

# Grid based Morphometric analysis using GIS techniques - A case study on Bhatkuli Taluka, Amravati District, and Maharashtra.

***Sumedh R. Warghat*[1]**

Assistant Professor, Shri Shivaji Science College, Amravati

Email Id- sumedhwarghat@gmail.com

## *Abstract*

*Morphometric analysis was carried out with the help of Geographical Information System (GIS) technique which evaluates the various valuable parameters for the Bhatkuli Taluka, Amravati district, Maharashtra. The study area is covered by (89 %) of quaternary alluvium and rest of the part is covered with Deccan trap Basalts. Under this present study, grid based morphometric analysis were carried out by using ArcGIS 9.3 software, to achieve the morphometric results .The study area was divided into 4 kmX4 Km sq.km, in grid pattern to start with; then for each grid the linear, aerial and relief aspects have been investigated for evaluating the stream behaviour, morphometric setting of streams within the drainage system, to study the hydrogeology, lithology, and geomorphology etc. of the area under study. Relief aspects are studied with help by Digital Elevation Models (DEMs), which was also used for visual interpretation, analysis of topography, landforms and modelling of surface processes. Further from the Digital Elevation Model (DEM), the slope map was prepared by using GIS technique. The drainage in study area show dendritic drainage pattern and VI$^{th}$ order stream revealing the homogeneity in texture and lack of structural control. The Hypsometric integral determined for the Bhatkuli taluka is 77.77 which suggest that the streams of study area are still in youth stage and therefore no structures need to be designed as it would cause silting problem. The overall studies stand significant in light of morphometric analysis carried out effectively by using remote sensing and GIS technique than the traditional method, which is time consuming. The methodology adopted in the present paper provides a user friendly environment and a powerful tool for interpretation and analysis.*

***Keywords:*** *GIS, Morphometric, DEM, Hypsometry.*

## INTRODUCTION

The morphometric analysis of the Bhatkuli Taluka was carried out by using GIS techniques. This study was carried out to understand the geological and geomorphological history of drainage basin and how the basin has evolved to the present day region. A large part of the study area is covered by Quaternary alluvium and rest of the part is lying over the Deccan trap Basalts. The study area comes under the Purna saline track. Horton (1932 and 1945) has carried out the revolutionary study for evaluating the morphometric set up. Melton (1958) and Miller (1953) has studied the geomorphic properties of matured drainage system. Morphometric analysis of a quantitative description of the drainage system which is an important aspect of the characterization of watersheds states Strahaler, (1952, 1956, 1957). Morphometric analysis require measurement of linear features, areal aspects gradient of channel network and contributing ground slopes of drainage basin was stated by Nautiyal (1994). Morphometry has provided the measurements and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms (Clarke, 1996).

The morphometric analysis of the drainage basin play a important role in understanding the hydro-geological behaviour of drainage basin and expresses the prevailing climate, geology, geomorphology and structure. It provides a quantitative description of the basin geometry to understand its slope, structural controls, geological and geomorphic history of drainage basin (Strahler, 1964). Morphometric analysis and Hypsometric analysis is used to assess the drainage characteristics of the river basins, (Rao and Babu (1995); Gangalakunta (2004); Korkalainen et al.2007; Manu and Anirudhan 2008; Magesh et al. 2011; Umrikar, 2016). In the areas surrounding the present study area and in some regions of India, some recent studies on morphometric analysis by using remote sensing and GIS technique are reported by Nag (1998), Sriniwasa et al. (2004), Javed et al.2009; Mishra and Nagrajan (2010), Nagrajan and Zende (2011), Pastapure and Avhad (2014), Pande and Moharir (2015); Meshram and Khadse, (2015). The remote sensing and GIS technique is a convenient method for morphometric analysis as the satellite images provide a synoptic view of a large area and is very useful in the analysis of drainage basin morphometry.

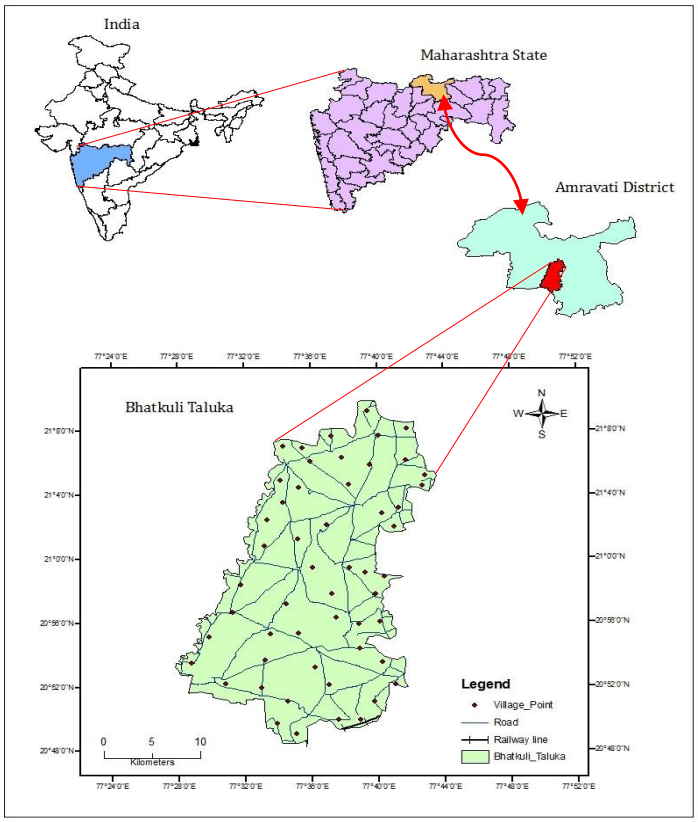


***Fig. 1****- Location map of study area*

## Study Area

The study area lies between the latitude N 20° 48' 25" to 20° 9' 54" and longitude E 77° 27' 51" to 77° 43' 27" and falls in Survey of India Toposheet no's 55 H/5, 55 H/9 and 55 G/12. The study area covers area of 581.62 Sq. km adjoin the area Chandur Bazar taluka is north direction, whereas Amravati in east, Daryapur taluka in west and Akola District in south direction of the study area. There are 137 villages in Bhatkuli taluka, all villages is well accessible by tar road network. The location map of study area is shown in figure 1.

## Geology

The study area forms a part of Purna sub-basin of the Tapti main basin. The area exhibits planner topography. About 516.31 sq.km area is occupied by quaternary alluvial complex and while rest by Deccan trap formation. Three basaltic lava flows were encountered between the altitudes of 295 to 325 m above M.S.L. Flows Nos. I, II, and III area of 'aa' type. The massive parts of all the flows are fine grained non porphyritic to sparsely porphyritic. Plagioclase and pyroxene act as phenocrysts in the groundmass showing predominantly intergrannuar and interested textures.

The sedimentary horizon, consisting of calcified clay, and silt, forming a part the older alluvial, is occupying about 88.77 % of the area covered by the quaternaries. A few outcrops of the underlying basalts are seen projecting through the older alluvium in southern part of the Bhatkuli. The younger alluvium is confined to the present day drainage. It overlies the older alluvium with district unconformity, marked by the presence of 1 to 2 m thick pebble bed. The pebble zone and coarse sand grade upwards into fine sand, silt and clay which exhibit sedimentary features like cross lamination and graded bending, representing typical fluvial environment. The lithological succession in the area mapped as per Bhai, (1990).

## METHODOLOGY

The morphometric parameters such as linear, aerial and relief aspect of the study area were determined and computed using GIS approach. The methodology adopted for the morphometric analysis is as follows;

- Entire study area is delineated from rectified mosaic survey of India topographic maps 55H/7, 55H/13 on scale 1:50000 with help of ArcGIS 9.3.
- Digitization of drainage in the study area from the georeference survey of India toposheet. The study area has been arbitrarily divided in into 4 km X 4 km grids. Grid based morphometric analysis is carried out for the study area.
- The drainage parameters were determined for each grid and their spatial variation map is prepared and studied in details for their control on natural resource of the taluka.
- The Morphometric parameters such as linear, aerial and relief aspects for the study area were computed as per methodology suggested by Horton (1932), Strahler (1952, 1964) etc.

Firstly from the satellite image the drainage characteristics have been extracted and drainage map has been prepared. This was done to confirm the morphometric characters from the survey of India toposheet.

## OBSERVATION& DISCUSSION

Morphometric parameters such as linear aspect, aerial aspect and relief aspect were determined and result for the same is displayed as spatial variation maps which has been prepared in GIS environment. The drainage map of study area as used obtained from satellite imagery as is as shown in the figure 2.

### Linear Aspect

In the linear aspect stream order *(Nu)*,

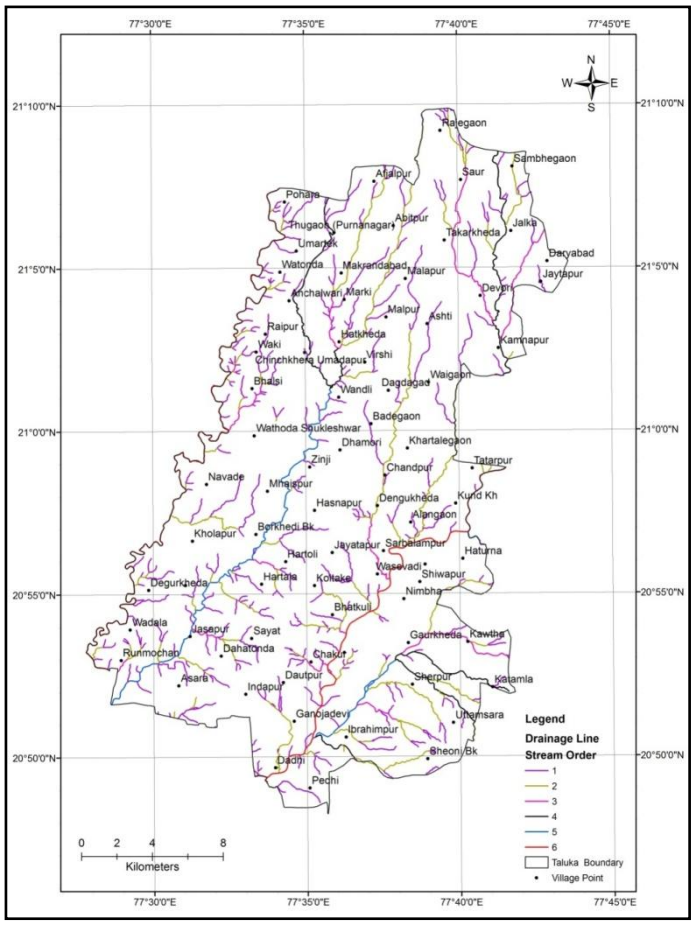


***Fig. 2****- Drainage map of study area*

stream length *(Lu)* and length of overland flow *(Lg)* where studied for Bhatkuli taluka and observation are presented in *Annexure- 1.* The same data has been used to prepare the spatial variation map length of overland flow (figure 3).

**Stream order *(Nu)***

Stream ordering refers to the determination of the hierarchical position of stream within drainage system. The stream ordering for selected study area to research work showing major $VI^{th}$ order drainage is observed for the Bhatkuli taluka. Drainage pattern of stream is observed in Taluka as Dendritic type. The stream in the study area has delineated in to grid square and number of stream ordering in each grid is representing in the *Annexure-1*. The spatial variation in stream number indicates the variance from (2 to 29). The maximum number of streams in grid no C-3. and lowest in grid no F-4 as the order of stream increases the number decreases.

**Stream Length *(Lu)***

The stream lengths in the Bhatkuli taluka is measured in GIS environment &

represented in the *Annexure-1*. The spatial variation in total stream length in each grid square range from 5.19 sq.km to 24.77 sq.km. The maximum total stream length is seen in Grid no C-1and lowest in grid B-0. Stream length is measure the hydrological characteristic of the underlying rock formation is which it flow. Total stream length decreases from the lower successive increase order

**Length of overland flow *(Lg)***

Hortan (1945) has define the length of flow of water over the ground befour it become concentrated in definite stream channels. The result is noticed that spatial variation in the length of overland flow from 0.32 to 2.07 along in the Bhatkuli taluka. The range of the length of overland flow is maximum in the grid no. H4 and lowest in the grid no.C-1. The higher value (2.07) of length of overland flow is indicative the higher degree of slope and erosion in some part of the study area.

**Aerial aspect**

Drainage Density (*Dd)*, Stream Frequency *(Fs)* and Constant channel maintenance *(Cm)* has been determine and tabulated for Bhatkuli taluka in the Annexure 1. Spatial variation of these aspects has been prepared and presented in (figure 4, figure 5 and figure 6) respectively.

**Drainage density *(Dd)***

Drainage density refers to the stream length per unit area. Horton (1945) defines drainage density as a ratio of total length of all stream segments in a given drainage basin to the total area of basin. The evaluated drainage density for the study area is varies in 0.24 to 1.55. The highest drainage density is found in the grid no. C-1 and lowest in the grid no. H-4.The higher value (1.55) of drainage density is indicative the higher degree of slope and erosion in some part of the study area. The drainage density is greater indicate, the more the runoff (Kale and Gupta 2001).

**Stream Frequency *(Fs)***

Stream frequency is the measures of the number of stream per unit area (Horton, 1932). In the present investigation the computed value of stream frequency is varies in 0.13 to 2 in the study area. The highest stream frequency is found in the grid no. G-1 and lowest in the grid no. F-4. The higher value (2) of stream frequency is indicative the higher degree of slope and erosion in some part of the study area.

**Constant channel maintenance *(Cm)***

Schumn (1956) has used the inverse of the drainage density having the dimension of length as a property termed constant of channel maintenance. This aspect remains

depended on the rock type, permeability, climatic regime, vegetation cover and the duration of erosion of the surface area. The constant channel maintenance (Cm) varies from 0.65 to 4.15 along in the Bhatkuli taluka. The range of the length of overland flow is highest in the grid no. H-4 and lowest in the grid no. C-1. The low value of low permeability (0.65) of constant of channel maintenance for the study area is indicative of low permeability, steep slope and highest surface runoff in some part.

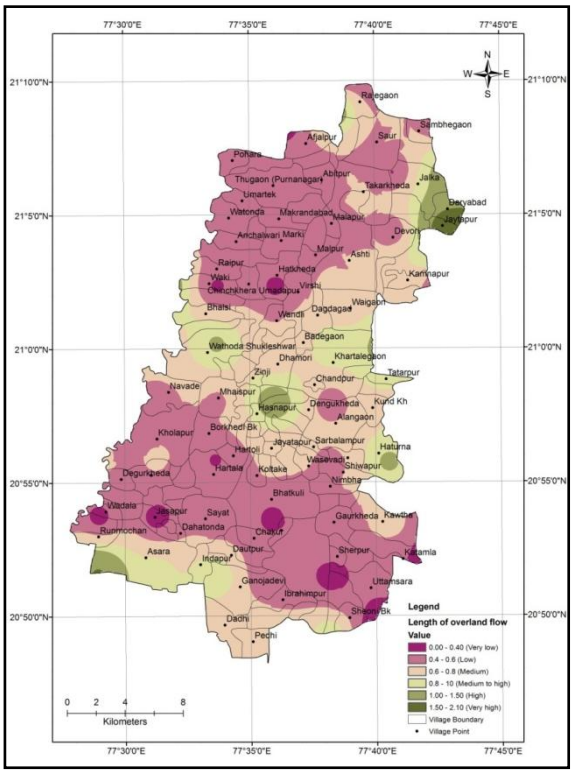


***Fig. 3-*** *Length of overland flow*

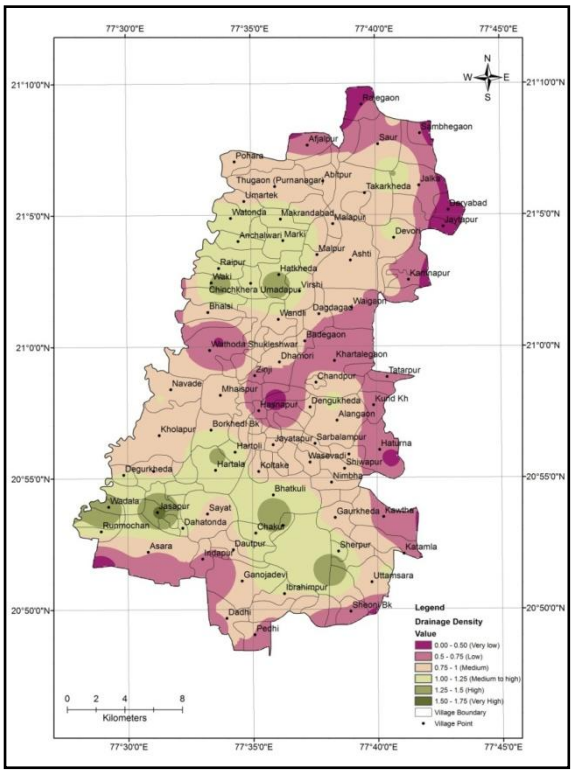


***Fig. 4-*** *Drainage density map*

**Relief Aspect**

The relief aspect has been studied by taking the DEM and hypsometric analysis. Digital elevation model (DEM) is a digital representation of the topographical surface feature. It is used for visual interpretation, analysis of topography, landforms, lithology as well as modelling of surface processes. (Sharma and Anukaran 2013). DEM map has been prepared with help contour in the topographic map and SRTM DEM of 90 m resolution using ArcGIS 9.3 software as shown in the Figure 7. In the study area DEM map indicates that the elevation range of the study area varies from 266 meter to 352 meter. The relief feature has been shown in the form of DEM. Slopes of any area directly gives the

geomorphic impression of the terrain slopes which are significant morphometric attributes in the study of landforms of a drainage basin (Singh and R Srivastava 1975).

sectional drainage basin area to elongation (Strahler, 1952; Langbein.et al.1974; Golding and Low, 1950; Chow 1964).

Hypsometric analysis has been carried out

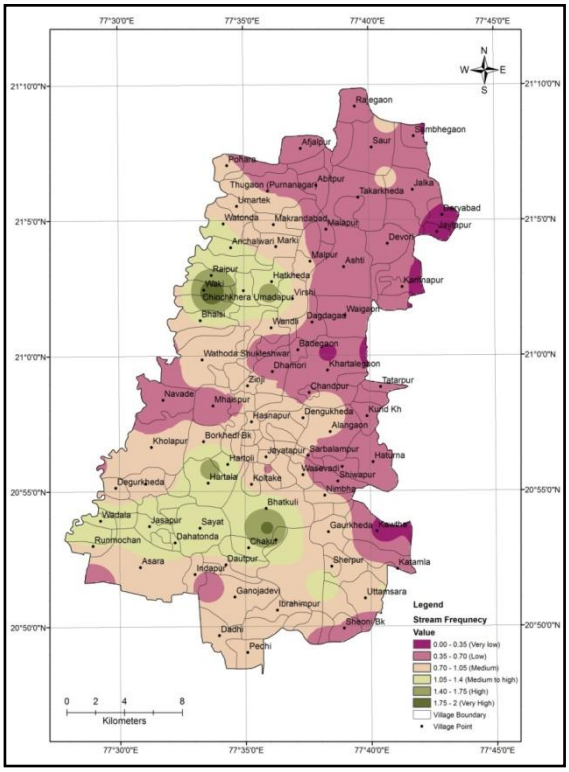


***Fig. 5****- Stream frequency map*

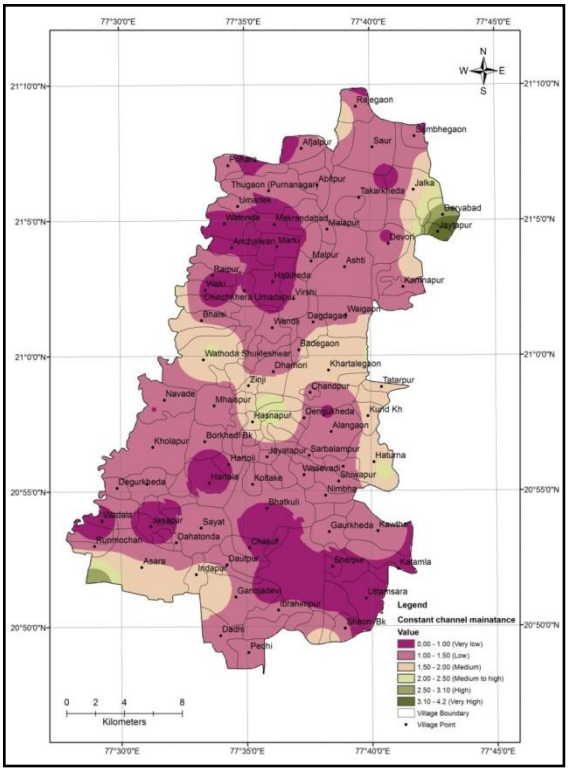


***Fig. 6****- Constant channel maintenance*

The slope map has been generated from DEM, the slope class of the study area has been determine and it has divided into four classes with range between 1-3 %, 3-6 %, 6-13%, and 13-26 % on the basis of slope of the surface as shown in the figure 8. Higher slope gradient results in rapid runoff due to soil loss or erosion occur.

**Hypsometric curve**

The hypsometric analysis determines the relationship of the horizontal cross-

by determining area-height relationship in the study area. The elevation difference between successive contour and their respective heights and relative area is measured with help of computer using ArcGIS environment within the contour. The height is obtained from elevation of the contour Hypsometric area analysis i.e. Hypsometry integral have calculated and the result value represented in the table-1. The result of the hypsometric integral analysis graph has shown in the figure 9.

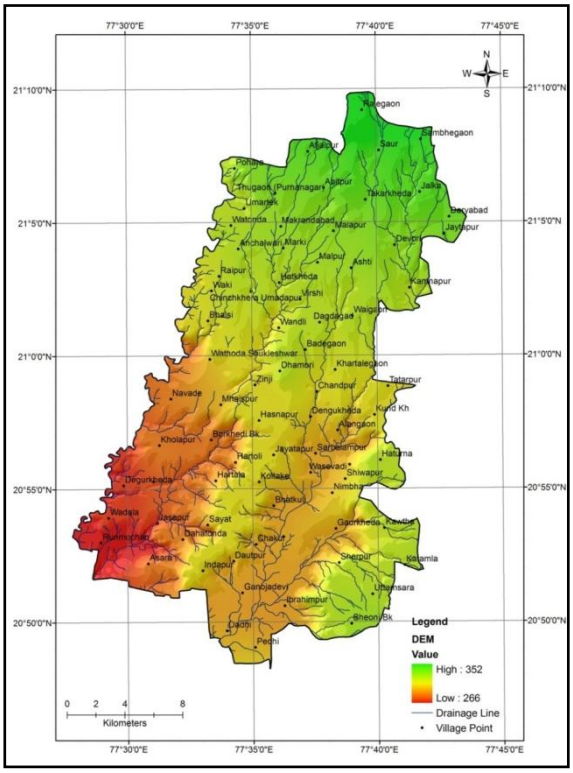


***Fig. 7:*** *Digital elevation model map*

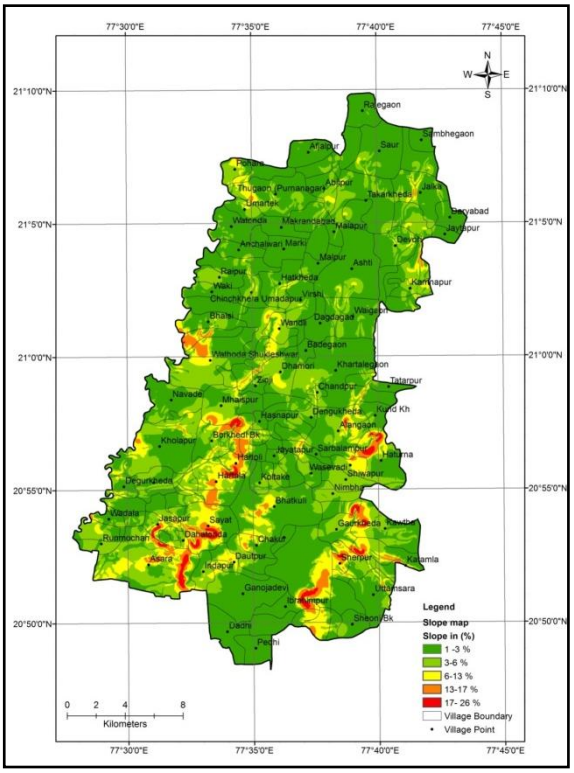


***Fig. 8:*** *Slope map of study area*

***Table 1:*** *Hypsometric Integral reading*

| Sr. No. | Elevation Range | Area (sq. km) | Area (%) | a/A | h/H |
|---|---|---|---|---|---|
| 1 | Below 270 | 1.327 | 1.327 | 1.00 | 0.002 |
| 2 | 270 – 280 | 19.372 | 20.699 | 0.89 | 0.036 |
| 3 | 280 – 290 | 92.405 | 113.105 | 0.78 | 0.194 |
| 4 | 290 – 300 | 163.736 | 276.841 | 0.67 | 0.476 |
| 5 | 300 – 310 | 109.972 | 386.812 | 0.56 | 0.665 |
| 6 | 310 – 320 | 107.930 | 494.743 | 0.44 | 0.851 |
| 7 | 320 – 330 | 51.929 | 546.672 | 0.33 | 0.940 |
| 8 | 330 – 340 | 32.156 | 578.828 | 0.22 | 0.995 |
| 9 | Above 350 | 2.793 | 581.620 | 0.11 | 1.000 |
| | **Total** | **581.620** | **100.000** | | |

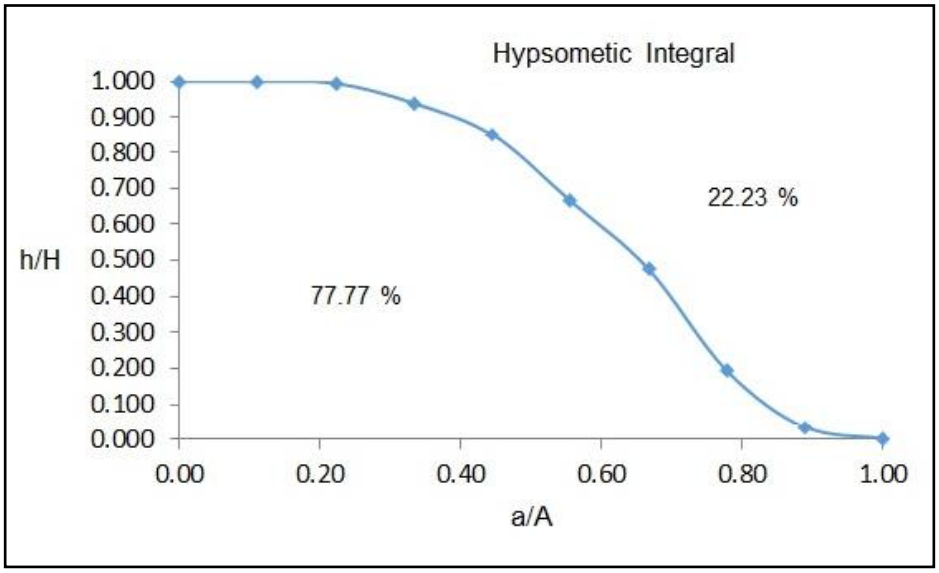


***Fig. 9:*** *Hypsometric Integral curve*

**RESULT**

The results obtained from morphometric analysis for the present study area, by studying their liner, aerial and relief aspect are stated below and the spatial variation maps which are prepared using GIS environment are also highlighted.

**Linear Aspect**

In the linear aspect of drainage network of the study like that stream order (Nu), stream number and length of overland (Lc) flow where studied for Bhatkuli Taluka. The maximum order of stream of Bhatkuli taluka is VI$^{th}$ order. The length of overland flow varies from 0.32 to 2.07 along in the Bhatkuli taluka. The range of the length of overland flow is maximum in the grid no H-4, and lowest in the grid no. C-1 while drainage density and drainage frequency is inversely related to the resources available.

**Aerial aspect**

The areal aspects include Drainage density (Dd), Stream frequency (Fs) and Constant of Channel Maintenance (Cm) and where studied for Bhatkuli Taluka. The Drainage density (Dd) for the study area varies from 0.24 to 1.55 the highest drainage density is in the grid no C-1 and lowest in the grid no H-4. The higher value (1.55) of drainage density is indicative of the higher degree of slope and erosion. The Stream frequency (Fs) for the study area varies from 0.13 to 2. The highest stream frequency in the grid no G-1 and lowest in the grid no F-4. The higher value of stream frequency is indicative of impermeable

formation while the low value is indicative high permeability. The Constant of channel maintenance (Cm) varies from 0.65 to 4.15 in the study area. The length of overland flow is maximum in the grid no H-4 and lowest in the grid no C-1. These observations coincided with the other areal parameter. The low value of constant of channel maintenance for the study area is indicative of low permeability, steep slope and highest surface runoff.

**Relief Aspect**

The relief aspects of the study area such as absolute relief, slope and hypsometric integral are calculated for the Bhatkuli taluka. It was found that from the DEM (Digital elevation model) map that absolute relief varies from 266 to 352 m. The slope map was prepared from the DEM map and the slope zone are classified into four slope zone 1-3 %, 3-6 %, 6-13 % and 13-26 %. Strahler (1952, 1968) has notified three types of landforms, namely young, mature and monadnock on the basis of hypsometric curve. The Hypsometric integral determined for the Bhatkuli taluka is 77.77 this indicate that the stream of Bhatkuli taluka are still in youth stage and therefore no structure need to be design as it would cause silting problem.

**CONCLUSION**

The present Morphometric analysis of Bhatkuli taluka; has provided valuable information of the surface form of the drainage pattern and also has helped to conclude on the region's topography, geological structures, runoff and hydrogeological properties of the underlying rock. From the study results on the stream order, the river has been designated as a Sixth-order. The maximum number of streams is found in grid no C-3 and lowest in grid no F-4. As the order of stream increases the number decreases. The maximum total stream length is seen in Grid no C-1 and lowest in grid B-0. Total stream length decreases from the lower successive increase order. The range of the length of overland flow is maximum in the grid no. H4 and lowest in the grid no.C-1. The higher value (2.07) of length of overland flow is indicative the higher degree of slope and erosion in some part of the study area. The highest drainage density is found in the grid no. C-1 and lowest in the grid no. H-4.The higher value (1.55) of drainage density is indicative the higher degree of slope and erosion in some part of the study area. The highest stream frequency is found in the grid no. G-1 and lowest in the grid no. F-4.The higher value (2) of stream frequency is indicative the higher degree of slope and erosion in some

part of the study area. The range of the length of overland flow is highest in the grid no. H-4 and lowest in the grid no.C-1. The low value of low permeability (0.65) of constant of channel maintenance for the study area is indicative of low permeability, steep slope and highest surface runoff in some part. DEM map prepared from the results noticed that the elevation range of the study area varies from 266 meter to 352 meter. The relief feature has been shown in the form of DEM. The slope map is also prepared and slope class is has categories into 1-3 %, 3-6 %, 6-13%, and 13-26 %. Higher slope gradient results in rapid runoff due to which the soil loss or erosion is found to occur. The Hypsometric integral result is noted that the river in the study area is in youth stage and therefore no structure need to be designed at present as doing so may cause silting problem.

## Annexure -1

### Annexure 1 a: Morphometric analysis parameters for Bhatkuli taluka, Amravati district, Maharashtra (On Grid basis)

| Sr.No | Grid Name | Area sq.km | Stream Order | | | | | | Total No. Stream | Total Length | Drainage Density | Stream Frequency | Length Of Over-land flow | Constant Channel Maintc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | First Order | Second order | Third order | Forth Order | Fifth Order | Sixth Order | | | | | | |
| 1 | A0 | 16 | 10 | 4 | 1 | 0 | 0 | 1 | 16 | 11.74 | 0.73 | 1.00 | 0.68 | 1.36 |
| 2 | A1 | 16 | 8 | 4 | 0 | 1 | 0 | 1 | 14 | 11.55 | 0.72 | 0.88 | 0.69 | 1.39 |
| 3 | A2 | 16 | 7 | 2 | 0 | 0 | 0 | 0 | 9 | 8.44 | 0.53 | 0.56 | 0.95 | 1.90 |
| 4 | A3 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | B0 | 16 | 3 | 0 | 1 | 0 | 1 | 1 | 6 | 5.19 | 0.32 | 0.38 | 1.54 | 3.08 |
| 6 | B1 | 16 | 13 | 3 | 0 | 0 | 0 | 0 | 16 | 9.27 | 0.58 | 1.00 | 0.86 | 1.73 |
| 7 | B2 | 16 | 7 | 1 | 0 | 0 | 0 | 0 | 8 | 8.05 | 0.50 | 0.50 | 0.99 | 1.99 |
| 8 | B3 | 16 | 7 | 3 | 1 | 1 | 1 | 1 | 14 | 20.00 | 1.25 | 0.88 | 0.40 | 0.80 |
| 9 | B4 | 16 | 10 | 6 | 1 | 1 | 1 | 0 | 19 | 23.75 | 1.48 | 1.19 | 0.34 | 0.67 |
| 10 | B5 | 16 | 9 | 4 | 4 | 0 | 0 | 0 | 17 | 16.78 | 1.05 | 1.06 | 0.48 | 0.95 |
| 11 | B6 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12 | C0 | 16 | 15 | 3 | 1 | 0 | 1 | 1 | 21 | 23.66 | 1.48 | 1.31 | 0.34 | 0.68 |
| 13 | C1 | 16 | 14 | 6 | 1 | 0 | 1 | 0 | 22 | 24.77 | 1.55 | 1.38 | 0.32 | 0.65 |
| 14 | C2 | 16 | 18 | 4 | 0 | 0 | 0 | 0 | 22 | 15.03 | 0.94 | 1.38 | 0.53 | 1.06 |
| 15 | C3 | 16 | 20 | 6 | 2 | 0 | 0 | 1 | 29 | 22.68 | 1.42 | 1.81 | 0.35 | 0.71 |
| 16 | C4 | 16 | 6 | 4 | 1 | 2 | 1 | 1 | 15 | 15.70 | 0.98 | 0.94 | 0.51 | 1.02 |
| 17 | C5 | 16 | 1 | 1 | 1 | 1 | 0 | 0 | 4 | 10.90 | 0.68 | 0.25 | 0.73 | 1.47 |
| 18 | D0 | 16 | 8 | 1 | 0 | 0 | 0 | 1 | 10 | 12.88 | 0.81 | 0.63 | 0.62 | 1.24 |

**Annexure -1**

**Annexure 1 b: Morphometric analysis parameters for Bhatkuli taluka, Amravati district, Maharashtra (On Grid basis)**

| Sr.No | Grid Name | Area sq.km | Stream Order | | | | | | Total No. Stream | Total Length | Drainage Density | Stream Frequency | Length Of Over-land flow | Constant Channel Maintc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | First Order | Second order | Third order | Forth Order | Fifth Order | Sixth Order | | | | | | |
| 19 | D1 | 16 | 7 | 3 | 0 | 0 | 1 | 1 | 12 | 12.77 | 0.80 | 0.75 | 0.63 | 1.25 |
| 20 | D2 | 16 | 17 | 5 | 1 | 0 | 1 | 0 | 24 | 20.80 | 1.30 | 1.50 | 0.38 | 0.77 |
| 21 | D3 | 16 | 8 | 2 | 1 | 0 | 0 | 0 | 11 | 12.45 | 0.78 | 0.69 | 0.64 | 1.29 |
| 22 | D4 | 16 | 3 | 4 | 1 | 0 | 0 | 1 | 9 | 14.44 | 0.90 | 0.56 | 0.55 | 1.11 |
| 23 | D5 | 16 | 5 | 1 | 0 | 0 | 1 | 1 | 8 | 7.55 | 0.47 | 0.50 | 1.06 | 2.12 |
| 24 | E0 | 16 | 5 | 2 | 0 | 0 | 0 | 1 | 8 | 16.06 | 1.00 | 0.50 | 0.50 | 1.00 |
| 25 | E1 | 16 | 6 | 2 | 0 | 0 | 1 | 0 | 9 | 14.02 | 0.88 | 0.56 | 0.57 | 1.14 |
| 26 | E2 | 16 | 9 | 1 | 1 | 0 | 1 | 0 | 12 | 6.57 | 0.41 | 0.75 | 1.22 | 2.44 |
| 27 | E3 | 16 | 9 | 4 | 1 | 0 | 0 | 0 | 14 | 17.01 | 1.06 | 0.88 | 0.47 | 0.94 |
| 28 | E4 | 16 | 3 | 3 | 0 | 0 | 1 | 1 | 8 | 10.47 | 0.65 | 0.50 | 0.76 | 1.53 |
| 29 | F0 | 16 | 4 | 1 | 1 | 0 | 0 | 1 | 7 | 11.92 | 0.75 | 0.44 | 0.67 | 1.34 |
| 30 | F1 | 16 | 10 | 2 | 1 | 0 | 0 | 0 | 13 | 7.68 | 0.48 | 0.81 | 1.04 | 2.08 |
| 31 | F2 | 16 | 7 | 0 | 0 | 0 | 1 | 0 | 8 | 13.24 | 0.83 | 0.50 | 0.60 | 1.21 |
| 32 | F3 | 16 | 4 | 1 | 0 | 0 | 0 | 0 | 5 | 9.01 | 0.56 | 0.31 | 0.89 | 1.78 |
| 33 | F4 | 16 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 5.97 | 0.37 | 0.13 | 1.34 | 2.68 |
| 34 | G0 | 16 | 5 | 2 | 0 | 0 | 0 | 1 | 8 | 5.29 | 0.33 | 0.50 | 1.51 | 3.02 |
| 35 | G1 | 16 | 22 | 7 | 2 | 0 | 0 | 1 | 32 | 21.36 | 1.34 | 2.00 | 0.37 | 0.75 |
| 36 | G2 | 16 | 14 | 3 | 3 | 3 | 1 | 0 | 24 | 22.01 | 1.38 | 1.50 | 0.36 | 0.73 |

## Annexure -1

### Annexure 1 c: Morphometric analysis parameters for Bhatkuli taluka, Amravati district, Maharashtra (On Grid basis)

| Sr.No | Grid Name | Area sq.km | Stream Order | | | | | | Total No. Stream | Total Length | Drainage Density | Stream Frequency | Length Of Over-land flow | Constant Channel Maintc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | First Order | Second order | Third Order | Forth Order | Fifth Order | Sixth Order | | | | | | |
| 37 | G3 | 16 | 7 | 2 | 0 | 0 | 0 | 0 | 9 | 12.63 | 0.79 | 0.56 | 0.63 | 1.27 |
| 38 | G4 | 16 | 4 | 2 | 1 | 1 | 0 | 0 | 8 | 12.47 | 0.78 | 0.50 | 0.64 | 1.28 |
| 39 | G5 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 40 | H0 | 16 | 14 | 2 | 0 | 1 | 0 | 1 | 18 | 18.39 | 1.15 | 1.13 | 0.44 | 0.87 |
| 41 | H1 | 16 | 11 | 3 | 1 | 1 | 0 | 0 | 16 | 18.84 | 1.18 | 1.00 | 0.42 | 0.85 |
| 42 | H2 | 16 | 6 | 1 | 0 | 0 | 0 | 0 | 7 | 15.37 | 0.96 | 0.44 | 0.52 | 1.04 |
| 43 | H3 | 16 | 6 | 0 | 2 | 1 | 0 | 0 | 9 | 17.12 | 1.07 | 0.56 | 0.47 | 0.93 |
| 45 | H4 | 16 | 1 | 1 | 1 | 0 | 0 | 0 | 3 | 3.86 | 0.24 | 0.19 | 2.07 | 4.15 |
| 46 | I 0 | 16 | 9 | 2 | 0 | 0 | 0 | 1 | 12 | 13.64 | 0.85 | 0.75 | 0.59 | 1.17 |
| 47 | I 1 | 16 | 8 | 1 | 0 | 1 | 0 | 0 | 10 | 15.29 | 0.96 | 0.63 | 0.52 | 1.05 |
| 48 | I 2 | 16 | 8 | 3 | 0 | 0 | 0 | 0 | 11 | 13.56 | 0.85 | 0.69 | 0.59 | 1.18 |
| 49 | I 3 | 16 | 7 | 3 | 1 | 1 | 0 | 0 | 12 | 20.17 | 1.26 | 0.75 | 0.40 | 0.79 |
| 50 | I 4 | 16 | 4 | 1 | 1 | 0 | 0 | 0 | 6 | 6.73 | 0.42 | 0.38 | 1.19 | 2.38 |
| 51 | I 4 | 16 | 4 | 1 | 1 | 0 | 0 | 0 | 6 | 6.73 | 0.42 | 0.38 | 1.19 | 2.38 |
| 52 | J0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 53 | J1 | 16 | 8 | 2 | 0 | 0 | 0 | 0 | 10 | 6.80 | 0.42 | 0.63 | 1.18 | 2.35 |
| 54 | J2 | 16 | 8 | 3 | 1 | 1 | 0 | 0 | 13 | 12.68 | 0.79 | 0.81 | 0.63 | 1.26 |
| 55 | J3 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**REFERENCES**

1. Bhai HY. Systematic Geological mapping of Deccan trap and Quaternary formation in parts of Amravati District and Akola district, Maharashtra. Rec. Geological Survey of India. 1990; 122 (Part 6), pp. 46-49
2. Chow VT. Handbook of Applied Hydrology. New York: McGraw-Hill. 1964.
3. Clarke JI. Morphometry from Maps. Essays in geomorphology. Elsevier Publications, New York. 1996; pp. 235-274.
4. Gangalakunta P. Drainage morphometry and its influence on landform characteristics in a basaltic terrain, central India: a remote sensing and GIS approach. Int J Appl Earth Obs Geoinform. 2004; 6:1–16
5. Golding BL, Low DE. Physical characteristics of driange basins. Journal of Hydraulics Division, Proceedings of the American Society of Civil Engineers. 1960; 86 (HY):1-11
6. Horton RE. Erosional Deveolpment of Stream and thier Drainage basin: Hydrological approch to Quantitative Morphology. Bullatin of Geological Society of America. 1945; Volume 5, pp. 275-370.
7. Horton RE. Drainage basin characteristics. Trans Am Geophys Union. 1932; 13:350–361
8. Javed A, Khanday MY, Ahmed R. Prioritization of subwatershed based on morphometric and land use analysis using remote sensing and GIS techniques. J Indian Soc Remote Sens. 2009; 37:261–274
9. Kale VS, Gupta A. Introduction to geomorphology. Orient Black Swan. 2001; p 280
10. Korkalainen THJ, Lauren AM, Kokkonen TS, et al. A GIS basedanalysis of catchment properties within a drumlin field. Boreal Environ Res. 2007; 12:489–500
11. Langbein, W.B. Topographical characteristics of drainage basin. U.S. Geological survey water supply paper. 1947; 968-C.
12. Magesh N, Chandrasekar N, Soundranayagam J, et al. Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu, India: a GISapproach. Environ Earth Sci. 2011; 64(2):373–381.
13. Manu MS, Anirudhan S. Drainage characteristics of Achankovil River Basin, Kerala. J Geol Soc India.2008; 71:84–850

14. Melton, MA. Geometrical Properties of Mature Drainage Systems and their representation in an E4 Phase. Jour. Geol. 1958; Vol. 66, pp. 35-54.
15. Meshram SA, Khadse SP. Morphometric Analysis of Madurai Basin –A case study of Cauvery sub watershed region of Tamil Nadu - India. International Journal of Advance Engineering and Research Development. 2015; *Volume 2, Issue 3, pp.23-32*
16. Miller VC. A Quantitative Geomorphic Study of drainage basin characteristics in the clinch Mountain Area, Virginia Tennessee Project NR 389-042. Tech. Report 3, Colombia Uni. Dept. of Geol. ONR. Geography Branch, New York. 1953.
17. Mishra S, Nagarajan R. Morphometric analysis and prioritization of sub-watersheds using GIS and Remote Sensing techniques: a case study of Odisha, India. International Journal of Geomatica and Geosciences. 2010; Volume 1 (No.03), pp. 501-510
18. Nag SK. Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. Journal of Indian Society of Remote Sensing. 1998; Volume 26 (1-2), pp. 69-76.
19. Nagrajan R, Zende AM. Drainage Morphometric Apporoch for Water Resource Devlopement of Sub Watershed in Krishna Basin. Internatinal Journal of Computer and Communication Technology. 2011; Volume 2 (Issue 8).
20. Nautiyal MD. Morphometric Analysis of a Drainage Basin using Aerial photographs: A case study of Khairakulli Basin, District Dehradun, Uttar Pradesh. Journal of the Indian Society of Remote Sensing. 1994; 22(4), pp 251-261.
21. Pande CB, Moharir K. GIS based quantitative morphometric analysisand its consequences: a case study from Shanunr River Basin, Maharashtra India. Appl Water Science June 2015, pp. 1-11
22. Pastapure BN and Avhad BC. Morphometric analysis of Asna river using GIS techniques. Research Front. 2014; Volume 2 (Issue 3), pp.13-20**.**
23. Rao JU, Babu VRRM. A quantitative morphometric analysis of Gundalakamma River Basin, Andhra Pradesh. Indian J Earth Sci. 1995; 22:63–74
24. Schumn SA. Evolution of drainage basins and slopes in bund land of Peth Amboy, New Jersey. Bull Geol Soc Am. 1956; 67:597–646

25. Sharma MP, Kujur Anukaran. ASTER DEM Based Studies for Geological and Geomorphological Investigation in and around Gola block, Ramgarh District, Jharkhand, India. International Journal of Scientific & Engineering Research. February 2012; Volume 3, Issue 2, pp. 1-5
26. Singh S, Srivastava R. Morphometric determinants of the Stage of Cycle of erosion, The Geographical Observer. 1975; 12, pp. 29-40.
27. Sriniwasa VS, Govinddaiah S, Gowda Honne H, et al. Morphometric Analysis of Sub-Watershed in the Pavagada area of Tumkur District, South India using Remote Sensing and GIS Technique. Journal of Indian Society of Remote Sensing. 2004; Volume 32, pp. 351-362.
28. Strahaler AN. Dynamic Basis for Geomorphology. Bulletian of Geological Society of America. 1952; Volume 63, pp. 617-639.
29. Strahaler AN. Hypsometric (Area-Altitude) analysis of erosional topography. Bullatain of Gelogical Society of America. 1953; Volume 63, pp. 1117-1124.
30. Strahaler AN. Quantitative Slope Analysis. Bullatain of Gelogical Society of America. 1956; Volume 67, pp. 571-596.
31. Strahaler AN. Quantitative Geology of Drainage basin and Channel networks. In Hand book of Applied Hydrology. 1964; (pp. 39-76). Ed. Ven Te Chow, McGraw Hill.
32. Strahler AN. (1968) Quantitative geomorphology. In: Fairbridge RW (ed) Encyclopedia of geomorphology. Reinhold Book Crop. 1968
33. Strahler AN. Quantitative Analysis of Watershed Geomorphology. Trans. Amer. Gephys. Union. 1975, Volume 38. pp. 913-920.
34. Umrikar BN. Morphometric analysis of Andhale watershed, Taluka Mulshi, District Pune, India. Appl Water Sci. March 2016, pp. 1-2.