

Research Article

Morphometric analysis of Byramangala Watershed, Bangalore Urban District, Karnataka, India

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Accepted 20 June 2015, Available online 27 June 2015, Vol.5, No.3 (June 2015)

Abstract

The study of drainage morphometric analysis and data for preparing Digital Elevation of Model (DEM) flow direction, flow accumulation, contour aspect and slope maps. Geographic Information System was used in evaluation of linear, areal and relief aspects of morphometric parameters. The drainage patterns of dendritic basin, which includes highest stream order up to 5 and the area covers 441sqkm. The Byramangala watershed area is major part of Kengeri. In this paper is an attempt to evaluate the groundwater system of Byramangala Reservoir watershed area, Kengeri, Bangalore Urban district, Karnataka. Hydrogeological investigations require an integrated approach. No systematic hydrogeological investigations have been conducted so far, though groundwater is replenishable natural resources, when withdrawals exceed the limits of dynamic recharge, it will cause irreversible damages. As in nature, South India is a hard rock terrain. In recent years, bore wells for agricultural purposes have been drilled on a massive scale by the farmers without carving for minimum interference distance to be maintained between the extraction structures. Thereby, groundwater levels are drastically affected. To reach this goal an integrated hydrogeological study in the whole area has not been attempted so far.

Keywords: Morphometric analysis, Massive scale, DEM, hydrogeological etc.

1. Introduction

Water is an important source for all living beings and prevails as the basic point for all activities of human beings. The acute shortage of water has been steadily increasing and on the other hand, the pollution level of water has been increasing every year due to reoccurrence of drought, rapid growth of population, expansion of irrigation and rate of industrialization and urbanization. The availability of surface water is not assured at all seasons, especially during summer because of poor rainfall enacting inability of surface water resource to fulfil the supply for all requirements enabling groundwater as the only alternate resource to meet out the above mentioned requirements.

Geomorphology is a scientific study of landforms and the processes that shape them. Geomorphological processes are generally complex and reflect interrelationship among the variables such as climate, geology, soil and vegetation (Boule et al., 1973). Hydrogeomorphology has been defined as an interdisciplinary science that focuses on the interaction and linkage of hydrologic processes with landforms or earth materials and the interaction of geomorphic processes with surface and subsurface water in

temporal and spatial dimensions (Sidle and Onda, 2004). By studying the hydro-geomorphological conditions of the basin, it is possible to decipher the groundwater potentiality.

Hydrogeology deals with the distribution and movement of groundwater in the soil and rocks of the earth's crust (commonly in aquifers). Study of the occurrence and behavior of groundwater as well as evaluation of aquifer parameters is of primary importance. It helps in quantification of groundwater potentiality of an area and in developing a digital model of the aquifer system for forecasting the water levels with or without additional stress. Combined analysis of landforms (geomorphology), rocks as well as structures (geology) such as faults, folds, fractures etc. in relation to groundwater occurrence with the help of remote sensing and ground truth verification is considered very useful in preparing integrated geomorphic and geologic maps for targeting groundwater. Remote sensing technology is ideal for hydrological and hydro-geological studies since terrain does control movement and accumulation of surface and groundwater (Shrivastava, 1974).

Drainage analysis is adopted for the purposes of integrated land and water resources management (d) and groundwater studies (Mishra et al., 2011). Several

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software packages provide methods for analyzing drainage basin parameters in raster grids of remote sensing images. However, it is evident that software for measuring watershed morphometric parameters using a GIS approach is required.

Remote sensing and Geographic Information System (GIS) have become the leading tools in the field of hydrological science. The importance of remote sensing technology for geomorphological studies has increased due to the establishment of its direct relationship with allied disciplines such as, geology, soils, vegetation/landuse& hydrology. The interpretation of satellite data in conjunction with sufficient ground truth information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characters (Das *et al.*, 1997, SrinivasRao *et al.*, 2000); and these may serve as direct or indirect indicators of the presence of groundwater (Ravindran and Jayaram, 1997Sreedevi *et al.*, 2001; GirishGopinath and Seralathan, 2004).

Aim

To understand the hydrological characteristics and delineation of the area

Objectives

To understand the geological and geomorphological conditions of Byramangala reservoir water shed.

To prepare the drainage, geomorphology,slope and Groundwater prospecting maps using geospatial techniques.

To analysis the bore well inventory data to find out the significance of groundwater occurrence

To identify the groundwater potential zones for development by integration of various thematic maps and GIS techniques for further development

Study Area

The study area is bounded in between latitudes $12^{\circ}45'00''$ N to $13^{\circ}00'00''$ N and longitudes $77^{\circ}23'00''$ E to $77^{\circ}35'00''$ E. It forms part of Survey of India Toposheet No. 57H/5 and 57H/9 covers an area of 441 square Km. Major part of the area belongs to Kengeri, Bangalore Urban district, Karnataka. (Fig 1 and 2). The watershed is drained by 1st to 5th order streams. The drainage is dendritic with flow direction from north to south. Ultimately forms the Vrishabhavatiriver.

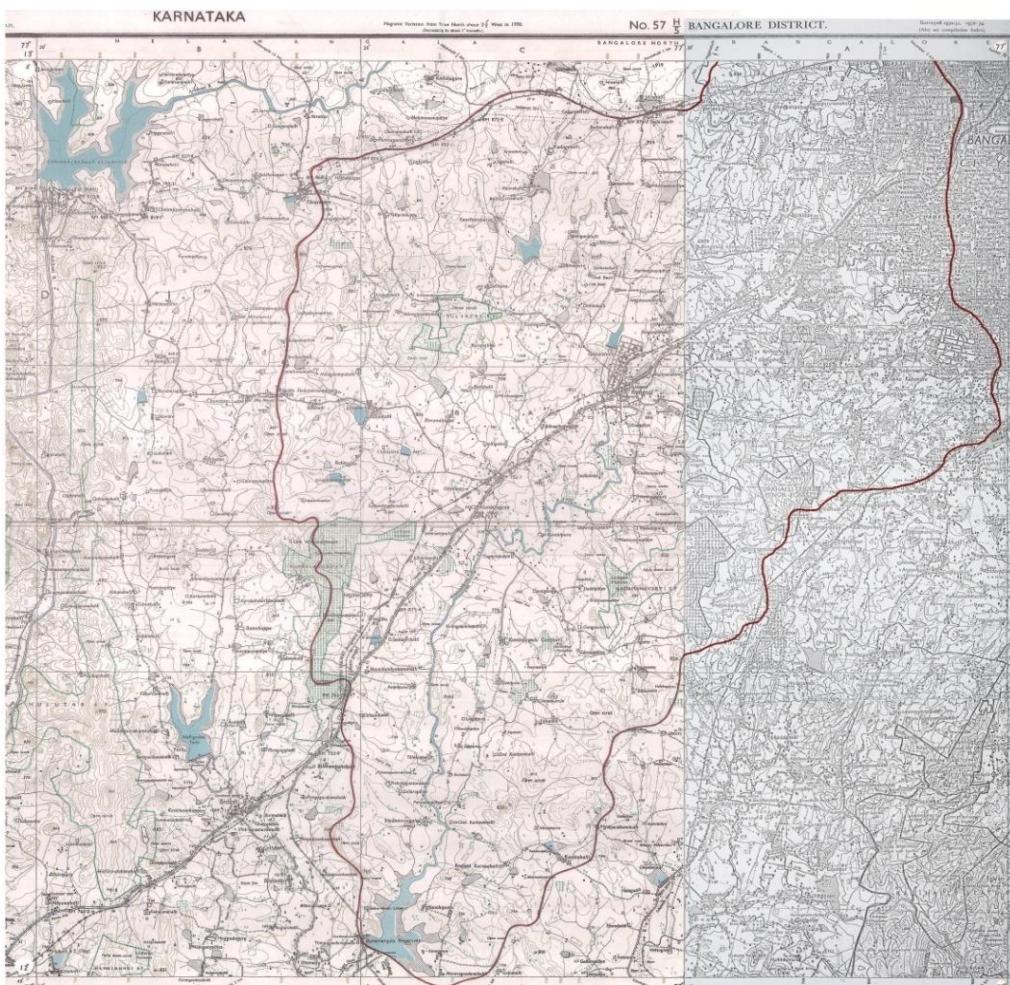


Fig 1 The toposheets of the study area

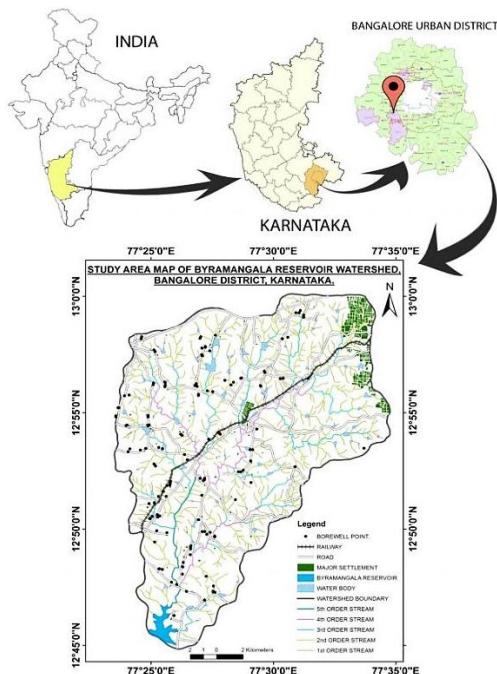


Fig 2 Location of the study area

Materials and Methods

In the present paper, an attempt has been made to delineate and characterize groundwater potential zones of the taluk by using GIS and Remote sensing data. Topographical maps, Map No. 57 H/5 and Map No. 57 H/9 prepared by Survey of India in the year 1975 and 1980 respectively, 1:50,000 scales are used to generate the base map of the study area. The hard copy of map was converted to digital form using scanner. The digital files were imported in Arc GIS 10, for georeferencing the map, control points were to be established and then the known geographic coordinates of these control points were entered and georeferenced. They were projected to Geographic Projection and mosaiced to get the study area.

Digitization is essentially a vectorization of raster data by tracing a mouse overfeatures displayed on a computer monitor. After image data was been geo-referenced and reprojected to geographic projection system. Drainage networks and contours were manually traced using mouse and vector features were created. Drainage lines were digitized and stream ordering was done in accordance with Strahler's (1957) method (**Fig. 3.4**).

The different thematic maps viz. digital elevation model, aspect, slope, contour, hillshade, flow direction, flow accumulation and drainage has been prepared through the standard visual interpretation techniques using topographic maps and its corresponding SRTM Satellite data. The ground truth verification of interpreted data has been carried out in the field and necessary modifications are incorporated in the thematic maps. GIS software like Arc GIS10 has been used for digitization, computation and output generation purposes.

Morphometric Analysis

Morphometric study has got its foundation from stream flow analysis. Morphometric analysis is the quantitative description and analysis of landforms as practiced in geomorphology that may be applied to a particular kind of landform or to drainage basins and large regions. Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds. Morphometric analysis requires measurement of linear features, aerial aspects and gradient of channel network of the drainage basin. Identification of drainage networks within basins or sub basins can be achieved using traditional methods such as field observations and topographic maps or alternatively with advanced methods using remote sensing and GIS. Morphometric analysis using GIS technique has emerged as a powerful tool in recent years. GIS technique is very useful in analyzing the drainage morphometry. In India, some of the recent studies on morphometric analysis using remote sensing and GIS technique are being done. Evaluation of morphometric parameters necessitates the analysis of various drainage parameters such as ordering of the various streams, measurement of basin area and perimeter, length of drainage channels, drainage density, stream frequency, bifurcation ratio, basin relief and Ruggedness number. The main objective of this study is using GIS technology to compute various parameters of mini watershed morphometric characteristics.

Morphometric parameters

Morphometric analysis is the measurement and mathematical analysis of the configuration of the

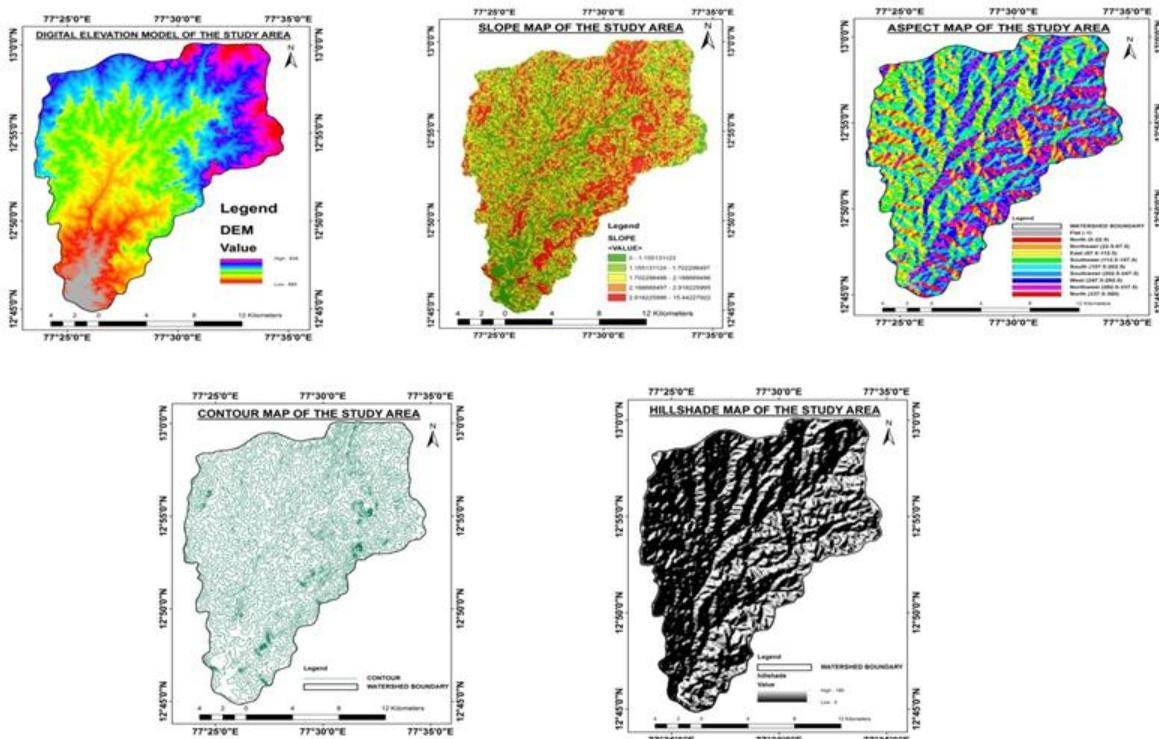
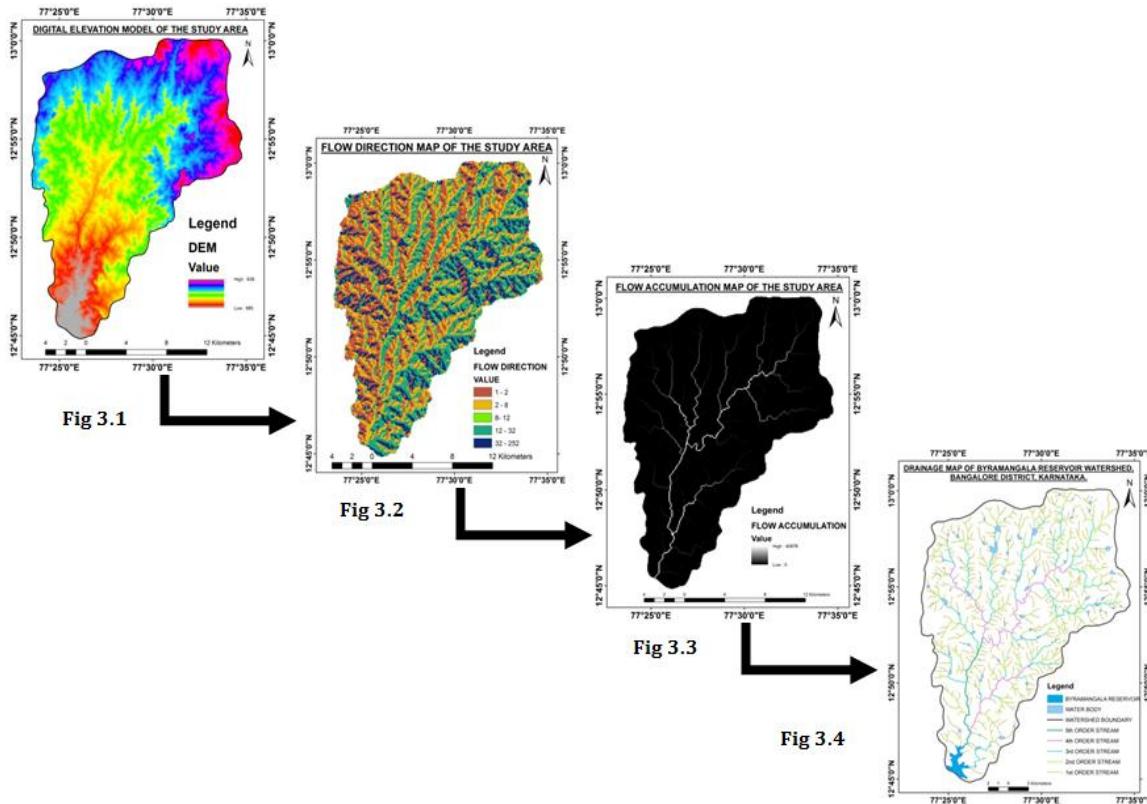


Fig. 4 Shows of DEM, Slope, Aspect, Hill shade and Contour maps of the study area

Earth's surface, shape and dimensions of its landforms. This analysis can be achieved through measurement of linear, aerial and relief aspects of basin and slope contributions. In the present paper, the morphometric analysis for the parameters namely stream order,

stream length, bifurcation ratio, stream length ratio, basin length, drainage density, stream frequency, elongation ratio, circularity ratio, form factor, relief ratio, etc. The formulae adopted for computation of the various morphometric parameters are given in **Table 1**.

Table 1: Formulae adopted for computation of morphometric parameters

S. No.	Mophometric Parameters	Formula	Reference
Drainage network:			
1	Stream order	Hierachial rank	Strahler (1964)
2	Stream number (Nu)	Order wise stream segments	Horton (1945)
3	Stream length (Lu)	Length of the Stream	Horton (1945)
4	Mean stream length (Lsm)	$Lsm = Lu / Nu$	Strahler (1964)
5	Stream length ratio (Slr)	$Slr = Lu / Lu - 1$	Horton (1945)
6	Bifurcation ratio (Br)	$Br = Nu / Nu + 1$	Schumm (1956)
7	Mean bifurcation ratio (Mbr)	$Mbr = \text{Average of bifurcation ratios of all orders}$	Strahler (1957)
Basin geometry:			
8	Basin elongation (Be)	Longest dimension of the basin parallel to the principal drainage line.	Schumm (1956)
9	Basin area (A)	Total area of basin in sq.km	GIS analysis
10	Basin perimeter (Bp)	Outer boundary of the basin that enclosed its area.	GIS analysis
11	Basin shape (Bs)	$Bs = Be^2 / A$	Horton (1956)
12	Form factor (Ff)	$Ff = A / Be^2$	Horton (1932)
13	Elongation ratio (Er)	$Er = (2 (\sqrt{(A / Pi)}) / Be)$	Schumm (1956)
14	Drainage texture (Dt)	$Dt = Nu / P$	Horton (1945)
15	Circularity ratio (Cr)	$Cr = (4 * Pi) * (A / Bp^2)$	Miller (1953)
Drainage texture analysis:			
16	Stream frequency (Sf)	$Sf = Nu / A$	Horton (1932)
17	Drainage Density (Dd)	$Dd = Lu / A$	Horton (1932)
18	Drainage intensity (Di)	$Di = Sf / Dd$	Faniran (1968)
19	Infiltration number (In)	$In = Sf * Dd$	Faniran (1968)
20	Drainage pattern	Based on influence of slope, lithology and structure.	Howard (1967)
21	Length of overland flow (Lof)	$Lof = (1 / Dd) * 2$	Horton (1945)
Relief characterization:			
22	Total relief (Tr) or relative relief	Elevation difference in kms between highest point of a watershed and the lowest points on the valley floor.	SOI toposheet
23	Relief ratio (Rr)	$Rr = Tr / Be$	Schumm (1956)
24	Ruggedness number (Rn)	$Rn = (Dd * Tr) / 1000$	Strahler (1964)

Abbreviations

A: Area of the basin (sq.km), Be: Basin elongation, Bp: Basin perimeter (km), Bs: Basin shape, Cr: Circularity ratio, Dd: Drainage density, Di: Drainage intensity , Dt : Drainage texture, Er: Elongation ratio, Ff: Form factor, In: Infiltration number, Lof: Length of overland flow, Lsm: Mean Stream Length, Lu: Total stream length of order 'u', Lu - 1: The total stream length of its next lower order, Nu: Total no. of stream segments of order 'u', Nu + 1: Number of segments of the next higher order, Pi: 'Pi' value i.e., 3.14, Br: Bifurcation ratio, Mbr: Average of bifurcation ratios of all orders, Rn: Ruggedness number, Rr: Relief ratio, Sf: Stream frequency, Slr: Stream length ratio, Tr: Total relief in kms.

Drainage Network

In the application of the Strahler stream order to hydrology, each segment of a stream or river within a river network is treated as a node in a tree, with the

next segment downstream as its parent. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. Streams of lower order joining a higher order stream do not change the order of the higher stream. Thus, if a first-order stream joins a second-order stream, it remains a second-order stream. It is not until a second-order stream combines with another second-order stream that it becomes a third-order stream.

Stream order (Sp)

The designation of stream order is the first step in any drainage basin analysis. The primary step in drainage basin analysis is to designate stream orders. The stream ordering has been done as per the Strahler's (1964) ordering scheme. Higher stream order is associated with greater discharge. The trunk stream, through which all discharge of water and sediment passes is therefore the stream segment of highest

order. The basin order goes up to 5th in the given study area.

Stream number (N μ)

The counting of stream channels in a given order is known as stream number. The number of stream of each order and the total number of streams were computed. It is also understood that the total number of stream decreases with stream order increases. There are 502 first order streams, 112 second order streams, 34 third order streams, 4 fourth order streams and 1 fifth order stream. Therefore there are 653 streams in the given study area.

Stream Length(Lu)

The stream length of a basin is the measure from the mouth of a river to the drainage divide. The total length of stream segments is highest in first order streams and decreases as the stream order increases. This may be due to the streams flowing from a region of higher to lower altitude, change in rock type and moderately steep slopes and probable uplift across the basin (Vittala et al, 2004 and Chopra et al., 2005). Addition of the lengths of all streams, in a particular order, defines total stream length. The stream length of first, second, third, fourth and fifth orders are 421.95 km, 142.19 km, 103.90 km, 44.75km and 16.85 km respectively. The total length of the stream is about 729.64 km.

Mean Stream Length (Lsm)

It is a characteristic property related to the drainage network components and its associated basin surfaces (Strahler, 1964). It is calculated by dividing the total stream length of order (u) by the number of streams of segments in the order. The mean stream length decreases from higher order to the next lower order. However, in some basins this may vary and this can be explained as a cause for changes in topographic elevation and slope of the area. The mean stream length in the study area for the 1st, 2nd, 3rd, 4th and 5th order is 0.84, 1.27, 3.05, 11.18 and 16.85 respectively.

Stream Length Ratio (RL)

It is defined as the ratio of the stream length of the one order to the next lower order of the stream segments (Horton, 1945). The result showed the RL values exhibits an increasing trend lower order. RL values for 1st, 2nd, 3rd, 4th and 5th order are 0.33, 0.73, 0.43, 0.37 and 0 respectively.

Bifurcation Ratio (Br)

It is defined as the ratio of the number of stream segments of given order to the number of segments of the next higher order. The higher value of Br in any area will suggest a strong structural control in the drainage pattern. Whereas a lower value of Br

indicates that the area has been less affected by structural disturbances (Strahler, 1964; Vittala et al., 2004 and Chopra et al., 2005). Br values for 1st, 2nd, 3rd, 4th and 5th order are 4.48, 3.29, 8.5, 4 and 0 respectively.

Mean Bifurcation Ratio (Mbr)

To arrive at a more representative bifurcation number, Strahler (1952) used a weighted mean bifurcation ratio obtained by multiplying the bifurcation ratio for each successive pair of orders by the total numbers of streams involved in the ratio and taking the mean of the sum of these values. Mean Bifurcation Ratio of the study area is 5.07.

Basin Geometry

Basin elongation (Be)

Several people defined basin elongation in different ways, such as Schumm (1956) who defined the basin elongation as the longest dimension of the basin parallel to the principal drainage line. The basin elongation determines the shape of the basin. High basin elongation indicates elongated basin. The basin elongation of the study area is 32km.

Basin Area (Bp)

The area of the watershed is another important parameter like the length of the stream drainage. Schumm (1956) established an interesting relation between the total watershed areas and the total stream lengths, which are supported by the contributing areas. The studied basin has an area of about 441 sq km.

Basin Perimeter (p)

It is the outer boundary of the watershed that encloses its area. It is measured along the divides between watersheds and may be used as an indicator of watershed size and shape. The perimeter of the basin is 98.34 km.

Form Factor (Ff)

This may be defined as the ratio of basin area to square of the basin elongation. The value of form factor would always be less than 0.754 (for a perfectly circular watershed). Smaller the value of form factor, more elongated will be the watershed. The watershed with high form factors have high peak flows of shorter duration, whereas elongated watershed with low form factor ranges from 0.42 indicating them to be elongated in shape and flow for longer duration. The study area has form factor of 0.43. It is an elongated basin.

Elongation Ratio (Er)

It is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. A

circular basin is more efficient in the discharge of runoff than an elongated basin. The values of vary from 0.6 to 1.0 over a wide variety of climatic and geologic type. Values close to 1.0 are typical of region of very low relief, whereas values in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope. It can be grouped into three class namely Circular (>0.9), Oval (0.9-0.8), and Less elongated (<0.7). The study area has an Elongation Ratio of 0.7. Thus the basin is oval.

Circularity Ratio(Cr)

The circularity ratio or Cr of the basin is the area of a circle having the same circumference as the perimeter of the basin. It is influenced by the length and frequency of stream, geological structures, landuse/landcover, climate, relief and slope of the basin. It is a significant ratio that indicates the dendritic stage of a watershed. Low, medium and high values of Cr indicate the young, mature, and old stages of the life cycle of the tributary watershed. The circularity ratio is 0.57.

Drainage Texture Analysis

Drainage Texture (Dt)

It is the total number of stream segments of all orders per perimeter of that area. The drainage texture depends upon a number of natural factors such as rainfall, vegetation, climate, rock and soil type, infiltration capacity, relief and stage of development. The drainage texture is classified into five class such as very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8), very fine (>8). In the study area, all the SWS value range above 10 which comes under the class very fine drainage texture. The drainage texture of the area is 6.64 and thus the drainage texture of area is fine.

Stream frequency(Sf)

The stream frequency (Sf) or channel frequency is the total number of stream segments of all order per unit area. Sf mainly depends on the lithology of the basin and the texture of the drainage network. The Sf and the drainage density values of the SWS are positively correlated. This indicates that the increase in stream population is connected to that of drainage density. The stream frequency is 1.48.

Drainage Density (Dd)

Drainage density is defined as the closeness in spacing of channels. It is a measure of the total length of the stream segment of all order per unit area. Slope gradient and relative relief are the main morphological factor of drainage density. Dd is significant as a factor determining the time of travel by water in a terrain. Low drainage density generally result in the area of highly resistant or permeable subsoil material and high drainage density is the resultant of weak or

impermeable subsurface material. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture. Drainage density is 1.65 per km.

Drainage Intensity (Di)

The drainage intensity is the ratio of the stream frequency to the drainage density. This low value of drainage intensity implies that drainage density and stream frequency have little effect on the extent to which the surface has been lowered by agents of denudation. With these low values of drainage density, stream frequency and drainage intensity, surface runoff is not quickly removed from the watershed, making it highly susceptible to flooding, gully erosion and landslides. The drainage intensity is 0.89.

Infiltration Number (In)

The infiltration number of a watershed is defined as the product of drainage density and stream frequency and given an idea about the infiltration characteristics of the watershed. The higher the infiltration number, the lower will be the infiltration and the higher run-off. The infiltration number is 2.44.

Drainage Pattern (Dp)

In the watershed, the drainage pattern reflects the influence of slope, lithology and structure. Finally, the study of drainage pattern helps in identifying the stage in the cycle of erosion. Drainage pattern presents some characteristics of drainage basins through drainage pattern and drainage texture. It is possible to deduce the geology of the basin, the strike and dip of depositional rocks, existence of faults and other information about geological structure from drainage patterns. Drainage texture reflects climate, permeability of rocks, vegetation, and relief ratio, etc. The longer the time of formation of a drainage basin is, the more easily the dendritic pattern is formed.

Length of Overland Flow(Lof):

This term refers to the length of the run of the rainwater on the ground surface before it is localized into definite stream channels (Horton, 1945). Since this length of overland flow, at an average, is about half the distance between the stream channels. The length of overland flow is 1.21.

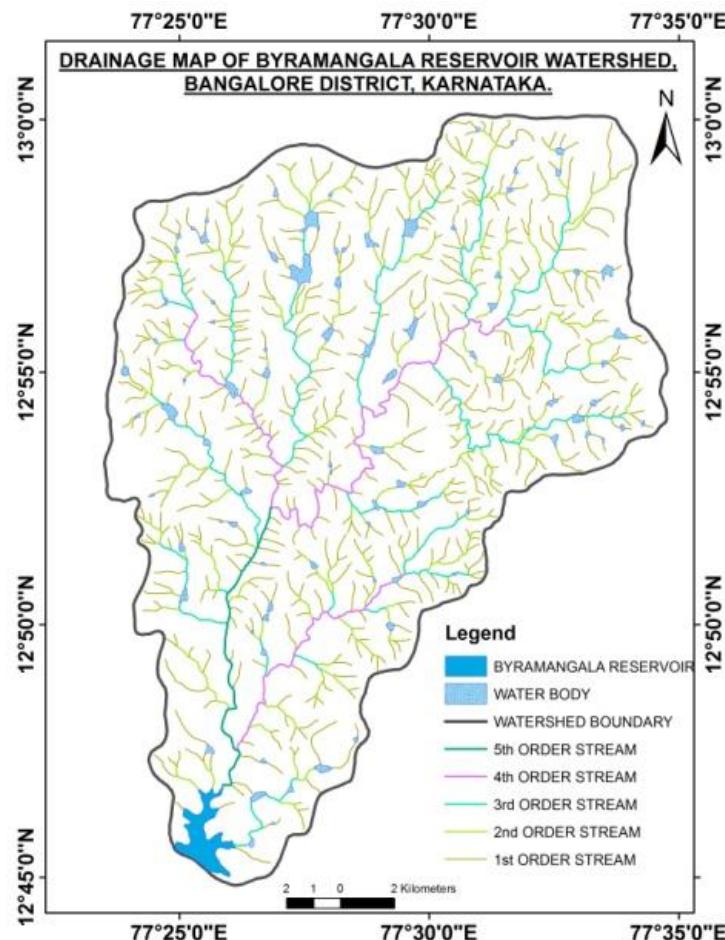
Relief Characterization

Relief Ratio (Rr)

Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor (in km) is known as the total relief of the river basin. The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line. The relief ratio is 0.007.

Table 2: Results of Morphometric Analysis

Sl. No	Parameters	Stream Order						Total
		I	II	III	IV	V	VI	
1	Number of streams	502	112	34	4	1	-	
2	Stream Length in Km (Lu)	421.95	142.19	103.9	44.75	16.85	-	
3	Mean Stream Length in Km (Lsm)	0.84	1.27	3.05	11.18	16.85	-	
4	Stream Length Ratio (RL)	II/I	III/I	IV/III	V/IV	VI/V	-	
		0.33	0.73	0.43	0.37	-		
5	Bifurcation Ratio (Rb)	I/II	II/III	III/IV	IV/V	V/VI	-	
		4.48	3.29	8.5	4	-		
6	Mean Bifurcation ratio (Rbm)				5.07			
	Perimeter (P) Km				98.34			
7	Basin elongation (Be) Km				32			
8	Basin Area(Km ²)				441			
9	Basin shape (Bs)				2.32			
10	Total Relief (Km)				0.25			
11	Relief Ratio (Rf)				0.007			
12	Drainage density (D)(Km/Km ²)				1.65			
13	Drainage Texture (Dt)				6.64			
14	Drainage Intensity(Di)				0.89			
15	Stream frequency(Fs)				1.48			
16	Form factor(Rf)				0.43			
17	Circularity ratio(Rc)				0.57			
18	Elongation Ratio(Re)				0.7			
19	Length of overland flow (Lg)				1.21			
20	Infiltration number(In)				2.44			

**Fig.5** Drainage map of the study area

Ruggedness Number (Rn)

Ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. Ruggedness number is 0.0004.

Conclusion

Remote sensing and GIS has proved to be efficient tool in drainage delineation and update in the present study and this updated drainage has been used for the morphometric analysis. The morphometric analysis of the drainage networks exhibits dendritic to sub dendritic drainage pattern and the variation in stream length ratio might be due to changes in slope and topography. The variation in values of bifurcation ratio among the watershed is ascribed to the difference in topography and geometric development. The stream frequencies of the study exhibits positive correlation with the drainage density values indicating the increase in stream population with respect to increase in drainage density. Drainage density is coarse texture. Elongation ratio shows that the basin is oval shape, while the remaining marks elongated pattern. The study comes across the conclusion that the Morphometric study for watershed especially for those which exposed seasonal fluctuation has a boost impact for water development, water sustainability and water resourcemanagement. The result presented and conclusion derived in this paper will be suggested and recommended to develop better water usage mechanism for better application of the watershed.

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