Geomorphological studies of the Purna river basin in Chharapati Sambhajinagar and Jalna District Maharashtra, India.

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Abstract

The study area is lying in Purna river basin and geology of the area is made up of the Deccan trap basalt. Occurrence of the Deccan trap is mostly indicates the presence of flat top surface hills. Topographic and landscapes features of Aurangabad district varies as it comprises high hill, low lying hills and plains. In this study efforts were made to morphometric analysis mainly consisting of quantitative parameters such as linear, aerial, relief aspects with the help of ArcGIS and SIO toposheets. The total length of all the streams is 4683.23 Km., drainage density of the watershed is 1, stream frequency is 0.57, ruggedness number is 0.42, supported by the constant of channel maintenance of that basin is 0.32 km^2/km., elongation ratio (Re) is 0.76 and circularity ratio is 0.29 indicates that the river is in mature stage of erosional development.

INTRODUCTION

Study area is located in Chhatrapati Sambhajinagar and Jalna District and it is situated in central part of Deccan basaltic plateau. The micro-watershed number GP-1, 2 and 6 of Purna river comprises 73 villages. Entire study area (Fig. 1) is spread in 15000 ha including forest land. Purna River is considered as one of the major rivers flowing in Chhatrapati Sambhajinagar district. The aim of the present study is to find out the morphometric attributes of the watershed GP-1, 2 and 6, to understand the drainage development of the area.

METHODOLOGY:-

In the present study the SOI toposheets of scale of 1:50000 have been utilized for building the maps. All drainages are traced and vector analysis is followed and UTM projection is used for calculating the datasets.

The methodology adopted here considered the micro-watershed No. GP-1, 2 and 6 comprises as one single macro watershed (Babar 2009) has been evaluated. The morphometric parameters of the watershed determined are linear, areal and relief aspect.

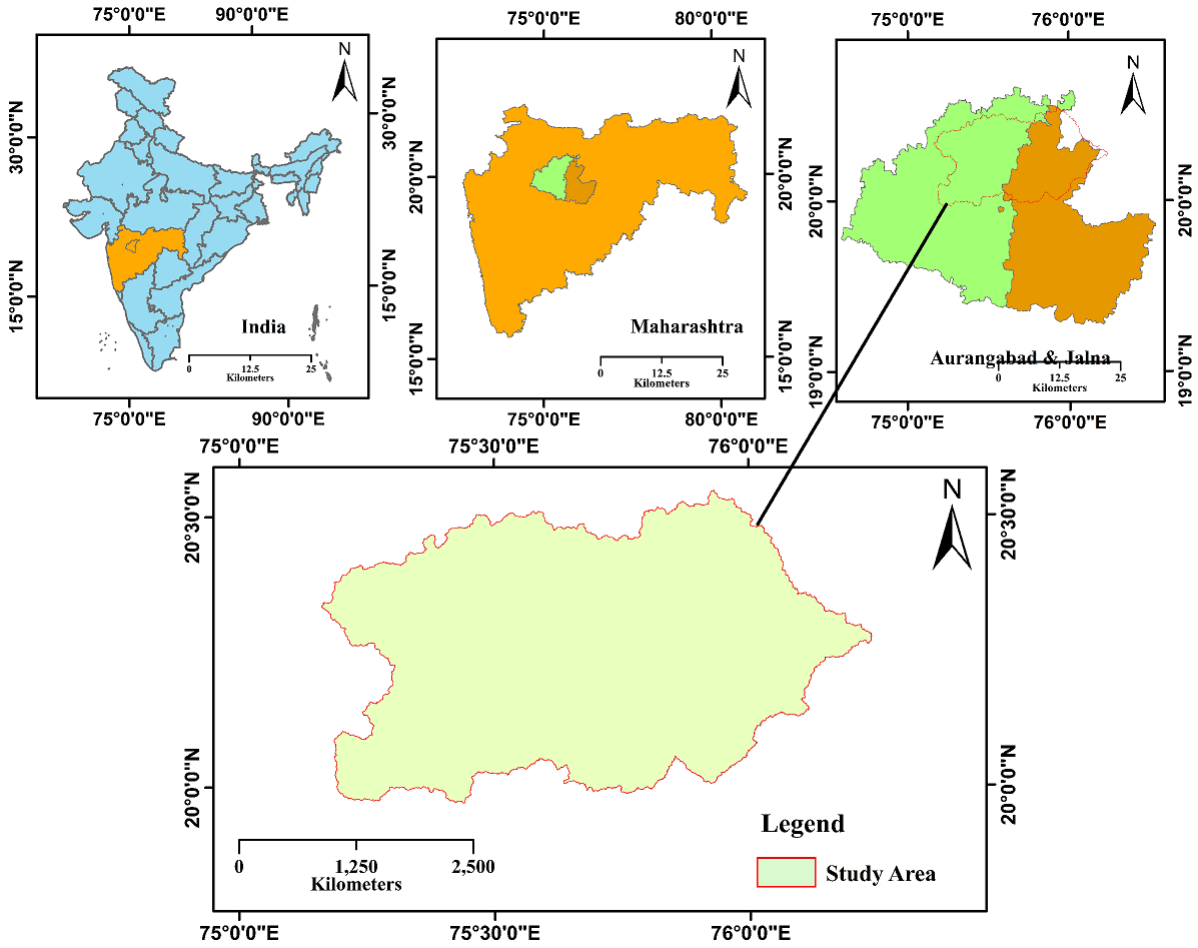

Fig. 1. Location Map of Study area.

GEOLOGY OF THE STUDY AREA:-

Study area has geology comprises of basalt rock and its types as it is the common rock type that found in major part of the Maharashtra. The nature of volcanic activity is produced the flows (Karmarkar et al. (1980). Lava flows are solidified as per the nature of the magma also the spreading of lava flows over an extent is also depend on the nature of lava i.e. fluidity. Spreading and solidification of the lava flows resultant into the thickness of a particular flow.

Basalt spread all over in study area and is overlain by the Quaternary sediments along the major river. Quaternary sediments consists sand, gravels, silt clay and alluvium. These sediments area deposited over flanks of rivers and its tributaries.

While demarcating the basalt flows exposed in the study area the concept of "Basalt flows" is used as defined by Karmarkar et al. (1980), who defined lava flows as "a Mass of lava which, irrespective of size and shape, is seen in the field to have been outpoured in dingle uninterrupted eruption, which having come after the solidification of at least the upper portion of the previous eruption and not being followed by another eruption before consolidation of at least its top portions, can be clearly demarcated in the field from overlying and underlying masses of lava flows."

The lithological succession of the study area is mention below in Table 1.

Table 1:- Lithological succession of the study area

Sr. No.	Age	Formation	Lithology
1	Holocene	Soil	Black cotton soil, Kankar deposits.
2	Pleistocene	Alluvium	Alluvium comprising sand, silt, clay, etc.
3	Upper Cretaceous to Lower Eocene	Deccan trap	Basalt and its different types, tachylitic basalt and Red boles, green boles are rare.

Basalts have its own variant due to its occurrence in nature. Generally basalt is found as Aa flow also defined as a Compact basalt and Pahoehoe flow defined as a Amygdaloidal basalt and vesicular basalt. Tachylitic basalt appeared in red and green color, red is significant in study area and green is rare. Tachylitic basalt occurred with the thickness varies form few inches up to 5 ft.

GEOMORPHOMETRIC ATTRIBUTES:-

The drainage map of the study area (Fig.2) is considered for the analysis of its all aspects in order of aerial, linear, shape aspects. The stream order system followed is as suggested by Strahler (1957) in the numbering the drainage networks. The highest stream order found in the watershed is of 6^{th} order. This analysis is further considered for determination of stream order, bifurcation ratio, length and length ratio, areal aspects like drainage density, stream frequency and shape aspects includes circularity ratio, elongation ratio, relief ratio and ruggedness number.

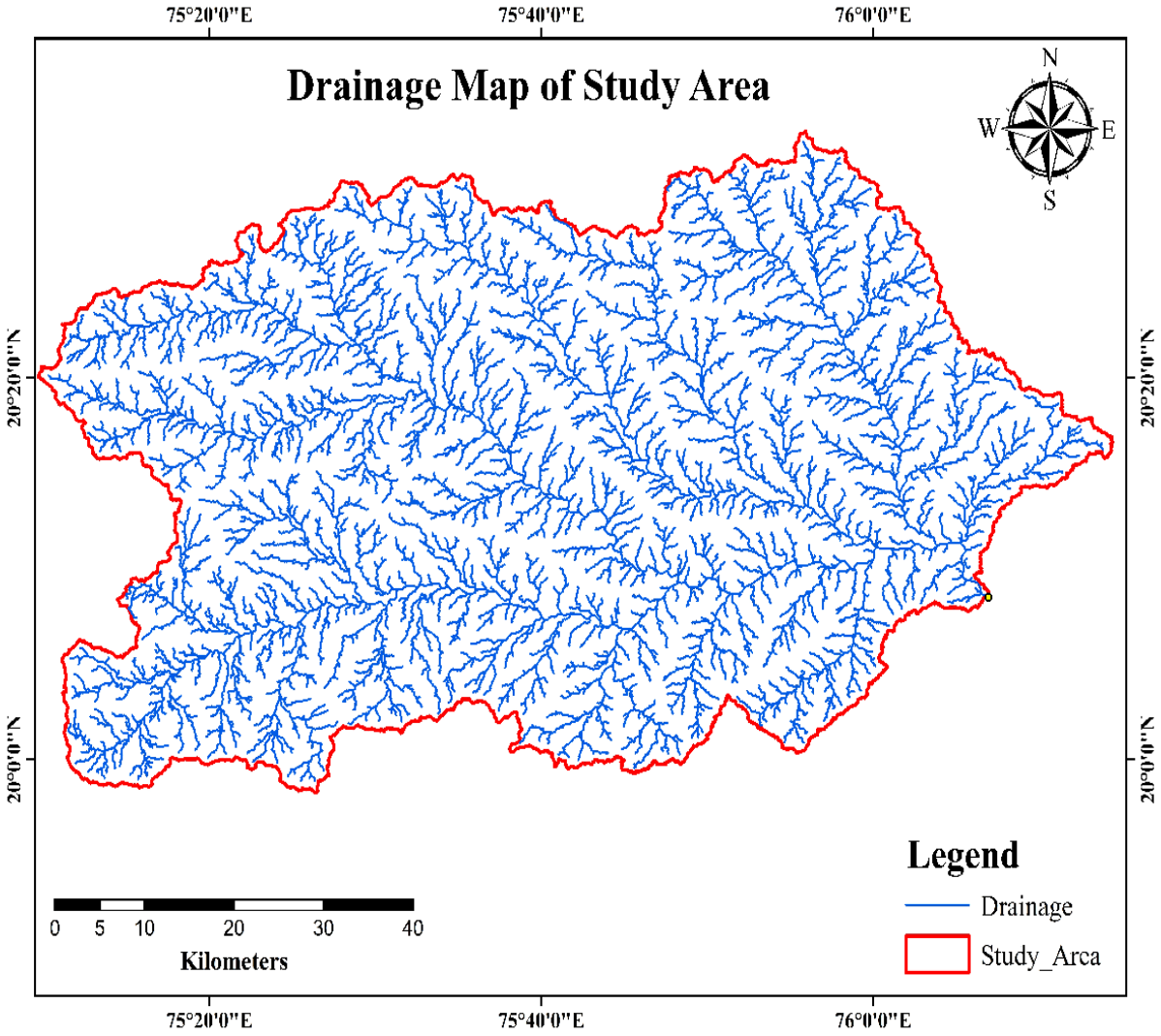

Fig. 2. Drainage Map of the Study area.

a) Linear Aspects

Each drainage basin has the line segments in terms of stream order. The stream order is the primary step in assessment of the watershed, which suggest hierarchic ranking of each stream. According to Strahler (1957) stream ordering system, each and every segments of the stream have been evaluated. The linear aspects are stream order (U), Number of Streams (Nu), Stream length(Lu), maximum basin length, bifurcation ratio, length ratio are given in the Table 2.

Table 2: Bifurcation Ratio and Stream Length Ratio

Stream order (U)	Number of Stream (N_μ)	Bifurcation Ratio (R_b)	Stream Length (Lμ) (KM)	Mean Stream Length ($\bar{L}$)	Stream Length Ratio (R_l)
1	2109	4.56	2481.77	1.18	0.49
2	463	5.09	1214.92	2.62	0.41
3	91	4.55	501.98	5.52	0.55
4	20	5.00	276.62	13.83	0.60
5	4	4.00	164.83	41.21	0.26
6	1		43.10	43.10	
Total	**2688**	**23.19**	**4683.23**	--	2.31

Bifurcation Ratio (Rb)

The bifurcation ratio (Rb) is the ratio between the branching patterns of the drainage network in the basin area. It is defined by Horton (1945) as, a ratio of a number of streams of the next higher order (Nu+1) with the stream order Nu. This provides quantitative information of the stream network evolution (Tejpal et.al 2009). This reflects the degree of the consequences of the drainage network (Horton 1945).

The formula expressed as, Rb = Nu / Nu + 1

Where, Nμ= number of streams of a given order, Nμ+1 number of streams of next higher order. The bifurcation values of the watershed have normal values between 4.55 and 5.00 (Table 2), which suggests no particular structural control in the watershed development.

Stream Length (Lu):

Study of stream length with respect to the stream order is of significance in understanding the spread of drainage network (Babar 2005). Stream length for the watershed of the given order is inversely proportional to the stream order. Stream of relatively smaller length are characteristics of area with greater slope. Stream length of watershed GP9 and its streams is measured with the help of ArcGIS 9.3 software. The total stream length found is 4683.23 km. The mean length of Channel Lu of order u is the ratio of the total length to the number of streams of a given order. Mean stream length of channel segments of a given order is greater than that of the next lower order but less than that of next higher order (Table 2).

Stream length ratio (Rl):

The ratio in between the average length of successive order is stream length ratio (Horton, 1945). Stream length ratio of the watershed is given in Table 2, which lies between 0.55 and 0.60.

b) Aerial Aspects

The aerial aspect has been considered the stretch of the basin with respect to calculation of line as well as the area. The aerial analysis considered here is of Drainage density, stream frequency, which is given in Table 3 for the watershed GP-1,2 and 6.

1. ***Basin Area:***

Basin area is the direct outcome of the drainage development in a particular basin. The total area of watershed is about 4695.52 Sq. Km. which indicate that rainwater will reach the main channel more rapidly, where the water has much further to travel.

2. *Perimeter of the Basin (P):*

In present work we used ArcGIS 9.3 software to analyze the perimeter of the watershed. The Perimeter of value watershed measured is 450.95 km.

3. *Drainage density (Dd)*

The drainage density is the relationship between total stream length and basin area. This shows the density of the drainages in the particular region. The drainage density is defined by Horton (1945) as, a ratio of total length of all stream segments in a given watershed to the total area of that watershed.

The drainage density (Dd) is expressed as,

$Dd = L/A$ L=Total length of stream segments, A= Area of watershed,

The value of drainage density determined is 1 Km/Km^2 (Table 2), which is a moderate value of Dd, This value indicates moderately permeable subsurface material (Singh 1998). The drainage density map of the area is given in (Fig. 3).

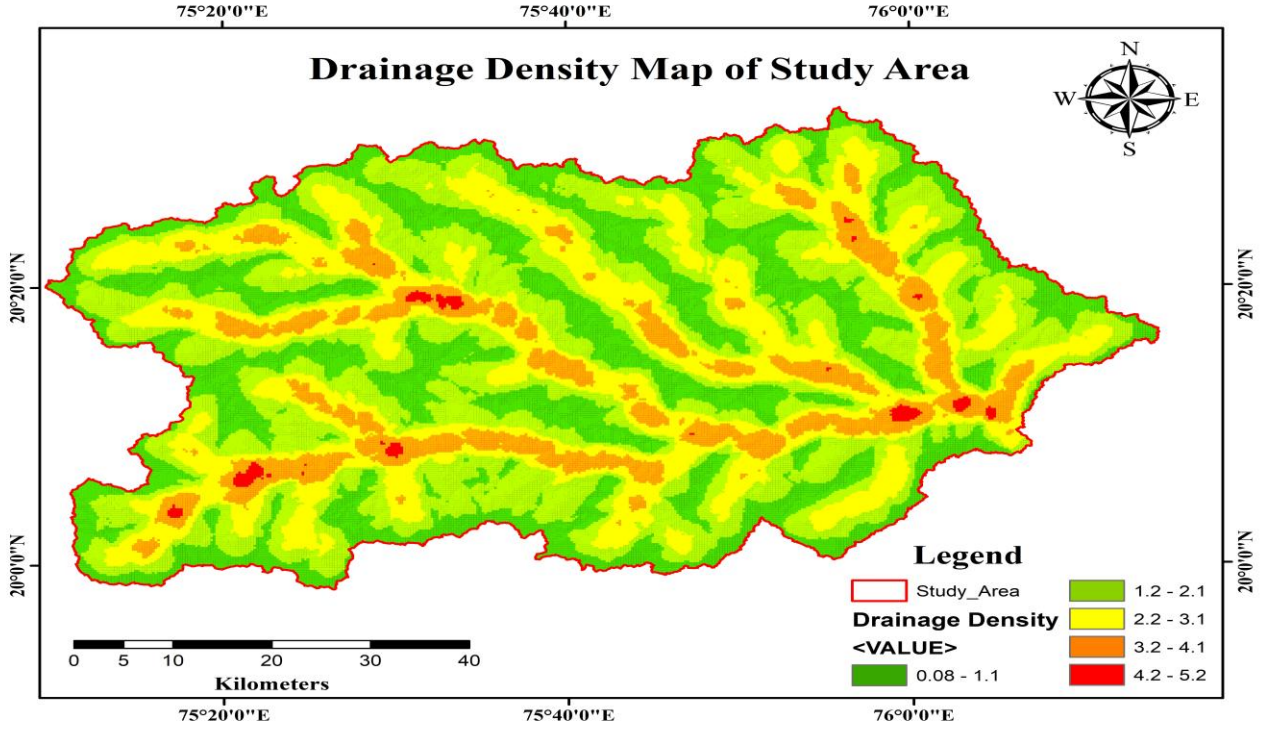

Fig. 3. Drainage density Map of the Study area.

4. *Stream frequency (Sf)*

The stream frequency is expressed as measure of the sum of total number of the streams and total basin area. This shows frequency of the stream segments in the particular region.

The stream frequency (Sf) is as follows,

$Sf = N/A$ N= total number of streams, A= Area of watershed

The values of the stream frequency lies between 0-2 is very poor, 2-4 is poor, 4-6 is moderate, 6-8 is high (Singh 1998). The Sf value in the study region found is 0.57 Streams/Km^2 indicating very poor stream frequency (Table 3).

c) Shape Aspects

The shape aspect of the watershed or sub-basin is considered to be external form or outline of the basin or watershed. This shape aspect has evolved from the tectonic activity which further connected to circular shape to elongate. As more elongation of a shape of the basin suggest more tectonic activity. The shape aspects consider area and line in extent of the longest stretch.

Table 3: Morphometric attributes of the study area.

Parameter	Values	Parameter	Values
Stream Order (μ)	I-VI	Form Factor (Ff)	0.45
Total Number of Streams (∑Nμ)	2688.00	Drainage Density (Dd) Km/Km^2	1.0
Total Stream Length (∑Lμ) L	4683.23	Stream Frequency (Sf) Streams/Km^2	0.57
Mean Stream Length (L^-)	1.18 – 43.10	Elongation Ratio (Re)	0.76
Stream Length Ratio (Rl)	0.26 – 0.49	4πA (Km^2)	59005.64
Bifurcation Ratio (Rb)	4.0 – 4.56	Circularity Ratio (Rc)	0.29
Mean Bifurcation Ratio (Rbm)	4.80	Highest Point (Z) on Basin perimeter (m)	933.4
Basin Area (A) Sq. Km	4695.52	Lowest Point (z) on Basin perimeter (m)	507.9
Basin Perimeter (P) km	450.95	Basin Relief (Br)	425.50
Square of Basin Perimeter (P2) km^2	203355.90	Ruggedness Number(Rn)	0.42
Max Basin Length (L) Km	101.9	Constant of channel maintenance	0.32

1. Elongation ratio (Re)

The elongation ratio is shape and aerial morphometric variable, which gives information of degree of the maturity of the basin. It deals with maximum length of the basin that may indicate structural control. The tectonically active areas shows elongated nature of the basin, whereas near to circular nature of the basin are tectonically inactive areas.

The elongation ration is expressed as,

$Re = \frac{2\sqrt{A/\sqrt{\pi}}}{Lb}$ A= Area, $\sqrt{\pi} = 1.7720$, Lb= Maximum length of the watershed

The value elongation ratio if lies closer to the <0.50 are tectonically active regions, 0.5-0.75 are moderately active, >0.75 are inactive regions (Bull and McFadden 1977). The Elongation ratio for the watershed is 0.76 indicating inactive region (Table 3).

2. Circulatory Ratio (Rc):

Circulatory ratio is the ratio of watershed area to the area of circle having the same perimeter as the basin (Miller, 1953).

$$Rc = 4\pi A/P2 \quad \ldots 6$$

It is influence more by the length, frequency and gradient of stream of various orders than slope conditions and drainage patter of the basins (Strahler, 1957). Circulatory ratio of the present watershed is 0.29 which is below (0.5) and shows moderately elongated basin with semi permeable homogeneous lithology (Table 3).

3. Form Factor Ratio (Rf):

Form factor ratio is the dimensionless ratio of the watershed area to the square of basin length (Horton, 1945).

$$Rf = A/Lb2 \quad \ldots 7$$

The form factor ratio value of the watershed is 0.45, which is nearer to zero and thus represents elongated in shape (Table 3).

4. Constant of Channel Maintenance (C):

The constant of channel maintenance is the inverse of drainage density (Schumm, 1956). There for, higher the drainage density lowers the constant of channel maintenance and vice versa. Regarding the watershed, the constant of channel maintenance is 0.32 km^2/km (Table 3).

Relief Aspect of Drainage Basin:

1. Basin Relief (H):

The vertical distance difference between point of maximum elevation and minimum elevation is the relief of basin. For study relief of the basin contour map (Fig. 4) are prepared through ArcGIS9.3. It is very useful for studying the maximum and minimum elevation of the basin (Fig. 4 Contour map). The maximum elevation is 933.4 meter and minimum elevation is 507.9 meter. Therefore, the basin relief of watershed is 425.50 meters (Table 03)

2. Relief Ratio (Rh):

When basin relief (H) is divided by maximum basin length (Lb) gives the relief ratio (Schumm, 1956). The relief ratio of watershed is 0.019, which indicates that the basin has moderate relief and moderate slope.

3. Ruggedness Number (Rn):

Ruggedness number is the product relief of basin (H) and drainage density (Dd). The value of ruggedness number of watershed found is 0.42 (Table 3), which indicates both relief and drainage density are moderate. Higher values are expected in a mountainous region of tropical and sub-tropical climate with higher rainfall (Schumm, 1956).

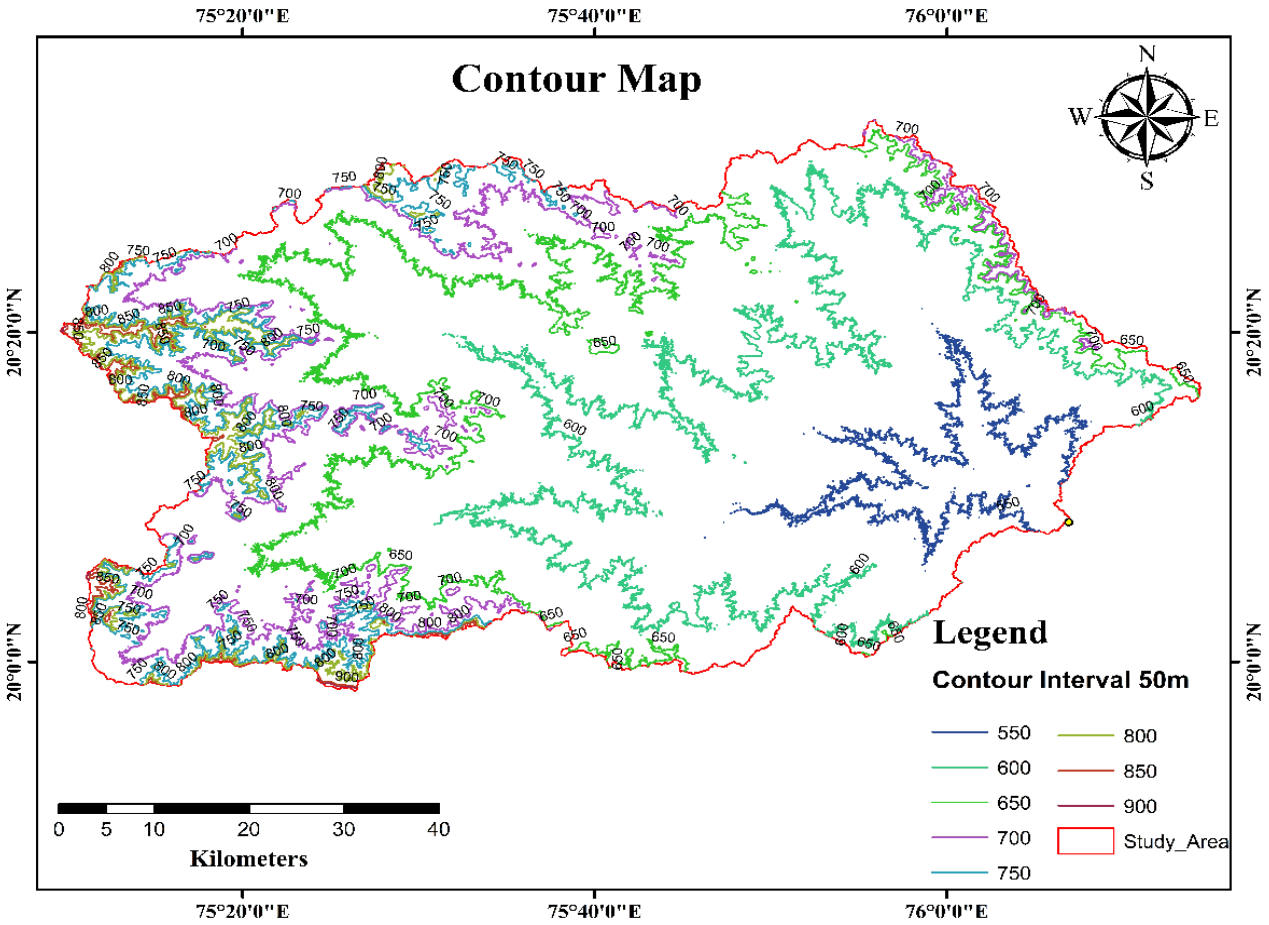

Fig. 4. Contour Map of the Study area.

Conclusions:

On the basis of quantitative analysis of morphometric study of GP-1, 2 and 6 watershed concluded that the watershed is 6th ordered and cover an area of about 4695.52 Sq. km. in Chh. Sambhajinagar and Jalna district of Maharashtra. The whole river contains 2688 streams and the total length of all the streams is 4683.23 km. The bifurcation ratio varies from 4.0 to 4.56, which indicate that there is no strong geological control in the watershed. The moderate drainage density (1.0) and high stream frequency (0.57 per km^2) indicates that the moderate runoff from the watershed. The relation between stream order and number of streams and relation between stream order and mean stream length shows that in watershed 6th order stream area show no structural disturbance in that area.

The circularity ratio is 0.29, which indicates that the basin is moderately elongated with semi permeable homogeneous lithology. The form factor ratio is 0.45, which is less than 0.5 and thus represents the watershed is moderately elongated in shape. The constant channel maintenance is 0.32, which indicate that the basin has lower value of the constant of channel maintenance which reflects the lithology has a moderate to low control on the watershed development, and that the surface has moderate permeability. This also means that the watershed has moderate infiltration rates, moderate surface runoff and less dissection of rocks.

The maximum elevation of the watershed is 933.4 meter and minimum elevation is 507.9 meter, therefore the relief is 425.50 meter. The relief ratio is 0.019, which indicates that the basin is with low relief and the value of ruggedness number is 0.42, which indicates both relief and drainage density are moderate for the watershed. The basin elongation ratio is 0.76, which indicates the basin is moderately elongated and tectonically inactive with drainage development is in mature stage of development.

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