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MORPHOMETRIC ANALYSIS AND DEVELOPMENT RAINFALL RUNOFF RELATIONSHIP IN CHANAL AND HIREHALLA WATERSHED, GADAG DISTRICT, KARNATAKA, INDIA

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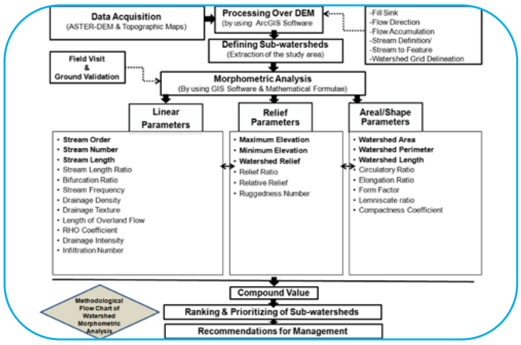
ABSTRACT :

Morphometric examination gives important experiences into the hydrological behaviour and possible effects on the watershed's eco-hydrological systems and socio-economic aspects. Morphometric investigation is a quantitative estimation and numerical examination of landforms (Clarke, 1996; Kaur, Singh, Verma, & Pateriy, 2014; Vaidya, Kuniyal, & Chauhan, 2013). It assumes a critical part in understanding the geo-hydrological qualities of a drainage basin comparable to the landscape qualities and its flow patterns.



It additionally assists with assessing the infiltration and runoff, and other related hydrological character of watershed for example, erosion and sediment transport which has major areas of strength for a for normal asset protection. Therefore, a nitty gritty morphometric investigation of Chanal and Hirehalla watershed (Gadag Area, Karnataka, India) was done to comprehend its hydrological reaction regarding geomorphology and drainage characteristics. This study uses different morphometric parameters to assess the watershed's shape, size, drainage pattern, relief and other significant geomorphic attributes.

KEYWORDS : *Morphometry, GIS, Remote Sensing, Runoff Estimation, Empirical method, and Chanal and Hirehalla watershed.*

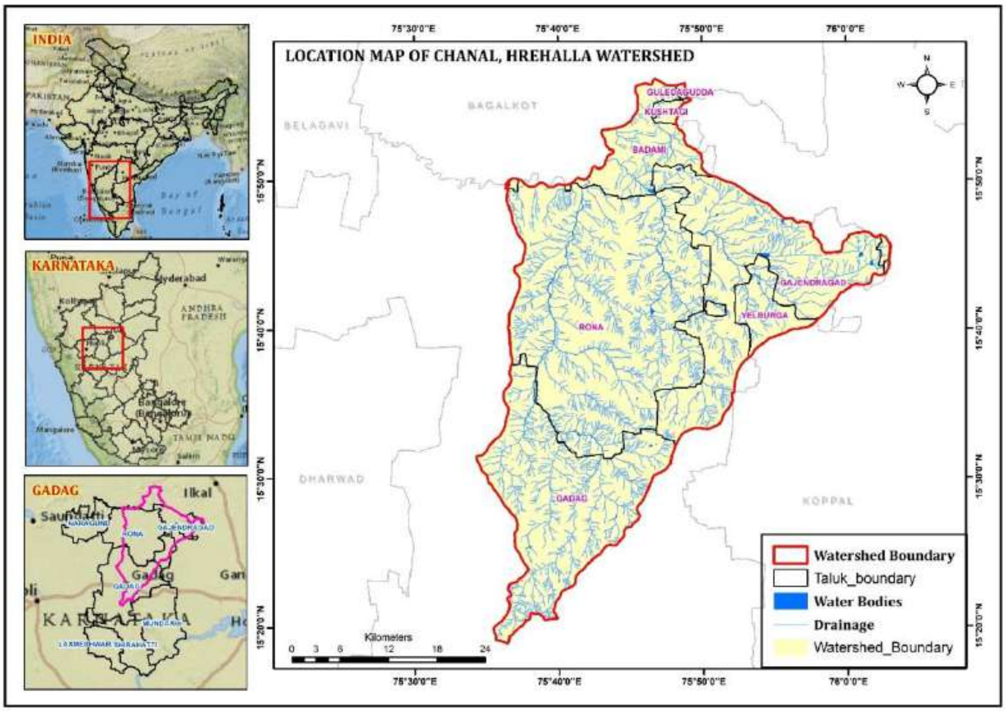
INTRODUCTION

Morphometric investigation is a quantitative methodology used to study and examine the shape, size, and other geometric properties of natural features, for example, landforms, rivers, watersheds, and drainage networks. It gives important experiences into the attributes and conduct of these elements, supporting different logical and designing disciplines, including hydrology, topography, geomorphology, and environmental management.

STUDY AREA:

Chanal and Hirehalla are head feeders of the river Malaprabha which streams in Gadag, Koppala and Bagalkot Districts before joining Malaprabha river in Badami Taluk of Bagalkot Region. Gadag region includes around 89 % of Chanal and Hirehalla watershed region, whereas remaining part of the watershed occupies Bagalkote(7%) and Koppala (4%) areas. Chanal and Hirehalla watershed lies between latitude 15°18'51.96"N" and 15°56'40.44"N and longitude 75°35'51.66"E and 76° 3'13.58"E. The catchment region of the watershed is 1518 km2. Hirehalla streams in South-North bearing, though Chanal Halla streams towards East-West and joins the river Malaprabha at Badami Taluk of Bagalkot District of Karnataka. The area of the Chanal and Hirehalla watershed is displayed in Figure 1.

Figure 1:



MATERIALS AND METHODS:

Morphometric examination of watershed was completed utilizing RS and GIS technology. SOI topo sheet maps at 1:50000 scale and ASTER DEM information were utilized for preparation of base maps and to do morphometric examination of watershed.

The drainage network of the watershed has been inferred by digitizing SOI 1:50000 topo sheet, 306 Micro-Watershed has been created from Watershed. Stream length and frequency were likewise recorded. Further, essential boundaries, for example, (a)drainage area, (b)perimeter, (c)basin length, (d)stream order and (e)mean stream length were determined. Utilizing primary investigation results, secondary parameters for example, (i) bifurcation ratio, (ii) mean stream length, (iii) drainage density, (iv) elongation ratio, (v) circulatory factor and (vi) form factor were determined.

An exhaustive examination of morphometric parameters was completed. Every parameter is characterized and explained in detail, alongside with its calculation method and interpretation. Instances of normally utilized parameters include (i)drainage area, (ii)stream order, (iii)stream length, (iv)bifurcation ratio, (v)drainage density, and (vi)relief ratio.

RESULTS AND DISCUSSION

Morphometry

The measurement and quantitative study of the earth's surface arrangement, shape, and features is known as morphometry (Clarke 1996). The morphometric investigation is brought out through estimation of (i) linear, (ii) areal and (iii) relief aspects of basin & slope contribution (Nag &

Chakraborty, 2003). Estimation of different morphometric parameters specifically (1) stream order, (2) stream length (Lu), (3) mean stream length (Lsm), (4) stream length proportion (RL), (5) bifurcation proportion (Rb), (6) mean bifurcation ratio(Rbm), (7) relief ratio (Rh), (8) drainage density (D), (9) stream frequency (Fs), (10) drainage texture (Rt), (11) from factor (Rf), (12) circulatory ratio (Rc), (13) elongation ratio (Re) and (14) length of overland flow (Lg) were assessed and the outcomes are introduced in Table-1 and Table-2. Figure 2 shows the drainage network diagram of the study area.

Figure 2:

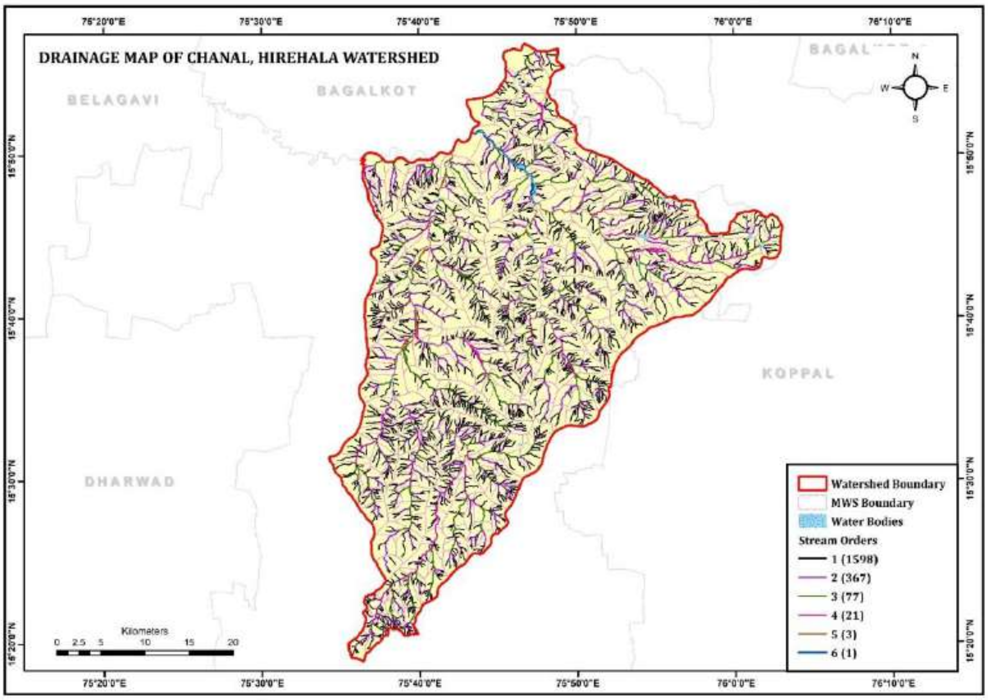


Table 1:

Parameter	Equation
1. Linear	
A. Stream Order (Strahler,1964)	Hierarchical Rank
B. Stream Number (Horton,1945)	Nu, No of Streams
C. Stream Length (Horton,1945)	Lu, Streams Length
D. Mean Stream Length (Lsm) (Schumn, 1956)	Lsm=Lu/Nu
E. Stream length ratio (Horton,1945)	RL=Lu/Lu-1
F. Bifurcation Ratio (Rbm) (Schumn, 1956)	Rb=Nu/Nu+1; Here, Nu=Total number of stream segment of order'u',Nu+1=Number of segment of next higher order.
2. Areal	
A. Drainage Density (Dd) (Horton, 1932)	Dd=L/A; Here, L=Total length of streams; A=Area of basin
B. Stream Frequency (Fs) (Horton, 1932)	Fs = N/A; Here, N=Total number of streams; A=Area of basin
C. Drainage Texture (Rt) (Horton, 1932)	Rt = N_1/P ; where, N_1=Number of 1^{st} order streams, P=Perimeter of basin.

D. Form factor (Rf) (Horton, 1932)	$Rf=A/(Lb)^2$; Here, A=Area of basin; Lb=Basin length
E. Circulatory ratio (Rc) (Miller, 1953)	$Rc=4\pi A/P^2$; where, A=, π=3.14, P=Perimeter of basin
F. Elongation ratio (Re) (Schumn, 1956)	$Re=2\sqrt{(A/\pi)}/Lb$; Here, A=Area of basin, π=3.14 and Lb=Basin length
G. Compactness Coefficient (Cc) (Horton, 1945)	Cc = 0.2821 x P/ A0.5 Here, A= Area of the basin, km2 P= Basin perimeter, km
3. Relief	
A. Maximum Basin Height(H)	H
B. Minimum Basin Height(h)	h
C. Basin relief (Bh) (Schumm, 1956)	Bh=H-h
D. Relief Ratio (Rh) (Schumm, 1956)	Rh=Bh/Lb, Here, Bh Basin Relief, Lb=Length of Basin
E. Ruggedness Number (Rn) (Schumm, 1956)	Rn=Bh*Dd Here, Bh Basin Relief, Dd=Drainage Density

Table 2(A)
Study Area Linear Aspect

Area in km^2	Length (km)	Stream orders (U)							Stream lengths (Lu)						
		1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
1518	**72**	1598	367	77	21	3	1	**2067**	1418.59	429.43	248.61	145.70	100.08	16.28	**2358.69**

Mean Stream length (Lsm)in Km							Stream length ratio (Rl)					
1	2	3	4	5	6	Average	R 2/1	R 3/2	R 4/3	R 5/4	R 6/5	Average
0.89	1.17	3.23	6.94	33.36	16.28	**17.68**	1.32	2.76	2.15	4.81	0.49	**2.30**

Bifurcation ratio (Rb)					
Rb 1/2	**Rb 2/3**	**Rb 3/4**	**Rb 4/5**	**Rb 5/6**	**Mean Bifurcation ratio (Rb)**
5.35	5.77	4.67	8	4	**5.56**

Table 2(B):
Study Area Areal Aspect

Drainage density	Drainage Texture	Stream Frequency	Elongation ratio	Circularity ratio	Form factor	Compactness Coefficient
1.55	7.07	1.36	0.3	0. 37	0.29	0.08

Table 2(C):
Study Area Relief Aspect

Elevation in 'm'		Basin relief	Relief ratio	Ruggedness Number
Max 'H'	Min 'h'	**(Bh)**	**(Rh)**	**(Rn)**
815	439	376	5.2	584.23

1. Linear Aspects

Table 2.A shows measurement of different linear parameters, that incorporate (A) Stream order, (B) Stream length, (C) Mean Stream length, (D) Stream length ratio, and (E) Bifurcation Ratio.

A. Stream Order(U):

Stream order is an action utilized in hydrology and river network examination to characterize and sort out the various levelled design of a stream. It gives an approach to numerically differentiate and rank the tributaries and main stream based on their position within the network.

As indicated by Horton's (1945) method, the smallest assigned as first-order streams. At the point when two first-order streams go along with, they structure a second-order stream. Likewise, when two second-order streams consolidate, they make a third-order stream, etc. The order of a stream increments by one each time two streams of similar order consolidate.

As the stream order increases, it can be observed that first order streams have the highest frequency and that stream frequency decreases (Table 2(A)).

B. Stream Length(Lu):

The term "stream length" refers to the length of a stream or river from its source to its mouth, or the point at which it meets a larger body of water, such as an ocean, sea, or lake. It's a fundamental feature that's used to define and contrast streams and rivers.

Using GIS software, stream length of different order in watershed has been calculated and is shown in Table 2(A).

Horton's proposed law has been used to calculate the Stream Length (Lu) (1945). First order stream fragments have the longest absolute lengths, and as stream order increases, these lengths get smaller.

C. Mean Stream Length (Lsm):

Mean stream length is distinguishing feature of drainage network and its related surfaces (Strahler;1964). The total stream length of the order divided by the total number the of streams obtains the mean stream length (Lsm). Mean stream length of study region differs from 0.89 to 16.28 as displayed in Table 2(A). It is seen in study region that mean stream length increments with increase in order, aside from last 2 orders for example in 5th and 6th order.

D. Stream Length Ratio(Rl):

Stream length ratio, which has a strong correlation with surface flow and discharge, is defined as the ratio of the mean stream length of a given order to the mean stream length of the next lower order (Horton 1945). Stream length ratio of study region is introduced in Table 2(A)and it differs from 0.49 to 4.81. In the study region, variations in stream length of various orders indicate variations in topography and slope.

E. Bifurcation Ratio(Rb):

The ratio of the number of stream segments of a given order to the number of segments of the next higher order is known as the bifurcation ratio (Schumn 1956). Horton (1945) thought about the bifurcation ratio as an index of the relief and the dissections. With the exception of areas where geology predominates, bifurcation ratios show little variation across different regions or ecological conditions, as demonstrated by Strahler's (1957) research. Bifurcation ratio differs from 4 to 5.77 in the study region. The bifurcation ratio varies from one order to the next. Chow (1964) expressed that Bifurcation ratio range from "3 to 5" doesn't practice a predominant effect on drainage pattern of watersheds.

2. Areal Aspects

Areal Aspects manage two-layered parameters like basin shape and region, (A) Drainage density, (B) Drainage texture, (C) Stream frequency, (D) Elongation ratio, (E) Circulatory ratio (F) Form factor and Compactness Coefficient.

Area of a basin is characterized as the total area flowing to a given outlet or release point. A Perimeter is the length of the outline of a basin that can be determined utilizing GIS Software. Area and perimeter of study region basin are 1518 km2 and 226 km.

A. Drainage Density (Dd):

Drainage Density (Dd) is the ratio of total channel fragment length cumulated for all orders with in a basin to the basin area. It is communicated in terms of km/km2. The drainage density is an expression of the closeness of spacing of channels (Horton, 1932) and in the current case, it will be it is viewed as low (1.55 km/sq.km) showing a highly permeable subsoil and thick vegetative cover (Nag & Chakraborty, 2003). Table 2(B) shows the drainage density of Chanal-Hirehalla watershed. High density is the consequence of weak or impermeable subsurface material, meager vegetation and mountainous relief. Low drainage density prompts to coarse drainage texture while high drainage density prompts fine drainage texture (Sandeep Soni,2016).

The field check of the study area additionally affirmed that the area is covered by highly permeable subsoil and thick vegetative cover.

B. Stream Frequency (Fs):

Stream frequency (Fs) was defined by Horton (1945) as the number of streams per unit area. Stream Frequency of study region is 1.36 km/km2 as introduced in Table 2(B). It shows a positive correlation with the watershed's drainage density, indicating a rise in stream population in response to an increase in drainage density.

C. Drainage Texture (Rt):

Drainage Texture (Rt) was defined by Horton (1964) as the complete number of stream segments of all orders of the area. Infiltration capacity is one of the single significant variables which impacts drainage texture which incorporates drainage density and stream frequency. Smith (1950) characterized the texture into 5 classes i.e., extremely coarse (<2), Coarse (2-4), moderate (4-6), fine (6-8) and exceptionally fine (>8). In the study region, the drainage density is 1.55 and texture 7.07 (Table 2(B)) demonstrating coarser texture.

D. Elongation Ratio (Re):

The Elongation Ratio was defined by Schumn (1956) as the ratio of the drainage basin's greatest length to the diameter of a circle in a similar area. Higher Elongation Ratio values indicate low runoff and high infiltration capacity in a given region. According to Singh and Singh (1997), a circular basin releases runoff more efficiently than an extended basin. According to Adhikari (2020), the elongation ratio values are assigned as follows: circular (0.9-1.0), oval (0.8-0.9), less extended (0.7-0.8), stretched (05.-0.7), and more elongated (<0.5). According to Table 2(B)), the study region's elongation ratio is 0.3, characterizing the basin as more elongated with a gentle slope and low relief.

E. Circulatory Ratio (Rc):

The area of the basin divided by the area of a circle whose circumference is comparable to the basin's perimeter is known as the circularity ratio (Mill operator, 1953). It is influenced by the watershed's relief, slope, land use/cover, length and frequency of streams, and geographical designs. The circularity ratio in Table 2(B) of the current review is 0.37, indicating low discharge and high subsurface penetrability.

F. Form Factor (Rf):

The ratio of the basin area to the square of the basin length is known as the form factor (Horton, 1932). The study area's form factor is 0.29, as shown in Table 2. (B). which indicates that the catchment is longer, resulting in a flatter peak flow observed over an extended period of time. Such an elongated basin's flood flow is easier to manage than that of a circular basin.

G. Compactness Coefficient (Cc):

A watershed's shape boundary, or smallness coefficient, is determined by dividing its perimeter by the circumference of a similar circular area within the watershed. According to Horton (1945), the Compactness Coefficient is solely dependent on the slope and is independent of the watershed's size. The study area's compactness coefficient is 0.04 (Table 2. (B)).

3. Relief Aspects

Relief Aspects manages three-layered parameters like (A) Basin Relief, (B) Relief Ratio and (C) Ruggedness Number.

A. Basin relief (Bh):

Basin relief is the greatest vertical distance between the least and most elevated places of a basin (Schumm, 1956). Basin relief is a significant element in understanding the denudational qualities of basin & assumes a critical part in landforms development, drainage development, surface and sub-surface water flow, penetrability & erosional properties of territory (Magesh et al. 2011). In current review of study region, the greatest level (H) is 815 m and least level (h) is 439 m. Consequently, the relief of study region basin is 376 m.

B. Relief Ratio (Rh):

Relief Ratio is characterized as ratio between total relief of basin i.e., rise distinction of most minimal and most noteworthy marks of basin, and longest dimension of basin parallel to principle drainage line (Schumm, 1956). High values of relief ratio demonstrates steep slope & higher relief and vice-versa. Runoff is quicker in steeper basins, delivering more peaked basin recharge and greater erosive power (Palaka and Shankar, 2016). In the current review Rh is 5.2 (Table 2(C)) demonstrating lower relief and gentle slope in study region.

C. Ruggedness Number (Rn):

Ruggedness Number is a product of basin relief (Bh) and drainage density (Dd). An incredibly high Ruggedness number happens when the two factors (Bh & Dd) are huge and slope is steep (Strahler, 1956). In the current review Ruggedness Number of study region is 584.23 (Table 2(C)) which has gentle slope and suggests less vulnerable to soil erosion (Schumm, 1956).

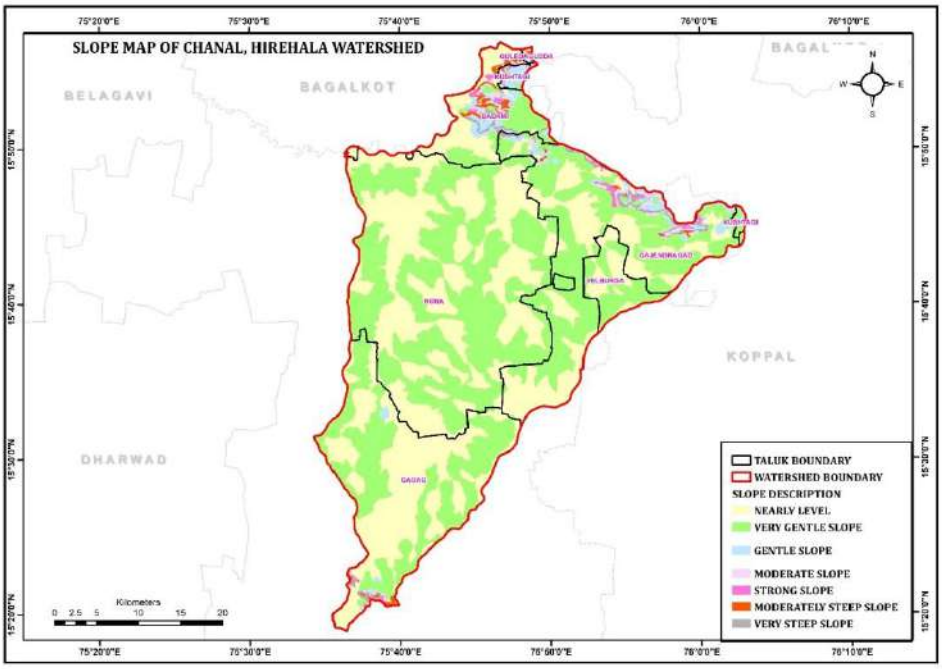
4. Slope:

Slope of an area is controlling component for surface & subsurface stream, accordingly affecting groundwater re-energize (Harvey and Bencala 1993). Infiltration is conversely connected with slope, for example gentler the slope, Infiltration is more and spillover is less. In concentrate the study area has a Nearly Level (0-1%) and Very Gentle Slope (1-3%) comprises about 93% (Table 3) of the absolute region, which shows that the Infiltration is more and spillover is less. Slope dissemination of the review region is displayed in Figure 3.

Table 3:

Sl No	Slope Type	Area in Ha	Area %
1.	Nearly Level (0-1%)	67581	44.52
2.	Very Gentle Slope (1-3%)	75078	49.46
3.	Gentle Slope (3-5%)	3836	2.53
4.	Moderate Slope(5-10%)	1637	1.08
5.	Strong Slope (10-15%)	1079	0.71
6.	Moderately Steep Slope (15-35%)	1045	0.69
7.	Very steep slope (35-50%)	1544	1.02

Figure 3:



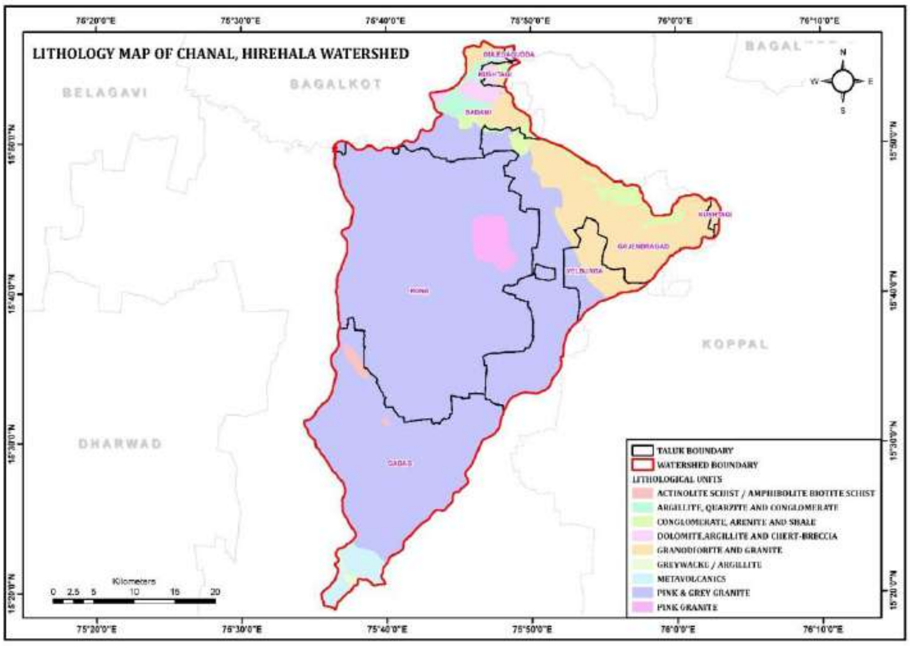
5. Geology:

Lithology guide of study region was arranged utilizing GSI map (Figure 4) as a base guide. 90% of Study region comprises granite which is an igneous rock (Table 4). Study area has uniform a lithology and is fundamentally permeable.

Table 4:

Sl No	Type	Area in Ha	Area %
1.	Pink & Grey Granite	115208.07	75.89
2.	Granodiorite and Granite	21665.63	14.27
3.	Conglomerate, Arenite and Shale	4202.90	2.77
4.	Metavolcanics	2862.99	1.89
5.	Pink Granite	2753.65	1.81
6.	Argillite, Quarzite and Conglomerate	2169.35	1.43
7.	Dolomite,Argillite and Chert-Breccia	2012.90	1.33
8.	Actinolite schist / Amphibolite Biotite Schist	631.14	0.42
9.	Greywacke / Argillite	293.86	0.19

Figure 4:



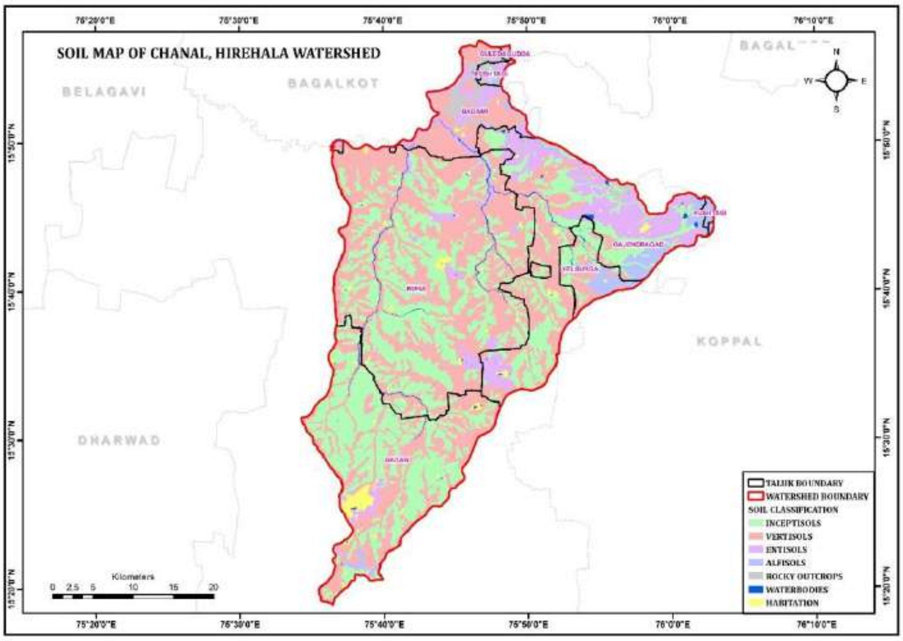
6. Soil:

The spatial dispersion of soils is displayed in the Figure-5. Classification of soils based on depends on US Department of Agriculture (USDA) classification. There are four significant soil types in the review region. Vertisols are the most ruling ones and involves around 45 % and spread over the downstream of the review region. This is trailed by inceptisols, entisols and alfisols. The rate dissemination of individual soil types is displayed in Table 5.

Table 5:

Sl No	Type	Area in Ha	Area %
1.	Vertisols	67802	44.67
2.	Inceptisols	56171	37.00
3.	Entisols	15321	10.09
4.	Alfisols	5036	3.32
5.	Rocky Outcrops	3468	2.28
6.	Built-up land	2561	1.69
7.	Water Bodies	1440	0.95

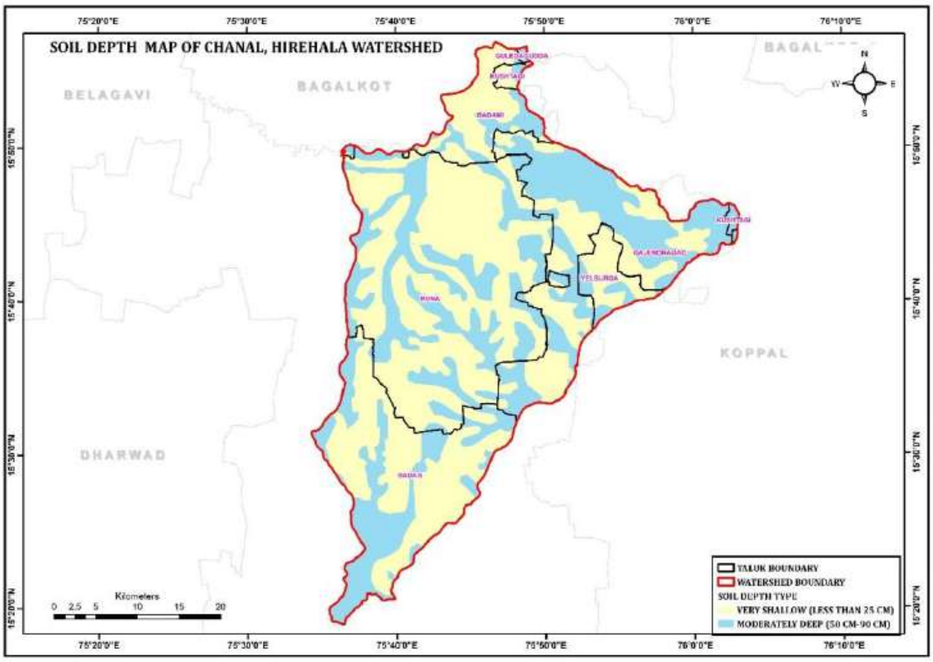
Figure 5:



7. Soil Depth:

Soil Depth can be characterized as soil profile from the top to parent material or bed rock. It contrasts altogether for various soil types. It is one of essential measure utilized in soil characterization. Soil depth is classified as are very shallow (under 25 cm), shallow (25 cm-50 cm), moderately deep (50 cm-90 cm), deep (90cm-150 cm) and very deep (in excess of 150 cm). Study region contains 2 kinds of profundity characterization I) very shallow (under 25 cm), which include 89,000 Ha (58%) and ii) moderately deep (50 cm-90 cm), which contains 62,800 Ha (42%). The spatial dissemination of soil depth is displayed in the Figure-6.

Figure-6:



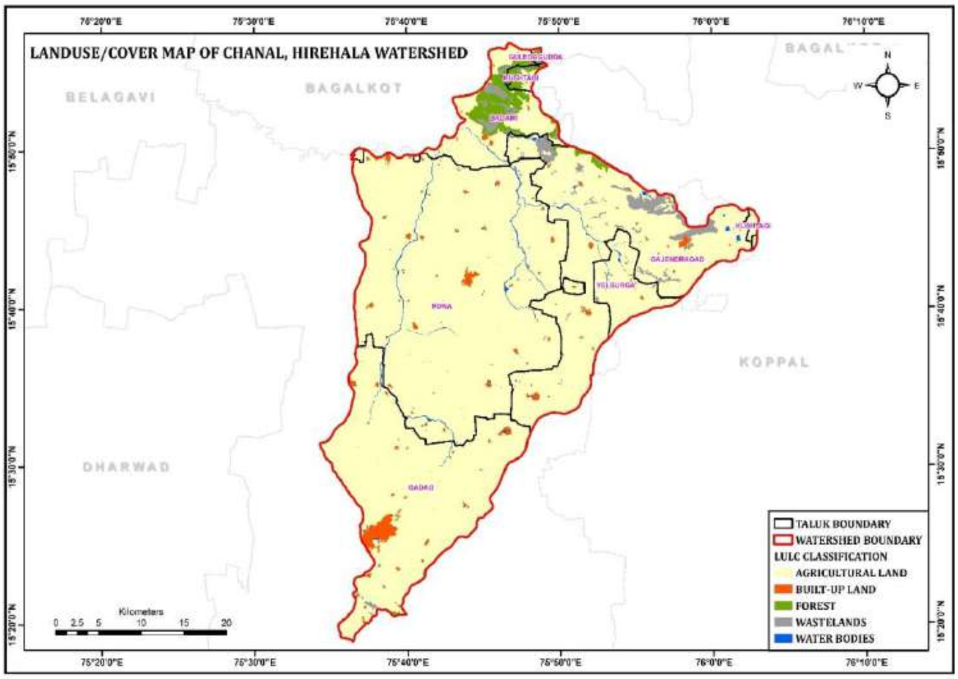
8. Land Use/Land Cover:

Land Use Land cover example of the study region is basic and contains Agriculture, Forest, Waste Land, Habitation and Water bodies. Significant piece of the study region is covered under Agriculture (92 %) trailed by waste Land (2.86%). The spatial distribution of the Land use is as displayed in Figure 7 and the geographical extents of the land use are displayed in (Table 6).

Table 6:

Sl No	Type	Area in Ha	Area %
1.	Agricultural land	139620	91.98
2.	Wastelands	4341	2.86
3.	Forest	3581	2.36
4.	Built-up land	2561	1.69
5.	Water Bodies	1416	0.93
6.	Others	281	0.19

Figure 7:



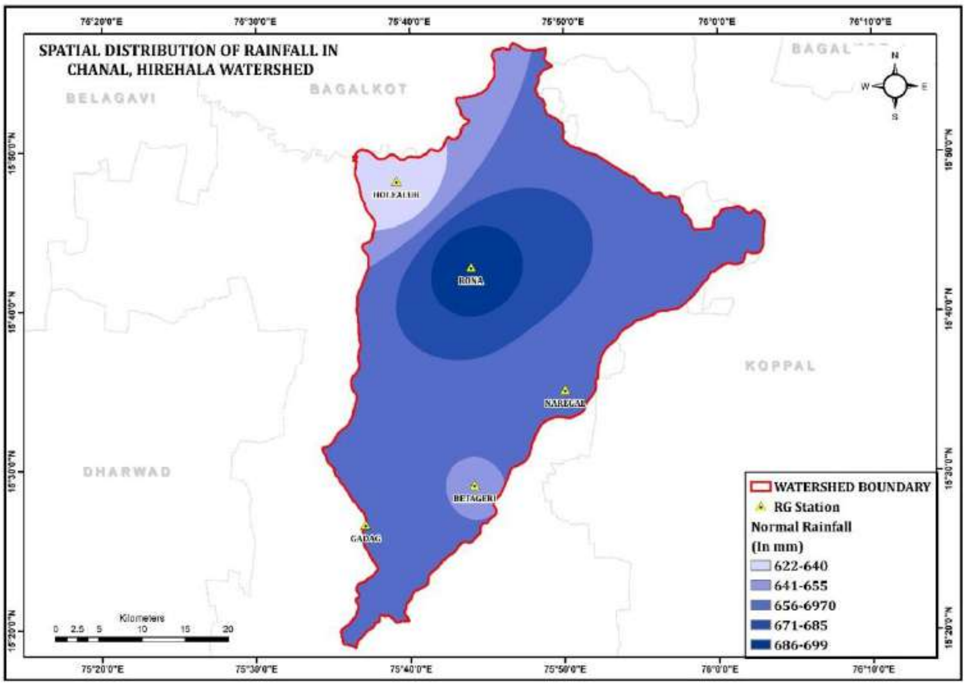
9. Rainfall:

Over 60% of precipitation is gotten during southwest rainstorm (June to September) and the rest from October to December. Spatial circulation of precipitation shows enormous varieties all around the study region. The precipitation received middle part of study region is fundamentally higher, while comparing to other region. Yearly annual precipitation is 659.9 mm (most noteworthy normal precipitation of 699.6 mm is from Rona Station and least is seen at Betageri Station 654.9 mm). The spatial dispersion of precipitation is displayed in Figure 8 and Station wise and season wise normal precipitation is show in Table 7.

Table 7:

Sl no	Station Name	Normal Pre-Monsoon Rainfall(in mm)	Normal Monsoon Rainfall(in mm)	Normal Post-Monsoon Rainfall(in mm)	Normal Annual Rainfall(in mm)
1.	Gadag	120.8	379	159.4	659.2
2.	Betageri	119.9	377	158	654.9
3.	Naregal	106.3	407	146.6	659.9
4.	Ron	113.5	432	154.1	699.6
5.	Hole Alur	94.2	387	141.6	622.8
Grand Total					**659.9**

Figure 8:



Runoff Estimation Using Empirical Methods:

In the event that precipitation power is more than the limit of soil penetration, a piece of precipitation would stream along the slant on the watershed surface and will be discharged by water bodies. This piece of precipitation which is quantifiable in the streams is called surface runoff (Alizadeh, 2009).

The assessment of runoff came about because of precipitation is prime significant in arranging and planning of water assets. Numerous specialists directed exploration to assess the surface runoff utilizing different empirical equations. Surface runoff measurement is one of main elements in hydrologic issues examination and water water resources management. In this review, empirical methods of runoff estimation are considered to appraise the runoff from catchment area of study region.

Assessment of runoff yield utilizing different empirical methods and strange's table was completed in the study area. Different empirical equations s, for example, Inglis and DeSouza, Khosla's Equation, Department of irrigation, India and Strange's table method were utilized for assessment of runoff. These exact conditions are depicted as follows:

1. **Inglis and DeSouza (1929)** developed two territorial formulae between yearly runoff R and yearly precipitation P in cm as follows (Subramanya, 2008):
   For Deccan plateau:
   $R = (\frac{1}{254}P) * (P - 17.8)$ (1)
   For Ghat regions of western India:
   $R = 0.85P - 30.5$ (2)

2. **Khosla's Equation:** In this technique, amount of monthly runoff is determined by following equation (Subramanya, 2008).
   $R_m = P_m - L_m$ (3)
   $L_m = 0.48\ T_m$ (4)
   Where, Rm is monthly runoff of watershed in cm, Pm is monthly precipitation in cm and Tm is mean monthly temperature in ˚C.

3. **Department of irrigation,India:** India Management of Reihand plan introduced the accompanying connection between how much yearly precipitation and runoff of Reihand Waterway (Gupta, 1992):
   $R = P - 1.17 \times P^{0.86}$ (8)
   Where, P is yearly precipitation in cm and, R is yearly runoff in cm.

4) **Strange's Tables:** Strange (1892) concentrated on the accessible precipitation and runoff in the border areas of present-day Maharashtra and Karnataka and has acquired yield proportions as elements of markers addressing catchment qualities. Catchments are named good, average and bad as indicated by the general sizes of yield they give. For instance, catchments with great vegetative cover and having soils of high penetrability would be delegated as bad, while catchments having soils of low porousness and having practically zero vegetative cover is named good. Technique for assessing the runoff volume in season is given (Subramanya, 2008). The correlation equation of best fitting lines relating yield proportion (Yr) to precipitation (P) could be communicated as,

Strange's table method

For *Good* catchment:			
For P<250 mm,	$Y_r = 7 \times 10^{-5} P^2 - 0.0003P$	$r^2 = 0.9994$	…(9a)
For 250<P<760 mm,	$Y_r = 0.0438P - 7.1671$	$r^2 = 0.9997$	…(9b)
For 760<P<1500mm,	$Y_r = 0.0443P - 7.479$	$r^2 = 1.0$	…(9c)
For *Average* catchment:			
For P<250 mm,	$Y_r = 6 \times 10^{-5} P^2 - 0.0022P + 0.1183$	$r^2 = 0.9989$	…(10a)
For 250<P<760 mm,	$Y_r = 0.0328P - 5.3933$	$r^2 = 0.9997$	…(10b)
For 760<P<1500mm,	$Y_r = 0.0333P - 5.7101$	$r^2 = 0.9999$	…(10c)
For *Bad* catchment:			
For P<250 mm,	$Y_r = 4 \times 10^{-5} P^2 - 0.0011P + 0.0567$	$r^2 = 0.9985$	…(11a)
For 250<P<760 mm,	$Y_r = 0.0219P - 3.5918$	$r^2 = 0.9997$	…(11b)
For 760<P<1500mm,	$Y_r = 0.0221 - 3.771$	$r^2 = 0.9997$	…(11c)

Where, Y_r = Percentage yield ratio = ratio of runoff to rainfall in percentage and P = Rainfall in mm.

Correlation Analysis of Empirical Methods for Runoff Estimation:

In this current review empirical methods such as, Inglis and DeSouza Method, Khosla's Method, Department of Irrigation, India and Strange's table method have been utilized to appraise the runoff for the review region utilizing precipitation information of 20 Years (2000-2020). The runoff assessed by different methods was looked at. The outcome got from the examination utilizing different exact strategies is displayed in Tables 8 and 9. The outcomes got from Department of Irrigation, India and Strange methods are are somewhat nearer and the outcome got from the Inglis and DeSouza method is marginally lower than the outcomes got from the Department of Irrigation, India and Strange methods, while results acquired from Khosla's method is generally higher than different methods. The variety between every one of the methods for runoff assessment against precipitation is graphically displayed in Figures 9 and 10.

Table 8:

Sl No	Year	Average Annual Rainfall in mm	Inglis and DeSouza formula (in mm)	Khosla's Formula (in mm)	Department of irrigation, India (in mm)	Strange's table method (in mm)	Averag of All (in mm)
1	2000	808.75	200.83	683.95	297.18	283.49	366.36
2	2001	561.85	84.91	437.05	187.86	174.42	221.06
3	2002	483.85	58.26	359.05	154.97	140.26	178.13
4	2003	396.1	34.01	271.3	119.22	101.82	131.58
5	2004	593.6	97.13	468.8	201.51	188.33	238.94
6	2005	727.25	157.26	602.45	260.34	246.86	316.72
7	2006	518.6	69.54	393.8	169.51	155.48	197.08
8	2007	902.75	257.59	777.95	340.44	325.13	425.27
9	2008	845	221.9	720.2	313.77	299.55	388.85
10	2009	1005.1	327.29	880.3	388.38	370.47	491.61
11	2010	987.5	314.72	862.7	380.08	362.67	480.04
12	2011	518.42	69.48	393.62	169.43	155.4	196.98
13	2012	492	60.82	367.2	158.36	143.83	182.55
14	2013	658.98	124.79	534.18	230.02	216.96	276.48
15	2014	743.3	165.43	618.5	267.54	253.89	326.34
16	2015	478.34	56.56	353.54	152.68	137.84	175.15
17	2016	376.76	29.48	251.96	111.54	93.35	121.58
18	2017	519.2	69.74	394.4	169.76	155.74	197.41
19	2018	449.98	48.18	325.18	141	125.42	159.94
20	2019	690.52	139.33	565.72	243.96	230.78	294.94
21	2020	783.5	186.78	658.7	285.69	272.3	350.86

Figure 9:

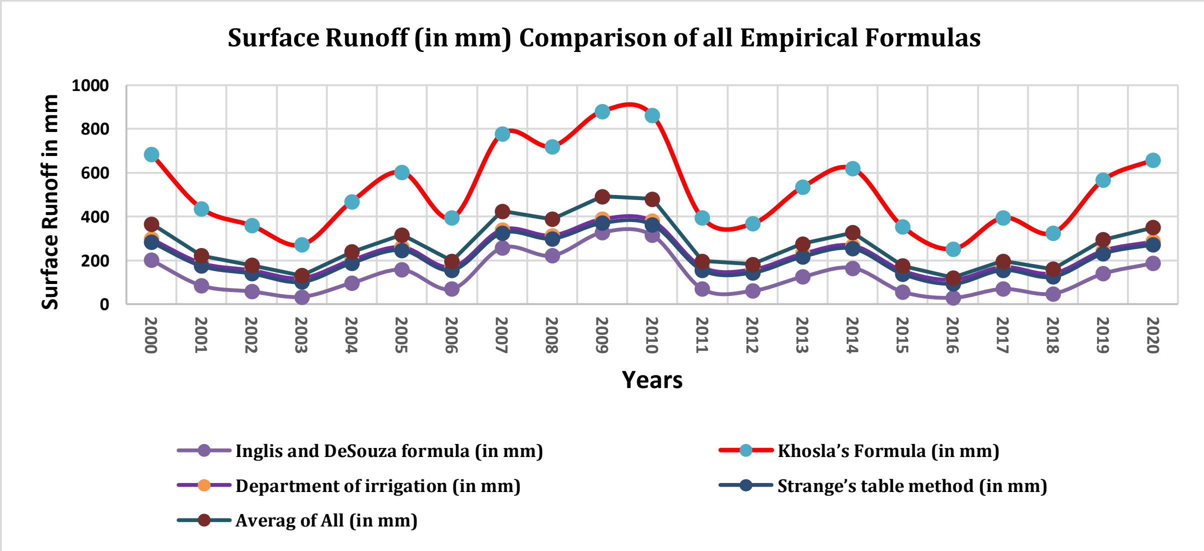
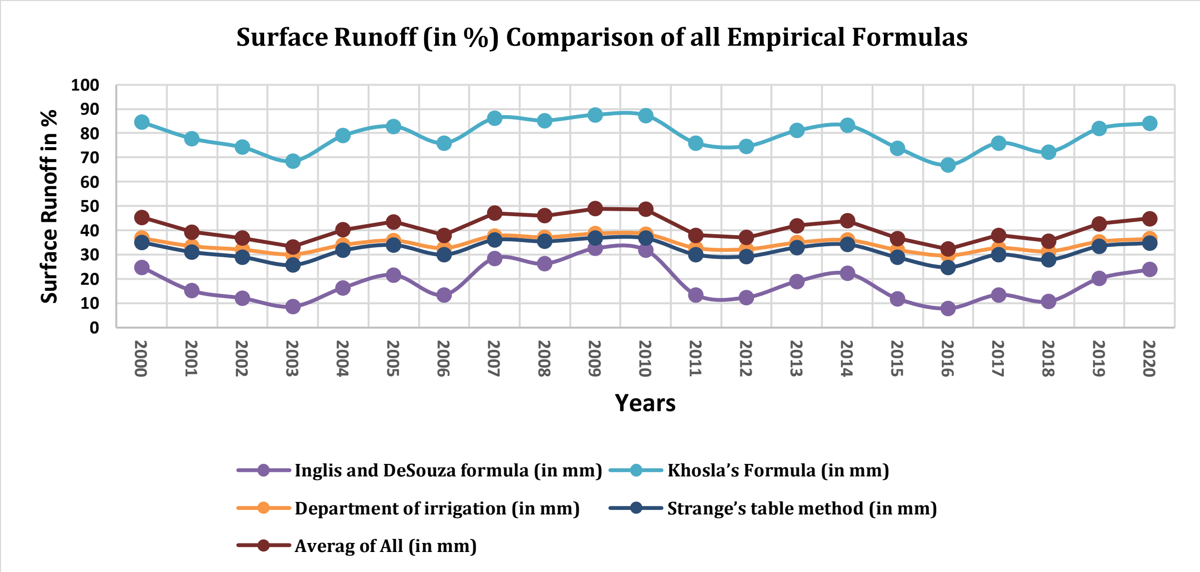


Table 9:

Sl No	Year	Average Annual Rainfall in mm	Inglis and DeSouza formula (in %)	Khosla's Formula (in %)	Department of irrigation, India (in %)	Strange's table method (in %)	Averag of All (in %)
1	2000	808.75	24.83	84.57	36.75	35.05	45.30
2	2001	561.85	15.11	77.79	33.44	31.04	39.35
3	2002	483.85	12.04	74.21	32.03	28.99	36.82
4	2003	396.1	8.59	68.49	30.1	25.71	33.22
5	2004	593.6	16.36	78.98	33.95	31.73	40.26
6	2005	727.25	21.62	82.84	35.8	33.94	43.55
7	2006	518.6	13.41	75.94	32.69	29.98	38.01
8	2007	902.75	28.53	86.18	37.71	36.02	47.11
9	2008	845	26.26	85.23	37.13	35.45	46.02
10	2009	1005.1	32.56	87.58	38.64	36.86	48.91
11	2010	987.5	31.87	87.36	38.49	36.73	48.61
12	2011	518.42	13.4	75.93	32.68	29.98	38.00
13	2012	492	12.36	74.63	32.19	29.23	37.10
14	2013	658.98	18.94	81.06	34.91	32.92	41.96
15	2014	743.3	22.26	83.21	35.99	34.16	43.91
16	2015	478.34	11.82	73.91	31.92	28.82	36.62
17	2016	376.76	7.82	66.88	29.61	24.78	32.27
18	2017	519.2	13.43	75.96	32.7	30	38.02
19	2018	449.98	10.71	72.27	31.33	27.87	35.55
20	2019	690.52	20.18	81.93	35.33	33.42	42.72
21	2020	783.5	23.84	84.07	36.46	34.75	44.78

Figure 10:



CONCLUSION:

From the incorporated examination of the morphometric parameters of the watershed, it is reasoned that the study area displays a dendritic drainage pattern. There is a slight variety in stream length ratio and bifurcation ratio as there are no massive changes in the slope and geography of the study region. Stream frequency of the watershed shows a positive connection with drainage density. Low drainage density in the study region shows profoundly permeable subsoil and thick vegetation cover and coarser surface. Elongation ratio of the study region shows that the watershed is more elongated with a delicate slope and low relief. The circulatory ratio of the watershed shows that there is a low discharge and high sub-surface penetrability. The total morphometric examination of the watershed showed that the given region has moderate to good groundwater possibilities.

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