International Journal of Engineering, Science and Mathematics
Vol. 13 Issue 4, April 2024,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

MORPHOMETRY STUDY OF HIREHALLA SUBWATERSHED, CHCCODI TALUK, BELAGAVI DISTRICT, OF GHATAPRABHA SUBBSAIN-K3

Gururaj Bandihal [1], V.S.Soraganvi [2], Purundara B.K [3], Basappa Meti [4],

1. Assisstant Professor, department of Civil Engineering, Basaveshwar EngineeringCollege, Bagalkote., Karnataka State, india.
2. Principal and Guide, Basaveshwar Engineering College, Bagalkote.Karnataka stateIndia.
3. CEO, Wateresearch, PVNAKSHAK, Belagavi.
4. Associate Professor, Department of Civil Engineering, Government EngineeringCollege, Haveri. Karnataka state India.

Abstract:

Morphometry is the measure of geometry of a watershed, in terms of size, shape, of watershed streams of different orders and relief of watershed.This is the basic requirement forany research on water resources and hydrology, related to any watershed, wherein, the data from morphometry is used for watershed prioritization, planning etc... This is needed for planning and design of hydraulic structures. Morphometry, involves measuring of length of streams of different orders , and using this preliminary data, secondary parameters like stream length, bifurcation ratio, elongation ratio and other catchment parameters will be determined. For, this, now, advanced methods like Remote sensing and Geographical Information Systems (GIS), can be used. These techniques are used, to extract streams , geological data and other relevant thematic layers required for morphometry mapping of watershed. RS and GIS provide economical and scientific means of data collection, required for morphometry mapping of any watershed. Through RS, the surface features related to geology such as rock type, lineaments, rock texture variation etc... can be extracted and these can be integrated in GIS , with DEM or contours. Thus, height variation, along with geological and soil features can be studied on a common platform and scale. Through remote sensing and GIS, it is possible to collect streams alignment and geometry, geology, geomorphology and soil data on larger scale, spread

spatially, in less time, through economical means. Thus, in this paper, an approach is made to carry out morphometry study of a sub watershed, using Remote sensing and GIS approach, and also, relate the effect of morphometry on runoff, which would providean estimate of the capacity of water harvesting structures needed in the sub watershed.

1.0 Introduction

Morphometry is useful in study of stream or river geometry, which indirectly indicates about the water resources availability and drainage density patterns of any watershed. A watershed is the high elevation ridge covering or sorrounding network of streams or drains, with area more than 10,000 sqkms. A sub watershed is an area of high elevation ridge line covering or sorrounding a tributary or drain of length less than 30km, with an area more than 400 sqkm.In the current work, a sub watershed, Hirehalla subwatershed, Ghataprabha Sub basin, Ciccodi Taluk, Belagavi district, with an area 460 sqkms is considered.

Morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimensions of its landforms (Clarke 1996). The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). The measurement of various morphometric parameters namely- stream order, stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), mean bifurcation ratio(Rbm), relief ratio (Rh) drainage density (D), stream frequency (Fs) drainage texture (Rt), from factor (Rf), circulatory ratio (Rc), elongation ratio (Re) length of overland flow (Lg) has been carried out

2.0 Objectives:

i.Morphometry mapping of study area
ii.Rainfall runoff analysis using Runoff coefficient and stranger method
iii.Determination of time of concentration of runoff at the basin outlet

3.0 STUDY AREA DESCRIPTION

The Study area is a sub watershed (CODE: 4D5D4) lies in Ghataprabha Sub BasinBelagavi district of Karnataka state, India and is surrounded by Raaibagh, Ciccodi, Gokak and Hukkeri taluks. The geographic location of the study area is in between 74.5 degrees East ,16.4 degrees North to 75 degrees East , 16.33 degrees North. The Size of the study area is 460 sqkms, consists of 6 **mini water sheds (4D5D4K, 4D5D4J, H, G, D, F)** , 37 micro water sheds, and 75 villages with about 2.5 lakhs population throughout the entire sub watershed.. Annual Rainfall of the study area ranges from 320mm to 661mm. There are 685 1ST ORDER STREAMS, 3 3rd order and 1 4th order stream running throughout the sub watershed.

Majority area of the sub watershed is covered under cropland, of around 350 square kilometres. There are around 1472 open wells in the study area (KSRSAC data).

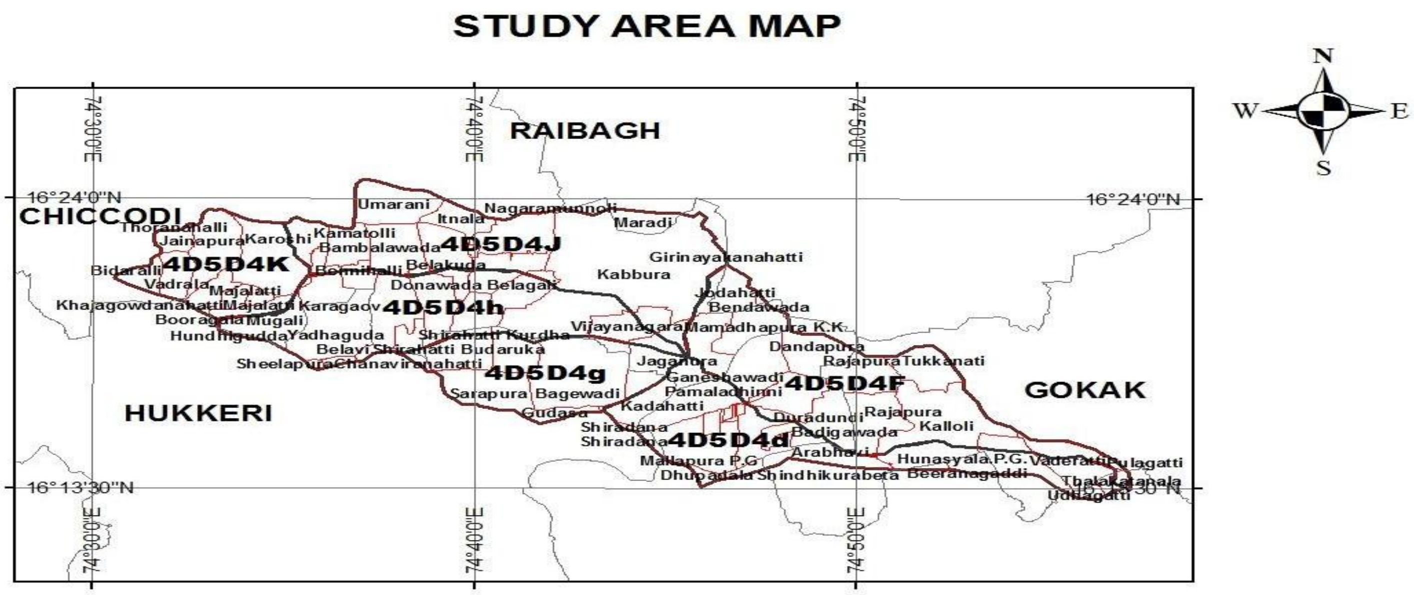

FIGURE-1- STUDY AREA LOCATION MAP

Table-1-Morphometric Parameters of HireHalla –Sub watershed –Gokak Taluk

Parameter	Equation
Linear	
Stream Order (Strahler,1964)	Hierarchical Rank
Stream Number (Horton,1945)	Nu,No of Streams
Stream Length (Horton,1945)	Lu, Length of Streams
Mean Stream Length (Lsm) (Schumn, 1956)	Lsm=Lu/Nu
Stream length ratio (Horton,1945)	RL=Lu/Lu-1
Bifurcation Ratio (Rbm) (Schumn, 1956)	Rb=Nu/Nu+1; where, Nu=Total number of stream segment of order'u',Nu+1=Number of segment of nexthigher order.
Areal	
Drainage Density (Dd) (Horton, 1932)	Dd=L/A; where, L=Total length of streams; A=Area ofbasin
Stream Frequency (Fs) (Horton, 1932)	Fs = N/A; where, N=Total number of streams; A=Areaof basin
Drainage Texture (Rt) (Horton, 1932)	Rt = N_1/P ; where, N_1=Total number of first order streams, P=Perimeter of basin.
Form factor (Rf) (Horton, 1932)	$Rf=A/(Lb)^2$; where, A=Area of basin; Lb=Basin length
Circulatory ratio (Rc) (Miller, 1953)	$Rc=4\pi A/P^2$; where, A=Area of basin,, π=3.14,P=Perimeter of basin
Elongation ratio (Re) (Schumn, 1956)	$Re=2\sqrt{(A/\pi)}/Lb$; where, A=Area of basin, π=3.14, Lb=Basin length
Compactness Coefficient (Cc) (Horton, 1945)	Cc = 0.2821 x P/ $A^{0.5}$ Where, A= Area of the basin,km2 P= Basin perimeter, km

Relief	
Maximum Basin Height(H)	H
Minimum Basin Height(h)	h
Basin relief (Bh) (Schumm, 1956)	Bh=H-h
Relief Ratio (Rh) (Schumm, 1956)	Rh=Bh/Lb,whereBh Basin Relief, Lb=Length of Basin
Ruggedness Number (Rn) (Schumm, 1956)	Rn=Bh*DdwhereBh Basin Relief,Dd=Drainage Density

3.1 Materials and Methods

Data Used: SOI topo sheets 1:50000 scale, KSRSAC shape files of Study area villages, and drainage map, geomorphology and soil shape files from KSRSAC.

3.1.1 Methodology:

1.Delineation of sub watershed boundary: Done in ARC GIS 10.0, using Hydrology option in ARC tool box, here, DEM (CARTOSAT-1) was given as input, here WATERSHED DELINIATOR COMMAND was used.

2.Delineation of Micro watershed Boundary: Using drainage shape files of KSRSAC and DEM in watershed delineator, Micro watershed boundaries were derived.

3.Stream Ordering: The shape files of drainages were quantified with stream orders, for thisSOI top sheets were alslo referred.

4.Runoff Calculation: The runoff coefficients were obtained for various land use types, soil types and slope (S.K..Garg Hydrology and water resources Engineering 2005 edition, page no 299) In Arc GIS, first the LU map was clipped WRT slope map of 5% and 10% respectively and thus, the average runoff coefficients were calculated. As Average runoff coefficient (ARC)= 0.4 (Runoff coeff for 5% slope) X settlement area + 0.3 (runoff coeff for 5% slope) X cultivable area+ 0.1 (runoff coeff for 5% slope) X open land area + 0.1 (runoff coeff for 5% slope) X Forest area or plantations area./ Total area of sub watershed. These areas are obtained by clipping LU map with slope map. Similar procedure is done for 10% slope also.The same procedure is repeated for runoff coefficient calculation for soil also

5.For calculation of time of concentration (TC), mannings formula V= (1/n) X (S^1/2) X (r^2/3) is used, where, S is basin slope, r is wetted perimeter, V – velocity of flow. To obtain data of slope, n and wetted perimeter, ARC GIS software was used. Using Velocity of flow, TV was calculated. TC=T0 + TV, T0 base flow, TV flow during full discharge in thestream.

3.1.2 SLOPE:

50% geographical area of the district falls under flat slope (0-3%), 20 % under very gentel slope (3-5%), 20% under moderate slope (5-8%) and 10% under steep slope (8% to 15%), the flat, slope, gentel and very gentel slopes are present at distance upto 15km away from the stream and major drain of the study area, Hirehalla, Slope % will play prominent role in Ground water potential, Ground water recharge, site selection for water harvesting structures, infiltration capacity. Flatter slopes result in formation of more number of 1st order streams, moderate and steep slopes result in 2nd order, 3rd order and 4th order streams, More area under flatter slopes indicate, more number of 1st order streams.

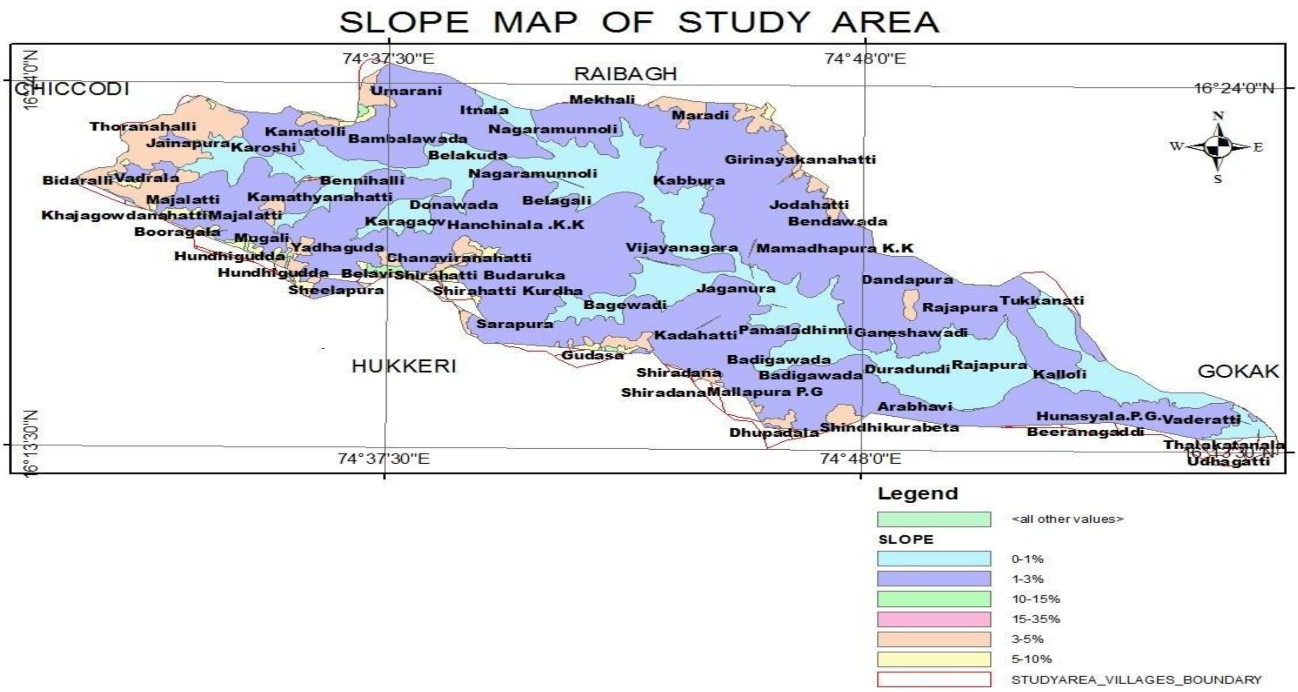

FIGURE-2- STUDY AREA SLOPE MAP

3.1.3 DRAINAGE:

There are in total, 655 1st order streams, 355 2nd order streams, 39 3rd order and 5 4th order streams and in total, the strem length of all streams is 811km. The average drainage density (km/sqkm) of the study area is 1.5km/sqkm. High drainage density is observed for Miniwatershed 4D5D4G (1.84 km/sqkm) and low draianage density is observed in mini watershed 4d5d4j (1.30 km/sqkm), much difference in the max and minimum drainage densities is not observed, since, maximum portion of the study area is under flat terrain. Drainage density is the direct indicator of Ground Water Potential (GWP) zones and recharge zones. Higher drainage density indicates lower potential of Ground Water Recharge zones (GWR) and GWP, but however, it contributes for runoff. All drainages follow dendritic pattern of drainage system in the study area. There is also, Variation in the stream length of different orders in study area reveal that there is a variation in slope and topography. The length ratio < 2, indicate potential for small water harvesting structure construction and stream length ratio >2, indicate more potential for large water harvesting structures.

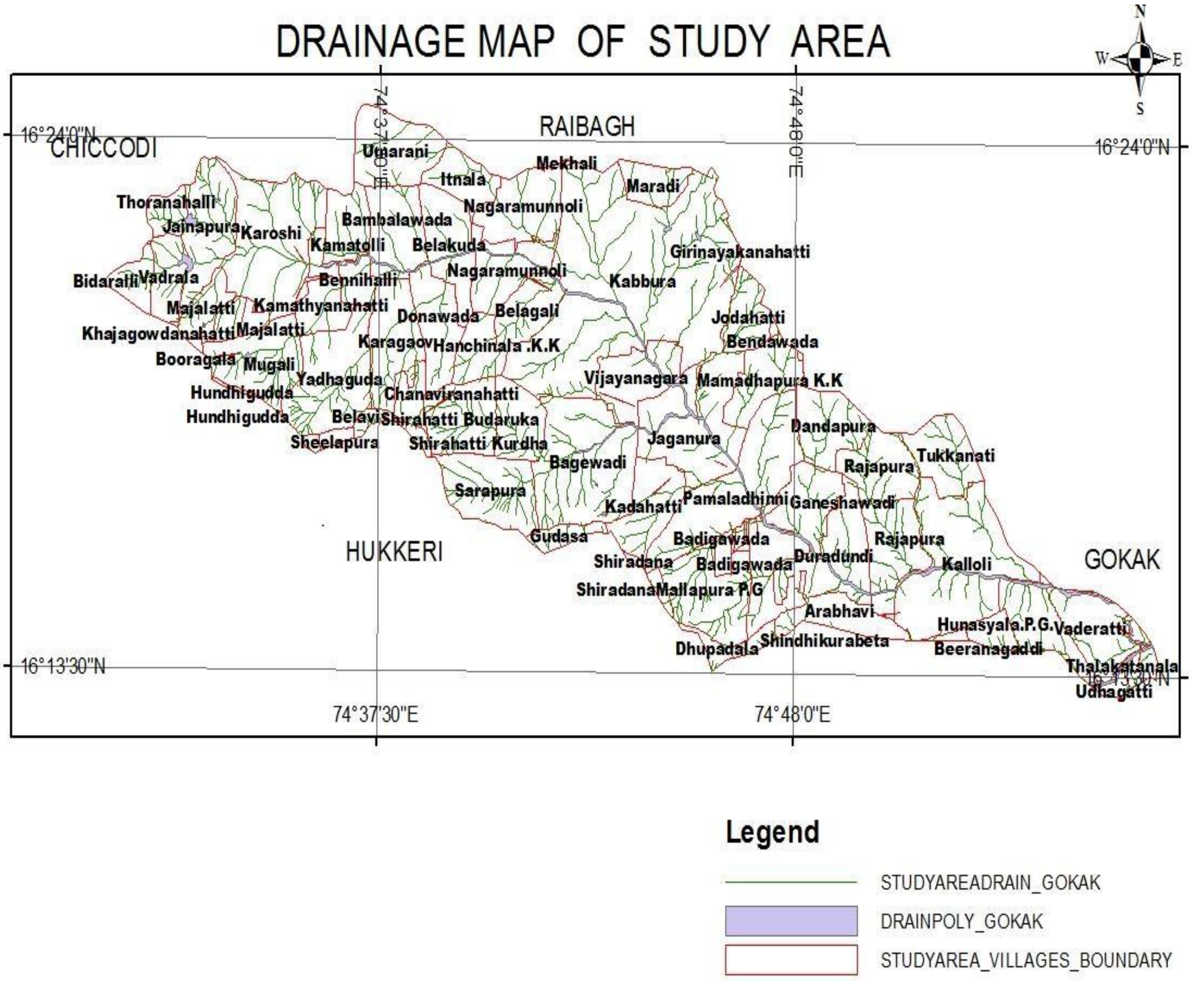

FIGURE-3- STUDY AREA DRAINAGE MAP

3.1.4 LINEAMENTS:

These are the deep geological structures which indicate discontinuity in the rock formation in linear fashion These extend to several meters below the ground level and these form good basis for ground waterpotential and also higher lineament density leads to the formation of higher number of 4^{th} order streams.

3.1.5 SOIL :

Soil plays important role in runoff and permiability. Clayeysoils have high runoff and low permiability. Sandy and loamy soils have high permiability, but low runoff. The soil types in the study area are loamy soils and clayey soils, majority soils are clayey soils covering 55% of the total area.

3.1.6 RAINFALL:

Rainfall varies from 350mm to 661mm annually throughout the study area. Maximum rainfall occurs in the month of august and this is widely Since, majority of the study area is under flat slope and fine soil, there is less contribution for runoff from the rainfall. Some portion of rainfall naturally recharges Ground water table.

4.0 RESULTS AND DISCUSSIONS

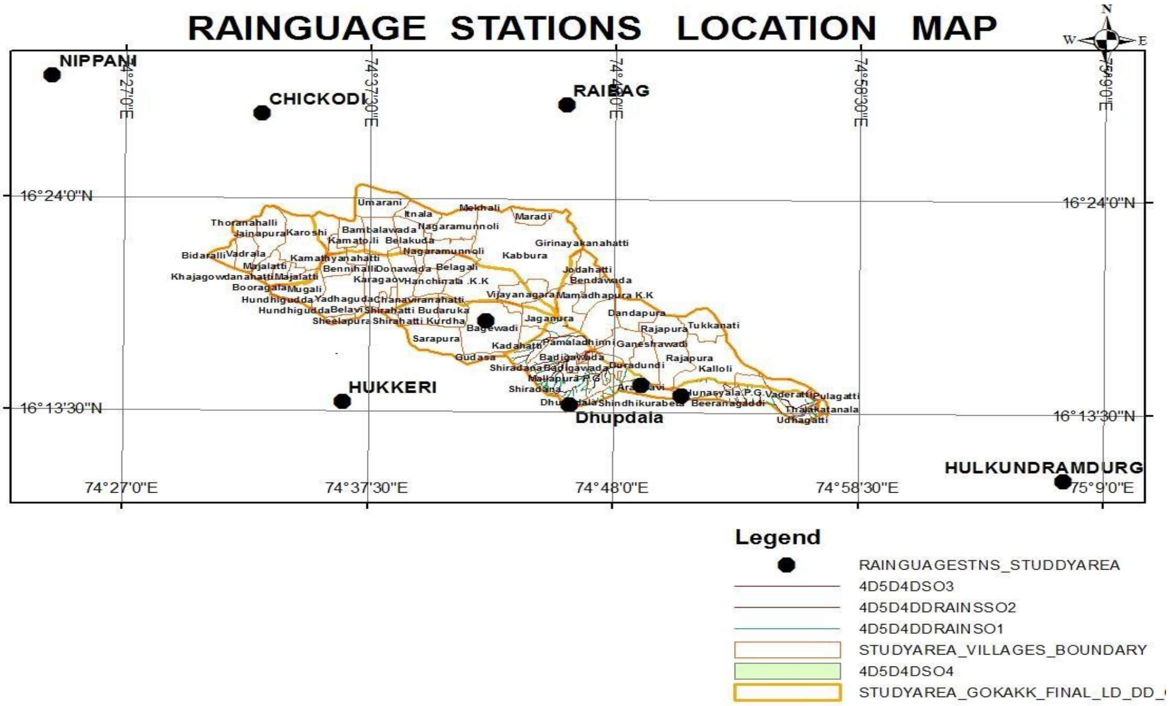

FIGURE-4- STUDY AREA RAIN GAUGE STATIONS MAP

4.1.1 RESULTS

MORPHOMETRY TABLES
Linear aspects of Study Area
Stream Order

TABLE-1 –STREM LENGTH AND ORDER

Area in km²	Length (km)(TOTAL PERIMETER)	Stream orders (U)							Stream lengths (Lu) KM						
		1	2	3	4	5	6	Total	1	2	3	4	5	6	Total
460	201	675	355	39	5	0	0	1074	495.6	237.184	27.249	51.7	0	0	811.73

TABLE-2 –MEAN STREAM LENGTH IN KM

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
3.021	2.73	3.302	51.7	0	0	**15.18**	1.99	0.38	24.03	0	0	**8.80**

TABLE-3 –AREAL ASPECT AND BIFURCATION RATIO

Areal Aspect of Study Area

Drainage Density Km/Km^2	**Drainage Texture**	**Stream Frequency**	**Elongation ratio**	**Circularity ratio**	**Form factor**	**Compactness Coefficient**
1.53	14.7(14.7/6=2.5)	15.61 (avg stream freq of 6 miniwater sheds=15.61/6=2.43)	0.42 (0.42=2.5/6)	0.45	0.18	1.6

TABLE-3A –AREAL ASPECT AND BIFURCATION RATIO

Bifurcation ratio (Rb)					
Rb 1/2	**Rb 2/3**	**Rb 3/4**	**Rb 4/5**	**Rb 5/6**	**Mean Bifurcation ratio (Rb)**
1.84	33.3	5.74	0	0	**13.71**

TABLE-4 –RELIEF ASPECT

Relief Aspect of Study Area

Elevation in 'm'		**Basin relief**	**Relief ratio**	**Ruggedness Number**
Max 'H'	Min 'h'	**(Bh)**	**(Rh)**	**(Rn)**
780	533	247	0.00475	331.23

4.1.2 RAINFALL RUNOFF CORRELATION

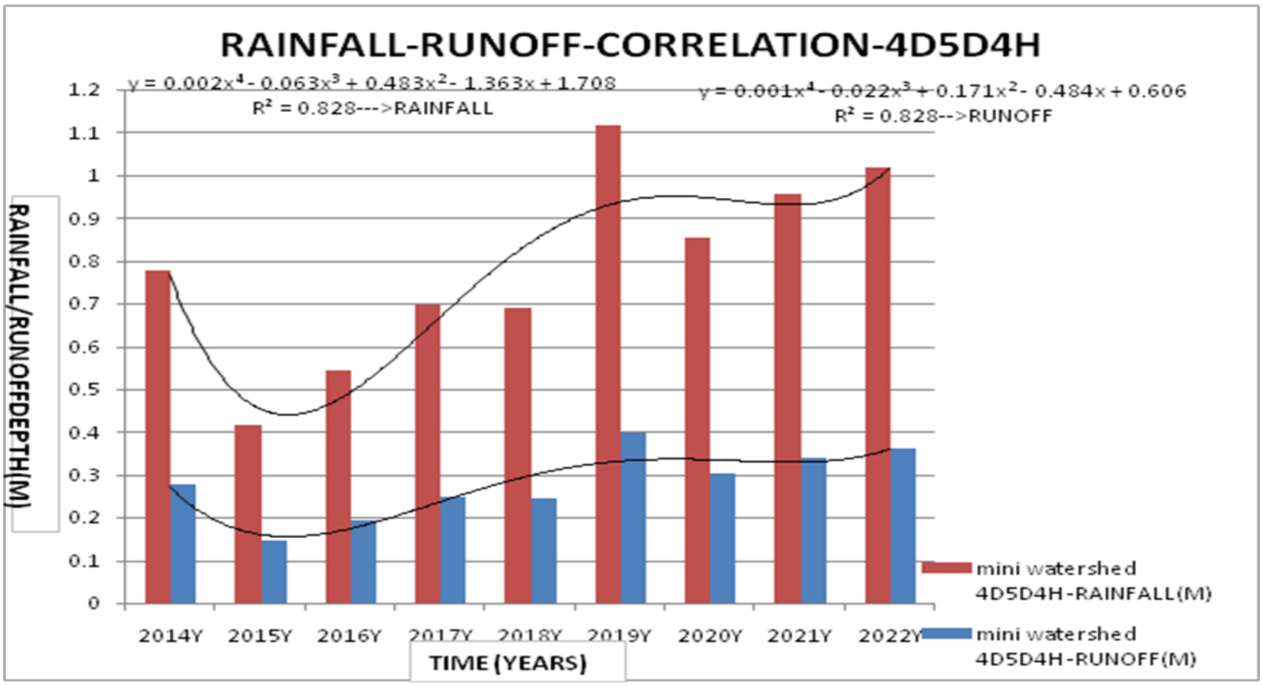

FIGURE-5- RAINFALL RUNOFF CORREELATION -4D5D4H

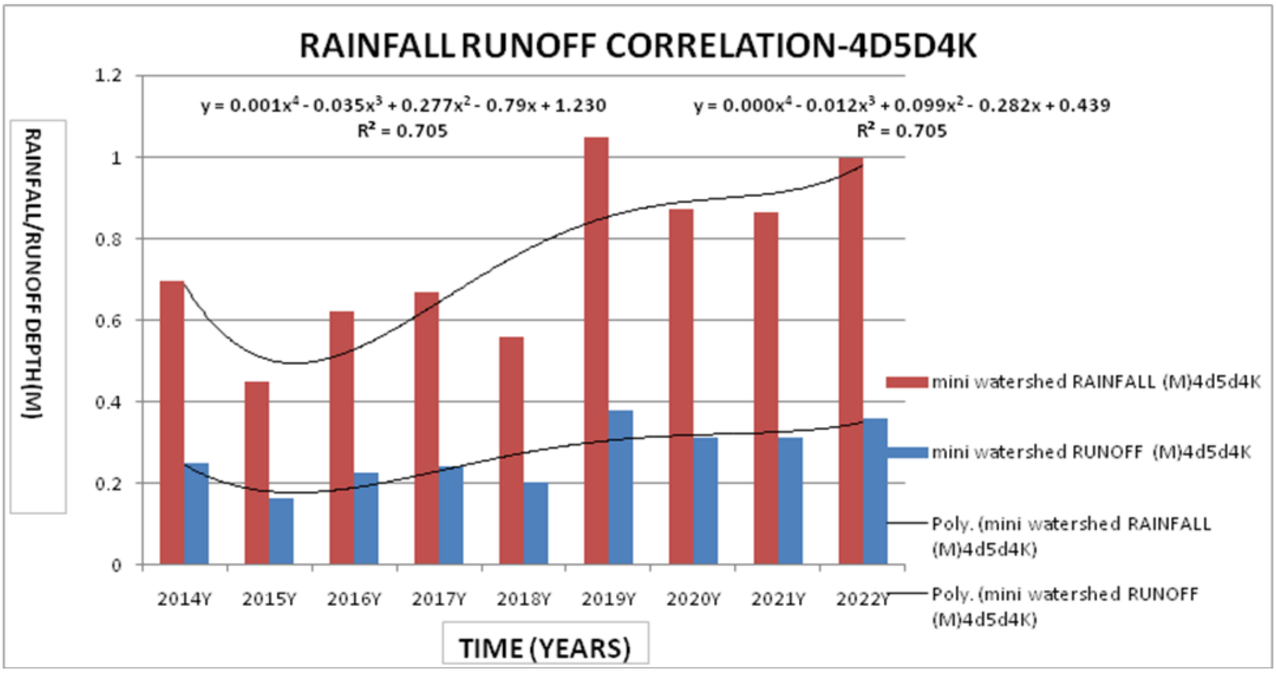

FIGURE-6- RAINFALL RUNOFF CORRELATION-4D5D4k- MINI WATERSHED

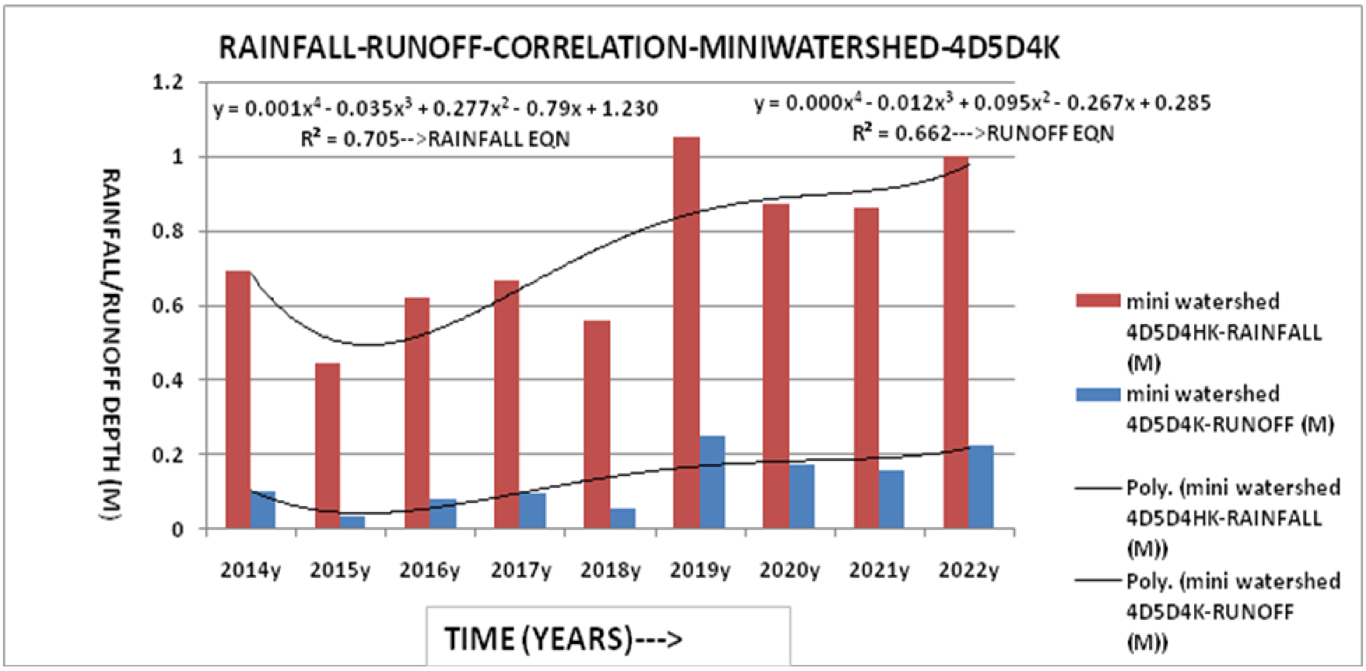

FIGURE-7- RAINFALL RUNOFF CORRELATION-4D5D4k- MINI WATERSHED

4.1.3 COMPARISION OF RUNOFF VOLUME BETWEEN RUNOFF COEFFCIENT METHOD AAND STRANGER METHOD (average rainfall of all mini watersheds and total runoff volume, average runoff coeff , 6nos mini watersheds)

TABLE-5 –Comparison of Runoff Volume by Runoff Coefficient and Stranger Methods

Sl.No	1	2	3	4	5	6	7	8	9
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Rainfall **(mm)**	634	352	438	590	486	946	790	795	972
Runoff Volume (Runoff coeff method)(mcum)	92	51	64	87	71	143	116	117	144
Runoff Volume (Stranger method)(mcum)	41	10	20	35	24	108	65	67	100

From, above table, it is clear that, Stranger method yields comparatively low runoff volume compared to runoff coefficient, this is for the reason that, in Stranger Runoff Percentages table, for medium rainfall of the order, 250mm to 1250mm, the runoff percentages are low. Hence, total runoff volume will be reduced in the sub watershed.

5.DISCUSSIONS:

Stream Order (U):
I)In the present study area (Hirehalla watershed) more number of 1st order streams are present (675), followed by 2nd order stream (355) . The number of 3rd and 4th orderstreams are 39 and 5 respectively, this shows lower runoff potentiality.

II)Stream Length (Lu): The stream length varies from 1.99 to 24, this shows abruptness variation in topography. The total length of stream segments is higher in 1st order 496 KM and minimum in 3rd order, 28 km .This shows good occurance and rechargability of ground water at the lower level of the subbasin .

III)Stream Length Ratio: The stream length ratio varies from 0.49 to 4.81. Variation in stream length of different orders in study area reveals that there is a gradual variation in slopeand topography.

IV)Bifurcation Ratio (Rb):

Bifurcation ratio varies from 4 to 5.77. Bifurcation ratio is not same from one order to itsnext order.

V)Drainage Density (Dd): It is found that in the present study area it is low (1.5 km/sqkm) that is a characteristic of highly permeable subsoil and thick vegetative cover (Nag &Chakraborty, 2003) and low runoff

VI)Stream Frequency (Fs):

Table-6-Relation between Stream Frequency and Drainage Density at Mini watershed Level

Drainage Density	Stream Frequency	Mini Watershed Code
1.486	2.3	4D5D4F
1.84	3.2	4D5D4G
1.504	**2.87**	**4D5D4H**
1.304	1.68	4D5D4J
1.723	3.02	4D5D4K
1.32	2.33	4D5D4D

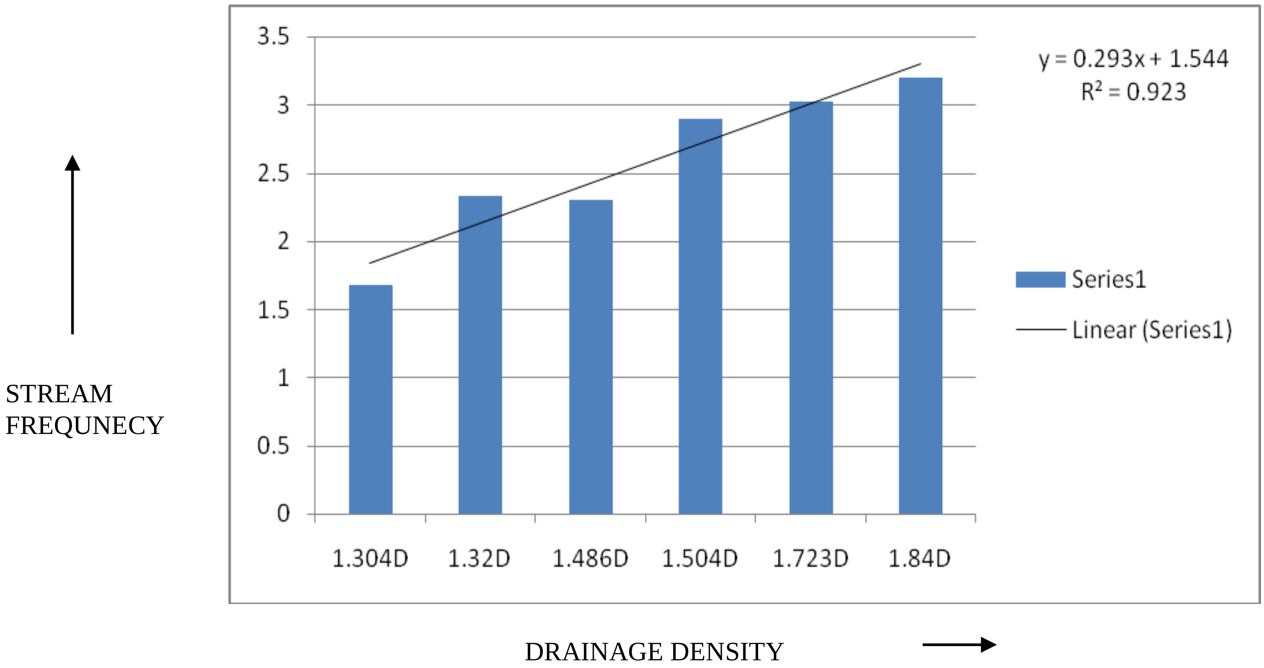

FIGURE-8- Graph Showing Relation between Stream Frequency and Drainage Density atMini watershed Level

From bar graph and map, it is evident that, subwater shed 4d5d4g is having more drainage density of 1.84, so here stream frequency is high 3.2, but 4d5d4j, is having less drainage density 1.3, so stream frequency s low for this mini watershed

VII)Drainage Texture (Rt):

In the present study area, the drainage density is 1.53 and the drainage texture is 2.5 (average), 14 (total water shed), but varies from 2.5 to 4 throughout the mini watershed.

Hence, the texture is coarse to moderate. So, ground water recharge potential is moderate throughout the sub watershed

VIII)Elongation Ratio (Re):
The elongation ratio of the study area is 0.42, indicating moderate infilteration capacity of thesub watershed.

IX)Circulatory Ratio (Rc): In the given study area, the circularity ratio is 0.42 indicateslow discharge and moderate subsurface permeability.

X)Form Factor (Rf):

The Form factor of sub watershed is 0.18 (average) which indicates that the catchment is elongated and therefore a flatter peak flow for longer duration is observed.

XI)Compactness Coefficient (Cc):

Compactness coefficient of study area is 1.6 and average compactness factor is 0.267 (average of 6 miniwatersheds)

XII)Basin relief (Bh):

In the present study area, the maximum height (H) is 780 m and minimum height (h) is 563m. Therefore, the relief of the basin is 207 m=780-563.

XIII)Relief Ratio (Rh):

High values of relief ratio indicate steep slope and low relief indicate flat slope. Runoff is faster in steeper basins, producing less peaked basin recharge and greater erosive power (Palaka& Shankar, 2016). In the present study area Rh is 0.0027 (1:371 gradient), hence, the present study area is flat.

XIV)Ruggedness Number (Rn):

The value of present study area is 310.5m, which has gentle slope and suggests less prone to soil erosion (Schumm, 1956).

XVGeology:

Litho logy map of the study area was prepared using Central Ground Water Board map of Belagavi district.. Study area compromises about 90% of basalt Rocks which is an igneous rock. Study area has uniform lithology and is structurally permeable.

XVI**CALCULATION OF DETENTION TIME**:

Detention time refers to the time at which water is retained in the drainage or stream bed, after, runoff ceases. Higher detention time, indicates higher inflow to ground water table. This is needed to determine discharge to storage structures like check dam.

Table-7- Calculation of Detention Time

Sl No	**Mini WATER SHED CODE**	**Mini Watershed area (sqkm) A (1)**	**Runoff Coeffcient K (2)**	**Rainfall mm P (3)**	**Runoff Depth=KP (4)**	**Runoff Volume = KAP (5)**
1	4d5d4G	50.34	0.33	962	0.32	16237748.56
2	4D5D4H	80.05	0.36	1016	0.37	28878723.44
3	4d5d4K	41.44	0.36	998	0.36	14772527.19
				Total (mcum)		**143561688.7**

Now from the above table, it is clear that, 4D5D4H mini watershed is having highest runoff 28.9 MCM, 4D5D4G, runoff volume is 16.23 MCM, 4d5d4k runoff volume is 14.3 MCM, Table-8- Velocity of stream Flow Calculation

Sl.No	Sub WATER SHE DCODE	manning N	Slope S	Hydraulic Depth(m)	V=(S^0.5)X (D^0.67)/n(m/s)	Highest elevation (m) h	Least elevation(m) Le
1	4d5d4G	0.025	0.01	3	8.350861	680	600
2	4D5D4H	0.025	0.01	3	8.350861	780	652
3	4d5d4K	0.025	0.01	3	8.350861	780	690

Manning N is determined referring to soil map, where for clayey soil, N=0.025 (surface roughness coefficient), Hydraulic depth= river stage = 3m (from Nagraj Patil paper on Groundwater fluctuation assessment using Visual Modflow flex)

Table-9- Determination of Time of Concentration (Tc)

Sl No.	SUB WATERSHEDCODE	**Elevation Difference H=h-Le (m)**	**River length (km) L**	**U=L^3 (CUM)**	**T0= (0.885 U/H) ^0.385 (hrs)**	**T0+(0.001L/V)=TC (hrs)**
1	4d5d4G	80	8.7	658.50	2.15	3.189778994
2	4D5D4H	128	10	1000	2.11	3.30270057
3	4d5d4K	90	9	729	2.13471495	3.212448189
	Total	244	70	343000	15.54233667	23.92470631

Total runoff volume is 143.56 MCM, this is the highest runoff volume, in 8 years from the sub watershed, I,e from 2014-2022. so this runoff volume is considered for detention time calculation, where, detention time = TC= T0+ (L/V), where, L-->length of stream from highest point to mini watershed outlet, V-->stream flow velocity T0-->Initial concentration time , hence, the total detention time TC will be calculated for 4D5D4H, 4D5D4G, 4D5D4K,mini watersheds and Final out let of the sub watershed.

Higher detention time, infers higher valley storage, which implies good ground water recharge potential. n--> is 0.025, I,e manning constant, roughness coefficient, but it is same for all mini watersheds, since, clayey soil is present below the streams , for clayey soil, n=0.025, slope is flat 0 to 1% for all the streams , since all streams pass through 0 to 1% slope. D=3m, since, the river stage maximum=3m (Assumed in a paper Ground water assessment using Modflowx software-Dr.Nagaraj Patil, DR.B.K.Purundara 2016, actually R= (A/D)^(2/3),where A is stream c/s area wetted D is wetted perimeter , but for streams, width is approximately 20 X D, so wetted perimeter is approximately = stream width B wetted area = BD so R= A/D= BD/B=D, Highest elevation, stream width, least elevation River length are obtained from SOI top sheets, using ARC GIS 10.2 software, slope and soil details obtained from KSRSAC data

XVII Relation between Mini watershed Area and Runoff Volume (2022)

Table-10 – Relation between mini watershed area and Runoff Volume

Sl.No	Mni WATER SHEDCODE	Mini water shed area (sqkm)	Run off vol _MCM
1	4d5d4K	41.44	14.77
2	4d5d4G	50.34	16.23
3	4d5d4D	66	21.57
4	4D5D4H	80.05	28.88
5	4d5d4f	95.96	27.66
6	4d5d4J	102.3	34.43

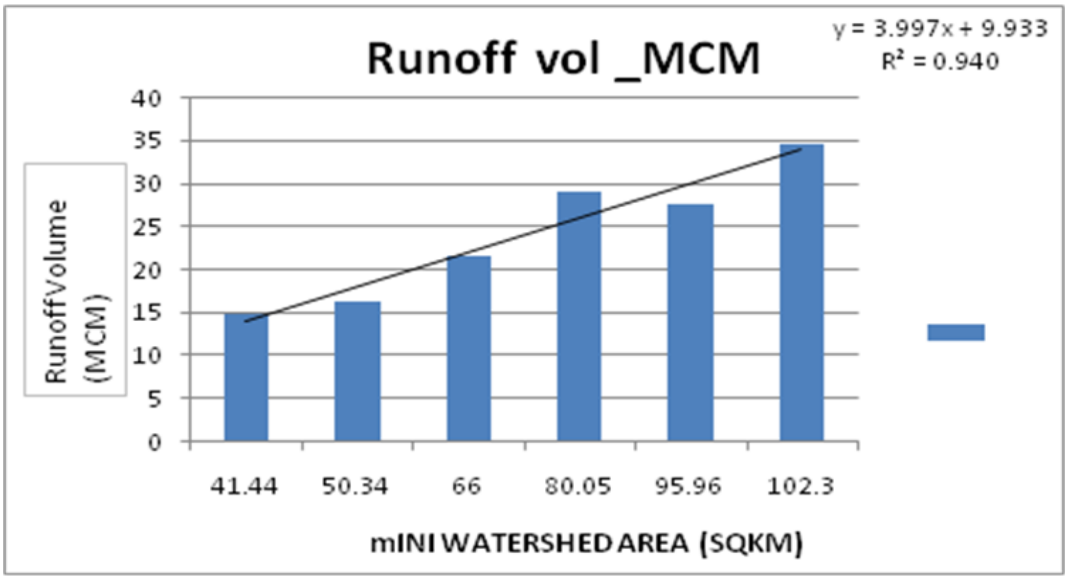

FIGURE-9- Graph Showing Relation between Runoff Volume and Mini watershed Area

Relationship between morphometry and Runoff: Morphometry deals with finding number of streams or various orders, these streams join the main stream in each mini watwershed. The 1st order and 2nd order streams join 3rd order streams, these streams i,e 2nd and 1st order streams, have their catchments, each micro watershed is a catchment for these streams, the 1st number of 1st order and 2nd order streams joining main stream in each mini watershed, contributes for runoff, along with rainfall depth, hence, here mini watershed 4D5D4K has less runoff volume of 10.2 MCM in year 2014, due to lesser stream length (72KM), but mini watershed 4D5D4H has highest runoff 22.2 MCM, due to higher stream length (139 KM), but 4D5D4F mini watershed , has higher area 95sqkm, more stream length than 4D5D4H, 182 KM, but due to low rainfall, runoff volume is less for 4D5D4F miniwatershed, comparedto 4D5D4H mini watershed.

Relation Between Morphometry and Geomorphology: The total length of streams of 1st order in the study area is 496 KM, but for 2nd order streams, it is 237KM, this indicates, there is structural disturbance and abrupt slope variation between 1st order and 2nd order stream, further, all 1st order streams originate from weathered basalt formations, In 4D5D4H, mini watershed, the area under weathered zones and dissected zones together, is 52 SQKM . In 4D5D4K, the area under weathered zones and dissected zones together, is 23 SQKM. So, number of streams is more for 4D5DH than 4D5DK. Hence 2nd order and 3rd order streams **are more in canal command area.**

Summary: Through the above study, it can be summarized that, in the mini watershed with higher length of streams, more potential for water harvesting is available,

6.0 CONCLUSION:

Morphometry of a sub watershed is an elaborate and tedious process of mapping of streams of different orders and other geometrical aspects, thus, conventional approach, proves to be costlier and tedious and time consuming procedure. This problem can be solved using GIS and Remote sensing approach, where, large scale mapping of drainages, streams, soil type and water sheds, is possible, at affordable costs, the satellite images obtained through remote sensing and all layers can be integrated in GIS. Hence, GIS and RS can be used in morphometry mapping of a watershed, such an attempt is made for Hirehalla subwater shed, where there are 675 1st order streams, 355 2nd order streams, 39 3rd streams, 5 4th order streams and 0 5th order and 6th order streams. The total length of 1st order streams is 495 KM, 2nd order streams is 237 KM, 39 KM for 3rd order, 42KM length of 4th order streams. The drainage density ranges from 1.22 to 1.84 km/sqkm.

REFEREENCES

1.S. Satheeshkumar · S. Venkateswaran, "**Predilection of sustainable recharge structures using morphometric parameters and decision making model in the Vaniyar sub basin**,"Applied Water sciences Journal, 2018.

2. Er.Afreeda.V, Dr.Balaji Kannan, "**Determination of watershed Morphological Parameters Using Remote Sensing and GIS**", IJEC, Volume 8, Issue 3. 2018

3.Dr.Nagaraj Patil, Santosh Dhungana, Dr.B.K.purundara, "**Assessment of Groundwater in Ghatprabha Sub-Basin Using Visual MODFLOW FLEX"**, International Journal of Earth Sciences and Engineering, Volume 09, issue no.04, August 2016.

4. Government of Karnataka, Annual Rainfall Reports from 2011-2016 and 2018 Directorate of Economics and Statistics , Bengaluru,

5.Santoshkumar.Garg , **" Irrigation and design of hydraulic structures",** engineering book, 16th edition, 2001, Khanna Publishers, New Delhi-110006.

6. Santoshkumar.Garg , "**Hydrology and Water resources Engineering"**, engineering book, 13th edition, 2004, Khanna Publishers, New Delhi-110006.

7.Amrutha Rani, R.Shreedhar,"**Study of Rainfall Trends and Variability for Belagavi District,"** IJRET: International Journal of Research in Engineering and Technology , Journal, August -2023.

8. CGWB Annual report on Belagavi district-2012