Morphometric Analysis of Jintur Sub-Watershed Drainage Basin through Remote Sensing and GIS

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Abstract: *In this study an attempt has been made to understand the morphometric characteristics of river in Jintur watershed basin with an aim to compute the detailed morphometric parameters and their bearing on the hydrological condition of the region. The analysis revealed that the drainage basin is characterized by dendrict to sub dendrict drainage pattern. The total number as well as total length of stream segments is maximum in first order streams and decrease as stream increases. The drainage frequency (Sf)value of 3.23 exhibits positive correlation with the drainage density value of 1.82 The drainage density(Dd) indicates clearly that the region has permeable sub soil and relatively dense vegetative cover. Calculated Circular ratio (Rc) value of 0.65 and elongation ratio (Re) value of0.67 indicates that the drainage basin is elongated in shape, has low discharge of runoff and relatively permeable sub soil condition. The value of form factor (Rf)0.35 represents a flattern peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. Hence from the study it is clear that the morphometric analysis by Remote sensing (RS) and GIS technique is very useful to understand the prevailing geo-hydrological characteristics and for watershed planning and management.*

Keywords: Linear parameters, drainage basin, morphometry, Relief aspects and GIS

1. Introduction

The morphometry analysis of the drainage basin and channel network play a significant role in comprehension of the geo hydrological nature of drainage basin. Potential assessment, ground water management, hydrological behavior, environmental assessment and pedology. Morphometry of the drainage basin is the measurement and mathematical analysis of the configuration of earth surface, shape and dimension of its landforms (Agrwal, 1998, obi Reddy et al 2002). Water demand and increasing population have become most important growing issue due to more and more urbanization taking place worldwide. Drainage basin analysis based on morphometric parameters is very important for watershed planning since it gives an idea about the basin physical characteristics in terms of slope, topography, soil condition, runoff characteristics surface water potential etc.The morphometric analysis of drainage basin and its stream system can be better achieved through measurement of linear,areal and relief aspects of the drainage basin (Biswas et al,1999). Comprehensive morphometric analysis of a basin is of great help in understanding the effect of drainage morphometry on landforms and their characteristics. Advantages of quantities analysis is that many of the basin parameters derived are in form of ratios, and dimensionless numbers, thus providing an effective comparison irrespective of the scale (Krishnamurty et al 1996).Remote sensing and GIS plays an important role in the study of morphometric characterization.GIS technique are currently used for measuring various terrain and morphometric parameters of the drainage basins or watersheds, as the provide a flexible environment and a prevailing tool for the manipulation and analysis of spatial information. Thus, the process is responsible for full understanding of hydrologic behavior of watershed. Similarly, some of the morphometric parameters,like circulatory ratio and bifurcation ratio are

input parameters in hydrological analysis (Esper,2008) and evaluation of surface water potential of an area. A more realistic approach of drainage morphometric analysis is employed by using the drainage network extracted from the Digital Elevation Model (DEM) as suggested by Bhat(2009).Inthis prespective, this study forms abasis for characterizing hydrologic behavior of Jintur watershed basin using morphometric procedure.

2. Study Area

The present study area is located in the Parbhani district of Maharashtra.Jintur sub watershed is part of Godawari-Purna sub basin, The location of the study area is shown in fig 1. The Jintur watershed sub-basin lies between76^0 26'36 to76^0 56'13 East longitude and19^0 17'43 to$19^0$44' 17 North latitude in Parbhani district of Maharashtra. The river in watershed is fourth order stream having low gradient. It rise from an elevation of 403m to 485 m with elevation difference of 82 m. The watershed encompasses an area of $56.38km^2$.The rainfall records shows that it is a region of moderate rainfall, where average annual rainfall stands at 647mm and temperature goes up to 42^0C summer and comes down to 11^0C in winter season. The climate of the district is Semi arid, humid and Subtropical. In the Survey of India Toposheet, it forms part of 56 A/6 on 1:50000 scale.(Fig.1)

3. Material and methods

Base map of the study area was prepared using the survey of India (SOI) Toposheet no 56A/6 .Remote sensing data of the study area acquired on 01 Jan 2014 procured.The satellite data was first georeferenced with the help of base map prepared using SOI Toposheet.Degital image processing techniques were applied on the images. Making use of spatial and radiometric enhancement techniques in

order to remove shadow and for proper tone and texture of the image. The watershed boundary of the study area was delineated using the SOI Toposheet on 1:50000 scale and remote sensing data. The drainage network was also delineated from SOI toposheet and remote sensing data. Field visit was made in order to collect the training sets for preparation of land use map of the study area. During the field visit actual ground conditions were verified and training sets for different latitudes were marked. The delineated watershed was further divided in to sub watershed and then sub watershed along the boundary were selected for morphometric analysis. The morphometric parameters for selected sub watersheds were calculated in GIS Environment. The input parameters for morphological studies such as perimeters, area, elevation, stream length etc. were obtained directly in Arc GIS 10.60Software using quary based algorithms. Other morphological parameters were calculated using formulae based on input values.
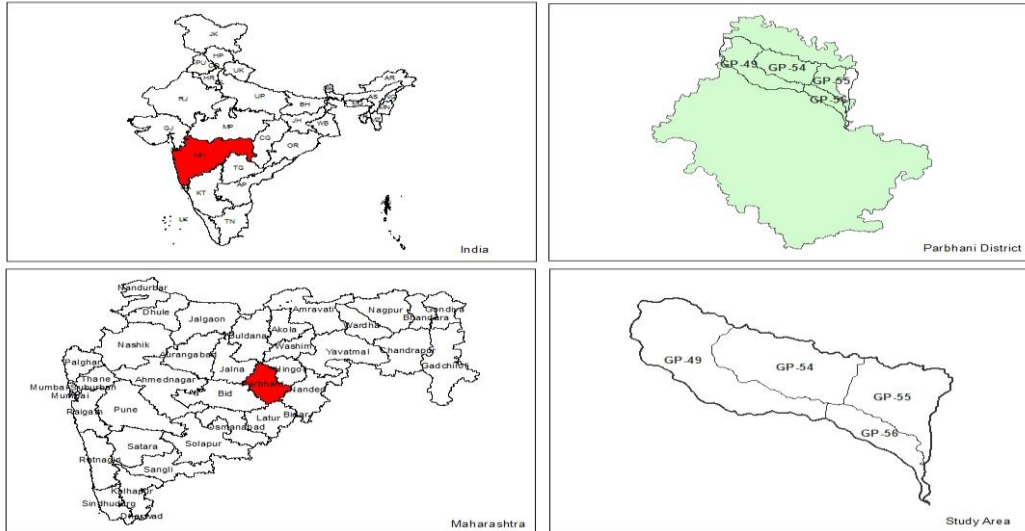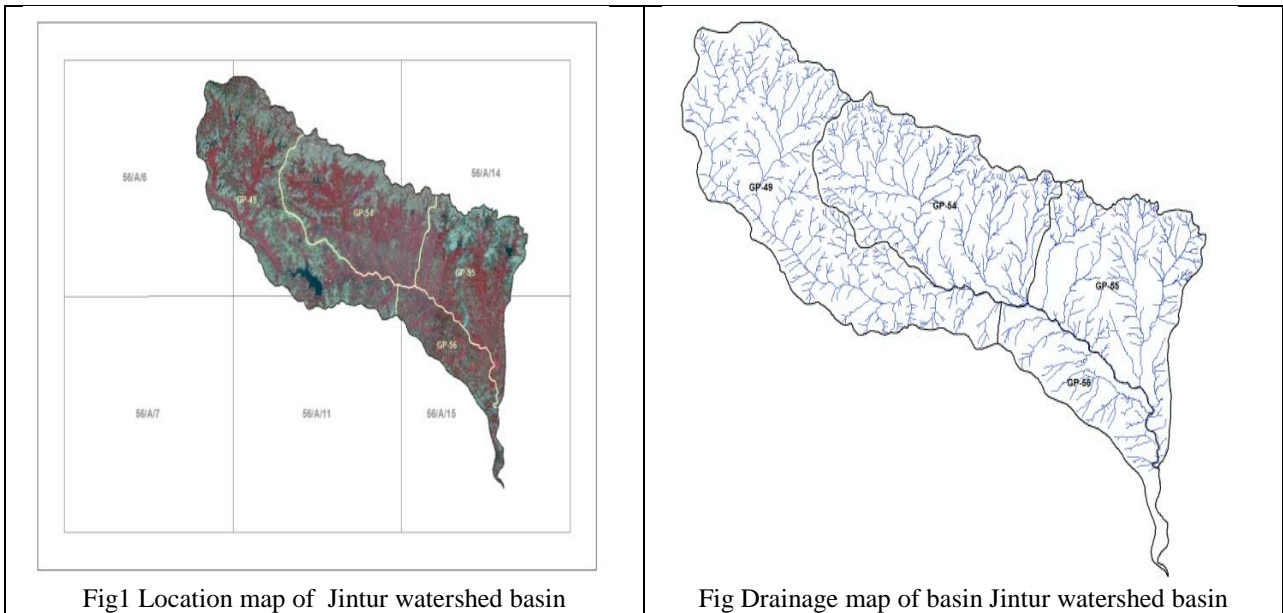

Figure 1: Location map of study area

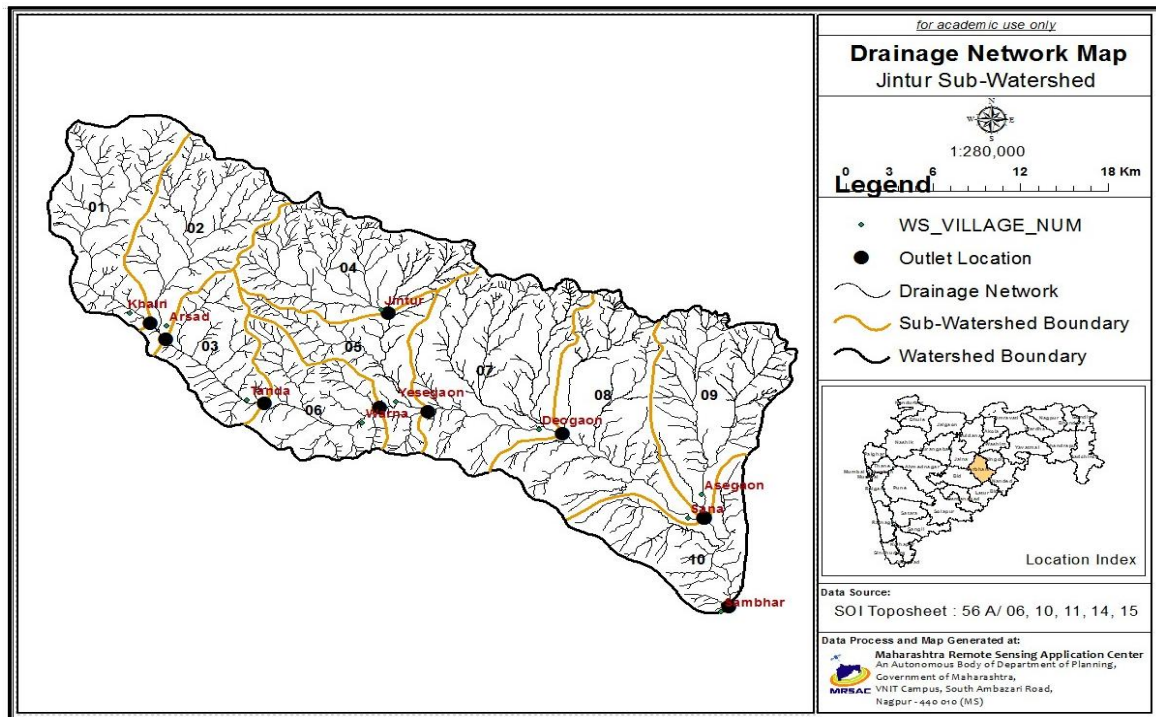| Fig1 Location map of Jintur watershed basin | Fig Drainage map of basin Jintur watershed basin |

Figure 4: Drainage order map of Yesegaon watershed basin

Morphometric parameters	Formula	Reference
Linear parameters		
Stream order (U)	Herarchical	Strahler(1964)
Srteam length (Lu)	Length of stream	Horton(1945)
Mean stream length (Lsm)	$Lsm=Lu/Nu$ Where, Lsm=Mean stram length Lu= Total stream length of order u Nu=Total No. of stream segment of order u	Strahler(1964)
Stream length Ratio (RL)	$RL=Lu/Lu-1$ Where, RL= Stream length Ratio LU= Total stream length of order u Lu-1= Total stream length of its next lower order	Horton(1945)
Bifurcation Ratio (Rb)	$Rb= Nu/Nu+1$ Where, Rb= Bifurcation Ratio Nu= Total No. of stream segments of order u Nu+1= Number of segments of next higher order	Schumm(1656)
Mean Bifurcation Ratio (Rbm)	Average of bifurcation ratios of all orders	Strahler (1957)
Aerial Parameters		
Drainage density(Dd)	$Dd=Lu/A$ Where, Dd= Drainage density Lu= Total stream length of all orders (km) A= Area of the basin km^2	Horton(1945)
Drainage Texture (Dt)	$T=Nu/P$ Where, Dt= Drainage Texture Nu= Total No. of stream segments of order u P= Perimeter (Km)	Horton(1945)
Stream Frequency(Fs)	$Fs=\sum Nu/A$ Where, Fs= Stream Frequency $\sum Nu$= Total No. of streams of all order A= Area of the basin km^2	Horton(1932,1945)
Form Factor(Ff)	$Ff=A/L^2$ Where, Ff= Form Factor A= Area of the basin km^2 L= basin length (km)	Horton(1932,1945

Elongation Ratio (Re)	$Re=2\sqrt{(A/\pi)}\div L$ Where, Re= Elongation Ratio, Π=3.14, A= Area of the basin km^2, L=Basin Length (km	Schumm(1656)
Circularity Ratio (Rc)	$Rc=4\pi A/P^2$ Where, Rc= Circularity Ratio (A= Area of the basin km^2 Π =3.14 P= Perimeter (Km	Miller (1953) Strahler (1957
Constant of channel maintenance (C)	C=1/Dd Where, C= Constant of channel maintenance (C) Dd= Drainage density	Schumm(1656)
Length of overland flow(Lg)	Lg=1/2Dd Where, Lg= Length of overland flow Dd= Drainage density	Horton(1945)
Relief Parameters		
Basin Relief (R)	R=H-h Where, R= Basin Relief H= Maximum elevation in meter h= Minimum elevation in meter	Hadley and Schumm (1961)
Relief ratio (Rr)	Rr=R/L Where, Rr= Relief ratio R= Basin relief L= Basin length in Km	Schumm (1956)
Ruggedness number(Rn)	Rn=R*Dd Where, Rn= Ruggedness number R= Basin relief Dd== Drainage density	Schumm (1956)

4. Results and Discussion

Morphometric parameters of Jintur watershed basin

4.1 Linear Aspects

The linear aspects of morphometric analysis of basin include stream order, stream lengt, mean stream length, stream length ratio and bifurcation ratio.

4.1.1 Stream order (U)
The smallest un branched fingertip streams are designated as 1st order, the confluence of two 1st order channels gives a channel segment of 2nd order, two second order streams joins to form a segment of 3rd order and so on. When two channel of different order join then higher order is mentioned. The trunk stream is the segment of higher order. It is found that in Jintur watershed basin river is of 5th order. In all 332 streams were identified of which 208 are first order,92 are second order, 9are third order, 21are fourth order and 2 are of fifth order. Drainage pattern of stream network from the basin have been observed as mainly of dendritict type which indicates the homogeneity in texture and lack of structural control.

4.1.2 Stream length (LU)

The stream length (Lu) has been computed based on the law proposed by Horton.stream length is one of the most significant hydrological features of the basin as it reveals surface run off characteristics. The stream of relatively smaller length is characteristics of areas with larger slopes and finer textures. Longer length of streams is generally indicative of flatter gradient. Generally, the total length of stream segments is maximum in first order stream and decreases as stream order increases. The numbers of streames are of various orders in a watershed are counted and their lengths from mouth to drainage divid are measured with the help of GIS software. The length of 1st order is 90.539km, 2nd order is 48.093km, 3rd order 30.442km, 4th order is 16.904km and 1.366km of fifth order,respectively

4.1.3 Mean stream length (Lsm)
The mean stream length is a characteristics property related to the drainage network and its associated surfaces (Strahler,1964). The mean stream length (Lsm) has been calculated by dividing the total stream length of order by number of streams. The mean stream length of study area is 1.348 km for 1st order,0.435km for 2nd order 0.522km for 3rd order 3.382km for 4th order 0.805km and 5th order is 0.683km ,respectively. The mean stream length of stream increases with increase of the order
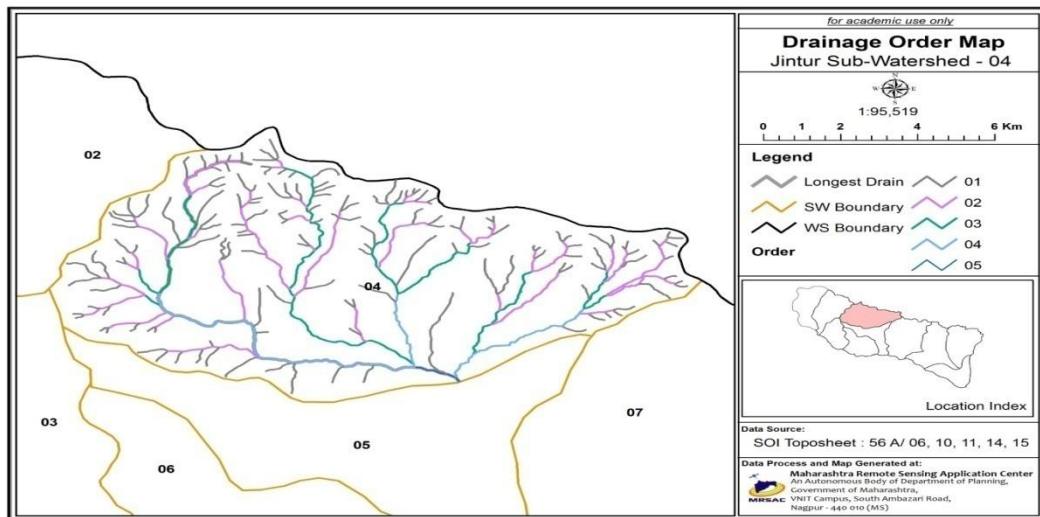
Figure 1: Drainage order map of Jintur Watershed Basin

Table 1: Basic morphometric characteristics of study area

Watershed Name	Drain order	Total Drain Length (m)	Drain Count	Bifurcation Ratio	Mean Stream Length (m)	Stream Length Ratio	RH. Co-Efficent
Jintur	1	90539.3	208		435.3		
	2	48093.3	92	2.3	522.8	0.5	0.23
	3	30442.0	9	10.2	3382.4	0.6	0.06
	4	16904.3	21	0.4	805.0	0.6	1.30
	5	1366.2	2	10.5	683.1	0.1	0.01
	Total	187345.1	332	5.9	1348.3	0.5	0.4

4.1.4 Stream length ratio (RL)

The stream length ratio can be defined as the ratio of mean stream length of a given order to the mean stream length of next lower order and has an important relationship with surface flow and discharge (Horton,1945).The RL values between streams of different order in the basin reveal that there are variations in slope and topography.

Table 2: Morphometric parameters of Jintur sub watershed basin

Sr No	Morphometric Parameters	Unit	Count
1	Watershed Name	Jintur	
2	Watershed Periphery	m	44659.68
3	Watershed periphery	Km^2	44.66
4	Watershed area	M^2	102864885.68
5	Watershed area	Ha	10286.49
6	Watershed area	Km^2	102.86
7	LONG_DRAIN	m	17185.00
8	Elevation High	m	534.00
9	Elevation Low	m	413.00
10	Elevation Difference	m	121.00
11	Slope	%	0.70
12	Total drain length	m	187345.12
13	Drain Count	Numbers	332
14	Average_Drain_Length	km	564.29
15	Drainage Density	Km/km^2	1.82
16	Drainage Frequency	Km^{-2}	3.23
17	Form Factor	-	0.35
18	Basin Shape	-	2.87
19	Circulatory Ration	-	0.65
20	Dimter of Circle	km	11.45
21	Elongation Ratio	-	0.67

22	Channel Maintenance	-	0.55
23	Length of Overland Flow	m	0.27
24	Max Basin Relief	m	121.00
25	Relative Relief	m	270.94
26	Relative Ratio	-	7.04
27	Ruggedness Number (RN)	-	220.37
28	Total Drain Length	Km	187.3
29	Long Drain	km	17.185
30	Bifurcation Ratio	-	5.85
31	Mean Stream Length	m	1348.32
32	Stream Length Ratio	-	0.45
33	Ruggedness Number	-	0.40

4.1.5 Bifurcation Ratio (Rb)

Bifurcation ratio (Rb) may be defined as the ratio of the number of streams segment of given order to the number of segment of the higher order (Schumn 1956).It is observed that Rb is not the same from one order to its next order. In the study area mean Rb of entire basin is 5.9.Usually these values are common in the areas where geologic structures do not exercise a dominant influence on the drainage pattern.

4.2 Aerial Aspects

It deals with the total area projected upon a horizontal plane contributing overland flow to the channel segment of the given order and includes all tributaries of lower order. It comprises of drainage density, drainage texture, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow.

4.2.1 Drainage density (Dd)

Horton (1932), introduced the drainage density (Dd) is an important indicator of the linear scale of land form elements in stream eroded topography. It is the ratio of total channel segment length cumulated for all order within a basin to the basin area, which is expressed in terms of Km/Km^2. The drainage density, indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. High drainage density is the resultant of weak or impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964). The drainage density (Dd) of study area is 1.82 Km/Km^2 indicating moderate drainage densities. The Moderate drainage density indicates the basin is highly permeable subsoil and vegetative cover (Nag, 1998).

4.2.2 Drainage Frequency (Fs)

Stream frequency (Fs), is expressed as the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. The Fs for the basin is 3.23. (Horton, 1932)

4.2.3 Form Factor (Ef)

It is defined as the ratio of the basin area to the square of the basin length. This factor indicates the flow intensity of a basin of a defined area (Horton, 1945). The form factor value should be always less than 0.7854 (circular basin). The smaller the value of the form factor, the more elongated will be the basin. Basins with high form actors experience larger peak flows of shorter duration, whereas elongated watersheds with low form factors experience lower peak flows of longer duration. The Ff value for study area is 0.35, indicating elongated basin with lower peak flows of longer duration than the average.

4.2.4 Circularity Ratio (Rc)

It is the ratio of the area of a basin to the area of circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate and slope of the basin. The Rc value of basin is 0.65 and it indicating the basin is characterized by moderate to low relief and drainage system seems to be less influenced by structural disturbances. The high value of circularity ratio shows the late maturity stage of topography.

4.2.5 Elongation Ratio (Re)

Schumm (1956) defined elongation ratio as the ratio of diameter of a circle of the same area as the drainage basin and the maximum length of the basin. Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler 1964). These values can be grouped into three categories namely (a) circular (>0.9), (b) oval (0.9-0.8), (c) less elongated (<0.7). The Re values in the study area is 0.67 indicating moderate to slightly steep

ground slope and area when collaborated with Strahler's range seem to suggest an elongated shape.

4.2.6 Length of overland flow (Lg)

It is the length of water over the ground surface before it gets concentrated into definite stream channel (Horton, 1945. The length of overland flow is approximately equal to the half of the reciprocal of drainage density. This factor is related inversely to the average slope of the channel and is quiet synonymous with the length of sheet flow to a large degree. The Lg value of study area is 0.27.

4.2.7 Constant channel maintenance (C)

Schumm (1956) used the inverse of drainage density as a property termed constant of stream maintenance C. This constant, in units of square feet per foot, has the dimension of length and therefore increases in magnitude as the scale of the land-form unit increases. The constant C provides information of the number of square feet of watershed surface required to sustain one linear foot of stream. The value C of basin is 0.55. It means that on an average 0.70 sq.ft surface is needed in basin for creation of one linear foot of the stream channel.

4.3 Relief Aspects

The relief aspects determined include relief ratio, relative relief and ruggedness number.

4.3.1 Relief Ratio (Rh)

The relief ratio (Rh) is ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line (shumm,1956). The Rh normally increases with decreasing drainage area and size of watersheds of a given drainage basin. (Gottschalk, 1964). Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1956). The value of Rh in basin is 7.04 indicating moderate relief and moderate slope.

4.3.2 Relative Relief (Rbh)

This term was given by Melton (1957). In the present study area it is obtained by visual analysis of the digital elevation model prepared from SRTM data. The elevation varies from 413.0 m to 534.0m which represent the land has gentle to moderate slope. Relative relief of study area is reported as 270.94.

4.3.3 Ruggedness number (Rn)

It is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is steep (Strahler,1956). The value of ruggedness number in present basin is 220.37.

5. Conclusion

GIS and Remote sensing techniques have proved to be accurate and efficient tool in drainage delineation and their updation. Bifurcation ratio, length ratio and stream order of basin indicates that the basin is fourth order basin with dendritic type of drainage pattern with homogeneous nature

and there is no structural or tectonic control. Relief ratio, Ruggedness number and interpretation of DEM of study area indicate moderate and high relief, low run off and high infiltrations with early mature stage of erosion development. Drainage density, texture ratio, circulatory ratio and elongation ratio shows that texture of basin is moderate and shape of basin almost elongated. The complete morphometric analysis of drainage basin indicates that the given area is having good groundwater prospect

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