ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

Morphometry of the Payaswini Watershed, Coorg District, Karnataka, India, Using Remote Sensing and GIS Techniques

D.N. Vinutha, * M.R. Janardhana

Research scholar, Dept of Earth Science & Resource Management, Yuvaraja's College, University of Mysore, Karnataka, India.

Assistant Professor, Dept of Earth Science & Resource Management, Yuvaraja's College, University of Mysore, Karnataka, India.

* Corresponding author

ABSTRACT: The study of various morphometric characteristics of the Payaswini watershed is important to evaluate landslide incidences occurring in a part of Coorg district of Karnataka state. In view of this, linear, areal and relief aspects of the Payaswini river basin , in addition to shape factors, were evaluated. Prior to watershed based morphometry, the study area was divided into seven sub-basins using Survey of India toposheets on 1:50000 scale, Ortho-rectified Landsat MSS and ETM imageries. Digital Elevation Model (DEM) prepared by using ASTER data and Geographical Information System (GIS) tool. More than 12 morphometric parameters were computed at watershed level. The study helps to identify landslide susceptible areas.

KEYWORDS: Morphometry, Landslide, Payaswini watershed, GIS, Coorg District.

I. INTRODUCTION

The hydrological response of a river basin can be interrelated with the physiographic characteristics of the drainage basin, such as size, shape, slope, drainage density and size, and length of the streams, etc. (Chorley 1969, Gregory and Walling 1973). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke, 1996). Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler, 1964). This analysis can be achieved through measurement of linear, aerial and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). Remote sensing and GIS techniques are used for assessing various terrain and morphometric parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information.

Payaswini watershed of mega Cauvery basin in the western part of Coorg district of Karnataka state has witnessed landslides caused by natural and anthropogenic factors. In order to explore the role of drainage in inducing the mass movement, watershed morphometric parameters were evaluated. The present paper mainly deals with the morphometric analysis of the Payaswini watershed to assess the drainage characteristics and its impact on the evolution of the landform. The evaluated parameters include stream number, order, frequency, density and bifurcation ratio and tabulated on the basis of areal, relief and linear properties of drainage channels using GIS.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

II. STUDY AREA

Payaswini river originates in a village called Koinadu of Coorg district in Karnataka state. It flows in a north-westerly direction through Sullia taluk of Dakshina Kannada district. It then flows west of Kasaragod district of Kerala state before discharging its water into Arabian sea. The watershed area of Payaswini in Karnataka state is 302.01 Sq Kms and sub-basins are located in toposheet No. 48p/6, p/7, p/10, p/11, between the geographical coordinates 1384930.38 to 1367688.55 North and 540671.13 to 573402.37 East (UTM) (Fig.1). The geological formations of the study area belong to Archaean metamorphic complex. The main rock types are charnockites, granitic gneisses, schists and dolerite. Major part of the study area is covered by granitic gneisses (Fig. 2). The rocks are highly weathered and at places, the soil cover extends to a depth of more than 10 m. The Coorg district is one of the major places that get heavy rainfall in

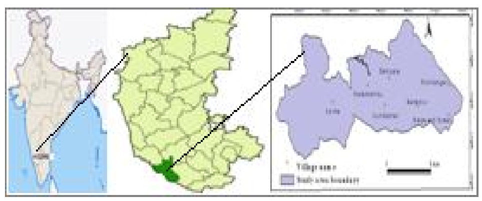

Fig. 1 Location Map Of The Study Area

India. The present landscape of the Coorg district under consideration is viewed as the product of a series of interactions between fluvial and denuded processes operating on underlying geology that has been subjected to past vertical tectonics (Vinutha et al., 2014). Sukumar and Ahalya (2013) carried out morphometric and terrain analysis of Payaswini river basin of Kerala and Karnataka states using GIS and their studies revealed that the tectonic forces have played a role in shaping the landforms in the study area and the river basin is dominated by erosional features than depositional features. The present study restricts to Payaswini sub basins in Karnataka state wherein the area is witnessing landslides of natural and anthropogenic causes. The study serves as a foundation for the analysis of landslides in the western part of the Coorg district of Karnataka state.

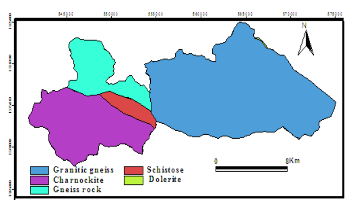

Fig. 2 Geology map of the Payaswini watershed

III.METHODS OF INVESTIGATION

In the present study, an attempt has been made to evaluate the morphometric parameters of watershed of Payaswini in Karnataka state. The watershed is divided into seven sub-basins (Fig. 3) using Survey of India toposheets on 1:50000 scale, Ortho-rectified Landsat MSS and ETM imageries. Digital Elevation Model (DEM) was prepared by using ASTER data and Geographical Information System (GIS) tool. Drainage map of the Coorg district as represented over the topographical maps was acquired from the Karnataka State Remote Sensing Centre (KSRSC), Bangalore, in Jpg format. Payaswini watershed was delineated in terms of surface watershed area based on topographic divides. The streams were geo-registered to the GIS using Universal Trans Mercator (UTM) coordinates (Fig. 3). Arc GIS 9.3 software was used to compute the different morphometric parameters. The methods listed by Vittala et al, 2004 were used for calculating the linear, areal and relief aspects in table 1. The results of the analysis are shown in tables from 2- 6.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

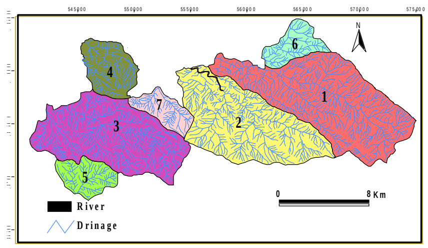

Fig. 3 Drainage map of the Payaswini watershed showing sub-basins

Sl.N.	Morphometric Parameters	Methods	References
1	Stream order	Hierarchial rank	Strahler (1964)
2	Stream length (Lu)	Length of the stream	Horton (1945)
3	Mean stream length(L sm)	Lsm= Lu/Nu Where, Lsm=Mean stream length Lu= Total stream length of order ‘u’ Nu=Total no.of stream segments of order ‘u’	Strahler(1964)
4	Stream length ratio(RL)	RL = Lu/Lu-1 Where, RL=Stream length ratio Lu=The total stream length of the order’u’ Lu-1= The stream length of its next lower order	Horton (1945)
5	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 the next higher order	Schumn(1956)
6	Mean bifurcation ratio(Rbm)	Rbm= Average of bifurcation ratios of all order	Strahler(1964)
7	Relief ratio (Rh)	Rh=H/Lb Where, Rh=Relief ratio H=Total relief (Relative relief) of the basin (Km) Lb=Basin length	Schumn(1956)
8	Drainage density(D)	D= Lu/A Where, D= Drainage density Lu=Total stream length of all orders A= Area of the basin (km^2)	Horton(1932)
9	Stream frequency(Fs)	Fs=Nu/A Where, Fs=Stream frequency Nu=Total no. of streams of all orders A= Area of the basin (km^2)	Horton(1932)
10	Drainage texture(Rt)	Rt=Nu/P Where, Rt=Drainage texture Nu=Total no. of streams of all orders P=Perimeter(km)	Horton (1945)
11	Form factor (Rf)	Rf= A/Lb^2 Where, Rf= Form factor A= Area of the basin (km^2) Lb^2= Square of basin length	Horton (1932)

12	Circularity ratio (Rc)	$Rc=4*Pi*A/P^2$ Where, Rc =Circularity ratio Pi= 'pi' value i.e.,3.14 A= Area of the basin (km^2) P^2= Square of the perimeter(km)	Miller(1953)
13	Elongation ratio (Re)	$Re=2\sqrt{(A/Pi)}/Lb$ Where, Re= Elongation ratio A=Area of the basin (km^2) Pi= 'pi' value i.e.,3.14 Lb= Basin length	Schumn(1956)
14	Length of overland flow (Lg)	Lg=1/D*2 Where, Lg=Length of overland flow D= Drainage density	Horton(1945)

Table 1 Methods adopted for the computation of morphometric parameters(after vittala et al, 2004)

IV.RESULTS AND DISCUSSION

The morphometric analysis is carried out through the assessment of linear, areal and relief aspects of the watershed. The results of each of the parameters are presented and discussed below.

1.Linear aspects

The linear parameters analyzed in the present study are stream order, stream length, mean steam length, stream length ratio and bifurcation ratio.

1.1 Stream Order

Ordering of stream is the first stage of basin analysis. It involves applying numerical value to a streams position and size in the basin. In the present study, ranking of streams has been carried out based on the Strahler (1952) method. The stream order, stream length, mean stream length and stream length ratio of the VII sub-basins of Payaswini are presented in Tables 2 and 3. Out of these I, II, III are of V orders whereas the remaining sub-basins are IV order. It is noticed that the maximum frequency is in case of first order streams and decrease in stream frequency as the stream order increases.

1.2 Stream length (Lu)

Stream length is one of the most significant hydro-geological features of the Payaswini watersheds. The total length of stream segments for all the VII sub-basins of Payaswini were measured using GIS software and were computed on the basis of the law proposed by Horton, 1945. From the Table 2, it is clear that the total length of stream segments increase as the stream order increase.

Table 2. Stream orders and Stream lengths of Payaswini watersheds

Sl. No.	Sub-basin name	Stream Order	Stream order					Stream length in km(Lu)				
			I	II	III	IV	V	I	II	III	IV	V
1	I	V	343.00	73.00	16.00	3.00	1.00	173.90	54.95	25.49	10.72	10.36
2	II	V	302.00	58.00	15.00	4.00	1.00	140.80	38.73	15.76	9.09	6.80
3	III	V	347.00	77.00	15.00	5.00	1.00	145.49	40.99	26.21	9.18	7.29

IJIRSET

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

4	IV	IV	99.00	19.00	5.00	2.00	0.00	45.67	9.80	7.65	6.75	0.00
5	V	IV	75.00	15.00	5.00	1.00	0.00	36.03	9.00	1.70	3.06	0.00
6	VI	IV	64.00	10.00	2.00	1.00	0.00	31.40	5.85	6.57	1.80	0.00
7	VII	IV	69.00	12.00	3.00	1.00	0.00	37.22	6.43	5.23	2.49	0.00

1.3 Mean stream length (Lsm)

Mean stream length (Lsm) is a dimensional property related to the drainage network components and is associated with basin surface (Strahler, 1964). It is seen that Lsm values exhibit variation form 0.34 to 10.36. The mean stream length increases with the increase in the order of the stream. However, some Sub-basins show opposite relationship because of variable lithology, slope and topography.

Table 3. Mean stream lengths and stream length ratios of Payaswini watershed

Sl. No.	Sub-basin name	Mean Stream length in km(Lsm)					Stream length ratio (RL)				
		I	II	III	IV	V	II/I	III/II	IV/III	V/IV	VI/V
1	I	0.51	0.75	1.59	3.57	10.36	0.32	0.46	0.42	0.00	0.00
2	II	0.47	0.67	1.05	2.27	6.80	0.28	0.41	0.58	0.75	0.00
3	III	0.42	0.53	1.75	1.84	7.29	0.28	0.64	0.35	0.79	0.00
4	IV	0.46	0.52	1.53	3.38	0.00	0.21	0.78	0.88	0.00	0.00
5	V	0.48	0.60	0.34	3.06	0.00	0.25	0.19	1.80	0.00	0.00
6	VI	0.49	0.59	3.29	1.80	0.00	0.19	1.12	0.27	0.00	0.00
7	VII	0.54	0.54	1.74	2.49	0.00	0.17	0.81	0.48	0.00	0.00

1.3 Stream length ratio (RL)

Horton's law of stream length states that mean stream length segments of each of the successive orders of a basin tends to approximate a direct geometric series with stream length increasing towards higher order of streams (Sangita, 2010). The stream length ratio between different sub-basins showed a change from one order to another order indicating the late youth stage of geomorphic development of streams in the inter- basin area, whereas the sub-basin II showed an increasing trend in the stream length ratio from lower order to higher order indicating their mature geomorphic stage.

1.4 Bifurcation ratio (Rb)

The bifurcation ratio is used to express the ratio of the number of streams of an order to the number of those in the next higher order (Horton, 1945; Strahler, 1964). Bifurcation ratios characteristically range between 2.0 and 6.40 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1957 and 1964). Mean bifurcation ratio (Table 4) lies between 3.84 - 4.86 indicating that the geologic structure do not distort the drainage pattern and may possibly indicate the antecedence nature of the Payaswini river.

Table 4. Bifurcation ratio and mean bifurcation ratio of Payaswini Watershed

Sl. No.	Sub- basin name	Bifurcation ratio (Rb)				Mean bifurcation ratio (Rbm)
		I/II	II/III	III/IV	IV/V	
1	I	4.70	4.56	5.33	0.00	4.86
2	II	5.21	3.87	3.75	4.00	4.21
3	III	4.51	5.13	3.00	5.00	4.41
4	IV	5.21	3.80	2.50	0.00	3.84
5	V	5.00	3.00	5.00	0.00	4.33
6	VI	6.40	5.00	2.00	0.00	4.47
7	VII	5.75	4.00	3.00	0.00	4.25

2. Relief aspects

Relief is the maximum elevation difference between the highest and the lowest points of a basin. Basin relief is an important factor in understanding the denudational characteristics of the basin (Sreedevi et al, 2009). The relief measurements such as relief ratio (Rh) and total relief have been carried out and the computed data are presented in Table 5. The elevations of the maximum and minimum points in the study area are 820 m and 1320 m above msl (Fig 4). The maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumn, 1963). Rh value has direct relationship between the relief and channel gradient. The Rh value normally increases with decreasing drainage area and size of the watersheds of a given drainage basin (Gottaschalk, 1964). In the study area, the values of relief ratio range from 0.07 - 0.2. High to very high relief and slope are characterized by high values of relief ratios. The Rh value of the sub-basins No. I is low suggesting low relative relief in the area and as the soil cover is thick, facilitates high infiltration of rain water.

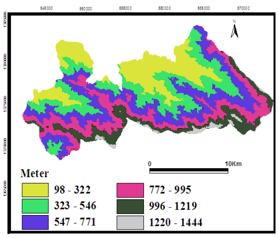

Fig. 4 DEM map of Payaswini watershed

Table 5. Relief aspects of Payaswini watershed

Sl.No.	Sub-basin name	Basin length(Lb) (km)	Total relief (Mtrs)	Relief ratio (Rh)
1	I	17.07	1180.00	0.07
2	II	11.55	1320.00	0.11
3	III	10.58	1210.00	0.11
4	IV	5.90	820.00	0.14
5	V	4.14	820.00	0.20
6	VI	4.87	780.00	0.16
7	VII	5.46	1000.00	0.18

IJIRSET

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

3. Areal Aspects and Form Factors

The areal parameters analysed in the present study are drainage density, stream frequency, texture ratio, form factor, circularity ratio, elongation ratio and the length of the overland flow. The computed values of these parameters are presented in Table 6 and discussed below.

3.1 Drainage density (D)

Drainage density (D) defined by Horton (1932), is one of the important indicators of the linear scale of landform elements in stream-eroded topography. Drainage density value of the Payaswini watershed in the study area lies in the range of 2.88 - 4.06. Maximum value of drainage density in the study area is observed in the sub-basin VII and minimum in the sub-basin II. It has been observed that low drainage density is found to be associated with regions having highly permeable subsoil material under dense vegetative cover and low relief. Where as high values are noted for the regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief. High infiltration capacity of the land/underlying rock and increasing transmissivity of the soil with thick vegetation are the characteristics of the high drainage density regions.

3.2 Stream Frequency (Fs)

The total number of stream segments of all orders per unit area is known as the stream frequency (Horton, 1932). The Fs values of the sub-basins of the study area are presented in Table 6. The Payaswini watershed has a stream frequency of 0.14 streams per km^2. It is noted that values of Fs vary from 4.64-6.72. High value of drainage frequency in sub-basins V and VII produces more runoff in comparison to others.

3.3 Drainage Texture (Dt)

Drainage texture is the total number of stream segment of all orders per perimeter of that area and infiltration capacity is the single important factor which influences drainage texture (Horton, 1945). The amount and type of vegetation, precipitation, infiltration capacity viz., absorption capacity of soil, underlying lithology, and relief aspect of the terrain influences the rate of surface run-off and affects the drainage texture of an area. Based on the drainage density five drainage textures have been classified (Smith, 1950). The drainage density less than 2 indicates very coarse, between 2 and 4 is related to coarse, between 4 and 6 is moderate, between 6 and 8 is fine and greater than 8 is very fine drainage texture. In this study there are two types of textures, coarse (I and II) and remaining falls under moderate class. The soft or weak rocks unprotected by vegetation produce a fine texture, whereas massive and resistant rocks cause coarse texture. The values of drainage texture ratio of the study area varies from 4.38-10.93.

3.4 Form factor (Rf)

Form factor may be defined as the ratio of the basin area to the square of basin length (Horton, 1932). The Rf values would always be greater than 0.78 perfectly for a circular basin. Smaller the value of form factor, more elongated will be the basin. Rf values of the study area are presented in Table 6. It is noted that Rf values vary from 0.32 - 0.85. The values of Rf in sub-basins V is > 0.78 indicate that they are circular where as Rf of remaining sub-basins lies below 0.78 suggesting elongated in shape and flow for longer duration.

3.5 Circularity Ratio (Rc)

The circulatory ratio is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the watershed. It is the ratio of the watershed area to the area of a circle having the same perimeter of the watershed. In the study area, the Rc values are range from 0.47-0.63. The I & VII sub-basins have values of Rc less than 0.5 indicating that they are elongated and highly permeable homogeneous geologic materials, whereas the remaining sub-basins have greater than 0.5 values suggesting that they are more or less circular in shape and are characterized by high to moderate relief and the drainage system are structurally controlled.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 5, July 2014

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

Table 6. Areal aspects and form factors of sub-basins of Payaswini watershed

Sl. No.	Sub-basin name	Sub-basin area (km2)	Perimeter (P) (km)	Drainage density(D) (km-1)	Frequency	Texture Ratio (Rt)	Form Factor (Ff)	Circularity Ratio (Rc)	Elongation Ratio (Re)	Length of Overland flow(Lg)
1	I	91.95	50.22	2.93	4.64	8.68	0.32	0.47	0.64	0.17
2	II	75.19	40.69	2.88	5.19	9.34	0.55	0.56	0.84	0.17
3	III	72.94	40.70	3.14	6.10	10.93	0.65	0.55	0.91	0.16
4	IV	20.77	22.57	3.36	6.02	5.54	0.60	0.51	0.87	0.15
5	V	14.49	17.03	3.43	6.61	5.64	0.85	0.63	1.04	0.15
6	VI	13.98	17.59	3.26	5.51	4.38	0.59	0.57	0.87	0.15
7	VII	12.65	18.43	4.06	6.72	4.61	0.42	0.47	0.74	0.12

3.6 Elongation Ratio (Re)

Elongation ratio is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (Schumm,1965). The elongation ratio values of the sub-basins vary from 0.64 - 1.04 which may be attributed to a wide variety of climatic and geologic types (Iqbal et al., 2012). The elongation ratio of > 1.0 indicate lower relief, <1.0 indicate high relief and steep slope. Sub-basin V has lower relief and other sub-basins are associated with high relief.

3.7 Length of overland flow (Lg)

It is the length of water flown over the ground before it gets concentrated into definite stream channels. This factor basically relates inversely to the average slope of the channel and is quit synonymous with the length of the sheet flow to the large degree. The Lg value of the study area shows variation from 0.12 to 0.17 kms. The values of Lg in sub-basin VII is lower values indicating high relief and remaining sub-basins having higher values and show low relief.

V. CONCLUSION

Morphometric analysis of Payaswini watershed has been carried out through measurement of linear, areal and relief aspects. It has been found that the study area has streams of 5th order and shows dendritic drainage pattern seen in all the VII sub-basins, indicating the homogeneity in texture and lack of structural control. Bifurcation ratio of the streams drained in the study area lies between 3.84 - 4.86 indicating that geologic structures do not distort the drainage pattern thus may point at the antecendence nature of the streams. The presence of the maximum number of the first order segments shows that the all sub-basins are subjected to erosion and also that some areas of the sub-basins are characterized by variations in lithology and topography. The values of the mean stream length varying from 0.34 to 10.36 clearly indicate the change in topographic elevation and slope of the Payaswini watershed. The elongation ratio value of the sub basin V is 1.04, which indicates that the major part of this sub-basin is of high relief. The length of overland flow (Lg) value of the study area shows variation from 0.12 - 0.17 kms. The value of Lg in sub-basin VII indicates high relief and remaining sub-basins having higher values point at low relief.

REFERENCES

[1] Clarke JI . Morphometry from maps. *Essays in geomorphology* 1996; 235--274.
[2] Chorley, R.J (1969). Introduction to Fluvial Processes. Bungay, UK: Methuen & Co Ltd.
[3] Gottschalk LC. Reservoir Sedimentation in: V.T. Chow (Ed.) *Handbook of Applied Hydrology. McGraw Hill Book Company, New York* 1964; Section 7-I.
[4] Gregory, K.J and Walling, D.E (1973). Drainage Basin Form and Process- a Geomorphological Approach. London: Edward Arnold.
[5] Horton RE. Drainage basin characteristics. *Trans. Am. Geophys* 1932; Union 13.350--361.

ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization *Volume 3, Special Issue 5, July 2014*

International Conference On Innovations & Advances In Science, Engineering And Technology [IC - IASET 2014]

Organized by

Toc H Institute of Science & Technology, Arakunnam, Kerala, India during 16th - 18th July -2014

[6] Horton RE. Erosional development of streams and their drainage basins Hydro physical approach to quantitative morphology, *Geol Soc Am. Bull* 1945; 56: 275--370.

[7] Mohd Iqbal , Haroon Sajjad and Bhat FA. Morphometric analysis of Dudhganga catchment, Kashmir valley, India using geographical information system. *International Journal of Current Research,* 2012;4(12), 410-416.

[8] Nag SK and Chakraborty S. Influences of rock types and structures in the development of drainage network in hard rock area. *Indian Soc remote Sensing.* 2003; 31(1), 25-35.

[9] Schumm SA. Sinuosity of alluvial rivers on the Great Plains, Bull. *Geol. Soc. Amer* 1963; 74: 1089-1100.

[10] Schumm SA and Lichty RW Time, Space, and Casualty in geomorphology, *American Journal of Science* . 1965; 263: 110-119.

Smith KG. Standards for grading textures of eritonal topography, *Am Jour Sci* . 1950;248: 655-668.

[11]Sreedevi PD, Owais S, Khan S.S and Ahmed S. Morphometric Analysis of a Watershed of South India Using SRTM Data and GIS, *J of the Geological Society of India* 2009; 73 (4**):** 543-552 .

[12]Strahler AN. Quantitative analysis of watershed geomorphology, Trans. *Am Geophys Union* .1957; 38: 913-920.

[13]Strahler A N. Dynamic Basin of Geomorphology. *Geol. Soc. Am. Bull*. 1952; 63.

[14]Strahler AN. Quantitative geomorphology of drainage basins and channel networks. In V. T. Chow (Ed.), *Handbook of Applied Hydrology. New York: McGraw Hill*. 1964; 4, 39-4,76).

[15]Sangita Mishra S. Nagarajan R. Morphometric analysis and prioritization of sub watersheds Using GIS and Remote Sensing techniques: a case study of Odisha, India. *International Journal Of Geomatics And Geoscienc* 2010; 1(3).

[16]Sukumar B, Ahalya Sukumar, Morphometric and terrain analysis of Payaswini river basin of Kerala and Karnataka states using GIS, *International journal of Geomatics and geosciences* 2013; 4(2).

[17]Vinutha DN, Sridhara Raje Ars K and Janardhana MR. Landform studies & Geomorphological mapping of a part of Coorg district, Karnataka state, *International Journal of Geology, Earth & Environmental Sciences* 2014; 4 (1),23-27.