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Morphometric Analysis of River Drainage Basin/Watershed using GIS and RS: A Review

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Abstract : Morphometry is the measurement and mathematical analysis of the earth's surface, shape, and dimension of the land forms. Morphometric analysis requires measurement of linear aspects, aerial aspect and slope of the drainage basin. In all 28 literatures, the researchers analyses the morphometric study for watershed management and prioritization of watershed using morphometric analysis through geoinformatics technology. We focus on matter of fact that is methodology, adopted, raw data used as input and process to study sustainable watershed management. The content of this review paper divided in to three sections namely Introduction, Methodology, and analysis, Conclusion followed by references.
Keywords: Drainage Basin, Digital Elevation Model, Morphometry, Remote Sensing and GIS

I. INTRODUCTION

Catchment area or drainage basin is an area drained by river system which includes all areas of land that collect precipitation of water and drain off into stream, stream system, lake or other body of water. Watershed Management is a technique to protect and improve the quality of the water and also control erosion in the catchment area in a comprehensive manner. Watersheds are classified into Mini watershed (1 to 100 ha), mMicro watershed (100 to 1000 ha) , Milli watershed (1000 to 10000 ha), Sub watershed (10000 to 50000 ha) & Macro watershed (> 50000 ha).

Morphology is the study of forms or structures which is quantitative determination of landform. Morphometric analysis is the measurement and mathematical evaluation of the earth's surface, shape and dimension of its landform (Agarwal , 1998; Obi Reddy et al, 2002). Morphometric analysis is very useful in drainage basin evaluation, silt erosion control, flood frequency analysis, watershed prioritization, natural resources management & conservation. Hydrological behavior depends on geomorphologic parameters which determines the variation in earth's surface from past to present. In many regions, most of the basins are either ungauged or difficult to access so study on geomorphology of basins become much more important. (Deepak Khare et.al 2014). Geomorphological analysis provides quantitative description of the basin geometry to understand inequalities or slopes in rock hardness, it's structure control and geological history of drainage basin (Strahler, 1964). Drainage basin is the fundamental hydrologic and geomorphic areal unit. Drainage line of any drainage basin area illustrates existing three dimensional geometry of region but assists for understanding its evolution process (K.R. Praveen, 2014).

Watershed Prioritization is the scientific process of watershed delineation and monitoring (Kartic Bera et.al; 2013). It is one of the most important aspects of planning and management of natural resources. The prioritizing of sub watershed based on Linear aspect (La) Areal aspects (Aa) & Relief Aspects (Ra) which are classified in 3 class i.e. high, medium, low. Morphometric analysis & Prioritization of river drainage basin using remote sensing and GIS techniques have been attempted by no. of researchers (Nag,1998; Agarwal,1998; Thakkar & Dhiman 2007; Akram Javed et al. 2009; Pareta 2011; Praphulla Singh 2011 Gajbhiye et al. 2014) and concluded that RS & GIS are most effective tools for integration of land use choose analysis morphometric analysis and soil erosion control to preserve land from further erosion.

II. METHODOLOGY AND ANALYSIS

Morphometric parameters of the drainage basins are calculated by GIS techniques where it is an effective tool for the analysis of spatial information.

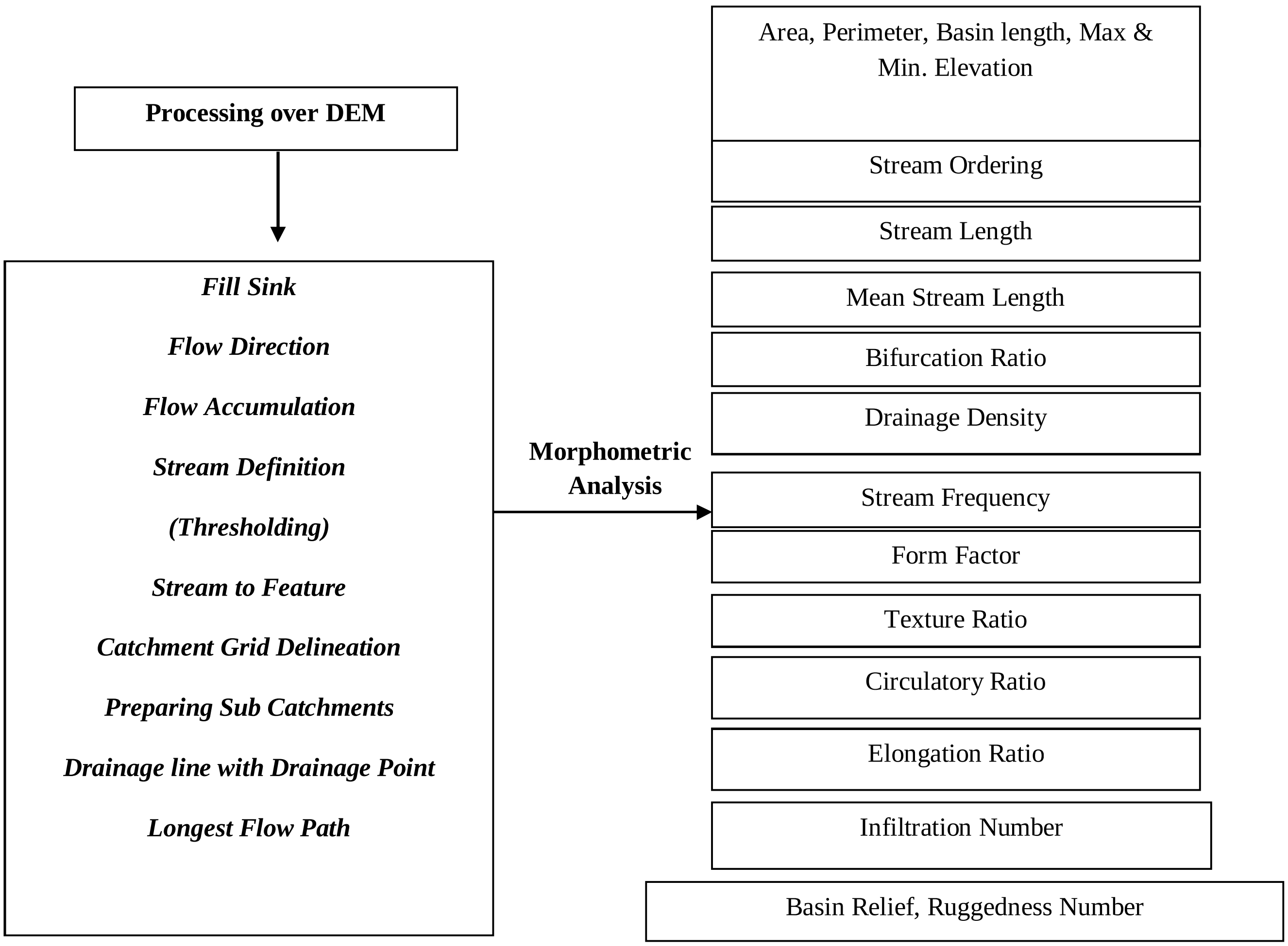
A. Data used

Topographical Map; Survey of India (SOI) Toposheets (1 : 50000 scale), Advanced Space Borne Thermal Emission & Reflection

(ASTER) DEM with 30 m spatial resolution, Shutter Radar Topography Mission (SRTM) with 90 m resolution, Remote sensing Data like 1RS – P6 (Resource SAT – 1), 1 RS – 1D. LISS 111, LISS ID PAN, 1 RS – P6 (Resource SAT – 1), LISS 1V were used as raw input data in all research papers [1] – [31].

B. Analysis and Process

Morphometric analysis of a drainage basin requires the delineation of all the existing streams, digitization of the drainage basin is carried out for morphometric analysis using ARC GIS 9.0 software, (Arc Hydro, Arc Swat tool) Geomatica Software, ERPAS IMAGINE 2010



C. Stream Order (U)

Stream Ordering has proposed by Strahler (1964). It is hierarchical relationship between stream segments and their connectivity to each other. A second order stream is created after two first order streams meet to each other.

D. Stream Number (Nu)

It is a number of streams and is inversely proportional to stream order. Number of streams decreases as the stream order increases. Horton (1945) states that the numbers of stream segments of each order form an inverse geometric sequence with order number.

E. Stream Length (Lu)

It is measure with respect to stream orders by using GIS Software which is proposed by Horton (1945). Horton's law of stream lengths supports the theory that geometrical similarity is preserved generally in watershed of increasing order (Strahler, 1964).

F. Mean Stream Length (LSM)

The mean stream length of a channel is the characteristic size of drainage network components and its contributing basin surface (Strahler, 1964). It is calculated by dividing the total stream length of order "u" by the number of stream of segments in the order. It is directly proportional to the basin area and its topography.

G. Stream Length Ratio (RL)

Horton (1945) states that the length ratio is the ratio of the mean of segments of order to mean length of segments of the next lower order, which tends to be constant throughout the successive orders of a basin. It has important relationship with surface flow and discharge and erosion stage of the basin.

H. Bifurcation Ratio (RB)

The bifurcation ratio is the ratio of the number of the stream segments of given order to the number of streams in the next higher order (Horton 1945). The higher values of Rb indicates strong structural control on the drainage pattern, while the lower values indicative of watershed that are not affect by structural disturbances. The lower bifurcation ratio values are characteristics of the watershed, which has suffered less structural disturbances and the drainage pattern has not been distorted by the structural disturbances. The bifurcation ratio is indicative parameter of shape of the basin also.

I. Drainage Density (DD)

Drainage density is the total stream length of all the streams in the watershed to the area of watershed. It helps in determining the permeability and porosity of the watershed. In general low drainage density is favored in regions of high resistant or highly permeable sub soil materials, under dense vegetation cover and where relief is low. High drainage density is favored in regions of weak or impermeable surface materials, sparse vegetation, and mountainous relief. The drainage density is governed by the factors like rock type, run off intensity, soil type, infiltration capacity and percentage of rocky area.

J. Stream/Drainage Frequency (FS)

Stream/Drainage Frequency is the total number of all the streams in the watershed to the area of watershed. A large basin may contain as many fingertip tributaries per unit of area as a small drainage basin, and in addition, it usually contains a larger stream or streams (Horton 1945). The Stream/drainage density values of the basins exhibits +ve correlation with the stream frequency indicating there is an increase in stream population with respect to increasing drainage density.

K. Texture Ratio (T)

It is the total number of stream sequence of all orders per perimeter of that area (Horton 1945). According to Horton (1945), infiltration capacity as the single important factor which influences drainage texture & considered drainage texture which includes drainage density & stream frequency. According to Schumm (1965), texture ratio is an important factor in the drainage morphometric analysis which is depending on the underlying lithology, infiltration capacity and relief aspect of the terrain.

L. Form Factor (RF)

Form factor is be defined as the ratio of basin area to square of the basin length (Horton 1932). Smaller the value of form factor, more elongated will be the basin. The basins with high form factors have high peak flows of shorter duration, whereas, elongated sub-watershed with low form factors have lower peak flow of longer duration. The value of form factor would always be greater than 0.78 for a perfectly circular basin.

M. Circulatory Ratio (RC)

Circularity ratio is the ratio of the basin area to the area of a same circumference perimeter as the basin, and expresses the degree of circularity of the basin (Miller 1953). He described the basin of the circularity ratios range 0.4 to 0.5 which indicates strongly elongated and highly permeable homogenous geologic materials. The circulatory ratio is depend with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin.

N. Elongation Ratio (RE)

It is the ratio between the diameter of the circle of the drainage basin and the maximum length of the basin (Schumm ,1956). Values near to 1.0 are the characteristics of the region of very low relief, while values in the range of 0.6 - 0.8 usually occur in the areas of high relief and steep ground slope (Strahler 1964). These values are further categorized as circular (>0.9), oval (0.9-0.8) and less elongated (<0.7).

O. Length of Overland Flow (LOF)

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It is a ratio between the diameter of a circle of that basin area to the length of basin. It is approximately equals to half of reciprocal of drainage density (Horton, 1945). The values of Lg are low in all watersheds indicating overall high relief in area.

P. Constant Channel Maintenance (C)

It is the inverse of drainage density or the constant of channel maintenance as a property of landforms (Schumm, 1956). The constant of channel maintenance indicates the relative size of landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957).

Q. Infiltration Number (IN)

The infiltration number of a watershed is defined as the product of drainage density and stream frequency and given an idea about the infiltration characteristics of the watershed. The higher the infiltration number, the lower will be the infiltration and the higher run-off.

R. Relief Ratio (RH)

The relief ratio is the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumm, 1956). The relief ratio normally increases with decreasing drainage area and size of the watersheds of a given drainage basin (Gottaschalk, 1964). Relief ratio is inversely proportional to the drainage area and the size of given drainage.

S. Ruggedness Number (RN)

Strahler's (1956) ruggedness number is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. An extreme high value of ruggedness number occurs when both variables are large and slope is not only steep but long as well (Strahler, 1956).

Formula for Computation of Morphometric Parameters

Aspects	Morphometric Parameters	Formula	References
LINEAR	Stream Order (U)	Hierarchical Order	Strahler, 1964
	Stream Length (Lu)	Length of the Stream in km	Horton, 1945
	Mean Stream Length (Lsm)	Lsm = Lu/Nu Where, Lu = Total stream length of order 'u'; Nu = Total no. of stream segments of order 'u'	Horton, 1945
	Stream Length Ratio (RL)	RL= Lsm / Lsm-1 Where, Lsm=Mean stream length of a given order ; Lsm-1= Mean stream length of next lower order	Horton, 1945
	Bifurcation Ratio (Rb)	Rb = Nu / Nu +1 Where, Rb = Bifurcation Ratio ; Nu = No. of stream segments of a given order ; Nu +1= No. of stream segments of next higher order	Schumn, 1956

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ARIAL	Drainage Density (Dd)	Dd = Lu/A Where, Dd = Drainage Density (1/km) ; Lu = Total stream length of all orders ; A = Area of the basin (km^2)	Horton, 1945
	Stream Frequency (Fs)	Fs = Nu/A Where, Fs = Stream Frequency ; Nu = Total no. of streams of all orders and ; A = Area of the basin (km^2)	Horton, 1945
	Texture Ratio (T)	T = Nu /P Where, Nu = No. of streams in a given order ; P = Perimeter of basin (km)	Horton, 1945
	Form Factor (Rf)	$Rf = A/Lb^2$ Where, A = Area of the basin ; Lb = Basin length	Horton, 1945
	Circulatory Ratio (Rc)	$Rc = 4\pi A/ P^2$ Where, A = Basin area (km^2) ; P= Perimeter of the basin (km)	Miller, 1953
	Elongation Ratio (Re)	Re= $\sqrt{A}$ /π / Lb Where, A= Area of the basin (km$^{2)}$; Lb= Basin length (km)	Schumn, 1956
	Length of Overland Flow (Lof)	Lof = 1/ 2Dd Where, Dd = Drainage Density	Horton, 1945
	Constant Channel Maintainance (C)	C = 1/ Dd Where, Dd = Drainage Density	Horton, 1945
	Infilteration Number (In)	In = Dd × Fs Where, Dd = Drainage density ; Fs = Drainage frequency	Faniran, 1968
RELIEF	Relief Ratio (Rh)	Rr = H / Lb Where, H = Basin Relief (km) ; Lb = Basin length (km)	Schumn, 1956
	Ruggedness Number (Rn)	Rn = H x Dd Where, H = Basin Relief (km) ; Dd = Drainage Density	Patton & Baker, 1976

Volume 5 Issue V, May 2017
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III. CONCLUSION

A. The study of morphometric analysis using GIS helps to analysis the drainage basin easily & accurately with have various watershed problems like drought area, soil erosion, change of land use land cover, watershed evaluation, flooding, groundwater potential zones & its Scarcity.

B. Many researchers found that GIS based approach in analysis at river basin is more appropriate than the conventional methods.

C. GIS based analysis with morphometric parameter gives a relationship between hydrological aspect, geological, topographical, pedological which is useful for planning & management of watershed construction & watershed structure (check dam, recharge shaft, percolation tank).

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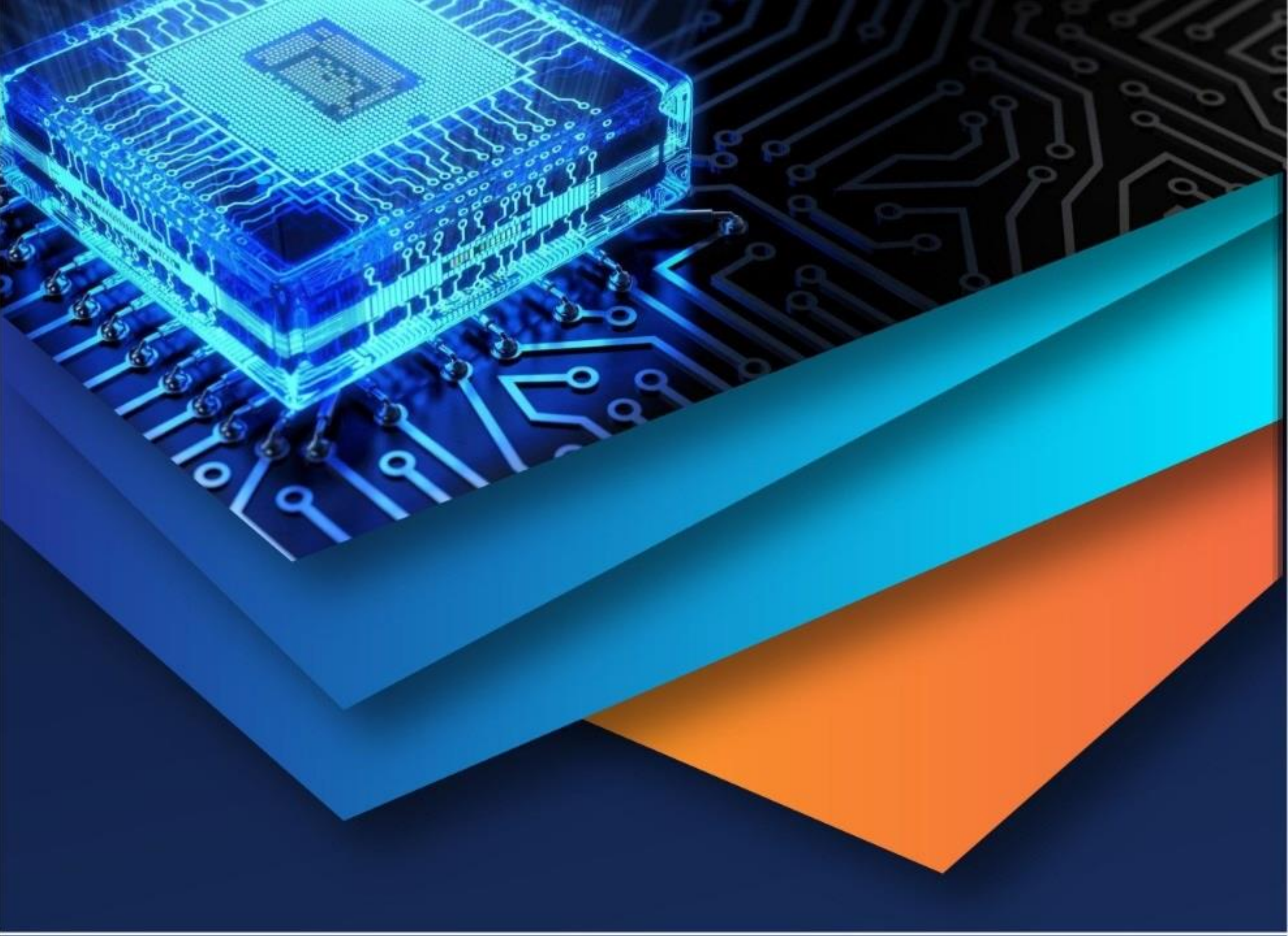

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