RESEARCH ARTICLE OPEN ACCESS

Morphometry Analysis Using SAGA GIS: A Case Study of Watershed – 63 of Narmada River, Gujarat, India.

Snehakumari S. Parmar*
**(Water Resources Engineering and Management Institute (WREMI), Samiala -391410, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda, Ta. & Dist.: Vadodara, Gujarat, India*

ABSTRACT
Morphometry is a term which includes the measurement and mathematical assessment of earth's surface and the dimension of the landforms. The aim of this study is to use GIS technique and remote sensing data integrally which will show how morphometry parameters are responsible for causing sedimentation by extracting river basin, stream networks and analyzing such parameters through Shuttle Radar Topographic Mission (SRTM), Digital Elevation Model (DEM). SAGA (System for Automated Geo-Scientific Analysis) GIS software with version 6.3.2 used for preparation of maps and to verify the spatial extent of area. Watershed number – 63 of Narmada river is selected for research work which is lying in middle Narmada river basin, situated in two districts, Narmada district of Gujarat and Nan durbar district of Maharashtra. The watershed contains 2 sub – watersheds. Integral results obtained from satellite data and GIS technique shows that study area comes under very high to severe soil erosion class because moderate to steep slope, moderate land use, homogeneity in basin texture, lack or moderate structural control exists. The study concludes that morphometric analysis along with GIS technique proves to be very helpful to identify the geo-hydrological, geomorphological characteristics of basin for planning, sustainable development and management of watershed.

***Keywords* -** Areal parameters, GIS, linear parameters, Morphometry, Narmada river watershed, relief parameters.

Date Of Submission: 26-01-2019 Date Of Acceptance:09-02-2019

I. INTRODUCTION

Morphometry may have explained as mathematical analysis carried out for a shape of element or dimensions of landforms and quantifying the configuration of the Earth's surface [1]. One of the most important characterization aspect of any basin is Morphometric analysis of that river basin. The analysis of morphometric parameters includes measurement of linear, aerial and relief aspects as well as gradient of channel network and contributing ground slope of the basin [2,3,4]. The objective of morphometry study is to carry out a quantitative explanation of the drainage system [4], which was conventionally developed by Horton in 1945 and modified by Strahler in the year of 1964. But nowadays Remote sensing and GIS techniques are adopted for analysis and to correlate periodic changes [3]. Such drainage basin analysis provide an important results in hydrological investigation such as assessment of groundwater potential and groundwater management, the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density, size and length of the tributaries, problem identification, assessment of potentials and management needs, identification of erosion prone areas, evolving water conservation strategies, selection of sites for check dams and reservoirs etc. [5]. These factors are evaluated using remote sensing technique and topographical map [2,4]. A subsequent objective is to optimize land-use activities of a watershed in such a way that soil erosion is minimised and maximizing the agricultural economic income [1]. Remote sensing and GIS techniques also used for purpose of delineation of boundary, updating and morphometric analysis of drainage basin. Watershed area is area on earth surface from where precipitation water collects and drain to a defined channel, stream or at particular point [6,7]. The dynamic nature of runoff is controlled by the geomorphologic structure of the catchment area and the induced runoff is very sensitive towards the morphometric characteristics of the contributing area such as slope, size and shape of drainage area, length of tributaries, drainage density, etc. [5,8,9].

Use of GIS is nowadays common in natural resources field like hydrologic and water driven demonstrating, mapping, and watershed administration and so on. The use of Geographic Information System (GIS) to compute soil losses became common in the last two decades. GIS provides a fast and efficient means of generating the input data required for these models. The use of Geographical Information System (GIS) methodology is well suited for the quantification of heterogeneity in the topographic and drainage features of a catchment. The objectives of this research were to use GIS for the discretization of the catchments into small grid cells and for the computation of such physical characteristics of these cells as slope, land use and soil type, all of which affect the processes of soil erosion and deposition in the different sub-areas of a catchment [10]. Furthermore, GIS methods are become helpful to divide the sub-areas into overland and channel types as well as in estimating the soil erosion in individual grid cells. GIS can deal with the problem of the spatial data management and it has the enough strength to develop interpretation for automated data, processing and overlaying maps for solving complex decision making problems with help of an emerging tool for forming biophysical information which tool is known as Remote Sensing process which is necessary for the GIS operations. Nowadays soil erosion and deposition are worldwide problems and not restricted to India. But, for purpose of sustainable development it is necessary to understand and solve the problem related to soil erosion by analysing morphometry characteristics of that area. For that precautions should be taken.

Here, some suggestions are given to prevent soil erosion:

- Commonly accepted surface stabilization and erosion control measures are Surface Roughening, Re-vegetation Seeding, Hydro-seeding, Sodding, Mulching, Matting, geotextile, Rock Riprap, Buffer Zones etc.
- Upstream sediment traps should be constructed for sediment routing and removal of trapped sediment from existing reservoirs.
- Contour farming and planting practices adopted along with slope of a hill and the natural contours of the land.
- Wind break should be planned for controlling Wind erosion. A windbreak may be constructed in form of row of trees, bushes etc.
- Deforestation of land should be prevented and adopting best practice for purpose of Afforestation.
- Terrafix erosion control retaining blocks can be hire in a variety of designs to suit most site conditions. It is an element which is environmentally acceptable.

II. OBJECTIVES OF PRESENT STUDY

The open Source Tool SAGA GIS 6.3.2 (System for Automated Geo-Scientific Analysis) was used to fulfil following objectives: To analyze morphometry parameters which are responsible for causing Sediment Yield and soil loss of Narmada middle basin watershed no. 63 lying in Narmada district in Gujarat and Nan- durbar districts in Maharashtra, India by using Remote Sensing and GIS Techniques.

III. STUDY AREA

The hydrological site selected for present study is the catchments of Narmada middle basin watershed no:63 (21° 49' 49.818" N; 73° 44' 54.6756" E) in Gujarat and (21° 54' 24.0876" N; 74° 1' 23.1204" E) in Maharashtra, India. The total area drained by the river is being 690 km2. Watershed code: NRDM077. Nature of stream is Katari nadi and Khat nadi. The study area falls under Survey Of India (SOI) Topo sheet numbers 46A, G. Gujarat and Maharashtra area major sharing states for this watershed. Narmada river having 3 sub-basins (1) Upper basin (2) middle basin (3) lower basin. Watershed no: 63 is part of middle basin and is located Narmada district of Gujarat and Nan durbar district of Maharashtra.

In this study, value of soil Erosion estimated using Revised Universal Soil Loss Equation (RUSLE) method and Universal Soil Loss Equation (USLE) method by dividing the watershed in sub watershed level or micro watershed level. Middle Narmada river basin having total 63 watersheds and watershed – 63 has two sub watersheds as given below in Fig. 1. Sub watershed - 1 having area 205 km2. Sub watershed – 1 which lies on upper side having rain gauge station Khasra. Sub watershed- 2 having area of 516.17 km2. Sub watershed – 2 which lies on lower side having rain gauge between Sankali and Piplod.

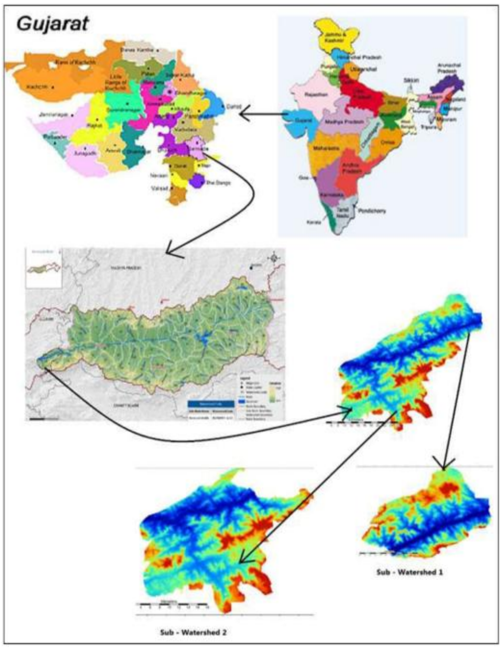

Fig.1 location plan of study area

IV. METHODOLOGY

This research is required for development of water conservation and soil conservation measures. The open-source software SAGA (System for Automated Geoscientific Analyses) GIS with version of 6.3.2 is used here for analysis work. Very less research work is carried out using SAGA GIS software. Due to this reason, it is aim that this research work would fill gap of knowledge up to certain extent and eventually encourages other researchers to use such soft wares. The Digital Elevation Model (DEM) were mosaicked and watershed boundary was delineated from Shutter Radar Topography Mission (SRTM) data of 30 meters resolution, which is freely available and downloaded from http:// www.earthexplorer.usgs.gov , using SAGA GIS software. Additionally, Co-ordinates transformation is required before using DEM with 30meter resolution or any of the bands to the Projected coordinate system consider as Kalianpur 1975/ India zone - lla to make all grids and shape in one projected zone of India. This data was subsequently utilized for creation of the drainage network which is created manually by digitizing drainage lines and overlaid on DEM in SAGA GIS or by creating flow accumulation map in SAGA GIS and these digitized drainage lines overlaid on DEM in SAGA GIS. With help of Google earth pro standard visual image interpretation method was carry out to recognize the elements such as texture of soil, size, shape, pattern, soil conservation practice and field knowledge was followed. Land use / land cover categories such as agriculture land, dense forest, open forest, open scrub, settlement, stone quarry, exposed rock, waste land and water body, etc. were delineated on the basis of image interpretation or unsupervised classification from SAGA GIS [8]. Apart from that digitization, editing in topology of building also achieved from SAGA GIS.

Then after, analysis of morphometric parameters has been evaluated for entire watershed – 63. Different parameters influencing each other in different ways. While applying stream ordering, Horton's law is followed for designating an un-branched stream as first order stream, when two first order streams join it is designated as second order stream. When two second order steams meet together it will form the third order stream and so on. The number of streams of each order are counted and recorded. The drainage map along with basin boundaries are digitized as a line coverage by giving unique id for each order of stream. The digitized map is edited and saved as line coverage in SAGA GIS Software. Direct measurements of geometric characteristics were taken in GIS software. For example, area and perimeter of basin area as well as its length and number of streams of different orders etc. were achieved using SAGA GIS.

While calculating linear aspect, high weightage has been provided for higher values. And in case of aerial aspect assigning low weightage for higher values. The basin which having lowest compound weight has been given highest or first priority for taking measures against soil losses [4]. Finally, the final priority classification has been divided into three major class groups and they are high priority, moderate priority and poor priority. The high priority or first priority should be given to such where reclamation process is required and action plan should take into consideration for soil conservation practices as well as and water conservations and flood management activities.

The basic fundamental parameters such as stream length, area, perimeter, number of streams and basin length are derived from drainage layer achieved in SAGA GIS. The values of other morphometric parameters are derived based on the formulae suggested by Horton, Miller, Schumn, Strahler, Nookaratm. The other remaining morphometric parameters are stream order, bifurcation ratio, drainage density, texture ratio, stream frequency, form factor, elongation ratio, circularity ratio and compactness constant. Furthermore, for the study area various researchers have proposed the values of these parameters that are obtained and indicated in respective descriptions.

4.1 Linear Aspects

In morphometric analysis, linear aspects of the basin includes analysis of certain parameters such as (1) the stream order (U), (2) stream length (Lu), (3) mean stream length (Lsm), (4) stream length ratio (RL) and (5) bifurcation ratio (Rb), were determined and results have been presented in Table 1. Stream links (the different drainage lines) and the nodes (the stream junctions/ confluences) characterise ' Linear aspects' of the basin.

4.1.1 Stream Order (U)

There are four different system of ordering streams that are given by Gravelius , Horton , Strahler and Schideggar. Strahler's system used repeatedly because of its simplicity and also it is a slightly modification of Hortons system. The smallest fingertip tributaries as well as un-branched fingertip streams tributaries are numbered as first order stream, the confluence or channels join of two first order channels give a channels segments of second order stream, same way two second order streams get merged together and form a segment of third order stream and so on. When two channel of different streams order join together then the higher stream order is maintained. The trunk stream is the stream segment of highest order. Fig. 2 shows how general view of stream order given by Strahler.

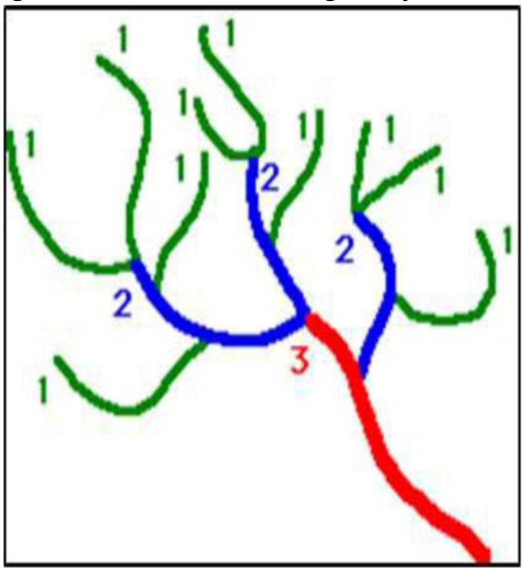

Fig. 2 Basics of Stream order given by Strehler

4.1.2 Stream Length (Lu)

Horton proposed the law to compute the value of stream length. Stream length may have considered as one of the most important hydrological features of the basin. Because it reveals surface runoff characteristics. Areas with larger slopes and finer textures are unique characteristics of streams having stream of relatively smaller length. Larger lengths are generally indicative of flatter gradient (Singh 1997). Usually, the first order stream having maximum total length of stream segments and decreases as the stream order increases (Horton, 1945). The total numbers of streams of various orders are counted for given watershed. Length of such streams are measured from mouth to drainage divide line. GIS software becomes helpful in this measurement. The change in length may indicate flowing of streams from high altitude, lithological variation and moderately steep slopes. This reveals very intensive assumption that the basin is subjected to erosion and also some areas of the basin are having unique characteristic due to the variation in lithology and topography.

4.1.3 Mean Stream Length (Lsm)

One of characteristics property regarding drainage networks is mean stream length and it is also important feature in case of associated surfaces of drainage network (Strahler, 1964). The mean stream length (Lsm) may defined as ratio of the total stream length of stream order divided by the number of stream. The mean stream length of stream increases with increase of the stream order.

4.1.4 Stream Length Ratio (RL)

The stream length ratio should be explained as the ratio of the mean stream length of a given order of stream divided by the mean stream length of next lower order stream. It has a supreme correlation with surface flow and discharge also (Horton, 1945). Total stream length of a given order is conversely associated with stream order, i.e., total stream length from the lower order to the successively higher orders get reduced. Such variation may be due to dissimilarities in slope and topography, it designates that the youth stage of geomorphic evolution in the streams of the study area.

4.1.5 Bifurcation Ratio (Rb)

Bifurcation ratio may be defined as it is the ratio of the number of stream segments of given order stream to the number of stream segments of the next higher order stream (Schumn 1956). A bifurcation ratio is representation of a small range of inequality for non- identical regions or non- identical environmental conditions, except where the geology influences exhibited by Strahler. Generally, these Rb values are common in the areas where geologic structures do not play a superior influence on the drainage pattern.

4.2 Relief Aspects

The relief aspects include relief ratio, relative relief and ruggedness number. Relief aspects in case of drainage basin mainly associated or interconnected with three dimensional (3D) features of the watershed basin. This involves features like area, volume and altitude of vertical dimension of landforms. In this analysis different morphometric parameters evaluated for purpose of analysing the terrain characteristics.

4.2.1 Relief Ratio (Rh)

The relief ratio may have defined as a ratio of maximum basin relief to maximum horizontal distance available along the longest dimension of the basin (in short basin length) which is parallel to the principal drainage line. Basin relief is vertical distance measured between lowest and highest point available in basin. Generally, the relief ratio, Rh increases while decreasing drainage area as well as the size of watersheds of a that particular drainage basin (Gottschalk, 1964). Relief ratio measures the comprehensive steepness of a drainage basin and Rh is also an indicator of the power of erosion process utilizing on slope of the basin.

4.2.2 Relative Relief (Rbh)

Relative relief termed as ‘amplitude of available relief’ or ‘local relief’ which is defined as the difference in height between the highest and the lowest points (maximum difference in height between two points) of a basin / unit area. This term was given by Melton in the year of 1957. In the present study area this value is obtained by visual analysis of the digital elevation model prepared from SRTM data. Also calculated in SAGA GIS by Diffusion Hillslope Evolution (FTCS) in which elevation difference directly achieves. Relative relief is one of most important morphometric parameter utilised for carrying out overall analysis of morphological characteristics of terrain area.

4.2.**3 Ruggedness number (Rn)**

This term was suggested by Melton. This term also known as Milton's ruggedness number. It is calculated by multiplication of maximum basin relief (H) and drainage density (Dd). Here basin relief (H) and drainage density (Dd) both parameters are having the same unit. when both parameters are large and slope is steep, a superlatively high value of ruggedness number occurs (Schumm, 1956). According to Strahler ruggedness number, its value indicates the structural complexity of the terrain which is mainly associated with relief and drainage density of such basin.

4.3 Aerial Aspects

The role of aerial aspects is to deal with the total area of basin which contributing or presenting from overland flow to the channel segment of the given stream order which is projected on a horizontal plane and also incorporates / integrates all tributaries of lower or following stream order. The aerial aspects include different morphometric parameters. For example, drainage density of basin, drainage texture of basin, stream frequency of different stream order, form factor, circularity ratio, elongation ratio and length of overland flow of basin area. In quantitative geomorphology area of a basin (A) and perimeter (P) proves to be significant parameters. The values of these parameters were calculated with help of SAGA GIS and formulas suggested by Horton, Strehlar, Schumn have been given in Table 1.

4.3.1 Drainage density (Dd)

Horton in 1932 initiated the drainage density (Dd) which is principal indicator of land form components in stream eroded topography. Drainage density is the ratio of total channel segment length cumulated for all order within a basin (Σ Lu) to the basin area (A) , which is expressed in terms of Km/Km2. The drainage density shows closeness of spacing of channels. A low drainage density is generally more likely to occur and high resistant of highly permeable subsoil material under dense vegetative cover and where relief is low. The weak or impermeable subsurface material represents high drainage density which may be due to, growing out sparse vegetation and mountainous relief. High drainage density shows the basin having fine drainage texture. The Moderate drainage density indicates the basin is highly permeable subsoil and vegetative cover.

4.3.2 Stream Frequency (Fs)

Stream frequency (Fs), is explained as the total number of stream segments of all order streams divided by unit area of basin (Horton, 1932). Stream frequency shows positive correlation with drainage density in the watershed which indicates that an increase in the population of stream with respect to increase in drainage density.

4.3.3 Texture Ratio (T)

Horton suggest that the drainage texture ratio may defined as the total number of stream segments of all stream order divided by perimeter of that basin area. This ratio depends on many natural factors like climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development.

4.3.4 Form Factor (Ff)

For Form factor (Ff) is explained as ratio of area of the basin divided by the square of the basin length. According to Horton in 1945 this factor shows the flow intensity of a basin area. If the basin is more elongated, then the smaller the value of the form factor will have achieved.Elongated watersheds with low form factors experience lower peak flows of longer duration. However if the basins with high form factors experience larger peak flows of shorter duration, form factor is the quantitative analysis of drainage basin in the form of outline.

4.3.5 Circulatory Ratio (Rc)

According to Millar in 1953, the ratio of the area of a basin divided by the area of a circle which has the same circumference value as the perimeter of the basin defined as Circularity Ratio. This ratio also gets affected by the value of frequency of streams, condition of geological structures, type of land use and land cover, climate condition, relief and slope of the basin. If the Rc value of basin is moderate, then it representing that the basin is characterized by moderate to low relief and drainage system seems to be less affected by structural disturbances. The high value of circularity ratio shows the late maturity stage of topography.

4.3.6 Elongation Ratio (Re)

According to Strahler in 1964 the Re values close to unity indicating that to regions of low relief, whereas values in the range 0.6–0.8 are usually associated with high relief value and also with steep ground slope value. The value of elongation ratio can be grouped into three categories. They name as (a) circular (>0.9), (b) oval (0.9-0.8),

(c) less elongated (<0.7). The Re values indicating moderate to slightly steep ground slope and area when collaborated with Strahler's range seem to suggest an elongated shape.

4.3.7 Length of overland flow (Lg)

According to Horton in 1945 the Length of Overland Flow (Lg) is defined as the length of water over the ground surface before it gets merged into specific stream channel. Horton also suggest that the length of overland flow (Lg) is also approximately equals to half of reciprocal of drainage density. The length of overland flow (Lg) is one of the most important parameter in analysis and also the independent variables which directly affecting hydrologic scenario of basin as well as the physiographic development of drainage pattern of basins.

4.3.8 Constant channel maintenance (C) Schumm in 1956 evaluated constant channel maintenance C. It is achieved from the inverse of drainage density which is expressed in units of square feet per foot and has the dimension of length. Therefore magnitude of C value increases as the scale of the land-form unit increases. In addition to this, the constant C provides information of the number of square feet of watershed surface required for sustaining one linear foot of stream.

4.3.9 Channel index (Ci) and valley index (Vi)

Generally, while determining the sinuosity parameters the river channel should get divided into number of stream segments. The measurement of various parameters like stream channel length, valley length, and shortest distance between the source and mouth of the river, is carried out with help of SAGA GIS. In this software air lengths tool used for calculation of Channel index and valley index. Table 1 shows method of expressing Morphometric analysis of a drainage basin using Geographic Information System.

Table I Method of expressing Morphometric analysis of a drainage basin using Geographic Information System

Morphometric Parameters	Formula / Definition
Linear Aspect	
Stream order (U)	Hierarchical Order
Stream Length (Lu)	Length of the stream
Mean stream length (Lsm)	Lsm = Lu / Nu Where, Lu=Mean stream length of a given order (km), Nu=Number of stream segment.
Stream length ratio (RL)	RL = Lu / Lu-1 Where, Lu= Total stream length of order (u), Lu-1=The total stream length of its next lower order.
Bifurcation Ratio (Rb)	Rb = Nu / Nu+1 Where, Nu=Number of stream segments present in the given order Nu+1= Number of segments of the next higher order
Relief Aspect	
Basin relief (Bh)	Vertical distance between the lowest and highest points of basin.
Relief Ratio (Rh)	Rh = Bh / Lb Where, Bh=Basin relief, Lb=Basin length
Ruggedness Number (Rn)	Rn=Bh × Dd Where, Bh= Basin relief, Dd=Drainage density
Aerial Aspect	
Drainage density (Dd)	Dd = L / A Where, L=Total length of stream, A= Area of basin.
Stream frequency (Fs)	Fs = N / A Where, L=Total number of stream, A=Area of basin
Texture ratio (T)	T = N1 / P Where, N1=Total number of first order stream, P=Perimeter of basin.
Form factor (Rf)	$Rf = A / (Lb)^2$ Where, A=Area of basin, Lb=Basin length
Circulatory ratio (Rc)	$Rc = 4 \pi A / P^2$ Where, A= Area of basin,π=3.14, P= Perimeter of basin.
Elongation ratio (Re)	$Re = \sqrt{(Au / \pi)} / Lb$ Where, A=Area of basin, π=3.14, Lb=Basin length
Length of overland flow (Lg)	Lg = 1 / 2 Dd Where, Drainage density
Constant channel maintenance(C)	C = 1 / Dd Where, Dd= Drainage density

V. RESULTS AND DISCUSSION

The result of entire work become helpful to predict the sediment yield with greater reliability by optimizing land-use activities of a watershed even with deficiency of recorded data apart from that it is very important for groundwater potential assessment and its management, environment assessment etc. Together, there is scarcity of detailed study of morphometry in particular basin. Instead of enough research work of environment study and geographical study are available for particular basin. It is hope that this research would definitely contribute to fill the gap of knowledge in particular area. Here, watershed number 63 having two sub watersheds. One of them named as Sub watershed number -1 and another one is sub watershed number – 2. Morphometric featured of sub watershed – 1 are shown in Fig. 3 and morphometric featured of sub watershed – 2 are shown in Fig. 4. Figures below shows ridges as a yellow colour and channels as in dark blue colour and peak points by red colour. Grey colour shows flat surface. This study becomes helpful to find out undulations and topography of watershed area.

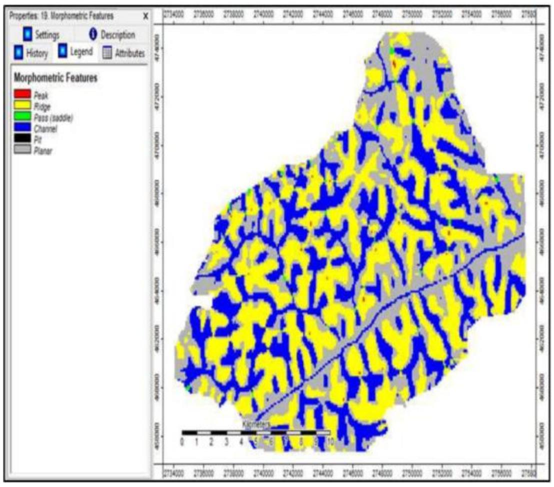

Fig. 3 Morphometric feature of sub – watershed – 1

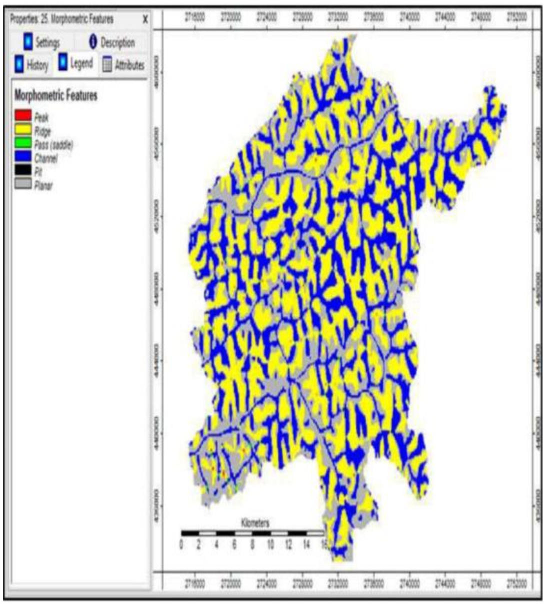

Fig. 4 Morphometric feature of sub watershed – 2

Table II (Part –I) Analysis of Morphometric parameters

Stream Order (U)	Stream Length (Lu)		Stream Number (Nu)	
-	**SW-1**	**SW-2**	**SW-1**	**SW-2**
-	**Meter**	**Meter**	-	-
First Order	69.6	146.48	21	64
Second Order	25.5	68.72	5	21
Third Order	24.05	38.31	1	4
Forth Order	0	45.22	0	2
Fifth Order	0	2.227	0	1
	Σ(Lu) = 119.15	**Σ (Lu) = 300.957**	**Σ(Nu) = 27**	**Σ(Nu) = 92**

Table II (Part –II) Analysis of Morphometric parameters

Stream Order (U)	Mean Stream Length (Lsm)		Stream length ratio	
	Lsm= Lu / Nu		**RL = Lu / Lu- 1**	
-	**SW-1**	**SW-2**	**SW-1**	**SW-2**
-	**Meter**	**Meter**	---	---
First Order	3.314	2.289	-	-
Second Order	5.1	3.272	0.366	0.469
Third Order	24.05	9.578	0.943	0.557
Forth Order	0	22.61	0	1.18
Fifth Order	0	2.227	0	0.049
	Σ (lsm) = 32.464	**Σ (lsm) = 39.976**	**Σ (RL) = 1.310**	**Σ (RL) = 2.256**

Table II (Part –III**)** Analysis of Morphometric parameters

Stream Order (U)	Bifurcation ratio		Stream Frequency	
	Rb = Nu / Nu + 1		**Fs = Nu / A**	
-	**SW-1**	**SW-2**	**SW-1**	**SW-2**
-	---	---	**Km^{-2}**	**Km^{-2}**
First Order	4.2	3.048	0.132	0.178
Second	5	5.25		

Order				
Third Order	0	2		
Forth Order	0	2		
Fifth Order	-	-		
	Σ(Rb) = 9.200	**Σ(Rb) = 12.298**	**------**	**------**

Table 2 shows the analysis of Morphometric parameters in five different part according to stream order. It has been found that the study area Narmada river tributaries is 5th order drainage basin. Due to the homogeneity in texture and lack of structural control the drainage patterns of stream network has been observed as mainly of dendritic type. For sub watershed number – 1 the length of first order stream (Lu) is 69.6 Km, second order stream is 25.5 Km, third order stream is 24.05 Km, and fourth order stream and fifth order stream are not there. And for sub watershed number – 2 the length of first order stream is 146.48 Km, second order stream is 68.72 Km, third order stream is 38.31 Km, and fourth order stream is 45.22 Km and fifth order stream is 2.22 Km. From first to fifth order stream having larger to smaller length i.e. gradient is initially flatter and then it becomes steeper as the stream order increases. This brings out strong assumption that the basin is subjected to erosion.

In this study total 119 numbers of streams (Nu) were identified out of which 85 first order streams in this 21 numbers of stream are in sub watershed -1 and 64 numbers of stream are laying in sub watershed - 2, 26 second order stream in which 5 numbers of stream are in sub watershed -1 and 21 numbers of stream are laying in sub watershed - 2, 5 third order stream in which 1 numbers of stream are in sub watershed -1 and 4 numbers of stream are laying in sub watershed - 2, and 2 fourth order stream and 1 fifth order stream.

Fig. 5 shows that how drainage lines appears in sub watershed – 1. Fig. 6 shows that how drainage lines appear in sub watershed – 2. First order, second order and third order streams were recognised in Fig. 5. Additionally, Fig. 7 and Fig.8 shows area and perimeter values achieved from SAGA GIS for sub watershed – 1 and sub watershed – 2 respectively.

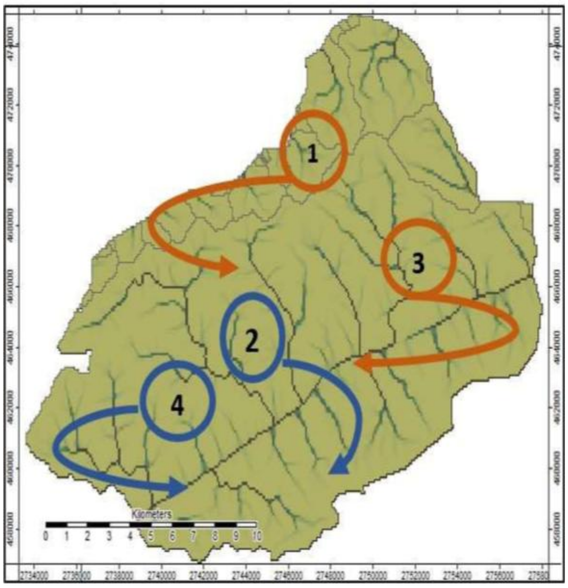

Fig. 5 Drainage lines in sub watershed – 1 showing different order stream

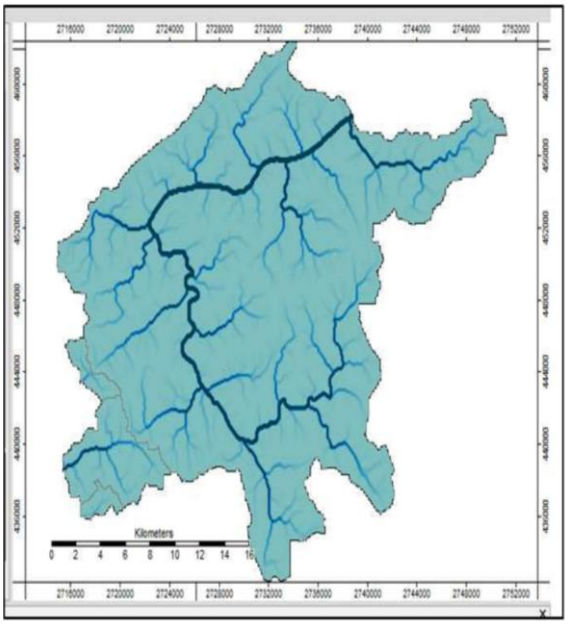

Fig. 6 Drainage lines in sub watershed – 2 showing different order stream

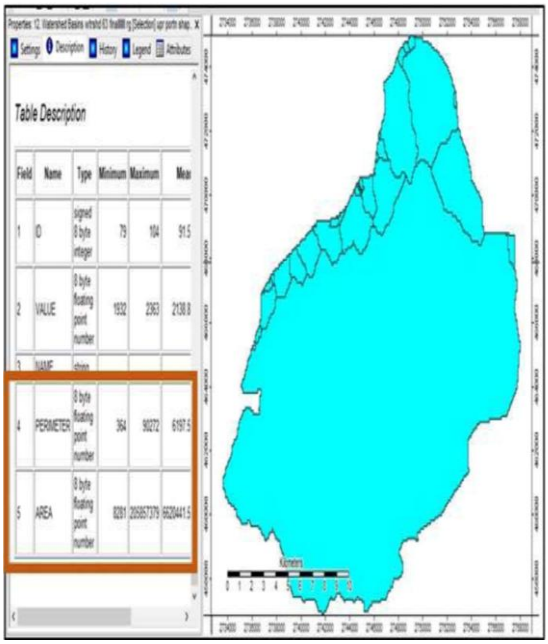

Fig. 7 Area and Perimeter of Sub watershed – 1

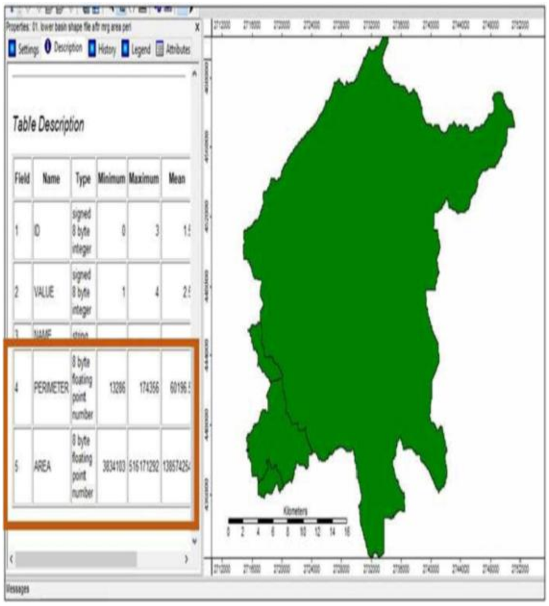

Fig. 8 Area and Perimeter of Sub watershed - 2

Area of Sub watershed – 1 is 205 km2 and Area of Sub watershed – 2 is 205 km2
Perimeter of Sub watershed – 1 is 90.27 km and Perimeter of Sub watershed – 2 is 174.35 km

Lb=basin length=distance between two far most points, 0.436 measure directly by ruler in SAGA = 48.76006
Lb for SW – 1 = 25177.03 meter and Lb for SW – 2 = 40333.41 meter

The value of mean stream length (Lsm) for sub watershed number - 1 is 3.314 for first order, 5.1 for second order, 24.05 for third order, fourth order and fifth order streams are not available. The mean stream length for sub watershed number - 2 is 2.289 for first order, 3.272 for second order, 9.578 for third order, 22.61 for fourth order and 2.227 fifth order streams are not available. It is an important feature in case of surfaces of drainage network distribution.

The stream length ratio (RL) for sub watershed number - 1 is 0.366 for second order, 0.943 for third order, fourth order and fifth order streams are not available. The stream length ratio for sub watershed number - 2 is 0.469 for second order, 0.557 for third order, 1.18 for fourth order and 0.049 for fifth order streams. This change might be responsible for variation in slope and topography also.

The mean values of Bifurgation ratio (Rb) of the entire basin shows that the basin is largely controlled by structure. In the study area Rb for sub watershed number - 1 is 4.2 for first order, 5 for second order, 0 for third and fourth order which is indicating that the basin is largely controlled by structure. The value of Rb for sub watershed number -2 is 3.048 for first order, 5.25 for second order, 2 for third order and 2 for fourth order. In this study area, the higher values of Rb show that an intensive structural control in the drainage development while on other side the lower values of Rb indicate that some of the area in the basin is less affected by structural disturbances.

The value of Stream Frequency Fs for the basin is 0.132 for sub watershed number -1 and 0.178 for sub watershed number - 2. It indicates that an increase in the population of stream with respect to increase in drainage density.

Table II (Part –IV) Analysis of Morphometric parameters

Elongation ratio		**Length of Overland Flow**		**Drainage density**	
Re = 2 (sqrt (A / pi)) / Lb		**Lg = 1 / D ^ 2**		**D = Total Lu / A**	
SW-1	**SW-2**	**SW-1**	**SW-2**	**SW-1**	**SW-2**
----	----	**km**	**km**	**km^{-1}**	**km^{-1}**
0.642	0.636	2.96	2.942	0.581	0.583

Table II (Part –V) Analysis of Morphometric parameters

Texture ratio		**Form factor**		**Circulatory ratio**	
T or Rt = Nu / P		**Rf or Ff = A / Lb ^ 2**		**Rc = 4 * pi * A / P ^ 2**	
SW-1	**SW-2**	**SW-1**	**SW-2**	**SW-1**	**SW-2**
km^{-1}	km^{-1}	---	---	---	---
0.299	0.528	0.324	0.317	0.316	0.221

The Re values for this present study area is 0.642 for sub watershed number -1 and 0.636 for sub watershed number -2 which is indicating that ground slope is moderate to slightly steep and area when collaborated with Strahler's range seem to suggest an elongated shape.

The Lg value of study area is 2.69 for sub watershed number – 1 and 2.942 for sub watershed number -2 indicating old topography.

The drainage density (Dd) of study area is 0.581 Km/Km2 for sub watershed number – 1 and 0.583 Km/Km2 for sub watershed number – 2 indicating moderate drainage densities. The Moderate drainage density (Dd) indicates the basin is highly permeable subsoil and vegetative cover and also indicates the closeness of spacing of channels.

The texture ratio (T or Rt) of the basin is 0.233 for sub watershed number -1 and 0.367 for sub watershed number - 2 and categorized as low in the nature.

The form factor (Ff) value for study area is 0.324 for sub watershed -1 and 0.317 for sub watershed number – 2. The value of form factor is smaller than the shape of basin is more elongated. Whereas elongated shape of watershed with low value of form factors mainly experience lower peak flows value for longer period of time. And if basins having high value of form factors then it experience occurrence of larger peak flows for shorter period of time.

The circularity ratio (Rc) value of basin is 0.316 for sub watershed – 1 and 0.221 for sub watershed - 2 and it indicating the basin having characteristic that moderate to low relief achieved and drainage system should be less influenced by any structural disturbances of soil formation. The basin is elongated and having low discharge and highly permeable homogenous geologic materials. The high value of circularity ratio shows the late maturity stage of topography.

Table II (Part –VI) Analysis of Morphometric parameters

Constant channel maintena -nce		**Basin relief**		**Relief ratio**		**Milton's Ruggedne ss number**	
C = 1 / D		**Bh = Ele Diff.**		**Rh = Bh / Lb**		**Rn = Bh * D**	
SW -1	**SW -2**	**SW -1**	**SW -2**	**SW – 1**	**SW - 2**	**SW - 1**	**SW -2**
km	**km**	**m**	**m**	**---**	**---**	**---**	**---**
1.721	**1.715**	**84.65**	**82.42**	**0.003**	**0.002**	**145.642**	**141.358**

The value of Constant channel maintenance (C) of basin is 1.721 for sub watershed – 1 and 1.715 for sub watershed - 2. Artificially maintaining channel capacity and riparian vegetation by periodic channel dredging, concrete lining, or irrigation is technically, economically, and environmentally infeasible to protect extensive channel networks. Channel maintenance flows are intended to maintain channel function. The Value of valley index achieves as 0.80 for sub watershed number – 1 and 0.88 for sub watershed number – 2. Here tool Valley Index used for finding out value of valley index. This result shows relative rate of uplift for study area. Fig. 9 and Fig. 10 shows valley index values for sub watershed – 1 and sub watershed – 2 respectively. These figures show these are the areas where chances of erosion are high due to its steepness.

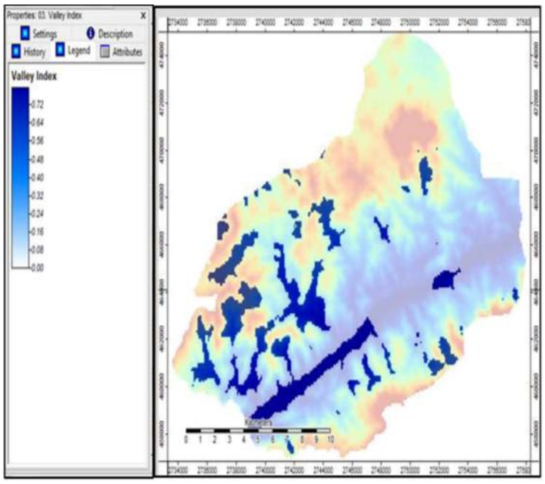

Fig. 9 Valley Index for sub watershed – 1

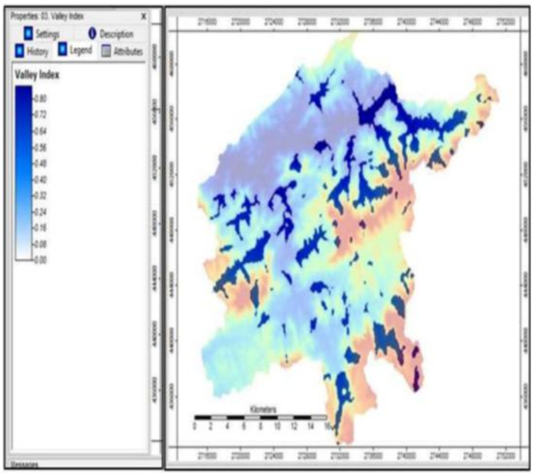

Fig. 10 Valley Index for sub watershed - 2

The value of Relief ratio (Rh) in basin is 0.003 for sub watershed – 1 and 0.002 for sub watershed – 2 indicating moderate relief and flat to moderately high slope. It is influenced by the slope of the basin and rock characteristics. Here in fig. 11 and fig.12 represents maximum height exist in area according to legends given on left side of figure in sub watershed – 1 and sub watershed-2 respectively. In this figures Red legend depicts steepness of land that leads to maximum erosion Red colour shows maximum height. Yellow colour shows moderate height and sea green and blue colour shoes moderate to low height. Generally, the Relief ratio indicates overall steepness of a drainage basin as well as it measures the intensity of soil erosion process occurring due to slope of the drainage basin.

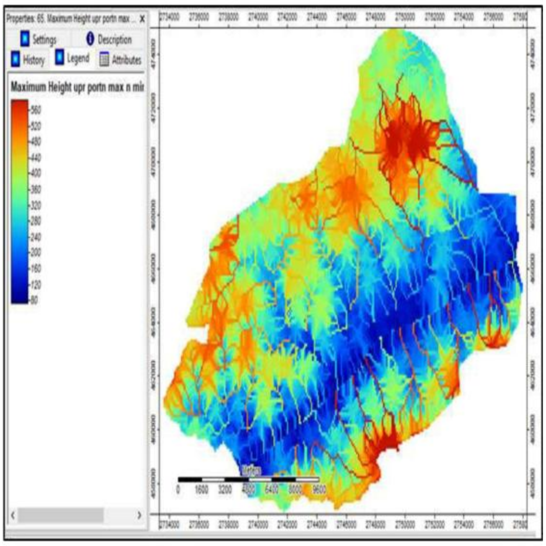

Fig. 11 Maximum height shown area in sub watershed – 1

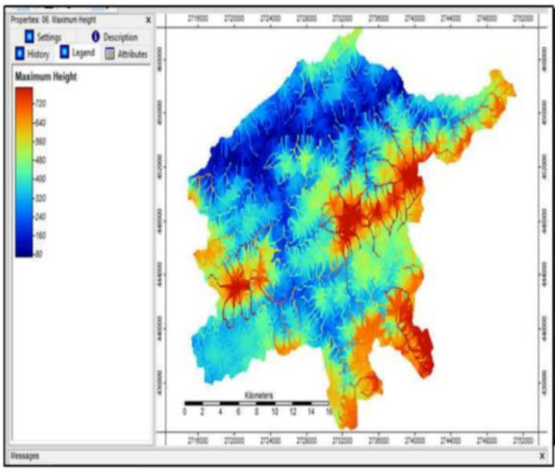

Fig. 12 Maximum height shown area in sub watershed –2

Tool used for Finding Basin relief is Diffusion Hillslope Evolution (FTCS) in SAGA GIS.

For SW -1 Elevation Difference = 0.74 * 111.385 = 84.65,

For SW -2 Elevation Difference = 0.76 * 111.385 =82.52 achieved from Histogram.

Here the values 0.74 and 0.76 collected from histogram of elevation difference. Multiplying this values by 111.385 because whatever values we achieved are in degree form and to convert this into meter. The elevation difference (Bh or H) for sub watershed – 1 is 84.65 meter and for sub watershed – 2 is 82.52 meter which represent the land has gentle to moderate slope. Fig. 13 and Fig. 14 represents elevation difference occur in sub watershed – 1 and sub watershed – 2 respectively. Brown colour in these figures shows hilly area and blue colour shows valley area.

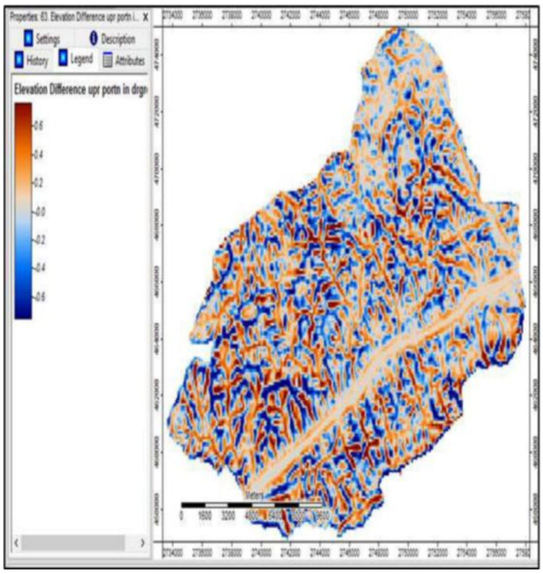

Fig. 13 Elevation difference for sub watershed – 1

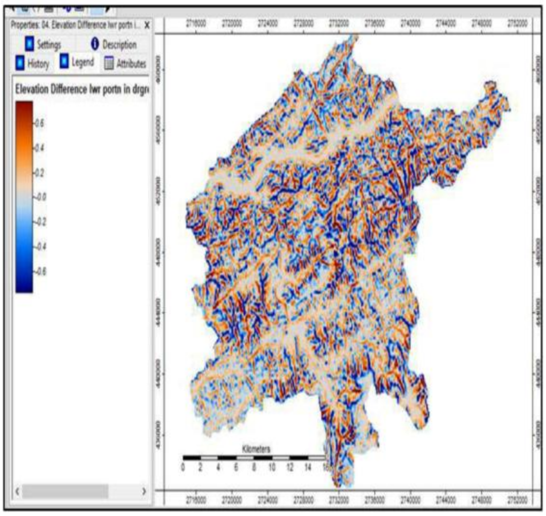

Fig. 14 Elevation difference for sub watershed – 2

The value of ruggedness number (Rn) in present basin is 145.64 for sub watershed – 1 and for sub watershed -2 is 141.39. An extremely high value of ruggedness number (Rn) represents that the structural complexity of the terrain is mainly associated with parameters like relief and drainage density. Fig. 15 and fig. 16 shows ruggedness number achieved in SAGA for sub watershed – 1 and sub watershed – 2 respectively. Red colour in below figures shows higher ruggedness number and chances of erosion occurrence is higher. Yellow and sea green colour shows moderate value of Rn and chances of erosion are also moderate.

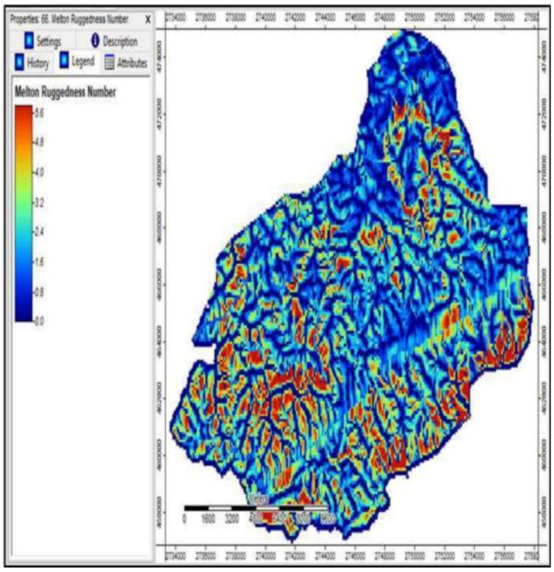

Fig. 15 Ruggedness number for sub watershed – 1

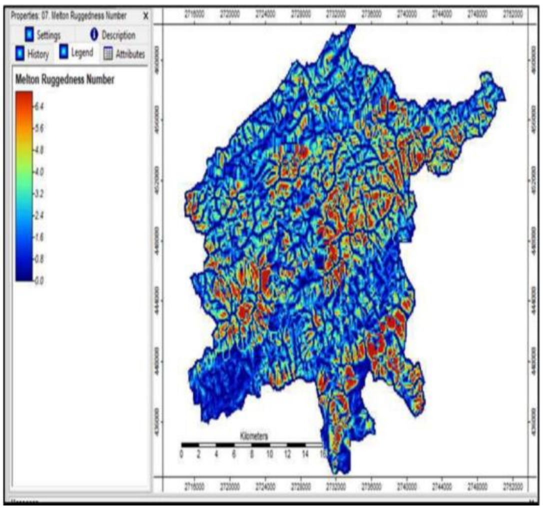

Fig.16 Ruggedness number for sub watershed - 2

VI. CONCLUSIONS

Analysis of morphometry parameters comes to the following conclusions:

The integral use of remote sensing data and GIS technique becomes helpful to find out the area which is affected by sedimentation process. From the morphometry analysis of basin, it has been found that the study area of Narmada river tributaries is an 5th order drainage basin which describe that the texture is homogeneous or homogeneity still exist and lack of structural control in soil strata. From first to fifth order stream, stream length decreases hence gradient is increase from flat to steep as the stream order increases. The relief ratio (Rh), the elevation difference (Bh or H) and circularity ratio (Rc) represents the basin having moderate relief and gentle to moderately high slope. Some areas of the basin are characterized by variation in lithology and topography. The mean values of bifurcation ratio (Rb) and circularity ratio (Rc) of the entire basin shows a moderate but not strong structural control or structural disturbances. An extreme high value of ruggedness number (Rn) indicates the structural complexity of the terrain. The Moderate drainage density (Dd) and circularity ratio (Rc) indicates the basin is highly permeable subsoil and vegetative cover. The Form factor (Ff), the elongation ratio (Re) and circularity ratio (Rc) value indicating elongated basin with lower / flatter peak flows of longer duration than the average. The elongation ratio (Re) values indicating moderate to slightly steep ground slope. The overland flow (Lg) value of study area indicating old topography. Due to this reasons watershed – 63 leads to moderately high to severe soil erosion effect and this will ultimately affect the life of dam. This methodology should also have adopted for other neighbouring watershed areas which are also contributing erosion at Sardar Sarovar dam site.

ACKNOWLEDGEMENTS

I feel glad to offer my sincerest gratitude and respect to god as well as my parents for their invaluable advice, and guidance from the foundational stage of this research and providing me extraordinary experiences throughout the work. I am immensely obliged to them for their elevating inspiration, encouraging guidance and kind supervision in the completion of my project. The door to reach them was always open whenever I ran into a trouble spot or had a question about my research. Author is also thankful to authorities of WREMI department for their constant encouragement and support and also for giving me the opportunity to work in this project.

REFERENCES

[1]. M.S.G. Rudraiah , V.S. Srinivas, Morphometry using Remote Sensing and GIS Techniques in the Sub-basins of Kagna river basin, Gulburga district, Karnataka, India, Indian Society Remote Sense. 36:351–60.

[2]. L.M. Mesa , Morphometric analysis of a subtropical Andean basin (Tucuman, Argentina), Environ Geol. 50 (8): 1235–1242.

[3]. K. Narendra, Morphometric Analysis of River Catchments Using Remote Sensing and GIS (A Case Study of the Sukri River, Rajasthan, International Journal of Scientific and Research Publications. Volume 3, Issue 6, June 2013 1 ISSN 2250-3153.

[4]. K.D. Swatantra, D. Sharma, N. Mundetia, Morphometric Analysis of the Banas River Basin Using the Geographical Information System,

Rajasthan, India." Hydrology 2015; 3(5): 47-54, Published online October 9, 2015. doi: 10.11648/j.hyd.20150305.11.

[5]. S.M. Ahmed, Drainage Basin Morphometric Analysis of Galagu Valley, Journal of Applied and Industrial Sciences. 2016, 4(1): 6-12, ISSN: 2328-4595 (PRINT), ISSN: 2328-4609 (ONLINE).

[6]. K. Uddin ,Estimation of Soil Erosion Dynamics in the Koshi Basin Using GIS and Remote Sensing to Assess Priority Areas for Conservation, PLoS ONE11(3):e0150494.doi:10.1371/journal.pone.0150494.

[7]. S. Vittala, Morphometric analysis of subwatersheds in the Pavagada area of Tumkur district, South India using remote sensing and GIS techniques, Jour. Indian Soc. Remote Sen., 4(32):351-362.

[8]. P.P. Nikhil Raj, P.A. Azeez, Morphometric Analysis of a Tropical Medium River System: A Case from Bharathapuzha River Southern India, Open Journal of Modern Hydrology, 2012, 2, 91-98http://dx.doi.org/10.4236/ojmh.2012.24011 Published Online October 2012 (http:// www.SciRP.org/ journal/ojmh).

[9]. M.L. Waikar, A.P. Nilawar, Morphometric Analysis of a Drainage Basin Using Geographical Information System: A Case study, International Journal of Multidisciplinary and Current Research, 25 February 2014, Vol.2 (Jan/Feb 2014 issue) (2321-3124), 180-184.

[10]. A. Javed, Estimation of Sediment Yield of Govindsagar Catchment, Lalitpur District, (U.P.), India, Using Remote Sensing and GIS Techniques." Journal of Geographic Information System, 2016, 8, 595-607.

[11]. K.R. Praveen, K. Mohan, S Mishra, A. Ahmad, V. N. Mishra, A GIS-based approach in drainage morphometric analysis of Kanhar River Basin, India, Appl Water Sci DOI 10.1007/s13201-014-0238-y.

[12]. S. Parmar, Sediment Yield Estimation Using SAGA GIS: A Case Study of Watershed – 63 of Narmada River, JASC: Journal of Applied Science and Computations, Volume 5, Issue 9, September/2018 ,ISSN NO: 1076-5131.

[13]. J.I. Clarke ,Morphometry from maps: essay in geomorphology, Elsevier Publ, Co, New York, pp 235–274.

[14]. M. Shaikh, F Birajdar, Analysis of Watershed Characteristics Using Remote Sensing and GIS Techniques, International Journal of Innovative Research in Science, Engineering and Technology ,Vol. 4, Issue 4, April 2015.

[15]. B.P.Chaitanya, M. Kanak,GIS based quantitative morphometric analysis and its consequences: a case study from Shanur River Basin, Maharashtra India, Appl Water Sci (2017) 7:861–871 DOI 10.1007/s13201-015-0298-7.

[16]. Sukristiyanti S. et al, Watershed-based Morphometric Analysis: A Review, Global Colloquium on GeoSciences and Engineering 2017 IOP Publishing ,IOP Conf. Series: Earth and Environmental Science 118 (2018) 012028 doi :10.1088/1755-1315/118/1/012028.

[17]. N. Rao ,S. Latha , A. Kumar, H Krishna., Morphometric Analysis of Gostani River Basin in Andhra Pradesh State, India Using Spatial Information Technology, International Journal Of Geomatics And Geosciences Volume 1, No 2, 2010.

Books:

[18]. Santosh Kumar Garg , Hydrology and Water Resources Engineering (Khanna Publishsers-Delhi; Twenty Third edition 1973)

[19]. G.L.Asawa, Irrigation and Water Resources Engineering (Newagepublishers ,1 January 2005)

[20]. Gajraj Singh, GIS in water resources engineering (Publisher: SBS Publisher & Distributors Edition: 2012)

Sneha kumari" Morphometry Analysis Using SAGA GIS: A Case Study of Watershed – 63 of Narmada River, Gujarat, India." International Journal of Engineering Research and Applications (IJERA), vol. 9, no.2, 2019, pp 39-51