"GEOMORPHOLOGICAL STUDY FOR RAINWATER HARVESTING IN SUS BASIN SOLAPUR DISTRICT"

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Abstract:

Sus basin, a tributary of Bhima River, the main feeder of Krishna River. The basin covers parts of Pandharpur, Mohol and Madhatalukas of Solapur district Maharashtra, India. Located on toposheet no. 47 O/5 and 47 O/6 on the scale of 1:50,000 lies between ($17^0 41'$ to $17^0 58'$N Latitude $75^0 20'$ to $75^0 30'$E Longitude) Covering of an area of 350 sq.kmGeomorphologicallySus basin is a fifth order basin. The bifurcation ratio shows linear relationship. The Sus basin is moderately compact and more elongated and has low texture ratio (0.842). The channel gradient is 3.21 m/km suggesting low relief. All parameters are helpful for rainwater harvesting.

Key Words : Harvesting, Geomorphology, Rainwater

1 Introduction:-

Geomorphology of an area is the result of dynamic processes on the earth surface causing divergent geomorphological set up. Physiography and rainfall together control runoff and infiltration. Therefore geomorphological analysis has wider scope in the hydrological studies. Fig No.1 represents geomorphological, geotechnical and natural hazards map of Solapur district. This map represents regions of middle level plateau, units of denudational origin of Deccan trap, alluvial terraces, older flood plains and flood plain. However, northern part of Sus basin falls under region of middle level plateau and rest of the basin represents denudational origin of Deccan trap.

2 Morphometric analysis:-

Morphometric analysis has been studied by picking up drainages from Sus basin watershed using Survey of India toposheet numbers 47 O/5 and 47 O/6 on the scale of 1:50000 and digitized in the Arch GIS software. Also initially Curvimeter and polar planimeter were used for length andarea measurements respectively. The drainage map of Sus basinis shown in fig.no.2. The basin represents dendretic drainage pattern.

2.1 Stream ordering:-

Stream orders were calculated using Strahlers method (Strahler,1964) and its length computed with the help of Arch GIS. The results show that the Sus basin is fifth order basin and the data of drainage parameters of Sus is presented in table no.1. However details of drainage parameter analysis are described in the following sections.

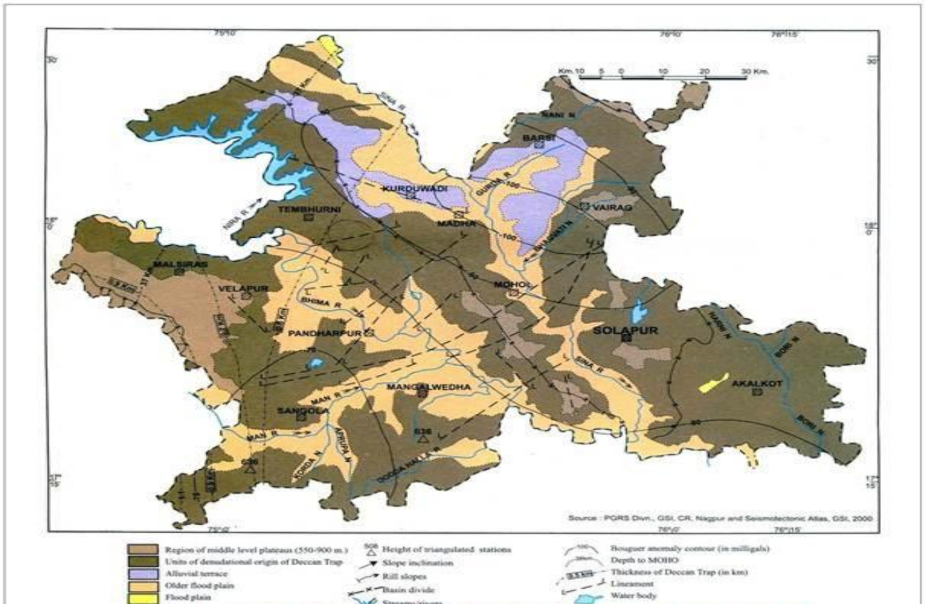

Fig. No.1 SOLAPUR DISTRICT GEOMORPHOLOGICAL, GEOTECHNICAL AND NATURAL HAZARDS MAP

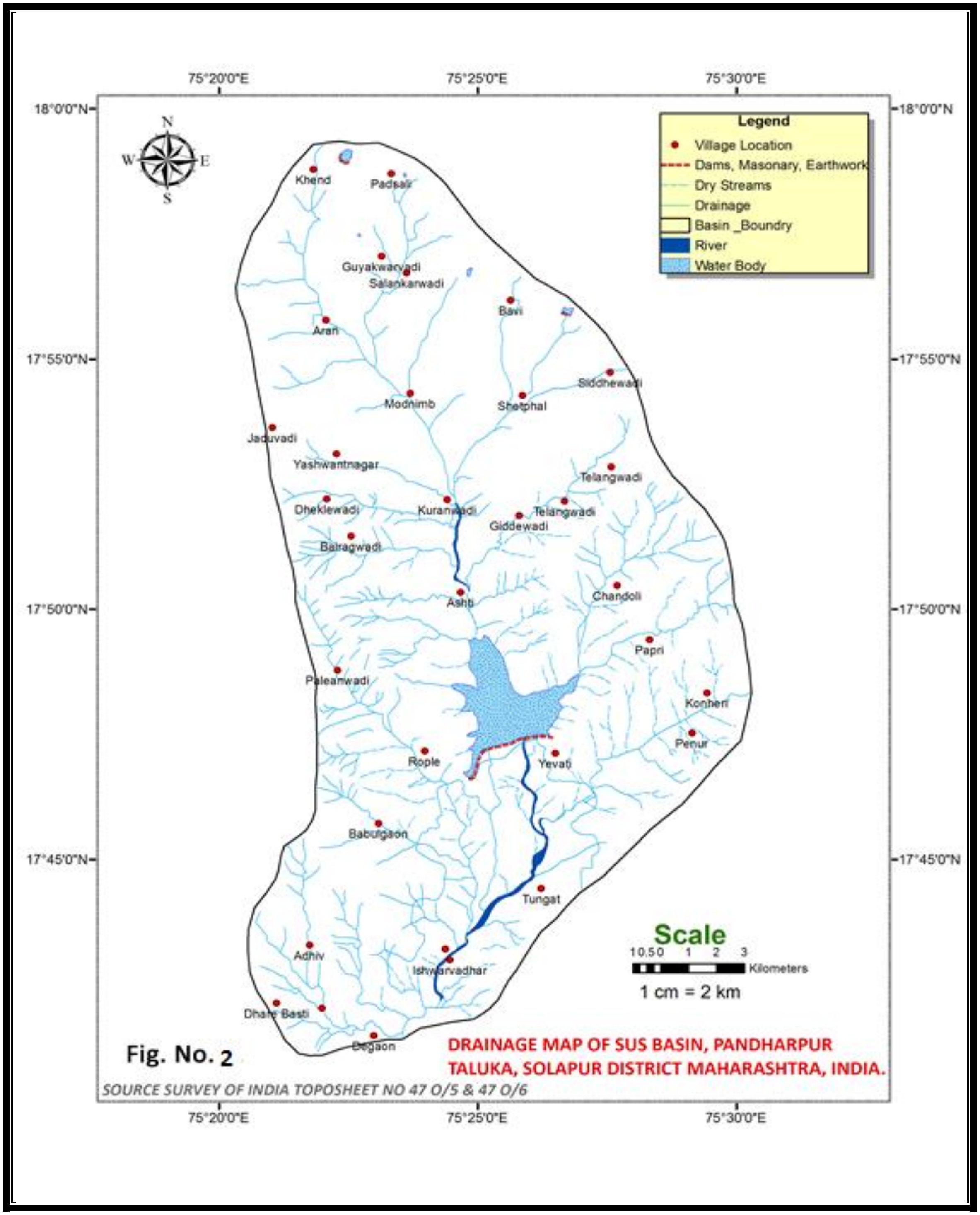

Fig. No. 2 DRAINAGE MAP OF SUS BASIN, PANDHARPUR TALUKA, SOLAPUR DISTRICT MAHARASHTRA, INDIA.

Table No.1 Drainage parameter of Sus basin

Stream order	Stream number	Stream length In km	Bifurcation Ratio	Total Basin area in sq.km	Drainage density	Drainage frequency	Drainage texture
1	282	208	4.41	301	1.15	0.969	0.842
2	64	98	5.33	162			
3	12	62	4	189			
4	3	23	3	261			
5	1	14	----	350			

2.2 Bifurcation ratio :-

The ratio of number of streams of higher order to the number of streams of lower order gives the bifurcation ratio, for Sus basin the bifurcation ratio varies between 3 and 5.33. Graphical representation of this data on semi logarithmic paper yields a linear relationship fig.no.3 (1).The weighted mean value 4.54 is obtained by dividing the product of number of streams used in ratio by mean bifurcation ratio. The data so obtained is given in the table 2.

2.3 Stream length:-

The total stream length as well as the mean stream length is calculated by measuring the stream segments for each order. The stream length ratio is the ratio of mean stream length to the stream length of the next lower order. This is calculated for each pair of successive orders, the mean length of stream increases with the order in direct proportion fig. 3(2) and brings out the exponential relation clearly. The total stream length, mean stream length, the stream length ratio andweighted mean length ratio is calculated and the data so obtained is presented in table no 3. The results arebased on Strahler's (1957) method, for stream ordering. The logarithmic plots of the total stream length against the stream order are also made, as suggested by Strahler's (1956) and referred also by Subramanyam (1977 to 1981) Brass in (1999) this is given in fig.3

First law of stream number is given by Horton (1945), for the present analysis this satisfies the straight line plots as shown in fig. 3(2). It is observed that out of four different values of bifurcation ratios calculated for the Sus drainage basin, all fall between3 and 5.33. This suggests that the Sus basin is in universal range of maturely dissected drainage basin and hence have structural (lineament) control, for stream flow, which helps infiltration of surface water.

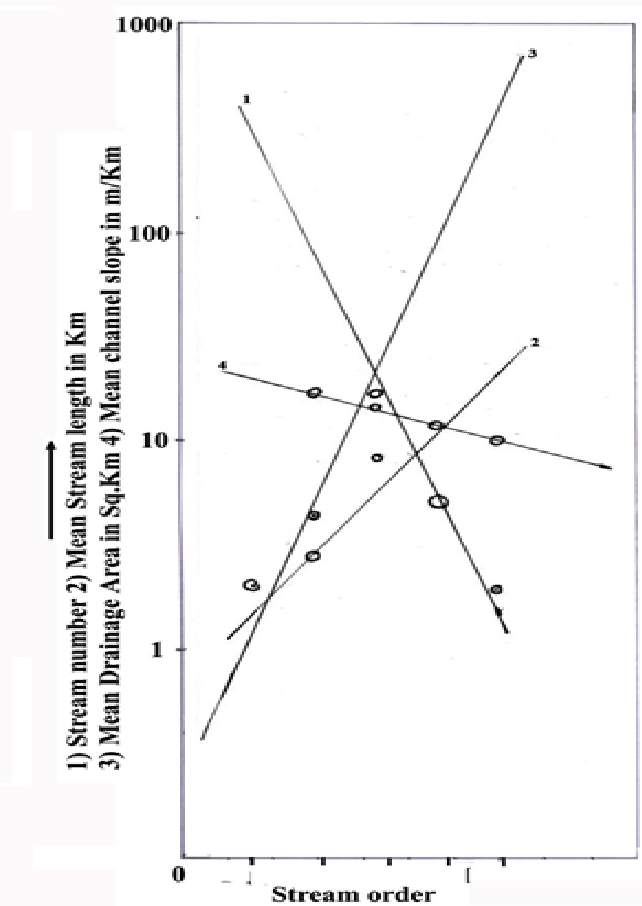

Fig. No.3 Semilogarithmic plots of stream order Vs stream number, stream lengths, mean drainage areas, mean channel slopes.

Table no. 2 BIFURCATION RATIO

Stream order 1	Stream number 2	Bifurcation ratio 3	Number of stream used in ratio 4	Product of 3×4 5
I	282	4.41	346	1525.8
II	64	5.33	76	408.08
III	12	4	15	12
IV	3	3	4	---
V	1	---	---	---
Total		16.74	441	2002.88

Mean bifurcation ratio = 4.18

Weighted mean = 2002.88 / 441

= 4.54

Table No. 3 STREAM LENGTH AND LENGTH RATIO

Stream order	Total stream length	Mean stream length	Length ratio	Length used in ratio
I	208	0.74	2.06	306
II	98	1.53	3.33	160
III	62	5.1	1.5	85
IV	23	7.66	1.82	37
V	14	14	---	---

Mean stream length ratio = 2.17

Weighted mean = 1352 / 588

= 2.3

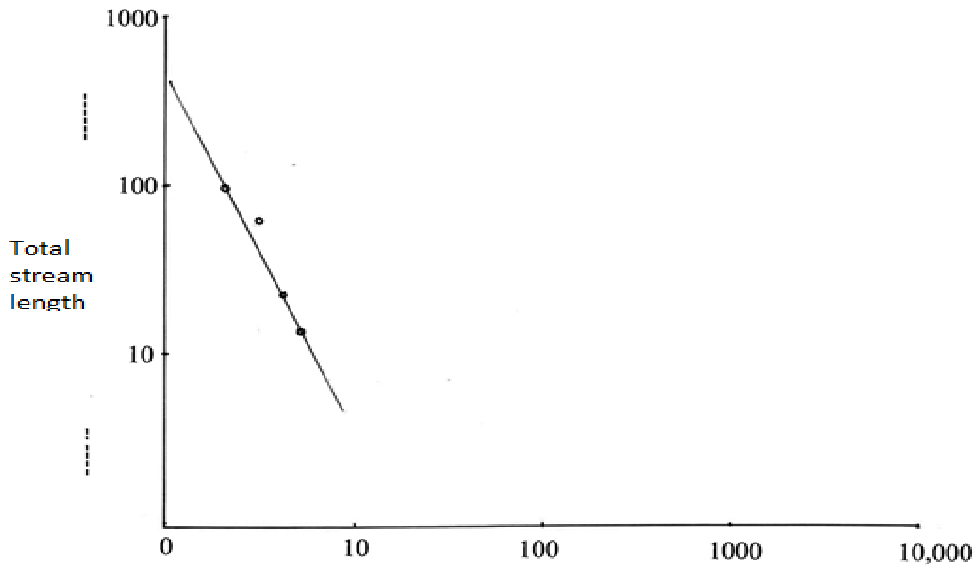

Fig. No . 4
Total stream length vs Stream order

The actual numbers of streams that are involved in the ratios appear to be more meaningful, computed from the weighted mean ratio. It is seen that theweighted mean ratio for the basin is 4.45, which is just the same as first / second and second / third and also with that of fourth / fifth order streams. This suggests that overall development of Sus basin is normal.

The semi logarithmic plots follow second law of stream length as suggested by Horton (1945). The plot of mean length against stream order show linear relationship fig.no.3(2). It has also been found that the value of mean length ratio and that of weighted mean length ratio are nearly same that is 2.17 and 2.3 respectively. This suggests that the basin is in mature stage of development and this condition helps enhancing percolation of water reaching water table.

3Areal aspects:

3.1Mean basin area:-

Basin area is one of the most important factors like stream length. The area of the different orders has been measured initially by planimeterand the data is refined by Arc GIS. The mean area of the basin of each order has been computed. Considering pairs of stream orders the area ratio were obtained, between the mean area of the basin of one order and that of the next lower order. From area ratio mean area ratio has been calculated. The values are presented in table no 4

By plotting contributing area of the basin of each order against the total length of stream in that particular order,Schum (1956) has come out with linear relationship between these two. The same plot has also been made by computing area and total length of stream within a particular basin for Sus basin the data is given in table no 5, this complies with the observations made by Schum (1956). This relationship has been presented in fig. 5.

Table no. 4AREA RATIO

Stream order	Mean area	Area ratio	Total area in sq. km.	Product of 3×4
I	1.06	2.38	301	716.38
II	2.53	6.22	162	1007.64
III	15.75	5.5	189	1039.5
IV	8.7	4.02	261	1049.22
V	350	---	350	
Total			1352	3812.74

Mean area ratio = 4.53

Weighted mean = 3812.74 / 1358

= 2.82

Table no. 5 AREA LENGTH DATA

Stream order	Total basin area	Mean area	Total stream length	Mean stream length
I	301	1.06	208	0.74
II	162	2.53	98	1.53
III	184	15.75	62	5.1
IV	261	8.7	23	7.66
V	349	350	14	14
Total	1257		405	

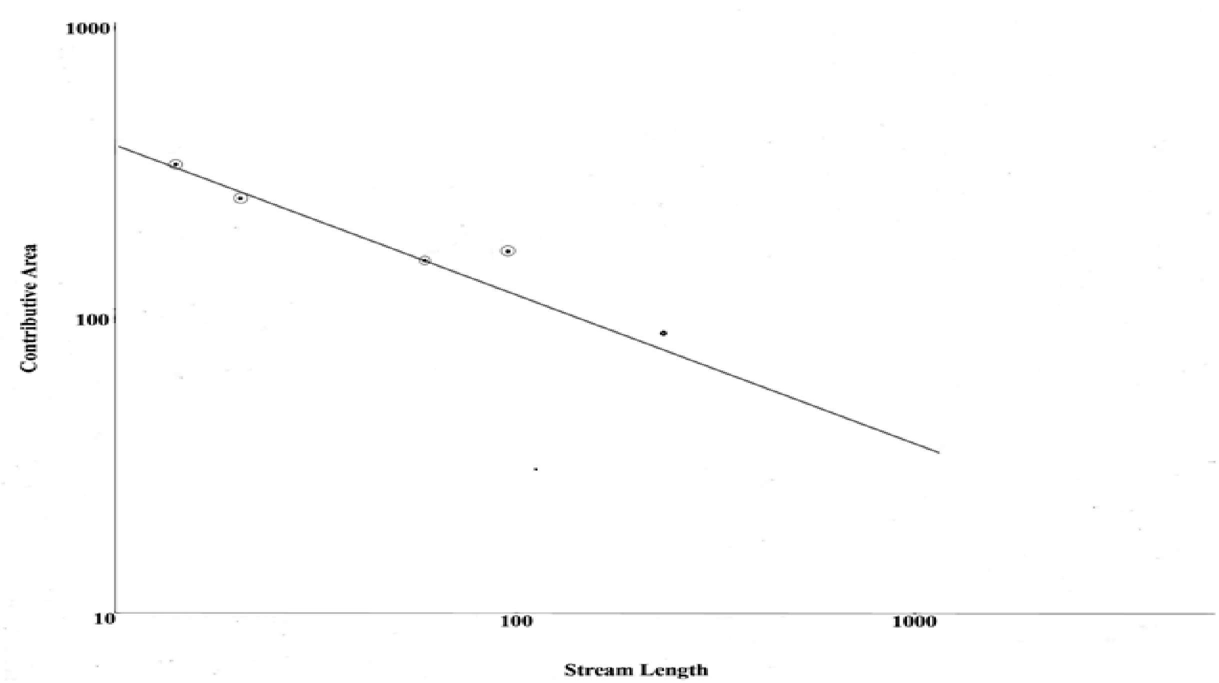

Fig.no.5 Total stream length vs contributive area

3.2 Basin configuration:-

This quantitative measurement is made by computing three dimensionless ratios for determining the shape of a drainage basin which are described in following ways.

Form factor- It is the ratio of basin area to the square of basin length. The form factor for the sus basin comes to 0.11.

Circulatory ratio- The ratio of area of the basin to the area of circle having the same circumference as the perimeter of the basin is called as circulatory ratio (Miller 1953). This is also called circularity or compactness ratio and for sus basin it comes to 0.142 and the data is given in table 6.

Elongation ratio:- It is the ratio between diameter of circle of the same area as that of the drainage basin and the maximum length of the basin, for sus basin elongation ratio comes to 2.77.

From the above three factors it can be stated that the average area of the streams of different order in a drainage basin increases geometrically with lower order basin area and show a linear relationship this is true also for Sus basin as given in fig. 3(3). Mean area ratio is 4.53. On the basis of values obtained for the Sus basin it can be inferred that in the Sus basin conditions are favorable for recharge of groundwater, as the ratio tends to higher value.

The sus basin is moderately compact and more elongated, the areal configuration shows that the basin has low circulatory and higher elongation ratio. The shape of basin is significant as it affects stream discharge characteristic, Strahler (1968). The results of shape aspects shows that surface water in Sus basin has to flow for longer distance, there by implying that there is more scope for infiltration as the water stays in the basin for longer time.

Drainage Density:-

Horton (1932), defined drainage density as the ratio of total stream length to total basin area, this gives the stream length within the basin per unit area. The analysis for Sus basin shows that the drainage density is 1.15. That is the length of the stream is1.15km per square kilometer which is lower value suggesting higher infiltration ratio.

Steam frequency:-

Stream frequency is the ratio of total number of streams to that of total drainage basin area (Horton, 1945). Stream frequency of the Sus basin is (0.969),this low value suggests that development of drainage network in Sus basin is controlled by lithology.

Drainage texture:-

Strahler(1964), Cottan(1935) and others have suggested the term drainage texture ratio to express the composition of a drainage network, using drainage density and steam frequency. Sus basin has low texture ratio (0.842). Ragarajan (2006) suggested that low texture ratio suggests higher infiltration, therefore, Sus basin may have higher infiltration rate.

length of overland flow:-

The length of overland flow is the distance between the stream channels. Horton (1945) used this term to refer the distance traveled by rain water on the ground surface, before it gets localized into definite channel. It is roughly equal to half of the reciprocal of the drainage density. Thus the overland flow for Sus basin is 0.434 kilometer. The value of 0.434 km means that the rain water has to run over this distance before getting concentrated in stream channel and corroborates low texture, derived for the basin and improves infiltration capacity.

Relief aspects:-

Channel gradient:-

Channel gradients are the total difference of altitude that is height above mean sea level, from the source to the mouth. The total difference in altitude has been divided by horizontal distance measured along the channel. The channel gradient computed for Sus basin is 3.21m/km. Semilogarithamic plot fig 3(4) shows linear relationship channel slope decreases as stream order increase.

Channel slope as function of order:-

The differences of altitude along the stream segment of various orders are determined. These mean differences in altitude are indicated for respective mean lengths, for each order and mean slopes are calculated for various orders. The ordinary mean value and weighted mean values are also calculated. The results obtained for Sus basin is presented in table no. 7. For Sus basin mean slope ratio is 0.88. The semi logarithmic plots of mean channel slope against stream order were obtained and are shown in fig. 3(4). The mean channel slope decreases with increasing stream order, the data for Sus basin is given in table no.7. From this it can be concluded that, there is definite relationship between the slope of the stream and their order and testifies the validity of Hortons(1945) law of stream slope. The slope from basin boundary is low, therefore provides good scope for infiltration of rain water and the area is considered as potential ground water zone and should be planned for detailed exploration.

Relief measures:-

It is the difference in elevation between source point to the mouth point of a basin, for Sus basin this difference is 90m and maximum measured length 30km. The ratio between maximum relief differences (H) to the maximum length is the relief measure, for sus basin it comes to 3.21.

Table no. 6 CRCULARITY RATIO

Particulars	SUS basin
Basin parameter	87.9 km
Radius of circle	14
Area of circle	615.44 sq. km
Circularity ratio	0.56

Equation used:- $$\mathbf{KA = 4\pi \frac{A}{P^2}}$$

$$= 4396 / 7726.4$$

$$= 0.568$$

Where KA = Circularity ratio

A = Drainage basin area

P = Perimeter of the basin

Table no. 7 MEAN STREAM SLOPE

Stream order	Mean basin length	Mean height difference	Mean gradient slope	Slope ratio
I	0.63	6.1	13.5	---
II	2.53	18	11.7	0.87
III	5.1	50	9.8	0.83
IV	7.66	60	7.83	0.8
V	14.6	80	5.47	0.698
Average	---	---	---	0.88

Relative relief is given by Melton's (1957) formula,

$$Rhv = \frac{100H}{5280}$$

Where P = Basin perimeter.
H = Relief difference.
For Sus basin,

$$Rhv = \frac{100\times 90}{5280\times 87.9\times 1000}$$

$$Rhv = 1.9\times 10^{-5}$$

Ruggedness number:-

For Sus basin Ruggedness number is (4.659×10^{-6}), (calculated from the basin relief and drainage density). The relief measure is the potential energy of the drainage system, Strahler (1968). The Ruggedness number (HD $=4.65\times10^{-6}$) is indicative of low relief and hence provide sufficient time for the movement of water over it and help infiltration.

Conclusion:

Geomorphologicaly the Sus drainage basin is of fifth order. Bifurcation ratio varies between 3 and 5.33 for different orders and the result yield a linear relationship with that of stream order. The weighted mean bifurcation ratio is 4.54 which is close to mean bifurcation ratio. The mean stream length ratio is 2.17 and weighted mean length ratios is 2.3 this agrees with the laws and shows normal development of basin and also suggest mature stage of development and such a development helps enhancing groundwater recharge.

Mean basin area ratio for the Sus basin is 4.53, therefore the area is favorable for groundwater recharge, as ratio tends to higher value. To describe the basin configuration of the Sus basin, form factor is calculated which comes to 0.11. The circularity or compactness ratio is 0.142 and elongation ratio is 2.77. From the above three factors it is noted that the average area of stream of different order in drainage basin increase geometrically with lower order basin area and show linear relationship.

The Sus basin is moderately compact and more elongated, the areal configuration shows the basin has low circularity and more elongation. Therefore the result for shape aspects shows that the surface water in Sus basin has to flow for longer distance (32km), there by implying that there is more scope for infiltration, as water stays in basin for longer time. The drainage density on an average is 1.15km/sq.km which is lower value suggesting lower run off and higher infiltration. The stream frequency of Sus basin is 0.969, which is related to lihtological control for development of drainage network. The Sus basin has low texture ratio (0.842). Low texture ratio suggests higher infiltration in Sus basin. Length of overland flow is (0.434km) which means rain water has run over this distance before getting concentrated in to the stream channel. This suggests that Sus basin has low texture which also helps to improve the infiltration capacity.

A channel gradient for Sus basin is 3.21m/km. Slope ratio is 0.88 and it is also observed that the mean channel slope decreases with increasing stream order. The slope of basin is low and hence the water has to flow for longer time which provides good scope for infiltration of rain water and the area is considered as potential groundwater zone. The relief measure for Sus basin is 3.21 suggesting low relief. The measure of potential energy of drainage system is calculated from the ruggedness number which comes to 4.659×10^{-6} this indicate that the basin has low relief and hence gives sufficient time for movement of water over it and helps infiltration.

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