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Geological and Geomorphological studies at Khadki Nala Basin, Mangalwedha Taluka, Solapur District, Maharashtra, India

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ABSTRACT

The linking of the geomorphological parameters and geology with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behavior of the different basins particularly of the ungauged basin in hard rocks like Deccan basalt.Thetechniques of geomorphometric analysis are useful in the quantitative description of the geometry of the drainage basins and its network which helps in characterizing the drainage network. The geomorphological landforms are important from the hydrological point of view and include the linear, aerial and relief aspects of the drainage basin. It has also been found that hydrogeologicalgeomorphological investigations besides helping in targeting potential zones for groundwater exploration provides inputs towards estimation of the total groundwater resources in an area, the selection of appropriate sites for artificial recharge and the depth of the weathering.

In present investigation KhadkiNala basin which falls geographically under Solapur district of Maharashtra, has been taken up for groundwater development. The area falls under the rain shadow zone and frequent drought is a common feature in the area due to adverse climatic conditions. Geologically the area falls under the hard rock terrain consisting of basaltic lava flows. Geology of KhadkiNala basin contain massive basalt, vesicular, weathered or zeolitic basalt and quaternary soil. The study area is located on Survey of India Topo Sheet No.47O/6, 47O/7 on the scale of 1: 50,000. It lies between latitudes 17^0 19' 00" N to 17^0 33' 00" N to and longitude 75^0 17' 00" E to 75^0 25' 00" E. The total area is about 167.26 sq.km. KhadkiNala Basin is a fifth order basin with a bifurcation ratio of 3.515, and the weighted mean bifurcation ratio is 4.39, indicating normal bifurcation ratio for all the orders of stream. Drainage density is 2.96, stream frequency is 1.55, the length of overland flow is 0.1689 km. The mean slope ratio is 1.746. The relief ratio is 4.52. The ruggedness number is 0.3286, which is considerably small indicative of mature basin. The hypsometric curves for KhadkiNala basin is 0.5.

KEYWORDS: KhadkiNala, Geomorphology, Morphometric analysis, Geological Map

INTRODUCTION

Geomorphology deals with the landforms in terms of its lithology, structure, basin geometry, drainage and other morphometric factors that result from the dynamic processes like rainfall, erosion and drainage patterns on the earth surface causing divergent geomorphological characteristics.The hydrologic factors like rainfall and runoff affects general hydrological setup of the basin.Therefore, geomorphological characteristics become much more important and significant for hydrological studies. Geomorphological parameters which has been used in deciphering their relationship with those of hydrology can broadly be classified as the linear and aerial aspects of channel system and the relief aspects of the basin. The geomorphological process include physical and chemical change modifies earth surface form. Geomorphological agents one capable of transporting earth material with the help of geometric agents.The linking of the geomorphological parameters and geology with the hydrological characteristics of the basin provides a simple way to understand the hydrologic behavior of the different basins particularly of the ungauged basin in hard rocks like Deccan basalt. The morphometric analyses provide information related to formation of various processes occurring on the surface of land, which

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can be better reflected through measurement of linear, aerial and relief aspects. It involves the evaluation of stream parameters through the measurements of various stream properties. According to Strahler's system of classification, the stream with no tributaries is designated as first-order, the stream formed by joining two first-order is designated as second -order and so on. In watershed basic unit is stream network which reveals structural, geological, and hydrological setup of the watershed. The study area is situated at about 55 km in west direction of Solapur city.The study area is located onSurvey of India Topo Sheet No.47O/6, 47O/7 on the scale of 1: 50,000. It lies between latitudes 17^0 19' 00" N to 17^0 33' 00" N to and longitude 75^0 17' 00" E to 75^0 25' 00" E. The total area is about 167.26 sq.km. Fig. no 1.1 represents the location map of KhadkiNala basin.

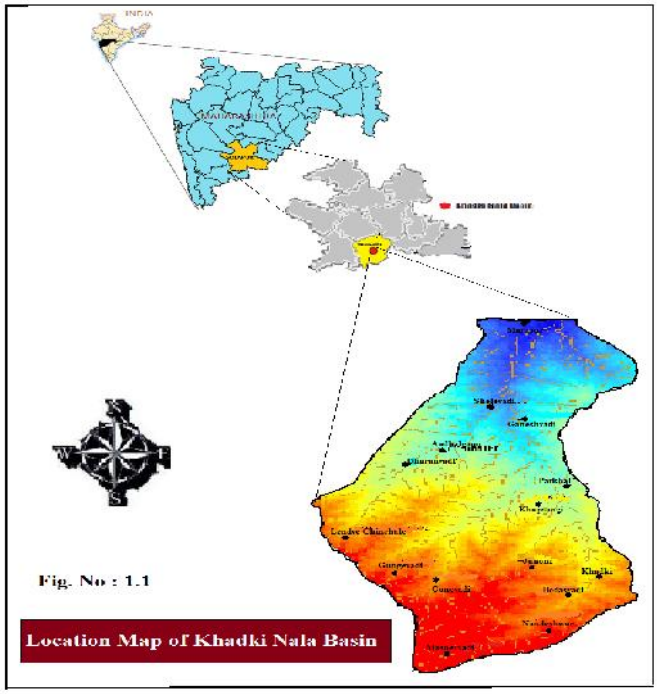

Fig. No 1.1 Location Map of KhadkiNala Basin, Mangalwedha taluka, Solapur District, Maharashtra, India

GEOLOGY OF KHADKI NALA BASIN

KhadkiNala basin is sub basin of Man river and occupies the south western part of Solapur district. The basin consists of unclassified basaltic lava flows (GSI, 2001) representing Indrayani stratigraphic unit of Sahyadri group of Deccan trap. Three lava flows of upper Cretaceous to lower Eocene age.The general dip of the basin is towards North direction. Massive basalt formation is exposed at south, central and north eastern portion of the basin around Masnervadi, Nandeshwar, Gonevadi, Junoni, Patkhal, Kupsangi, Gungevadi, Khadki, Bodasvadi villages. North eastern direction of Ganeshvadi village also exhibit massive basaltic formation. The thickness of this flow is about 68 m. Vesicular basalt or Zeolitic basalt is exposed in north east to north west portion of the basin as well as in some eastern portion of basin. Vesicular basalt or zeolitic basalt is of thickness 30 m and occurring north direction of Dharanvadi, Andhalgaon villages, north eastern direction of Shelevadi village. While some portion is also exposed at south direction of Khupsangi village. Weathered basalt is exposed in the around Shelevadi, Ganeshvadi, LendveChinchale villages. Weathered basalt is also exposed at north eastern direction of Nandeshwar, East direction of Khadki and South direction of Patkhal village. Weathered basalt is thickness of about 25 meters. However, Exposure of alluvium, having thickness five to eight meters are the Quaternary formations exposed in the basin towards south direction of Nandeshwar village, north west and south west direction Masnervadi village and small portion of alluvium is

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exposed at south direction of Gonevadi village along the stream. Fig. No 1.2 represents geological map of khadkiNala basin.

RESULT AND DISCUSSION

GEOMORPHOLOGY OF KHADKI NALA BASIN

Geomorphological investigations for KhadkiNala basin have been carried out to find the linear, areal and relief aspects. The results for linear aspects are given in Table 1.1 and that for areal and relief aspects in 1.2 respectively.

1.1 Linear aspects of basin

The linear aspect consists of studies on stream order, bifurcation ratio and stream length ratio. Such studies help to understand the development of the basin, erosional characteristics and near surface fault and fracture patterns in the creation of streams.

1.1.1 Stream Order

Stream order from KhadkiNala basin have been classified using Strahler (1953) classification scheme and are presented in table 1.1.KhadkiNala basin on this basis is classified as a fifth order basin.

1.1.2 Bifurcation Ratio.

Bifurcation ratio is the ratio of number of streams of higher order to the number of streams of lower order. Bifurcation ratio is related to the structural control on the drainage development

(Nautiyal, 1994; Strahler, 1964; Chow, 1964). The range of bifurcation ratio value is between 1.5 and 7.14. Thecontrol on the drainage development.The weighted mean value is obtained by dividing, the product of number of streams and bifurcation ratio by number of streams used in the ratio. For the KhadkiNala basin bifurcation ratio is 3.515

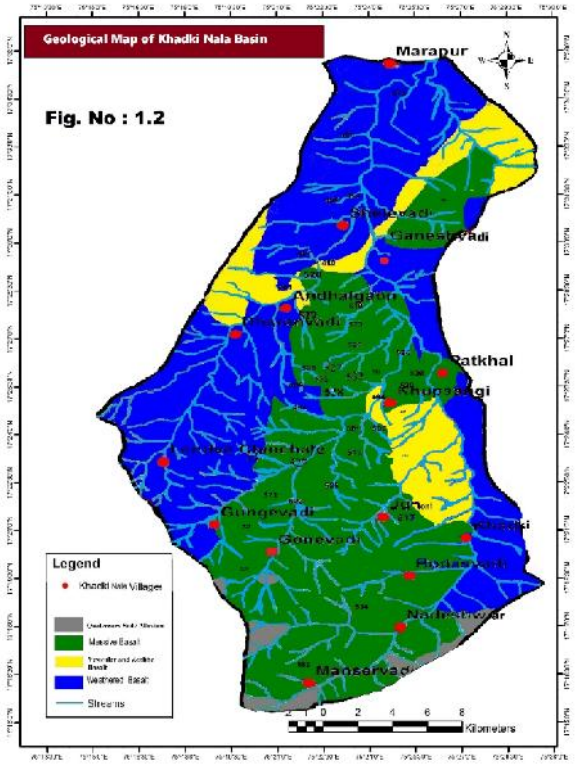

Fig. No 1.2 Geological Map of KhadkiNala Basin, Mangalwedha taluka, Solapur District, Maharashtra, India

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1.1.3 Mean Bifurcation Ratio

The mean bifurcation ratio is the average of bifurcation ratios of all orders. For the KhadkiNala basin the value is 3.515 (Table 1.1). These values of mean bifurcation ratio are relatively lower and hence suggest geological heterogeneity, higher permeability and structural control in the area.

Table No. 1.1 Geomorphological Parameters of Linear Aspects of KhadkiNala Basin.

Stream Order	Number of Streams	Stream Length	Mean stream length	Bifurcation Ratio	Mean Bifurcation Ratio
I	200	269.1	1.34	3.92	
II	50	151.2	3.02	7.14	3.515
III	6	42.6	7.1	1.5	
IV	3	48.6	16.2	1.5	
V	1	26.5	26.5		
Total	260	538	54.16	14.06	

1.2 Areal aspects of the basin

Arial measure of a drainage basin network relates too many of its hydrologic characteristics. The various parameters are determined and are given in the Table 1.2.

1.2.1 Basin Area

The rate of runoff of any drainage basin depends on its area and physiography. The drainage basin area is a dimensional parameter and it is denoted by A. The drainage basin is instrumental in governing the rate at which water is supplied to the main stream as it precedes to the outlet. Area of basin of a particular order is defined as the total area projected upon a horizontal plane, contributing overland flow to the channel segment of a given order including all the tributaries of the lower order. The factors which are dependent on the basin length are length of stream, degree of slope, drainage frequency, drainage density, shape parameters (i.e., form factor, circulatory ratio and elongation ratio), rainfall, rate of runoff etc. Larger the area, smaller is the runoff and vice versa. The shape of the basin is significant since it affects the stream discharge characteristics (Strahler, 1969). Table 1.2 show that geographical area of KhadkiNala basin is 167.26 km^2

1.2.2 Length of the Basin

Several people defined basin length in different ways, such as Schumm, (1956) defined the basin length as the longest dimension of the basin parallel to the principal drainage line. Gregory and Walling, (1973) defined the basin length as the longest in the basin in which the end being the mouth. Gardiner, (1975) defined the basin length as the length of the line from a basin mouth to a point on the perimeter equidistant from the basin mouth in either direction around the perimeter.

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Length of KhadkiNala basin is 24.54 km

1.2.3 Basin Perimeters.

Length boundary of a basin is known as the perimeter of the basin and it is denoted by P. The factors that aredependent on the basin parameter are elongation ratio and circulatory ratio. Earlier, the perimeter was measured withchartometer (i.e., a map measurer). All segments within the specified drainage network were used to measuresuccessively without pause or recorded the cumulative length appeared on the dial of the chartometer. Perimeters ofdifferent sub-watersheds were derived from GIS software that automatically gives the perimeter of the basin.

1.2.4 Drainage Density (Dd)

Drainage density is defined as the mean length of the streams within a basin per unit area (Horton, 1932). The drainage density indicates the closeness of spacing of channels in the basin and provides a quantitative measure of the average length of stream channels. Low drainage density is observed in regions of highly permeable subsoil material, dense vegetative cover, and under low relief. High drainage density is the resultant of impermeable subsurface material, sparse vegetation and mountainous relief. Low drainage density leads to coarse drainage texture while, high drainage density leads to fine drainage texture (Strahler, 1964). For KhadkiNala basin drainage density is 2.96, the drainage densities are low and hence represent permeable subsoil.

1.2.5 Stream Frequency (Fs)

Horton (1932) introduced stream frequency as the number of stream segments per unit area. It is obtained by dividing the total number of streams to the total drainage basin area. The stream frequency (Fs) for the basin exhibit positive correlation with the drainage density indicating the increase in stream population with respect to increase in drainage density. Table no 1.2 show that, stream frequency for KhadkiNala basin is 1.55.

1.2.6 Drainage Texture

Drainage texture is one of the important aspects of geomorphology. The relative spacing of drainage and drainage texture depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. Drainage texture (Dt) is total number of stream segments of all orders per perimeter of that area (Horton, 1945). Smith, (1950) has classified drainage texture into five different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8).Drainage texture for the KhadkiNala basin is given in Table 1.2. KhadkiNala basin show moderate drainage texture.

1.2.7 Form Factor

The ratio of the basin area to the square of basin length is called the form factor. It is a dimensionless property and is used as a quantitative expression of the shape of basin. The value of form factorwould always be less than 0.7854 (for a perfectly circular basin). Smaller the value of form factor, more elongated willbe the basin. The basins with high form factor have high peak flows of shorter durations, whereas, elongated subwatershedwith low form factor have lower peakflow of longer duration. Flood flows of such elongated basins areeasier to manage than of the circular basin. Form factor for KhadkiNala basin is 0.2777.

1.2.8 Circulatory Ratio

It is ratio of the area of the basin to the area of circle having the same circumference as the perimeter of thebasin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land use/land cover,climate, relief and slope of the basin The value rangesfrom 0.2 to 0.5. It is the significant ratio which is indicative of the stage of dissection in the study region. The low, medium and high values are correlated with youth, mature and old stage of a drainage basin respectively. Circulatory ratio for KhadkiNala basin is given in table no 1.2

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Table No. 1.2 Geomorphological Parameters of Areal and Relief Aspects of KhadkiNala Basin

Sr. No	Morphometric Parameter	Mathematical Expressions	Reference	Estimated values for KhadkiNala basin
	Areal Aspects			
1	Basin Area (A) ($Km^{2)}$	Area from which water drains to a common stream and boundary determined by opposite ridge	Strahler (1932)	167.26
2	Perimeter (P) (Km)	Length measured along basin boundary	Horton (1932)	63.55
3	Basin Length (Lb) (Km)	Straight line distance between outlet of the basin and the furthest point on the ridge	Horton (1932)	24.54
4	Length of Main Channel (CL) (Km)		Horton (1932)	32.45
5	Drainage Density (Dd)	Dd=Lu/A	Horton (1932)	2.96
6	Stream Frequency (Fs) $(Km)^2$	Fs=Nu/A	Horton (1932)	1.55
7	Drainage Texture (D_t)	Dt= Nu/P	Horton (1945)	4.09
8	Form Factor (F_t)	$Ff=A/Lb^2$	Horton (1932)	0.2777
9	Circulatory Ratio (Rc)	$Rc = 4\pi A/P^2$	Miller (1953)	0.5201
10	Elongation Ratio (Re)	Re=Diameter/Basin length	Schumm (1956)	0.425
11	Fitness Ratio (Rt)	Rf=CL/P	Melton, (1957)	0.5106
12	Shape Factor (BS)	Bs = Lb2/A	Horton (1945)	3.60
13	Wandering Ratio (Rw)	Rw=CL/Lb	Surkan, 1967	1.32
14	Lemniscate's (K)	$K=Lb^2/4*A$	Chorely, (1957)	0.90
15	Constant of Channel Maintenance (1/D) (Kms^2 / Km)	Inverse of drainage density $1/D_d$	Schumm, (1956)	0.3378
16	Drainage Intensity (DI)	$Di=Fs/D_d$	Faniran, (1968)	0.5236
17	Infiltration Intensity (I_f)	$If=Fs\times D_d$	Zovoiance (1985)	4.58
18	Length of Overland Flow (Lg) (Km)	$Lg=1/D_d\times 2$	Horton (1945)	0.1689
19	Compactness coefficient (Cc)	$Cc = 0.2821\ P/A^{0.5}$	Horton (1945)	1.3861
	Relief Aspects			
20	Basin Relief (H)	H=Z-z Z=maximum elevation of the basin, z=minimum elevation of the basin	Rudraiah (2008)	111
21	Relief Ratio (Rhl)	$Rhl=H/L_b$	Schumn (1956)	4.52
22	Relative Releif (Rhp)	Rhp=H/P	Schumn (1956)	1.746
23	Ruggedness Number (Rn)	Rn= Dd*(H/1000)	Strahler's, (1968)	0.3286
24	Basin Slope (S_b)	$S_b= H/L_b$	Miller (1953)	4.52
25	Channel Gradient (Cg)	$Cg= H/\{(\pi/2)\}*C_{IP}$ C_{IP}=Longest dimension parallel to the drainage line = L_b	Chandrashekar (2006)	2.88

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1.2.9 Elongation Ratio (Re)

Schumm, (1965) defined elongation ratio (Re) as the ratio of diameter of a circle of the same area as the basin to the maximum basin length. It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin. Analysis ofelongation ratio indicates that the areas with higher elongation ratio values have high infiltration capacity and low runoff. Elongation ratio for KhadkiNala basin is 0.425 which is more elongated in shape. The varying slopes of watersheds can be classified with the help of the index of elongation ratio as:

1. Circular 0.9 to 1.0 2. Oval 0.8 to 0.9 3. Less elongated 0.7 to 0.8
4. Elongated 0.5 to 0.7 5. More elongated <0.5

1.2.10 Fitness Ratio (Rt)

As per Melton, (1957) the ratio of main channel length to the length of the watershed perimeter is fitness ratio, which is a measure of topographic fitness. The results of KhadkiNala basin is shown in Table 1.2. The fitness ratios of KhadkiNala basin is 0.5106.

1.2.11 Shape Factor (Bs)

It is defined as the ratio of the square of the basin length to area of the basin (Horton 1945) and is in inverseproportion with form factor (Rf). Shape factor for KhadkiNala basin is 3.60

1.2.12 Wandering Ratio (Rw)

The wandering ratio is defined as the ratio of the mainstream length to the valley length. Valley length is the straight-line distance between outlet of the basin and the farthest point on the ridge, (Smart &Surkan, 1967). Wandering ratio for KhadkiNala basin is 1.32.

1.2.13Lemniscate's (K)

Chorely, (1957) express the lemniscate's value to determine the slope of the basin. The formula to compute (k) is: k = Lb2 / 4 * A. Where, Lb is the basin length (Km) and A is the area of the basin (km2). Lemniscate's value is given in table no 1.2

1.2.14 Constant of Channel Maintenance (1/D)

Schumm, (1956) used the inverse of drainage density or the constant of channel maintenance as a property of landforms. The constant indicates the number of km 2/km of basin surface required to develop and sustain a channel 1 Km long. The constant of channel maintenance indicates the relative size of the landform units in a drainage basin and has a specific genetic connotation (Strahler, 1957). In the present study the constant of channel maintenance for KhadkiNala basin is given in table 1.2.

1.2.15 Drainage Intensity (DI)

Faniran, (1968) defines the drainage intensity as the ratio of the stream frequency to the drainage density. The low value of drainage intensity is indicative of low denudation. This is because of drainage density and stream frequency has little effect on denudation. The values are relatively low implying that drainage density and stream frequency have little effect (if any) on the development. Therefore, low values of drainage density, stream frequency and drainage intensity represent low runoff and hence higher infiltration.

1.2.16 Infiltration Intensity (I_f)

The infiltration number of a watershed is defined as the product of drainage density and stream frequency and gives an idea about the infiltration characteristics of the watershed. In filtration intensity for KhadkiNala basin is given in table no 1.2

1.2.17 Length of Overland Flow (Lg)

Horton (1945) used this term to refer to the length of the run of the rainwater on the ground surface before it is localized into definite channels. Overland flow on an average is about half the distance between the stream channels. Horton, suggested that it is roughly equal to half the reciprocal of the drainage density. The length of overland flow is 0.1689. The Value is given in table 1.2. The value is low indicative of higher infiltration.

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1.2.18 Compactness coefficient (Cc)

Compactness coefficient (Cc) can be represented as basin perimeter divided by the circumference of a circle to the same area of the basin and also known as the Gravelius index (GI). Lower values of this parameter indicate more elongation of the basin and less erosion, while higher values indicate less elongation and high erosion. The result of compactness coefficient is given in table no 1.2. The value of compactness coefficient is about 1.3861.

1.3 Relief Aspects of Basin

Relief aspects of KhadkiNala basin are given in table no 1.2. The relief aspects are explained as follow

1.3.1 Basin Relief (H)

Basin relief is the maximum vertical distance between the lowest and highest elevation in a basin. This is an important factor in understanding the denudational characteristics of a basin**.** Basin relief for KhadkiNala basin is 111 m

1.3.2 Relief Ratio (Rhl)

Difference in the elevation between the highest point of a watershed and the lowest point on the valley floor is known as the total relief of the river basin. The relief ratio may be defined as the ratio between the total relief of a basin and the longest dimension of the basin parallel to the main drainage line (Schumm, 1956). The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin was suggested by Schumm, who found that sediment loss per unit area is closely correlated with relief ratios. Relief ratio is given in table no 1.2

1.3.3 Relative Releif (Rhp)

The relative relief is the difference between maximum reliefs from the highest point on the watershed perimeter to the mouth of the stream. Relative Releif (Rhp) is given in table no 1.2.**1.3.4 Ruggedness Number (Rn)**

Strahler's, (1968) defined ruggedness number as the product of the basin relief and the drainage density and usefully combines slope steepness with its length. The low ruggedness value of watershed implies that area is less prone to soil erosion and have intrinsic structural complexity in association with relief and drainage density. Ruggedness number is of KhadkiNala basin is 0.3286.

1.3.5 Basin Slope (S_b)

It is defined as the slope is a measure of the steepness of a line, or a section of a line, connecting two points in a same basin. Bain slope of the basin is given in in table no 1.2.

1.3.6 Channel Gradient (Cg)

Itis the grade measured by the ratio of drop in elevation of a stream per unit horizontal distance, usually expressed as feet per mile or meters per kilometer. Channel gradient for KhadkiNala basin is 2.88.

CONCLUSIONS

The geological study of KhadkiNala basin was revealed that the general dip of the basin is towards North direction. Geology of KhadkiNala basin shows massive basalt, weathered basalt, vesicular/zeolitic basalt and quaternary soil. The linear aspect of study shows that KhadkiNala basin is classified as fifth order basin, according to Strahler classification. The bifurcation ratio and the weighted mean bifurcation ratio, indicating normal bifurcation ratio for all the orders of stream. Aerial aspect suggest that the basin is compact and more elongated and water has to travel for moderate distance and thus moderate scope for infiltration. For KhadkiNala basin, drainage density is 2.96, stream frequency is 1.55 the length of overland flow is 0.1689 km, and this means that the rainwater has to run over this distance before getting concentrated in the stream channels. This suggest that drainage texture is moderate therefore, moderately better for infiltration. The ruggedness number is 0.3286, which is considerably small indicative of mature stage of basin

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