Morphometric Analysis of Kaswali River Basin, Kachchh, Gujarat, western India using Remote Sensing and GIS

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Abstract: The study of drainage basin provides valuable information about the geological and evolutionary history of the area. In hydrology, the morphometry of drainage basin and river networks provide clues on water discharge, maximum and minimum specific runoff and their spatial variation.The drainage network transport water and the sediments of a basin through a single outlet, which is marked as the maximum order of the basin and conventionally the highest order stream available in the basin considered as the order of the basin. The size of rivers and basins varies greatly with the order of the basin. Ordering of streams is the first stage of basin analysis.The drainage morphometric characteristics are important to understanding the underlain structure, geomorphological formations and hydrological characteristics of any basin. It also plays an important role to characterize the soil erosion, food condition and geomorphological processes. The different morphometric characteristics like linear parameters (stream order, stream number, bifurcation ratio, strength length, and mean stream length), aerial or basin parameters (circularity ratio, elongation ratio, drainage density, drainage frequency) and relief parameters (dissection index, ruggedness index, hypsometric characteristics) are important for any river basin management. In the present study some linear aspect like Stream order, Stream Number, Bifurcation Ratio and Mean Bifurcation Ratio are calculated for the Kaswali River.

Keywords: Morphometric Analysis, Kaswali, River Basin, Remote Sensing and GIS.

I. INTRODUCTION

The drainage ofKachchh is largely governed by the combination of lithology and tectonics. The central part ofthe mainland forms the main water divide separating the basins with numerous consequent streams draining the slopes with a radial pattern and debouch into the Arabian Sea, the Gulf ofKachchh and the plain ofBanni / the Rann in west, south and north respectively. The north flowing streams, originating from the northern slopes of the Central highland, join the streams originated from the Northern Hill Range and pour their water into the Chhari, Bhukhi, Nirona (Trambo), Kaila, Pur (Khari) and Kaswali streams and these streams debouch into the Rann making conspicuous alluvial fans (Singh, 2012).

The streams of the Kachchh region are ephemeral and carry water only during monsoon. Many streams like Kankawati, Kaswali, Kharod, Rukmavati and Bhukhi etc. show very broad channels and vertical cliffy banks in their lower reaches. The relatively well carved valleys which now have very little water, is the characteristics of the drainage of Kachchh Mainland which indicates that the area had experienced a more wet climatic phase in the past during which the streams carried more water and sediment load and the stream dissection was more effective. Generally, the drainage pattern of the area is dendritic in nature which typically develops in areas with homogenous lithologies in terms of weathering that provide no preferred direction to the development of stream channels. At several places, which are marked by the domes and plug like features, radial pattern has also developed. The drainage systems developed in the area around KMF and passing through the fault zone have been chosen for detailed analysis to evaluate the effect oftectonism in the area during the recent past (Singh, 2012).

II. GEOLOGY OF THE STUDY AREA

In Kas Hills, the Jumara Formation is exposed as string of circular to elliptical inliers at the core of the small domes. These are the easternmost outcrop of the Jumara Formation in the Northern range of the Mainland. The Member IV is represented by15 ft. bed containing a single band of oolitic marl, locally pebbly. The Member II here is only represented by the Ridge Sandstone Bed which is about 135 ft. thick. This is underlain by shale, sandstone and marlite beds which perhaps represent the Member I (Biswas, 1993). The formation is represented here by the Members II, III and IV. The top of this part is marked by a thin grey hard fossiliferous and conglomerate band. The upper part of the Member consists of grey and yellow gypseous shales, overlain by a 80 ft. thick bed of sandstone; The sandstone is brown to red, medium to fine grained, massive, friable and quartzose. It is hard and calcareous towards the top (Biswas, 1993). The Kaswali River flows from in between from the Habo Dome and Kas Hills composed of Mesozoics.

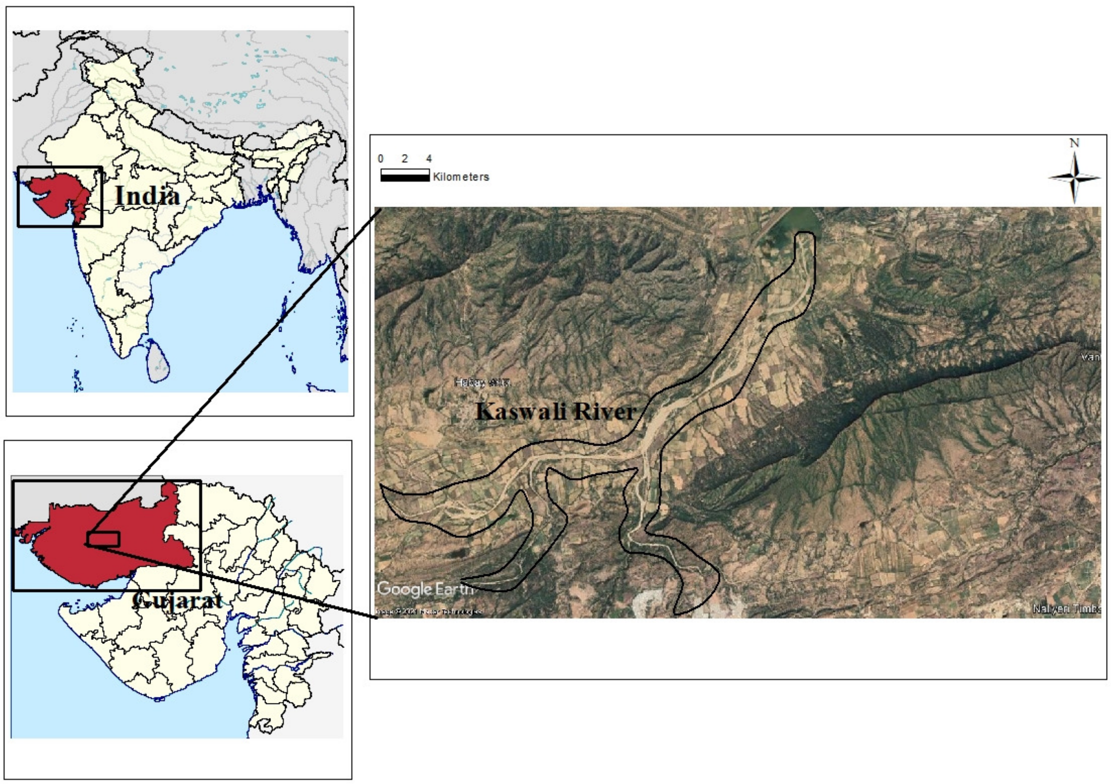

Figure.1: Location map of the Kaswali River Basin, Gujarat.

III. DRAINAGE PATTERN

In a definite drainage basin, the streams may flow in a specific arrangement which is termed as drainage pattern. This stream flow over or through the landscape to carve out its valley, is predominantly controlled by the geological and topographical structure of the underlying rocks (Siddiqui et al., 2014). As the stream tries to reach the base level which is generally the sea level, it will encounter several structural obstacles and in its course of descent, tries to seek path of least resistance. Most of the streams are guided by nature and arrangement of bedrocks as they respond directly to structural control. The drainage pattern also reflects the original slope of land, original structure, diastrophism along with geologic and geomorphic history of drainage basin (Siddiqui et al., 2014). The drainage network development provides clues which can be used to understand the history ofdevelopment ofthe landscape ofthe area.

The Kaswali River is identified as 5th order stream whereas Kaila and Chhari are 6thorder and Pur and Nirona are 7th order streams. Total channel length and stream frequencies are quite high in all the river basins (Table 1). Length and number oflower order streams suggest moderate to high head-water relief in the head water area, however, lesser number and length of the higher order streams suggest small extent ofthe river basins. At most of the part, Kaswali River demonstrates trellis pattern by at the Habo Dome and Kas Hills, the drainage pattern is Radial type.

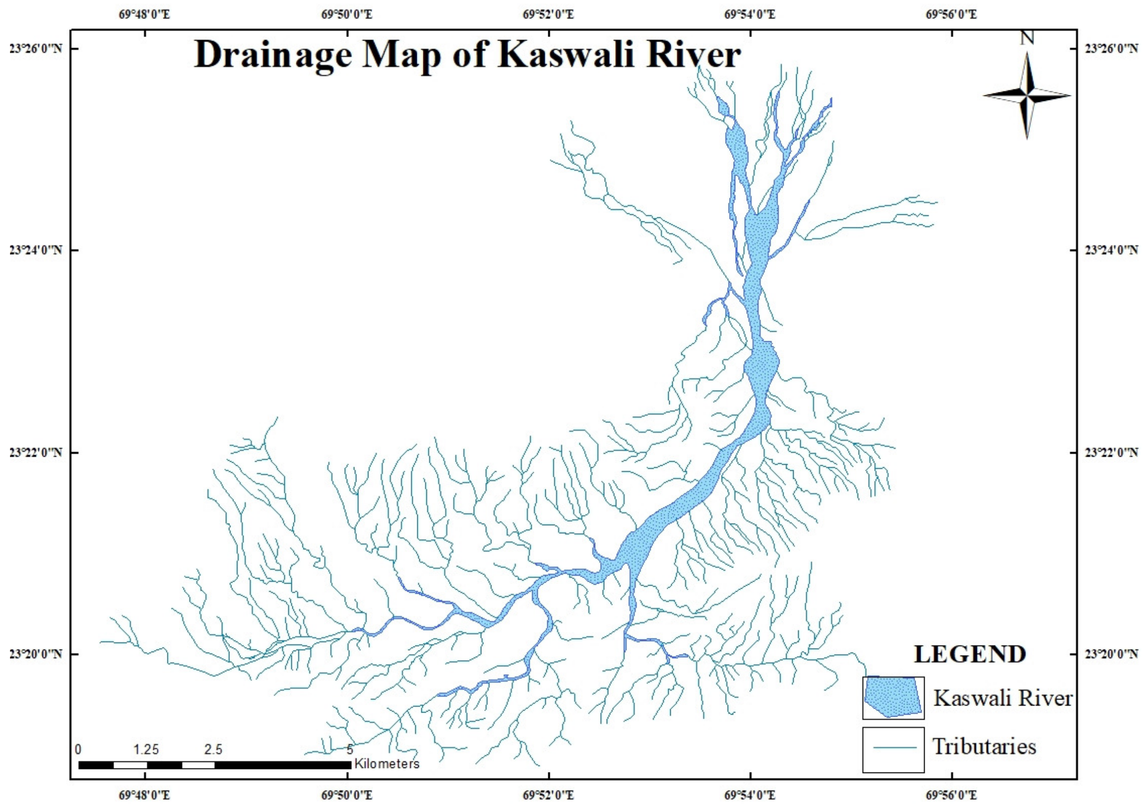

Figure.2: Drainage map of the Kaswali River Basin, Gujarat.

IV. MORPHOMETRIC PARAMETER OF RIVER BASIN

A. Stream Order (u)

The first step in drainage basin analysis is designation of stream orders, following a system introduced by Strahler (1964). In the drainage map of the basin, the network is divided into channel segments and has been assigned a sequence of numbers to the orders according to the hierarchy of orders of magnitude. According to Strahler (1964) system of ordering, each fingertip channel is assigned as a segment of the first order and the number increases by one when two different order streams meet together, the order remains as that of the higher order stream. In Horton's method, a first-order stream is an un-branched tributary, a second-order stream is a tributary formed by two or more first-order streams. A third-order stream is a tributary formed by two or more secondorder streams and so on. In general, an nth order stream is a tributary formed by two or more streams of order (n-1) and streams of lower order.

Strahler (1964) invented ordering method has been selected for the present study. According to Strahler method, first-order streams are the furthest upstream channels that have no tributaries. A tributary is a stream that joins another stream reach or body of water. When two first-order streams unite, they form a second order stream. In the same way, when two second-order streams unite a third-order stream is created, and so on. Where two streams of different order join, for example a first and third-order, the combined stream retains the order of the higher order stream contributing to it. The main assumption behind this ordering system is that when two similar order streams join to create the next higher order stream, mean discharge capacity is doubled. The stream order is a measure of the degree of stream branching with in a basin. The main channel through which most of water discharged marked as highest order stream of any particular drainage basin. This stream order depends on basin shape, size and relief characteristics of such basin. Most studies indicate the increasing order of streams in the mountain–plain humid environment than plateau–plain sub-humid environment.

B. Stream Number (Nu)

The count of stream channel in its order is known as stream number. The number of stream segments decreases as the order increases. The higher amount stream order indicates lesser permeability and infiltration Stream number is directly proportional to size of contributing watershed to cannel dimensions. It is obvious that the number of stream of any given order will be fewer than for the net lower order but more numerous than for the next higher order. The number of stream decreases as the stream order increases. The stream number shows stream number usually decreased in geometric progression as the stream order increase.

Nu is number of streams of order u.

Nu = N1+N2+…+Nn

Where, N1 = First order stream

N2 = Second order stream

Nn = Number of stream

C. Bifurcation Ratio

The bifurcation ratio (Rb) is defined as the ratio of number of the stream segments of given order to the number of segments of the next higher order. The Bifurcation Ratio is the fundamental importance in drainage basin analysis as it is the foremost parameter to link the hydrological regime of a sub-basin under topological and climatic conditions. It helps to have an idea about the shape of the basin as well as in deciphering the runoff behavior (Shah et al., 2021). It is calculated by

$Rb = Nu/Nu + 1$

Strahler (1964) demonstrated that bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. It is observed from the 'Rb' is not same from one order to its next order. It is considered an important parameter, denoting the water carrying capacity and related food potentiality of any basin. The value normally ranges from 2 to 5 (Joji et al., 2013).These irregularities are dependent upon the geological and lithological development of the drainage basin (Strahler, 1964). The Bifurcation Ratio of the Kaswali River basin indicates that they arise from hilly terrains and have high gradient. This ratio is generally higher for lower orders and higher bifurcation ratios may be attributed to the high degree of tectonic activity in the area during Quaternary period (Neotectonism) (Singh, 2012).

Table 1. Calculation of Bifurcation Ratio

Stream Order (u)	Stream Number (Nu)	Bifurcation Ratio (Rb)
1	276	3.942
2	70	3.50
3	20	5.0
4	4	4.0
5	1	-
MEAN BIFURCATION RATIO = 3.369		

D. Mean Bifurcation Ratio

The Mean Bifurcation Ratio is in between 3-5. So the geological structures do not distort the drainage pattern (Nautiyal, 1994). Lower order streams are in higher number due to its upper mountain course. Also, higher number of streams in upper reaches indicates the occurrence of young topography adjacent to the stream concerned. The sudden decrease in 3rd and 4th order of streams indicates its major morphological change (Mahala, 2019). Higher number of streams throughout the different orders indicates its high erosion characteristics. The high number of lower order streams (1st, 2nd and 3rd order) increase the amount of water received which ultimately creates huge water flux in lower reaches of basin (Mahala, 2019). The irregularities are due to strong geological and lithological controls of the basin. Also, high bifurcation ratio in higher order streams indicates large amount of water received in upper basin area (Shah et al., 2021). But low Rb and related lower number streams in lower reaches increase water pressure. In the present study Mean Bifurcation Ratio calculated is 3.369 which indicates that the sub-basin area is not affected by major structural disturbances.

E. Texture Ratio

Texture ratio (T) is an important factor in the drainage morphometric analysis anddepends on the underlying lithology, infiltration capacity and relief aspect of the terrain. It is the ratio ofnumber of all the 1st order streams

(N1) to the perimeter ofthe basin. The perimeter of the Kaswali River Basin is 45.89 km. It is 6.01 for the Kaswali River.

IV. CONCLUSION

The Kaswali River shows Dendritic Drainage pattern. Tree like branching or veins of leaf pattern formed by stream is known as Dendritic pattern (Fig.2). The stream order in the study area are comprises 1^{st} order to 5^{th}order that shows discharge capacity of the river basin is low to moderate. The number of streams of Kaswali River are 371 of which 276, 70, 20, 4 and 1 streams belongs to 1^{st},2^{nd},3^{rd},4^{th} and 5^{th} orders respectively (Table No.1). Lower order streams are in higher number due to its upper mountain course. Also, higher number of streams in upper reaches indicates the occurrence of young topography adjacent to the stream concerned. The sudden decrease in 3^{rd} and 4^{th} order of streams indicates its major morphological change. Texture ratio of Kaswali basinis 6.01 which is high. This high texture ratio is indicative of recent upliftment. The ruggedness is about 0.5 to 0.7 for Kaswali, Pur and Chhari basins. These values suggest high drainage density and comparatively low relief, indicating neotectonic activity in the area. Trend analysis of the $1^{st}$and 2^{nd} order streams of the Kaswali basin indicates that majority of the streams are oriented in the NNW-SSE direction and a quite few in the NE-SW to ENE-WSW directions (Singh, 2012). This analysis reveals that the lower order streams are governed by the tilting ofthe basins. Geomorphological parameters developed for the study of alluvial system have been used extensively as a valuable tool to explore various aspects of the tectonic influences on the tectonically active areas. Studies related to long-term dynamics of fluvial systems and their responses to external controls provide important clues to geomorphic evolution of an area. Though tectonics plays the most important role in carving the landscape of an area (Burbank, 1992) but climate and sea level changes also play their role in the process of sedimentation (Blum et al., 1994).Morphometric analysis of the river basins combined with fluvial depositional history, geological, tectonic and co-seismic features have helped in understanding the landscape evolution of the fluvial systems. The present drainage ofthe northern hill range ofthe Kachchh basin is incisive as evidenced by 15-20 m high alluvial cliffs and knick points observed in the long profiles of the rivers (Singh, 2012).

V. ACKNOWLEDGEMENT

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