Prioritization of watersheds of Ozat river basin based on morphometric analysis using remote sensing and GIS

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Abstract
Watershed prioritization has gained importance in natural resources management, especially in the context of watershed management. Watershed management encompasses various activities from watershed delineation to monitoring. The present research attempted to study various morphological characteristics and to implement Remote Sensing and Geographical Information System (GIS) techniques for identification and prioritization of critical sub watersheds situated in region of Ozat river basin, Gujarat. The morphometric analysis of river basin helps to explore the interrelationship between hydraulic parameters and geomorphologic characteristics. Various morphometric parameters, namely linear and shape have been determined for each watersheds and assigned ranks on the basis of value/relationship so as to arrive at a compound value for a final ranking of the watershed. There are in total 4 sub-watersheds which have been delineated and taken up for prioritization based on morphometric analysis using GIS and RS techniques. Detailed morphometric analysis was carried out using ArcGIS V10.1. The value of compound parameter for all 4 watersheds varied from 27 to 32. The watershed G1C4 (compound parameter value 27) receives the highest priority value and so it becomes potential prioritized candidate for applying soil conservation measures, in contrast to the other watersheds with low priorities are subjected to lower degree of erosion. The morphometric properties and prioritization for each watershed will be useful for the sound planning of conservation measures, water harvesting, and groundwater recharge projects on watershed base.

Keywords: Watershed, Prioritization, Morphometry, Ozat River basin, DEM

1. Introduction
A drainage basin or watershed is an extent or an area of land where surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. The watershed plays a dominant role in the development of landforms and therefore, the study of drainage basin has a great significance in geomorphic studies (Chandrashekar et al., 2010) [1]. A watershed is an ideal unit for management of natural resources like land and water for achieving sustainable development. The watershed management concept recognizes the interrelationships among the linkages between uplands, low lands, land use, geomorphology, slope and soil. A comprehensive watershed management programme may have multiple objectives such as controlling damaging runoff and managing and utilizing the same for useful purposes, controlling erosion and reduction in the sediment production, enhancing ground water storage and appropriate use of the land resources in the watershed (Sebastian et al., 1995).

Soil and water conservation are the key issues in watershed management while demarcating watersheds. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal, 1998; Obi Reddy et al., 2002)[3,30]. It is a significant tool for prioritization of sub watersheds even without considering the soil map (Biswa et al., 1999) [3]. Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds (Strahler, 1964) [48]. A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behaviour of surface drainage networks (Horton, 1945; Leopold & Maddock, 1953) [15,18]. The success of watershed development programme revolves around the conservation of soil and water resources in that watershed and hence, it is imperative to
prioritize the watersheds on the basis of conservation and developmental needs. River basins comprise a distinct morphologic region and have special relevance to drainage pattern and geomorphology (Doornkamp et al., 1971; Strahler, 1957). Pioneering work on the drainage basin morphometry has been carried out by Horton (1932, 1945), Miller (1953), Smith (1950), Strahler (1964) and others. In India, some of the recent studies on morphometric analysis using remote sensing technique were carried out by Natuial (1994), Srivastava (1997), Nag (1998) and Srinivasa et al. (2004). The remote sensing and GIS technique is a convenient method for morphometric analysis as the satellite images provide a synoptic view of a large area and is very useful in the analysis of drainage basin morphometry. GIS and remote sensing (RS) techniques are proved to be proficient tools for morphometric characterization of sub watersheds (Singh, 1994; Grohmann, 2004; Sreedevi et al., 2013, 2005; Aher et al., 2010; Mahadevaswamy et al., 2011). Therefore, in this research an attempt has been made for prioritization of sub-watersheds through analysis of the natural drainage system that implements a novel approach by investigating various morphological characteristics by accomplishing better accuracy in identification and prioritization of sub-watersheds.

### 1.1 Study Area
The Ozat River basin is extended between latitude of 21° N to 22° N and longitude of 70° E to 71° E (Figure 1), covering an catchment area of 3176.24 km². Eight major reservoirs were constructed across the Ozat river basin namely Amipura, Dhradaf, Jhanjeshri, Madhuvanti, Magharadi, Magharadi, Pasawala, Uben. The Holy Girnar, a circular hill massif made up of intrusive rocks rises to impressive heights, the highest peak, attains a height of 1046 m above mean sea level. Terrain elevation varies from 1046 m as maximum to 1 m as minimum (above mean sea level of India). The large difference in the contour value is due to the Girnar Mountain situated in middle of the basin. These rivers originate in the central plateau region of Saurashtra and meanders in a radial pattern through the plains to meet the Arabian Sea. After flowing through the district for a distance of 125.27 km, it drains into the Arabian Sea. The important tributaries of the Ozat river are Ambajal, Popatdi, Uben, Utavali, Bhandukia, Jhanjeshri, Fulsar and Lol, in which Abajal and Popatdi are right bank tributaries while Uben and Utavali are left bank tributaries of this river. The study area located in toposheets No. 41G10, 14, 15, 41K02, 03, 06, 07, 10, 11, 14 and 15 prepared by Survey of India. The climate of the project area can be classified as tropical and sub-tropical. The types of soil are fine, clay, loamy and rock found in the basin. Soil depth is varies between 25cm to 150cm throughout the entire river basin.

### 2. Materials and Methods
For morphometric analysis, drainage map of the study area was prepared from Cartosat-DEM using ArcGIS 10.1 adopting the standard procedures (Band, 1986; Gurnell & Montgomery, 1999; Maidment, 2002; Morris and Heerdegen, 1988). The DEM data of study area were collected from BISAG, Gandhinagar as well as from BHUVAN online portal. Further, the pre-processed DEM was used for extraction and quantification of morphometric parameters. The toposheets were used from Survey of India of scale of 1:50000 for reference purpose. In order to analyze the morphometric parameters, boundaries of 4 Seventh-order sub basins have been extracted (Fig. 4). The drainage network of the basin and the stream ordering was analyzed according to Horton (1945), Strahler (1958, 1964), Verstappen (1983), Patton (1988), Ritter, Kochel, and Miller (1995), Macka (2001), Reddy, Maji, and Gajbhiye (2004), Rudraiah et al., (2008), Mesa (2006) and Ozdemir and Brid (2009) (Fig. 3). The formulae adopted for computation of morphometric parameters are given in Table 1.

#### A) Morphometric Analysis of Watershed
Morphometric analysis is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimensions of its landforms. The quantitative analysis of morphometric parameters is found to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. The following methodology was adapted for giving stream order in the drainage map of study area. The stream ordering was done using Strahler (1964) technique manually. The drainage map of basin was opened into the ArcMap environment as. mxd file using Add Data. The stream ordering was done in ArcMap manually using Editor Tool. Each stream segment was edited and stream order was given in attribute table simultaneously. The various tools like Flip, Merge, Clip, Union, Flow Length etc. were used to change the direction of flow and to join the stream segment, respectively. Simultaneously the CARTOSAT image of study area (Fig. 2) was used to view the flow direction of each stream segment. Then this drainage map was then clipped into 4 watersheds using clipping tool for further geomorphological analysis. The methodology adopted to determine the morphometric parameters were described in subsequent subheads.

#### 2.1 Linear Aspects of Watersheds
Linear aspects of the basin are related to the channel pattern of the drainage network, wherein the topographical characteristics, stream segments in terms of open links of network system analyzed.

#### 2.1.1 Stream Order
The first step in a drainage basin analysis is numbering of stream orders, following a system introduced in the United States by Horton (1945). The stream order represents the degree of stream branching with watershed. Each length of stream is designated by its order. Generally, the Nth order stream is formed by two or more (n-1)th order streams and streams of lower orders. The highest order stream is known as trunk or principal stream through which all discharge of watershed passes through the outlet. The concept of stream order is used to calculate other indicators of drainage characters of a watershed Horton (1932, 1945), led to the development of law of drainage composition and Strahler, (1964) suggested the stream ordering system. The designation of stream orders is the first step in drainage basin analysis and expresses the hierarchical relationship between stream segments, their connectivity and the discharge arousing from contributing catchments. Stream order map of Ozat River Basin is shown in Fig.3.

#### 2.1.2 Stream Number
The count of stream channels in each order is known as stream numbers (N). According to Horton's law (1945) of stream numbers, the numbers of streams of different order in
a given drainage basin tend to approximate as inverse geometric sequences with the order number.

2.1.3 Bifurcation Ratio (Rb)
The bifurcation Ratio (Rb) is defined as the ratio of the number of streams of any order (Nu) to the number of streams of the next lower order (Nu+1). The value of Rb, ranges from 2 to 4. Strahler (1957) [47] demonstrated that bifurcation ratio shows a small range of variation for different regions or for different environment except where the powerful geological control dominates. Horton (1945) [15] considered the bifurcation ratio as index of relief and dissertation.

\[ R_b = \frac{N_u}{N_{u+1}} \]

Where, Rb = bifurcation ratio
N_u = number of streams of order u
N_{u+1}= number of streams of order u+1

2.1.4 Stream Length (Lu)
The extent of stream length on a watershed reveals the characteristics size of the various components of drainage network and its contributing surface area. Stream length is one of the most significant hydrological features of the basin as it reveals surface runoff characteristics streams of relatively smaller lengths are characteristics of areas with larger slopes and finer textures. All lengths of the drainage lines are measured with the help of statistical functions of Arc GIS software package. Stream lengths are defined in km. To find out the mean stream length of channel of order u, the total length is divided by number of segments (Nu) of that order. Thus,

\[ \overline{L_u} = \frac{\sum_{i=1}^{N_u} L_{u,i}}{N_u} \]

Where, \( \overline{L_u} \) = Average length of the channel of order u, km
N_u = total no of streams of order u, km

2.1.5 Stream Length ratio (R_L)
Horton (1945) [15] defined the stream length ratio as the ratio of mean length, Lu of segments of order u to mean length of segments of the immediate lower order, Lu-1. Thus,

\[ R_L = \frac{\overline{L_u}}{\overline{L_{u-1}}} \]

Where, R_L = Stream length ratio
\( \overline{L_u} \) = Average length of the channel of order u, km
\( \overline{L_{u-1}} \) = total no of streams of order u, km

2.1.6 Length of overland flow
The overland flow refers to that flow of precipitated water, which moves over the land surface leading to the stream channels, while the channel flow reaching to the outlet of watershed is referred as surface, runoff. The overland flow is significant in the smaller watershed, whereas; runoff is in bigger watershed. Horton (1945) [15] 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. Since this length of overland flow, at an average, is about half the distance between the stream channels, Horton, for the sake convenience, had taken it to be roughly equal to half the reciprocal of the drainage density.

\[ L_B = \frac{A}{2L} \]

Where, Lg = Length of overland flow in km.
A = Area of basin in sq. km.
L = Total length of stream in km.

2.2 Aerial Aspects of Watersheds
Aerial parameters included drainage density, stream frequency, elongation ratio, and form factor. They all are the factors which indicate the shape of the basin. If the values of these parameters exceed one for the basin, then it indicates that the basin has approached roundness.

2.2.1 Drainage density (D_d)
Horton (1945) [15] defined D_d as the total length of channels (Lu) in a catchment divided by the area (A) of the catchment. Drainage density is a better quantitative expression to the dissection and analysis of landform, although a function of climate, lithology and structures and relief history of the region can finally use as an indirect indicator to explain, those variables as well as the morphogenesis of landform.

\[ D_d = \frac{\sum_{k=1}^{K} \sum_{i=1}^{N_u} L_{u,i}}{N_u} \]

Where, D_d = Drainage density in km/km².
Lu = total length of channels in basin in km.
Au = total area of the basin in km².
K = trunk order of stream segment
N = total no. of streams

2.2.2 Stream Frequency (F_S)
The stream frequency (F_S) of the basin may be defined as the number of streams per unit area (Horton, 1945) [15]. It mainly depends on the lithology of basin and reflects the texture of the drainage network. Greater the drainage density and stream frequency in a basin, the runoff is faster, and therefore, flooding is more likely in basin with a high drainage and stream frequency kale (2001) [17]. Stream frequency (F_S) is related to permeability, infiltration capacity and relief of a sub watershed.

\[ F_S = \frac{\sum_{k=1}^{K} N_u}{A_k} \]

Where, F_S = stream frequency in 1/km²
\( \sum_{k=1}^{K} N_u \) = total number of stream-segments of all orders
A_k = basin area of the trunk order k in km².
k = trunk order

2.2.3 Circularity ratio (R_C)
A dimensionless circularity ratio (R_C) is the ratio of basin area to the area of circle having the same perimeter as the basin. For the out-line form of watershed (Strahler, 1964, Miller, 1953) [48, 23] used a dimension less circularity ratio as a quantitative method. It is influenced by the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the watershed. It is expressed as:
\[ R_c = \frac{4\pi A}{P^2} \]

Where, \( R_c \) = circularity ratio
A = basin area, \( \text{km}^2 \)
P = perimeter of the basin, km

2.2.4 Elongation ratio (Re)
The elongation ratio (Re) is the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956) \[39\]. This ratio ranges from 0.6 and 1.0 over a wide variety of climate and geologic types (Strahler, 1965). 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.

\[ R_e = \sqrt{\frac{4A}{\pi L_b}} \]

Where, \( R_e \) = elongation ratio
A = basin area, \( \text{km}^2 \)
L_b = maximum basin length, km.

2.2.5 Form Factor (Re)
Form Factor (Ft) is defined as the ratio of the basin area to the square of the basin length Horton (1932) \[14\]. The value of form factor would always be less than 0.754 (for a perfectly circular watershed). Smaller the value of form factor, more elongated will be the watershed.

\[ Ft = \frac{A_u}{L_b^2} \]

Where, \( F_t \) = form factor
A_u = basin area in \( \text{km}^2 \)
L_b = maximum basin length in km.

2.2.6 Compactness Coefficient (Cc)
The compactness coefficient is the ratio of catchment perimeter to that of equivalent circle having area as that of the basin (Gravelius, 1914) \[10\]. The \( C_c \) is independent of size of watershed and dependent only on the shape.

\[ C_c = \frac{(0.2821 \times P)}{A^2} \]

Where, \( C_c \) = compactness coefficient
A = basin area in \( \text{km}^2 \)
P = perimeter of the basin in km.

2.2.7 Drainage Texture (Tr)
The drainage texture (Tt) depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. It is the total no. of stream segments of all orders per perimeter of the area. Drainage texture is one of the important concepts of geomorphology which measures for the relative spacing of drainage lines. Drainage texture depends on the underlying lithology, infiltration capacity and relief aspect of the terrain. T is total number of stream segments of all orders per perimeter of that area (Horton, 1945) \[13\].

\[ T = \frac{N_u}{P} \]

Where, T = drainage texture, per km.
\( N_u \) = total no. of streams of all orders
P = perimeter of the basin in km.

2.3 Relief Aspects of Watersheds
Relief aspects include the relief measures and ruggedness number, which are related to the elevation difference at various points in a basin.

2.3.1 Relief
It is defined as the elevation difference between the reference points located in the drainage basin. Basin relief aspects of the sub basins play an important role in drainage development, surface and subsurface water flow, permeability, landforms development and erosion properties of the terrain. Relief is an important attribute of terrain in general and the drainage watershed is in particular. According to Strahler (1968) relief measures are indicative of the potential energy of the drainage stem because of its elevation above mean sea level.

\[ \text{Relief of basin} = \frac{H}{L} \]

Where, R_h = relief ratio
H = relief in km.
L = horizontal length in km.

2.3.2 Relief ratio (Rh)
It is the ratio of relief to the horizontal distance on which relief was measured. 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) \[39\]. The possibility of a close correlation between relief ratio and hydrologic characteristics of a basin suggested by Schumm (1956) \[39\] who found that sediments loose per unit area is closely correlated with relief ratio.

\[ R_{hp} = \frac{H \times 100}{P} \]

Where, \( R_{hp} \) = relative relief
H = relief in km.
P = perimeter of basin in km.

2.3.3 Relative relief (Rhp)
It is the ratio of relief to the perimeter of basin. It is an important morphometric variable used for the overall assessment of morphological characteristics of terrain. Melton (1958) suggested calculating the relative relief by dividing the difference of height between the highest and lowest points in the basin (H) with basin perimeter (P). It is calculated as,

\[ R_{hp} = \frac{H}{L} \]

2.3.4 Channel Slope (Cg)
Horton (1945) \[15\] expressed the relationship in form of law called as laws of stream slopes, which is an inverse geometric series law. It is given by Broscoe (1959) \[4\].

\[ C_g = \frac{H}{1.57 \times L} \]

Where, \( C_g \) = channel slope, \( \text{km/km} \)
H = relief in km.
L = basin length in km.
2.3.5 Ground Slope (Sg)
Slope is the most important and specific feature of the earth's surface form. Maximum slope line is well marked in the direction of a channel reaching downwards on the ground surface. It is the ratio of relief and horizontal distance. It is the product of drainage density and relief of the basin.

\[ S_g = \frac{H}{L_g} \]

Where, \( S_g = \) ground slope, km/km
\( H = \) relief in km.
\( L_g = \) horizontal length in km.

B) Watershed Prioritization
The morphometric parameters i.e Bifurcation ratio (Rb), Stream Frequency (Fb), Length of overland flow (Lg), Texture Ratio(T), Drainage Density (Dd), Elongation Ratio (Re), Form Factor (Rf), Circulatory Ratio (Rc) and Compactness Coefficient (Cc) are also termed as erosion risk assessment parameters or linear parameters and have been used for prioritizing watersheds (Biswas et al., 1999) \(^3\). These linear parameters such as Bifurcation ratio (Rb), Stream Frequency (Fb), Length of overland flow (Lg), Texture Ratio (T), Drainage Density (Dd), and relief parameters like relief, relative relief and relief ratio have a direct relationship with erodibility, higher the value, more is the erodibility. Hence for prioritization of watershed, the highest value of linear parameter was rated as rank 1, second highest value was rated as rank 2 and so on, and the least value was rated last in rank.

Shape parameters such as Elongation Ratio (Rf), Stream Frequency (Fb), Circulatory Ratio (Re) and Compactness Coefficient (Cc) have an inverse relationship with erodibility (Ratnam et al., 2005) \(^39\); lower the value, more is the erodibility. Thus the lowest value of shape parameters was ranked as rank 1, next lower value was ranked as rank 2 and so on and the highest value was ranked last in rank. Hence, the ranking of the watersheds has been determined by assigning the highest priority/rank based on highest value in case of linear parameters and lowest value in case of shape parameters. After the ranking has been done based on every single parameter, the ranking values for all the linear and shape parameters of each watershed were added up for each of the 4 watersheds to arrive at compound value (Cp). Based on average value of these parameters, the watershed having the least rating value, was assigned highest priority; next higher value was assigned second priority and so on (Mishra et al.; 2010) \(^29\). The watershed which got the highest Cp value was assigned last priority.

3. Results and Discussion
Morphometric analysis gives a quantitative description of drainage basin. The drainage dynamics of the Ozat River Basin has been intended using morphometric analysis. The calculated value of all the parameters is given in Table 1 and 2. The Basin is divided into 4 watersheds with codes viz. 5G1C2, 5G1C3, 5G1C4 and 5G1C5 shown in Fig 4.

3.1 Linear Aspects of the Watershed
Linear aspects of the 4 watersheds, related to the channel patterns of drainage network where in the topological characteristics of the stream segments in terms of open links of the stream network system are analysed. The results have been tabulated in the table 1 and 2 as a whole and sub watersheds. The present study has adopted the widely used method of Strahler. The study area is a 7th order drainage basin covering an area of 3176.44 km\(^2\). Lower stream lengths are likely to have lower runoff (Chitra et al., 2011) \(^8\).

3.1.1 Mean Bifurcation ratio (Rb)
Bifurcation ratio (Rb) can be defined as the ratio of the number of stream segments of a given order to the number of segments of the next higher order (Schumm, 1956) \(^39\). Horton (1945) \(^15\) considered the bifurcation ratio as an index of relief and dissections. In general, it is observed that Rb is not the same from one order to its next higher order. Mean bifurcation ratio is an indicator of structural complexity and permeability of the terrain and is thus negatively correlated with the permeability of a watershed. High Rb indicates early hydrograph peak with a potential for flash flooding during the storm events which results in degradation of top soil (Howard 1990; Rakesh et al. 2000) \(^34, 55\). The relationship of Rb with erosion susceptibility of an area is same as is imparted by drainage density and stream frequency. Usually all these values are less than 10 indicating that the geologic structures do not exercise a dominant influence on the drainage pattern of the river basin (Thomas et al., 2010) \(^50\). The mean bifurcation ratio of all the sub watersheds is found very low which indicates that basin and its watersheds possess well developed drainage network. 5G1C4 shows highest Rb of 3.82 and thus possesses lowest permeability among other sub watersheds and was thus assigned rank 1. Sub watersheds 5G12 (3.51), 5G1C3 (3.49) and 5G1C5 (3.63) were assigned ranks 3, 4 and 2 respectively. i.e. low value. For Ozat basin the value of mean bifurcation ratio were 3.96, which supports the results of water sheds.

3.1.2 Stream length ratio
Stream length ratio may be defined as the ratio of the mean length of the one order to the next lower order of the stream segment (Horton, 1945) \(^15\). The value of stream length ratio varied widely 0.43 to 0.59 which shows the early stage of maturity of the watershed.

3.1.3 Length of overland flow (Lg)
A larger value of length of overland flow indicates longer flow path and thus, gentler slopes (Sethupathi et al., 2011) \(^40\). The Length of overland flow for basin 0.3389 km and for watersheds ranges from 0.2432-0.6845 km. The watersheds 5G1C5 having lower values of length of overland flow comes under the influence of high structural disturbance, low permeability, and steep to very steep slopes and high surface runoff. Other remaining watersheds having length of overland flow greater than 0.25 are under very less structural disturbance, less runoff conditions and having higher overland flow. For basin it is greater than 0.25 it comes under very less structural disturbance, less runoff conditions and having higher overland flow (Mishra et al., 2011) \(^25\).

3.2 Aerial Aspects of the Watershed
The parameters which are governed by the area of the drainage basin are classed as areal aspects of the basin. Results have been given in Table 1 and 2.

3.2.1 Drainage density (Dd)
Horton (1932) \(^14\) reported that the drainage density Dd is an important indicator of the linear scale of landform elements in stream eroded topography. It is the ratio of total channel segment length cumulated for all order within a basin to the basin area, which is expressed in terms of km/km\(^2\).

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The drainage density indicates the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole basin. The low drainage density is more likely to occur in a region of highly resistant and permeable subsoil material under dense vegetative cover, and low relief. High drainage density is the resultant of weak or 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) [48]. The drainage density for watersheds varies from 0.73 to 2.06. The watershed 5G1C5 show high drainage density (greater than 2 km/km²) due to the presence of impermeable sub surface material, sparse vegetation and high relief. Whereas remaining watersheds namely 5G1C2 (0.73), 5G1C3 (1.23) and 5G1C4 (1.50) fall under low drainage density indicate the region has highly permeable subsoil and dense vegetation cover (Mishra et al., 2011) [25].

3.2.2 Stream frequency (Sf)
Stream frequency (Sf) is expressed as the total number of stream segments of all orders per unit area (Horton, 1932) [14]. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. Reddy et al. (2004) [38] identified that low values of Sf designate occurrence of permeable subsurface material and low surface relief. The stream frequency for watersheds varies from 0.41 to 2.29 and for basin 0.68 it is low due to permeable rocks the surface runoff is low and infiltration capacity is high within in the study area. The stream frequency for all 4 watersheds of the study area show positive correlation with the drainage density, which indicate that the stream population increases with the increase of drainage density (Chitra et al., 2011) [6].

3.2.3 Circularity ratio (Re)
A dimensionless circularity ratio (Re) is the ratio of basin area to the area of circle having the same perimeter as the basin (Strahler, 1964, Miller, 1953) [48, 23]. It is influenced by the length and frequency of streams, slope, geological structures, and climatic condition of the area. It is also an indicator of the dendritic stage of the watershed. Low, medium, and high values of Re show the young, mature, and old phases of the cycle of the tributary watershed (John Wilson et al., 2012; Rai et al., 2018). The circularity ratio for watersheds varies from 0.28 to 0.61 and for basin it is 0.11 which indicates the basin is at an early stage of topographical maturity and elongated in shape, low discharge of runoff and highly permeability of the subsoil condition.

3.2.4 Elongation Ratio (Re)
Values of Re generally vary from 0.6 to 1.0 over a wide variety of climatic and geologic types. Re values close to unity correspond typically to regions of low relief, whereas values in the range 0.6–0.8 are usually associated with high relief and steep ground slope (Strahler, 1964) [48]. These values can be grouped into four categories: circular (> 0.9), oval (0.8–0.9), less elongated (0.7–0.8) and elongated (< 0.7). The elongation ratio of the basin watersheds is varies from 0.66 to 1.36. The watersheds 5G1C2 (0.66) and 5G1C4 (0.67) are elongated in nature. The watersheds 5G1C3 (0.94) and 5G1C5 (0.90) shows circular shape watersheds in nature, while value of elongation ratio for the basin found 0.69 indicating the elongated shape of the basin.

3.2.5 Form Factor (Rf)
According to Horton (1932) [14], form factor (Rf) is nothing but the ratio of the basin area to the square of the basin length. The Rf indicates the flow intensity of a basin of a defined area (Horton, 1945) [19]. In general, the form factor value is always less than 0.78 (the value for perfectly circular basin). The smaller the value of the form factor, the more elongated will be the basin. Basins with high form factors experience larger peak flows of shorter duration, whereas elongated watersheds with low form factors experience lower peak flows of longer duration. The form factor for basin is 0.37 and for basin watersheds varying from 0.33 to 0.69. The Rf value for Ozat River Basin is 0.37, indicating elongated basin with lower peak flows of longer duration than the average. Watershed morphology has a deep impact on watershed hydrology (Tucker and Bras, 1998) [51]. The watershed 5G1C3 and 5G1C5 are circular in shape showing less side flow for shorter duration and high main flow for longer duration (Chitra et al., 2011) [6].

3.2.6 Compactness coefficient (Cf)
The compactness coefficient for watersheds ranges from 1.28 to 1.51 and for basin it is 3.00. They have elongated shape so they have enough time for discharge (Hadely et al., 1961).

3.2.7 Drainage texture (T)
Drainage texture is greatly influenced by infiltration capacity (Horton 1945) [15]. Regions of low infiltration capacity will give rise to higher T and thus will lead to more erosion. Therefore, the watershed with highest Rt which in this watershed is 5G1C2 (17.63) was given rank 1 indicating that it is most susceptible to erosion due to low infiltration capacity. Accordingly, the sub watershed with lowest Rt i.e. 5G1C2 (1.86) was assigned rank 4, which indicated that it has least susceptibility to erosion. Sub-watersheds 5G1C3 (5.96) and 5G1C4 (5.15) were assigned ranks from 2 to 3 respectively. N The drainage texture (T) for watersheds varies from 1.86 to 17.63. For watershed 5G1C5 it is greater than 8 indicating very fine texture i.e higher runoff potential while 5G1C3 and 5G1C4 are moderate in nature. The rest watershed 5G1C2 is coarser in nature i.e. having less runoff potential. For basin it is 7.80 showing very fine nature (Pal et al., 2012) [32].

3.3 Relief Aspects of the Watershed
3.3.1 Basin relief (H)
Basin relief (H) is one of the relief measures of a basin, and defined as the difference between maximum and minimum elevation in the basin. It gives an idea of the ground surface gradient from the water divide to the outlet of the basin. It is suggested that low relief ranges between (0 m to 100m), moderately relief between (100m to 300 m) and high relief (above 300m). The relief of basin is 1.044 km. The study area (Ozat River basin, 1.044 km) is of high relief region as it is greater than 0.3 km. The high relief value indicates low gravity of water flow as well as infiltration and high runoff conditions (Nongkynrih et al., 2011) [29]. The relief for watersheds varies from 0.047 to 1.035 km. The watersheds 5G1C2 is of low relief region, 5G1C3, 5G1C4, and 5G1C5 are of high relief region.

3.3.2 Relief ratio
The relief ratio for watersheds varies from 0.0012 to 0.0272 and for basin it is 0.0114. It was noticed that the higher values of relief ratio indicated steep slope and high relief (5G1C3
and 5G1C4 watersheds), while the lower values in case of watersheds 5G1C2 and 5G1C5 indicated the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope (GSI, 1981) [11].

3.3.3 Relative relief
Relative relief is an important morphometric variable used for the assessment of morphological characteristics of any topography (Gayen et al., 2013) [9]. The relative relief for watersheds varies from 0.04 to 0.62 and for basin it is obtained as 0.17. The watersheds having higher relative relief have higher runoff potential than others. Therefore, the watershed 5G1C2 and 5G1C3 are having the lowest and highest runoff potential.

3.3.4 Channel slope
For watersheds it is varies between 0.0008 km/km to 0.0173 km/km and for basin it is 0.0072 km/km. The higher channel slopes in 5G1C3 (0.0173) watershed indicated less time of concentration i.e. peak flow occurs in short time while lower slope in 5G1C2 (0.0008) watershed indicated less peaked flow for longer duration. Therefore, while constructing the water harvesting structures on channel of watershed 5G1C3, the outlet should be designed of higher discharge capacity and the rest components like headwall, sidewall and wing wall should also be of higher height for the designed storage capacity (Suresh, 2002) [49]. The drop structures in series in the channels of this watershed are recommended.

3.3.4 Ground slope
For watersheds it is obtained as 0.0012 km/km to 0.0272 km/km and for basin 0.0114 km/km. The higher ground slopes in case of 5G1C3 lying in upper reach of the basin indicates lower time of concentration of overland flow. Also, the possibilities of soil erosion will be higher in this watershed.

3.4 Watershed Prioritization
The watershed prioritization is done on the basis of linear parameters. The higher the values of these parameters, higher will be the degree of hazardous. The shape parameters like elongation ratio, circularity ratio, form factor and compactness coefficient varying inversely with the same (Mishra et al., 2011) [20]. The prioritization ranking was given based on the degree of hazardous and the final prioritization was done on the basis of compound parameter obtained from averaging the values of the rankings of the linear and shape parameters allotted to the watersheds (Table 2).

4. Discussion
Usually, morphometric analysis of drainage system is prerequisite to any hydrological study. The present study demonstrates the usefulness of GIS for morphometric analysis and prioritization of the watersheds of Ozat river basin, Gujarat. The watershed 5G1C2 and 5G1C5 are possess highest priority 1 with the C_p value 2.67, which indicate greater degree of erosion and it becomes potential candidate for applying soil conservation measures, while the other watersheds with lower priorities 5G1C3 and 5G1C4 are subjected to lower degree of erosion. Thus the morphometric properties determined for this basin as whole and for each watershed will be useful for the sound planning of water harvesting and groundwater recharge projects on watershed base.

5 Acknowledgments
The authors are grateful to the Bhaskaracharya Institute for Space Applications and Geo-Informatics (BISAG) and their technical staff, Gandhinagar, Gujarat for providing GIS laboratory, computing facilities and helped us to get results of better quality.

Table 1: Values of Morphometric parameters for watersheds

<table>
<thead>
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<th>Name of the Watershed</th>
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<th>Aspects of Shape Parameter</th>
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<td>2</td>
</tr>
<tr>
<td></td>
<td>R*</td>
<td>S*</td>
</tr>
<tr>
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<td>5G1C5</td>
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<td>0.41</td>
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</table>

Table 2: Ranking values for Watershed Prioritization

<table>
<thead>
<tr>
<th>Name of the Watershed</th>
<th>Watershed Priority Ranking for Linear Parameter (Assigned rank 1 to the lowest value of individual parameter)</th>
<th>Watershed Priority Ranking for Shape Parameter (Assigned rank 1 to the Highest value of individual parameter)</th>
<th>C_p</th>
<th>Final Priority</th>
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<td>S*</td>
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"2473"
Fig 1: Location Map of Study Area in India

Fig 2: DEM image of Ozat River Basin

Fig 3: Drainage Order Map Ozat River Basin
6. References


