Morphometric Analysis with Reference to Hydrogeological Repercussion on Domri River Sub-basin of Sindphana River Basin, Maharashtra, India

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Abstract The morphometric analysis of Domri river sub-basin is carried out in order to hydrological implication. For this purpose some basic parameters are measured including basin perimeter, basin length, elevation and other aerial parameters were calculated by using Arc Map (10.1) software. Total area of the sub-basin is 274.68 km^2. Geologically investigated area is covered by Deccan volcanic basalts which are Cretaceous to lower Eocene and Quaternary alluvium occurred along the gullies and both banks of the river. Quantitative analysis of drainage network shows that the dendritic to sub dendritic drainage pattern is developed in the sub-basin. Bifurcation ratio of Domri river sub-basin increases from 1st and 2nd order but decreases in 4th and 5th order stream because it is not affected by any structural control. Drainage texture in the investigated sub-basin indicates massive and resistant rocks cause coarse texture. Drainage morphometry is useful to signifying the construction sites for artificial recharging structures for implication of hydrology.

Keywords: *Domri River sub-basin, morphometry, hydrological implication, Maharashtra, India*

Cite This Article: Jadhav Snehal I. and Md. Babar, "Morphometric Analysis with Reference to Hydrogeological Repercussion on Domri River Sub-basin of Sindphana River Basin, Maharashtra, India." *Journal of Geosciences and Geomatics* 1, no. 1 (2013): 29-35. doi: 10.12691/jgg-1-1-5.

1. Introduction

Morphometric analysis will help to quantify and understand the hydrological characters and their results will useful input for a comprehensive water resource management and plans. Morphometric studies involve evaluation of streams through the measurement of various stream properties. Horton (1945) 'law of stream lengths' suggests a geometric relationship between the number of stream segments in successive stream orders and landforms. Quantitative description of the basin morphometry also requires the characterization of linear and areal features, gradient of channel network and contributing ground slopes of the drainage basin. Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Clarke, 1966, Babar and Kaplay, 1998 and Obi Reddy et al 2002). The morphometric study of the drainage basin aims to acquire accurate data of measurable features of stream network. Drainage provides a basic to understanding of initial slope, inequalities in rock hardness, structural control, geological and geomorphological history. The basin morphometric characteristics of various basins have been studied by many researchers using conventional methods (Smith 1950, Strahler 1957 and Shah and Babar 2009) and remote sensing and GIS methods (Lattman and Parizek, 1964; Bedi and Bhan, 1978; Raju et al, 1985; Satyanarayana 1991 and Srinivasa Rao et al, 1997). In various researches, morphometric analyses were used for basin characterization (Sinha et al, 1990; Kulkarni et al 1994; Adyalkar et al, 1996; Goswami et al, 1996; Srinivasa Rao et al, 1997; Bhagwan, 1998; and Patil et al, 1999). Correspondingly, morphological characteristics such as stream order, drainage density, channel slope, relief, length of overland flow, stream frequency and other morphological aspects of watershed are important in understanding the hydrology (Romshoo Shakil Ahmad et al 2012).

The main objective of the study to computed basin morphometric characteristics for various parameters. The quantitative analysis of morphometric parameters is found to be of enormous effectiveness in river basin assessment, watershed prioritization for soil and water conservation and natural resources management at watershed level (Biswas et al 1999; Panda and Sukumar, 2010 and Nag and Lahiri, 2011).

Domri Sub-basin of Sindphana River is chosen for present morphometric analysis. Domri sub-basin is a tributary stream of Sindphana River which is itself a major tributary of Godavari River in west central part of Maharashtra state, India Figure 1. Domri River originates near Karanjwan village (18º35'N; 75º53'E) in Beed District and confluence with Sindphana near Sirasmarg village (19º11'N; 75º66'E). Total area of the sub-basin is 274.68 Km^2.

Study area belongs to survey of India toposheet numbers 47N/5, 47N/9, 47M/12. Geologically; the entire study area (sub-basin) is covered by Deccan Basalt formations comprising nearly horizontal lava flows. These flows have been considered to be a result of fissure type of lava eruption during late Cretaceous to early Eocene period. The types of basalt occurring in the area are compact basalt, vesicular-amygdaloidal basalt and red bole beds (Tachylitic bands) as observed in the well sections. The Deccan Basalt in this area has been assigned to Ajanta formations which are stratigraphic equivalents of Upper Ratangad formations of Western Maharashtra comprising compound flows (Godbole et al, 1996).

As the basalts are formed by cooling and solidification of the lava, they contain gas cavities and also joints which are the contraction cracks developed during cooling of the lava. But all the basalt flows do not contain gas cavities and joints and therefore on the basis of presence or absence of gas cavities, basalt flows are grouped into two categories:

1. Vesicular amygdaloidal basalt (Compound, Pahoehoe type)
2. Non-vesicular or compact basalt (Simple, aa type)

The study area falls under the semi arid climatic zone. The average annual rainfall is about 666 mm. Rainfall data of 15 years from 1998 to 2012 occurring in the area under study is considered for three rain gauge stations including Beed, Dharur and Majalgaon Figure 2.

In Deccan Basalt terrain groundwater occurs in the exposed lave flows and under semi-confined conditions in the flows at deeper level. Lithological distinctiveness of this hard rock suggests that the groundwater is present in the pore spaces of the vesicular basalt and in the jointed and fractured portions of massive parts of the flows. The primary porosity in the basalts is associated with the vesicles, which are the pore spaces developed due to the escape of volatile and gases when the lava erupts on the surface as a lava flow. This primary porosity in the basalt is naturally limited and related to the quantum of gasses/volatile in the eruptive phase, which forms the basalt flow. The groundwater in the study, therefore, is restricted mostly to the zones of secondary porosity developed in rocks due to fractures, joints and weathering.

Two distinct types of lava flows have distinct qualities as for as their porosity and permeability are concerned. These are described in detail below:

In compound Pahoehoe flow the original gas cavities are filled up with secondary minerals obliterating original vesicular nature. Due to presence of amygdules, fresh amygdaloidal basalt is free from joints and occurs as homogeneous, watertight mass (Patil et al, 1999, Babar, 2001 and Babar 2002). The compound Pahoehoe basalt unit is usually more susceptible to weathering and exhibits deep weathering profile. It is characterized by the formation of sheet joints. Sheet joints are also developed at the contact between the vesicular compound Pahoehoe and the simple basalt flows that is within the contact zone. Such weathered compound Pahoehoe flows contains groundwater. (Deolankar, 1980, Lawrence, 1985 and Kulkarni and Deolankar, 1995). However, quantity of groundwater depends upon the thickness of weathered zone.

The simple basalt flows are demarcated into two parts according to their hydrogeological characters. The top portion of this flow is vesicular, unjointed and watertight in fresh condition, but produces sheet jointing due to weathering. The middle and lower parts of the simple basalt flow are jointed. The joints and fracture zones, which have a discrete distribution in space and orientation, have been reported and described by various researchers (Powar, 1981; Peshwa et al, 1987, Kale and Kulkarni, 1992 and Kulkarni, 1992). Such fracture zones transect several Deccan basaltic units and constitute recharge conduits (lateral as well as down ward transmission of water) for deeper Deccan basaltic aquifers (Kulkarni et al., 1994). However, quantity of percolation of water depends upon joint spacing and pattern of jointing. Water can percolate through closely spaced joints faster as compared to broadly spaced and non-interconnected joints (Kulkarni, and Deolankar, 1995, Kulkarni et al., 1994).

2. Materials and Methodology

The SOI toposheet maps (47N/5, 47N/9, 47M/12) on 1:50000 scales in paper format were used as reference and base map preparation. The SOI toposheets were geometrically rectified and geo referenced to world space coordinate system using digital image processing software (ArcMap 10.1) and digitization work has been carried out for entire analysis of basin morphometry. The order was given to each stream followed by Strahler (1957) stream ordering system. Analysis of various drainage parameters namely ordering of the various streams and measurement of area of basin, perimeter of basin, length of drainage channels, drainage density (Dd), drainage frequency, bifurcation ratio (Rb), texture ratio (T) and circulatory ratio (Rc), Stream frequency (Fs), Elongation ratio (Re), form factor (Rf), total basin relief (Rh) and relief ratio (Rh) of the basin were computed.

3. Results and Discussion

Detailed qualitative analysis has been carried out for the study area from the drainage map Figure 1. The sub-basin has been analyzed through measurement of linear, aerial and relief aspects and slope contribution. Different morphometric parameters of sub-basin are given in the Table 1 and Table 2.

3.1. Linear Aspects

Liners aspect point of view we have measurement of stream order, stream length, mean stream length, stream length ratio and bifurcation ratio.

3.1.1. Stream Order

The primary step in any drainage basin analysis is order designation, stream orders and is based on ranking of streams. Ranking of streams has been carried out based on the method proposed by Strahler. It is observed that the maximum frequency is in the case of first order streams. It is also noticed that there is a decrease in stream frequency as the stream order increases. Figure 3(A) indicates semi-log plot of stream order (u) versus number of streams.

3.1.2. Stream Length

Stream length is one of the most important hydrological features of the basin as it reveals that the surface run-off behaviors, The quantity of streams of different orders in a sub-watershed is count and their lengths from mouth to drainage divider are measured. The stream length (Lu) has been computed based on the law planned by Horton (1932) for the Domri sub-basin. Figure 3(B) illustrates the semi-log plot of stream order versus mean stream length. Generally total length of stream segments is maximum in first order streams and decreases as the stream order increases.

3.1.3. Mean Stream Length

The mean stream length is a dimensionless property, characterizing the size aspects of drainage network and its linked surface (Strahler 1957). It is obtained by dividing the total length of stream order by total number of segments in the order Table 1 and Table 2. The present area mean stream length varies from 0.59 to 30.20 of Domri river sub-basin. Mean stream length of any given order is greater than that of the lower order and less than of its next higher order.

3.1.4. Stream Length Ratio

It is the ratio between mean lengths of streams of any two successive orders. Horton (1945) law of stream length states that mean length of stream segments of each of the successive orders of a basin tends to roughly a direct geometric series, with stream lengths increasing towards higher stream order. Study area shows variation in stream length ratio between streams of different order. Change of stream length ratio from one order to another order indicates their late youth stage of geomorphic development.

3.1.5. Bifurcation Ratio

The bifurcation ratio (Rb) means number of stream segments given order 'Nu' to the number of streams in the next higher order (Nu+1) Table 1 and Table 2. Horton (1945) considered the bifurcation ratio as index of relief and dissertation. Strahler (1957) 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 these irregularities are dependent upon the geological and lithological development of the drainage basin Strahler (1957). The lower values of Rb are characteristics of the sub-basin which have suffered less structural disturbances (Strahler 1957) and drainage pattern has not been distorted because of the structural disturbances (Nag 1998). The mean bifurcation ratio (Rbm) may be defined as the average of bifurcation ratios of all order Table 1. In the present case, Rbm is 5.21, which falls under normal basin category (Strahler 1957).

3.1.6. Relief Ratio

Difference in the elevation between highest point of a basin (on the main divide) and lowest point on the valley floor is known as total relief of the river basin. The relief ratio may be defined as the ratio between total relief of a basin and longest dimension of basin parallel to main drainage line (Nag 1998). The possibility of a close connection between relief ratio and hydrological characteristics of a basin suggested by scheme who found that sediments loose per unit area is closely correlated with relief ratios. In the study area, the value of relief ratio is 0.0105. It is noticed that the high value of Rh indicate steep slope and high relief (324 m asl).
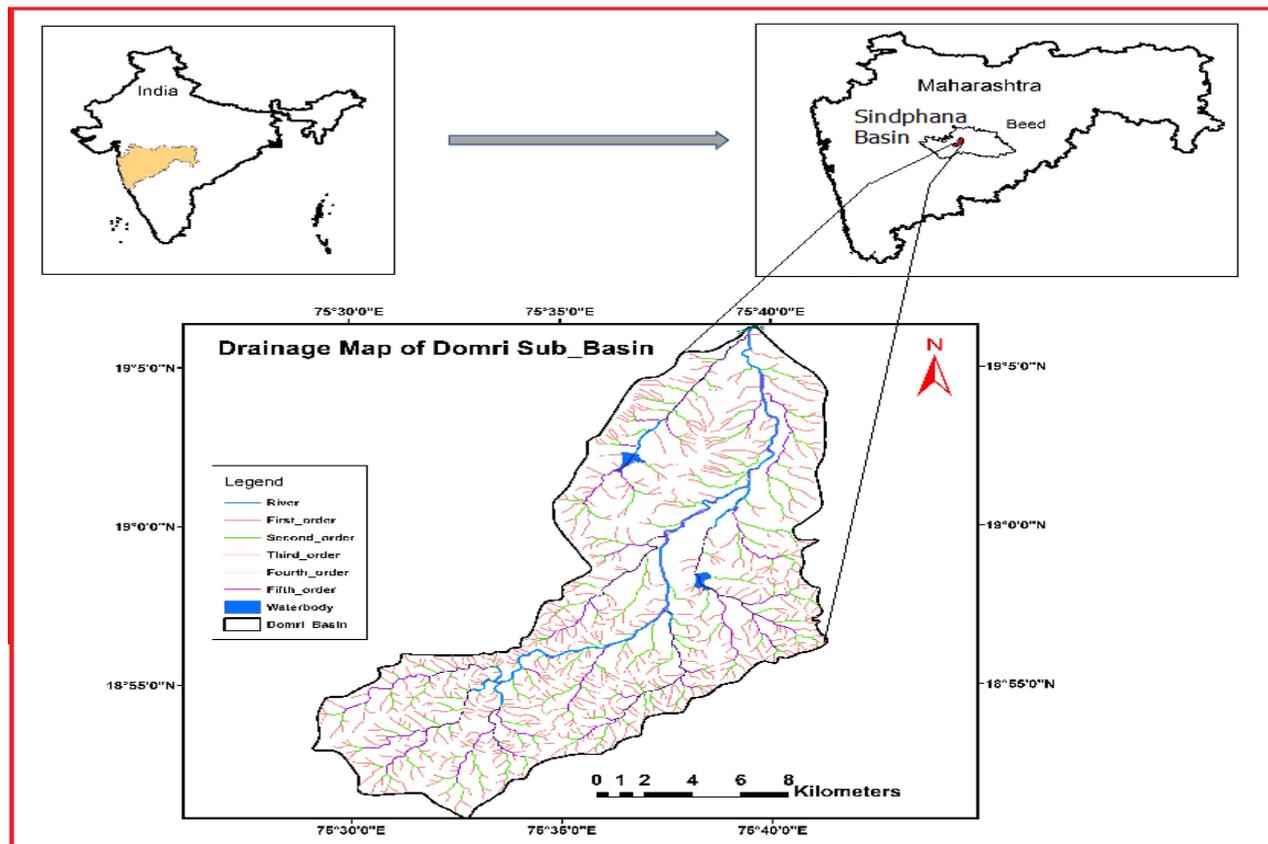

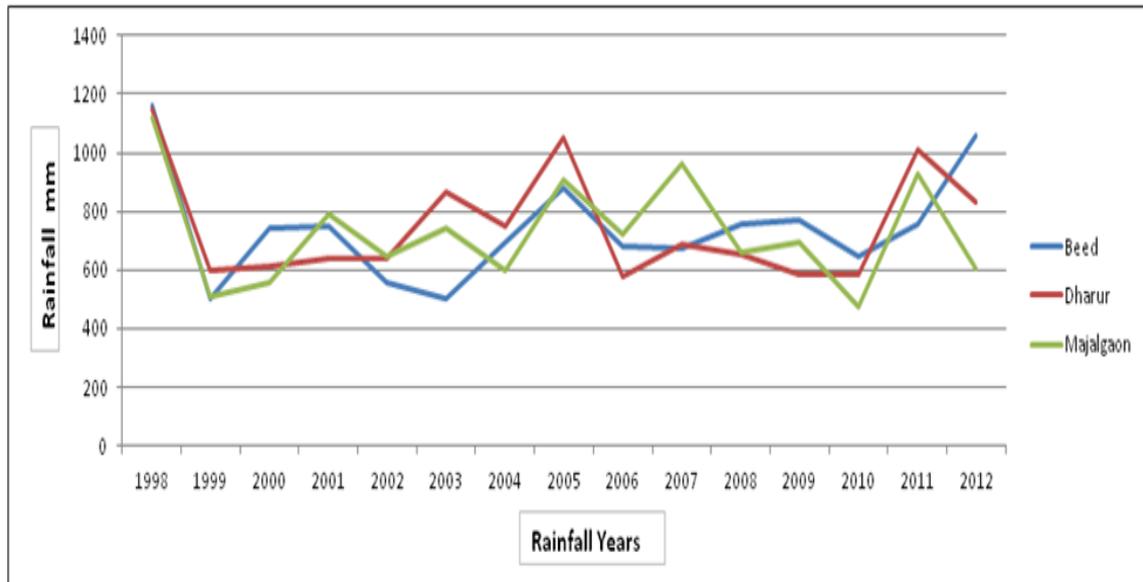**Figure 1.** Location and drainage map of Domri sub-basin

Figure 2. Rainfall at three rain gauge stations in study area

Table 1. Linear aspects of the Domri river sub-basin in Beed district

Stream Order u	Number of Streams N_u	Bifurcation ratio Rb	Total length of Streams Km L_u	Mean Stream Length (L) Km	Length Ratio RI
1	667		394.37	0.59	
		3.73			1.36
2	179		144.39	0.81	
		5.26			2.65
3	34		72.58	2.13	
		4.86			3.22
4	7		48.05	6.86	
		7.00			4.40
5	1		30.20	30.20	
Total/Mean	888	5.21	689.59	40.59	2.91

Table 2. Aerial aspects of the Domri River sub-basin in Beed District Maharashtra

| Sr. No.	Morphometric Parameters	Symbol/Formula	Domri river
1	Area (Sq. Km)	A	274.68
2	Perimeter (Km)	P	88.13
3	Drainage density (Km/Sq. Km)	$D = L_u / A$	2.51
4	Stream frequency	$F_s = N_u/A$	3.23
5	Texture ratio	$T = N_1/P$	58782.71
6	Basin length (Km)	L_b	30.9
7	Elongation ratio	$Re=2 \sqrt{(A/Pi)} /Lb$	0.61
8	Circularity ratio	$Rc = 4 \prod A / P^2$	0.44
9	Form factor	$Rf = A / Lb^2$	0.29
10	Drainage Texture (T)	$T = Dd \times Fs.$	8.10
11	Length of Overland flow (Km)	$Lof = 1/2Dd$	0.19
12	Height of the highest point on the basin	H max	805
13	Lowest point of the river basin	H min	481
14	Total basin relief	(Rh)	324
15	Relief ratio	$Rh= H/ Lb$	0.0105
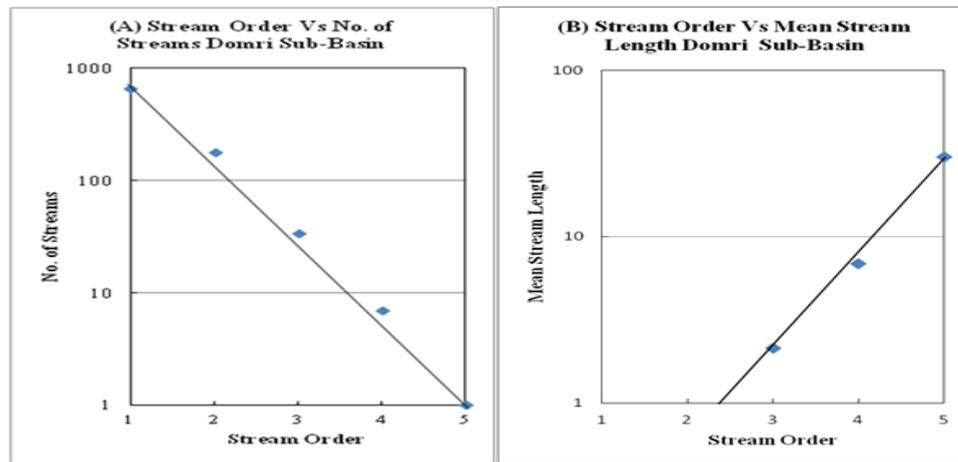
Figure 3. (A). Semi-log plot of stream order (u) versus number of streams of Domri sub-basin (B) Stream order (u) versus mean stream Length of Domri sub-basin

3.2. Aerial Aspects

In aerial aspect point of view measurement the different morphometric parameters like drainage density, texture ratio, stream frequency, form factor, circularity ratio, elongation ratio and length of overland flow have been discuss in details.

3.2.1. Drainage Density

It is a work out of the length of stream per unit (Horton 1932) in the watershed. It is significant point in the linear scale of landform elements in stream eroded topography and does not change regularly with orders within the basin. Drainage density value is 2.51 Km/Km^2 of Domri river sub-basin. Density factor is related to climate, type of rocks, infiltration capacity, vegetation cover, surface roughness has no significance co-relation with drainage density. The amount and type of precipitation can influence directly the quality and character of surface run-off an area with high precipitation as thunder showers loses greater percentage of rainfall, absorption capacity of soil, which influences the rate of surface run-off, affects the drainage texture of an area. The related situation of lithology and geological structures semi arid regions have finer drainage density generally results in the areas of highly resistant or permeable subsoil material, dense vegetation and low relief. High drainage density is the resultant of weak or impermeable sub surface material, thin vegetation and mountainous relief.

3.2.2. Stream Frequency

Stream frequency of the basin may be defined as the ratio of the total numbers of segments cumulated for all orders with a basin to the basin area (Horton 1945). In the present area the value of stream frequency is 3.23.

3.2.3. Form Factor

The form factor (Rf) points outlines form of a drainage basin competent of being understand and affects stream discharge behaviours. The ratio of the basin area to the square of basin length is called the form factor (Horton 1932). It is dimension less property and is used as a quantitative appearance of the shape of basin form. The form factor of Domri sub-basin is 0.29. A form factor

nearer to zero indicates a highly elongated shape and the value that is closer to 1 indicates circular shape.

3.2.4. Circularity Ratio

Basin of the circularity ratio (Rc) is a shape measured depending on stream flow in the sub basin. The circularity ratio is influence by the length and frequency of stream. Geological structures, land use, land cover, climate relief and slopes of the basin. In the present study, the circularity ratio is 0.44. The circularity ratio 0.44 in Domri sub-basin indicates that it is less circular, more elongated and is characterized by high to moderate relief and drainage system may be structurally controlled.

3.2.5. Elongation Ratio

The shape of the any basin is conveyed by an elongation ratio (Re), it is the ratio between the diameter of the circle of the same area as the drainage basin and the maximum (Schumm 1956). A circle basin is more capable for discharge of run-off than an elongation basin. These values can be grouped into 4 categories namely (a) Circle (> 0.9), (b) Oval (0.9 to 0.8), (c) Less elongated (0.8 to 0.7) and (d) Elongated (< 0.7). The elongation ratio of sub-basin of the study area is 0.61 indicates elongated sub-basin.

3.2.6. Length of Overland Flow

Length of overland flow (Lof) is one of the most important independent variables moving both hydrological and physiographical development of drainage basins (Schumm 1956). From Table 2, it can be seen that length of overland flow of Domri sub-basin is 0.19.

3.2.7. Drainage Texture (T)

The drainage texture may be defined as the relative spacing of drainage lines. The drainage density and drainage frequency have been jointly defined as drainage texture can be expressed by the equation (Smith 1950).

$$T = Dd \; X \; Fs.$$

Based on the values of T it is classified by Smith (1950), < 4 Coarse, 4-10 Intermediate, 10 -15 Fine, >15 Ultra Fine (bad land topography). Domri river sub-basin drainage texture is 8.10, indicates massive and resistant rocks cause intermediate coarse texture.

3.3. Hydrogeology

Groundwater in Deccan Basalt terrain occurs under phreatic conditions in the exposed lava flows and under semiconfined conditions in the flows at deeper level (Babar 2002 and Babar and Kaplay, 2003). Lithological studies suggest that groundwater is present in the pore spaces of the vesicular basalt (compound) and in the jointed (Figure 4A) and fractured portions of massive (simple) parts of the flows. The primary porosity in the basalts is associated with the vesicles, which are the pore spaces developed due to the escape of volatile and gases when the lava erupts on the surface as a lava flow. This primary porosity in the basalt is naturally limited and related to the quantum of gasses/volatile in the eruptive phase, which resulted in the basalt flow. Basalt flows can be separated by red bole beds and at places by ropy lava flows (Figure 4B). The groundwater in the study area therefore is restricted mostly to the zones of secondary porosity developed in these rocks due to weathering of compound basalt flow (Figure 4C), fractures and joints in simple basalt flow (Figure 4D).

From the hydrogeological point of view, the frequency and extent of jointing, fracturing and the flow contacts and weathering along them are the most significant parameters imparting permeability and porosity for forming suitable groundwater reservoirs in the Deccan Basalt terrain. The vesicular zones occurring in the upper parts of flows or units, though porous, are not permeable, as the vesicles are not interconnected. Secondly, the vesicles are generally filled with amygdules, green earth, glassy material etc. The red bole layer, flow breccia with secondary mineral development and the massive parts of the flow, with non-interconnected joints, are impervious. The secondary porosity (Joints and fractures) generally reduces with depth and hence the near surface (unconfined) aquifer system rarely, extends below 30 m depth (Agashe, 1990 and Babar and Kaplay, 2003).

Figure 4. (A)Simple (Compact) basalt flow, (B) Ropy lava structure on the top of compound (Amygdaloidal) basalt flow, (C) Dug well in compound (Amygdaloidal) basalt flow photo taken in summer 2013 and (D) Dug well in Simple (Compact) basalt

4. Conclusion

Quantitative analysis of drainage network found that the dendritic to sub dendritic drainage pattern is developed in the area. Bifurcation ratio of the sub-basin increases from 1st and 2nd order but decreases in 4th and 5th order stream because not affected by structure control. Drainage texture of the investigated watershed indicates massive and resistant rocks cause intermediate coarse texture. In the sub-basin area basalt flows are of two types such as Compound (Pahoehoe type) and Simple (aa type) having different groundwater characteristics. In the study area it is restricted mostly to the zones of secondary porosity developed due to fractures, joints and weathering. Dug wells are recommended in the weathered areas. Most of the dug wells in the sub-basin dry up during pre monsoon period, hence bore wells and dug-cum bore wells are recommended for these areas.

Acknowledgement

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