Morphometry, Hypsometry Analysis and Runoff Estimation of Aam Talab Watershed Raichur, Karnataka

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ABSTRACT

Aam Talaab also known as Maavina Kere or mango beach is one of the major attractions of Raichur. It is located between Latitude 16º10'49.5'' N to 16º11'27.8'' N Latitude and 77º20'36'' E to 77º23'26'' E Longitude and an area of 4.77 km^2, having maximum length of 3.98 km. The maximum and minimum elevation of the basin is 491 m and 404 m above MSL, respectively. The values of Stream frequency is 6.50, Form factor 0.30, Shape factor 3.32, Elongation Ratio 0.62, Circularity Ratio 0.39, Drainage density 2.66, Length of overland flow 0.19. The study of hypsometric properties of Aam Talab watershed using hypsometric integral (HI) and hypsometric curve retrieved in that, HI value is 0.52 and hence watershed falls under the Mature Stage. Rainfall was estimated by considering precipitation data from 1998 to 2016 it was found that maximum percentage of runoff took place in 2009 and minimum in the year 2012.

Key words: *Aam Talab, Antecedent Moisture Condition, GIS, Hypsometry, Hydrological Soil Group, Runoff.*

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1 INTRODUCTION

Aam Talaab also known as Maavina Kere or mango beach is one of the major attractions of Raichur. Covering an area of 150 acres, the Aam-talab, situated in the south-west region of the hill fort in the heart of Raichur city, was constructed during the Kakatiya dynasty when the original fort wall of Raichur was built by Kakatiya queen Rudramma Devi of Warangal in 1294 A.D. Watershed is a natural hydrological entity from which runoff resulting from precipitation flows past a single point into large stream, river, lake or ocean. Morphometric analysis provides quantitative description of the basin geometry to understand initial slope or inequalities in the rock hardness, structural controls, recent diastrophism, geological and geomorphic history of drainage basin (Strahler, 1964). Morphometric analysis requires measurement of linear features, gradient of channel network and contributing ground slopes of the drainage basin. . A major emphasis in geomorphology over the past several decades has been on the development of quantitative physiographic methods to describe the evolution and behavior of surface drainage networks (Horton, 1945). The influence of drainage morphometry is very significant in understanding the landform processes, soil physical properties and erosional characteristics. The hypsometric analysis can be used as a morphometric parameter, i.e. hypsometric integral, to deduce its relationship with the area of watersheds. Statistical analysis of these parameters has been carried out by classifying them into different classes based on the natural breaks method. This brings out strong relationships for hypsometric integral classes and area classes with the number of watersheds in respective classes and the total area occupied by respective hypsometric and area classes.

2 MATERIALS AND METHODS

2.1.1 Study Area

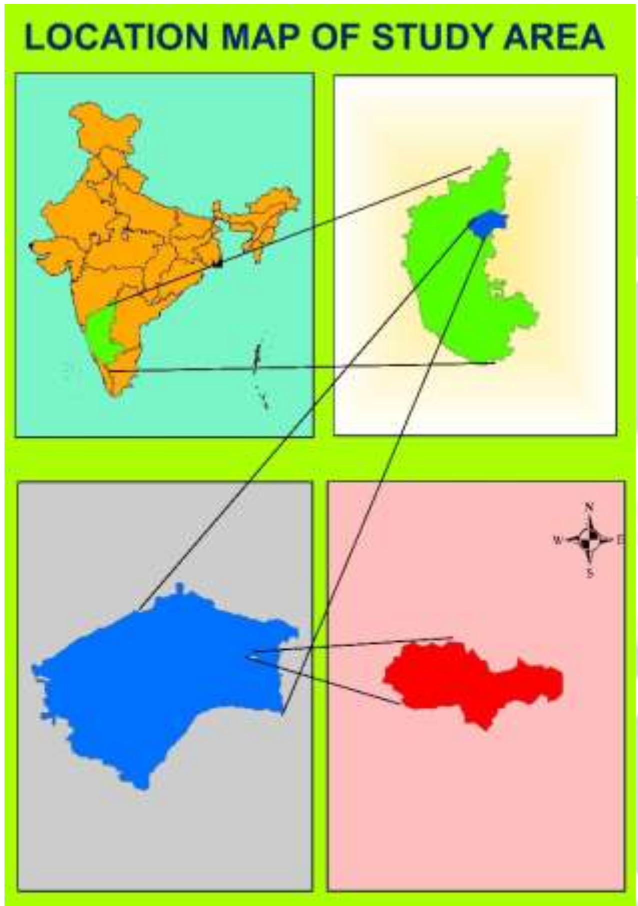

Fig 1 Location Map of Study Area

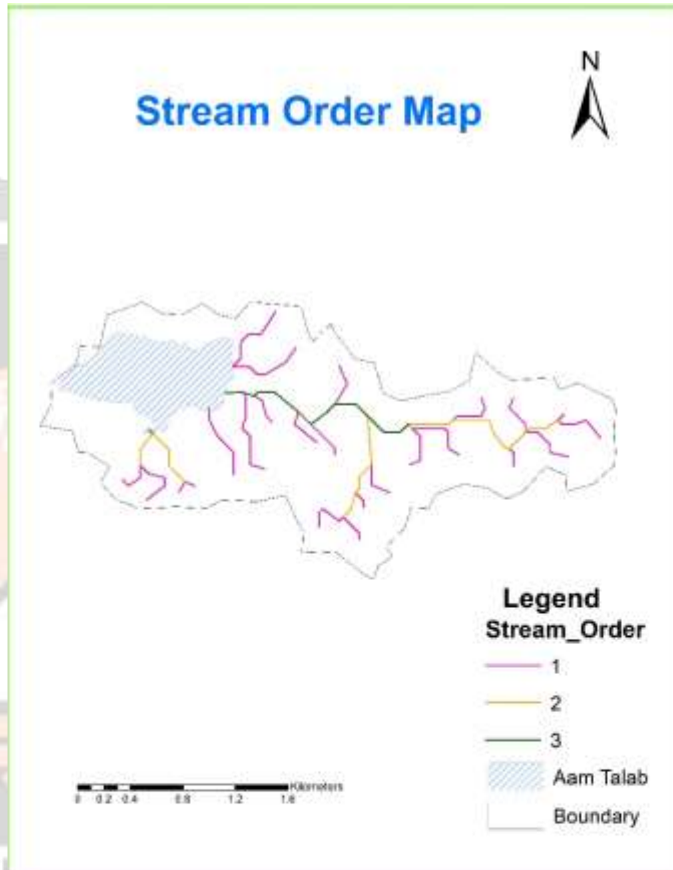

Fig 2 Stream order Map

The Study Area is located between Latitude 16º10′49.5″ N to 16º11′27.8″ N Latitude and 77º20′36″ E to 77º23′26″ E Longitude and an area of 4.77 km^2, having maximum length of 3.98 km. The maximum and minimum elevation of the basin is 491 m and 404 m above MSL, respectively. Location of the study area is shown in figure 1, Stream Order is shown in figure 2 and DEM is shown in figure 19.

2.1.2 Data

- Rainfall data for a period of 19 years was collected from Department of Econimics and statics, Bangalore.
- Soil Map and Land use land cover Map was collected from KSRSAC, Bangalore.
- SRTM data of 30M was downloaded from Earth Explorer

Fig 3 Satellite Image of Study area

Fig 4 Google Image of Study area

Fig 5 Location of Points on AAM Talab

Fig 6 Location of Point 1 on Aam Talab

Fig 7 Location of Point 2 on Aam Talab Showing Well

Fig 8 Location of Point 3 on Aam Talab

Fig 9 Location of Point 7 on Aam Talab

- Figure 10 shows discharge of drainage water in aam talab
- Figure 9, 12 and 14 shows the condition of water in aam talab
- Figure 7 and 13 shows Location of wells in aam talab
- Figure 10 shows medical waste thrown in aam talab

Fig 10 Location of Point 4 on Aam Talab Disposal of Drainage water in Lake

Fig 11 Location of Point 5 on Aam Talab

Fig 12 Quality Of water in Aam talab

Fig 13 Location of Well 2

Fig 14 Pollution in Aam talab Water

Fig 15 Disposal Of Medical Waste In Aam talab

Fig 16 Baffaloes taking bath in Aam Talab

Fig 17 Dry Garbage thrown in Aam Talab

Fig 18 Childrens Playing in Aam talab

2.2 Methodology

2.2.1 Morphometric analysis

DEM data is used to calculate the flow direction a staple for determining many important hydrologic parameters stream network is determined by using Arc GIS tools. Quantitative morphometric analysis was carried out for watershed for linear aspects, areal aspects and relief aspects. The analysis was carried out using Arc GIS. The detailed list of various morphological characteristics derived for Table 1 is used for calculating the morphometric parameters of the mini watersheds.

Table 1 Formulae adopted for computation of Morphometric parameters

Sl no	Morphometric parameters	Formula	Reference
1	Stream order	Hierarchial rank	Strahler (1964)
2	Stream length (Lu)	Length of the stream	Horton (1945
3	Mean stream length (Lsm)	Lsm = ? Lu / Nu Where, Lsm = Mean stream length Lu = Total stream length of order 'u' Nu = Total no. of stream segments of order 'u'	Strahler (1964)
4	Stream length ratio (RL	RL = Lu / Lu – 1 Where, RL = Stream length ratio Lu = The total stream length of the order 'u' Lu – 1 = The total stream length of its next lower order	Horton (1945)
5	Bifurcation ratio (Rb)	Rb = Nu / Nu + 1 Where, Rb = Bifurcation ratio Nu = Total no. of stream segments of order 'u' Nu + 1 = Number of segments of the next higher order	Schumn (1956)
6	Relief ratio (Rh)	Rh = H / Lb Where, Rh = Relief ratio H = Total relief (Relative relief) of the basin (km) Lb = Basin length	Schumn (1956)
7	Drainage density (D)	D = Lu / A Where, D = Drainage density Lu = Total stream len gth of all orders A = Area of the basin (Sq km)	Horton (1932)
8	Stream frequency (Fs)	Fs = Nu / A Where, Fs = Stream frequency Ns = Total no. of streams segments A = Area of the basin (Sq km)	Horton (1932)
9	Form factor (Rf)	Rf = A / Lb Where, Rf = Form factor A = Area of the basin (Sq km) Lb = basin length	Horton (1932)
10	Circularity ratio (Rc)	$Rc = (4 * Pi * A)^{1/2} / P^2$ Where, Rc = Circularity ratio Pi = 'Pi' value i.e., 3.14 A = Area of the basin (Sq km) P^2 = Square of the perimeter (km)	Miller (1953)

11	Elongation ratio (Re)	Re = 2 (A/Pi)½ / Lb Where, Re = Elongation ratio A = Area of the basin (Sq km) Pi = 'Pi' value i.e., 3.14 and Lb = Basin length	Schumn (1956)

2.2.2 Hypsometric Analysis

The curve shows how much area lies above and below marked elevation intervals. The areas used are therefore those of horizontal slices of the topography at any given level. This method produces a cumulative curve, any point on which expresses the total area (reduced to horizontal projection) lying above that plane.

The curve can also be shown in non-dimensional or standardized form by scaling elevation and area by the maximum values. The non-dimensional hypsometric curve provides a hydrologist or a geo-morphologist with a way to assess the similarity of watersheds.

A hypsometric curve is a histogram or cumulative distribution function of elevations in a geographical area. Differences in hypsometric curves between landscapes arise because the geomorphic processes that shape the landscape may be different.

Hypsometric curve is developed and maintained in a steady state as relief slowly diminishes. The monadnock phase with abnormally low hypsometric integral, when it does occur, can be regarded as transitory, because removal of the monadnock will result in restoration of the curve to the equilibrium form. From inspection of many natural hypsometric curves and the corresponding maps, A N Strahler estimates that transition from the inequilibrium (youthful) stage to the equilibrium (mature) stage corresponds roughly to a hypsometric integral of 60%, but that where monadnocks become conspicuous features the integrals drop below 35%.

The hypsometric integral was estimated using the elevation-releif ratio method proposed by Pike and Wison (1971).

The relationship is expressed as

$$H = \frac{(\text{Emean} - \text{Emin})}{(\text{Emax} - \text{Emin})} \qquad \text{Eq. (1)}$$

Where,

Emean = mean elevation of the watershed

Emin = minimum elevation within the watershed

Emax = maximum elevation within thw watershed.

2.2.3 Runoff Estimation

Runoff means the draining or flowing off of the precipitation from a catchment area through a surface channel. It thus represents the output from the catchment in a given unit of time.

2.2.3.1 Soil Conservation Service (SCS) Curve Number Model

In this model, runoff will be determined as a function of current soil moisture content, static soil conditions, and management practices. Runoff is deduced from the water available to enter the soil prior to infiltration. The SCS curve number method is developed from many years of stream flow records for agricultural watersheds in several parts of the United States. The method is also called hydrologic soil cover complex number method. It is based on the recharge capacity of a watershed. The recharge capacity can be determined by the antecedent moisture contents and by the physical characteristics of the watershed.

2.2.3.2 Runoff volume

The SCS curve number method is based on the water balance equation and developed on two fundamental hypotheses;

i. Ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration.
ii. The amount of initial abstraction is some fraction of the potential infiltration.

The first hypothesis is expressed as;

$$\frac{Q}{P-Ia} = \frac{F}{S} \qquad (2)$$

where Q is the runoff, P is the rainfall and F is the actual infiltration and it is the difference between the potential and accumulated runoff.

The SCS developed an index, which is called runoff curve number (CN) to represent the combined hydrologic effects of soil, land use, agricultural land treatment class, hydrologic condition and antecedent soil moisture. These factors can be assessed from soil surveys, site investigation and land use maps. Thus, a runoff curve number is defined to relate the unknown S as spatially distributed variable as

$$CN = \frac{25400}{S + 254} \qquad (3)$$

2.2.3.3 Determination of Curve Number (CN)

The SCS cover complex classification consists of three factors: land use, treatment of practice and hydrologic condition. There are approximately eight different land use classes that are identified in the tables for estimating curve number. This separation reflects the different hydrologic runoff potential that is associated with variation in land treatment. The hydrologic condition reflects the level of land management; it is separated with three classes as poor, fair and good. Not all of the land use classes are separated by treatment or condition.

CN values for different land uses, treatment and hydrologic conditions were assigned based on the curve number table. Runoff Curve Numbers for (AMC II) hydrologic soil cover complex is shown in Table 2.

Sl No	Land use	Hydrologic Soil Group			
		A	B	C	D
1	Agricultural land without conservation (Kharif)	72	81	88	91
2	Double crop	62	71	88	91

3	Agriculture Plantation	45	53	67	72
4	Land with scrub	36	60	73	79
5	Land without scrub (Stony waste/rock outcrops)	45	66	77	83
6	Forest (degraded)	45	66	77	83
7	Forest Plantation	25	55	70	77
8	Grass land/pasture	39	61	74	80
9	Settlement	57	72	81	86
10	Road/railway line	98	98	98	98
11	River/Stream	97	97	97	97
12	Tanks without water	96	96	96	96
13	Tank with water	100	100	100	100

Table 2 Runoff Curve Numbers for (AMC II) hydrologic soil cover complex

2.2.3.4 Hydrological Soil Group Classification

SCS developed a soil classification system that consists of four groups, which are identified as A, B, C, and D according their minimum infiltration rate. The identification of the particular SCS soil group at a site can be done by one of the following three ways (i).soil characteristics (ii).county soil surveys and (iii).minimum infiltration rates. Table 3 shows the minimum infiltration rates associated with each soil group.

Soil Group	Minimum Infiltration Rate (mm/hr)
A	7.62 - 11.43
B	3.81 - 7.62
C	1.27 - 3.81
D	0 - 1.27

Table 3 Minimum infiltration rates associated with each soil group (Mc Cuen, 1982)

2.2.3.5 Antecedent Moisture Condition (AMCs)

Antecedent Moisture Condition (AMC) refers to the water content present in the soil at a given time. The AMC value is intended to reflect the effect of infiltration on both the volume and rate of runoff according to the infiltration curve. The SCS developed three antecedent soil-moisture conditions and labeled them as I, II, III. These AMC's correspond to the following soil conditions. Table 4 shows the AMC's classification.

AMC_S	FIVE DAYS ANTECEDENT RAINFALL (mm)	
	Dormant season	Growing season
I	< 12.7 mm	<35.56 mm
II	12.7-27.94 mm	35.56-53.34 mm
III	> 27.94 mm	53.34 mm

Table 4 Antecedent Moisture Condition (AMCs)

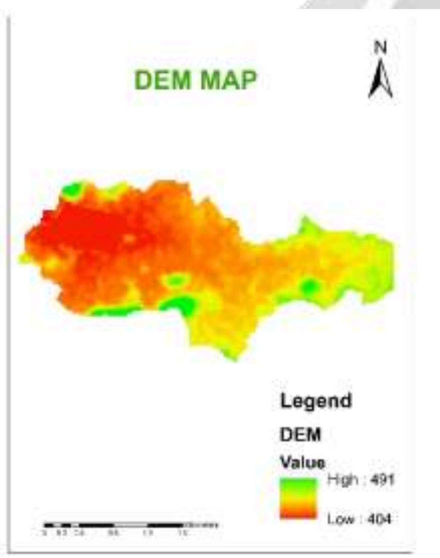

Fig 19 DEM of study area

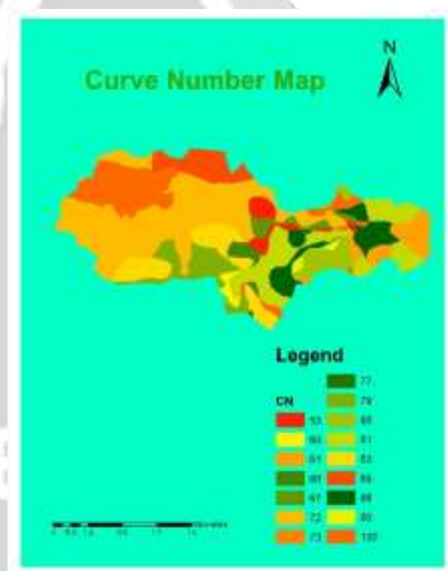

Fig 20 CN Map

3 Results

3.1 Morphometric analysis

Quantitative Morphometric analysis were carried out for watershed. The results of Morphometric characteristics are presented in Tables 5 and 6.

Table 5 Morphometric Parameters

Sl No	Watershed Parameters	Units	Watershed 1
1	Watershed Area	Sq.Km	4.77
2	Perimeter of the Watershed	Km	12.33
3	Watershed Stream Highest Order	No.	3
4	Maximum Length of watershed	Km	3.98
5	Maximum width of Watershed	Km	1.42
6	Cumulative Stream Segment	Km	31
7	Cumulative Stream Length	Km	12.68
8	Drainage Density	Km /Sq.km	2.66
9	Constant of Channel Maintenance	Sq.Km/Km	0.38
10	Stream Frequency	No/Sq.Km	6.50
11	Form Factor		0.30
12	Shape Factor		3.32
13	Circularity Ratio		0.39
14	Elongation Ratio		0.62
15	Compactness Coefficient		1.59
16	Total Watershed Relief	m	87
17	Relief Ratio		0.0218
18	Relative Relief		0.0070
19	Ruggedness Number		0.00023
20	Texture Ratio		1.94
21	Length Of overland flow		0.19

Table 6 Morphometric Characteristics

Name	Stream order	No. Of streams	Total length of streams (km)	Cumulative length (km)	Mean stream length (km)	Bifurcation ratio (km)	Length ratio
Mini Watershed	1	24	8.05	8.05	0.34		
	2	5	2.96	11.01	0.59	4.80	1.76
	3	2	1.67	12.68	0.84	2.5	1.41

3.2 Hypsometric analysis

Table 7 Calculations of Percentage Hypsometric curve Aam Talab watershed

Sl No	Elevation (m)	Area (sq.km)	Altitude (m)	Elevation difference	e/E	cumulative area (Sq.km)	a/A
1	404	0	491	87	1.0000	0.00	0.0000
2	404-410	1137523	490	86	0.9451	1137522.82	0.2386
3	410-415	938915	485	81	0.8901	2076437.77	0.4355
4	415-420	694420.8	480	76	0.8352	2770858.61	0.5811
5	420-425	829546.5	475	71	0.7802	3600405.08	0.7551
6	425-430	471666.4	470	66	0.7253	4072071.45	0.8540
7	430-435	352195.2	465	61	0.6703	4424266.69	0.9279
8	435-440	143502.8	460	56	0.6154	4567769.47	0.9580
9	440-445	71142.46	455	51	0.5604	4638911.93	0.9729
10	445-450	23205.49	450	46	0.5055	4662117.42	0.9778
11	450-455	22844.27	445	41	0.4505	4684961.70	0.9826
12	455-460	21930.55	440	36	0.3956	4706892.24	0.9872
13	460-465	14620.26	435	31	0.3407	4721512.50	0.9902
14	465-470	16447.73	430	26	0.2857	4737960.23	0.9937
15	470-475	14620.28	425	21	0.2308	4752580.51	0.9967
16	475-480	5482.552	420	16	0.1758	4758063.06	0.9979
17	480-485	6396.483	415	11	0.1209	4764459.54	0.9992
18	485-490	2741.347	410	6	0.0659	4767200.89	0.9998
19	490-491	913.7818	404	0	0.0000	4768114.67	1.0000

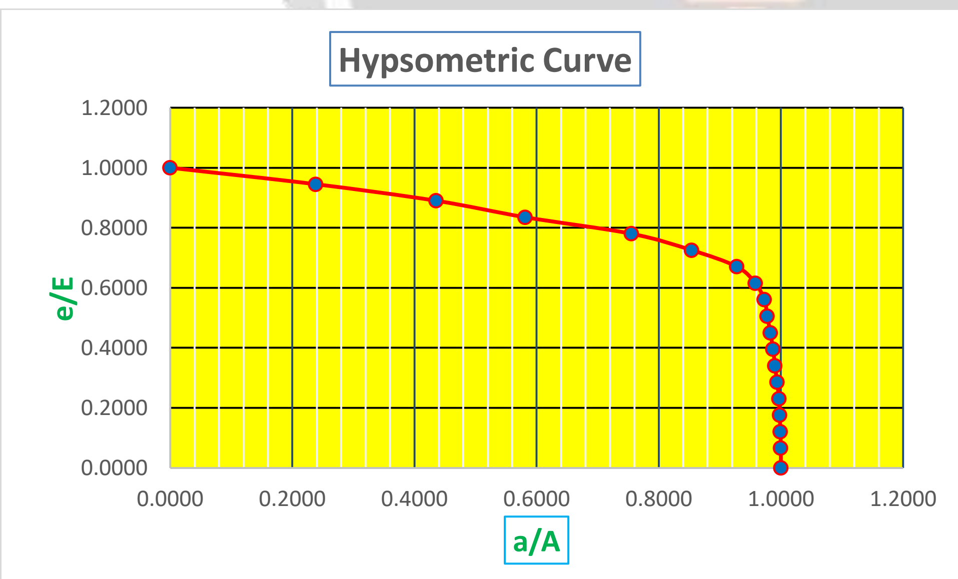

Fig 21 Hypsometric Curve

The study of hypsometric properties of Aam Talab watershed using hypsometric integral (HI) and hypsometric curve retrieved in that, HI value is 0.52 and hence the watershed falls under the mature stage.

3.3 Runoff Estimation

Year	Rainfall (mm)	Runoff (mm)	Runoff (m)	Volume cubic meter	Volume TMC
1998	1080.20	119.8872	0.11989	571862.150	0.02021
1999	632.30	122.24	0.12224	583084.800	0.02060
2000	698.00	108.4185	0.10842	517156.019	0.01827
2001	743.20	203.8809	0.20388	972512.131	0.03436
2002	421.50	87.05831	0.08706	415268.151	0.01467
2003	494.30	59.08157	0.05908	281819.071	0.00996
2004	620.80	142.9055	0.14291	681659.081	0.02409
2005	786.10	114.5306	0.11453	546310.769	0.01930
2006	387.20	103.3275	0.10333	492872.168	0.01742
2007	820.80	237.8707	0.23787	1134643.085	0.04009
2008	673.10	177.8937	0.17789	848552.991	0.02998
2009	977.80	434.8389	0.43484	2074181.423	0.07329
2010	650.00	112.8334	0.11283	538215.146	0.01902
2011	441.60	156.3009	0.15630	745555.414	0.02634
2012	247.00	17.94282	0.01794	85587.243	0.00302
2013	538.10	128.7468	0.12875	614122.353	0.02170
2014	770.20	241.0077	0.24101	1149606.897	0.04062
2015	319.90	40.7043	0.04070	194159.522	0.00686
2016	545.60	148.8575	0.14886	710050.468	0.02509

Table 8 Runoff Values

4 CONCLUSIONS

The length of overland flow in Watershed in the present study is less than 0.3. Hence, the Watersheds selected for study have Smaller flow paths associated with less infiltration and high runoff. The Drainage density is 2.66 km/km^2 indicating Moderate texture. The shape ratio shows the watersheds are elongated to oval shape. Stream frequency is Moderate. The relative relief ratio for Aam Talab lake is 0.007056.The higher relative relief indicates that it is composed of resistant rock patches and lower relief ratio indicates less resistant patches of rocks. The study of hypsometric properties of Aam Talab watershed using hypsometric integral (HI) and hypsometric curve retrieved in that, HI value is 0.52 and hence watershed falls under the Mature Stage. This aam talab which was said to be around 150 hectares has been reduced by a margin of more than 40 percent due to disposal of dry waste and dumping there is always a scarcity of exitinguishing , drainage water is also disposed into it buffaloes are allowed to taken bath in same water ,there are two wells in the aam talab which are almost diluted with sewage water children do play and swim in same water due to which they may get disease .City munipal council should take more interest in keeping the aam talab clean free from pollution which is present in heart of city . Raichur city which is surrounded by two rivers like tungabadra and Krishna but the minimum per capita demand. The volume of runoff generated is shown in table 8. There is a need of proper planning for water system in raichur even this water can be treated and used for different purpose.

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