Runoff Estimation in Watershed GP-10 using NRCS-CN and GIS

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Abstract: *Runoff is an important parameter in any catchment; especially areas where rainfall is scant. Estimation of runoff can provide us the better planning and management of water resources of any region. Marathwada region has experienced extreme water scarcity due to unpredictable and meager rainfall. Present study uses the NRCS-Curve Number method to estimate the runoff of watershed GP-10 using GIS. The landuse and soil layers are used to find curve number and the runoff is calculated with ArcGIS software. The runoff of year 2006 is* 627.24 *mm and is highest recorded over span of 10 years and minimum runoff in year 2009 is* 50.303*mm.This study attempts the assessment of runoff, a hydrologic parameter of catchment.*

Index Terms **–Runoff, NRCS-CN, GIS**

I. INTRODUCTION

Runoff finds various applications in water resources and is significant as it contributes to hydrological cycle. There are many methods to find runoff but the Natural Resources Soil Conservation- Curve Number method (NRCS-CN) is one of the most widely used method for computing runoff. It is relatively simple method as it requires only one parameter Curve Number (CN) along with rainfall data for estimation of runoff. The Curve number depends on Antecedent moisture condition (AMC), Hydrologic Soil Group (HSG) and Landuse of the area. The Curve Number method developed by the National Resource Conservation Service formerly known as Soil Conservation Service, US Department of Agriculture. Present study has the objective to estimate runoff GP-10 for long term planning and organization of water resources.

II. STUDY AREA

The study area is watershed named GP-10 and it lies in Aurangabad district, Maharashtra. The total area of watershed is 367 km^2. It comes under toposheet 47 M/5, 47 M/9.It covers about 325 km^2 areas and is bounded by $19^0$34’44’’ and $20^0$0’7’’ North latitudes and $75^0$11’45’’ and $75^0$34’30’’ East longitudes. The average rainfall of Aurangabad is 725.8 mm. The monsoon season is from june to september while the summer is from march to may. The average lowest temperature is 12° C while average highest temperature is 39°C.

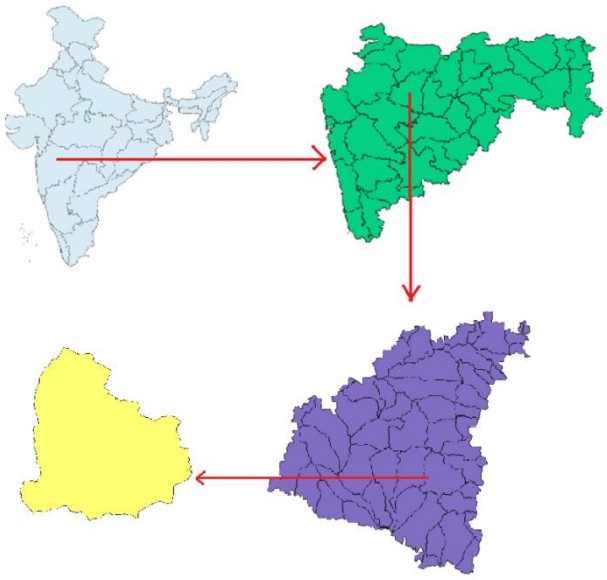

Figure 2.1: Study Area- Watershed GP-10

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III. RESEARCH METHODOLOGY

3.1 Rainfall Runoff modelling:

The Natural Resources Soil Conservation- Curve Number method (NRCS-CN) was developed by USDA. The basis of SCS-CN method is calculation of water balance of the rainfall (Subramanya, 2008) given by equation 3.1. Other two other elementary assumptions are given by equation 3.2 and equation 3.3,

$$Q = P + I_a + F \qquad (3.1)$$

$$\frac{Q}{P - I_a} = \frac{F}{S} \qquad (3.2)$$

$$I_a = \lambda S \qquad (3.3)$$

Where,

P= total rainfall depth (mm), I_a is initial abstraction (mm), F= cumulative infiltration minus the initial abstraction, Q = direct runoff, S= Maximum Potential Retention (mm).

0

The ratio λ is dimensionless quantity and varies from 0.1 to 0.4. For Indian conditions having black cotton soil, it is equal to 0.3 for Antecedent Moisture Condition (AMC) I condition and 0.1 for AMC II and AMC III condition. As the study area lies in black cotton soil zone, the values of λ are used as 0.1 for AMC I and 0.3 for AMC II, III in estimation of runoff.

Combining Equation 3.1, Equation 3.2 and Equation 3.3, Runoff (Q) can be computed as,

$$Q = \frac{(P - \lambda S)^2}{P + (1 - \lambda)S} \qquad (3.4)$$

Also the Maximum Potential retention S is given by

$$S = (25400 \div CN) - 254 \qquad (3.5)$$

Where, CN is dimensionless number, 0 < CN <100, depending on AMC condition, HSG and landcover respectively. The Antecedent Moisture Condition (AMC) condition is defined on the total rainfall of previous five days before the event. The curve numbers for AMC II (average condition) for each landcover-soil compound can be found in (Handbook of Hydrology 1972), for Indian conditions. The AMC III, AMC I can be found out by Equation 3.6, 3.7

$$CN\ III = \frac{CN\ II}{0.427 + 0.00573\ CN\ II} \qquad (3.6)$$

$$CN\ I = \frac{CN\ II}{2.281 - 0.01281\ CN\ II} \qquad (3.7)$$

3.2 Data and Sources of Data

The data required for this study is given in table 3.1

Table 3.1: Data and Data Sources

Sr. No.	Type of Data	Source
1	Watershed boundary	Groundwater Surveys and Development Agency (GSDA)
2	Rainfall data	Hydrology Project, Nasik
3	Soil map	National Bureau of Soil Survey & Land Utilisation Planning (NBSS & LUP)
4	Landuse	http://www.bhuvan.nrsc.gov.in/

3.3 Runoff Computation

Geographic Information System (GIS) was used as a tool for estimating the runoff. On Arc-GIS interface the watershed was digitized from the watershed map provided by GSDA. Landcover map downloaded from **http://www.bhuvan.nrsc.gov.in/**was clipped using study area polygon and then digitized to create landuse classes. The soil map from NBSS & LUP was also digitized and reclassified into Hydrological Soil groups (HSGs). Union of these polygons created landuse soil combination polygon. Curve numbers were assigned according to each combination of landuse and HSG.

Theissen Polygon was established in Arc-GIS using the location coordinates of three rain gauges. For these three polygons weighted CN II was found out by formula given in equation 3.8,

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$$CN_w\ II = \frac{C_1A_1 + \cdots + C_nA_n}{A_1 + \cdots + A_n} \qquad (3.8)$$

Where, CN_W II= weighted CN II,

C_1, C_2…, Cn= Curve numbers for respective combination of landcover and HSG

A_1, A_2…, An = Area for respective curve numbers

Rainfall data was analyzed for each storm event in each theissen polygon. According to AMC condition the runoff for individual storm event is calculated by equation 3.4 using weighted CN II, CN I or CN III. Runoff is calculated by aggregating runoff for individual storms event over the year.

IV. RESULTS AND DISCUSSION

4.1 Landuse :

According to land type the runoff varies. The runoff is more in region having impervious surface and less where there is pervious surface and water can infiltrate. Majority of land in watershed is agricultural land. The Landcover details are given in Table 4.1

Table 4.1: Landuse , HSG, CN and respective areas for different gauge stations

Landuse	HSG	CN	Aurangabad		Bangaon		Dhorkin	
			Area	CN *Area	Area	CN *Area	Area	CN *%Area
Agriculture	B	86	59.282	5098.237	65.760	5655.328	0.620	53.322
	C	90	25.757	2318.112	109.512	9856.063		
Fallow land	B	79	4.895	386.744	6.841	540.451	0.0006	0.0485
	C	86	0.859	73.915	7.940	682.870		
Plantation	B	55	0.049	2.708	0.061	3.361		
	C	69	0.398	27.46	0.027	1.891		
Urban	B	86	12.924	1111.432	2.539	218.320		
	C	91	3.409	310.252	2.298	209.136		
Mining	B	80	0.15	12.002	0.019	1.534		
	C	85	0.001	0.082	0.010	0.832		
Decidious forest	B	44	0.3560	15.678	8.463	372.377		
	C	60	0.004	0.231	0.438	26.308		
Scrub forest	B	47	0.121	5.674	2.922	137.313		
	C	64	0.002	0.133	0.881	56.388		
Rocky barren	B	80	0.101	8.105	0.077	6.143		
	C	85	0.135	11.444	0.008	0.685		
Scrub	B	80	13.417	1073.397	21.025	1682.025	0.653	52.208
	C	85	0.552	46.932	3.194	271.475		
Waterbodies	B	100	1.287	128.689	0.928	92.815		
	C	100	0.400	39.971	7.857	785.743		
Total			124.100	10671.21	240.801	20601.056	1.273	105.579

Table 4.2: Values of Maximum Potential Retention (S) for different Curve Numbers of different gauge stations

	Aurangabad			Bangaon			Dhorkin		
	CN I	CN II	CN III	CN I	CN II	CN III	CN I	CN II	CN III
CN	72.90	85.98	93.49	72.19	85.55	93.27	68.03	82.92	91.92
S	94.40	41.39	17.6472	97.84	42.89	18.31	119.33	52.31	22.34

4.2 Soil:

The runoff depends on soil type. Higher the infiltration rate of the soil lesser is the runoff. The study area consists of 2 HSGs B, C having moderately low runoff potential and moderately high runoff potential. The landuse and HSG map of study area are shown in figure 4.1 and 4.2 respectively.

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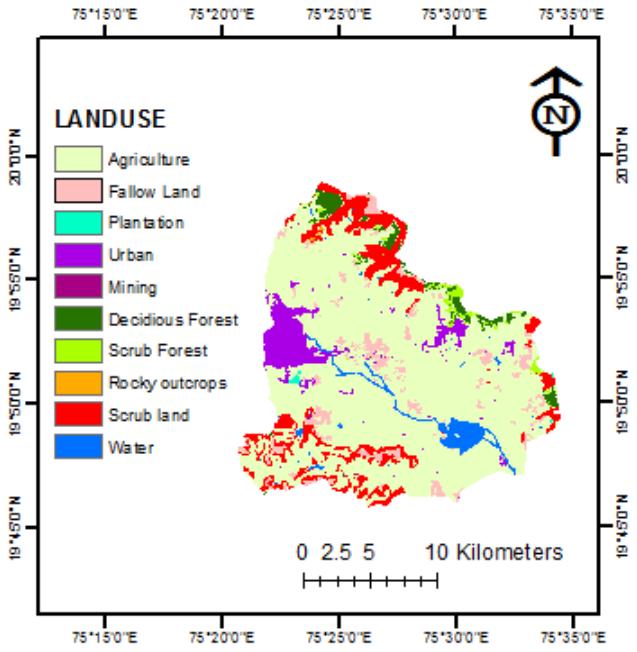

Figure 4.1: Landuse of Study Area

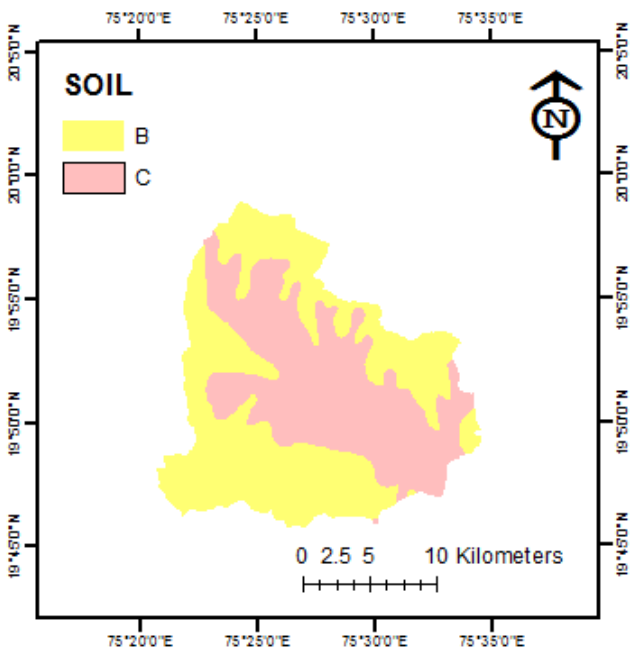

Figure 4.2:Hydrological Soil Group of Study Area

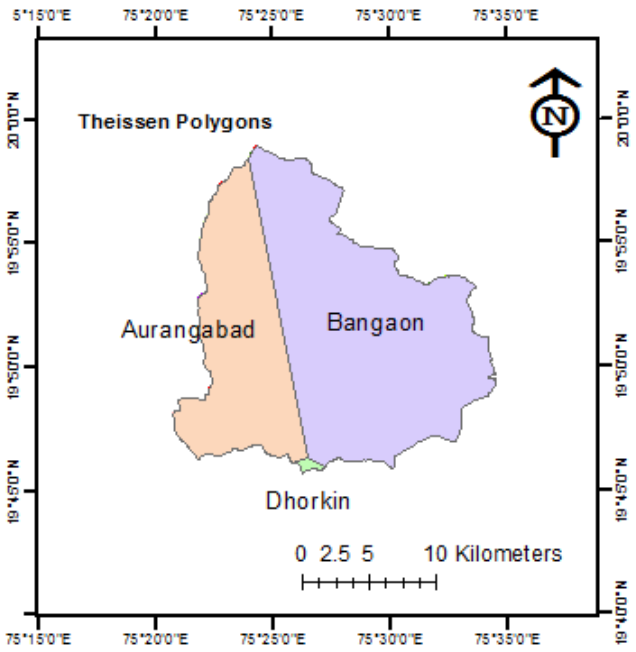

Figure 4.3: Theissen Polygons for Study Area

4.3 Runoff:

The runoff of the catchment was computed in Table 4.3. The highest total runoff was found in year 2006 which is 627.24 mm and lowest in 2012 is 50.303 mm. The bar charts of different station are shown in figure 4.4. The watershed has total area of 366.17 km^2. The runoff volume was also computed by multiplying watershed area by runoff depth. The runoff quantity shows that there is huge scope for conserving the water that goes away as direct runoff for the future uses. This water can be stored and used when the rainfall is scarce.

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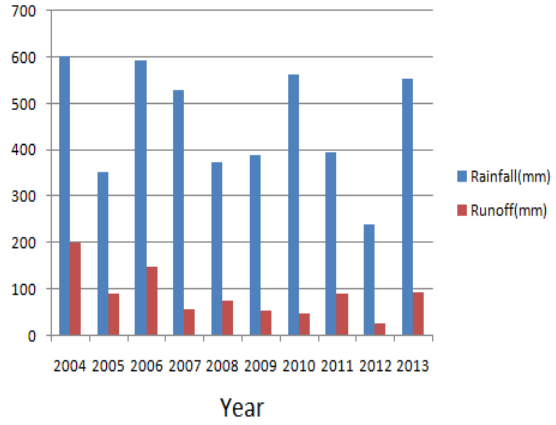
Table 4.3: Annual estimation of Runoff for different gauges

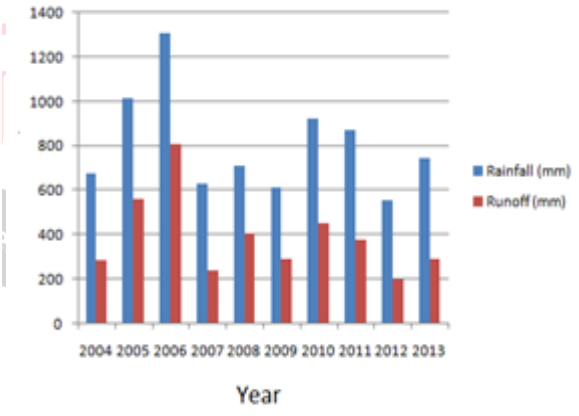
Sr. No	Year	Aurangabad					
		Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)	Rainfall (mm)	Runoff (mm)
1	2004	674.45	136.916	486	135	603.6	197.19
2	2005	1013.8	473.313	757	111.047	353.9	90.84
3	2006	1306.6	584.331	1170.2	286.404	593.4	144.93
4	2007	629.4	95.287	954.2	651.904	529.6	52.89
5	2008	710.18	382.17	492.2	322.460	375	75.1
6	2009	615.8	151.718	479.2	199.279	390	51.74
7	2010	923.9	273.282	756.3	138.026	562	46.62
8	2011	874.5	337.776	473.2	6.436	395.26	89.41
9	2012	558	135.67	280.2	48.445	239.04	26.01
10	2013	745	199.539	551.4	104.081	555.13	89.73

Table 4.4: Total Runoff and Runoff Volume Calculations

Year	Rainfall (weighted)	Runoff (weighted)	Runoff Volume (m^3)
2004	550.2765	120.114	43,982,232
2005	842.6304	349.07	127,818,883
2006	1212.422	627.24	229,676,593
2007	842.6457	244.532	89,540,299
2008	565.6693	260.83	95,508,578
2009	525.1849	81.563	29,866,144
2010	812.425	185.529	67,935,160
2011	608.933	205.554	75,267,837
2012	374.206	50.303	18,419,454
2013	617.026	99.796	36,542,335



(a)



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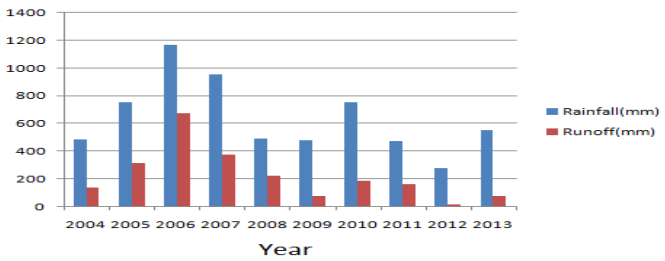

(C)

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Figure 4.3(a), (b), (c): Rainfall –runoff correlation of station Dhorkin, Aurangabad, Bangaon respectively

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